

OCL Documentation

Christian Damus, Adolfo Sánchez-Barbudo
Herrera, Axel Uhl, Edward Willink and contributors

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Chapter 1. Overview and Getting Started

For a quick demonstration of OCL enrichment of an Ecore meta-model with computed constraints go to [Getting Started](#).

A PDF version of this documentation is available at [OCL 2021-06 \(6.15.0\) Documentation](#).

1.1. What is OCL?

- *EMF is Modeled Structure*

The Eclipse Modeling Framework (*EMF*) supports the definition of structural meta-models and the subsequent use of models conforming to these meta-models. EMF also supports generating of Java code to represent the meta-models. Additional Java code can be provided to add behavior to the structural meta-models.

- *OCL is EMF and Modeled Behavior*

OCL provides a modeling language that allows the behavior to be embedded within the structural meta-models or provided as a complement to those meta-models. As a modeling language, OCL understands the models and so OCL code is much more compact than the equivalent Java. OCL code can be statically checked, whereas the corresponding Java code often uses reflection and so cannot be checked.

Eclipse OCL is an implementation of the OMG OCL 2.4 specification for use with Ecore and UML meta-models.

1.2. How Does It Work?

OCL is a programming language, so you will want to edit it, execute it and debug it.

1.2.1. Editing

Eclipse OCL supports entry of semantically checked OCL expressions

- embedded within Ecore using the [OCLinEcore](#) editor
- as complementary documents using the [Complete OCL](#) editor
- interactive entry and evaluation using the [Interactive OCL](#) console.
- programmatic entry and evaluation using the [Java API](#)

EMF supports entry of unchecked OCL

- embedded within Ecore using the Sample Ecore Editor properties view

Eclipse UML supports entry of unchecked OCL

- embedded within UML OpaqueExpressions using the UML Model Editor properties view

[Papyrus](#) supports entry of semantically checked OCL expressions

- embedded within UML OpaqueExpressions using the [Essential OCL](#) editor

1.2.2. Execution

Eclipse OCL supports OCL execution

- interactive entry and evaluation using the [Interactive OCL](#) console.
- programmatic entry and evaluation using the [Java API](#)

EMF support for generated models enables OCL execution of

- constraints, operation bodies and property initializers using the [Java API](#)

EMF support for dynamic models enables OCL execution of

- constraints using the [Validation Delegate](#) API
- operation bodies using the [Invocation Delegate](#) API

- property initializers using the [Setting Delegate](#) API
- queries using the [Query Delegate](#) API

All OCL execution is normally interpreted and starts from the OCL source text (Concrete Syntax). There is therefore a first time parsing overhead to create the compiled form (Abstract Syntax). The compiled form is cached to avoid repeated parsing costs.

Alternatively the direct Java code generator may be used as described in the [Code Generator Tutorial](#).

1.2.3. Debugging

Since OCL is used embedded in a larger environment, debugging is not easy to provide for OCL in isolation. The [OCL debugger](#) provides a variety of launch mechanisms that enable re-use of model element and/or constraint selections.

Alternatively the following approaches may be useful within other tools

- use the hover-text in the semantic editor to understand the expression types
- use the quick-fixes in the semantic editor for possible corrections
 - if the same fix is suggested more than once, try restarting the editor
- use the completion assist in the semantic editor for possible syntaxes
- use intermediate invariants to check partial results
- use the optional explanation messages for an invariant to provide a 'printf'
- use the [Interactive Xtext OCL](#) console to practice a problematic expression on a model

1.2.4. Testing

Once again, since OCL is used embedded in a larger environment, testing is not easy to provide for OCL in isolation. The following approaches may be useful.

- use the [Interactive Xtext OCL](#) console to practice sub-expressions of a problematic expression on a model

The Eclipse OCL development uses an extended JUnit framework that allows the Eclipse OCL code to be tested by assertions such as:

```
assertQueryInvalid(null, "let b : Boolean = null in true and b");
assertQueryResults(null, "Set{'b'}", "Set{'a', 'b', 'c'} - Set{'c', 'a'}");
```

(The null first argument may be a context object.)

See the `org.eclipse.ocl.xtext.tests` plugin for further details.

1.3. Eclipse OCL is Extensible

The Classic Eclipse OCL is used as a component in a variety of other Eclipse projects such as Acceleo, BIRT, GMF, Modisco, QVTo. Ecore models are used directly, which leads to some internal difficulties.

The new Unified Eclipse OCL exploits Xtext and uses Ecore models indirectly via a UML-aligned Pivot models. This provides a choice between the classic APIs that offer limited forward functionality, and the new APIs that some of which are promoted to non-experimental form in the Mars release. Many remain experimental and internal.

The new code already offers a fully modeled Standard Library that can be extended or replaced. The new OCL grammars are extended internally from Essential OCL to OCLinEcore or Complete OCL, and externally to QVT Core and QVT Relational. The associated Concrete Syntax to Abstract Syntax mapping is not yet model-driven and so harder to extend.

Full model-driven extensibility is planned for a future release.

1.4. Who Uses OCL and Eclipse OCL?

The OCL specification is defined by the *OMG*. It originally evolved as part of *UML* where it is used for the detailed mathematical aspects that are not appropriate for graphical exposition. OCL 2.0 was split off from UML 2.0 in recognition of its greater utility.

Within the OMG context, OCL has been re-used as the foundation for the MOFM2T(Model to Text) Model-to-Text transformation language and the *QVT* Model-to-Model transformation language. Eclipse implementations of these are available as the Acceleo and QVT Operational projects.

Eclipse OCL is an implementation of the OCL specification for use in conjunction with EMF and in particular Ecore and UML2 meta-models. As the behavioral extension for EMF, Eclipse OCL can be used wherever EMF can.

As a specification language, OCL is frequently used when the behavior of models is formally specified. The use of OCL as an execution language has been hindered by the quality of tool support. Beyond the research domain, many usages have been proprietary. One advanced proprietary usage at SAP has been contributed to Eclipse OCL and is available as the [Impact Analyzer](#). This supports strategic planning of run-time notifications so that derived model properties can be updated efficiently in response to a change to a model. Thousand-fold speed improvements are achievable on large models using OCL rather than Java because OCL has a formal model-based semantics that is amenable to analysis.

The use of OCL in general is eased by the provision of good editors exploiting Xtext to provide comprehensive semantic feedback in a familiar editing style.

The use of OCL for execution is enhanced by providing direct Java code generation for OCL embedded in models. This should alleviate many of the performance concerns for interpreted execution of embedded OCL.

Debugging of OCL execution is now possible using the OCL debugger and the OCL Console can be used for OCL experimentation.

1.5. Who is Behind Eclipse OCL?

Eclipse OCL is an Open Source project. The original code for OCL 1.x was contributed by IBM. It has evolved to support OCL 2.x under the auspices of Eclipse.

There is now a significant personnel and corporate overlap between the Eclipse OCL committers and the OMG OCL *RTF* and so Eclipse OCL is pioneering solutions to many of the under-specification problems in the OCL specification.

You can expect future changes in OMG OCL to have an implementation in Eclipse OCL to demonstrate their viability. It is likely that the next version of the OCL specification will use Eclipse OCL and M2T(Model to Text) tooling to eliminate inconsistencies. Eclipse OCL is currently in use to check that the OCL used in the UML 2.5 specification is syntactically and semantically correct.

Direct tooling of the UML 2.5 and OCL 2.5 specifications for a future Eclipse release may demonstrate that the OCL aspects of the specifications is also functionally consistent.

1.6. Getting Started

For a very quick demonstration of OCL, you may follow this very abbreviated version of the [OCLinEcore tutorial](#), where you can find [Installation](#) instructions. Once you have the OCL Examples and Editors feature installed you may follow these instructions to get an insight into the capabilities of OCL and the Eclipse OCL tooling.

Invoke **File->New->Project...** then select **Examples** then **OCL (Object Constraint Language) Plugins** then **OCLinEcore Tutorial** and **Finish** to create a small example project called **org.eclipse.ocl.examples.project.oclinecoretutorial**. It contains

- **model/Tutorial.ecore** - a small Library meta-model
- **model/Tutorial.xmi** - an even smaller Library model
- **model/Tutorial.genmodel** - a generator for Java code

Select **model/Tutorial.ecore** and use the right button to invoke **Open With->OCLinEcore Editor**. This gives you a textual view of the Ecore file with embedded OCL invariants such as the Book constraint

```
invariant SufficientCopies:  
    library.loans->select((book = self))->size() <= copies;
```

This invariant is named SufficientCopies. It

- navigates from the implicit self (a Book)

- via the library
- to its loans which it searches
- to select those loans that satisfy the predicate
 - loaned book is equal to the self Book
- the size (number) of loans is computed
- and compared to the number of copies of the self Book

The invariant is satisfied if it evaluates true; i.e. if the number of loans is less than or equal to the number of copies.

You can see this invariant at work, by selecting **model/Tutorial.xmi** and using the right button to invoke **Open With->Sample Reflective Ecore Model Editor**. This gives you a tree view of a small library model.

Expand the root element and then select the **Library lib** element and use the right button menu to invoke **Validate**. You should get a pop-up reporting problems during Validation. Click **Details** and you will see that one of the problems is with the **SufficientCopies** invariant we have just looked at. If you browse the Properties View for **model/Tutorial.xmi**, you can verify that there are three loans but only two copies for the offending Book.

You may evaluate custom OCL queries interactively. From the editor for **Tutorial.xmi**, invoke **OCL->Show Xtext OCL Console** from the context menu. Select **Book b2** in the editor, then in the bottom line of the console enter the OCL expression **loans.member** and then Enter. The results are shown in the panel and identify that all three loans are by **Member m3**.

The expression **loans.member** is an abbreviated form of **self.loans->collect(aLoan : Loan | aLoan.member)** and demonstrates OCL's ability to perform many useful navigations over multi-element properties. The expression

- navigates from self, the Book b2 selection
- to its loans, using Book::loans which is a derived property defined in OCL
- for each of the loans, the iterator variable, aLoan, is assigned to the loan and
 - the body, aLoan.member is evaluated to return the member making the loan
- the resulting members are collected to return a collection result
- the result is displayed on three lines in the results panel

You can step through execution using the OCL debugger. In the Console View type PageUp to restore the earlier text entry, then with **Book b2** still selected in the editor, click the debug icon in the Console tool bar. The debugger should open automatically, but if it doesn't, use **Window->Show View->Debug** from the Eclipse menu bar. The Variables View shows model element values. Click F5 or Step Into a few times to progress execution.

You have now seen

- an Xtext editor that embeds OCL directly in Ecore models to provide programmed enrichment
- execution of OCL while validating a model using conventional Ecore tooling
- an interactive Console for custom OCL evaluations
- execution of a derived property defined in OCL
- the ability of OCL to express operations on multi-elements compactly
- the ability to debug OCL execution and browse data

You have not

- written any Java code
- generated any plugins
- needed to start an additional Eclipse session

Please follow the tutorials, examples and reference material for further information.

Chapter 2. Users Guide

The core functionality of OCL that supports expressions over models is called the Essential OCL. This language is of very limited use by itself since there is no way in which the models can be provided. Essential OCL is therefore extended in various ways to provide this missing context.

The [Complete OCL](#) provides a language for a document in which OCL complements an existing meta-model with invariants, and additional features.

[OCLinEcore](#) embeds OCL within the annotations of an Ecore model to enrich that model.

UML supports the use of OCL constraints as a form of `OpaqueExpression`, and UML tools such as Papyrus support those constraints for UML models.

The Eclipse OCL project provides four OCL languages to support these usages.

- [Essential OCL](#) provides the core extensible capability of specifying expressions for models.
- [Complete OCL](#) provides the ability to use OCL in a self-standing document to complement an existing meta-model with invariants, and additional features.
- [OCLinEcore](#) enables OCL to be embedded within an Ecore meta-model to add invariants for classifiers, bodies for operations and computed values for properties.
- [OCLstdlib](#) supports the definition of the standard and custom OCL Standard Libraries.

2.1. The two Eclipse OCLs

The Eclipse OCL project is making a transition to a new underlying infrastructure.

2.1.1. The Classic Eclipse OCL metamodels

The Classic code base emphasized utility for Java programmers. It originally supported Ecore meta-models and evolved to support UML as well. An OCL Console was added to support interactive experimentation with OCL expressions.

Interactions with the QVTd project resulted in a refactoring of the grammars so that they could be extended for use by QVT. At the same time the grammars were migrated to use LPG 2.

The dual support for Ecore and UML was achieved by a shared generic meta-model in which the distinctions between Ecore and UML meta-models were accommodated by substantial (often ten parameter) template parameters lists. Sometimes these lists are hidden by derived bindings, but sometimes the full lists are exposed. This gives rather cumbersome Java code for the OCL developers and OCL consumers alike.

The classic evaluator is tightly coupled to Ecore which might appear efficient, but the lack of separation of OCL-specification semantics from Java-implementation semantics makes accurate implementation of equality in nested collections hard to achieve.

The classic code endeavored to comply with OCL specification despite significant ambiguities in the specification, but since the classic code evolved from an OCL 1.x compliance and Ecore utility there are a number of areas where accurate OMG compliance is hard to achieve.

The classic code is provided primarily by the following plugins

- org.eclipse.ocl
- org.eclipse.ocl.ecore
- org.eclipse.ocl.uml

2.1.2. The Unified or Pivot Eclipse OCL metamodel

The Unified or Pivot metamodel is a prototype for a resolution of a number of fundamental problems with the OCL 2.4 specification. The Pivot metamodel is derived from the UML metamodels for UML and OCL to provide a unified metamodel for UML with executable semantics.

In practice, when using the Pivot metamodel for Ecore or UML metamodels, a Pivot metamodel instance is created on the fly to provide the unified merged OCL functionality for the Ecore or UML metamodel instances.

From the specification perspective, the Pivot metamodel

- is UML-aligned
- supports modeling of the OCL standard library
- supports ‘merging’ of additional Complete OCL definitions
- supports an interchangeable XMI representation
- supports a fully reflective `oclType()`

From the Eclipse perspective, the Pivot metamodel

- hides Ecore differences with respect to EMOF
- hides MDT/UML2 differences with respect to UML
- allows much of the semantics to be defined by a single library model
- allows user extension and replacement of the library model
- allows for exact OMG compliance

At the same time, the Values package that forms part of the specification has been partially implemented. This allows a clear separation of OCL-semantics.

The unified code is provided by the

- `org.eclipse.ocl.pivot`

with additional optional support for UML in

- `org.eclipse.ocl.pivot.uml`

Additional editing functionality using Xtext is provided by plugins sharing the prefix

- `org.eclipse.ocl.xtext`

Further functionality that remains of example quality may be found in plugins sharing the prefix

- `org.eclipse.ocl.examples`

All APIs in Xtext and Examples plugins are preliminary, as are APIs in classes including ‘internal’ in method, class or package name.

2.1.3. The transition

This transition started in the Helios (3.0) release for which Xtext editors were provided for OCLinEcore, Complete OCL and the OCL Standard Library. There was then no Pivot meta-model and so the editors offered only syntactic validation. It was not possible to persist an AST as XMI or to evaluate code that had been parsed by the Xtext parsers. It was necessary to re-parse with the LPG parsers.

In the Indigo (3.1) release, the Pivot metamodel prototype was introduced and used to support semantic validation within the Xtext editors. The OCL Standard Library was realised using the Pivot metamodel and a new highly extensible evaluator was implemented. These facilities are used by the new OCL Xtext Console.

Therefore when using the OCL Xtext Console the contributing tools are

- Essential OCL Xtext editor
- Pivot Metamodel
- OCL-2.5.oclstclib library
- Pivot Evaluator
- Pivot Debugger

When using the classic OCL Console the contributing tools are

- LPG parser and hand-coded Syntax Helper
- Ecore (or UML) metamodel bindings
- Hand coded library implementation
- Classic evaluator

Since these tools are different there may be occasions where the increased OMG compliance of the Pivot metamodel gives different behavior to the classic metamodels.

In the Juno (3.2/4.0) release, there is a preliminary Java code generator for the Pivot metamodel so that all the parsing overheads and significant parts of the execution overheads of OCL embedded in Ecore models occurs at genmodel time rather than during execution.

In the Kepler (3.3/4.1) release, the code generator was substantially improved and a number of internal APIs have evolved accordingly. UML support was improved to facilitate usage within Papyrus, and extensibility was improved for use by QVTd.

In the Luna (3.4/5.0) release, further code generation improvements have been made and major new User Interface capabilities added. There is at last an OCL debugger and a Constraint Validity View.

In the Mars (1.0/6.0) release, the transition is nominally complete and the main `org.eclipse.ocl.examples.*` plugins have been renamed to `org.eclipse.ocl.*`. All functionality should use the new Pivot metamodel by default. However the classic Ecore and UML support will remain for compatibility. Unfortunately time ran out and so review and revision had to be truncated. Documentation is sadly deficient.

The Neon (1.1/6.1), Neon++(1.2/6.2), Oxygen (1.3/6.3) and Photon (1.4/6.4) resolve a variety of extensibility issues highlighted by Eclipse QVTd. (The double Neon release was necessitated by SSPI breakage in Xtext 2.9. The Neon release continuing with pre-Xtext 2.9 API, Neon++ migrating.)

Hopefully the future (2.0/7.0) release will track the actual OCL 2.5 submission.

2.1.4. Migration

The difficulties of moving from the Ecore/UML-based OCL to the Pivot-based OCL depend on the style of usage.

2.1.4.1. Language

The OCL Concrete Syntax is the same for both Eclipse OCLs and Pivot-based Xtext tooling has been in use for Ecore-based OCL for a few releases.

The Pivot-based OCL supports a number of new prototype facilities such as null-free collections, template types, map types and lambda types that are not available with the Ecore-based tooling.

2.1.4.2. AS Models

The Abstract Syntax models are superficially similar; both have an `OCLEExpression`, however the details are quite different.

The OMG OCL specification requires the AS model to be serializable in XML. This is not possible with the current OCL specifications. The intent is partially satisfied for the Ecore/UML-based models using proprietary solutions. The Pivot-based models are fully serializable and prototype a solution that may be adopted by OCL 2.5.

The Ecore/UML-based models extend the `Ecore.ecore/UML.ecore` models and so use for instance `EStructuralFeature/org.eclipse.uml2.uml.Property` as the type of a `PropertyCallExp.referredProperty`.

The Pivot-based models are UML-aligned and self-contained and so a `PropertyCallExp.referredProperty` is an `org.eclipse.ocl.pivot.Property`. Property names are derived from UML but made consistent; 'many' properties use a plural name; and 'composed' properties use 'owned'/'owning'. Thus UML's `Class.ownedAttribute` aligns to Pivot's `Class.ownedProperties`.

Since the Pivot-based models have no dependence on an external model, the Pivot Visitors provide an ability to visit all classes, whereas the Ecore/UML-based visitors are partial; Ecore/UML classes must use an `EcoreSwitch` instead.

The Ecore/UML based models have no support for UML reflection. A form of reflection is available with `eClass()`, but the result type names are necessarily `EClass`.

The Pivot-based models support consistent reflection using `oclType()` which return an `ocl.eclipse.ocl.pivot.Class`.

The Ecore/UML-based OCL does not use models for additional facilities defined by Complete OCL; an irregular Java API is available.

The Pivot-based approach creates an additional Package for the Complete OCL contributions and behaves as if the complementing Package was merged with the complemented Package.

2.1.4.3. CS Models

The Concrete Syntax models are non-normative and have very little commonality.

The Ecore/UML-based models are designed for use with the LPG LALR parser.

The Pivot-based models are designed for use with Xtext and LL ANTLR tooling.

Any user code that uses the CS models is likely to be very tightly coupled to internal APIs and so will need rebuilding and quite possibly updating for each new release.

2.1.4.4. The OCL Facade

The complexities of the underlying OCL support are hidden by an OCL Facade, with similar interfaces in all three variants.

- `org.eclipse.ocl.ecore.OCL`
- `org.eclipse.ocl.uml.OCL`
- `org.eclipse.ocl.pivot.utilities.OCL`

Contrasting the deliberately similar examples in

- [Classic Ecore/UML Programmers Guide](#)
- [Unified or Pivot Programmers Guide](#)

may be instructive.

The Pivot approach is simplified a little by the dual Facade/Handle behavior which ensures that OCL facilities are garbage collected.

2.1.4.5. The OCL Architecture

While many of the internal classes share similar intents and names between the approaches, the details have evolved as the new approach has learned from its predecessor

- long template parameter lists are eliminated
- APIs are more strongly typed using e.g. `TypedElement` rather than String 'name' arguments
- API compatible extension APIs are folded into a single new API
- full auto-generated Visitor hierarchies are exploited

and of course Xtext is far from identical to LPG.

2.1.5. APIs

Eclipse OCL has two different styles of APIs

2.1.5.1. Tool APIs

The major tool APIs originally provided by the `org.eclipse.ocl.OCL` class have evolved only slightly to `org.eclipse.ocl.ecore.OCL` and `org.eclipse.ocl.uml.OCL` for the classic metamodels and `org.eclipse.ocl.pivot.OCL` for the Pivot metamodel.

These APIs support the use of OCL as a tool to parse and evaluate constraints and queries.

These APIs will change very little; just the package changes according to the chosen metamodel representation.

2.1.5.2. Internal APIs

The internal parsing APIs were made public in 1.3.0 to support parser extension by QVT. These APIs are very tightly coupled to a particular LPG implementation of a particular OCL grammar formulation. It is extremely difficult to replicate these APIs for the ANTLR grammar that underlies the Xtext editors. It is

also doubtful whether these APIs can be preserved as the OCL specification is clarified to more clearly specify what words are reserved and what is extensible.

It is therefore unlikely that the internal APIs for the classic metamodels will be replicated for the Pivot metamodel. However since an LPG grammar is significantly (ten-times) smaller and perhaps a bit faster (two-times) it is planned to provide an automated Xtext to LPG translation so that a smaller LPG grammar can populate the same auto-generated Concrete Syntax structures as the ANTLR grammar.

This functionality is intended to form part of a new grammar extension API that will enable OCL-extending languages such as QVT to re-use and extend not only the grammar but also all the semantic scope resolution and concrete to abstract syntax mappings.

2.1.5.3. Versions

Eclipse version numbering policy requires that a major version change occurs when any re-exported component has a major version number change. Consequently when Eclipse UML moved from to UML 2.4 support (4.0.0) and again to UML 2.5 (5.0.0) a corresponding change was forced on the Classic UML support and this is the number that then applies to the whole of Eclipse OCL. However the Ecore dependencies are unchanged and so Ecore dependent releases have advanced more slowly; 3.2 accompanying 4.0 and now 3.5 accompanying 6.0.

This is probably just as confusing for the developers as for consumers. It is however necessary to ensure that the minor changes in the Classic Ecore functionality are not presented as major changes to consumers.

The current OCL version variously referred to as:

- 6.0 as the outer version of the OCL master feature
- 3.5 as the version of the Ecore OCL plugins (compatible with 3.0)
- 1.0 as the version of the new Pivot OCL plugins

2.2. The Essential OCL Language

The core functionality of OCL that supports expressions over models is called the Essential OCL. This language is of very limited use by itself since there is no way in which the models can be provided.

Essential OCL is extended in various ways to provide this missing context.

The [Complete OCL](#) provides a language for a document in which OCL complements an existing meta-model with invariants, and additional features. Complete OCL is part of the OMG OCL specification.

[OCLinEcore](#) embeds OCL within the annotations of an Ecore model to enrich that model. OCLinEcore is defined an Eclipse OCL. It is not part of the OMG OCL specification.

UML supports the use of OCL constraints as a form of OpaqueExpression, and UML tools such as Papyrus support those constraints for UML models.

2.2.1. Syntax

The Eclipse OCL realization of the Essential OCL grammar is provided in the following subsections, starting with the expression terms and then elaborating the operators.

2.2.1.1. Grammar Implementation

The grammar used by the Xtext editors may be found at:

`/src/org/eclipse/ocl/examples/xtext/essentialocl/EssentialOCL.xtext`

in the `org.eclipse.ocl.xtext.essentialocl` plugin.

2.2.1.2. Grammar Approach

The OCL 2.4 grammar is ambiguous and consequently has disambiguating rules. How those disambiguating rules are applied is an implementation detail.

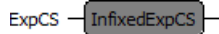
The disambiguating approach taken in Eclipse OCL is to parse an unambiguous larger language that unifies all the ambiguities. Subsequent semantic validation distinguishes between the ambiguities and diagnoses expressions from the larger language that are not valid OCL expressions.

From a technical point of view this makes the grammar simpler and more regular, and the implementation more modular and configurable by the library model.

From a user's point of view, slightly wrong expressions may be syntactically valid and so semantic validation may produce a more helpful diagnostic. However completion assist may offer illegal expressions from the larger language.

2.2.1.3. OCL Expression

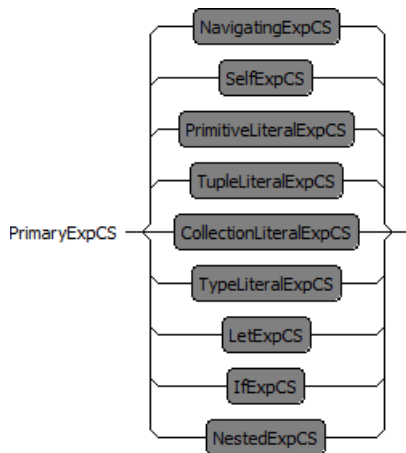
The Exp syntax defines an OCL expression.



Expressions consist of a variety of operators and expression terms that are defined at the top level by an [InfixExp](#). We will first define the terms of an expression and then define the various forms of operators that bind expression terms together.

2.2.1.4. PrimaryExp

The PrimaryExp syntax identifies the basic building blocks of an OCL expression.



Literals such as

- [PrimitiveLiteralExpCS](#) - true or 3.14159
- [CollectionLiteralExpCS](#) - Set{1..5}
- [TupleLiteralExpCS](#) - Tuple{name:String='me',at:String='here'}
- [TypeLiteralExpCS](#) - Integer or Set<Integer>

The context object

- [SelfExpCS](#) - self

Compound expressions such as

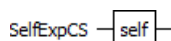
- [NestedExpCS](#) - (x)
- [IfExpCS](#) - if x then y else z endif
- [LetExpCS](#) - let x : Integer in x + x

Navigation expressions such as

- [NavigatingExpCS](#) - x or x.Y::z->iterate(a:Integer;acc:Integer|acc+a)

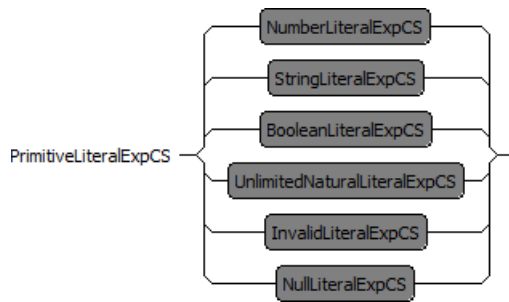
2.2.1.5. SelfExp

The SelfExp syntax supports the use of the prevailing context object in an expression.



2.2.1.6. PrimitiveLiteralExp

The PrimitiveLiteralExp syntax supports the use of a known value in an expression.

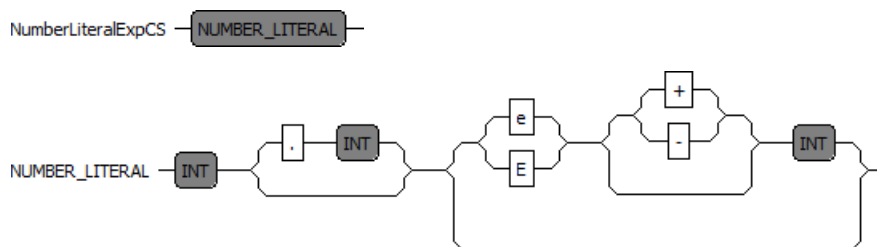


The value may be

- [NumberLiteralExpCS](#) - 4 or 3.14159
- [StringLiteralExpCS](#) - 'a string'
- [BooleanLiteralExpCS](#) - true or false
- [UnlimitedNaturalLiteralExpCS](#) - *
- [InvalidLiteralExpCS](#) - invalid
- [NullLiteralExpCS](#) - null

2.2.1.7. NumberLiteralExp

The NumberLiteralExp syntax supports the use of a numeric value in an expression.



A numeric value is

- an integer such as 4
- fixed point number such as 3.1
- floating point number such as 12.8e-5.

A numeric value does not have a leading -; negative numbers are parsed as the application of a unary negate operator to a positive number.

A numeric value may not have a trailing decimal point.

A numeric value may not have a redundant leading zero.

2.2.1.8. StringLiteralExp

The StringLiteralExp syntax supports the use of a string value in an expression.



A string is specified as a character sequence between single quotes.

e.g. 'This is a string'

The standard Java and C backslash escapes can be used for awkward characters such as a single quote.

\b -- #x08: backspace BS

\t -- #x09: horizontal tab HT

\n -- #x0a: linefeed LF

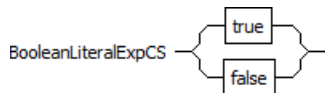
\f -- #x0c: form feed FF

\r -- #x0d: carriage return CR

\" -- #x22: double quote "
 \' -- #x27: single quote '
 \\ -- #x5c: backslash \
 \x Hex Hex -- #x00 to #xFF
 \u Hex Hex Hex Hex -- #x0000 to #xFFFF

2.2.1.9. BooleanLiteralExp

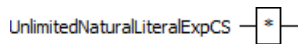
The BooleanLiteralExp syntax supports the use of boolean values in an expression.



The Boolean values are `true` and `false`.

2.2.1.10. UnlimitedNaturalLiteralExp

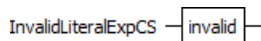
The UnlimitedNaturalLiteralExp syntax supports the use of the non-numeric unlimited value in an expression.



The Non-numeric unlimited value is `*`. Other UnlimitedNatural values are [NumberLiteralExpCS](#).

2.2.1.11. InvalidLiteralExp

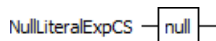
The InvalidLiteralExp syntax supports the use of an invalid value in an expression.



The invalid value is `invalid`.

2.2.1.12. NullLiteralExp

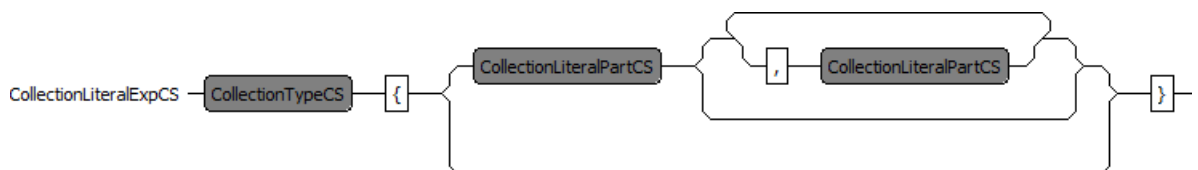
The NullLiteralExp syntax supports the use of a null or unspecified value in an expression.



The null value is `null`.

2.2.1.13. CollectionLiteralExp

The CollectionLiteralExp syntax supports the creation of a collection of values for use in an expression.



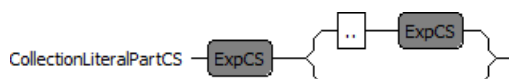
A collection literal comprises the [CollectionType](#) followed by braces enclosing a comma-separated list of zero or more [CollectionLiteralParts](#).

e.g. `Sequence{1, 2, 4..6}`

Note that null, collection and tuple values are permitted in collections but that invalid values are not. A collection 'containing' an invalid value is flattened to the invalid value.

2.2.1.14. CollectionLiteralPart

The CollectionLiteralPart syntax supports the use of a value or range of values in a collection of values.



A single item collection literal part may be any expression (except invalid). e.g. `1+2`

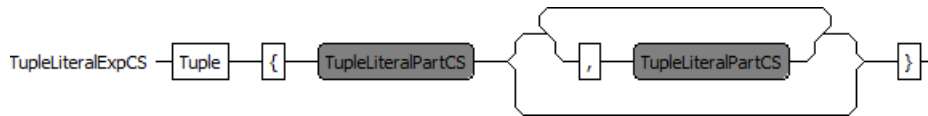
A multi-item collection literal part comprises the inclusive range of values between two integer limits.

`1..3` is the three values 1, 2, 3.

`1..-1` is the three values 1, 0, -1.

2.2.1.15. TupleLiteralExp

The TupleLiteralExp syntax supports the use of a tuple of named expression values in an expression.

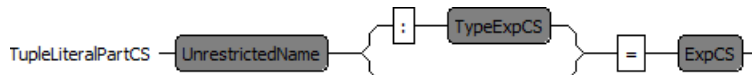


A tuple literal comprises the `Tuple` keyword followed by braces enclosing a comma-separated list of one or more [TupleLiteralParts](#).

`Tuple{year:Integer='2000',month:String='January',day:Integer='1'}`

2.2.1.16. TupleLiteralPart

The TupleLiteralPart syntax supports the use of a named expression value in a tuple of such values.

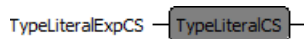


The part comprises the name, an optional type and a value. If the type is omitted, it is inferred from the value.

`leapyear : Boolean = true`

2.2.1.17. TypeLiteralExp

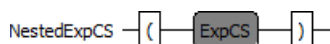
The TypeLiteralExp syntax supports the use of types as values in an expression. This is useful for expressions such as `myCollection.oclAsType(Set<MyType>)`.



A TypeLiteralExp comprises a [TypeLiteral](#).

2.2.1.18. NestedExp

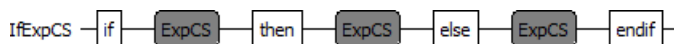
The NestedExp syntax supports the use of an inner expression as a term in an outer expression ensuring that the operator precedence of the inner expression is not affected by the outer expression,



A nested expression is just an expression surrounded by parentheses.

2.2.1.19. IfExp

The IfExp syntax supports the use of a conditional choice of expression value in an expression.



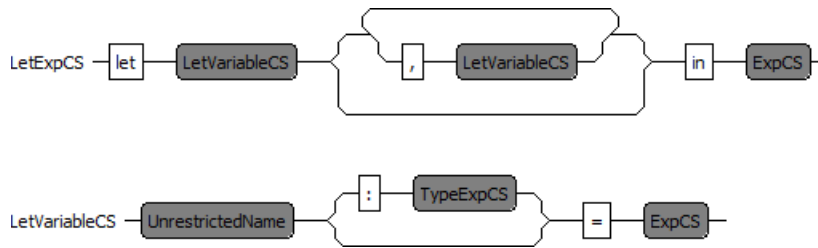
An if expression comprises a condition expression to be tested followed by a then-expression to be evaluated if the condition is true and an else-expression for evaluation if the expression is false.

`if this.size > that.size then this else that endif`

Note that the else-expression is required and so there is no ambiguity when multiple if expressions are nested.

2.2.1.20. LetExp

The LetExp syntax supports the introduction of local variables to facilitate re-use of intermediate results within an expression.



A let expression comprises the let keyword followed by one or more comma-separated let variables and then the in keyword and the in-expression to be evaluated with the help of the extra variables.

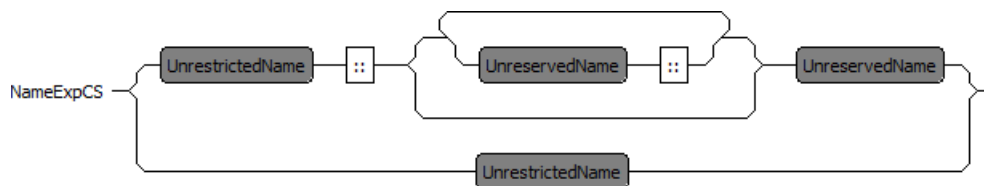
Each let variable comprises a name, an optional type and an expression to initialize the variable. If the type is omitted, it is inferred from the initializer.

```
let test : String = 'prefix[contents]suffix',
    start : Integer = test.indexOf('['),
    finish : Integer = test.indexOf(']')
in test.substring(start,finish)
```

The let syntax has no terminating keyword such as endlet and so there is an ambiguity for for instance `1 + let b : Integer = 2 in b + 4`. The ambiguity is resolved as `1 + let b : Integer = 2 in (b + 4)` by selecting the longest possible in-expression.

2.2.1.21. NameExp

The NameExp syntax supports the use of the name of a model element such as a property, operation or type in an expression.

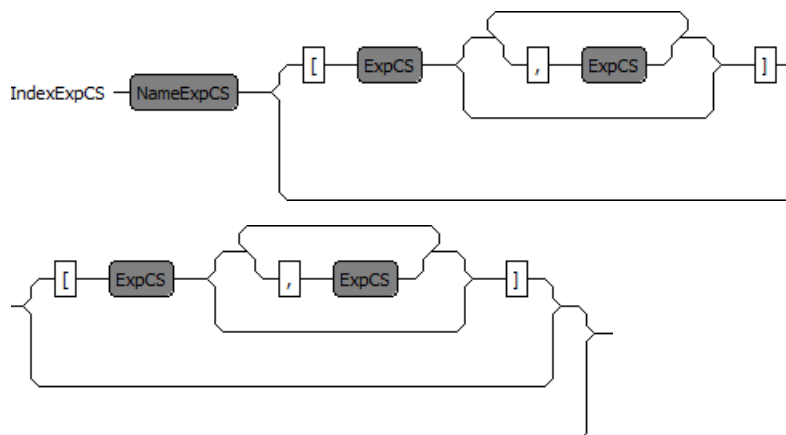


A name expression comprises a name optionally prefixed by double-colon separate path names.

The first name is an [UnrestrictedName](#), that is a name that does not clash with any OCL reserved words such as `else` or built-in types such as `String`. Subsequent names are [UnreservedName](#) allowing the re-use of built-in type names but not reserved words.

2.2.1.22. IndexExp

The IndexExp syntax supports the application of qualifiers to a model property to distinguish the source or select a particular association.

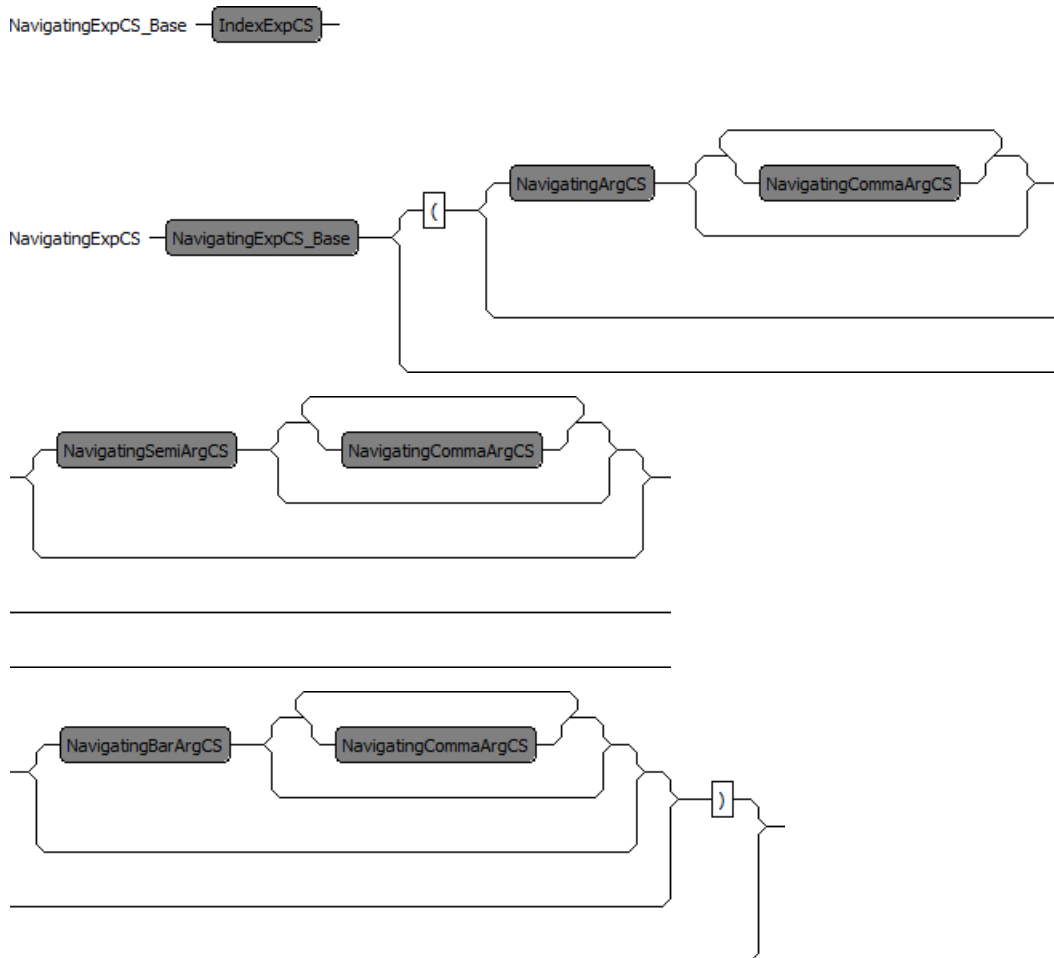


A [NameExp](#) identifying a model property is optionally qualified by a first list of qualifiers and a second list of qualifiers.

This syntax is experimental and the qualifiers are not yet supported for evaluation.

2.2.1.23. NavigatingExp

The NavigatingExp syntax supports the navigation of models using model properties, operations and iterations.



An [IndexExp](#) identifying a potentially qualified model feature is optionally followed by a parenthesized arguments. If the parenthesized arguments are omitted the model feature should be a Property. If the arguments are present the model feature should be an iteration or operation.

The diverse syntaxes specified by OCL 2.4 for OperationCallExpCS and IteratorExpCS create ambiguities that are difficult to parse. The merged grammar used by Eclipse OCL gathers argument contributions without imposing premature validation.

The parenthesized arguments may be empty, or may comprise one or more parameters, optional accumulators and optional bodies.

The comma-separated list of parameters starts with a NavigatingArgCS, followed by any number of NavigatingCommaArgCS.

```
simpleCall(simpleArgument)
```

The optional comma-separated list of accumulators are introduced by a semi-colon-prefixed NavigatingSemiArgCS, followed by any number of NavigatingCommaArgCS.

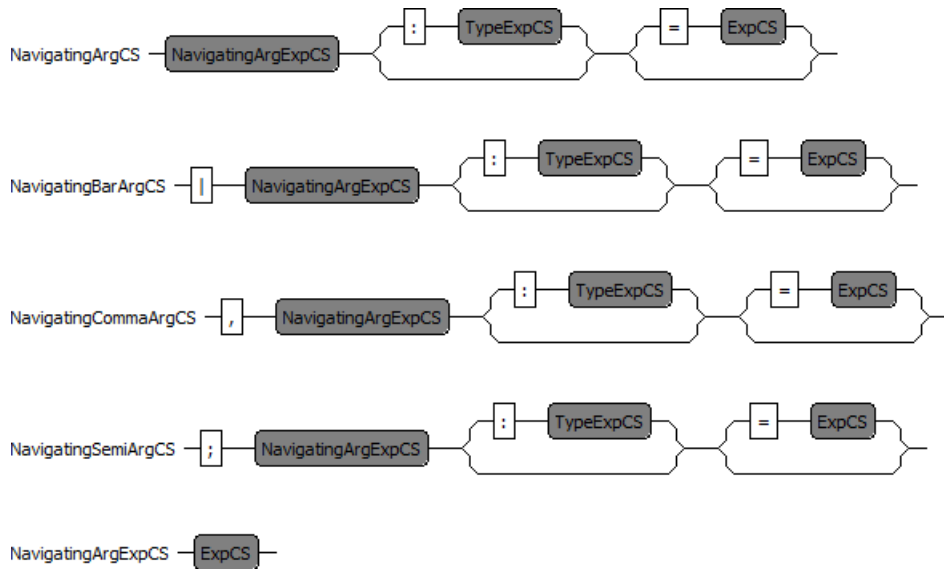
```
some->iterate(p; anAccumulator : Integer = 0 | p.size())
```

The optional comma-separated list of bodies are introduced by a vertical-bar-prefixed NavigatingBarArgCS, followed by any number of NavigatingCommaArgCS.

```
some->exists(p | p.size())
```

2.2.1.24. NavigatingArg

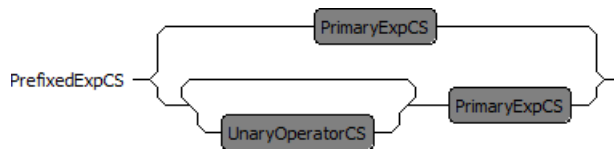
The NavigatingArg syntaxes supports the parsing of potential parameters, accumulators and bodies for use in NavigatingExps.



Each syntax supports an optional type and an optional initializer for an expression.

2.2.1.25. PrefixedExp

The `PrefixedExp` syntax supports the application of zero or more prefix unary operators to an expression.



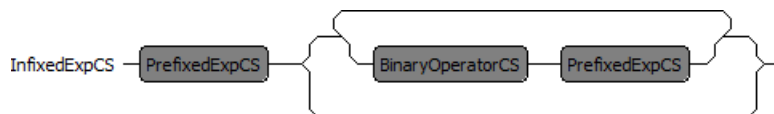
The prefix operator precedes an expression: `-4` or `not(this or that)`

The unary operators are

- `-` negate
- `not` logical complement

2.2.1.26. InfixExp

The `InfixExp` syntax supports the application of zero or more infix binary operators between expression terms.



The infix operators separate expression terms: `1 + 2 / 3 * 4 / 5 + 6`.

The infix operators are

- The [NavigationOperators](#)
- `*`, `/` multiply and divide
- `+`, `-` add and subtract
- `<`, `<=`, `>=`, `>` relational comparisons
- `=`, `<>` equality and inequality
- `and` logical and
- `or` inclusive or
- `xor` exclusive or
- `implies` logical implication

The precedence and associativity of the operators is defined by the OCL Standard Library model, not by the grammar. The OCL 2.4 library precedence is as presented above with all operators left associative. The example above is therefore interpreted as $(1 + ((2 / 3) * 4) / 5) + 6$.

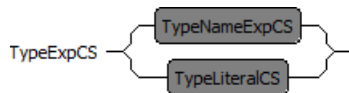
2.2.1.27. NavigationOperators

The NavigationOperators operators are

- . for object navigation
- -> for collection navigation

2.2.1.28. TypeExp

The TypeExp syntax supports the use of types as expressions.

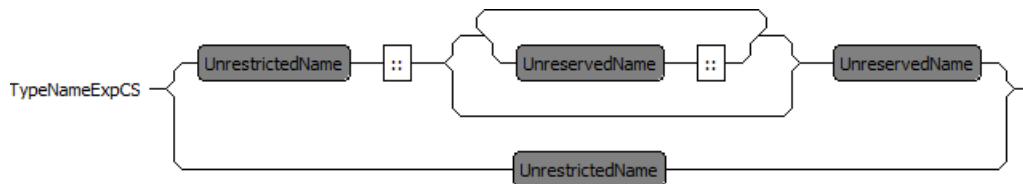


A type expression may be a

- [TypeNameExpCS](#) - a user-defined type
- [TypeLiteralCS](#) - a built-in or aggregate type

2.2.1.29. TypeNameExp

The TypeNameExp syntax supports the use of a user-defined types as a declaration or expression.

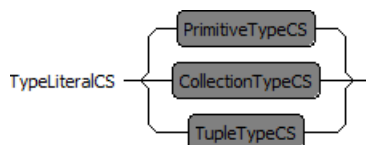


A name expression comprises the name of a type optionally prefixed by double-colon separate path names.

The first name is an [UnrestrictedName](#), that is a name that does not clash with any OCL reserved words such as `else` or built-in types such as `String`. Subsequent names are [UnreservedName](#) allowing the re-use of built-in type names but not reserved words.

2.2.1.30. TypeLiteral

The TypeLiteral syntax supports the use of built-in or aggregate types as declarations or expressions.

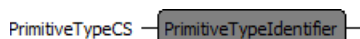


A Type literal may be a

- [PrimitiveTypeCS](#)
- [CollectionTypeCS](#)
- [TupleTypeCS](#)

2.2.1.31. PrimitiveType

The PrimitiveType syntax supports the definition of a built-in type for use in a declaration or expression.



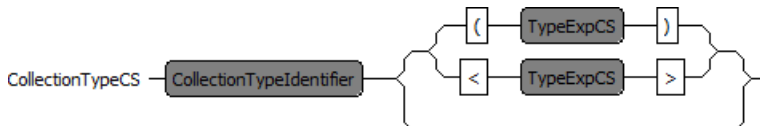
The built-in types are

- Boolean
- Integer

- Real
- String
- UnlimitedNatural
- OclAny
- OclInvalid
- OclVoid

2.2.1.32. CollectionType

The CollectionType syntax supports the definition of a collection type for use in a declaration or expression.



A collection type comprises the CollectionTypeIdentifier followed by a [Type Expression](#) defining the type of the collection elements.

Set(String) or Sequence<Bag<Integer>>

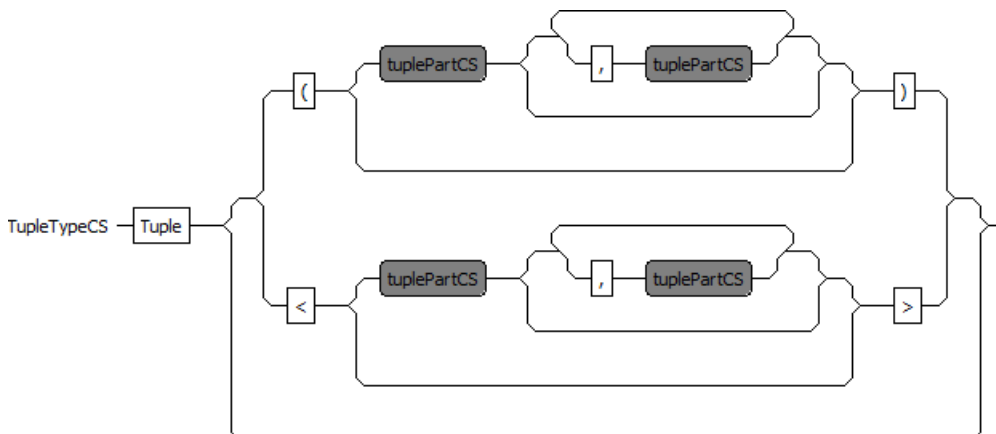
The built-in CollectionTypeIdentifiers are

- Collection
- Bag
- OrderedSet
- Sequence
- Set

OCIL 2.4 specifies the use of parentheses to surround the element type. Eclipse OCL additionally allows angle brackets as specified by UML and as may be required to support more general templated types.

2.2.1.33. TupleType

The TupleType syntax supports the definition of a tuple type for use in a declaration or expression.



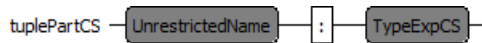
A tuple type comprises the Tuple keyword followed by a comma-separated list of one or more [TupleParts](#).

OCIL 2.4 specifies the use of parentheses to surround the parts. Eclipse OCL additionally allows angle brackets as specified by UML and as may be required to support more general templated types.

Tuple<year:Integer,month:String,day:Integer>

2.2.1.34. TuplePart

The TuplePart syntax supports the definition of an element of a TupleType.



The part comprises the name and a type and a value.

```
leapyear : Boolean
```

2.2.1.35. UnreservedName

The Essential OCL reserved words are and, else, endif, false, if, implies, in, invalid, let, not, null, or, self, then, true, xor. These can only be used as names when escaped as in `_'self'`.

2.2.1.36. UnrestrictedName

The Essential OCL restricted words are the reserved words above and the OCL reserved type names which are Bag, Boolean, Collection, Integer, Lambda, OclAny, OclInvalid, OclMessage, OclSelf, OclVoid, OrderedSet, Real, Sequence, Set, String, Tuple, UnlimitedNatural. An UnrestrictedName can be used in any context. The reserved type names can be used following a `::` qualification, Without qualification unrestricted names must be escaped as `_'Boolean'`.

Lambda is used in experimental syntax that realizes iterator bodies as lambda-expressions.

2.3. The OCLinEcore Language

Ecore Abstract Syntax supports the use of OCL embedded within EAnnotations.

The OCLinEcore language provides a textual Concrete Syntax that makes both Ecore and OCL accessible to users. Examples may be found in [OCLinEcore Library Metamodel](#) and [OCLinEcore Helpers](#).

The OCLinEcore tooling provides a rich editing environment based on Xtext with strong semantic checking.

OCLinEcore is more than just an editor for OCL in Ecore, it is useful for

- providing a coherent textual view of an Ecore meta-model
- providing syntax sugar for some Ecore conventions
- editing and validating OCL
- integrating OCL into Ecore

It is planned to take the syntactic sugar further and provide full support for all class-related UML concepts. The language therefore uses UML as its point of reference wherever possible.

The OCLinEcore tooling may be used directly on *.ecore files, or on their *.oclinecore textual counterparts.

Please follow the [OCLinEcore tutorial](#) for an introduction to the language and its tooling.

2.3.1. Syntax

The OCLinEcore syntax has a consistent structure influenced by the informal definitions in OMG specifications and by the Ecore hierarchy. Most Ecore concepts are represented by a syntax of the form:

- optional primary adjectives
- mandatory keyword
- mandatory name facet
- further facets
- an optional braced clause of secondary adjectives
- an optional braced clause of elements
 - composed elements
 - annotations

- constraints

Thus in:

```
abstract class Example extends Base { interface } { ... }
```

- `abstract` is a primary adjective
- `class` is a keyword
- `Example` is the name facet
- `extends Base` is a further facet
- `{ interface }` supports the secondary interface adjective.
- `{ ... }` provides a nested context for class content.

2.3.1.1. Grammar Implementation

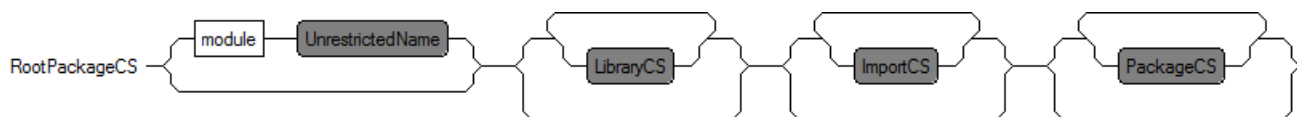
The grammar used by the Xtext editors may be found at:

/src/org/eclipse/ocl/examples/xtext/oclincore/OCLinEcore.xtext

in the `org.eclipse.ocl.xtext.oclincore` plugin. The `OCLinEcore` grammar extends the Essential OCL grammar.

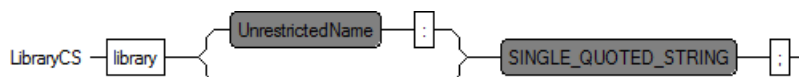
2.3.1.2. Module

The Module syntax supports the overall structure of an Ecore file



The definition of the module comprises

- optional module declaration
- optional specification of the OCL Standard libraries
- optional import of referenced Ecore or UML or OCLinEcore resources
- a hierarchy of [Packages](#)

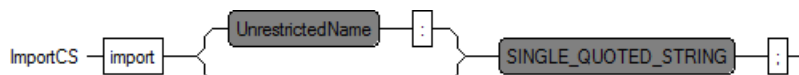


Zero or more external libraries may be imported so that their definitions are merged to form a composite library of basic and extended evaluation capability.

The implicit import of the default OCL Standard Library is suppressed, if any library is imported. The default library may be extended by specifying it as the first library import.

```
library ocl : 'http://www.eclipse.org/ocl/3.1.0/OCL.oclstdlib'
```

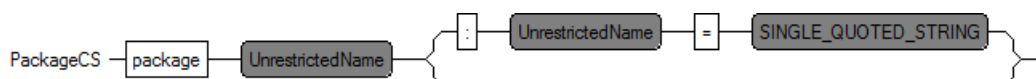
The namespace URI of the first library package defines the namespace URI of the composite library. The namespace URI of subsequent library imports may not conflict, but may be null.



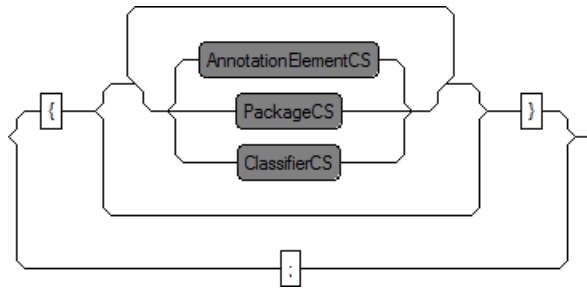
Zero or more external metamodels may be imported.

2.3.1.3. Package

The Package syntax supports a nested hierarchy of packages and classifiers



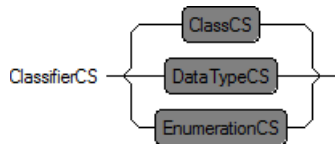
A Package has a name and optionally a namespace prefix and namespace URI.



The content of a Package may comprise [Packages](#), [Classifiers](#) and [Annotations](#).

2.3.1.4. Classifier

The Classifier syntax supports the definition of types within a [Package](#).



A Classifier may be

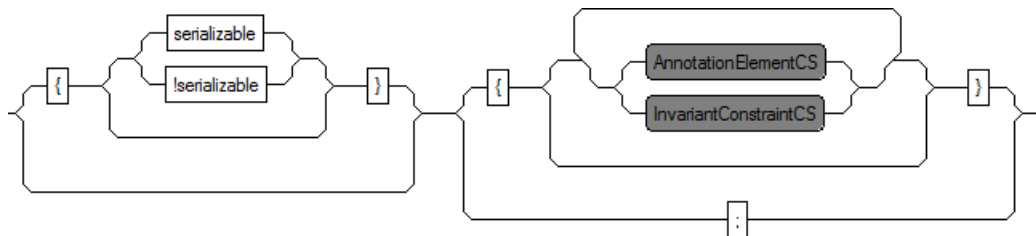
- a [Class](#)
- a [DataType](#)
- an [Enumeration](#) with associated [EnumerationLiterals](#)

2.3.1.5. DataType

The DataType syntax supports the definition of an EDataType.



A DataType has a name and optionally template parameters and an instance class name.



A DataType may be serializable; by default it is not.

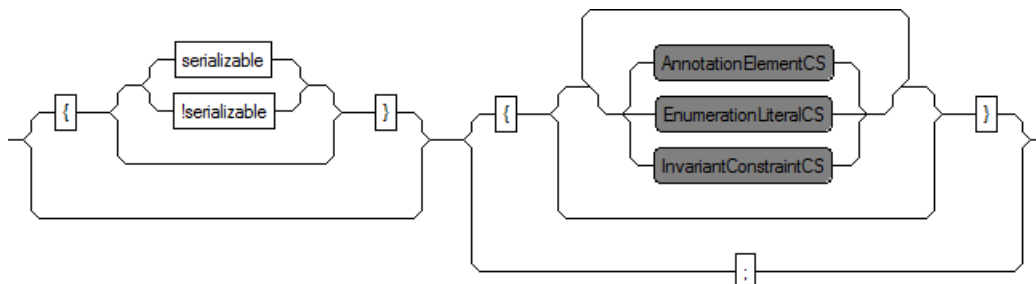
The content of a DataType may comprise [invariants](#) and [Annotations](#).

2.3.1.6. Enumeration

The Enumeration syntax supports the definition of an EEnum.



An Enumeration has a name and optionally template parameters and an instance class name.

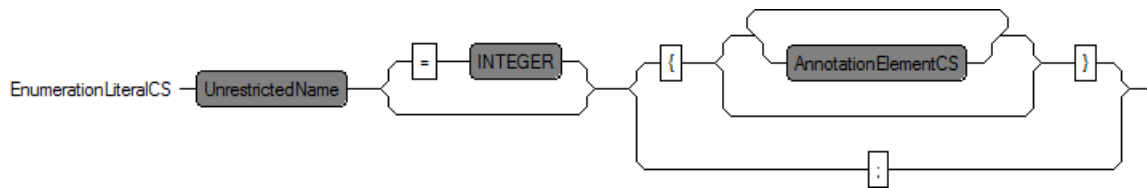


An Enumeration may be serializable; by default it is not.

The content of an Enumeration may comprise enumeration literals, [invariants](#) and [Annotations](#).

2.3.1.7. EnumerationLiteral

The EnumerationLiteral syntax supports the definition of an EEnumLiteral.



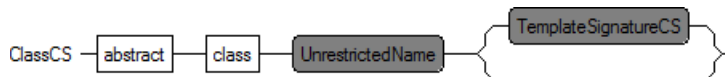
An EnumerationLiteral has a name and optionally a value.

The content of an EnumerationLiteral may comprise [Annotations](#).

2.3.1.8. Class

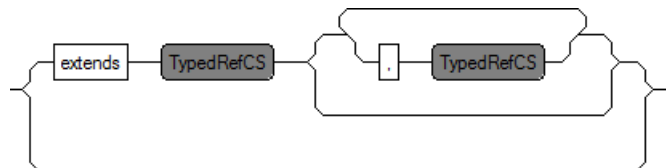
The Class syntax supports the definition of an EClass.

- optional abstract prefix
- optional extension of other classifiers
- optional invariants, annotations, features and operations



A Class may be abstract has a name and optionally template parameters.

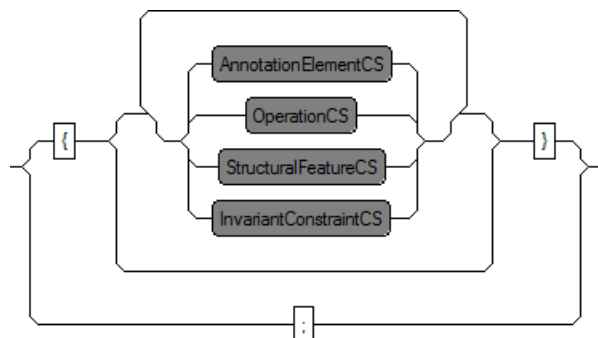
(NB, the 'abstract' prefix is optional, even though the figure indicates that it is mandatory.)



A Class may extend one or more other [Classes](#) that may be specialized using the template parameters.



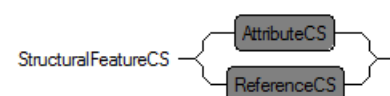
A Class may have an instance class name, and may also be declared to be an interface.



The content of a Class may comprise [Annotations](#), [Operations](#), [StructuralFeatures](#) and [invariants](#).

2.3.1.9. StructuralFeature

The StructuralFeature syntax supports the definition of the StructuralFeatures.

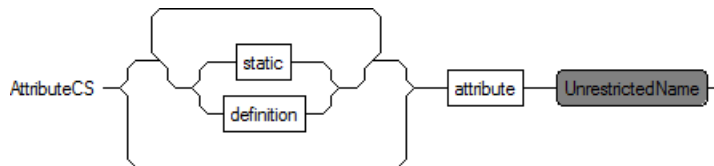


A StructuralFeature may be

- an [Attribute](#)
- a [Reference](#)

2.3.1.10. Attribute

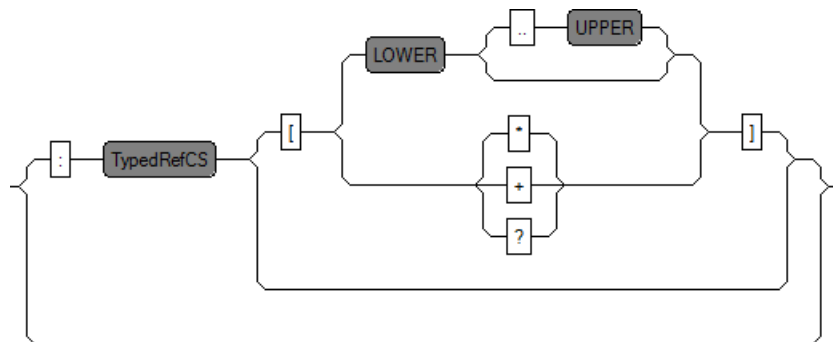
The Attribute syntax supports the definition of an EAttribute; a Property with a DataType value.



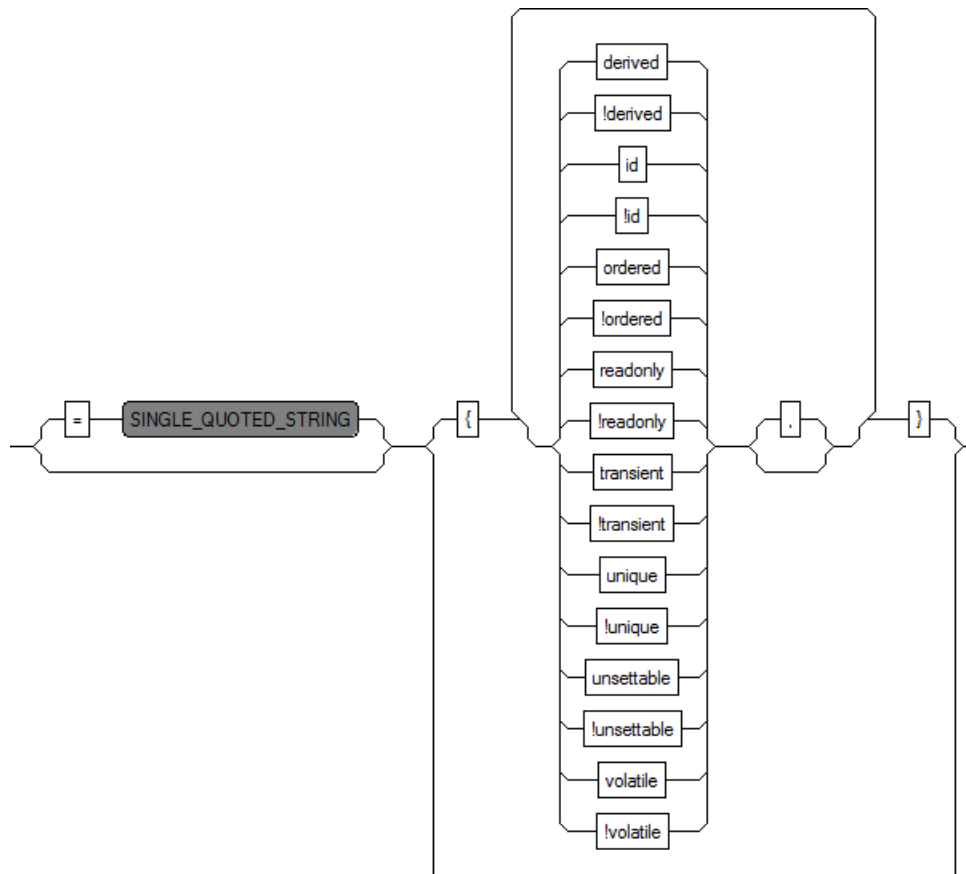
An Attribute may be static and has a name.

The *static* qualifier supports declaration of static properties which are supported by UML and OCL. Note that Ecore does not support static properties.

The *definition* qualifier is an obsolete experimental syntax for Complete OCL definitions.

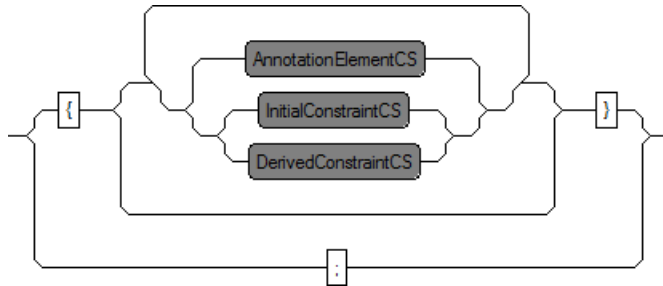


An Attribute may may have a [Type](#) and multiplicity.



An Attribute may a simple initializer and a variety of qualifiers:

- `derived` specifies a derived attribute (default `!derived`)
- `id` specifies that the attribute provides the identifier if its class (default `!id`)
- `ordered` specifies that the attribute elements are ordered (default `!ordered`)
- `readonly` specifies that the attribute elements are readonly (not changeable) (default `!readonly`)
- `transient` specifies that the attribute elements are computed on the fly (default `!transient`)
- `unique` specifies that there are no duplicate attribute elements (default `unique`)
- `unsettable` specifies that attribute element may have no value (default `!unsettable`)
- `volatile` specifies that the attribute elements are not persisted (default `!volatile`)



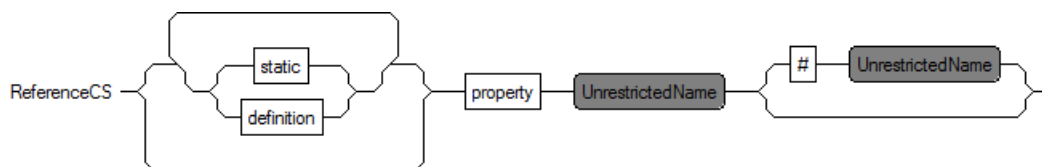
The content of an Attribute may comprise [Annotations](#), initial and derived [constraints](#).

A simple constant value may be defined using the initializer. A computed value requires the use of a constraint. If both initial and derived constraints are present, the initial constraint is ignored.

The defaults for multiplicity lower and upper bound and for `ordered` and `unique` follow the UML specification and so corresponds to a single element Set that is `[1] {unique, !ordered}`. Note that UML defaults differ from the Ecore defaults which correspond to an optional element OrderedSet, that is `[?] {ordered, unique}`.

2.3.1.11. Reference

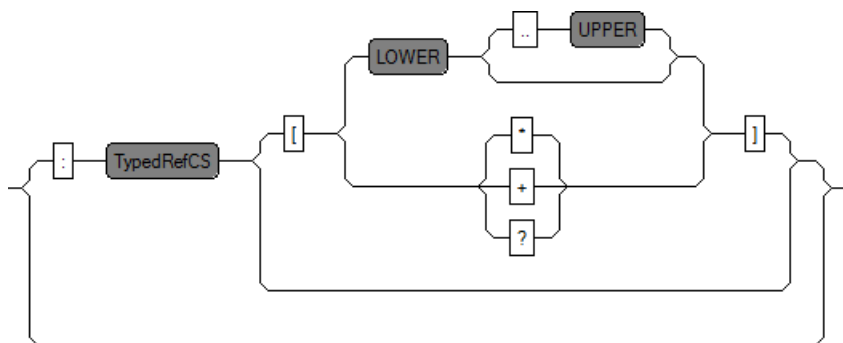
The Reference syntax supports the definition of an EReference; a Property with a Class value.



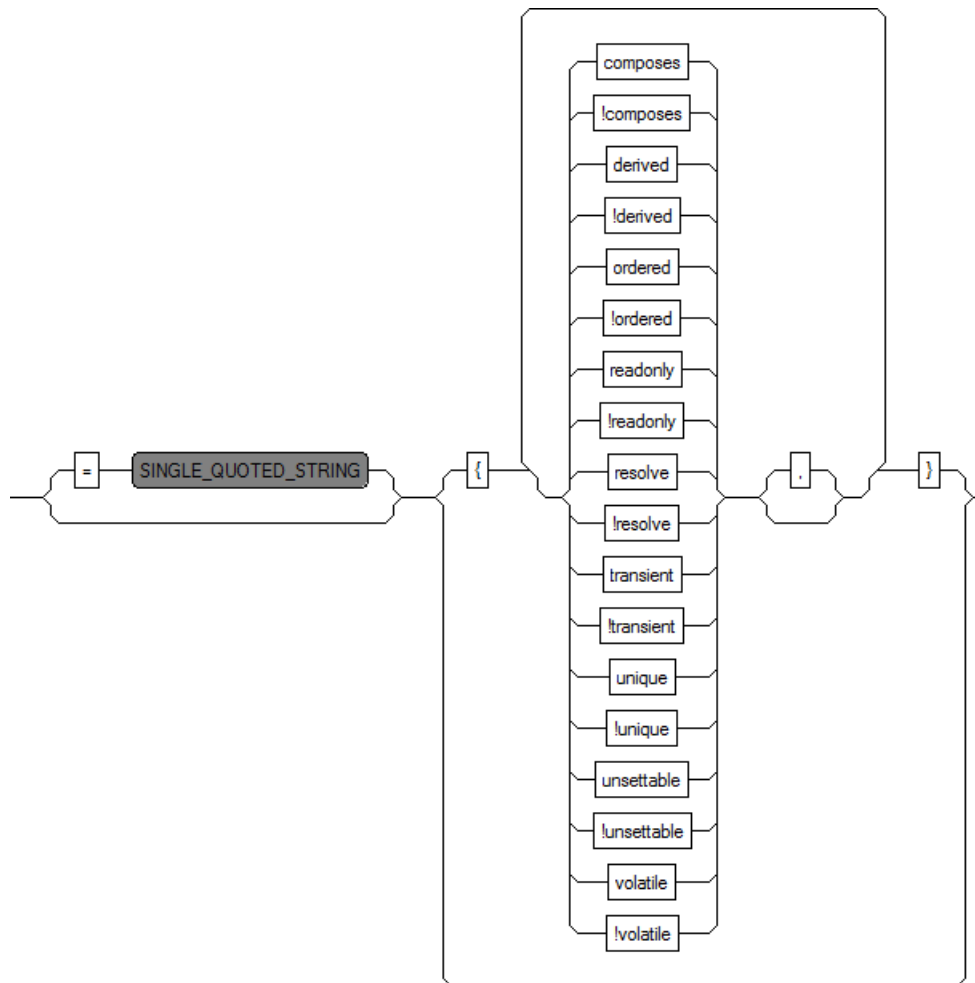
An Reference may be static and has a name and optionally an opposite name.

The `static` qualifier supports declaration of static properties which are supported by UML and OCL. Note that Ecore does not support static properties.

The `definition` qualifier is an obsolete experimental syntax for Complete OCL definitions.

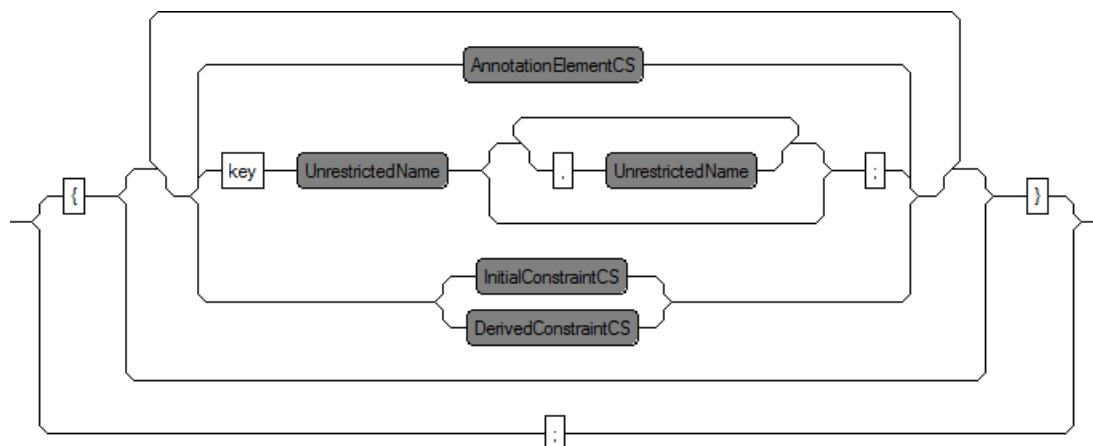


A Reference may may have a [Type](#) and multiplicity.



A Reference may a simple initializer and a variety of qualifiers:

- `composes` specifies a composed (containing) reference (default `!composes`)
- `derived` specifies a derived reference (default `!derived`)
- `ordered` specifies that the reference elements are ordered (default `!ordered`)
- `readonly` specifies that the reference elements are readonly (not changeable) (default `!readonly`)
- `resolve` specifies that the reference elements proxies may need resolution (default `!resolve`)
- `transient` specifies that the reference elements are computed on the fly (default `!transient`)
- `unique` specifies that there are no duplicate reference elements (default `unique`)
- `unsettable` specifies that reference element may have no value (default `!unsettable`)
- `volatile` specifies that the reference elements are not persisted (default `!volatile`)



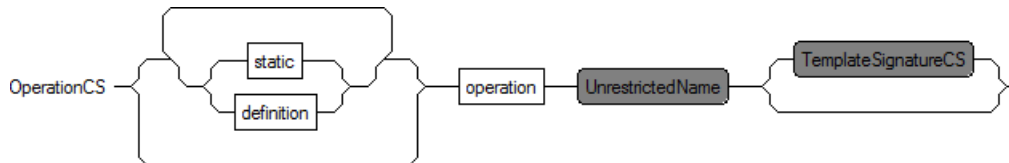
The content of a Reference may comprise keys, [Annotations](#), initial and derived [constraints](#).

A simple constant value may be defined using the initializer. A computed value requires the use of a constraint. If both initial and derived constraints are present, the initial constraint is ignored.

The defaults for multiplicity lower and upper bound and for ordered and unique follow the UML specification and so corresponds to a single element Set that is `[1] {unique, !ordered}`. Note that UML defaults differ from the Ecore defaults which correspond to an optional element OrderedSet, that is `[?] {ordered, unique}`.

2.3.1.12. Operation

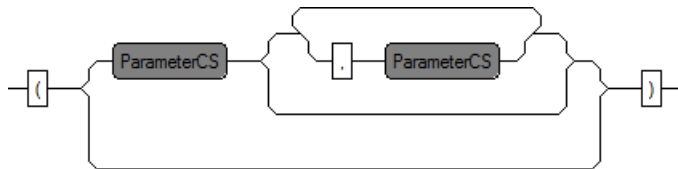
The Operation syntax supports the definition of an EOperation.



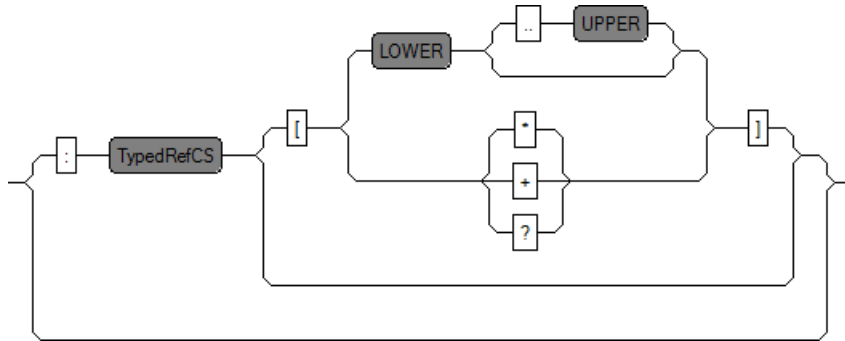
An Operation may be static and has a name and optionally template parameters.

The `static` qualifier supports declaration of static operations which are supported by UML and OCL. Note that Ecore does not support static operations.

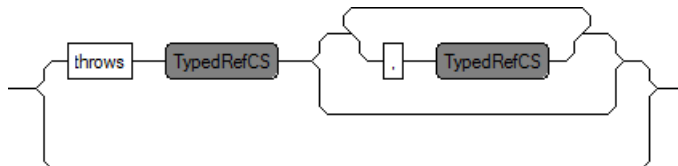
The `definition` qualifier is an obsolete experimental syntax for Complete OCL definitions.



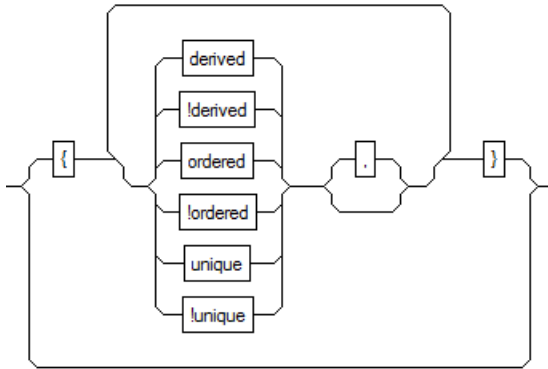
An Operation has zero or more [Parameters](#).



An Operation may have a return [Type](#) and multiplicity.

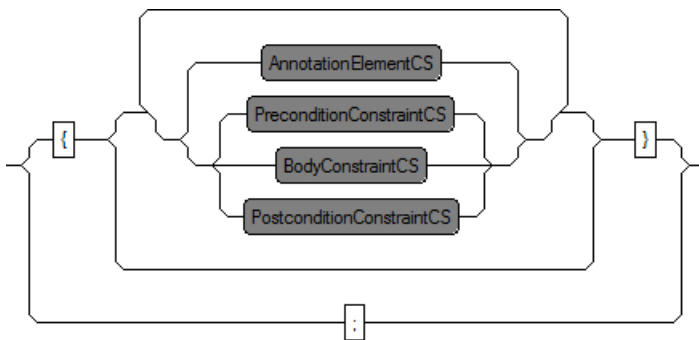


An Operation may declare zero or more throw [Exceptions](#).



An Operation may have a variety of qualifiers:

- `derived` specifies a derived operation (default `!derived`)
- `ordered` specifies that the returned elements are ordered (default `!ordered`)
- `unique` specifies that there are no duplicate returned elements (default `unique`)



The content of an Operation may comprise [Annotations](#), precondition, postcondition and body [constraints](#).

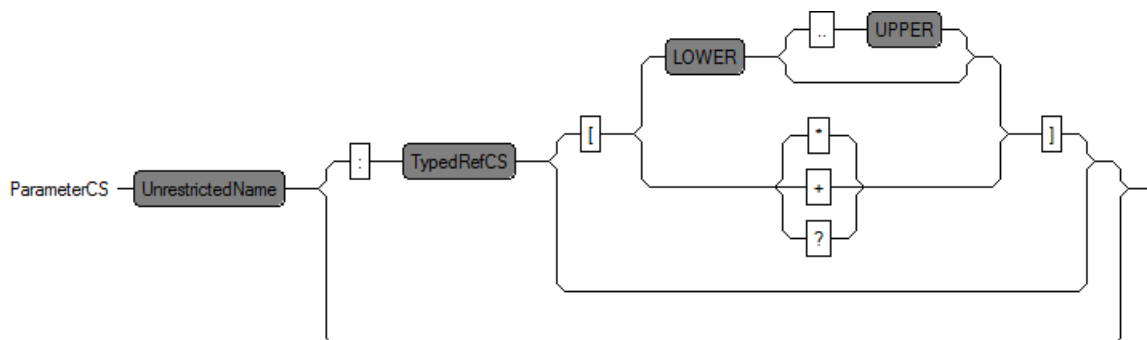
The `static` qualifier supports declaration of static operations which are supported by UML and OCL. Note that Ecore does not support static operations.

The `definition` qualifier is an obsolete experimental syntax for Complete OCL definitions.

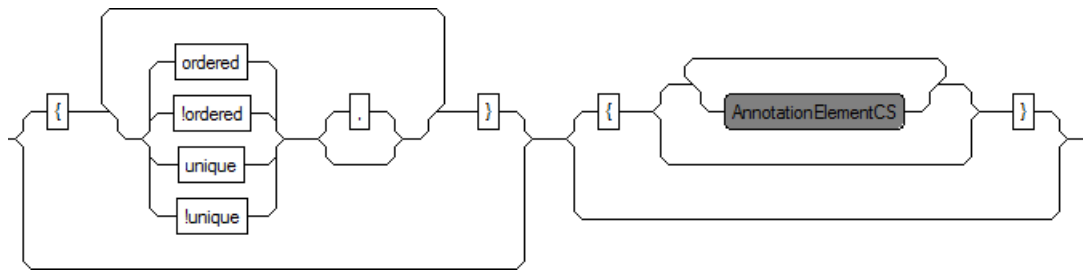
The defaults for multiplicity lower and upper bound and for `ordered` and `unique` follow the UML specification and so corresponds to a single element Set that is `[1] {unique, !ordered}`. Note that UML defaults differ from the Ecore defaults which correspond to an optional element OrderedSet, that is `[?] {ordered, unique}`.

2.3.1.13. Parameter

The Parameter syntax supports the definition of an EParameter.



A Parameter has a name, optional "Type:#OCLinEcore-TypeRef and multiplicity



A Parameter may have a variety of qualifiers:

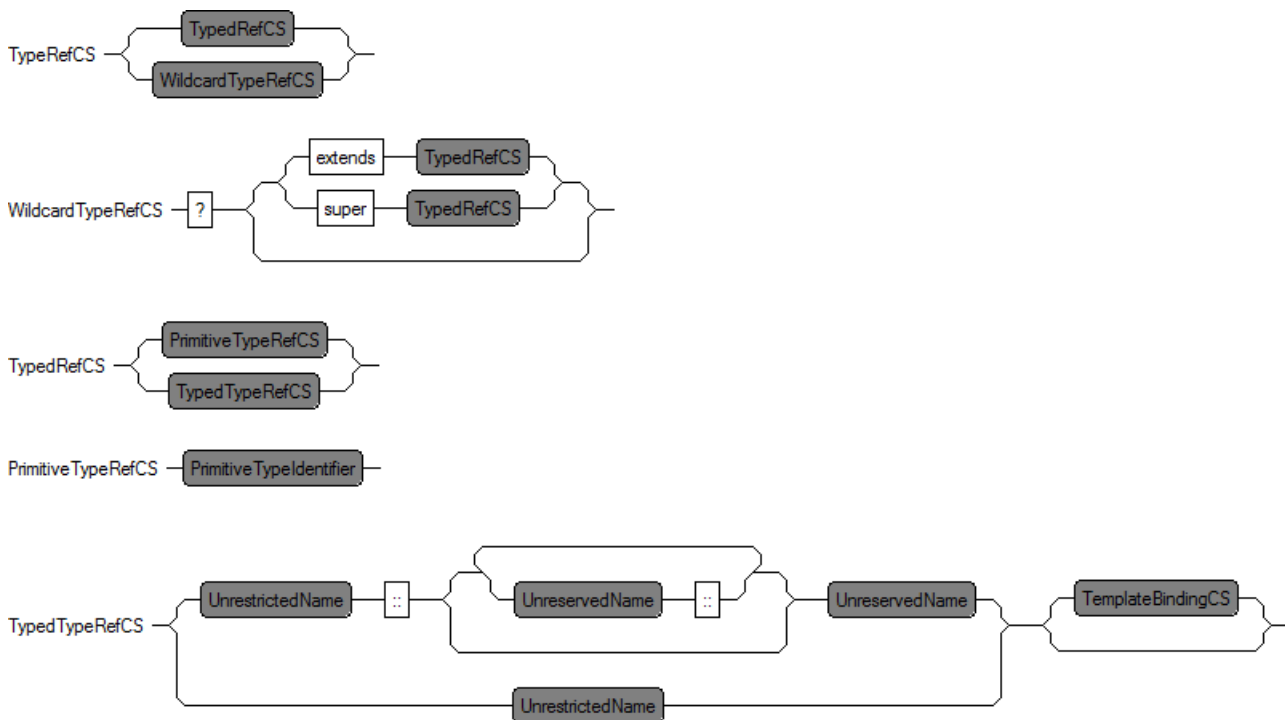
- `ordered` specifies that the returned elements are ordered (default `!ordered`)
- `unique` specifies that there are no duplicate returned elements (default `unique`)

The content of a Parameter may comprise [Annotations](#).

The defaults for multiplicity lower and upper bound and for `ordered` and `unique` follow the UML specification and so corresponds to a single element Set that is `[1] {unique, !ordered}`. Note that UML defaults differ from the Ecore defaults which correspond to an optional element `OrderedSet`, that is `[?] {ordered, unique}`.

2.3.1.14. Types

The Type syntax supports the definition of `EType` and `EGenericType` in conjunction with an `ETypedElement`. The syntax is very similar to Java.



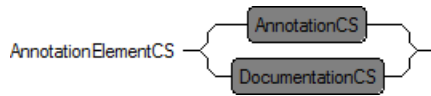
PrimitiveTypeRefCS provides access to the built-in OCL types and their corresponding Ecore counterparts

OCL type	Ecore type
Boolean	EBoolean
Integer	EBigInteger
Real	EBigDecimal
String	EString
UnlimitedNatural	EBigInteger

TypedTypeRefCS provides for user defined types and their template parameterisation.

2.3.1.15. AnnotationElement

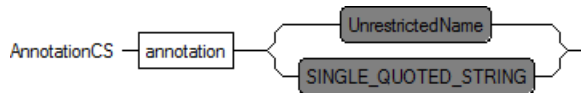
The AnnotationElement syntax supports the definition of an EAnnotation hierarchy with details, references and contents.



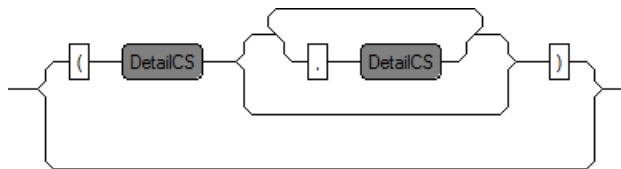
An AnnotationElement may be [Annotation](#) or [Documentation](#).

2.3.1.16. Annotation

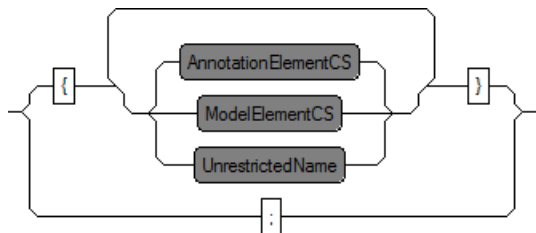
The Annotation syntax supports the definition of an EAnnotation hierarchy with details, references and contents.



An Annotation has a source URI, which may be specified without quotes if the URI is just a name.



An Annotation may have [Details](#).

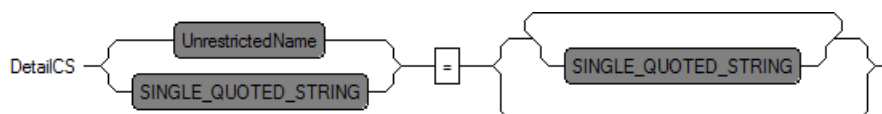


The content of an Annotation may comprise

- [Annotations](#)
- content elements
- names that reference other elements

2.3.1.17. Detail

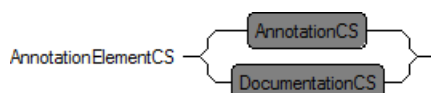
The Detail syntax supports the definition of a detail of an EAnnotation.



A detail comprises a detail key and optional value.

2.3.1.18. Documentation

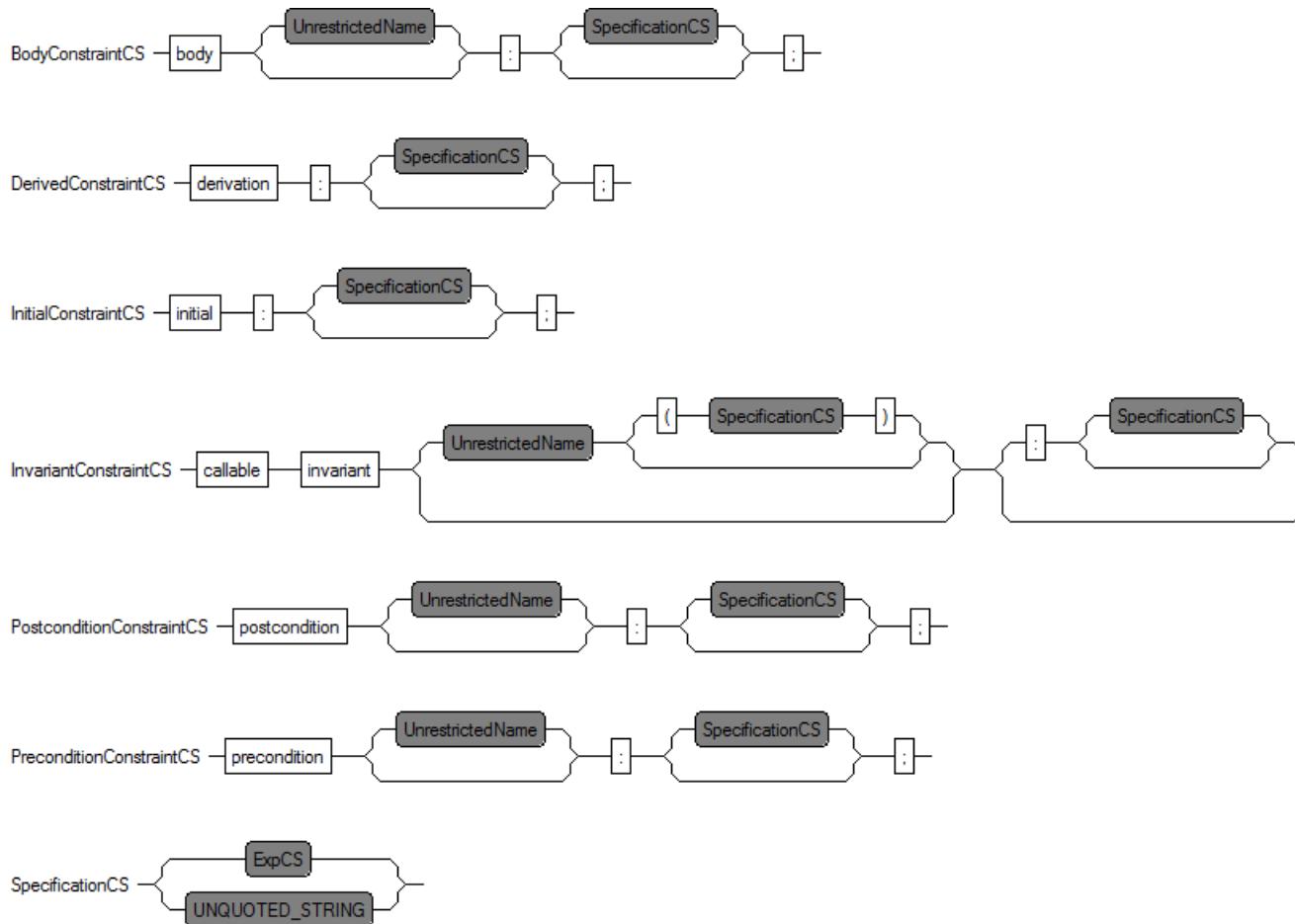
The Documentation syntax is an experimental syntactic sugar for a genmodel annotation.



It is likely to be replaced by a Javadoc-style comment that will be persisted in Ecore.

2.3.1.19. Constraints

The Constraints syntax supports the embedding of OCL expressions as invariants for classes, as preconditions, postconditions or bodies for operations and initial or derived values for properties.



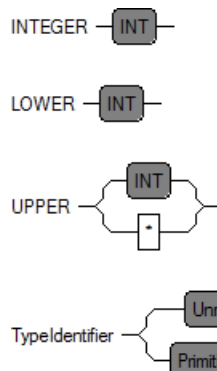
The integration occurs through the *SpecificationCS* rule that invokes an [ExpCS](#). (The alternative *UnquotedString* is an implementation detail that supports the import from Ecore where the OCL is in unparsed textual form rather than an analyzed syntax tree.)

A class invariant may be *callable* to specify that the Ecore representation is to use the EOperation rather than EAnnotation representation.

A class invariant optionally supports a second OCL expression as a parenthesis on the invariant name. This parenthesized expression is invoked when an invariant fails in order to provide a user-defined failure message. Whether this message is an error or a warning is determined by the evaluation of the invariant:

2.3.1.20. Terminals

The OCLinEcore grammar extends the Esstia OCL grammar which should be consulted for definition of INT, and ExpCS.



2.3.1.21. Names

An Unrestricted name is any name other than the OCL reserved keywords. See [UnrestrictedName](#).

An Unreserved name is any name other than the OCL reserved keywords above or the OCL reserved types. See [UnreservedName](#).

If you need to use any of these names or non-alphanumeric names, you must use the escaped string syntax for a name: e.g. `_'true'`. The usual Java backslash escapes, with the exception of octal are supported: `_'new-lines\n\x0a\u000a'`

2.3.1.22. Comments

Single line comments are supported by ignoring all text following `--`.

Multi line comments are supported by ignoring all text within `/* ... */`.

Documentation comments are supported for all text within `/** ... */`. Unfortunately no documentation EAnnotation is currently created.

2.3.2. Limitations

OCLinEcore supports the full capabilities of Ecore, however the support for upper and lower bounds on generic types has not been adequately tested.

OCLinEcore provides primary syntaxes for some Ecore conventions such as genmodel annotations and constraints; much more support is needed for feature maps.

2.4. The Complete OCL Language

The Complete OCL provides a language for a document in which OCL complements an existing meta-model with invariants, and additional features.

2.4.1. Syntax

The Complete OCL syntax is defined by the OMG OCL 2.4 specification.

The syntax comprises keywords such as `context` followed by appropriate names and punctuation and OCL expressions.

With the exception of `endpackage` there is no terminating punctuation and so the consequences of a syntax error can be quite far-reaching while editing a document. Concentrate on the first error.

A substantial example of Complete OCL may be found by installing the [RoyalAndLoyal Example Project](#).

2.4.1.1. Grammar Implementation

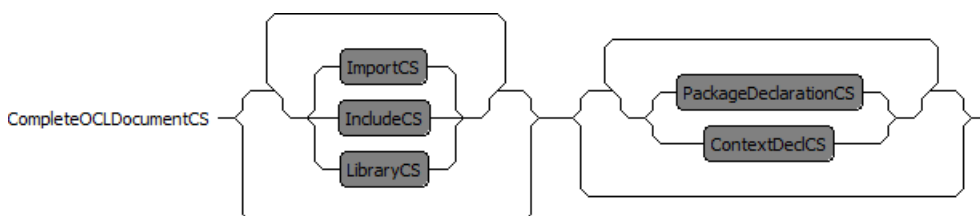
The grammar used by the Xtext editors may be found at:

`/src/org/eclipse/ocl/examples/xtext/completeocl/CompleteOCL.xtext`

in the `org.eclipse.ocl.xtext.completeocl` plugin. The Complete OCL grammar extends the Essential OCL grammar.

2.4.1.2. Complete OCL Document

The Document syntax defines a Complete OCL document, for which `*.ocl` is the default extension.

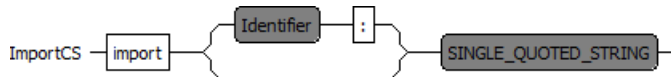


A Complete OCL document may

- import meta-models to be complemented
- include additional Complete OCL documents
- specify one or more Standard Library documents

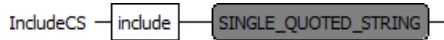
and then provide complements for one or more Packages, Classifiers or Features.

The import, include and library declarations are Eclipse OCL extensions. The OCL 2.4 specification provides no mechanism for a Complete OCL document to reference external material.

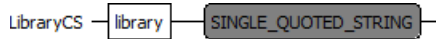


The primary definitions of each meta-model may be imported by specifying the URI of a Package and optionally an alias for that Package.

The import may be from a *.ecore, *.uml or *.oclinecore file.



Additional documents complementing meta-model may be included by specifying the URI of the Complete OCL document.



Zero or more external libraries may be imported so that their definitions are merged to form a composite library of basic and extended evaluation capability.

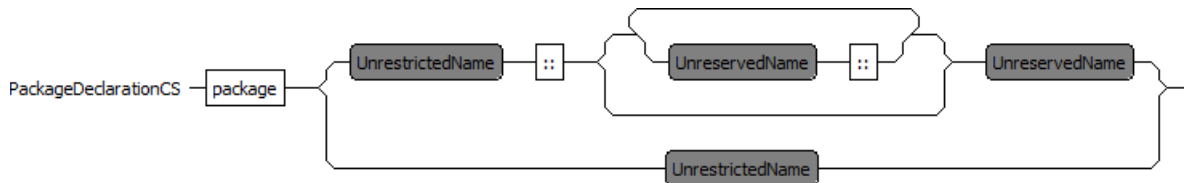
The implicit import of the default OCL Standard Library is suppressed, if any library is imported. The default library may be extended by specifying it as the first library import.

```
library ocl : 'http://www.eclipse.org/ocl/3.1.0/OCL.oclstdlib'
```

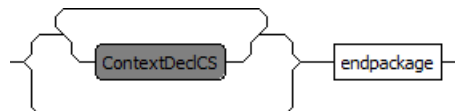
The namespace URI of the first library package defines the namespace URI of the composite library. The namespace URI of subsequent library imports may not conflict, but may be null.

2.4.1.3. PackageDeclaration

The PackageDeclaration syntax identifies a Package to be complemented.



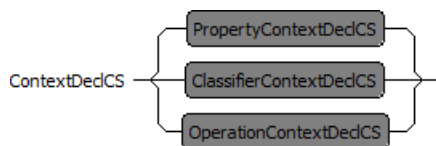
The package keyword is followed by the optionally qualified name of the package to be complemented.



The name is followed by the [declaration contexts](#) to be complemented and finally an endpackage keyword.

2.4.1.4. ContextDecl

The ContextDecl syntax identifies a model element to be complemented.

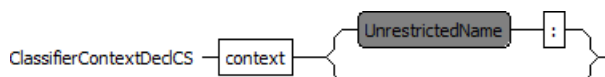


A complemented context may be a

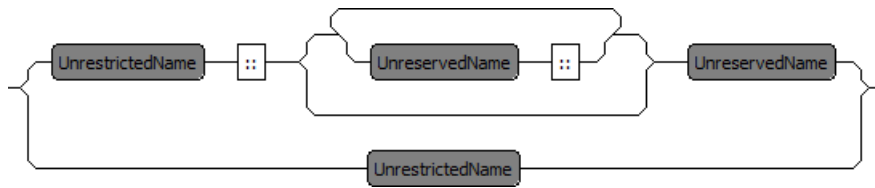
- [Classifier Context](#)
- [Operation Context](#)
- [Property Context](#)

2.4.1.5. ClassifierContextDecl

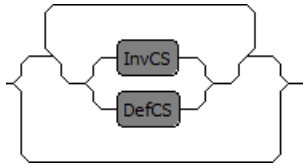
The ClassifierContextDecl syntax identifies a Classifier to be complemented.



The context keyword is followed by an optional declaration of the name of the context variable. If omitted the context variable is named `self`.



Then the optionally qualified name of the classifier to be complemented is defined. Qualification is required if the classifier context is specified directly as part of the document. Qualification may be omitted when the classifier context is specified as part of a package declaration.

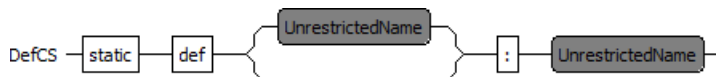


Finally the content of the classifier context may comprise

- [Def](#) to define an additional feature
- [Inv](#) to define an invariant

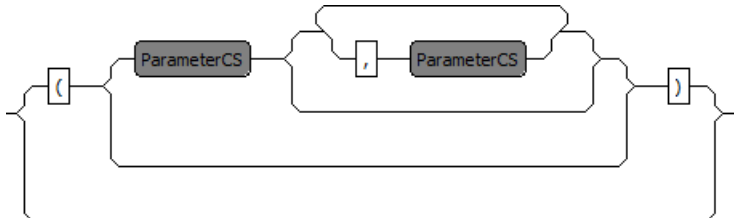
2.4.1.6. Def

The Def syntax defines an additional Feature for a Classifier.

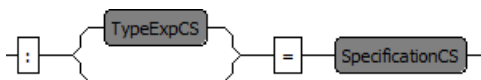


The definition may define a static feature with a feature name.

A further name may be specified for no very obvious purpose other than symmetry with an invariant. The optional name is not used.



A parenthesized [parameter](#) list must be specified to define an operation and omitted for a property definition.

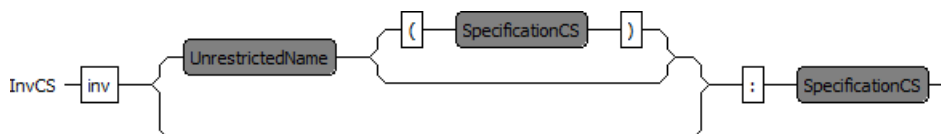


Then the property or optional operation return [type](#) is specified followed by the [specification](#) of the property initializer or operation body.

An additional definition is usable within an OCL expression as if it was defined in the complemented meta-model. For the purposes of reflection the additional appear as part of the complemented meta-model, however they remain complements and are not persisted with that meta-model.

2.4.1.7. Inv

The Inv syntax defines an invariant for a Classifier.



The inv keyword is followed by an optional invariant name an optional violation message and the [specification](#) of the invariant.

The optional name may be used by validation environments to identify the invariant in a control panel and in diagnostic messages.

The optional violation message provides an OCL expression that may be used by a validation environment to provide a custom message to explain a broken invariant. The severity of the invariant violation may be controlled by the value of the invariant expression.

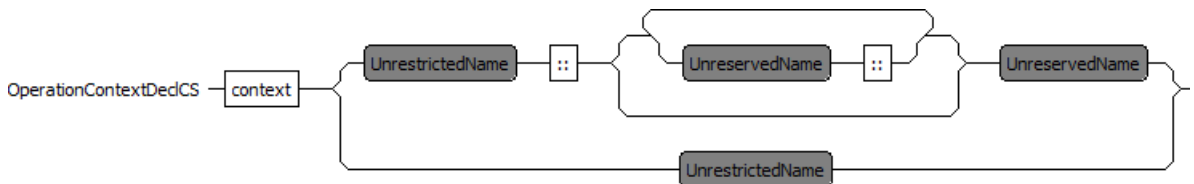
- true indicates that the invariant was satisfied
- false indicates that the invariant was violated with warning severity
- null indicates that the invariant was violated with error severity
- invalid indicates that the invariant failed to evaluate

In the Indigo release, the local variables of the invariant are not accessible to the violation message expression. This will be changed in a future release.

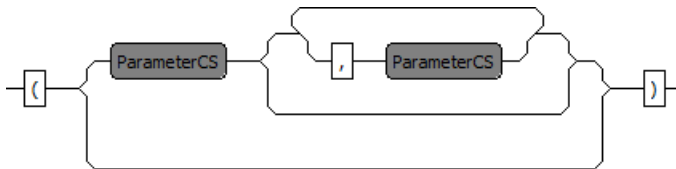
In the Indigo release, custom messages are available when a CompleteOCLEObjectValidator is used as the EValidator. This is not the case for validation in the Sample Ecore Editor and so a default message using the invariant name and the failing object is provided.

2.4.1.8. OperationContextDecl

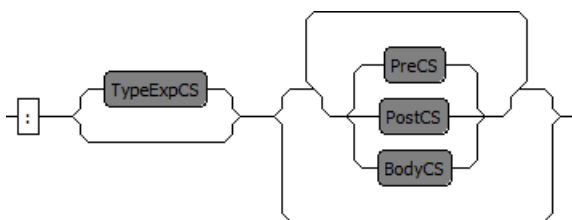
The OperationContextDecl syntax identifies an Operation to be complemented.



The context keyword is followed by the optionally qualified name of the operation to be complemented. Qualification is always required since the operation context may be specified as part of the document or a package declaration but not a classifier.



The name is followed by a parenthesized [parameter](#) list.



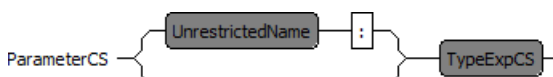
Finally an optional return [type](#) and the operation constraints are specified. The operation constraints may comprise

- a [Body](#) to define operation body
- [Pre](#) to define a precondition on the operation
- [Post](#) to define a postcondition on the operation

Any number of preconditions and postconditions can be specified. Only one body is permitted.

2.4.1.9. Parameter

The Parameter syntax identifies a Parameter of an Operation to be complemented.



A parameter comprises an optional name and Essential OCL [type](#) declaration.

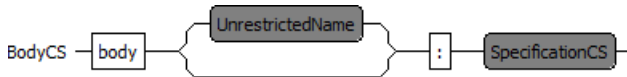
The parameter name may be omitted for [Operation Contexts](#) if the parameter name is not used by any of the constraints.

The parameter name is required for [Operation Definitions](#).

Note that the type declarations are Essential OCL types such as `Sequence<String>` rather than UML's and OCLinEcore's `String[*] {ordered !unique}`. There are plans to unify these syntaxes.

2.4.1.10. Body

The Body syntax defines the body for a complemented Operation.

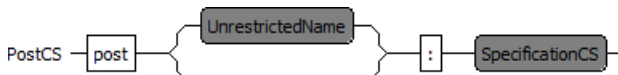


The body keyword is followed by an optional name and the body [specification](#).

The optional name is not used.

2.4.1.11. Post

The Post syntax defines a postcondition for a complemented Operation.



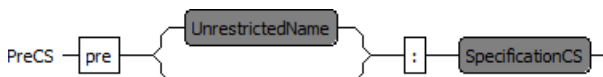
The post keyword is followed by an optional name and the postcondition [specification](#).

The optional name may be used by a validation environment to identify a failing postcondition.

The Indigo release parses and persists postconditions but does not evaluate them.

2.4.1.12. Pre

The Pre syntax defines a precondition for a complemented Operation.



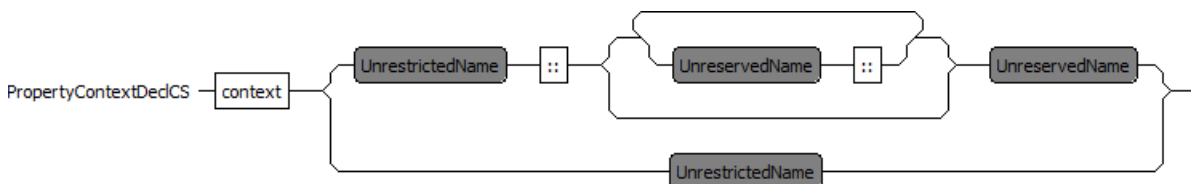
The pre keyword is followed by an optional name and the precondition [specification](#).

The optional name may be used by a validation environment to identify a failing precondition.

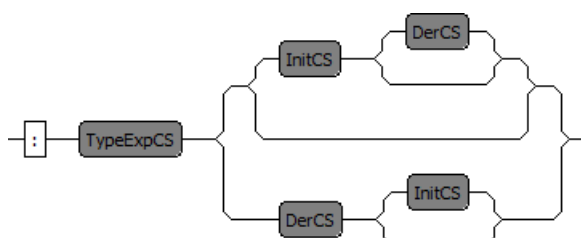
The Indigo release parses and persists preconditions but does not evaluate them.

2.4.1.13. PropertyContextDecl

The PropertyContextDecl syntax identifies a Property to be complemented.



The context keyword is followed by the optionally qualified name of the property to be complemented. Qualification is always required since the property context may be specified as part of the document or a package declaration but not a classifier.



Finally the property [type](#) and the property constraints are specified. The property constraints may comprise

- an [Init](#) to specify an initialization
- a [Der](#) to specify a derivation

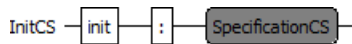
An initialization is specified to define the property value when the property is created.

A derivation is specified to define the property value at all times.

It does not therefore make sense to specify both an an initial and an all-time value. If both are specified the derivation is used.

2.4.1.14. Init

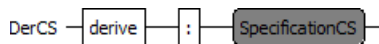
The Init syntax defines an initial value for a complemented Property.



The init keyword and colon are followed by the initial value [specification](#).

2.4.1.15. Der

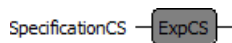
The Der syntax defines a derived value for a complemented Property.



The der keyword and colon are followed by the derived value [specification](#).

2.4.1.16. Specification

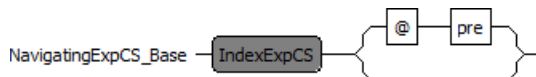
The Specification syntax provides an OCL expression to specify some aspect of a complemented model.



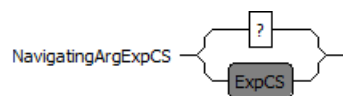
The specification comprises and [Essential OCL Expression](#).

2.4.1.17. NavigatingExp

The NavigatingExp syntax defines enhancements to the [Essential OCL NavigatingExp](#) syntax.



The name of a model element may have a further @pre qualification for use within an operation postcondition. It allows the postcondition to access the value on entry to an operation.



? may be specified as the argument in a navigating expression to indicate unknown values when testing sent messages.

2.4.1.18. NavigationOperators

The [Essential OCL NavigationOperators](#) are extended to support

- ^ to test whether a message has been sent message
- ^^ to reference the content of a message

2.4.1.19. UnreservedName

The Complete OCL reserved words are unchanged from Essential OCL, consequently a Complete OCL Unreserved name is the same as an [Essential OCL UnreservedName](#).

2.4.1.20. UnrestrictedName

The Complete OCL has two additional built-in types: `OclMessage` and `OclState`. These names and the [Essential OCL RestrictedNames](#) are not available without qualification or escaping.

2.5. The OCL Standard Library Language

The OCL Standard Library Language is used to define the OCL Standard Library, for which *.oclstdlib is the default extension.

The standard library can be replaced or extended.

The source for the OCL Standard Library may be found at model/OCL-2.5.oclstdlib in the org.eclipse.ocl.pivot plugin.

2.5.1. Syntax

2.5.1.1. Grammar Implementation

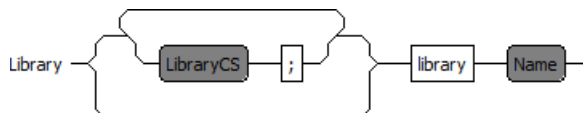
The grammar used by the Xtext editors may be found at:

/src/org.eclipse.ocl/examples/xtext/oclstdlib/OCLstdlib.xtext

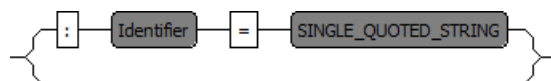
in the org.eclipse.ocl.xtext.oclstdlib plugin. The OCL Standard Library grammar extends the Essential OCL grammar.

2.5.1.2. OCL Standard Library Document

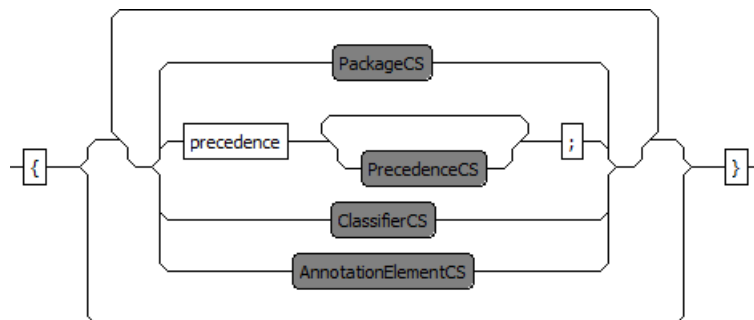
The Library syntax defines an OCL Standard Library document, for which *.oclstdlib is the default extension.



Zero or more library documents may be imported for use within the composite library whose name must be specified.

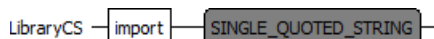


A namespace prefix and namespace URI may optionally be specified.



The body of the document comprises

- optional module declaration
- optional specification of the OCL Standard libraries
- optional import of referenced Ecore or UML or OCLinEcore resources
- [Precedences](#)
- a hierarchy of [Packages](#)
- a hierarchy of [Classifiers](#)
- Annotations



Zero or more external libraries may be imported so that their definitions are merged to form a composite library of basic and extended evaluation capability.

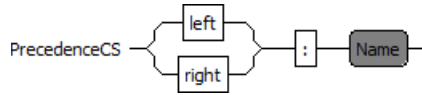
The default library may be extended by specifying it as the first library import.

```
library 'http://www.eclipse.org/ocl/3.1.0/OCL.oclstdlib'
```

The namespace URI of the first library package defines the namespace URI of the composite library. The namespace URI of subsequent library imports may not conflict, but may be null.

2.5.1.3. Precedence

The Precedence syntax defines the precedence and associativity of infix operators.

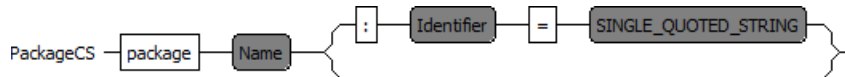


Each entry in a list of precedences names a precedence level that can then be used by an infix operator. Each level can be either left or right associative.

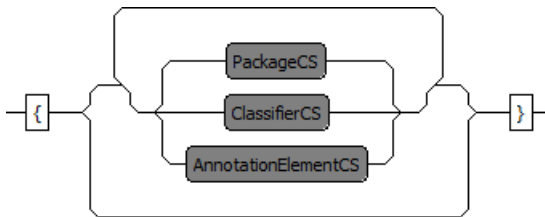
Multiple lists of precedence levels can be merged from imported libraries provided the lists are interleavable with conflict or ambiguity.

2.5.1.4. Package

The Package syntax defines a nested hierarchy of packages and classifiers.



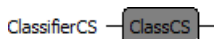
A Package has a name and optionally a namespace prefix and namespace URI.



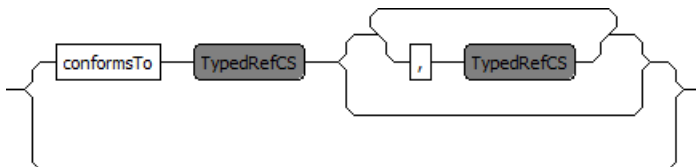
The content of a Package may comprise [Packages](#), [Classifiers](#) and Annotations.

2.5.1.5. Class and Classifier

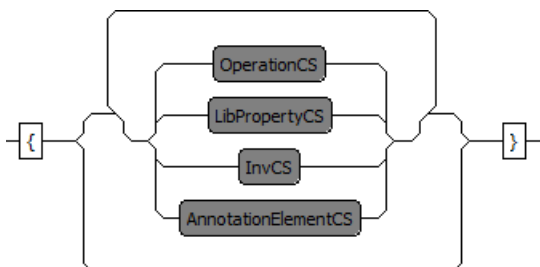
The Class and Classifier syntax define a type within a Package.



A Class has a name and optionally template parameters. A class may also name the metatype such as `PrimitiveType` that the Class is an instance of.



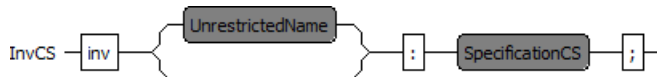
A Class may extend one or more other Classes that may be specialized using the template parameters.



The content of a Class may comprise [Operations](#), [Properties](#), [Invariants](#) and Annotations.

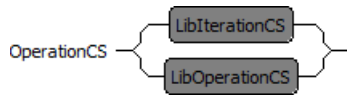
2.5.1.6. Inv

The Inv syntax defines an invariant constraint.



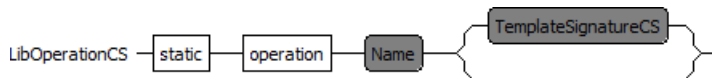
2.5.1.7. Operation

The general Operation syntax defines a conventional Operation or Iteration.

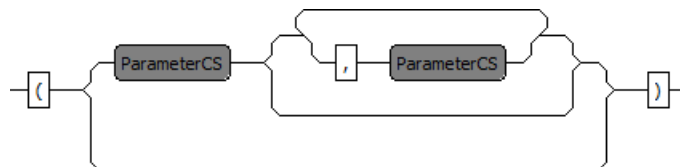


2.5.1.8. LibOperation

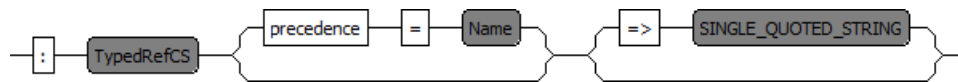
The LibOperation syntax defines a conventional Operation.



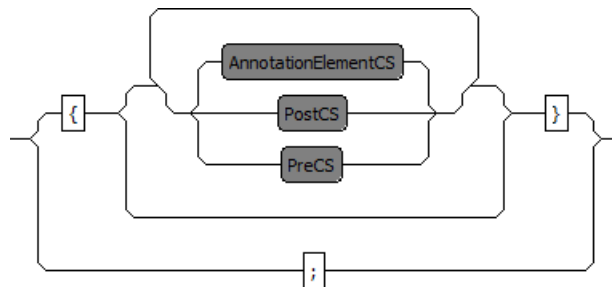
An Operation may be static and has a name and optionally template parameters.



An Operation has zero or more [Parameters](#).



An Operation has a return Type. An infix operation may specify a precedence level. An operation may specify the name of a Java class implementing the `org.eclipse.ocl.pivot.library.LibraryOperation` interface. This class is used when evaluating the operation.

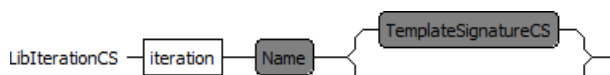


The content of an Operation may comprise [Preconditions](#), [Postconditions](#) and Annotations.

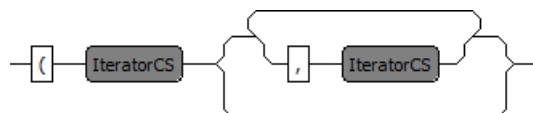
The `static` qualifier supports declaration of static library operations such as `allInstances()` that are invoked on types rather than objects.

2.5.1.9. LibIteration

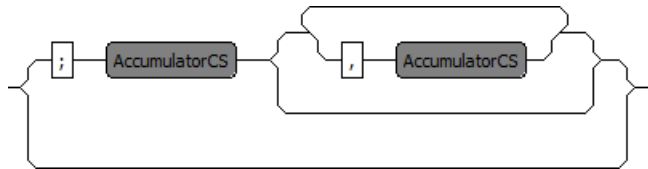
The LibIteration syntax defines an Iteration.



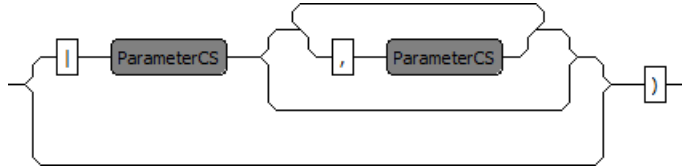
An Iteration has a name and optionally template parameters.



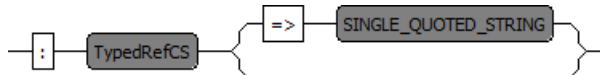
An Iteration has one or more comma-separated [Iterators](#).



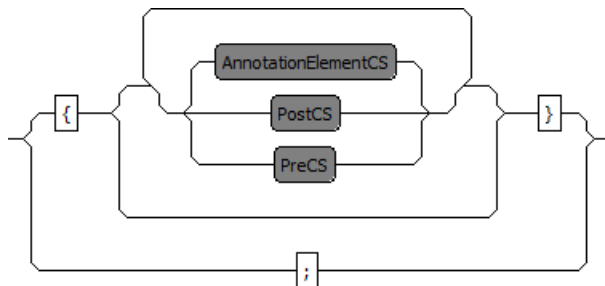
Optionally following a semicolon, an Iteration has one or more comma-separated [Accumulators](#).



Optionally following a bar, an Iteration has one or more comma-separated [Parameters](#).



An Iteration has a return Type. An Iteration may specify the name of a Java class implementing the `org.eclipse.ocl.pivot.library.LibraryIteration` interface. This class is used when evaluating the iteration.



The content of an Iteration may comprise [Preconditions](#), [Postconditions](#) and Annotations.

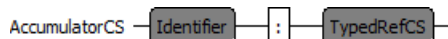
2.5.1.10. Iterator

The Iterator syntax defines an Iterator.



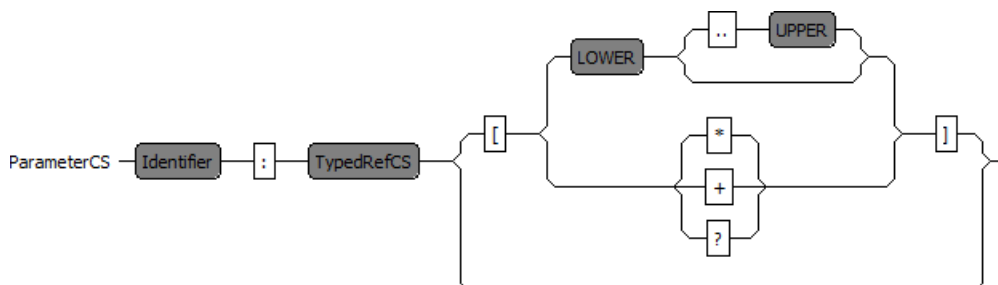
2.5.1.11. Accumulator

The Accumulator syntax defines an Accumulator.



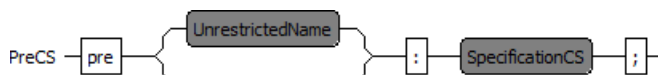
2.5.1.12. Parameter

The Parameter syntax defines a Parameter.



2.5.1.13. Pre

The Pre syntax defines a precondition constraint.



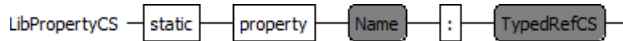
2.5.1.14. Post

The Post syntax defines a postcondition constraint.

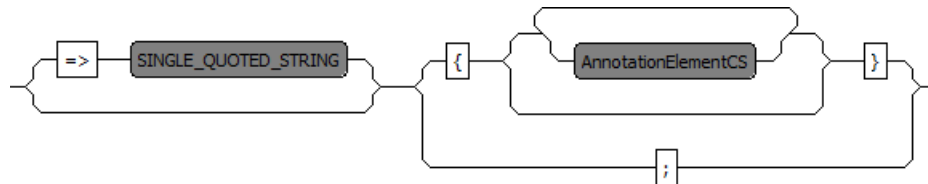


2.5.1.15. LibProperty

The LibProperty syntax defines an Property.



An Property may be static and has a name and a Type.

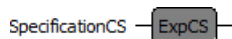


A Property may specify the name of a Java class implementing the `org.eclipse.ocl.pivot.library.LibraryProperty` interface. This class is used when evaluating the iteration.

The content of a Property may comprise Annotations.

2.5.1.16. Specification

The Specification syntax integrates an OCL Expression as the specification of a constraint.



2.6. Editors

The four editors are all generated using [Xtext](#), and so exhibit similar behavior to other Eclipse editors.

The standard facilities are

- syntax coloring
- folding
- outline view
- hover text
- syntax validation
- semantic validation

The following facilities have partial functionality

- go to definition
- content assist
- templates
- quick fixes
- find references

The following facilities have little or no functionality

- rename element
- final validation

2.6.1. Syntax coloring

The editors use similar colors to JDT.

- green for comments
- bold purple for keywords
- grey for numbers

- blue for strings

Additionally

- italics for text referencing a definition

References for which the name of the definition matches a keyword use italics in the same way as other cross references. Names of a definition matching a keyword use bold purple in the same way as keywords.

The syntax coloring may be changed using the **Window->Preferences->OCL** pages.

2.6.2. Validation

Syntax errors are detected and offending text is underlined with accompanying annotations and problem markers.

If there are no syntax errors, semantic validation is performed with similar feedback of problems. Semantic validation is not performed when there are syntax errors since a single syntax error may provoke many hundreds of semantic errors. These can make the original syntax error difficult to resolve.

The use of the well-formedness rules for a final validation of the Abstract Syntax is only partially implemented, since correction of the OCL in the OMG specification is still work in progress.

By default, the Xtext nature is not added to projects using OCL editors and so no builder runs in the background creating problem markers for OCL files. This is generally beneficial when you have many files for which the over-enthusiastic rebuilds waste build time, or experimental files for which the many errors clutter the Problem View.

If your OCL is good quality, you may activate the Xtext nature and builder by selecting the project and then invoking **Configure->Add Xtext Nature**.

2.6.3. Hover Text

Hover text has been implemented to provide feedback on the usage and type of expression terms. For instance hovering over the size operation in the example below reveals that it is an Operation for the Loan specialization of Collection.

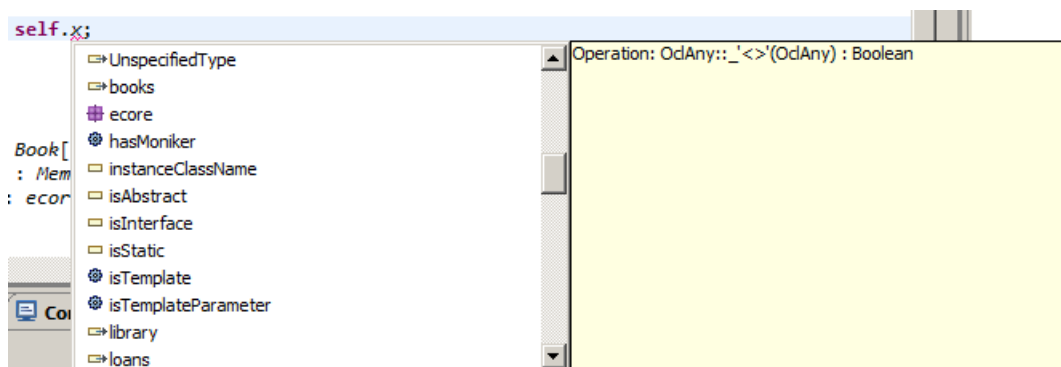
body: *loans->size()* < copies;

Operation: Collection<Loan>::size<Loan>() : Integer

(Note that the Class specialization for Loan is incorrectly shown again as an Operation specialization.)

2.6.4. Content Assist

Typing **Ctrl** and **Space** activates the Content Assist pop-up to offer suggestions as to what might be typed to the right of the cursor.



2.6.5. Code Templates

Code templates are provided for many of the major constructs and some expression elements.

You may define your own templates. If you would like to contribute them, please raise a Bugzilla.

2.6.6. Open Declaration

It is possible to navigate to a definition provided an editor is already open for the definition.

2.7. OCL Nature and Builder Auto-Validation

The build of an OCL or OCL-containing source file validates the source file and updates markers in the Problems View to identify issues that the user may care to address. Double-clicking on the Problems View Marker opens an editor to facilitate fixing the problem.

The build validation occurs whenever a source file changes or is ‘cleaned’ and when the containing project has the OCL nature configured.

If the Eclipse Workspace is configured to auto-build, the OCL builder runs automatically and so auto-validation occurs.

2.7.1. Configuring the OCL Nature and Builder

The OCL Nature may be added or removed from a Project by selecting the project in an Explorer View and invoking **Configure->Convert to OCL Project** or **Configure->Unconfigure OCL** from the context menu. Alternatively the new Project Natures page may be used from the Project Properties page.

Configuring the OCL nature modifies the **.project** file to add the **org.eclipse.ocl.pivot.ui.oclnature** nature and **org.eclipse.ocl.pivot.ui.oclbuilder**. The builder has an argument dictionaries to select file extensions and file paths that are included or excluded by the builder.

```
<arguments>
  <dictionary>
    <key>disabledExtensions</key>
    <value>*,essentialocl</value>
  </dictionary>
  <dictionary>
    <key>disabledPaths</key>
    <value>bin/**,target/**</value>
  </dictionary>
  <dictionary>
    <key>enabledExtensions</key>
    <value>ecore,ocl,oclinecore,oclstdlib,uml</value>
  </dictionary>
  <dictionary>
    <key>enabledPaths</key>
    <value>**</value>
  </dictionary>
</arguments>
```

The default configuration enables validation of **ecore,ocl,oclinecore,oclstdlib,uml** extensions and disables all other extensions, redundantly adding an explicit **essentialocl** exclusion to make the syntax more obvious to a casual reader. (*.essentialocl files may contain a single OCL expression, but since they lack any embedding within a model, they are not generally useful.)

The default configuration enables all paths except the **bin** and **target** paths where the Java builder or Maven builders may place copies of files that are not usually worth revalidating as distinct files.

The configuration in the **.project** file may be edited with a text editor; there is currently no dedicated user interface.

2.7.2. Ecore and UML Auto-Validation

The EMF and UML projects provide no nature or builder and so Problems View markers for *.ecore and *.uml files are dependent on the problems in the prevailing selection at the time of the preceding manual validation.

Since OCL may be embedded with *.ecore or *.uml files, the OCL nature and builder provide the option to auto-validate these files.

By default, your project has no OCL nature so no Ecore or UML auto-validation occurs.

If you choose to add the OCL nature, the default settings that enable *.ecore and *.uml auto-validation apply. The Problems View markers resulting from auto-validation are updated after a file is saved; any markers that the Ecore or UML editors created are replaced.

If you find that the auto-validation of some *.ecore and *.uml causes problems, perhaps because the reported errors are not a concern for your usage, you may edit the **.project** file configuration.

You may remove **ecore** and/or **uml** from the **enabledExtensions** to suppress Ecore and/or UML auto-validation completely.

You may add individual files or file patterns to the **disabledPaths** to be more selective about disabling auto-validation.

2.7.3. Building on pre-Photon / 2018 releases

The OCL builder and nature are new in the Eclipse OCL 2018 release (Photon). They comply with the standard Eclipse idiom.

In earlier releases, the EMF idiom was followed whereby Problems View markers were created by their save action of an appropriate editor. Problems in files that had not been saved were often not visible and so diagnosis only occurred when some consuming application complained..

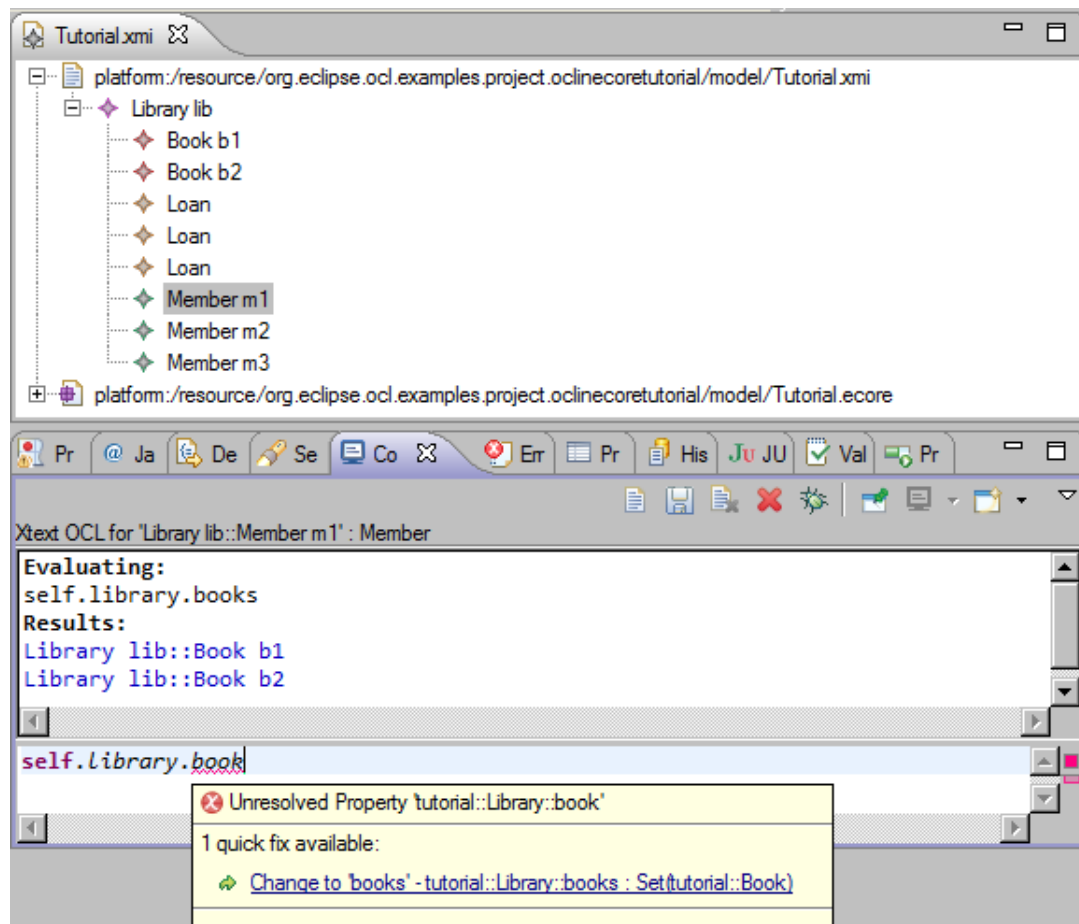
2.8. Console

There are two interactive OCL consoles that enable OCL expressions to be evaluated on a model.

The classic **Interactive Console** may be created by invoking **OCL->Show OCL Console** from the right button menu of some model editors such as the **Sample Ecore Model Editor**. Alternatively the **Console** view may be created by **Window->Show View->Console** followed by selecting **Interactive OCL** from the **Open Console** pull-down in the **Console** View tool bar. See the [OCLinEcore Tutorial](#) for detailed step-by-step pictures.

The Pivot **Interactive Xtext Console** may be similarly created by **OCL->Show Xtext OCL Console** from the menu or **Interactive Xtext OCL** from the pull-down.

The two consoles should exhibit similar behaviors, however not all facilities of the classic console have yet been reproduced on the new.



The Console, shown in the bottom half of the figure, comprises a combined Title and Tool Bar, Results Panel and Entry Panel.

2.8.1. Context Object Selection

Expressions are evaluated with respect to a context object `self` that has a corresponding metamodel type. This object is defined by selecting any widget whose implementation is adaptable to an `EObject`. Therefore selecting an `EAttribute` in the Sample Ecore Editor will make the selected `EAttribute` `self` and `EAttribute` the metamodel type. In the figure selecting the Member named `m1` in the Sample Reflective Ecore Model Editor has made Member the select type of `self` and `m1` the selected context object. For the Pivot Console there is additional support to use selections from the Outline of an Xtext editor or Variables View of the OCL Debugger as the context object.

The Pivot Console displays the selected object and type in the Console title.

The classic Console relies on the platform selection mechanism to show the selected object in the overall Eclipse Status display at the bottom left of the workspace window. This display may be lost when the selection is changed to a non-`EObject` selection.

2.8.2. Editing

The bottom panel supports entry and evaluation of a multi-line expression. The expression is evaluated when **Enter** is entered.

The classic Console has hand-coded syntax highlighting and context assist that may be activated by typing **Ctrl + Space**.

The Pivot Console uses the Xtext EssentialOCL editor and largely auto-generated syntax highlighting, error indications, hover text, quick fixes and context assist that may be activated by typing **Ctrl + Space**.

The content assist for the Pivot Console has not yet been customized, so the classic Console content assist is probably more comprehensive, however the Pivot Console shares the same library definitions as the other editors and so is more consistent.

2.8.3. Editor Keys

The **Page-Up** and **Page-Down** keys may be used to scroll through the history of input commands enabling previous commands to be re-used. Use of the Page keys is necessary since the input is potentially multi-line and so **Up** and **Down** navigate over the multiple lines.

2.8.4. Results

The larger middle panel displays the results of each evaluation in a scrolling window.

2.8.5. Tool Bar

2.8.5.1. Ecore/UML binding

The classic Console provides a selection to determine whether the context object has a type defined by an Ecore or UML metamodel. This selection is not required for the Pivot Console which automatically converts Ecore or UML models to Pivot models.

2.8.5.2. M1/M2

The classic Console provides a selection to determine whether the selected metamodel binding is that for objects (M2) or types (M1). This selection is not needed for the Pivot Console since the Pivot metamodel is an instance of itself.

2.8.5.3. Clear Console

The standard clear console functionality clears the results pane.

2.8.5.4. Close Console

The standard close console functionality closes the current console.

2.8.5.5. Debug

Starts the [OCL Debugger](#) using the current mouse selection as self and the text in the Console input as the expression to execute.

2.8.5.6. Load/Save an expression

The classic Console provides an ability to save and reload edited expressions as XMI files. The XMI is a pragmatic Eclipse Ecore realisation of the OCL specification for which XMI interchange is not realisable.

The Pivot Console provides a similar ability to save and reload edited expressions as XMI files. The XMI is a prototype that might evolve and be adopted by a future version of the OCL specification. *This functionality has not been properly tested.*

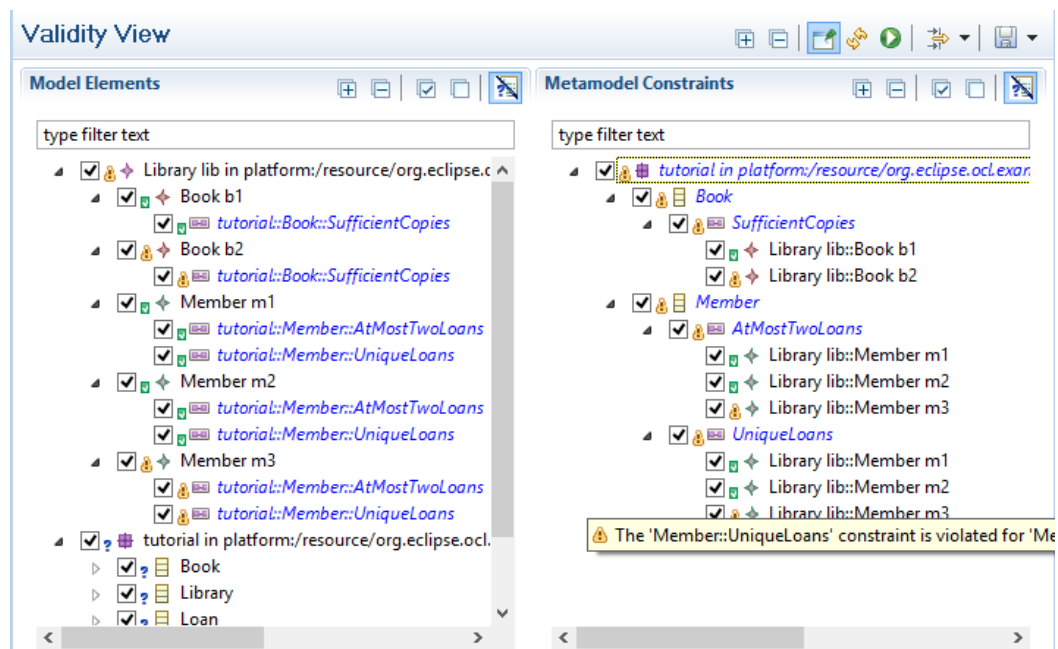
2.9. Validity View (new in Luna)

The standard EMF validation capabilities provide a useful overview of problems:

- as markers in the source model,
- as markers in the Problems View,
- in Pop-up dialogs.

The **Validity View** provides a much more detailed view of the problems and so assists in debugging bad models and/or bad constraints.

The **Validity View** may be shown by invoking **OCL->Show Validity View** from the right button menu of some model editors such as the **Sample Ecore Model Editor**. Alternatively the **Validity View** view may be created by **Window->Show View->Other... OCL->Validity View**.



The left-hand pane titled Model Elements provides a tree view of the Resources in a ResourceSet in a similar fashion to the Sample Ecore Editor. However an additional child element (in blue italics) is added for each constraint applicable to its parent element. Checkboxes enable or disable the element from re-validations and JUnit-like status icons show the status of the most recent validation. Hovertext provides further detail.

The right-hand pane titled Metamodel Constraints provides a tree view of the model hierarchies that contribute constraints. An additional child element is added for each model element to which the constraint applies.

The displays track the mouse selection in other views. Whenever the mouse selection can be resolved to an EObject, that EObject's ResourceSet populates the left hand pane and constraints affecting the left hand pane populate the right hand pane. Tracking the mouse selection is quite expensive, and probably irritating. It can be inhibited by pinning the view to the current selection.

There is generally much too much detail if all elements and constraints are considered and so the view provides many facilities to facilitate focusing on the interesting combinations.

2.9.1. View Tool Bar

The View Tool Bar is at the top and right of the view following the Validity View title. It provides facilities common to both Model Elements and Metamodel Constraints.

2.9.1.1. Expand All

The plus icon causes the Model Elements and Metamodel Constraints to be fully expanded to display all their contents. Beware that for large models this may result in slow screen updates.

2.9.1.2. Collapse All

The minus icon causes the Model Elements and Metamodel Constraints to collapse to display only their top level elements.

2.9.1.3. Pin

The pin icon toggles the track current cursor selection. When unpinned, the default, any change in mouse selection may cause recomputation of Model Elements and Metamodel Constraints contents. When pinned the contents are stable.

2.9.1.4. Refresh

The double arrow icon causes the Model Elements and Metamodel Constraints to be recomputed. This may be necessary for a metamodel change to be used.

2.9.1.5. Run

The white triangle in green circle icon runs a validation on all enabled model element/constraint combinations updating the status indications for constraints in the left hand Model Element and model elements in right hand Constraint pane.

2.9.1.6. Filter

The Filtering menu hides unwanted contributions to the display. Each of the validation result statuses can be individually enabled.

- Show all errors
- Show all infos
- Show all failures
- Show all warnings
- Show all successes

By default none of the selections are enabled so everything is shown. As soon as a specific status is enabled all display elements with other non-enabled statuses are hidden. Thus selecting just "Show all warnings" hides error/info/failure/success results.

2.9.1.7. Save

The floppy disk icon supports export of the validation results.

The available export formats are extensible through the `org.eclipse.ocl.examples.emf.validation.validity.validity_exporter` extension point.

The default exporters support

html

An HTML file summarising the results.

model

An XMI model conforming to `validity.ecore` containing all results with references to the model elements and constraints.

text

A text file summarising the results.

2.9.2. Model Elements Pane

The Model Elements Pane is the left hand pane of the Validity View.

It comprises a title and tool bar, text filter and scrollable tree of model elements and their constraints.

2.9.2.1. Model Elements Tool Bar

The Model Elements Tool Bar is at the top and right of the left hand pane following the Model Elements title. It provides facilities specific to the Model Elements.

Expand All

The plus icon causes the Model Elements to be fully expanded to display all their contents. Beware that for large models this may result in slow screen updates.

Collapse All

The minus icon causes the Model Elements to collapse to display only their top level elements.

Enable All

The tick icon causes all Model Elements to be enabled and so included in the next validation.

Disable All

The no-tick icon causes all Model Elements to be disabled and so excluded from the next validation.

Show/Hide disabled

The document icon with a query controls whether disabled Model Element selections are visible. A diagonal strikethrough shows when selections are hidden.

By default disabled selections are hidden, which allows the unwanted root elements of large models to be unchecked and so hidden before a slow attempt is made to display them.

2.9.2.2. Text Filter

The text filter takes a StringMatcher pattern that selects which elements are visible. The pattern may contain

- a * to match zero or more characters
- a ? to match exactly one character
- a \ to escape the following character

2.9.2.3. Model Elements tree

The scrollable tree shows the containment hierarchy of all elements in the ResourceSet containing the model element identified by the mouse selection.

The +/- collapse/expand icons preceding each element enable interesting elements to be shown and others folded away.

Each element is preceded by a check box that enables its usage within the next validation run. All elements may be enabled or disabled using the icons in the Model Elements Tool Bar. Enabling/disabling individual elements enables/disables the element's descendants and propagates a partial enable/disable to the element's ancestors.

The checkbox is followed by a validation status icon.

- tick for validation successful
- red cross for validation unsuccessful but incomplete
- blue cross for validation failure (incomplete)
- amber warning for a validation warning
- question mark for no validation performed

The status icon is followed by an element-specific icon identifying its type and label.

Double-clicking a leaf Constraint in the left-hand pane makes the corresponding constraint and parent model-element visible in the right-hand pane.

2.9.2.4. Model Elements Context Menu

The context menu in the model elements tree offers the following facilities in addition to those also available in the toolbar.

Validate Selection

Revalidates all constraints applicable to the selected Model Element and its children.

Debug Single Enabled Selection

Launches the debugger for the selected Model Element and associated Constraint.

The entry is greyed out if more than one Constraint is selected, so the invocation should normally be made from a leaf Constraint result.

Debug launching is only available for OCL constraints in Luna SR0.

Show in Editor

Opens an editor for the selected Model Element or Metamodel Constraint.

Opening is not available for all forms of constraint in Luna SR0.

2.9.3. Metamodel Constraints Pane

The Metamodel Constraints Pane is the right hand pane of the Validity View.

It comprises a title and tool bar, text filter and scrollable tree of metamodel constraints and the model elements to which they apply.

2.9.3.1. Metamodel Constraints Tool Bar

The Metamodel Constraints Tool Bar is at the top and right of the right hand pane following the Metamodel Constraints title. It provides facilities specific to the Metamodel Constraints.

Expand All

The plus icon causes the Metamodel Constraints to be fully expanded to display all their contents. Beware that for large models this may result in slow screen updates.

Collapse All

The minus icon causes the Metamodel Constraints to collapse to display only their top level elements.

Enable All

The tick icon causes all Metamodel Constraints to be enabled and so included in the next validation.

Disable All

The no-tick icon causes all Metamodel Constraints to be disabled and so excluded from the next validation.

Show/Hide disabled

The document icon with a query controls whether disabled Metamodel Constraints selections are visible. A diagonal strikethrough shows when selections are hidden.

By default disabled selections are hidden, which allows the unwanted root elements of large metamodels to be unchecked and so hidden before a slow attempt is made to display them.

2.9.3.2. Text Filter

The text filter takes a StringMatcher pattern that selects which elements are visible. The pattern may contain

- a * to match zero or more characters
- a ? to match exactly one character

- a \ to escape the following character

2.9.3.3. Metamodel Constraints tree

The scrollable tree shows the containment hierarchy of all constraints applicable to model elements in the ResourceSet containing the model element identified by the mouse selection.

The +/- collapse/expand icons preceding each element enable interesting elements to be shown and others folded away.

Each element is preceded by a check box that enables its usage within the next validation run. All elements may be enabled or disabled using the icons in the Model Elements Tool Bar. Enabling/disabling individual elements enables/disables the element's descendants and propagates a partial enable/disable to the element's ancestors.

The checkbox is followed by a validation status icon.

- tick for validation successful
- red cross for validation unsuccessful but incomplete
- blue cross for validation failure (incomplete)
- amber warning for a validation warning
- question mark for no validation performed

The status icon is followed by an element-specific icon identifying its type and label.

Double-clicking a leaf Model Element in the right-hand pane makes the corresponding Model Element and parent Metamodel Constraint visible in the left-hand pane.

2.9.3.4. Metamodel Constraints Context Menu

The context menu in the metamodel constraints tree offers the following facilities in addition to those also available in the toolbar.

Validate Selection

Revalidates all model elements applicable to the selected constraint and its children.

Debug Single Enabled Selection

Launches the debugger for the selected Model Element and associated Constraint.

The entry is greyed out if more than one Constraint is selected, so the invocation should normally be made from a leaf Model Element result.

Debug launching is only available for OCL constraints in Luna SR0.

Show in Editor

Opens an editor for the selected Model Element or Metamodel Constraint.

Opening is not available for all forms of constraint in Luna SR0.

2.9.4. Constraint Locators

The constraints displayed in the right hand pane are located by constraint locators that are registered with the `org.eclipse.ocl.examples.emf.validation.validity.constraint_locator` extension point. A constraint locator implements `org.eclipse.ocl.examples.emf.validation.validity.locator.ConstraintLocator` or the `org.eclipse.ocl.examples.emf.validation.validity.ui.locator.ConstraintUILocator` to define location, presentation, execution and debug launching of a particular kind of constraint.

Constraint locators are associated with metamodel namespaces which are determined by the nsURI of the EPackage that contains the EClass of a Model Element EObject. Constraint locators may be registered for a particular metamodel namespace or for no namespace. Those registered for no namespace are activated whenever a namespace is encountered for which no specific constraint locators are registered.

The following Constraint Locators are available by default.

2.9.4.1. `org.eclipse.ocl.examples.emf.validation.validity.locator.EClassConstraintLocator`

This constraint locator supports discovery of constraints realized by invariant EOperations in the Java code generated by an EMF genmodel.

2.9.4.2. org.eclipse.ocl.examples.emf.validation.validity.locator.EValidatorConstraintLocator

This constraint locator supports reflective discovery of validateXXXX methods in the Java code generated by an EMF genmodel using the EValidatorRegistry to identify the relevant Java code.

2.9.4.3. org.eclipse.ocl.examples.validity.locator.DelegateUIConstraintLocator

This constraint locator supports OCL constraints represented as EAnnotations in Ecore metamodels.

2.9.4.4. org.eclipse.ocl.examples.validity.locator.PivotUIConstraintLocator

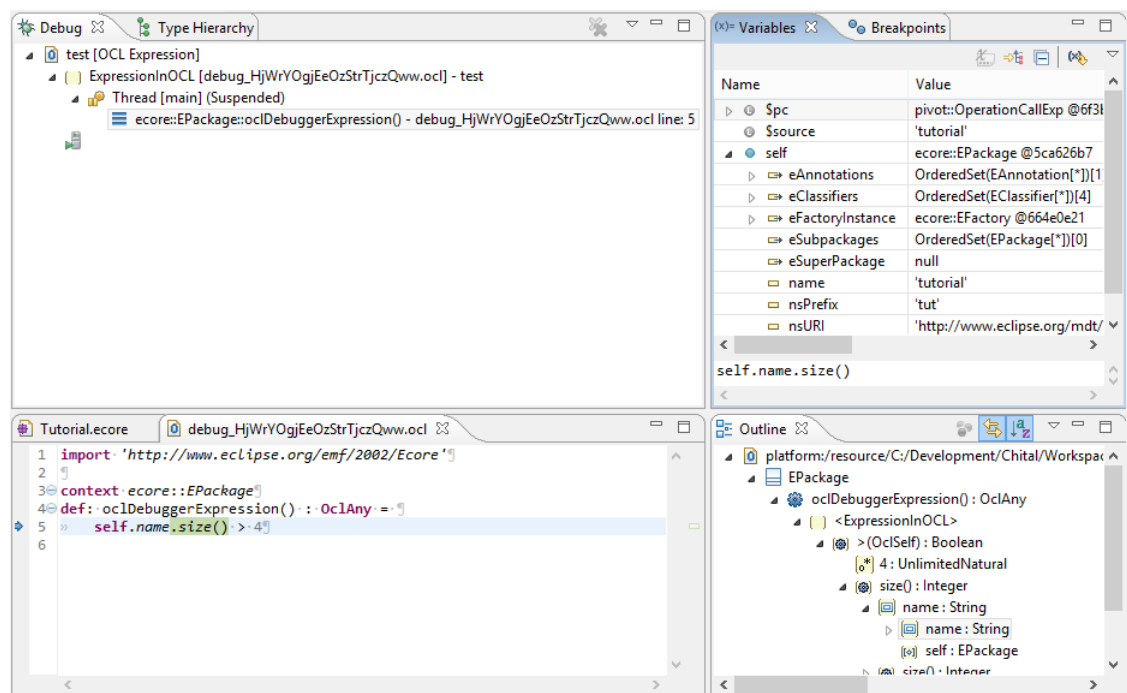
This constraint locator supports discovery of org.eclipse.ocl.pivot.Constraint classes in Pivot metamodels.

2.9.4.5. org.eclipse.ocl.examples.validity.locator.UMLUIConstraintLocator

This constraint locator supports discovery of org.eclipse.uml2.uml.Constraint classes in UML metamodels.

2.10. Debugger (new in Luna)

The OCL debugger supports debugging OCL constraints. It is a customization of the standard Eclipse debugger and so most of the facilities should be familiar to users of the Eclipse Java debugger.



The screenshot shows

- Debug Stack Trace showing the context of nested evaluation environments
- Variables View showing intermediate and local variables
- Editor showing input and context after a couple of steps
- Outline showing the Concrete Syntax Tree context

The OCL Debugger is very new, there are no doubt many opportunities for ergonomic improvements and bug fixes. Please raise a [Bugzilla](#).

2.10.1. Launching

Launching the debugger for an OCL constraint requires the user to provide two pieces of information

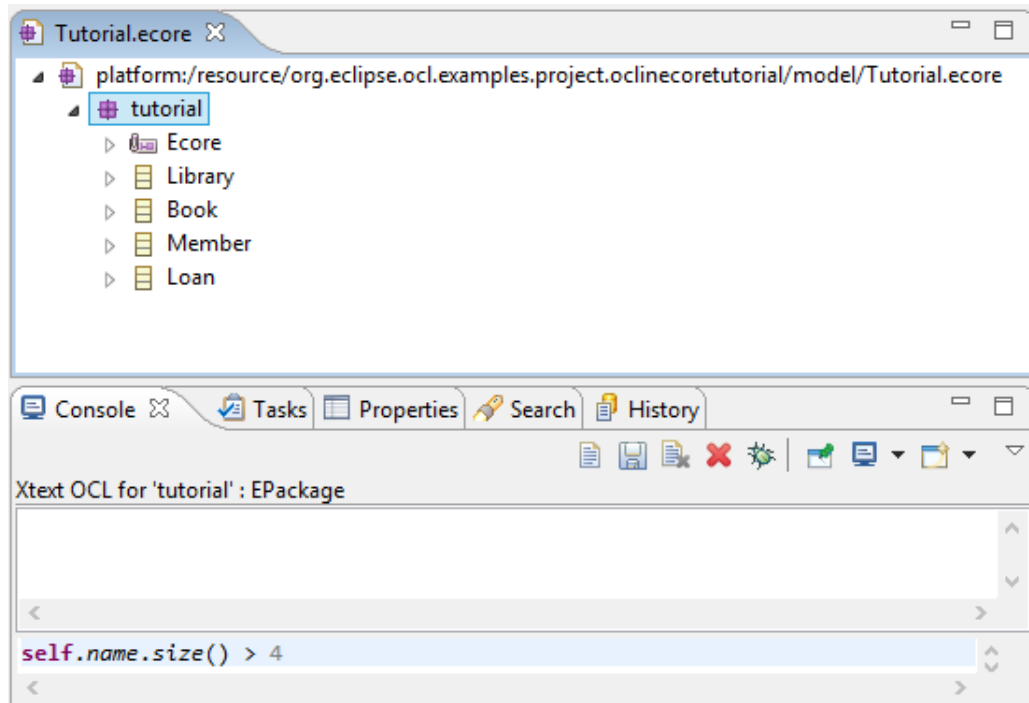
- the expression or constraint to evaluate

- the self object upon which to operate

These may be provided in a variety of ways

2.10.1.1. Selected model object and manually entered expression

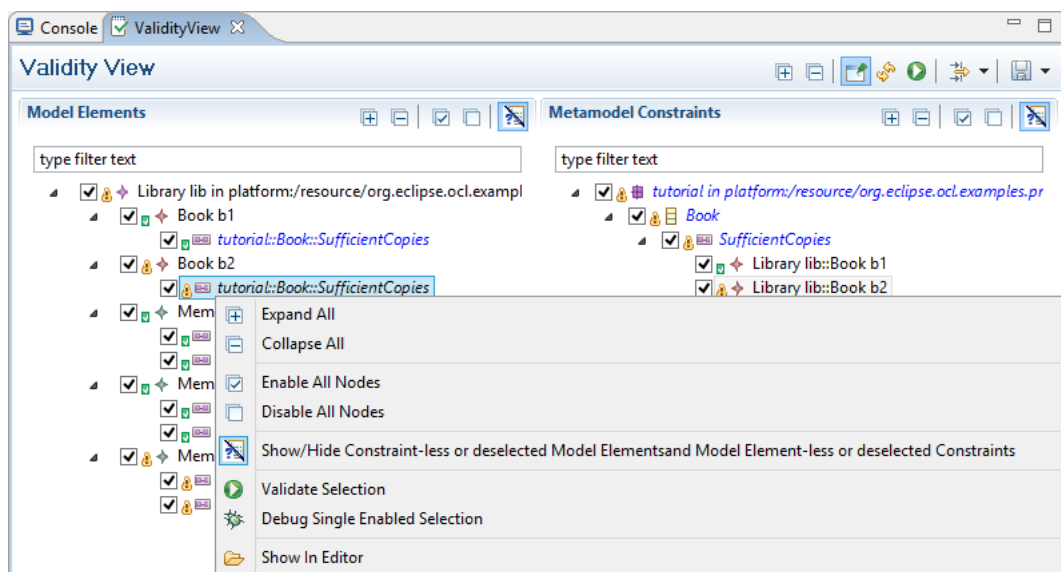
An arbitrary OCL expression may be entered in the Xtext OCL Console and evaluated on a model object selected using a mouse selection. The Debugger is invoked from the debug icon on the Console Tool Bar.



Clicking the debug icon creates a dummy Complete OCL file and then launches the debugger. The expression is encapsulated as an `oclDebugExpression` operation extension to the type of the selected object. The file provides the source for source level debugging. The console may be re-used while debugging.

2.10.1.2. Selected model object/constraint combination

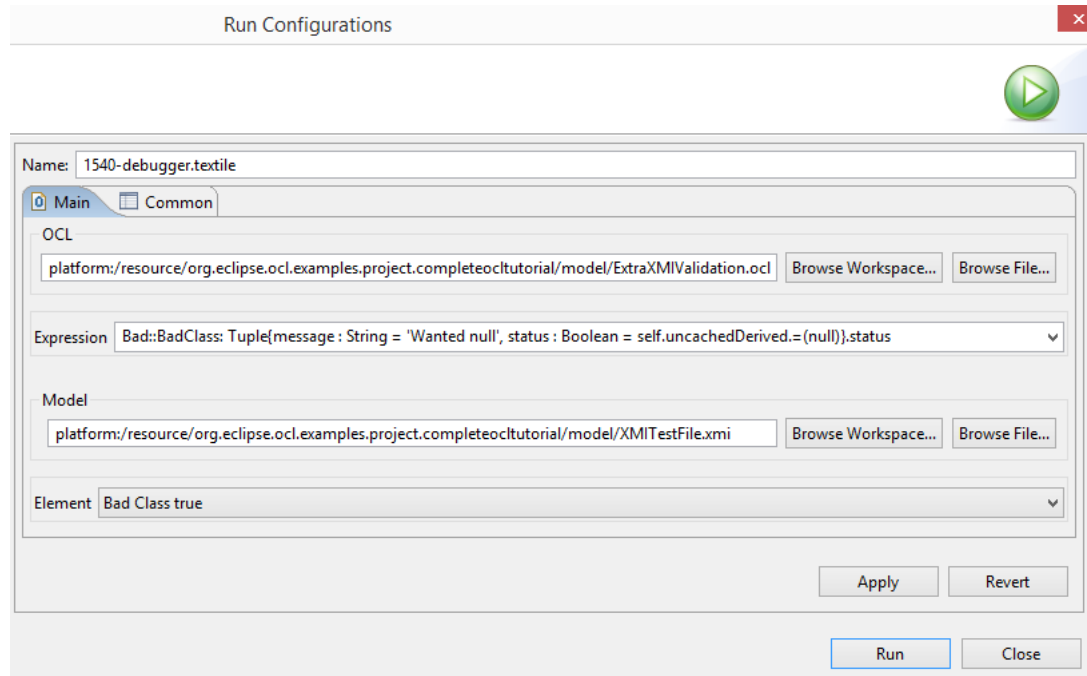
The Validity View provides fine-grained display of the evaluation of each constraint applicable to a model element and vice-versa. One of these model element/constraint combinations may be selected and the debugger launched using **Debug Single Enabled Selection** to investigate why validation is producing unexpected results.



2.10.1.3. Selected model object and selected constraint

An OCL Expression launch configuration may be created to select a model element and a constraint for execution or debugging.

The launch configuration may be created using **Run->Run Configurations...** or **Debug->Debug Configurations...** from the Eclipse Menu Bar. This requires both Model Element and Constraint to be selected separately.



Alternatively the context menu in model editors offers an **OCL->Debug...** option that creates a Debug Configuration in which the Model Element is pre-selected from the invoking context.

2.10.2. Stepping

OCL expressions can be very compact and generally occur embedded in a larger application. The debugger is therefore optimized for this usage.

Rather than the line-based stepping typical of the Java debugger, the OCL debugger supports term by term stepping, highlighting the next term to be evaluated and showing the intermediate results as \$-prefixed names in the Variables View.

The OCL debugger interpretation of the Step functionalities is adjusted to facilitate stepping to many points in a complex expression without needing to reformat the source with line breaks..

The [Example Debugger View](#) shows the imminent execution of “.size()” after stepping into “self” and “.name”.

2.10.2.1. Step Into

A single OCL AST node is executed. The results can be inspected as inputs of a subsequent AST node.

2.10.2.2. Step Over

Execution proceeds until the next OCL AST node is associated with a new source line number.

2.10.2.3. Step Return

Execution proceeds until the next OCL AST node is associated with a reduced stack depth. Iterations introduce nested stack entries so step return can step out of an iteration. let expressions and nested OCL calls also introduce additional stack nesting.

2.10.2.4. Resume

Execution proceeds until the next breakpoint.

2.10.3. Variables View

The Variables View enables the local variables and intermediate results to be examined using OCL syntaxes such as single quotes for Strings.

The [Example Debugger View](#) shows the “self” variable, which is an “ecore::Package” instance, opened to show its fields, amongst which the name is ‘tutorial’.

Intermediate variables are named using the property name of the subsequent AST node’s input. Thus “\$source” shows the OperationCallExp.source input already computed as “self.name”. Multiple inputs are disambiguated by suffixing as in “\$argument[0]”.

“\$pc” identifies the next instruction, which can be examined in just the same way as any other variable.

2.10.4. Breakpoints View

Line breakpoints can be set in the Complete OCL editor and examined in the Breakpoints View. Execution stops when an OCL AST node has been executed that is associated with the line of a breakpoint.

No filtering facilities are yet available.

2.10.5. Outline View

The Outline currently shows the OCL Concrete Syntax Tree which is structurally similar to the Abstract Syntax Tree that is executed. .

It would be more useful to show the AST and support Node breakpoints on it.

2.11. OCL Integration

The [OCLinEcore Editor](#) enables OCL to be embedded in Ecore. This section explains how that OCL is executed.

The [Complete OCL](#) editor enables OCL to be provided as a complementing document. This section explains how that complement is installed to become part of the complemented model.

The [Interactive OCL](#) console allows you to load OCL and execute OCL expression interactively.

The [Java API](#) explains how you can take control of the OCL installation and activation.

2.11.1. OCL execution in Ecore / EMF Delegates

The EMF delegate mechanisms and EAnnotations that enable EMF to delegate to OCL to support

- validation of invariants
- execution of operation bodies
- evaluation of property initial and derived values

are described in the [Delegates](#) section of the Programmers Guide.

2.11.2. Custom Validation Messages

Eclipse OCL supports the production of custom messages by defining a String-valued message expression as a parenthesized clause on an invariant.

2.11.2.1. Underlying support

An OCL invariant is an expression that returns a true or false value.

In Juno and Kepler, Eclipse OCL supported an extension whereby a null return indicated an ‘error’ rather than a ‘warning’, and an invalid return was ‘fatal’.

Luna supports a rich-invariant idiom whereby an invariant can compute a tuple of results, only one of which is actually returned by tooling that does not understand the idiom. Rather than

```
invariant InvariantName:  
  boolean-valued-invariant-expression;
```

You can code additional information by recoding

ocl-status-expression

as

```
invariant InvariantName:
  Tuple{
    status=boolean-valued-invariant-expression,
    message=string-valued-message-expression,
    severity=integer-valued-severity-expression, -- -ve error,0 ok,+ve warn
    ... -- more custom fields as desired
  }.status;
```

The idiom is a little verbose, but compatible with all OCL tooling. Eclipse OCL provides some editor enhancements to make the usage more acceptable.

2.11.2.2. Editor syntax

In the OCLinEcoreTutorial Example there is an alternative syntax for custom messages.

```
invariant SufficientCopies:
  library.loans->select((book = self))->size() <= copies;
```

may be changed to

```
invariant SufficientCopies('There are '
+ library.loans->select((book = self))->size().toString()
+ ' loans for the ' + copies.toString() + ' copies of \'' + name + '\':
library.loans->select((book = self))->size() <= copies;
```

to replace the default diagnostic:

```
The 'SufficientCopies' constraint is violated on 'Book b2'.
```

by

```
There are 3 loans for the 2 copies of 'b2'.
```

Unfortunately, in the Photon release, EMF does not support this customization. This must be activated explicitly using an EValidator that is aware of the ValidationDelegateExtension extended API. This is available by using the [OCLinEcoreEObjectValidator](#).

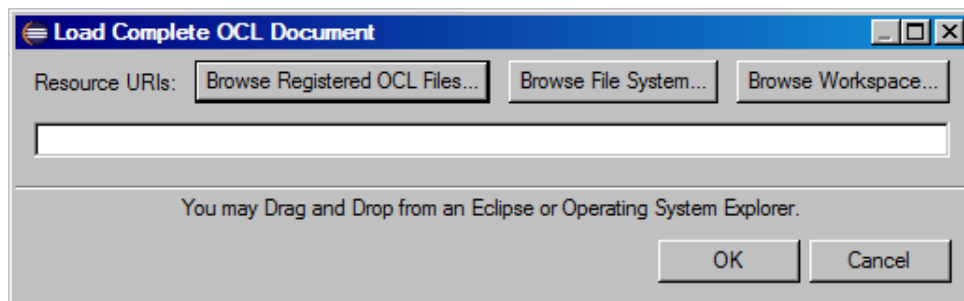
2.11.3. CompleteOCL Validation

Integration of Complete OCL documents is harder because Complete OCL complements pre-existing models. These cannot always be aware of the existence of that complement, since the author of a model cannot know what complements may be added by its users.

The complete model formed from the primary models and the OCL complements is application-specific and so applications must gather the contributions together. Prior to the Indigo release, this restricted Complete OCL usage to Java applications that could gather the complements.

The [CompleteOCLEObjectValidator](#) may be used to install a Complete OCL document.

In many editors an **OCL->Load Document** is available in the context menu to facilitate loading a complementary Complete OCL document.



You may drag and drop one or more files from within Eclipse or outside Eclipse into the dialog, or use one of the browser buttons to locate a Complete OCL document.

2.11.3.1. Browse Registered OCL Files...

The `org.eclipse.ocl.xtext.completeocl.complete_ocl_registry` may be used to register Complete OCL files against the nsURIs that they complement. These extension points may be defined in plugins or projects.

In either case clicking **Browse Registered OCL Files...** presents a list of registered Complete OCL documents applicable to the context from which the dialog was invoked.

2.11.3.2. Browse File System...

The **Browse File System...** button present a file system explorer so that a Complete OCL document file can found anywhere.

2.11.3.3. Browse Workspace...

The **Browse Workspace...** button present a workspace explorer so that a Complete OCL document file can found within the workspace.

2.11.4. OCLinEcore for Xtext Validation

If you want to use OCLinEcore as a validation language for Xtext you must:

Use a manually maintained Ecore model to define your parsed grammar model, otherwise your embedded OCL will be lost each time you regenerate the editor. For non-trivial models, switching from auto-generated to manual maintenance is a good idea, since you may need to control changes carefully to maintain upward compatibility for existing models.

Modify the Validator class generated by genmodel to extend OCLinEcoreEObjectValidator rather than EObjectValidator. See [OCLinEcoreEObjectValidator](#) for details.

2.11.5. Complete OCL for Xtext Validation

If you want to use Complete OCL as a validation language for Xtext, you may use the [CompleteOCLEObjectValidator](#) to register the Complete OCL for EMF Validation. This may readily be achieved by reusing the empty example JavaValidator created by Xtext to install the Complete OCL. If your Xtext language is *States*, and your Complete OCL is *model/States.ocl* in *StatesProject* you should change your StatesJavaValidator to:

```
public class StatesJavaValidator extends AbstractStatesJavaValidator
{
    @Override
    public void register(EValidatorRegistrar registrar) {
        super.register(registrar);
        StatesPackage ePackage = StatesPackage.eINSTANCE;
        URI oclURI = URI.createPlatformResourceURI(
            "/StatesProject/model/States.ocl", true);
        registrar.register(ePackage,
            new CompleteOCLEObjectValidator(ePackage, oclURI));
    }
}
```

2.12. OCL in UML (using Papyrus)

(This documentation applies to Papyrus 1.0.0.)

The behaviour of a UML model may be elaborated using OCL to define

- operation bodies
- property derivations/initializers
- class invariants to be observed by user model instances
- stereotype invariants to be observed by user model elements
- guards for state machines

2.12.1. UML Integration

Although the UML metamodel makes extensive use of OCL to specify its own well-formedness, there is no explicit ability to use OCL within UML. Usage of OCL, or any other language, is enabled by the flexibility of the ValueSpecification class and the OpaqueExpression extension.

The metamodel specifies the usage of a ValueSpecification wherever a value can sensibly be provided by a variety of technologies. Simple values can be provided by, for instance, a LiteralString or LiteralInteger.

More interesting values by an OpaqueExpression that has two interesting list features, one of language names and the other of string bodies in the corresponding language. The lists provide an ability to provide implementations in a variety of languages. In practice only one is used and if the language name is omitted, an implementation default of OCL is assumed.

Specification of a behaviour such as “name.toUpper()” can be achieved by an OpaqueExpression in which the language is Sequence(‘OCL’) and the body is Sequence(‘name.toUpper()’). The OCL is therefore embedded in a textual form that has no knowledge of the classes in the OCL metamodel.

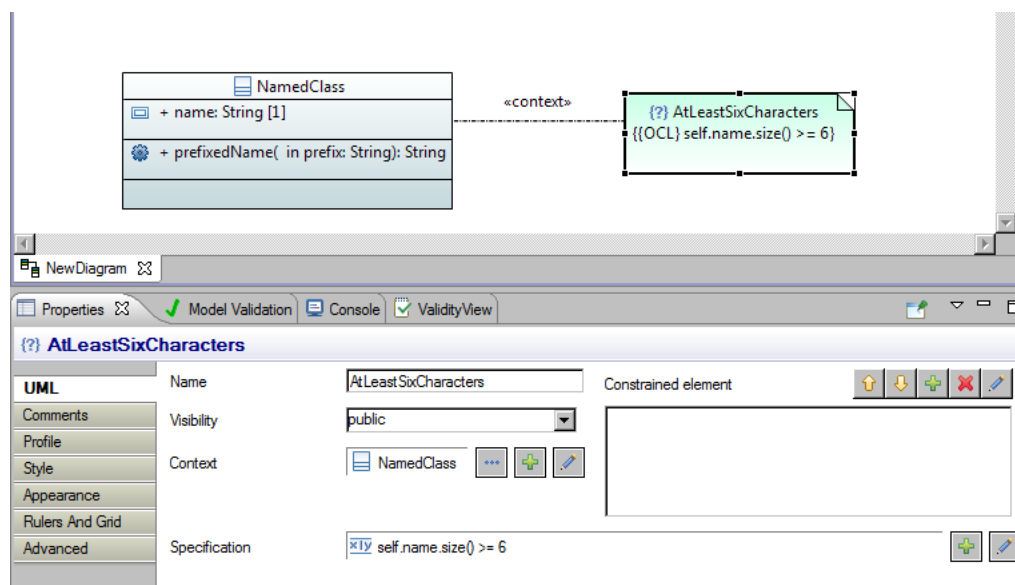
Users of the OCL Java API may avoid the need to incur OCL parsing costs by exploiting OCL’s ExpressionInOCL class that extends ValueSpecification and delegates functionality to an OCLExpression.

2.12.2. Class Diagram

2.12.2.1. Class Invariant

A class invariant specifies a constraint that must be true for all well-formed instances of the class. It is specified in Papyrus, by:

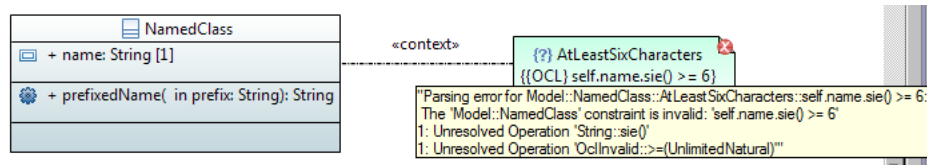
- create a Constraint Node on a Class Diagram
 - select Constraint on palette
 - click on diagram where you want it
 - click on the Class you want as the Constraint context
- optionally replace the auto-generated Constraint name
 - select the Constraint
 - type a new name in the Properties View
- define the Specification of the Constraint with OCL text
 - select the Constraint
 - type F2 (or click again) to open the Essential OCL editor
 - enter the required constraint text
 - click outside the editor to close



The «Context» link provides a graphical view of the Context selection in the Properties View. It is the context that defines the type of OCL’s self and so defines what is constrained.

You may edit the OCL text using direct edit as described above or from The Properties View. (Note that the editor has a significant start up time on the first usage, so be patient).

Your OCL text entry is validated automatically; an error or warning marker will be shown on the Constraint if it is not satisfactory. Once you have corrected the errors you may need to invoke **Validate->Model Tree** to make the marker go away.



2.12.2.2. Operation Precondition, Postcondition and Body

Preconditions specify constraints that must be satisfied before operation execution starts.

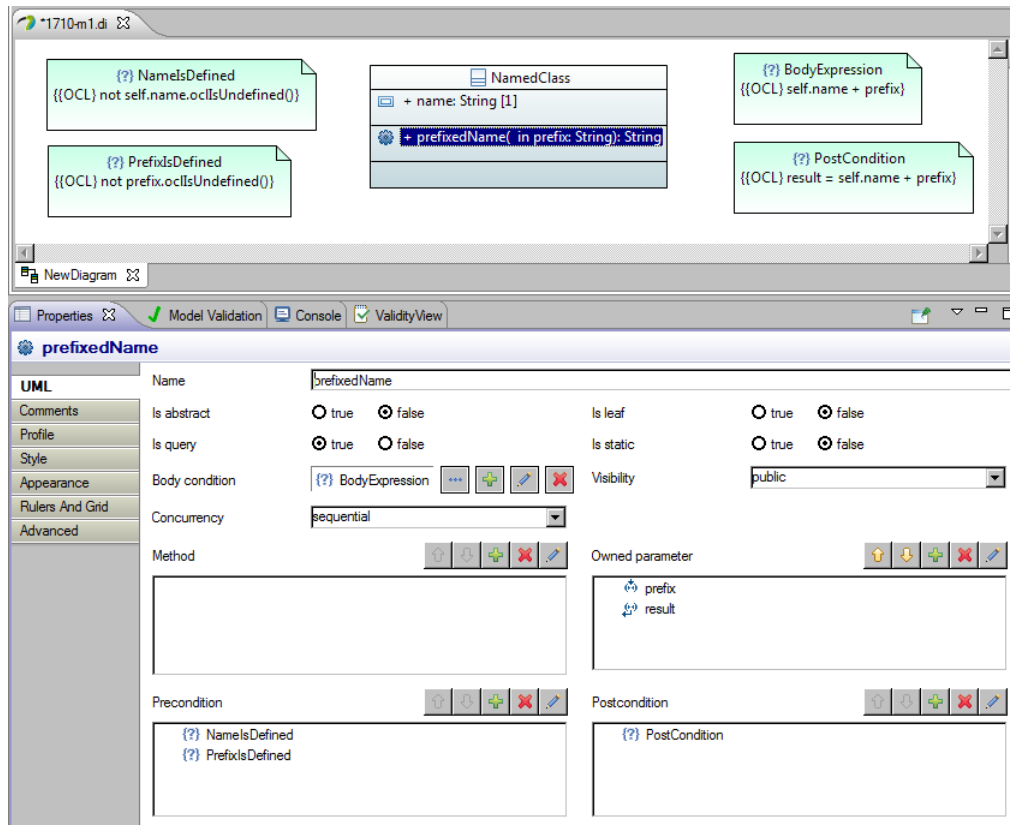
Postconditions specify constraints that must be satisfied after operation execution finishes. Postconditions may use the reserved parameter name `result` to refer to the one result permitted by OCL. The `@pre` suffix may be used to refer to the state of variables prior to execution of the operation.

In OCL, a body-expression defines the functionality of a query operation as a result-type-valued expression such as `some-computation`. In contrast in UML, a body-condition defines the functionality of the operation as a Boolean-valued constraint on the result such as `result = (some-computation)`. Papyrus supports the OCL interpretation and so the `result = (...)` wrapper may be omitted.

In Papyrus, once the operation has been defined, preconditions, postconditions and a body-condition are all drawn by

- create a Constraint Node on a Class Diagram
 - select Constraint on palette
 - click on diagram where you want it
 - type Esc since context links cannot be drawn to operations
- optionally replace the auto-generated Constraint name
 - select the Constraint
 - type a new name in the Properties View
- define the Constraint Context
 - select the Operation
 - use the appropriate Add Elements (+ icon) for Precondition or Postcondition, or the Body condition ... browser to locate the constraint
- define the Specification of the Constraint with OCL text
 - select the Constraint
 - type F2 (or click again) to open the Essential OCL editor
 - enter the required constraint text
 - click outside the editor to close

Note that the context of Operation Constraints must be specified by assigning a Constraint to one of the precondition/postcondition/bodycondition roles. Assignment of the context of the constraint directly fails to allocate the constraint to its role.



Note that in Papyrus 1.0, there is no stereotype display to indicate the precondition/postcondition/body-condition role.

Note that the OCL expressions for preconditions and postconditions should be Boolean-valued. The result-valued body-expression form should be used for a body-condition.

The owning type of the Operation is used as OCL's `self` context.

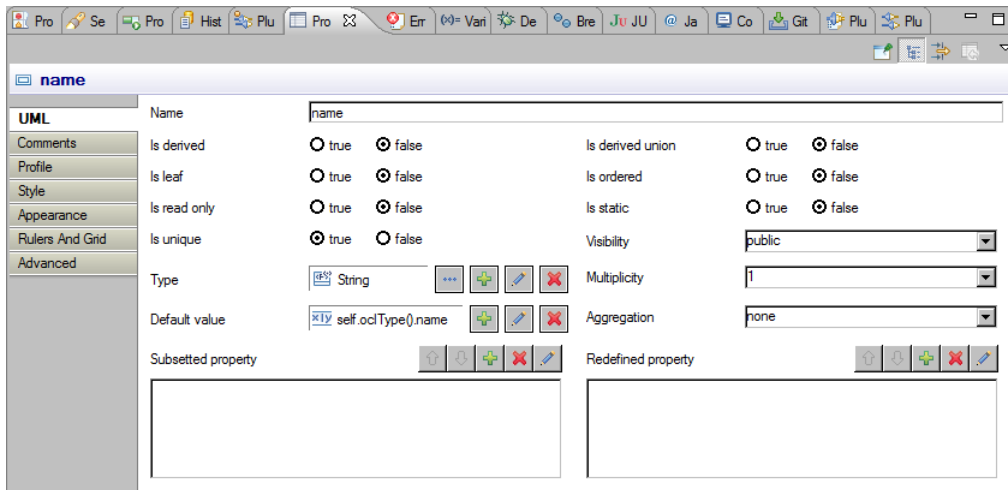
The Operation should be a query if a body-condition is provided.

In Luna, use of `result` within postconditions incorrectly reports an unknown property. The error can be ignored.

2.12.2.3. Property Initializers

An `OpaqueExpression` whose value is an OCL expression string can be used to define the default or derived value of a Property initializer.

- select the Property to make the Properties View relevant
- click the Create a new Object (+ icon) for the Default value
- Select `OpaqueExpression` from the menu
- click the Add elements (+ icon) for the Language
- select OCL in the left pane and click the right arrow to move to the right pane
- click OK
- enter the OCL text in the large pane
- click OK

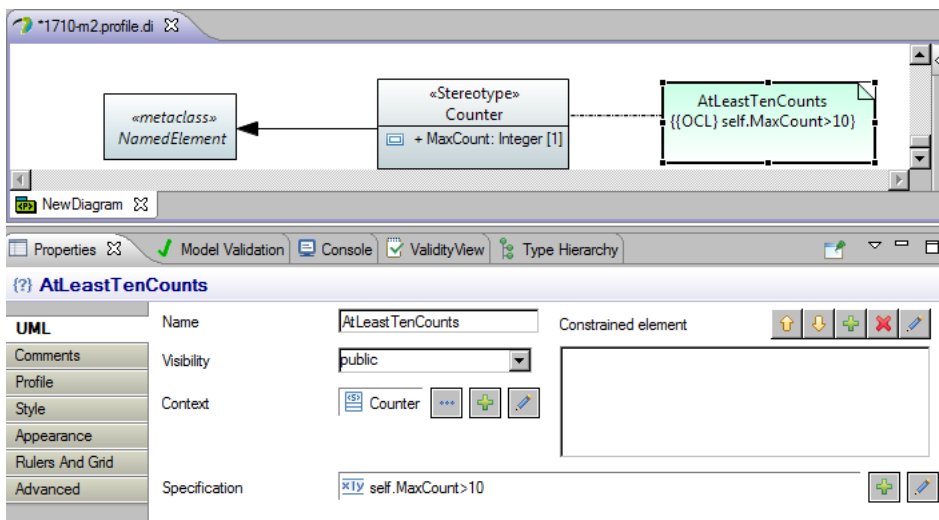


Unfortunately, in Luna, the context does not appear to be correctly set for editor, so there is an error on `self` and no syntax help.

2.12.2.4. Profile Constraint

A Profile Constraint is very similar to a Class Invariant. However since the Profile is Constraint is drawn at M2, it may be evaluated at M1 to check a UML Class Diagram for consistency. In contrast a Class Invariant drawn at M1, may be evaluated by user tooling at M0 to validate user models. It is specified in Papyrus, by:

- create a Constraint Node on a Profile Diagram
 - select Constraint on palette
 - click on diagram where you want it
 - click on the Stereotype you want as the Constraint context
- optionally replace the auto-generated Constraint name
 - select the Constraint
 - type a new name in the Properties View
- define the Specification of the Constraint with OCL text
 - select the Constraint
 - type F2 (or click again) to open the Essential OCL editor
 - enter the required constraint text
 - click outside the editor to close



The OCL text can also be edited within the Properties View.

2.12.3. State Machine Diagram

The primary element of a StateMachine diagram is the StateMachine, which is a Type, but does not normally have Properties. A StateMachine should therefore be defined as a nested type of a containing type. This may be achieved within Papyrus Model Explorer by dragging the StateMachine to be a child of a Class.

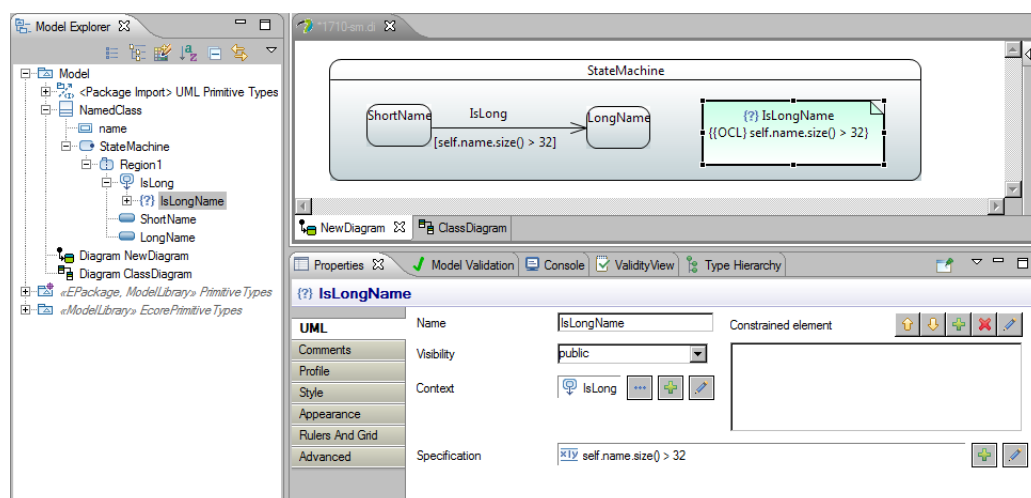
2.12.3.1. Statemachine Constraint

A Constraint may be applied to a Statemachine in the same way as for a Class to specify an invariant of the Statemachine.

2.12.3.2. Statemachine Transition Guard

The guard condition of a Statemachine Transition may be specified by associating a Constraint with a Transition. The Transition should already exist and the Statemachine should be a nested type of a suitable type for OCL's `self`. The guard condition is drawn in Papyrus by

- create a Constraint Node on a StateMachine Diagram
 - select Constraint on palette
 - click on diagram where you want it
 - optionally enter the required constraint text
 - type Esc to close editor
- optionally replace the auto-generated Constraint name
 - select the Constraint, if not already selected
 - type a new name in the Properties View
- define the Constraint Context
 - select the Constraint, if not already selected
 - use the Context ... browser in the Properties View to locate the transition
- define the Specification of the Constraint with OCL text
 - select the Constraint, if not already selected
 - type F2 (or click again) to open the Essential OCL editor
 - enter the required constraint text
 - click outside the editor to close



The required Transition is specified as the Guard of the Transition.

The owning type of the Statemachine defines OCL's `self`. In the absence of an owning type `self` will be undefined and OCL constraint validation will fail. You must therefore ensure that the StateMachine has a Class parent and that the Class has the required properties; name for this example. Once Class and properties are defined using a Class diagram. The

2.13. OCL Constraint Examples for UML (using Papyrus)

(This documentation applies to Papyrus 3.0.0 and Eclipse Oxygen.)

The [OCL in UML \(using Papyrus\)](#) section shows how Papyrus may be used to create and maintain OCL expressions that enrich a UML model or profile.

In this section we show how some simple and not so simple OCL examples can solve useful specification problems.

OCL Constraints may be specified at any meta-level. A class-level defines the types and properties that are used by the instance-level. The OCL constraints validate that the instances are compliant. The OCL therefore executes on instances of the instance-level using the types and properties of the class-level.

A Constraint may be used just to document the design intent, but given an appropriate environment a constraint may be tested and/or used to verify the consistency of models. This may be

- a test model defined by using UML InstanceSpecification to instantiate the UML model.
- a live model created by instantiating the Ecore equivalent of the UML model
- a UML model that conforms to a UML profile

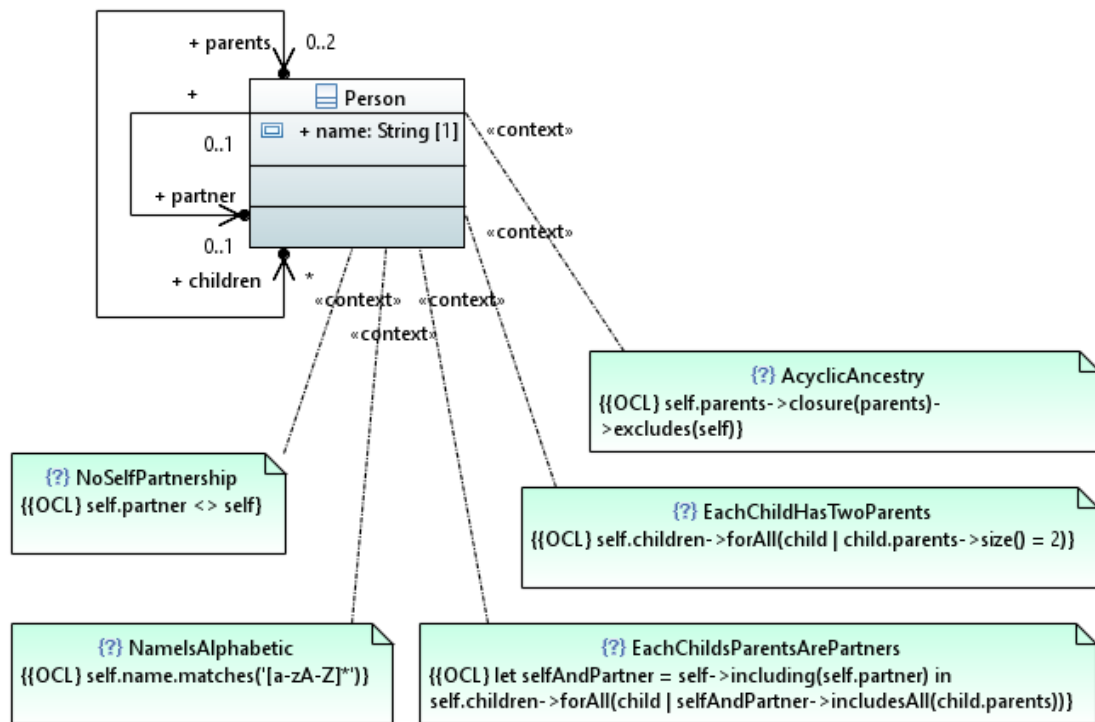
In all cases when a validation of the model is requested, the validator attempts to execute each possible constraint on each possible instance to which it applies. When executing the constraint, the validator binds the `self` variable to the instance to be validated. The type of `self` is determined by the context of the Constraint. In Papyrus this context is determined by the non-Constraint end of the `<<context>>` link from Constraint. The result of evaluating a Constraint should `true` or `false`. If `true`, the constraint is satisfied. If `false` the constraint is violated and some diagnostic should be shown to the user.

In [Model Constraints](#), we provide examples that apply to the elements of UML model. The Constraints are evaluated on the instances of the model. How violations are diagnosed depends on the synthesis of model instances and the corresponding run-time environment.

In [Profile Constraints](#), we provide examples that apply to the elements of a UML profile. The Constraints are evaluated to verify consistent usage of the elements in the model. Violations are diagnosed within the UML editor.

2.13.1. Model Constraints

2.13.1.1. Simple Metamodel

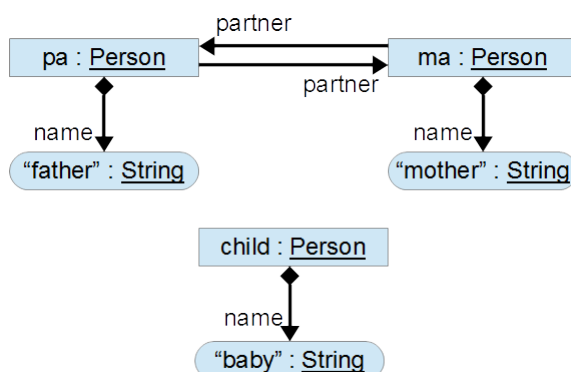


The figure shows a metamodel specified in UML as a Papyrus Class Diagram. The upper half shows a simple metamodel comprising just a **Person** class. A **Person** has a **String**-valued **name** and may have a **partner**, **parents** and/or **children**.

Some constraints such as the `parents[0..2]` limitation on the the number of **parents** to 2 may be specified directly using UML capabilities without any use of OCL. But many more challenging restrictions require OCL constraints, for which five examples are provided in the lower half of the figure.

2.13.1.2. Scalar Constraints

To help understand the way in which OCL evaluates, it is helpful to consider some instances that conform to the constrained model



The figure shows a model comprising three persons whose names are **father**, **mother** and **baby**.

The notation in the figure is similar to a UML Object Diagram. *This should be drawable in Papyrus, unfortunately a number of bugs prevent this in the Oxygen release of Papyrus.* The notation deviates slightly from UML by only underlining type name, and by using rounded rectangles to distinguish **DataType** values from **Class** instances.

The three instances of `Person` are shown as three rectangles, with an instance name such as `pa` and underlined type `Person`. The three names are shown as rounded rectangles with values such as `father` and type `String`. The association between a `Person` instance and their name is shown by a directed link from the `Person` instance to the value. The link is labelled with the relationship role which is `name`.

The `partner` relationship role is similarly shown by a directed link from `pa` to `ma` and vice-versa.

NameIsAlphabetic

The simplest example constraint uses a regular expression to specify that the name must consist of just alphabetic characters.

```
self.name.matches(' [a-zA-Z]* ')
```

The `.` is the OCL Object navigation operator. It separates a cascade of navigation steps each of which returns a result value.

Evaluation starts at `self`, which rather like `this` in Java, is bound to an object whose type is the context of the Constraint. The result is therefore a `Person` object such as `pa`.

The property navigation step `name`, traverses the relationship whose role is `name`. The navigation steps from `pa` to the `father` value. The result is a `String` comprising `father`.

The operation call step `matches(' [a-zA-Z]* ')`, executes the regular expression matching function using the provided regex. The final result is `true` or `false`.

NoSelfPartnership

Another very simple example constraint checks that the `partner` relationship does not have the same `Person` as both its source and target.

```
self.partner <> self
```

The OCL comprises two navigation expressions separated by the infix `<>` operator.

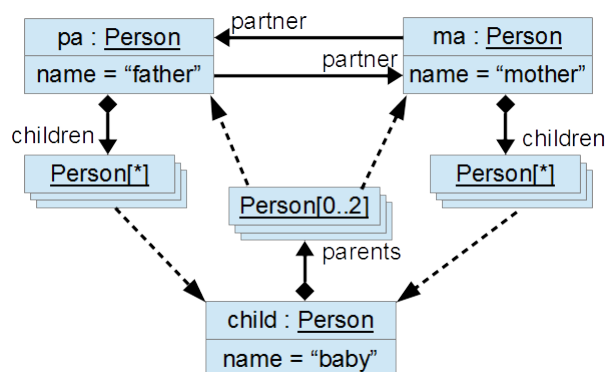
The first, `self.partner`, navigates from `self` to compute a result comprising the `partner` of the `self` context instance.

The second, `self` just returns the context instance.

The not-equals `<>` infix operator compares its preceding and following arguments and provides a `true` result when the arguments are not-equal, `false` when equal.

2.13.1.3. Collection Constraints

The one-to-one relationships between objects and values have a simple implementation typically involving a pointer. One-to-many and many-to-many relationships are more complex since a collection of values is involved.



The figure above elaborates the earlier figure to show the to-many relationships. The figure also uses a simpler representation of the object to value relationships by embedding each name value within its `Person` instance. One-to-one object relationships such as `partner` are unaffected. To-many relationships such as `parents` are shown using a multi-object drawn as three overlaid rectangles. Each multi-object is typically a collection owned by the relationship source and shown by a solid arrow

labelled with the relationship name. Each element of the collection is identified by a dashed arrow. `child` therefore has two parents; `pa` and `ma`. Many-to-many relationships are convently realized as independent one-to-many relationships in each direction. The `children` opposite of `parents` is therefore shown by a `children` multi-object for each parent identifying the one child.

When Ecore is used to implement UML, the multi-object is realized in exactly this way by an `EList`.

OCML provides an ability to use these multi-objects within expressions. The multi-object is a `Collection`, or more specifically a `Bag`, `OrderedSet`, `Sequence` or `Set` depending on whether the to-many-relationship is specified to be ordered and/or unique.

In OCL, `->` is the collection navigation operator that enables an evaluation to exploit all the target objects.

EachChildHasTwoParents

Each child should have two parents, but in any finite model there must be some `Person` instances for which the parents are omitted. Hence the model specifies a `[0..2]` multiplicity rather than precisely `[2..2]`. We may remedy this deficiency with an OCL constraint.

```
self.children->forAll(child | child.parents->size() = 2)
```

The `self` and `children` navigate from the context object to locate the collection of all children of the context instance as the navigation result.

The `->` collection operator and the subsequent `forAll(child | ...)` iteration cause an iteration to be performed over the children, assigning each child in turn to the `child` iterator variable. The `...` iterator body is evaluated for each child and accumulated so that the result of the `forAll` is only `true` if the body evaluation for each `child` is also `true`.

The iteration body navigates from each `child` to select the collection of all of its `parents`. Then the `->` collection navigation operator invokes the collection operation `size()` to compute the size of the collection. This size is compared using the `=` (equals) operator to the constant `2`. The iteration body therefore returns `false` unless the number of parents is equal to `2`.

This example can be written more compactly as

```
children->forAll(parents->size() = 2)
```

since an implicit iterator is the default source for navigation within an iteration body, and `self` is the default outside.

AcyclicAncestry

The instances of a user model often form an acyclic graph. It is therefore desirable to specify this as an OCL constraint so that any cycles are detected by an OCL model validator. This is fairly easy to specify with the help of the OCL transitive closure iteration.

```
self.parents->closure(parent | parent.parents)->excludes(self)
```

Once again the `self.parents` navigation returns the collection of all parents of the context instance. This collection is used as a seed from which the `closure(parent | ...)` collection iteration grows the final result by repeatedly aggregating the result of the `...` body evaluation. Each element of the interim result is bound to the `parent` iterator until there are no values left in the result for which the iteration body has not been evaluated.

The `parent.parents` iteration body just returns all parents of a given parent so that the closure progressively aggregates the grandparents then great-grandparents, then ...

Once the `closure` completes, it returns a `Set` (or `OrderedSet`) of all ancestors which is passed to the `excludes` Collection operator to confirm that the `self` instance is not an ancestor of itself.

This example can be written more compactly as

```
parents->closure(parents)->excludes(self)
```

EachChildsParentsArePartners

A user model may not always allow arbitrary relationships between its instances. An OCL constraint can impose discipline, and within a more complex OCL constraint one or more let-variables may provide structure that aids readability.

In our example we may wish to impose a requirement that the two parents of a child are partners.

```
let selfAndPartner = self.oclAsSet()->including(self.partner) in
self.children->forAll(child | selfAndPartner->includesAll(child.parents))
```

The `let selfAndPartner ... in ...` assigns the value of a first ... expression to the `selfAndPartner` let-variable so that `selfAndPartner` can then be used in the evaluation of the second ... expression that provides the final result. The let-variable allows a sub-computation to be re-used many times, or just to be assigned to a readable name.

The let-variable is computed by first using `self.oclAsSet()` to compute a single element Set containing `self`. It then uses the collection operation `including(self.partner)` to compute another set containing all (one) elements of the original set and also including another element. The result is therefore a set of the two elements, `self` and `self.partner`.

As before `self.children->forAll(child | ...)` binds each child to the `child` iterator and requires that the ... body evaluates to true for all values of `child`. The body verifies that the pair of persons cached in the `selfAndPartner` includes each person identified by `child.parents`.

This example can be written more compactly as

```
let selfAndPartner = self->including(partner) in
children->forAll(selfAndPartner = parents)
```

The more compact form exploits an implicit invocation of `oclAsSet()` that occurs when a `->` collection navigation operator has a non-collection as its source.

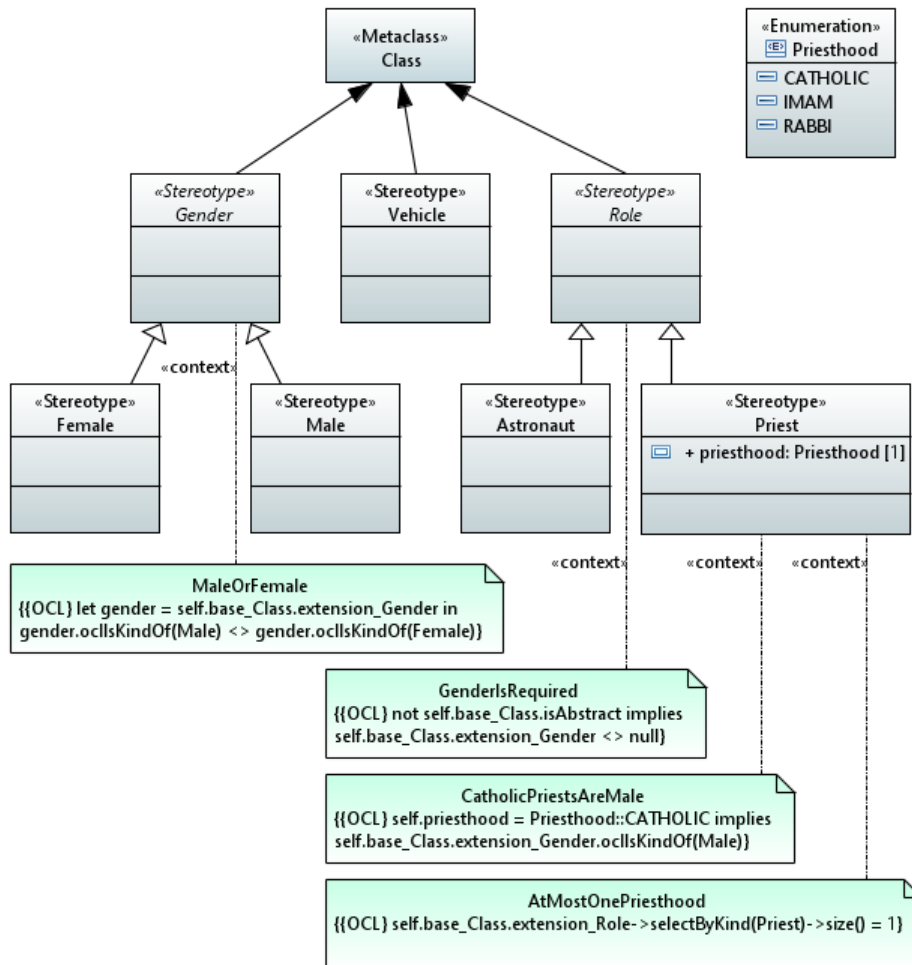
Eliminating the explicit `child` iterator from the `forAll` iteration is permissible but perhaps unwise since an occasional OCL user may struggle to understand whether the final `parents` is `self.parents` or `child.parents`.

2.13.2. Profile Constraints

A UML Profile provides an ability to extend an existing metamodel by defining Stereotypes that may be added to elements of the metamodel. The `Ecore.profile.uml` which annotates `UML.uml` to define the Eclipse UML support is a good example of such usage. The contrived example here that extends a single class metamodel would be much better realized by a new metamodel.

2.13.2.1. Example Profile

Our contrived example provides two forms of extension, `Gender` and `Role` intended for a `Person` element, but since we are defining a profile we must define the extension for `Person`'s metaclass which is `Class`. We also define another extension, `Vehicle`, that is sensible for a `Class` but clearly stupid for a `Person`.



A Person may have a Gender defined as an abstract stereotype from which the concrete Male and Female stereotypes derive.

A Person may have one or more Role's defined as an abstract stereotype from which the concrete Astronaut and Priest stereotypes derive. A Priest provides an additional priesthood enumeration property that identifies the religious affiliation of the priest.

These definitions are drawn as an extension link from a base stereotype such as Gender, to a metaclass, such as Class. The link is a UML Extension that is a form of Association and so has two automatically synthesized Property elements for its ends. The property role names are derived by applying base_ or extension_ prefixes to the target class/metaclass names. The base_Class property therefore identifies the Class metaclass end of the Extension, and the extension_Gender identifies the Gender end.

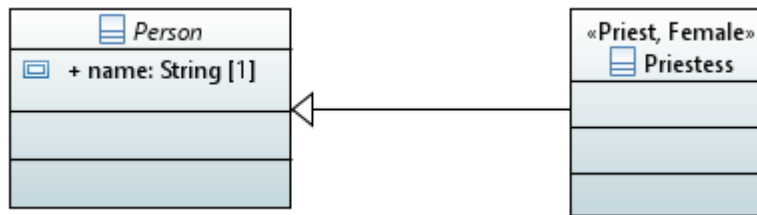
The extension_ property has a multiplicity for which [0..1] specifies that at most one application of the Gender stereotype is permissible. Alternatively a [0..*] multiplicity specifies that zero or more applications of the Role stereotype are possible; a priest may also be an astronaut. Specification of non-zero lowerbounds is possible but not generally appropriate since the application is to the metaclass. Mandating that a Gender is always applied leads to stupidities if a completely independent class such as an Road are also modeled.

The extension multiplicity provides a very limited imposition of design rules on the use of the stereotypes. Generally much more complex rules requiring OCL constraints are required. Four examples are shown and explained later.

(The Oxygen release of Papyrus provides a misleading editing interface for stereotype multiplicities. Use only the advanced properties after selecting the extension in the Model Explorer View).

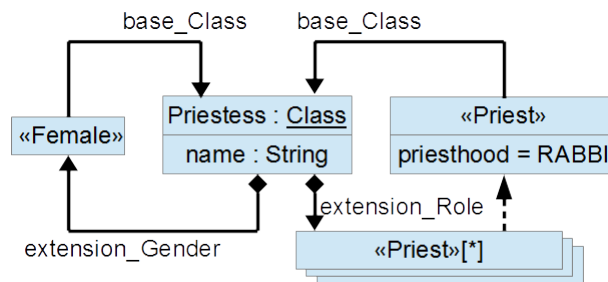
2.13.2.2. Example Profiled Model

The application of stereotypes is relatively straightforward and not the topic of this section. A profile is applied to the model, so that its stereotypes can be applied to the elements.



Applied stereotypes are shown within guilemets. The example above shows definition of a derived Person class named Priestess to which the Female and Priest stereotypes have been applied. Not shown in the diagram, is the definition of the Priest::priesthood metaproperty with the RABBI value.

The UML representation is deceptively simple and consequently rather confusing when writing OCL constraints. We need to look at the equivalent object model that the OCL evaluation uses.



The figure shows just the Priestess class. In the centre, an instance of the Class metaclass is instantiated as a Class named Priestess with the inherited String-valued Property named name. Each Stereotype metaclass is instantiated as an element without a type specification. The elements are named Priest and Female.

The type specification is missing because the UML specification has no primary need for the concept of a stereotype instance. This omission leads to a complexity in the XMI serialization for UML. The omitted type is indicated by the guilemets surrounding the names.

The relationships between Priestess and «Female» show the synthesized base_Class and extension_Gender relationships. Note that it is extension_Gender rather than extension_Female since the profile defined Gender as an extension of the Class metaclass. Female is a derivation of the defined extension.

The relationships between Priestess and «Priest» are more complex since more than one Role may be applied. The extension_Role therefore identifies a collection of zero or more Role's. The example shows that the collection contains just the one «Priest» element.

We may now examine some example constraints to see how this model is used by constraint evaluation.

MaleOrFemale

A simple example constraint on an abstract «Gender» stereotype confirms that only one of the «Female» or «Male» stereotypes is applied.

```
let gender = self.base_Class.extension_Gender in
gender.ocIsKindOf(Male) <> gender.ocIsKindOf(Female)
```

The navigation starts with self bound to a «Gender» instance since that is the «context» of the Constraint definition. Navigation to base_Class locates the instance of Class to which the stereotype

is provided. The further navigation to `extension_Gender` locates a «Gender» instance for any corresponding application of the stereotype. This instance is saved in the `gender` let-variable.

The subsequent operation navigation from `gender` using `oclIsKindOf(Male)` returns `true` if `gender` is a `Male` stereotype instance, `false` otherwise. The similar test for `oclIsKindOf(Female)` is compared so that the constraint is only `true` when the applied stereotypes differ.

This Constraint is somewhat redundant since the at-most-one multiplicity on a «Gender» stereotype inhibits any double application. The let-variable `gender` is therefore always the same as `self`. This constraint can therefore be written more compactly as:

```
true
```

GenderIsRequired

A more useful constraint mandates that every non-abstract class to which a «Role» is applied also has an application of the «Gender» stereotype.

```
not self.base_Class.isAbstract implies
self.base_Class.extension_Gender <> null
```

When this is evaluated for our single instance example model, evaluation starts with `self` bound to the «Priest» stereotype instance since the «context» of the constraint definition is the `Role` from which `Priest` derives.

`self.base_Class` navigates from the «Priest» stereotype instance to the `Priestess` class instance, where the `isAbstract` navigation is used to test the `UML::Class::isAbstract` property to determine whether `Priestess` is abstract or not.

The `x implies y` infix operator is often more readable than `(not x) or y`; it conveniently short-circuits evaluation of a garbage second expression when the first expression is `false`. In this example the subsequent evaluation is bypassed for instances of abstract classes.

The `self.base_Class.extension_Gender` navigates first to the `Priestess` class instance and then on to a «Gender» stereotype instance. This navigation returns a non-null object if there is such an instance, or `null` if there is not. The `<> null` comparison therefore returns `true` when a `Gender` stereotype has been applied; or `false` when not-applied.

Note that the examples specify a relevant stereotype as the «context». It is possible to write an identical constraint when the `Class` metaclass is specified as the «context».

```
not isAbstract implies
extension_Role->notEmpty() implies
extension_Gender <> null
```

However this is inefficient since it must be executed for all possible classes where it performs a double test 'any Role' then 'check Gender'. By defining the constraint on the `Role`, the first test is performed for free. Redundant evaluations for e.g. `Road` elements are avoided. Of course a separate constraint that `Role` should only be applied to `Person` may be desirable.

```
base_Class.oclIsKindOf(Person)
```

CatholicPriestsAreMale

Stronger constraints may mandate a business rule such as requiring that `CATHOLIC` priests are male.

```
self.priesthood = Priesthood::CATHOLIC implies
self.base_Class.extension_Gender.oclIsKindOf(Male)
```

The left hand side of the `implies` restricts the constraint to the case where the `priesthood` meta-property has been assigned the `CATHOLIC` enumeration value. In our single class example, a `Priestess` is assigned the value `RABBI` and so the test always fails. If a further `CatholicPriest` class is defined, this constraint then becomes useful, since the right hand side of the `implies` expression checks that the «Gender» stereotype instance is present and is a «Male» stereotype instance.

AtMostOnePriesthood

Since multiple «Role» stereotype instances are permitted, we may require a business rule to prohibit the application of two `Priest` stereotypes.

```
self.base_Class.extension_Role->selectByKind(Priest)->size() = 1
```

As before `self` is a «Role» stereotype instance so that navigation to `base_Class` identifies the `Person` class that has been stereotyped. The `extension_Role` identifies the collection of all applied `Role` stereotypes since multiple applications are permitted.

The `->` collection navigation operator and the collection operation `selectByKind(Priest)` returns a filtered collection that selects only those stereotype instances that are, or derive from, the `Priest` stereotype. The further `->` collection navigation operator and the `size()` collection operation compute the size of this collection. The constraint result is `true` if the size equals 1; `false` otherwise.

`->notEmpty()`

The `->notEmpty()` collection navigation and operation is convenient to test whether one or more applications of a stereotype are present.

```
self.base_Class.extension_Role->notEmpty()
```

It is not uncommon to see `->notEmpty()` used when at most one application is possible.

```
self.base_Class.extension_Gender->notEmpty()
```

This is not wrong, but is slightly inefficient since it provokes the following automatic non-collection to set conversion.

```
self.base_Class.extension_Gender.oclAsSet()->notEmpty()
```

It is more efficient to write

```
self.base_Class.extension_Gender <> null
```

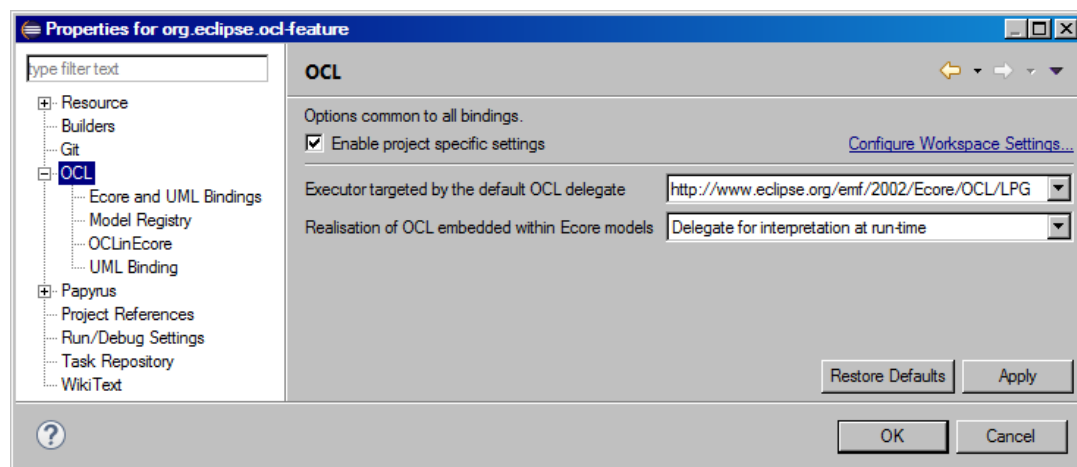
2.14. User Interface

The user interface comprises

- [Editors](#)
- [Console](#)
- [Debugger](#)
- [Validity View](#)
- [Workspace Preference Pages](#)
- [Project Property Pages](#)
- [OCL->Load Document Menu Action](#)

2.14.1. Project Property Pages

The Project Property Pages are accessible by invoking **Properties** from the right button context menu of a project.



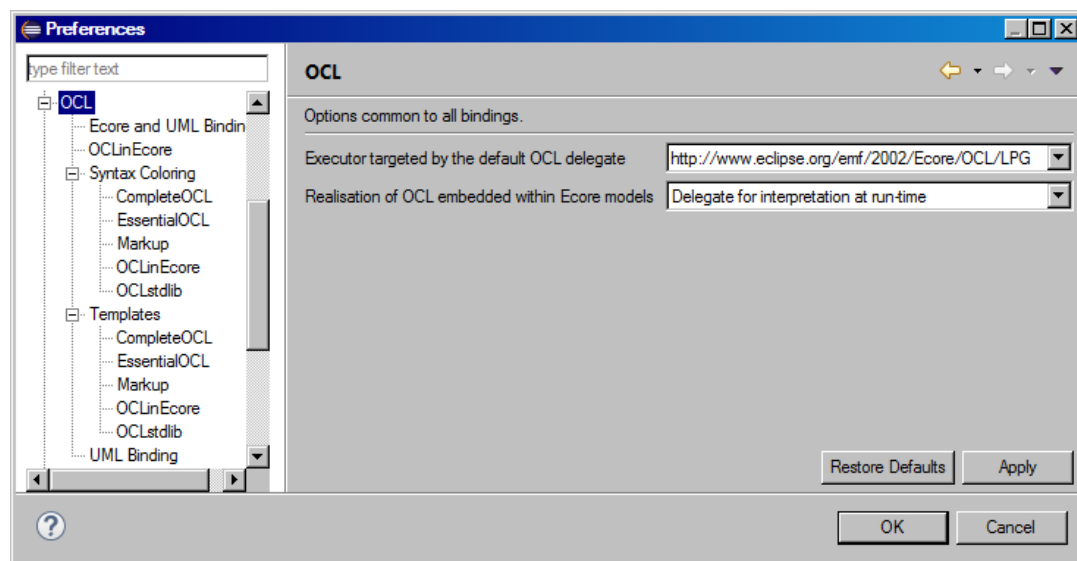
In principle, it is possible to specify project-specific settings, however in practice is not often possible for application code to determine the prevailing project. Project-specific properties are therefore often ignored and may be removed in a future release.

The Property pages are:

- [Overall Options](#)
- [OCLinEcore editor Options](#)
- [Options applicable to the Ecore and UML bindings](#)
- [Options applicable to just the UML bindings](#)
- [The Model Registry](#)

2.14.2. Workspace Preference Pages

The Workspace Preference Pages are accessible by invoking **Preferences** from the **Window** menu on the toolbar.



The Preference pages are:

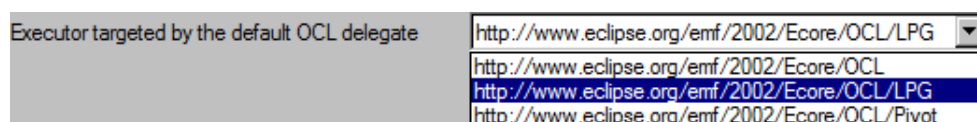
- [Overall Options](#)
- [OCLinEcore editor Options](#)
- [Options applicable to the Ecore and UML bindings](#)
- [Options applicable to just the UML bindings](#)
- [Editor Syntax Coloring](#)
- [Editor Templates](#)

2.14.3. Overall Options

The two overall options are independent of the Ecore/UML/Pivot bindings.

2.14.3.1. Default Delegation Mode

The Eclipse OCL project provides two execution engines which may be used to support EMF Delegates.



<http://www.eclipse.org/emf/2002/Ecore/OCL/LPG>

EMF Delegate annotations referencing the <http://www.eclipse.org/emf/2002/Ecore/OCL/LPG> URI are serviced by the classic evaluator that uses the LPG parser.

This URI was introduced in the Indigo release.

<http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot>

EMF Delegate annotations referencing the <http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot> URI are serviced by the new experimental evaluator that uses the UML-aligned Pivot model.

This URI was introduced in the Indigo release and was imposed by the Indigo OCLinEcore editor.

<http://www.eclipse.org/emf/2002/Ecore/OCL>

EMF Delegate annotations referencing the <http://www.eclipse.org/emf/2002/Ecore/OCL> URI are serviced by the evaluator selected on the preference page by the [Default Delegation Mode](#).

This URI was introduced in the Helios release and was imposed by the Helios OCLinEcore editor.

Use of an Indigo or Juno editor converts the URI to use the Pivot evaluator.

In Kepler, a prevailing URI in the input file is preserved, unless changed by the context menu setting. If no prevailing URI exists a default is determined by an OCLinEcore preference setting that defaults to the Pivot evaluator.

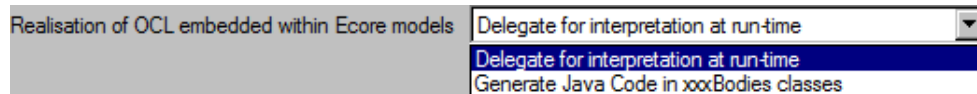
2.14.3.2. Code Generation Mode

Juno introduced an experimental ability to replace the delegated interpreted execution of OCL by direct execution of compiled Java code. This facility has been substantially improved and tested for the Kepler release.

Optimisations for Luna included inlining the bodies directly into the EMF Impl classes.

Mars has useful fixes and benefits from safe navigation analyses.

Further optimisations are scheduled for future releases.



This option may be selected to change the realization of OCL option.

Delegate for interpretation at run-time

Selecting the default delegation mode retains the Helios and Indigo functionality whereby **genmodel** generates Java code that encodes the OCL expressions as text strings. Each expression is lazily compiled at run-time with the result being cached to reduce overheads for repeated execution.

Generate Java code in xxxBodies classes

Selecting Java code generation causes **genmodel** to run Xtend templates that generate

- a *Package Tables.java* file
- inline OCL implementations within the *Class Impl.java* files

The tables file contains an optimised model representation allowing polymorphic operations to be dispatched in constant time.

The implementation files contain Java code corresponding to each OCL expression defining operation bodies or property initializers.

Disclaimer: the generated code is experimental has yet to be optimized and so is only about five times faster than the interpreted execution.

2.14.4. Ecore and UML Options

The options for the Ecore and UML bindings.

Ecore and UML Bindings

Configure the severities for problems diagnosed by the LPG parser.

Reference the defined property or operation in a def: expression as a constrained element of the constraint, in addition to the context classifier.	False
Interpolate <, <=, >, and >= operations when a model type defines a Java-style compareTo(...) operation.	False
Allow Integer Literals that exceed 32-bit limits.	False
Warn when the OCL 2.1 parsing of distinct xor, or, and precedences leads to a different parse to the OCL 2.0 specification of all levels equal.	False
Resolve package qualification by outward name lookup as specified by OCL 2.2, and/or by alias from an import declaration.	By Name
Process Java-like backslash escape sequences as specified by OMG Issue 14357 for OCL 2.3	True
Accept 'static' as part of a definition constraint as specified for OCL 2.2.	True
Treat operation overload resolution as a compilation error, rather than an arbitrary selection of the first best match.	False
Use of the closure() iterator specified by OCL 2.3.	Ok
Use of the toUpper() and toLower() operations on Strings.	Warning
Use of " escape sequence for single-quotes in string literals.	Warning
Use of "..." escape sequence for element names consisting of multiple OCL tokens.	Warning
Ambiguity when an unnavigable but named association end has the same name as the implicit name of an unnamed association end.	Error
Declaring (using the concrete syntax) an operation or property context in a classifier that inherits the feature (rather than declaring a redefinition of the feature as the context). This is allowed by the MDT OCL implementation but is not, strictly speaking, well-formed OCL.	Warning
Use of an operation name conceptually as in 7.4.8.	Error
any() return value when nothing is selected, "invalid" is correct Use "null" to retain the erroneous pre-Kepler resolution of the OCL 2.3.1 ambiguity.	null
Closure result includes the sources as specified by OCL 2.3 rather than the traditional Classic OCL behavior of excluding them.	False
Implement lax handling of null values in certain OclAny-defined operations.	True
Use the actual (dynamic) rather than the declared (static) source type to select the called operation.	False
Static instance for the implicit-root-class option token.	null

2.14.5. UML Options

The options for the UML binding.

UML Binding

Configure the severities for problems diagnosed by the LPG parser.

UML metaclass to consider as an OCL Association Class.	Association
Working with M1 instance models or M0 objects.	Automatically determine the effective modeling level from the context element.

2.14.6. Model Registry

The Model Registry is now deprecated.

2.14.7. Syntax Coloring

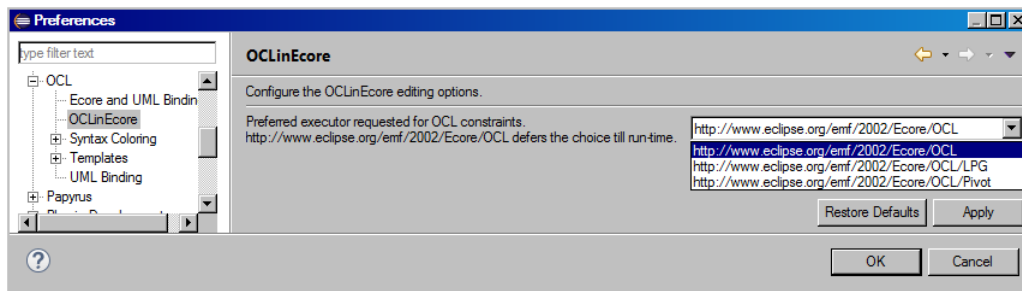
The standard Xtext syntax coloring facilities are provided for each of the OCL editors.

2.14.8. Editor Templates

The standard Xtext editor template facilities are provided for each of the OCL editors.

2.14.9. OCLinEcore Options

The options for the OCLinEcore editor.



OCL embedded in Ecore can be executed with either the Classic evaluator or the new Pivot evaluator depending on the URI used to define the embedded EAnnotations. This preference determines the URI written to Ecore files when no URI was previously in use.

Selecting <http://www.eclipse.org/emf/2002/Ecore/OCL> makes no choice and so defers to the user's [run-time delegation choice](#).

Selecting <http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot> is recommended since the OCLinEcore editor and Pivot evaluator both use the Xtext parser. This should avoid problems whereby not all facilities of the new Pivot grammar are supported by the Classic grammic or LPG evaluator.

Selecting <http://www.eclipse.org/emf/2002/Ecore/OCL/LPG> may be appropriate if evaluation using the classic LPG evaluator is important.

Chapter 3. The OCL Standard Library

This documentation on the OCL Standard Library is auto-generated from the `org.eclipse.ocl.pivot/model/OCL-2.5.oclstclib` that defines the behaviour of the Pivot evaluator and the Xtext editors. It is similar to the OCL 2.4 functionality. It is a prototype of functionality for OCL 2.5 where the use of models may eliminate ambiguities.

The library support for the Ecore and UML bindings in Luna has been upgraded so that the available operations are similar to those documented here for the Pivot binding.

3.1. Precedences

NAVIGATION > UNARY > MULTIPLICATIVE > ADDITIVE > RELATIONAL > EQUALITY > AND
> OR > XOR > IMPLIES

3.2. Bag(T)

A bag is a collection with duplicates allowed. That is, one object can be an element of a bag many times. There is no ordering defined on the elements in a bag. Bag is itself an instance of the metatype `BagType`.

conformsTo [Collection\(T\)](#)

Operations

`=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

True if `self` and `bag` contain the same elements, the same number of times.

`<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

`excluding(object : OclAny[?]) : Bag(T)`

The bag containing all elements of `self` apart from all occurrences of `object`.

`excludingAll(objects : Collection(OclAny)) : Bag(T)`

The bag containing all elements of `self` apart from all occurrences of all objects.

`flatten(T2)() : Bag(T2)`

Redefines the `Collection` operation. If the element type is not a collection type, this results in the same bag as `self`. If the element type is a collection type, the result is the bag containing all the elements of all the recursively flattened elements of `self`.

`including(object : T[?]) : Bag(T)`

The bag containing all elements of `self` plus `object`.

`includingAll(objects : Collection(T)) : Bag(T)`

The bag containing all elements of `self` and `objects`.

`selectByKind(TT)(type : TT[?]) : Bag(TT)`

`selectByType(TT)(type : TT[?]) : Bag(TT)`

Iterations

`closure(i : T[1] | lambda : Lambda T() : Set(T)[?]) : Set(T)`

The closure of applying `body` transitively to every distinct element of the source collection.

`collect(V)(i : T[?] | lambda : Lambda T() : V[?]) : Bag(V)`

`collectNested(V)(i : T[?] | lambda : Lambda T() : V[?]) : Bag(V)`

The Bag of elements which results from applying `body` to every member of the source nonordered collection.

`reject(i : T[?] | lambda : Lambda T() : Boolean[1]) : Bag(T)`

The sub-bag of the source bag for which `body` is false.

`self->reject(iterator | body) = self->select(iterator | not body)`

```
.
select(i : T[?] | lambda : Lambda T() : Boolean[1]) : Bag(T)
```

The sub-bag of the source bag for which body is true.

```
self->select(iterator | body) =
self->iterate(iterator; result : Bag(T) = Bag{} |
if body then result->including(iterator)
else result
endif)
```

```
sortedBy(i : T[?] | lambda : Lambda T() : OclAny[?]) : Sequence(T)
```

Results in the Sequence containing all elements of the source collection. The element for which body has the lowest value comes first, and so on. The type of the body expression must have the < operation defined. The < operation must return a Boolean value and must be transitive (i.e., if $a < b$ and $b < c$ then $a < c$).

3.3. Boolean

The standard type Boolean represents the common true/false values. Boolean is itself an instance of the metatype PrimitiveType (from UML).

conformsTo [OclAny](#)

Operations

```
=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY
```

Returns true if the logical value of self is the same as the numeric value of object2, false otherwise.

```
<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY
```

Returns true if the logical value of self is the not same as the numeric value of object2, false otherwise.

```
allInstances() : Set(OclSelf)
```

Returns Set{false, true}.

```
and(b : Boolean[?]) : Boolean[?] invalidating validating precedence: AND
```

false if either self or b is false. Otherwise invalid if either self or b is invalid. Otherwise null if either self or b is null. Otherwise true.

```
body: if self.oclIsInvalid() then
    if b.oclIsInvalid() then self
    elseif b = false then false
    else self
    endif
elseif self = false then false
elseif b.oclIsInvalid() then b
elseif b = false then false
elseif self = null then null
elseif b = null then null
else true
endif
```

```
and2(b : Boolean[?]) : Boolean[?]
```

false if either self or b is false. Otherwise true.

```
body: if self = false then false
    elseif b = false then false
    else true
    endif
```

```
implies(b : Boolean[?]) : Boolean[?] invalidating validating precedence:
IMPLIES
```

true if self is false, or if b is true. Otherwise invalid if either self or b is invalid. Otherwise null if either self or b is null. Otherwise false.

```

body: if self.ocIsInvalid() then
    if b.ocIsInvalid() then self
    elseif b = true then true
    else self
    endif
elseif self = false then true
elseif b.ocIsInvalid() then b
elseif b = true then true
elseif self = null then null
elseif b = null then b
else false
endif

```

implies2(b : Boolean[?]) : Boolean[?]

true if self is false, or if b is true. Otherwise false.

```

body: if self = false then true
    elseif b = true then true
    else false
    endif

```

not() : Boolean[?] validating precedence: UNARY

true if self is false. false if self is true. null if self is null. Otherwise invalid.

```

body: if self.ocIsInvalid() then self
    elseif self = null then null
    else self = false
    endif

```

not2() : Boolean[1]

true if self is false. Otherwise false.

```

body: if self then false else true endif

```

or(b : Boolean[?]) : Boolean[?] invalidating validating precedence: OR

true if either self or b is true. Otherwise invalid if either self or b is invalid. Otherwise null if either self or b is null. Otherwise false.

```

body: if self.ocIsInvalid() then
    if b.ocIsInvalid() then self
    elseif b = true then true
    else self
    endif
elseif self = true then true
elseif b.ocIsInvalid() then b
elseif b = true then true
elseif self = null then null
elseif b = null then null
else false
endif

```

or2(b : Boolean[?]) : Boolean[?]

true if either self or b is true. Otherwise false.

```

body: if self = true then true
    elseif b = true then true
    else false
    endif

```

toString() : String[1]

Converts self to a string value.

xor(b : Boolean[?]) : Boolean[?] precedence: XOR

true if self is true and b is false, or if self is false and b is true. false if self is true and b is true, or if self is false and b is false. Otherwise invalid if either self or b is invalid. Otherwise null.

```

body: if self.ocIsInvalid() then self
      elseif b.ocIsInvalid() then b
      elseif self = null then null
      elseif b = null then null
      else self <> b
      endif

```

```

xor2(b : Boolean[?]) : Boolean[?]

```

true if self <> b Otherwise false.

```

body: self <> b

```

3.4. Class

conformsTo [OclAny](#)

3.5. Collection(T)

Collection is the abstract supertype of all collection types in the OCL Standard Library. Each occurrence of an object in a collection is called an element. If an object occurs twice in a collection, there are two elements.

This sub clause defines the properties on Collections that have identical semantics for all collection subtypes. Some operations may be defined within the subtype as well, which means that there is an additional postcondition or a more specialized return value. Collection is itself an instance of the metatype `CollectionType`.

The definition of several common operations is different for each subtype. These operations are not mentioned in this sub clause.

The semantics of the collection operations is given in the form of a postcondition that uses the `IterateExp` of the `IteratorExp` construct. The semantics of those constructs is defined in Clause 10 (“Semantics Described using UML”). In several cases the postcondition refers to other collection operations, which in turn are defined in terms of the `IterateExp` or `IteratorExp` constructs.

Well-formedness rules

A collection cannot contain `invalid` values.

context Collection inv: self->forAll(not ocIsInvalid())

conformsTo [OclAny](#)

Attributes

lower : Integer[1]

Evaluates to the lower bound on the number of collection elements.

upper : Integer[1]

Evaluates to the upper bound on the number of collection elements.

Associations

elementType : T[1]

Evaluates to the type of the collection elements.

Operations

=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY

True if `c` is a collection of the same kind as `self` and contains the same elements in the same quantities and in the same order, in the case of an ordered collection type.

<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY

True if `c` is not equal to `self`.

asBag() : Bag(T)

The Bag that contains all the elements from `self`.

asOrderedSet() : OrderedSet(T)

An `OrderedSet` that contains all the elements from `self`, with duplicates removed, in an order dependent on the particular concrete collection type.

`asSequence()` : `Sequence(T)`

A `Sequence` that contains all the elements from `self`, in an order dependent on the particular concrete collection type.

`asSet()` : `Set(T)`

The `Set` containing all the elements from `self`, with duplicates removed.

`count(object : OclAny[?])` : `Integer[1]`

The number of times that `object` occurs in the collection `self`.

`excludes(object : OclAny[?])` : `Boolean[1]`

True if `object` is not an element of `self`, false otherwise.

`excludesAll(T2)(c2 : Collection(T2))` : `Boolean[1]`

Does `self` contain none of the elements of `c2`?

`excluding(object : OclAny[?])` : `Collection(T)`

The collection containing all elements of `self` apart from `object`.

`excludingAll(objects : Collection(OclAny))` : `Collection(T)`

The collection containing all elements of `self` apart from all occurrences of all `objects`.

`flatten(T2)()` : `Collection(T2)`

If the element type is not a collection type, this results in the same collection as `self`. If the element type is a collection type, the result is a collection containing all the elements of all the recursively flattened elements of `self`.

`includes(object : OclAny[?])` : `Boolean[1]`

True if `object` is an element of `self`, false otherwise.

`includesAll(T2)(c2 : Collection(T2))` : `Boolean[1]`

Does `self` contain all the elements of `c2`?

`including(object : T[?])` : `Collection(T)`

The collection containing all elements of `self` plus `object`.

`includingAll(objects : Collection(T))` : `Collection(T)`

The collection containing all elements of `self` and `objects`.

`intersection(u : UniqueCollection(T))` : `Set(T)`

The intersection of `self` and a unique collection; the set of all elements that are in both `self` and `u`.

`intersection(c : Collection(T))` : `Bag(T)`

The intersection of `self` and `bag`; the bag of all elements that are in both `self` and `c`.

`isEmpty()` : `Boolean[1]`

Is `self` the empty collection?

Note: `null->isEmpty()` returns true in virtue of the implicit casting from `null` to `Bag{}`.

`max()` : `T[1]`

The element with the maximum value of all elements in `self`. Elements must be of a type supporting the max operation. The max operation – supported by the elements – must take one parameter of type `T` and be both associative and commutative. `UnlimitedNatural`, `Integer` and `Real` fulfill this condition.

`min()` : `T[1]`

The element with the minimum value of all elements in `self`. Elements must be of a type supporting the min operation. The min operation – supported by the elements – must take one parameter of type `T` and be both associative and commutative. `UnlimitedNatural`, `Integer` and `Real` fulfill this condition.

`notEmpty()` : `Boolean[1]`

Is `self` not the empty collection?

`null->notEmpty()` returns `false` in virtue of the implicit casting from `null` to `Bag{}`.

```
product(T2)(c2 : Collection(T2)) : Set(Tuple(first:T[1],
second:T2[1]))
```

The cartesian product operation of `self` and `c2`.

```
selectByKind(TT)(type : TT[?]) : Collection(TT)
```

```
selectByType(TT)(type : TT[?]) : Collection(TT)
```

```
size() : Integer[1]
```

The number of elements in the collection `self`.

```
sum() : T[1]
```

The addition of all elements in `self`. Elements must be of an `OclSummable` type to provide the `zero()` and `sum()` operations. The *sum* operation must be both associative: `a.sum(b).sum@ = a.sum(b.sum@)`, and commutative: `a.sum(b) = b.sum(a)`. `Integer` and `Real` fulfill this condition.

If the *sum* operation is not both associative and commutative, the *sum* expression is not well-formed, which may result in unpredictable results during evaluation. If an implementation is able to detect a lack of associativity or commutativity, the implementation may bypass the evaluation and return an `invalid` result.

```
union(c : Collection(T)) : Bag(T)
```

The bag consisting of all elements in `self` and all elements in `c`.

Iterations

```
any(i : T[?] | body : Lambda T() : Boolean[1]) : T[?]
```

Returns any element in the *source* collection for which *body* evaluates to `true`. Returns `invalid` if the *body* evaluates to `invalid` for any element, otherwise if there are one or more elements for which the *body* is `true`, an indeterminate choice of one of them is returned, otherwise the result is `invalid`.

```
let source : Collection(T)=..., body : Lambda T() : Boolean=... in source->any(iterator | body) = source->select(iterator | body) >asSequence()>first()
```

```
collect(V)(i : T[?] | lambda : Lambda T() : V[?]) : Collection(V)
```

The Collection of elements that results from applying *body* to every member of the source set. The result is flattened. Notice that this is based on `collectNested`, which can be of different type depending on the type of source. `collectNested` is defined individually for each subclass of `CollectionType`.

```
collectNested(V)(i : T[?] | lambda : Lambda T() : V[?]) : Collection(V)
```

The Collection of elements which results from applying *body* to every member of the source collection.

```
exists(i : T[?] | lambda : Lambda T() : Boolean[?]) : Boolean[?]
```

Results in `true` if *body* evaluates to `true` for at least one element in the source collection.

```
exists(i : T[?], j : T[?] | lambda : Lambda T() : Boolean[?]) : Boolean[?]
```

```
forAll(i : T[?] | lambda : Lambda T() : Boolean[?]) : Boolean[?]
```

Results in `true` if the *body* expression evaluates to `true` for each element in the source collection; otherwise, result is `false`.

```
forAll(i : T[?], j : T[?] | lambda : Lambda T() : Boolean[?]) : Boolean[?]
```

```
isUnique(i : T[?] | lambda : Lambda T() : OclAny[?]) : Boolean[1]
```

Results in `true` if *body* evaluates to a different value for each element in the source collection; otherwise, result is `false`.

```
iterate(Tacc)(i : T[?]acc : Tacc[?] | lambda : Lambda T() : Tacc[?]) : Tacc[?]
```

```
one(i : T[?] | lambda : Lambda T() : Boolean[1]) : Boolean[1]
```

Results in `true` if there is exactly one element in the source collection for which *body* is `true`.

```
reject(i : T[?] | lambda : Lambda T() : Boolean[1]) : Collection(T)
```

The sub-collection of the source collection for which body is false.

```
select(i : T[?] | lambda : Lambda T() : Boolean[1]) : Collection(T)
```

The sub-collection of the source collection for which body is true.

```
sortedBy(i : T[?] | lambda : Lambda T() : OclAny[?]) : Sequence(T)
```

Results in the Collection containing all elements of the source collection. The element for which body has the lowest value comes first, and so on. The type of the body expression must have the < operation defined. The < operation must return a Boolean value and must be transitive (i.e., if $a < b$ and $b < c$ then $a < c$).

3.6. Enumeration

@Deprecated: Use OclEnumeration The Enumeration type is the type of an OrderedSet of EnumerationLiteral.

conformsTo [OclAny](#)

Attributes

allLiterals : OrderedSet(EnumerationLiteral)

Evaluates to the literals of the enumeration.

Operations

allInstances() : Set(OclSelf)

Return a set of all enumeration values of self.

3.7. EnumerationLiteral

The standard type EnumerationLiteral represents a named constant value of an Enumeration.

conformsTo [OclAny](#)

Attributes

Enumeration : Bag(Enumeration[*|?])

OclEnumeration : Bag(OclEnumeration[*|?])

3.8. Integer

The standard type Integer represents the mathematical concept of integer. Integer is itself an instance of the metatype PrimitiveType (from UML).

conformsTo [Real](#)

Operations

*(i : OclSelf[?]) : Integer[1] precedence: MULTIPLICATIVE

The value of the multiplication of self and i.

+(i : OclSelf[?]) : Integer[1] precedence: ADDITIVE

The value of the addition of self and i.

-() : Integer[1] precedence: UNARY

The negative value of self.

-(i : OclSelf[?]) : Integer[1] precedence: ADDITIVE

The value of the subtraction of i from self.

/(i : OclSelf[?]) : Real[1] invalidating precedence: MULTIPLICATIVE

The value of self divided by i. Evaluates to invalid if r is equal to zero.

abs() : Integer[1]

The absolute value of self.

div(i : Integer[?]) : Integer[1]

The number of times that `i` fits completely within `self`.

`max(i : OclSelf[?]) : Integer[1]`

The maximum of `self` and `i`.

`min(i : OclSelf[?]) : Integer[1]`

The minimum of `self` and `i`.

`mod(i : Integer[?]) : Integer[1]`

The result is `self` modulo `i`.

`toString() : String[1]`

Converts `self` to a string value.

`toUnlimitedNatural() : UnlimitedNatural[1]`

Converts a non-negative `self` to an `UnlimitedNatural` value. A negative `self` is converted to `invalid`. An automatic coercion may be synthesized if the coercion enables an operation reference to be resolved in an expression where no operation was available without coercion.

3.9. Map(K, V)

A `Map` provides a Set of key values, each of which has an associated value. Keys and values may be null, but neither may be `invalid`.

conformsTo [OclAny](#)

Associations

`keyType : K[?]`

The key type of the key-value pairs of `self`.

`valueType : V[?]`

The value type of the key-value pairs of `self`.

Operations

`=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

Evaluates to `true` if `self` and `s` contain the same elements.

`<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

`at(key : OclAny[?]) : V[?] invalidating`

The value of the map at `key`.

`excludes(key : OclAny[?]) : Boolean[1]`

`True` if `key` is not one of the keys of `self`, `false` otherwise.

`excludes(key : OclAny[?], value : OclAny[?]) : Boolean[1]`

`True` if `key` and `value` are not a key-value pair of `self`, `false` otherwise.

`excludesAll(K2)(coll : Collection(K2)) : Boolean[1]`

`True` if none of the elements of `coll` are keys of `self`, `false` otherwise.

`excludesMap(K2, V2)(map : Map(K2, V2)[?]) : Boolean[1]`

`True` if none of the key-value pairs of `map` are also key-value pairs of `self`, `false` otherwise.

`excludesValue(value : OclAny[?]) : Boolean[1]`

`True` if `value` is not one of the values of `self`, `false` otherwise.

`excluding(key : OclAny[?]) : Map(K, V)[?]`

The map containing all key-value pairs of `self` except any whose key is `key`.

`excluding(key : OclAny[?], value : OclAny[?]) : Map(K, V)[?]`

The map containing all key-value pairs of `self` except any whose key is `key` and whose value is `key`.

`excludingAll(keys : Collection(OclAny)) : Map(K, V)[?]`

The map containing all key-value pairs of `self` except any whose key is included in `keys`.

`excludingMap(K2, V2)(map : Map(K2, V2)[?]) : Map(K, V)[?]`

The map containing all key-value pairs of `self` except any which is also included in `map`.

`includes(key : OclAny[?]) : Boolean[1]`

True if `key` is one of the keys of `self`, false otherwise.

`includes(key : OclAny[?], value : OclAny[?]) : Boolean[1]`

True if `key` and `value` are a key-value pair of `self`, false otherwise.

`includesAll(K2)(coll : Collection(K2)) : Boolean[1]`

True if all the elements of `coll` are keys of `self`, false otherwise.

`includesMap(K2, V2)(map : Map(K2, V2)[?]) : Boolean[1]`

True if all of the key-value pairs of `map` are also key-value pairs of `self`, false otherwise.

`includesValue(value : OclAny[?]) : Boolean[1]`

True if `value` is one of the values of `self`, false otherwise.

`including(key : K[?], value : V[?]) : Map(K, V)[?]`

The map containing all of the key-value pairs of `self` and an additional key-value pair for `key` and `value`. If `key` is already a key of `self`, the old value pair is replaced by `value`.

`includingMap(K2, V2)(map : Map(K2, V2)[?]) : Map(K, V)[?]`

The map containing all of the key-value pairs of `self` and `map`. The values associated with key-value pairs in `map` replace those in `self` where the same key is used by both maps.

`isEmpty() : Boolean[1]`

True if `self` is the empty map, false otherwise.

`keys() : Set(K)`

A Set comprising all the keys of the key-value pairs in `self`.

`notEmpty() : Boolean[1]`

True if `self` not the empty map, false otherwise.

`size() : Integer[1]`

The number of key-value pairs in `self`.

`values() : Bag(V)`

The Bag comprising all the values of the key-value pairs in `self`.

3.10. OclAny

The number of elements in the collection `self.essences`. `OclAny` is itself an instance of the metatype `AnyType`.

All classes in a UML model inherit all operations defined on `OclAny`. To avoid name conflicts between properties in the model and the properties inherited from `OclAny`, all names on the properties of `OclAny` start with 'ocl.' Although theoretically there may still be name conflicts, they can be avoided. One can also use qualification by `OclAny` (name of the type) to explicitly refer to the `OclAny` properties.

Operations of `OclAny`, where the instance of `OclAny` is called `object`.

Attributes

`OclInvalid : Bag(OclInvalid[*|?])`

Operations

`=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

True if `self` is the same object as `object2`. Infix operator.

post: result = self = object2

`<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

True if `self` is a different object from `object2`. Infix operator.

post: result = not (self = object2)

`oclAsSet() : Set(OclSelf)`

Returns a Set with `self` as the sole content, unless `self` is null in which case returns an empty set,

`oclAsType(TT)(type : TT[?]) : TT[1] invalidating`

Evaluates to `self`, where `self` is of the type identified by `TT`. The type `TT` may be any classifier defined by OCL or a user metamodel; if the actual type of `self` at evaluation time does not conform to `TT`, then the `oclAsType` operation evaluates to `invalid`.

If `self` is a multiply classified instance, the current classification used for OCL navigation is changed to the classification to which `TT` conforms. The `oclAsType` call is not well-formed if the classification is ambiguous.

In the case of feature redefinition, casting an object to a supertype of its actual type does not access the supertype's definition of the feature; according to the semantics of redefinition, the redefined feature simply does not exist for the object. However, when casting to a supertype, any features additionally defined by the subtype are suppressed.

```
post IsSelf: result = self
```

`oclIsInState(statespec : OclState[?]) : Boolean[1]`

Evaluates to true if the `self` is in the state identified by `statespec`.

`oclIsInvalid() : Boolean[1] validating`

Evaluates to true if the `self` is equal to `OclInvalid`.

`oclIsKindOf(type : OclType[?]) : Boolean[1]`

Evaluates to true if the type of `self` conforms to `type`. That is, `self` is of type `type` or a subtype of `type`.

`oclIsNew() : Boolean[1]`

Can only be used in a postcondition. Evaluates to true if the `self` is created during performing the operation (for instance, it didn't exist at precondition time).

`oclIsTypeOf(type : OclType[?]) : Boolean[1]`

Evaluates to true if `self` is of the type `type` but not a subtype of `type`.

`oclIsUndefined() : Boolean[1] validating`

Evaluates to true if the `self` is equal to `invalid` or equal to `null`.

`oclLog() : OclSelf[?]`

Evaluates to the `self`, with the side effect of generating a log message comprising `self`.

`oclLog(message : String[?]) : OclSelf[?]`

Evaluates to the `self`, with the side effect of generating a log message comprising `message` followed by `self`.

`oclType() : OclSelf[1]`

Evaluates to the most derived type of which `self` is currently an instance. If `self` is an instance of a multiply classified type, the return is the most derived type of the current classification which is established when the instance is passed to OCL, or re-established by an `oclAsType()` call.

`oclTypes() : Set(OclSelf[*|?])`

Evaluates to all of the most derived type of which `self` is an instance. The return from `oclTypes()` is normally equivalent to that from `oclType()` unless `self` is an instance of multiply classified type.

`toString() : String[1]`

Returns a string representation of `self`.

3.11. OclComparable

The type `OclComparable` defines the `compareTo` operation used by the `sortedBy` iteration. Only types that provide a derived `compareTo` implementation may be sorted.

conformsTo [OclAny](#)

Operations

`<(that : OclSelf[?]) : Boolean[1] precedence: RELATIONAL`
 True if self is less than that.

`<=(that : OclSelf[?]) : Boolean[1] precedence: RELATIONAL`
 True if self is less than or equal to that.

`>=(that : OclSelf[?]) : Boolean[1] precedence: RELATIONAL`
 True if self is greater than or equal to that.

`>(that : OclSelf[?]) : Boolean[1] precedence: RELATIONAL`
 True if self is greater than that.

`compareTo(that : OclSelf[?]) : Integer[1]`
 Return -ve, 0, +ve according to whether self is less than, equal to , or greater than that.
 The compareTo operation should be commutative.

3.12. OclElement

The type `OclElement` is the implicit supertype of any user-defined type that has no explicit supertypes. Operations defined for `OclElement` are therefore applicable to all user-defined types.

conformsTo [OclAny](#)

Attributes

`OclElement : Bag(OclElement[*|?])`
`OclElement : Bag(OclElement[*|?])`
`oclContents : Set(OclElement)`

The composed contents of self.

Associations

`oclContainer : OclElement[?]`

The object for which self is a composed content or null if there is no such object.

Operations

`allInstances() : Set(OclSelf)`

Return a set of all instances of the type and derived types of self.

`oclAsModelType(TT)(type : TT[?]) : TT[1] invalidating`

Evaluates to self, where self is of the model type identified by TT.

Most model elements have metamodel types for use with `oclAsType`, but no model type and so the return is `invalid`.

Model elements such as UML's `InstanceSpecification` that do support distinct model and metamodel types return self with the cast type TT that may be used for further navigation. If the actual model type of self at evaluation time does not conform to TT, then the `oclAsType` operation evaluates to `invalid`.

If self is a multiply classified instance, the current classification used for OCL navigation is changed to the classification to which TT conforms. The `oclAsModelType` call is not well-formed if the classification is ambiguous.

```
post IsSelf: result = self
```

`oclContainer() : OclElement[?]`

Returns the object for which self is a composed content or null if there is no such object.

`oclContents() : Set(OclElement)`

Returns the composed contents of self.

`oclIsModelKindOf(type : OclType[?]) : Boolean[1]`

Evaluates to true if the type of self conforms to the model type type. That is, self is of type type or a subtype of type.

The return is normally `false` since few model elements have model types. UML's `InstanceSpecification::classifier` provides a multiple classification for a model type.

`oclModelType() : OclSelf[1]`

Evaluates to the most derived model type of which `self` is currently an instance. If `self` is an instance of a multiply classified model type, the return is the most derived type of the current classification which is established by an `oclAsModelType()` call.

The return is normally `invalid` since few model elements have model types. UML's `InstanceSpecification::classifier` provides a multiple classification for a model type.

`oclModelTypes() : Set(OclSelf[*|?])`

Evaluates to all of the most derived model types of which `self` is an instance. The return from `oclModelTypes()` is normally equivalent to that from `oclModelType()` unless `self` is an instance of multiply classified model type.

The return is normally `invalid` since few model elements have model types. UML's `InstanceSpecification::classifier` provides a multiple classification for a model type.

3.13. OclEnumeration

The `OclEnumeration` type is the implicit supertype of any user `Enumeration` type.

conformsTo [OclType](#)

Attributes

`allLiterals : OrderedSet(EnumerationLiteral)`

Evaluates to the literals of the enumeration.

Operations

`allInstances() : Set(OclSelf)`

Return a set of all enumeration values of `self`.

3.14. OclInvalid

The type `OclInvalid` is a type that conforms to all other types. It has one single instance, identified as `invalid`. Any property call applied on `invalid` results in `invalid`, except for the operations `oclIsUndefined()` and `oclIsInvalid()`. `OclInvalid` is itself an instance of the metatype `InvalidType`.

conformsTo [OclVoid](#)

Associations

`oclBadProperty : OclAny[?]`

An `oclBadProperty` may be used as a placeholder in an unsuccessfully created `OCLExpression`.

Operations

`=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

Returns `invalid`.

`<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

Returns `invalid`.

`allInstances() : Set(OclSelf)`

Returns `invalid`.

`and(b : Boolean[?]) : Boolean[?] validating precedence: AND`

`implies(b : Boolean[?]) : Boolean[?] validating precedence: IMPLIES`

`oclAsSet() : Set(OclSelf)`

`oclAsType(TT)(type : TT[?]) : TT[?]`

`oclBadOperation() : OclAny[?]`

An `oclBadOperation` may be used as a placeholder in an unsuccessfully created `OCLExpression`.

`oclIsInvalid() : Boolean[1] validating`

```
oclIsKindOf(type : OclType[?]) : Boolean[1]
oclIsTypeOf(type : OclType[?]) : Boolean[1]
oclIsUndefined() : Boolean[1] validating
oclType() : OclSelf[1]
or(b : Boolean[?]) : Boolean[?] validating precedence: OR
toString() : String[1]
Returns 'invalid'.
```

3.15. OclLambda

The type `OclLambda` is the implicit supertype of all `Lambda` types. The operations defined for `OclLambda` therefore apply to all `lambda` expressions.

conformsTo [OclAny](#)

3.16. OclMessage

OclMessage This sub clause contains the definition of the standard type `OclMessage`. As defined in this sub clause, each `ocl` message type is actually a template type with one parameter. 'T' denotes the parameter. A concrete `ocl` message type is created by substituting an operation or signal for the T.

The predefined type `OclMessage` is an instance of `MessageType`. Every `OclMessage` is fully determined by either the operation, or signal given as parameter. Note that there is conceptually an undefined (infinite) number of these types, as each is determined by a different operation or signal. These types are unnamed. Every type has as attributes the name of the operation or signal, and either all formal parameters of the operation, or all attributes of the signal. `OclMessage` is itself an instance of the metatype `MessageType`.

`OclMessage` has a number of predefined operations, as shown in the OCL Standard Library.

conformsTo [OclAny](#)

Operations

```
hasReturned() : Boolean[1]
```

True if type of template parameter is an operation call, and the called operation has returned a value. This implies the fact that the message has been sent. False in all other cases.

```
isOperationCall() : Boolean[1]
```

Returns true if the `OclMessage` represents the sending of a UML Operation call.

```
isSignalSent() : Boolean[1]
```

Returns true if the `OclMessage` represents the sending of a UML Signal.

```
result() : OclAny[?]
```

Returns the result of the called operation, if type of template parameter is an operation call, and the called operation has returned a value. Otherwise the `invalid` value is returned.

3.17. OclSelf

The pseudo-type `OclSelf` denotes the statically determinate type of `self` in `Operation` and `Iteration` signatures. Instances of `OclSelf` are never created.

conformsTo [OclAny](#)

3.18. OclState

conformsTo [OclAny](#)

3.19. OclStereotype

The type `OclStereotype` is the implicit supertype of any UML stereotype. Operations defined for `OclStereotype` are therefore applicable to all UML stereotypes.

conformsTo [OclType](#)

Operations

`allInstances() : Set(OclSelf)`

Return a set of all instances of the stereotype and derived types of self.

3.20. OclSummable

The type `OclSummable` defines the sum and zero operations used by the `Collection::sum` iteration. Only types that provide derived sum and zero implementations may be summed.

conformsTo [OclAny](#)

Operations

`sum(that : OclSelf[?]) : OclSelf[?]`

Return the sum of self and that.

The sum operation should be associative.

`zero() : OclSelf[?]`

Return the 'zero' value of self to initialize a summation.

`zero().sum(self) = self`.

3.21. OclTuple

The type `OclTuple` is the implicit supertype of all `Tuple` types. The operations defined for `OclTuple` therefore apply to all tuples.

conformsTo [OclAny](#)

Operations

`=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

`<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

3.22. OclType

The type `OclType` is the implicit supertype of any UML type. Operations defined for `OclType` are therefore applicable to all UML types.

conformsTo [OclElement](#)

Operations

`conformsTo(type2 : OclType[?]) : Boolean[1]`

Returns true if type2 conforms to self.

3.23. OclVoid

The type `OclVoid` is a type that conforms to all other types except `OclInvalid`. It has one single instance, identified as `null`, that corresponds with the UML `LiteralNull` value specification. Any property call applied on `null` results in `invalid`, except for the `oclIsUndefined()`, `oclIsInvalid()`, `=(OclAny)` and `<>(OclAny)` operations. However, by virtue of the implicit conversion to a collection literal, an expression evaluating to `null` can be used as source of collection operations (such as 'isEmpty'). If the source is the `null` literal, it is implicitly converted to `Bag{}`.

`OclVoid` is itself an instance of the metatype `VoidType`.

conformsTo [OclAny](#)

Operations

`=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

Redefines the `OclAny` operation, returning `true` if object is `null`, `invalid` if object is `invalid`, `false` otherwise.

`<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

```
allInstances() : Set(OclSelf[*|?])  
Returns Set{null}.  
and(b : Boolean[?]) : Boolean[?] precedence: AND  
implies(b : Boolean[?]) : Boolean[?] precedence: IMPLIES  
oclAsSet() : Set(OclSelf)  
oclIsInvalid() : Boolean[1] validating  
oclIsUndefined() : Boolean[1] validating  
or(b : Boolean[?]) : Boolean[?] precedence: OR  
toString() : String[1]  
Returns null.
```

3.24. OrderedCollection(T)

The OrderedCollection type provides the shared functionality of the OrderedSet and Sequence collections for which the elements are ordered. The common supertype of OrderedCollection is Collection.

conformsTo [Collection\(T\)](#)

Operations

```
at(index : Integer[?]) : T[?] invalidating  
The i-th element of ordered collection.  
first() : T[?] invalidating  
The first element in self.  
indexOf(obj : OclAny[?]) : Integer[1] invalidating  
The index of object obj in the ordered collection.  
last() : T[?] invalidating  
The last element in self.
```

3.25. OrderedSet(T)

The OrderedSet is a Set, the elements of which are ordered. It contains no duplicates. OrderedSet is itself an instance of the metatype OrderedSetType. An OrderedSet is not a subtype of Set, neither a subtype of Sequence. The common supertype of Sets and OrderedSets is Collection.

conformsTo [OrderedCollection\(T\)](#), [UniqueCollection\(T\)](#)

Operations

```
=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY  
<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY  
-(s : UniqueCollection(OclAny)) : OrderedSet(T) precedence: ADDITIVE  
The elements of self, which are not in s.  
append(object : T[?]) : OrderedSet(T)  
The set of elements, consisting of all elements of self, followed by object.  
appendAll(objects : OrderedCollection(T)) : OrderedSet(T)  
The set of elements, consisting of all elements of self, followed by objects.  
excluding(object : OclAny[?]) : OrderedSet(T)  
The ordered set containing all elements of self apart from object.  
The order of the remaining elements is not changed.  
excludingAll(objects : Collection(OclAny)) : OrderedSet(T)  
The ordered set containing all elements of self apart from all occurrences of all objects.  
flatten(T2)() : OrderedSet(T2)
```


`including(object : T[?]) : OrderedSet(T)`

The ordered set containing all elements of `self` plus `object` added as the last element if not already present.

`includingAll(objects : Collection(T)) : OrderedSet(T)`

The ordered set containing all elements of `self` plus `objects` added as the last elements.

`insertAt(index : Integer[?], object : T[?]) : OrderedSet(T)`
invalidating

The ordered set consisting of `self` with `object` present at position `index`.

`prepend(object : T[?]) : OrderedSet(T)`

The sequence consisting of `object`, followed by all elements in `self`.

`post IsAtStart: result->at(1) = object`

`post IsShiftedAlong: Sequence{1..self->size()->forAll(index | self->at(index) = result->a`

`post IsSizePlusOne: result->size() = self->size() + 1`

`prependAll(objects : OrderedCollection(T)) : OrderedSet(T)`

The sequence consisting of `objects`, followed by all elements in `self`.

`reverse() : OrderedSet(T)`

The ordered set of elements with same elements but with the opposite order.

`selectByKind(TT)(type : TT[?]) : OrderedSet(TT)`

`selectByType(TT)(type : TT[?]) : OrderedSet(TT)`

`subOrderedSet(lower : Integer[?], upper : Integer[?]) : OrderedSet(T)`
invalidating

The sub-set of `self` starting at number `lower`, up to and including element number `upper`.

Iterations

`closure(i : T[1] | lambda : Lambda T() : OrderedSet(T)[?]) : OrderedSet(T)`

The closure of applying `body` transitively to every distinct element of the source collection.

`collect(V)(i : T[?] | lambda : Lambda T() : V[?]) : Sequence(V)`

`collectNested(V)(i : T[?] | lambda : Lambda T() : V[?]) : Sequence(V)`

The sequence of elements that results from applying `body` to every member of the source ordered collection.

`reject(i : T[?] | lambda : Lambda T() : Boolean[1]) : OrderedSet(T)`

The ordered set of the source ordered set for which `body` is false.

`select(i : T[?] | lambda : Lambda T() : Boolean[1]) : OrderedSet(T)`

The ordered set of the source ordered set for which `body` is true

`sortedBy(i : T[?] | lambda : Lambda T() : OclAny[?]) : OrderedSet(T)`

Results in the ordered set containing all elements of the source collection. The element for which `body` has the lowest value comes first, and so on. The type of the `body` expression must have the `<` operation defined. The `<` operation must return a Boolean value and must be transitive (i.e., if `a < b` and `b < c`, then `a < c`).

3.26. Real

The standard type `Real` represents the mathematical concept of real. Note that `Integer` is a subclass of `Real`, so for each parameter of type `Real`, you can use an integer as the actual parameter. `Real` is itself an instance of the metatype `PrimitiveType` (from UML).

conformsTo [OclComparable](#), [OclSummable](#)

Operations

`=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

Returns true if the numeric value of `self` is the same as the numeric value of `object2`, false otherwise.

`<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

Returns true if the numeric value of `self` is not the same as the numeric value of `object2`, false otherwise.

`*(r : OclSelf[?]) : Real[1] precedence: MULTIPLICATIVE`

The value of the multiplication of `self` and `r`.

`+(r : OclSelf[?]) : Real[1] precedence: ADDITIVE`

The value of the addition of `self` and `r`.

`-() : Real[1] precedence: UNARY`

The negative value of `self`.

`-(r : OclSelf[?]) : Real[1] precedence: ADDITIVE`

The value of the subtraction of `r` from `self`.

`/(r : OclSelf[?]) : Real[1] invalidating precedence: MULTIPLICATIVE`

The value of `self` divided by `r`. Evaluates to invalid if `r` is equal to zero.

`abs() : Real[1]`

The absolute value of `self`.

`floor() : Integer[1]`

The largest integer that is less than or equal to `self`.

`max(r : OclSelf[?]) : Real[1]`

The maximum of `self` and `r`.

`min(r : OclSelf[?]) : Real[1]`

The minimum of `self` and `r`.

`round() : Integer[1]`

The integer that is closest to `self`. When there are two such integers, the largest one.

`toString() : String[1]`

Converts `self` to a string value.

3.27. Sequence(T)

A sequence is a collection where the elements are ordered. An element may be part of a sequence more than once. Sequence is itself an instance of the metatype `SequenceType`. A `Sentence` is not a subtype of `Bag`. The common supertype of `Sentence` and `Bags` is `Collection`.

conformsTo [OrderedCollection\(T\)](#)

Operations

`=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

True if `self` contains the same elements as `s` in the same order.

`<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

`append(object : T[?]) : Sequence(T)`

The sequence of elements, consisting of all elements of `self`, followed by `object`.

`appendAll(objects : OrderedCollection(T)) : Sequence(T)`

The sequence of elements, consisting of all elements of `self`, followed by `objects`.

`excluding(object : OclAny[?]) : Sequence(T)`

The sequence containing all elements of `self` apart from all occurrences of `object`.

The order of the remaining elements is not changed.

`excludingAll(objects : Collection(OclAny)) : Sequence(T)`

The sequence containing all elements of `self` apart from all occurrences of all objects.

`flatten(T2)() : Sequence(T2)`

Redefines the Collection operation. If the element type is not a collection type, this results in the same sequence as `self`. If the element type is a collection type, the result is the sequence containing all the elements of all the recursively flattened elements of `self`. The order of the elements is partial.

`including(object : T[?]) : Sequence(T)`

The sequence containing all elements of `self` plus object added as the last element.

`includingAll(objects : Collection(T)) : Sequence(T)`

The sequence containing all elements of `self` plus objects added as the last elements.

`insertAt(index : Integer[?], object : T[?]) : Sequence(T) invalidating`

The sequence consisting of `self` with object inserted at position `index`.

`prepend(object : T[?]) : Sequence(T)`

The sequence consisting of object, followed by all elements in `self`.

`prependAll(objects : OrderedCollection(T)) : Sequence(T)`

The sequence consisting of objects, followed by all elements in `self`.

`reverse() : Sequence(T)`

The sequence containing the same elements but with the opposite order.

`selectByKind(TT)(type : TT[?]) : Sequence(TT)`

`selectByType(TT)(type : TT[?]) : Sequence(TT)`

`subSequence(lower : Integer[?], upper : Integer[?]) : Sequence(T)`

`invalidating`

The sub-sequence of `self` starting at number `lower`, up to and including element number `upper`.

Iterations

`closure(i : T[1] | lambda : Lambda T() : OrderedSet(T)[?]) : OrderedSet(T)`

The closure of applying body transitively to every distinct element of the source collection.

`collect(V)(i : T[?] | lambda : Lambda T() : V[?]) : Sequence(V)`

`collectNested(V)(i : T[?] | lambda : Lambda T() : V[?]) : Sequence(V)`

The sequence of elements that results from applying body to every member of the source ordered collection.

`reject(i : T[?] | lambda : Lambda T() : Boolean[1]) : Sequence(T)`

The subsequence of the source sequence for which body is false.

`select(i : T[?] | lambda : Lambda T() : Boolean[1]) : Sequence(T)`

The subsequence of the source sequence for which body is true.

`sortedBy(i : T[?] | lambda : Lambda T() : OclAny[?]) : Sequence(T)`

Results in the Sequence containing all elements of the source collection. The element for which body has the lowest value comes first, and so on. The type of the body expression must have the `<` operation defined. The `<` operation must return a Boolean value and must be transitive (i.e., if `a < b` and `b < c` then `a < c`).

3.28. Set(T)

conformsTo [UniqueCollection\(T\)](#)

Operations

`=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

Evaluates to true if `self` and `s` contain the same elements.

`<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

`-(s : UniqueCollection(OclAny)) : Set(T) precedence: ADDITIVE`

The elements of `self`, which are not in `s`.

`excluding(object : OclAny[?]) : Set(T)`

The set containing all elements of `self` without `object`.

`excludingAll(objects : Collection(OclAny)) : Set(T)`

The set containing all elements of `self` apart from all occurrences of all `objects`.

`flatten(T2)() : Set(T2)`

Redefines the `Collection` operation. If the element type is not a collection type, this results in the same set as `self`. If the element type is a collection type, the result is the set containing all the elements of all the recursively flattened elements of `self`.

`including(object : T[?]) : Set(T)`

The set containing all elements of `self` plus `object`.

`includingAll(objects : Collection(T)) : Set(T)`

The set containing all elements of `self` and `objects`.

`selectByKind(TT)(type : TT[?]) : Set(TT)`

`selectByType(TT)(type : TT[?]) : Set(TT)`

Iterations

`closure(i : T[1] | lambda : Lambda T() : Set(T)[?]) : Set(T)`

The closure of applying body transitively to every distinct element of the source collection.

`collect(V)(i : T[?] | lambda : Lambda T() : V[?]) : Bag(V)`

`collectNested(V)(i : T[?] | lambda : Lambda T() : V[?]) : Bag(V)`

The Bag of elements which results from applying body to every member of the source nonordered collection.

`reject(i : T[?] | lambda : Lambda T() : Boolean[1]) : Set(T)`

The subset of the source set for which body is false.

`select(i : T[?] | lambda : Lambda T() : Boolean[1]) : Set(T)`

The subset of set for which `expr` is true.

`sortedBy(i : T[?] | lambda : Lambda T() : OclAny[?]) : OrderedSet(T)`

Results in the ordered set containing all elements of the source collection. The element for which body has the lowest value comes first, and so on. The type of the body expression must have the `<` operation defined. The `<` operation must return a Boolean value and must be transitive (i.e., if `a < b` and `b < c`, then `a < c`).

3.29. State

conformsTo [OclState](#)

3.30. String

The standard type `String` represents strings, which can be both ASCII or Unicode. `String` is itself an instance of the metatype `PrimitiveType` (from UML).

conformsTo [OclComparable](#), [OclSummable](#)

Operations

`=(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

`<>(object2 : OclSelf[?]) : Boolean[1] precedence: EQUALITY`

`<(s : OclSelf[?]) : Boolean[1] precedence: RELATIONAL`

True if `self` is less than `s`, using the locale defined by looking up `oclLocale` in the current environment.

`<=(s : OclSelf[?]) : Boolean[1] precedence: RELATIONAL`

True if `self` is less than or equal to `s`, using the locale defined by looking up `oclLocale` in the current environment.

`>=(s : OclSelf[?]) : Boolean[1]` precedence: RELATIONAL

True if `self` is greater than or equal to `s`, using the locale defined by looking up `oclLocale` in the current environment.

`>(s : OclSelf[?]) : Boolean[1]` precedence: RELATIONAL

True if `self` is greater than `s`, using the locale defined by looking up `oclLocale` in the current environment.

`+(s : String[?]) : String[1]` precedence: ADDITIVE

The concatenation of `self` and `s`.

`at(i : Integer[?]) : String[1]` invalidating

Queries the character at position `i` in `self`.

`characters() : Sequence(String)`

Obtains the characters of `self` as a sequence.

`compareTo(that : OclSelf[?]) : Integer[1]`

The comparison of `self` with `that`. -ve if less than, 0 if equal, +ve if greater than.

`concat(s : String[?]) : String[1]`

The concatenation of `self` and `s`.

`endsWith(s : String[?]) : Boolean[1]`

Returns true if `self` ends with the string `s`. Every string ends with the empty string.

`equalsIgnoreCase(s : String[?]) : Boolean[1]`

Queries whether `s` and `self` are equivalent under case-insensitive collation.

`indexOf(s : String[?]) : Integer[1]`

Queries the first index in `self` at which `s` is a substring of `self`, or zero if `s` is not a substring of `self`.

The empty string is a substring of every string at index 1 (and also at all other indexes).

`lastIndexOf(s : String[?]) : Integer[1]`

Queries the last in `self` at which `s` is a substring of `self`, or zero if `s` is not a substring of `self`. The

empty string is a substring of every string at index `self-size()+1` (and also at all other indexes).

`matches(regex : String[?]) : Boolean[1]`

Use a regular expression match and return true if `self` matches `regex`, false otherwise.

`replaceAll(regex : String[?], replacement : String[?]) : String[1]`
invalidating

Return a string derived from `self` by replacing all matches of `regex` by `replacement`.

`replaceFirst(regex : String[?], replacement : String[?]) : String[1]`
invalidating

Return a string derived from `self` by replacing the first match of `regex` by `replacement`.

`size() : Integer[1]`

The number of characters in `self`.

`startsWith(s : String[?]) : Boolean[1]`

Returns true if `self` starts with the string `s`. Every string starts with the empty string.

`substituteAll(oldSubstring : String[?], newSubstring : String[?]) : String[1]`

Return a string derived from `self` by replacing all occurrences of `oldSubstring` by `newSubstring`.

`substituteFirst(oldSubstring : String[?], newSubstring : String[?]) : String[1]`

Return a string derived from `self` by replacing the first occurrence of `oldSubstring` by `newSubstring`. Returns invalid if there is no first occurrence.

`substring(lower : Integer[?], upper : Integer[?]) : String[1]`
invalidating

The sub-string of `self` starting at character number `lower`, up to and including character number `upper`. Character numbers run from 1 to `self.size()`.

`toBoolean() : Boolean[1]` invalidating

Converts `self` to a boolean value.

`toInteger() : Integer[1]` invalidating

Converts `self` to an Integer value.

`toLower() : String[1]`

This is a deprecated variant of `toLowerCase()` preserving compatibility with traditional Eclipse OCL behaviour.

`toLowerCase() : String[1]`

Converts `self` to lower case, using the locale defined by looking up `oclLocale` in the current environment. Otherwise, returns the same string as `self`.

`toReal() : Real[1]` invalidating

Converts `self` to a Real value.

`toString() : String[1]`

Returns `self`.

`toUpper() : String[1]`

This is a deprecated variant of `toUpperCase()` preserving compatibility with traditional Eclipse OCL behaviour.

`toUpperCase() : String[1]`

Converts `self` to upper case, using the locale defined by looking up `oclLocale` in the current environment. Otherwise, returns the same string as `self`.

`tokenize() : Sequence(String)`

Partition `self` into a sequence substrings separated by any of space, line-feed, carriage-return, form-feed and horizontal-tab delimiters. The delimiters are omitted from the return.

`tokenize(delimiters : String[?]) : Sequence(String)`

Partition `self` into a sequence substrings separated by characters in the delimiters. The delimiters are omitted from the return.

`tokenize(delimiters : String[?], returnDelimiters : Boolean[?]) : Sequence(String)`

Partition `self` into a sequence substrings separated by characters in the delimiters. If `returnDelimiters` is true the returned sequence includes the delimiters, otherwise the delimiters are omitted.

`trim() : String[1]`

Return `self` with leading and trailing whitespace removed.

3.31. Type

The UML Type is the supertype of anything that may be used as a type.

`conformsTo` [OclType](#)

Operations

`conformsTo(type2 : Type[?]) : Boolean[1]`

Returns true if `type2` conforms to `self`.

3.32. UniqueCollection(T)

The `UniqueCollection` type provides the shared functionality of the `OrderedSet` and `Set` collections for which the elements are unique. The common supertype of `UniqueCollection` is `Collection`.

conformsTo [Collection\(T\)](#)

Operations

`-(s : UniqueCollection(OclAny)) : UniqueCollection(T) precedence: ADDITIVE`

The elements of `self`, which are not in `s`.

`intersection(c : Collection(T)) : Set(T)`

The intersection of `self` and `c` (i.e., the set of all elements that are in both `self` and `c`).

`symmetricDifference(s : UniqueCollection(OclAny)) : Set(T)`

The set containing all the elements that are in `self` or `s`, but not in both.

`union(s : UniqueCollection(T)) : Set(T)`

The set consisting of all elements in `self` and all elements in `s`.

Iterations

`sortedBy(i : T[?] | lambda : Lambda T() : OclAny[?]) : OrderedSet(T)`

Results in the ordered set containing all elements of the source collection. The element for which body has the lowest value comes first, and so on. The type of the body expression must have the `<` operation defined. The `<` operation must return a Boolean value and must be transitive (i.e., if `a < b` and `b < c`, then `a < c`).

3.33. UnlimitedNatural

The standard type `UnlimitedNatural` is used to encode the non-negative values of a multiplicity specification. This includes a special *unlimited* value (*) that encodes the upper value of a multiplicity specification. `UnlimitedNatural` is itself an instance of the metatype `UnlimitedNaturalType`.

Note that `UnlimitedNatural` is not a subclass of `Integer`.

conformsTo [OclComparable](#)

Operations

`max(i : OclSelf[?]) : UnlimitedNatural[1]`

The maximum of `self` and `i`.

`min(i : OclSelf[?]) : UnlimitedNatural[1]`

The minimum of `self` and `i`.

`oclAsType(TT)(type : TT[?]) : TT[?] invalidating`

Evaluates to `self`, where `self` is of the type identified by `T`. The type `T` may be any classifier defined in the UML model; if the actual type of `self` at evaluation time does not conform to `T`, then the `oclAsType` operation evaluates to `invalid`.

The standard behavior is redefined for `UnlimitedNatural`. Numeric values may be converted to `Real` or `Integer`, but the *unlimited* value may not. Conversion of *unlimited* to `Real` or `Integer` returns `invalid`.

`toInteger() : Integer[1] invalidating`

Converts `self` to an `Integer` value unless `self` is *unlimited* in which case `self` is converted to `invalid`.

Chapter 4. Tutorials

The [OCLinEcore tutorial](#) shows how

- to install OCL and the additional Editors and Examples
- to use the OCLinEcore editor
 - to edit Ecore meta-models
 - to enrich Ecore meta-models with OCL invariants, bodies and values
- to use embedded OCL for validation of models
- to use the OCL Console to practice evaluation of OCL
- to generate Java code for Ecore that uses the embedded OCL

The [Working with Classic OCL tutorial](#) shows how

- the OCL Parser may be invoked from Java
- the OCL evaluator may be invoked from Java

4.1. OCLinEcore tutorial

This tutorial has been refreshed for Eclipse 2021-06; Eclipse 4.20, EMF 2.26, OCL 6.15.0.

- The graphical styling of some screenshots may be slightly out of date.

4.1.1. Overview

In this example you will

- Create an Ecore model using the OCLinEcore text editor
- Create a dynamic instance of that Ecore model
- Enrich the Ecore model with OCL using the OCLinEcore text editor
- Validate the model and observe the OCL enrichments
- Use the Interactive OCL Console to execute the OCL enrichments

The above is all performed without generating any Java code; the models exploit EMF's dynamic capabilities and the OCL integration.

You may then

- Create an Ecore genmodel
- Generate Java code for the Ecore model that invokes the OCL expressions.

See the [OCL Debugger tutorial](#) for debugging See the [Code Generator tutorial](#) for Java code generation

4.1.2. References

This tutorial assumes that the reader is familiar with generating models using EMF. The reader is referred to [Generating an EMF Model](#).

Other references:

- The Object Constraint Language: Getting Your Models Ready for MDA. Jos Warmer and Anneke Kleppe. (Addison-Wesley Object Technology)
- [OCL specification](#).
- [OCLinEcore wiki page](#).

4.1.3. Installing the Eclipse OCL Examples

Please see the [Instructions for installing the OCL Editors](#).

4.1.4. Troubleshooting

The editor currently provides syntax and semantic validation. It does not yet apply all the well-formedness validation rules, so some problems may be unreported. This is work in progress. Sometimes spurious errors are displayed, which may go away with a **Save**, but may require an editor close and reopen.

4.1.5. Using the OCLinEcore text editor for Ecore

There are many different (compatible) ways to create and edit Ecore models.

- An Ecore Model may be created from an XSD schema file
- An Ecore Model may be created from a Rose model file
- An Ecore Model may be created from annotated Java file
- The Sample Ecore Editor provides tree editing
- The Ecore Tools project provides graphical editing
- Papyrus provides UML editing that may be converted to Ecore

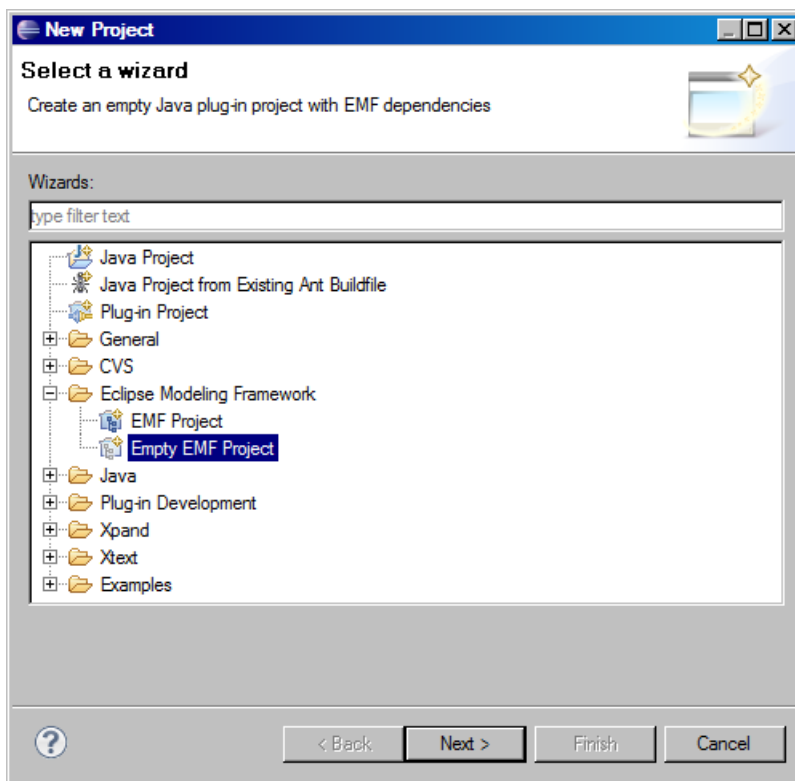
Here we introduce the OCLinEcore editor that provides text editing, which is appropriate when a non-trivial amount of OCL enrichment is required.

All the above approaches update a *.ecore file, so the user is free to choose whichever editing approach is best suited for the planned changes.

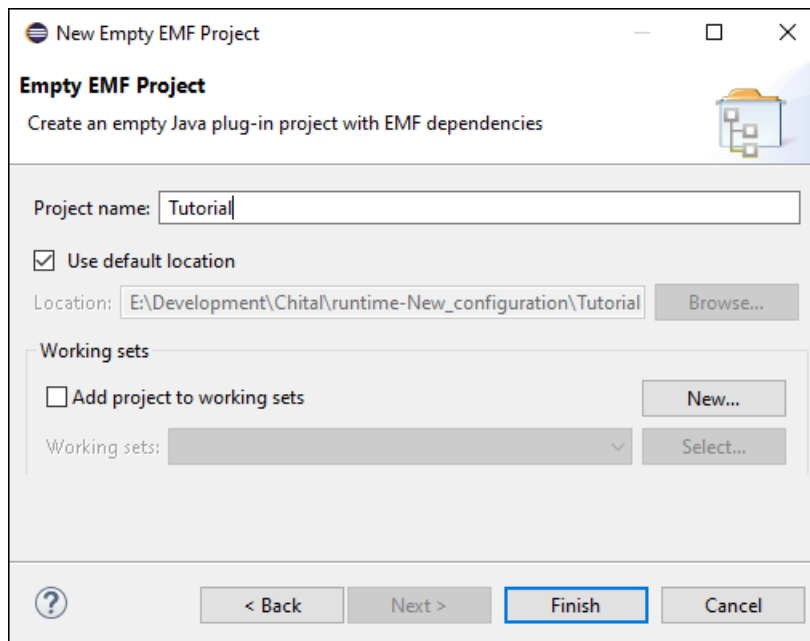
4.1.5.1. Create a New EMF Project

We will first create a new project for this example; so invoke **File->New->Project...** (left-click the **File** menu, then left-click **New**, then left-click **Project...**).

In the **New Project** dialog left-click to expand **Eclipse Modeling Framework**, then left-click to select **Empty EMF Project**.



Left-click on **Next** and in the **New Empty EMF Project** dialog type **Tutorial** as the project name.

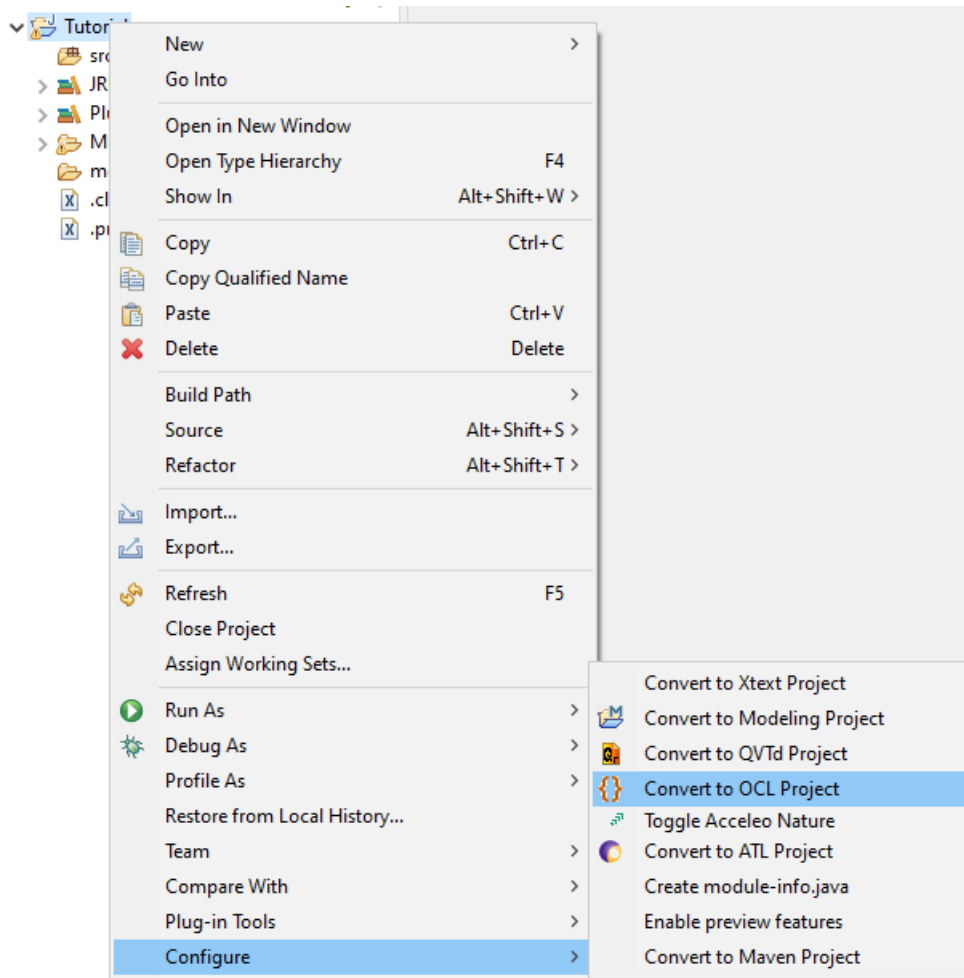


Left-click on **Finish**.

4.1.5.2. Convert to an OCL Project

An OCL project, analogously to many other Eclipse projects, has an OCL nature and an OCL builder that compile OCL resources so that any problems are shown as error/warning/info markers in the **Problems View**.

The OCL nature may be added to our project by right-clicking on the project and then invoking **Configure->Convert to OCL Project** from the context menu.



- The OCL nature may be removed by **Configure->Unconfigure OCL**.

Adding the OCL nature makes the project also-an-OCL-project. It does not displace any other natures that the project already has.

It is not necessary to add the OCL nature, but if you omit this step, every time you open an OCL editor, a pop-up will offer to add the OCL nature for you.

The EMF and UML2 projects do not provide corresponding natures to validate *.ecore or *.uml files. This would leave any OCL embedded in Ecore or UML unchecked and the user unaware of problems. The OCL nature therefore validates *.ecore or *.uml files as well as OCL files by default. This default can be adjusted by editing the value of the enabledExtensions in the .project file.

```

<buildCommand>
  <name>org.eclipse.ocl.pivot.ui.oclbuilder</name>
  <arguments>
    <dictionary>
      <key>disabledExtensions</key>
      <value>*,essentialocl</value>
    </dictionary>
    <dictionary>
      <key>disabledPaths</key>
      <value>bin/**,target/**</value>
    </dictionary>
    <dictionary>
      <key>enabledExtensions</key>
      <value>ecore,ocl,oclinecore,oclstdlib,uml</value>
    </dictionary>
    <dictionary>
      <key>enabledPaths</key>
      <value>**</value>
    </dictionary>
  </arguments>
</buildCommand>

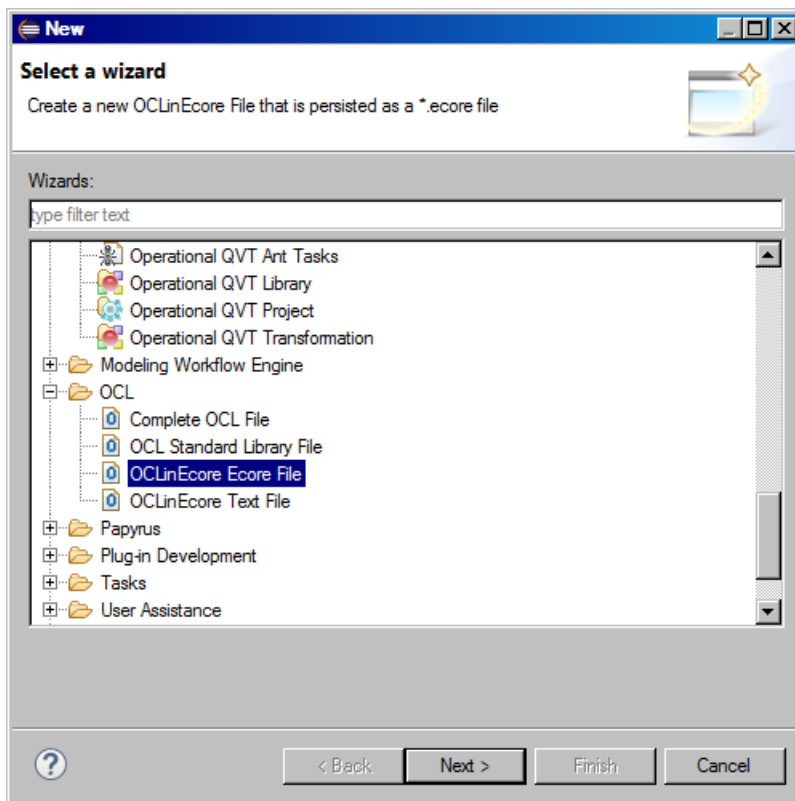
```

If you cannot see files such as **.project**, open the **View** menu by clicking the top right tool bar icon of the **Package Explorer** and enable visibility of **.resources** in the **Filters**.

4.1.5.3. Create a New Ecore Model

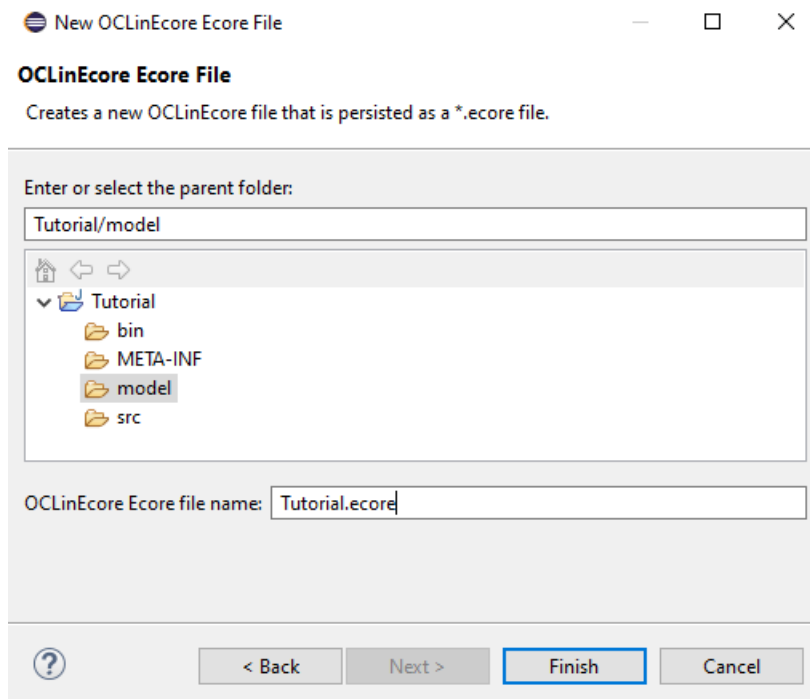
We will now create a new model for this example.

First right-click on the **model** folder in the **Tutorial** project to define the target folder and pop-up the context-sensitive menu. Select **New->Other...** then select the **OCLinEcore Ecore File** from the **OCL** category.



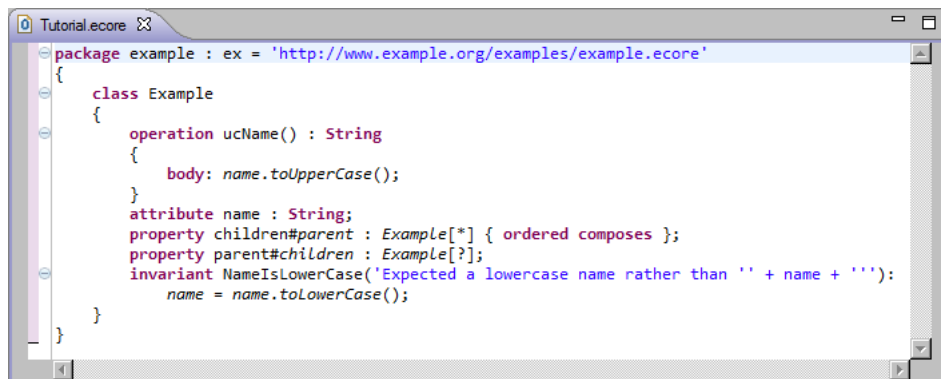
The alternative **OCLinEcore Text File** creates a ***.oclinecore** text file which preserves whitespace and comments more faithfully but which must be converted to a ***.ecore** file for many modeling purposes.

Left-click **Next** and enter **Tutorial.ecore** as the file name.



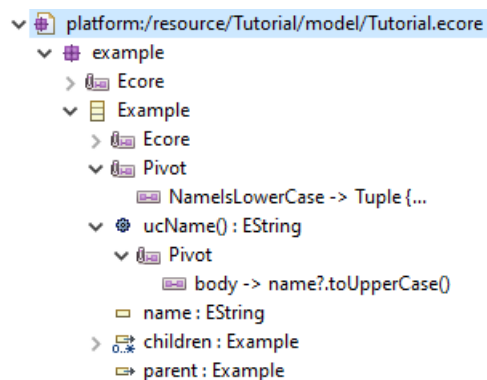
Left-click **Finish** to open up an editor with some minimal example content demonstrating

- the nesting of attributes or operations or invariants within classes within packages
- use of OCL to define the body of an operation
- the syntax for mutually opposite properties
- use of OCL to define an invariant and a custom error message



Close the editor by left-clicking the cross on the editor tab.

You can see the normal Ecore view of the file by right-clicking on the **Tutorial.ecore** file to pop-up the context-sensitive menu and select **Open With->Sample Ecore Model Editor**.



Close the editor by left-clicking the cross on the editor tab.

4.1.5.4. Edit Ecore Model as OCLinEcore

We will now open the Ecore model using the OCLinEcore text editor and provide some initial content.

Right-click on the **Tutorial.ecore** file to pop-up the context-sensitive menu and select **Open With->OCLinEcore Editor**.

Now follow the following procedure to cut and paste the following text into the editor.

- select all existing content (e.g. Ctrl-A)
- delete all (e.g. Ctrl-X)
- open [\[Text for cut and paste\]](#)
- select and copy the text (e.g. Ctrl-A and Ctrl-C) from the browser
- paste (e.g. Ctrl-V) in the original editor
- save the contents (e.g. Ctrl-S)

```
import.ecore : 'http://www.eclipse.org/emf/2002/Ecore#/' ;

package tutorial : tut = 'http://www.eclipse.org/mdt/ocl/oclinecore/tutorial'
{
    class Library
    {
        attribute name : String;
        property books#Library : Book[*] { composes };
        property loans : Loan[*] { composes };
        property members#Library : Member[*] { composes };
    }

    class Book
    {
        attribute name : String;
        attribute copies : Integer;
        property library#books : Library[?];
    }

    class Member
    {
        attribute name : String;
        property library#members : Library[?];
    }

    class Loan
    {
        property book : Book;
        property member : Member;
        attribute date :.ecore::EDate[?];
    }
}
```

The syntax is defined in [OCLinEcore](#). It emulates OMG specifications with 'name : type[multiplicity] { properties }'.

- import associates an alias with an external EPackage.
- package introduces an EPackage with name, nsPrefix and nsURI.
- class introduces an EClass with name and optional superclasses.
- attribute introduces a property with a datatype type (an EAttribute).
- property introduces a property with a class type (an EReference).
- # introduces an opposite role name.
- _ 'xxx' escapes an awkward or reserved word identifier.

The import URI is the URI of a Package, so in the example the `http://www.eclipse.org/emf/2002/Ecore` is the URI of the model, # is the fragment separator and / is the path to the Package at the root of the XMI document.

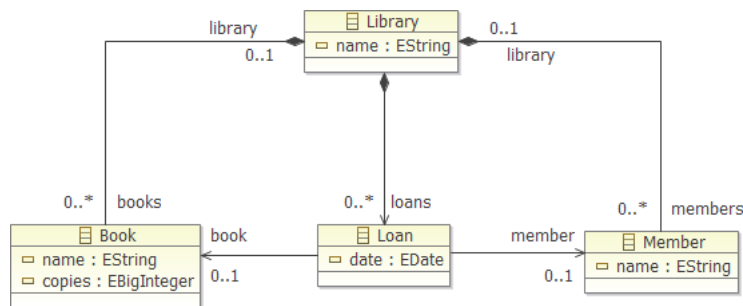
Completion assist (Ctrl Space) may be used for syntax assistance.

Format (Ctrl-Shift F) may be used to auto-format a selected range.

In order to discover a syntax for which completion assist is insufficient, you may use the Sample Ecore Editor on a test file to create the kind of Ecore element that you require, and then open the test file with the OCLinEcore editor to see the corresponding textual syntax.

4.1.5.5. The Tutorial Meta-Model

The example meta-model models a library with members and books and loans of books to members. It may be viewed graphically using the Ecore Tools (not part of this tutorial).



Note that this diagram is an Ecore Diagram rather than a UML Diagram and so the default multiplicities for attributes is Ecore's [0..1] rather than OCLinEcore's and UML's [1..1].

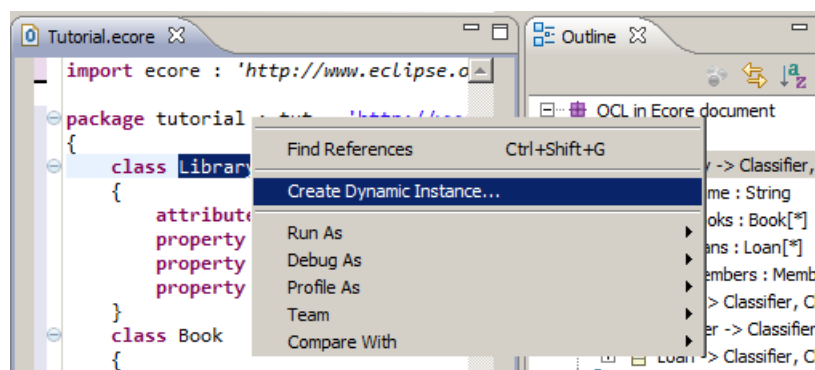
Note also that the OCL types String and Integer map to EString and EBigInteger in Ecore.

4.1.6. Create a Dynamic Model Instance

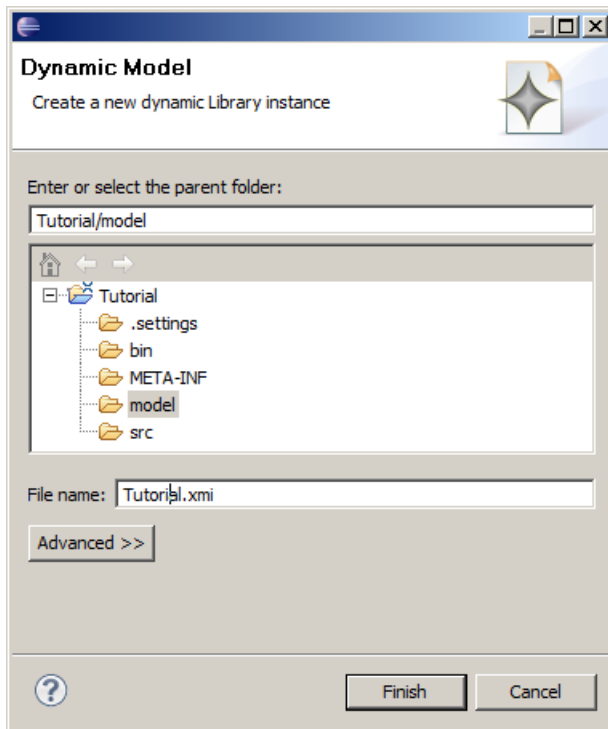
At this point a corresponding EMF tutorial would show how to generate Java code for the meta-model and an editor for the meta-model. Here we are concerned with modeling, so we will continue with the models alone.

In the editor view, double-click on **Library** to select it and then right-click to show the context-sensitive menu and then left-click on **Create Dynamic Instance...** to start to create a new Dynamic Model with Library at its root.

Creating a Dynamic Instance requires a valid *.ecore file to exist. It does not work when editing *.oclinecore files.

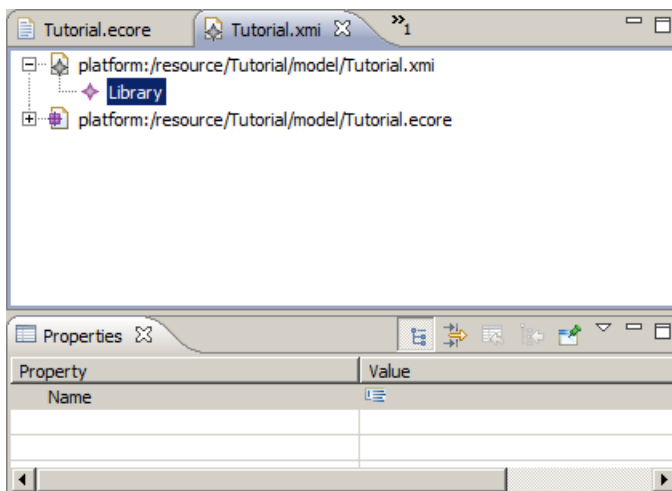


In the **Create Dynamic Instance** dialog select **Tutorial/model** as the parent folder and enter **Tutorial.xmi** as the file name for the dynamic model instance and left-click **Finish**.



The model is automatically opened for editing.

- If it does not open with the Sample Reflective Ecore Model Editor, close the editor and open explicitly using **Open With->Sample Reflective Ecore Model Editor**. This gives a tree-like presentation of the model. The properties of each node can be seen in the Properties View.

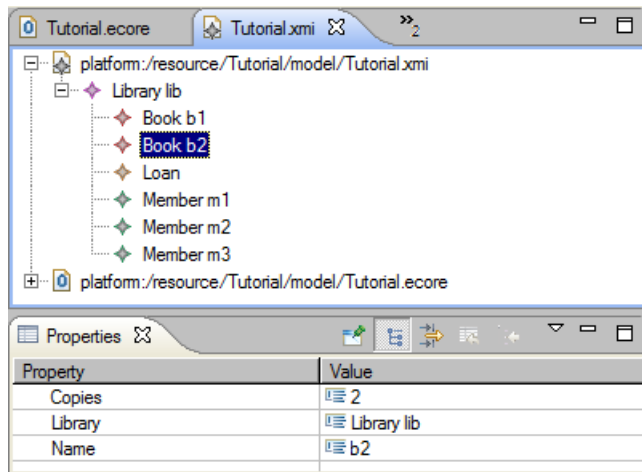


- If the Properties View is not visible, right-click within the editor and left-click on **Show Properties View**.

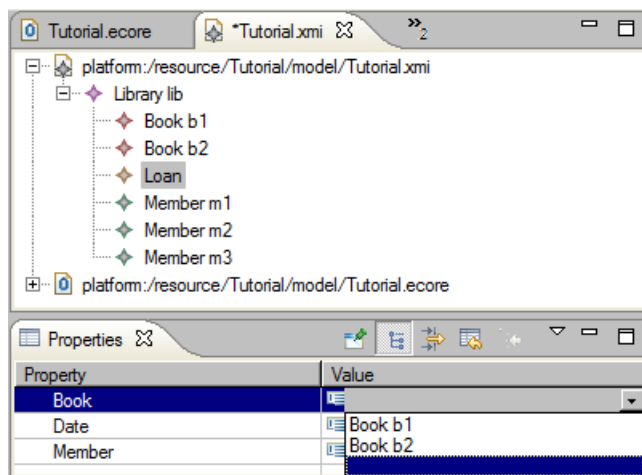
Select the **Library** and give it a name such as **lib**.

From the right-button menu for **Library** use **New Child->Books Book** twice, use **New Child->Loans Loan** once and **New Child->Members Member** three times to populate the model with two books, one loan and three members.

Left-click to select each of the Books and Members in turn and enter a name such as **b1** or **m2** using the Properties View. Specify that **b1** has one copy and that **b2** has 2 copies.

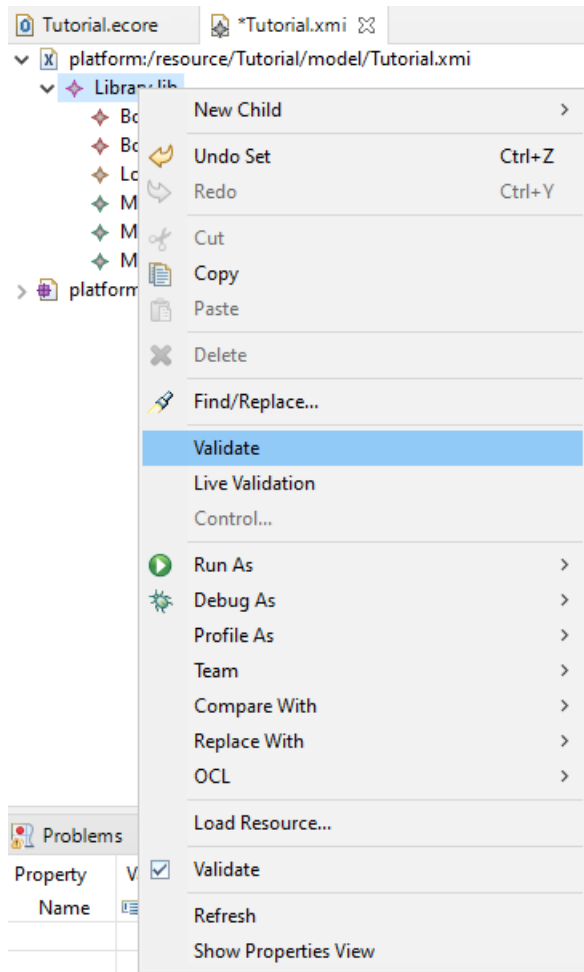


The books and members now have distinct titles in the outline. When you left-click to select the Loan and edit its Book and Member attributes, the associated pull-down has meaningful entries. Specify that the Loan is for b2 by m3.

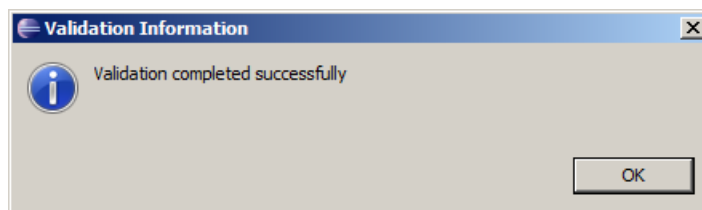


The configuration so far is simple, three members, two books and one loan. We can validate that this by right-clicking on the Library node, and left-clicking to **Validate** Library and all its children.

Beware. If you have installed WST for web support, or M2E for Maven support, there is a rival **Validate** with a checkbox near the bottom of the menu. It does not appear to do anything useful for EMF-based models. The correct **Validate** is the one just above **Live Validation**.



Since the model is so simple, it is difficult to have anything wrong; most of the illegal modeling options such as a Loan composing rather than referencing a Book are prevented by the Editor's enforcement of the meta-model.



- If you have an error at this point, a **Details** button will lead you to some diagnostics that may clarify the problem. Pasting the following XMI into **Tutorial.xmi** should also resolve an entry problem.

```
<?xml version="1.0" encoding="ASCII"?>
<tut:Library xmi:version="2.0" xmlns:xmi="http://www.omg.org/XMI"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:tut="http://www.eclipse.org/mdt/ocl/oclincore/tutorial"
  xsi:schemaLocation="http://www.eclipse.org/mdt/ocl/oclincore/tutorial Tutorial.ecore"
  name="lib">
  <books name="b1" copies="1"/>
  <books name="b2" copies="2"/>
  <loans book="//@books.1" member="//@members.2"/>
  <members name="m1"/>
  <members name="m2"/>
  <members name="m3"/>
</tut:Library>
```

We will now create two further identical loans of b2 by m3. This may conveniently be performed by left-clicking to select the existing loan, typing Ctrl-C to copy it, left-clicking to select the Library as the new parent, then typing Ctrl-V to paste it on the library. Repeat so that there are three identical loans.

Validating the library should still be successful, although it is clearly wrong for the two copies of b2 to participate in three loans.

4.1.7. Enrich the meta-model with OCL

The semantic constraint that a book cannot be borrowed more times than there are copies of the book is a simple example of a constraint that cannot be expressed by simple multiplicities; a more powerful capability is required that may potentially require evaluation of functions of almost arbitrary complexity. The Object Constraint Language provides this capability.

The constraint can be realized as an invariant on a book that specifies that that (the size of the (selection of loans involving the book)) is less than or equal to (the number of copies of the book).

```
invariant SufficientCopies:
    library.loans->select(book=self)->size() <= copies;
```

In more detail:

- an invariant is defined whose name is `SufficientCopies`
- within the invariant on a `Book`, `self` is the instance of `Book` being validated.
- `library.loans`, which is short for `self.library.loans`, navigates to the library and then to all loans in the library.
- `->select(...)` is a collection iteration over the loans. It selects each loan for which its argument expression is true
- `book=self`, which is short for `aLoan : Loan | aLoan.book = self`, uses the `aLoan` iterator over each loan to select those for which the book is the book being validated
- `->size()` is a collection operation that just counts the number of selected loans
- `<= copies`, which is short for `<= self.copies` converts the count to `true` if it is consistent, or `false` if inconsistent.
- it used to be necessary to close an XML editor such as **Tutorial.xmi** before modifying its meta-model since

a wide variety of unpleasant errors could occur if the meta-model changes after the model is loaded. This EMF limitation now appears to have been resolved. It is nonetheless prudent to do so.

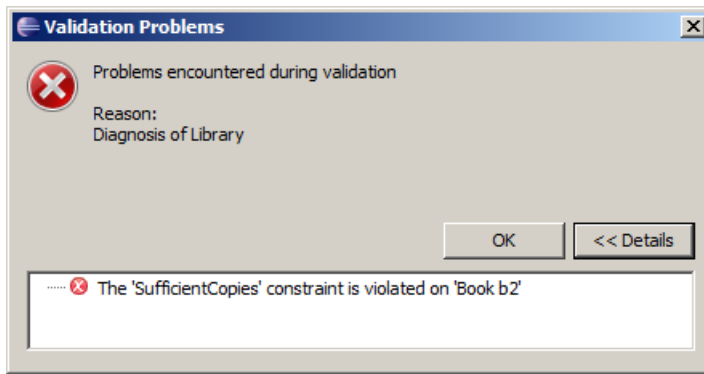
Add the invariant shown below to the meta-model.

```
class Book
{
    invariant SufficientCopies:
        library.loans->select(book=self)->size() <= copies;
    attribute name : String;
    attribute copies : Integer;
    property library#books : Library[?];
}
```

[\[Text for cut and paste\]](#)

The required semantic is expressed by the `SufficientCopies` invariant constraint for a `Book`. For a valid model the `SufficientCopies` invariant must always be true.

If you reopen the **Tutorial.xmi** editor and invoke **Validate** for the `Library`, you will now get a validation error. Left click **Details** for details.



The **Details** identifies that the `SufficientCopies` invariant is not satisfied for the `b2` book.

Alternatively you may enable **Live Validation** so that validation happens automatically with error icons and hover text identifying problems.

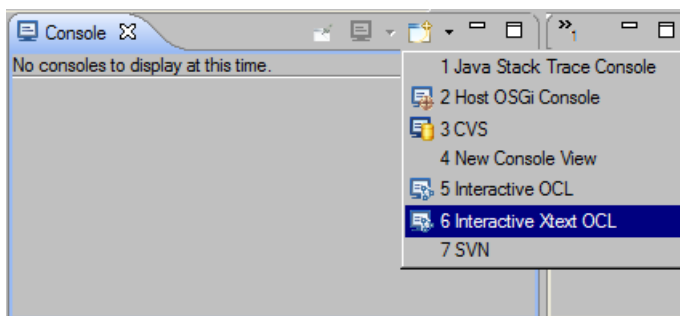
If you now change the first loan so that `b1` is borrowed and then validate again, the problem is resolved. It is all right for `m3` to borrow the one copy of `b1` and the two copies of `b2`.

Before introducing a further constraint of no duplicate loans, we will show how OCL expressions can be exercised. OCL is a very powerful compact language; the example hides a loop over all the loans. More complex examples may easily involve three or four levels of hidden loops on a single line, but may equally easily have simple errors. It is therefore helpful to simplify expressions and use helper operations and properties to modularise them. These may then be exercised using the OCL Console or debugged using the [OCL Debugger](#).

4.1.8. The OCL Console

The OCL Console supports interactive execution of an OCL expression in the context of a model instance.

To make the OCL Console visible, first make the **Console** view visible by **Window->Show View->Console**. Then right click on the **Open Console** and left click on **Interactive Xtext OCL**.



Alternatively, you can just invoke **OCL->Show Xtext OCL Console** from the right button menu within the **Sample Ecore Editor** or **Sample Reflective Ecore Editor**.

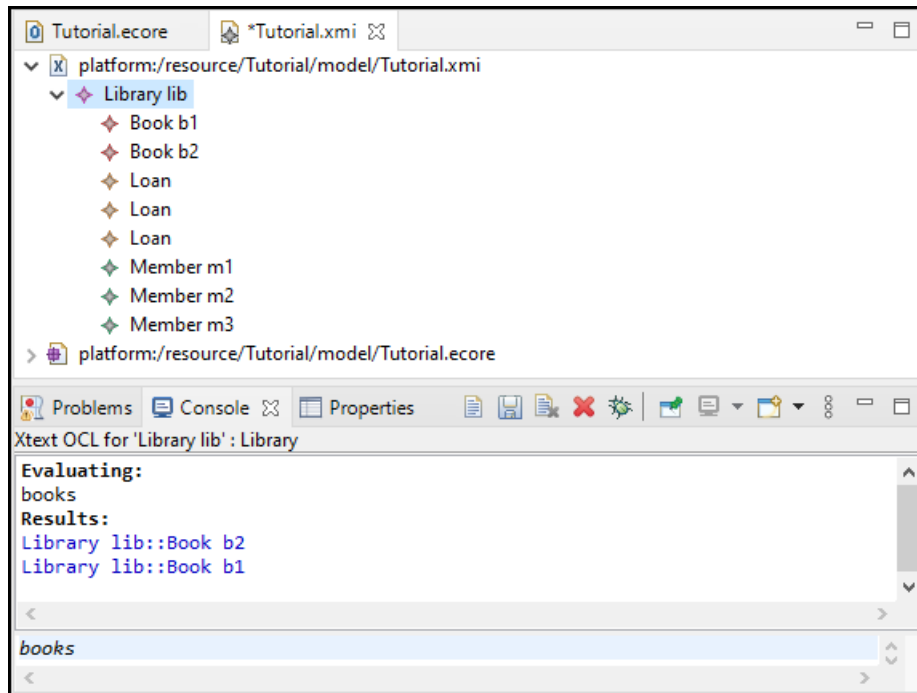
The **Xtext OCL** console is new Xtext-based functionality that uses the Pivot binding. It is faster, and more compliant with the OCL specification, than the **OCL** console that uses the LPG parser and Ecore binding.

The **Interactive Xtext OCL** console comprises two main text panes. The upper pane displays results. The lower pane supports entry of queries.

Left-click to select the `Library` in the `Tutorial.xmi` as the context for a query. The title of the console view shows that the `Library` has been selected as OCL's `self`.

Type `books` followed by a new line into the lower pane of the console.

The result of evaluating this query for the `Library` is shown.



Substantial OCL queries spanning many lines may be entered and so the cursor up and cursor down keys move across lines. If you want to access an earlier query, you may use the **Page Up** or **Page Down** keys to save typing them again.

You can examine the execution of the query within our example invariant by selecting each of the books in turn and executing `library.loans->select(book=self)`, to see that b1 has one Loan and b2 two.

4.1.9. Helper Features and Operations

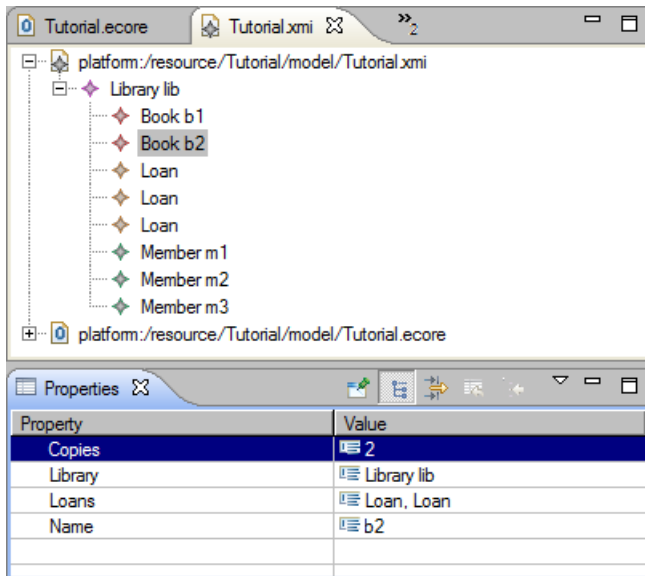
We will now introduce some helper attributes and operations to make the OCL clearer and provide a richer meta-model API. Close the **Tutorial.xmi** editor and modify the meta-model to include the derived loans property and the helper operation `isAvailable()`. Simplify the invariant to use the derived property.

```
class Book
{
    invariant SufficientCopies:
        library.loans->select(book=self)->size() <= copies;
    attribute name : String;
    attribute copies : Integer;
    property library#books : Library[?];
    property loans : Loan[*] { derived,volatile }
    {
        derivation: library.loans->select(book=self);
    }
    operation isAvailable() : Boolean[?]
    {
        body: loans->size() < copies;
    }
}
```

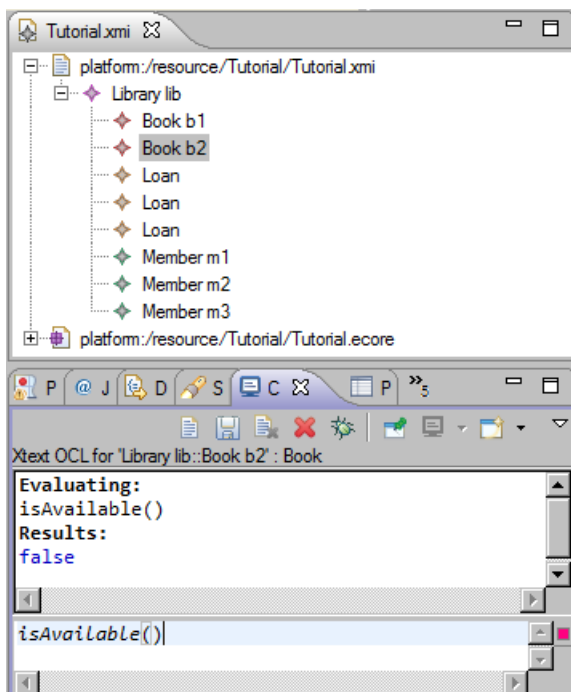
[\[Text for cut and paste\]](#)

- Note that the derived property must also be volatile to avoid problems when a model is loaded but has no content.

Reopen **Tutorial.xmi** and select **Book b2** so that the derived property is visible in the **Properties** view.



The helper operation can be evaluated in the **Console** view by selecting book b2 and typing `isAvailable()` for execution. (It is no longer necessary to close and reopen the Console after a metamodel change.)



We will now add further helpers and constraints to enforce an at most two loans per member policy and to require loans to be unique.

- It is prudent, but perhaps no longer necessary, to close **Tutorial.xmi** and the Console while changing the meta-model.

```

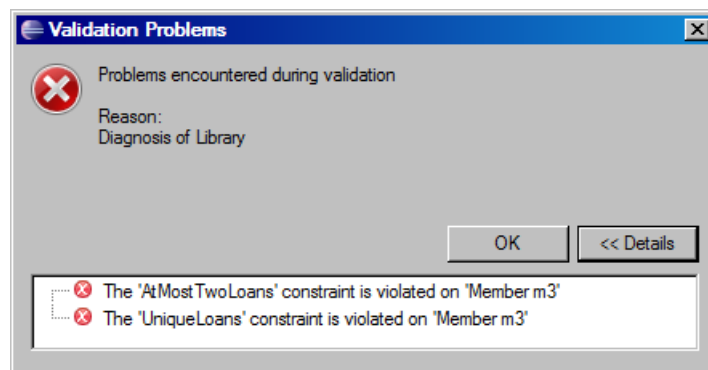
class Member
{
    invariant AtMostTwoLoans:
        Loans->size() <= 2;
    invariant UniqueLoans:
        Loans->isUnique(book);
    attribute name : String;
    property library#members : Library[?];
    property loans : Loan[*] { derived,volatile }
    {
        derivation: library.loans->select(member=self);
    }
    property books : Book[*] { derived,volatile,!unique }
    {
        derivation: loans->collect(book);
    }
}

```

[\[Text for cut and paste\]](#)

The additional books property may be evaluated in the OCL Console to show which books each member has on loan. The property may also be seen in the **Properties** view.

Select the library again and invoke **Validate** from the right button menu. There are now two validation failures.



4.1.10. Generating Java Code

We have shown how OCL may be used to enrich Ecore meta-models, how model instances can be created and validated and how expressions can be evaluated, all without generating any Java code. The OCLinEcore support provides the requisite Ecore EAnnotations to ensure that the dynamic execution of EMF activates an OCL interpreter where OCL functionality is required.

Exactly the same facilities are available if you generate Java code for the Ecore model and as a result you gain some speed benefits. You have two choices for the realization of the OCL embedded with Ecore models.

- Generate Java code within the *Impl classes
- Delete for interpretation at run-time

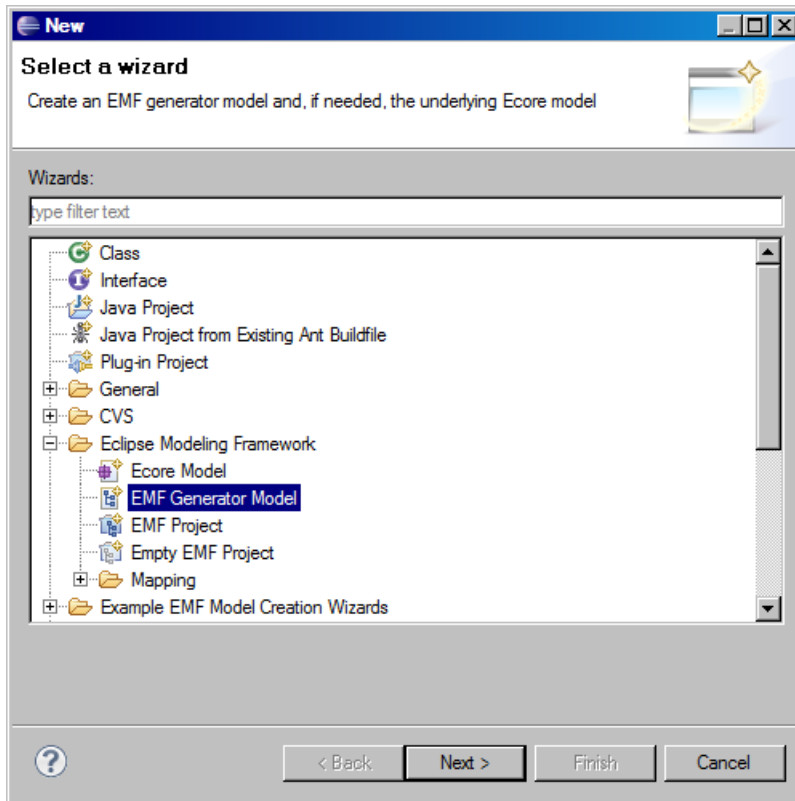
The first newer approach takes longer to generate the model since the OCL is compiled to Java incurring parser overheads at compile-time. However the OCL runs approximately five times faster and has fewer dependencies since no parsing is necessary at run-time. This approach is described in the [Code Generation Tutorial](#).

The second older approach embeds the OCL in the Java as unparsed strings so that parsing occurs overheads at run-time. The generated Java is smaller since the executable Java for OCL is larger than uncompiled strings.

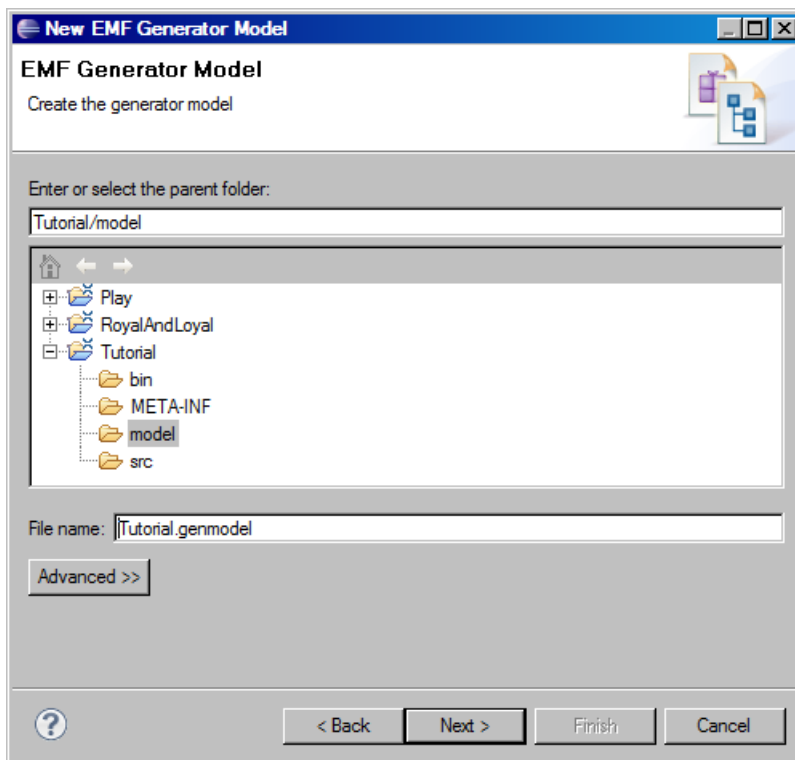
We continue here with the older approach for which delegation to yyje interpreter is selected as a root **Window->Preferences->OCL** realization preference.

Generating Java code is exactly the same as for any other EMF project. (Prior to EMF 2.8, there was one important difference; you must explicitly set **Operation Reflection** to true. The default for this changed to true in EMF 2.8.)

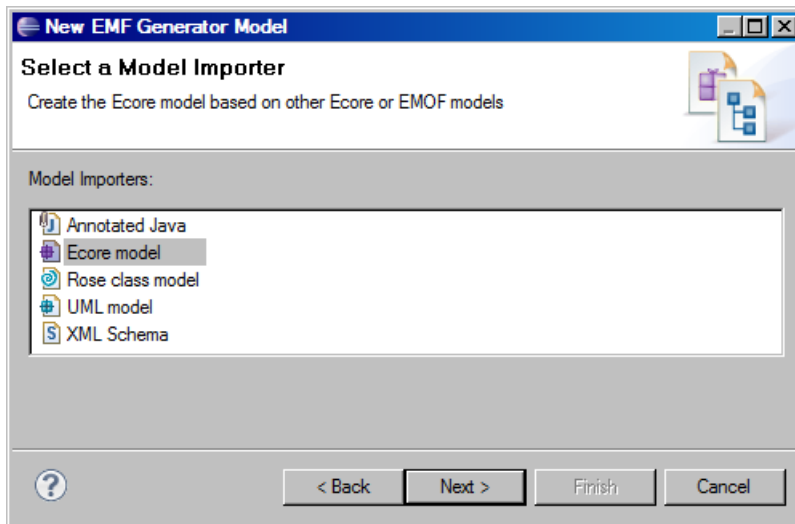
Select the **Tutorial.ecore** file and invoke **New->Other...** from the right button menu and select **Eclipse Modeling Framework** and **EMF Generator Model**.



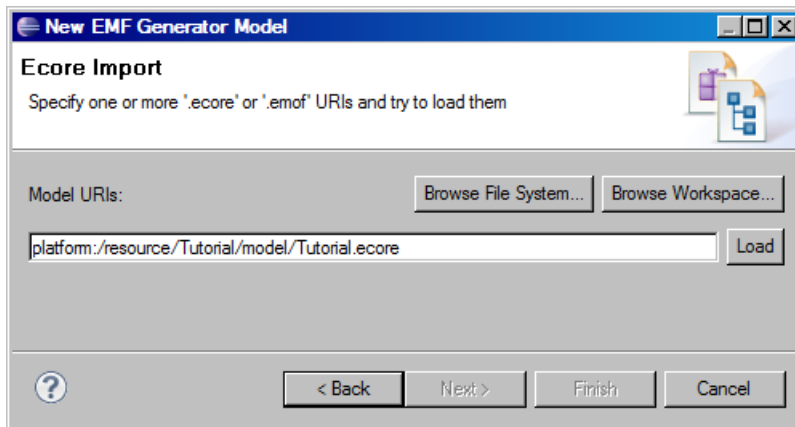
Select **Next**.



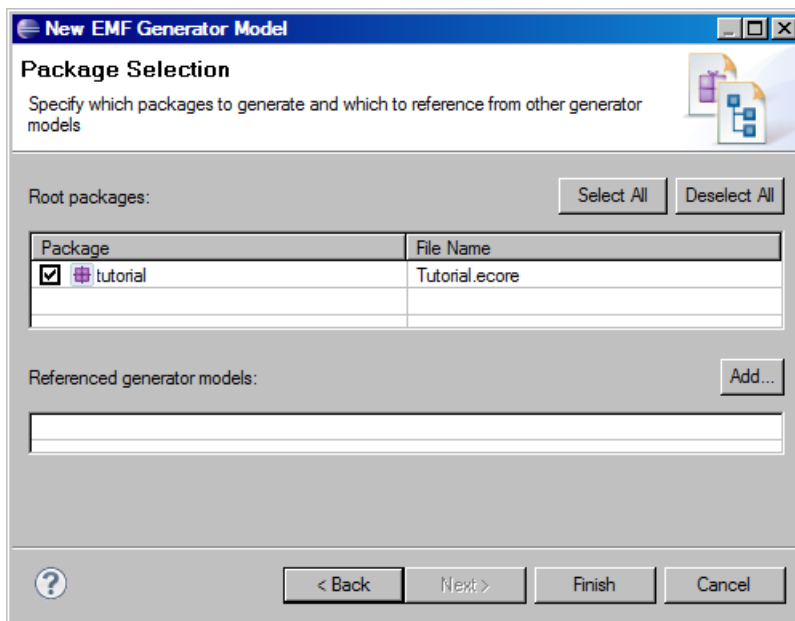
Select **Next**.



Select **Next**.

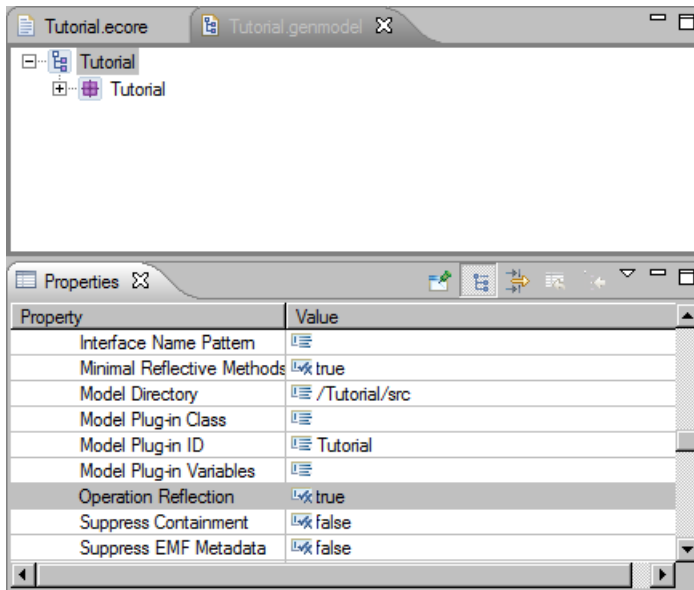


Select **Load** and **Next**.



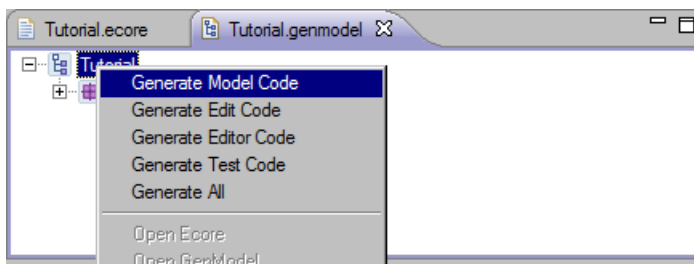
Select **Finish**.

The **Tutorial.genmodel** editor opens.



Most of the default settings are suitable. The one that may not be is highlighted. Select the root **Tutorial** and scroll down the **Properties** view and set **Operation Reflection** to true if it is not already true. (As from EMF 2.8 the default is true.)

You may now invoke **Generate Model Code** from the right button menu of either **Tutorial** to generate Java models that invoke OCL.



4.1.10.1. Java Details

You can check that the OCL appears in your Java by looking at **tutorial.util.TutorialValidator.java** where you'll find the OCL expression as a String awaiting compilation at run-time, and the validate invocation that triggers that compilation and execution.

```
protected static final String MEMBER__AT_MOST_TWO_LOANS__EEXPRESSION = "\n" +  
    "\t\t\t\t\tloans->size() <= 2";  
  
public boolean validateMember_AtMostTwoLoans(Member member, DiagnosticChain  
        diagnostics, Map<Object, Object> context) {  
    return  
        validate  
            (TutorialPackage.Literals.MEMBER,  
             member,  
             diagnostics,  
             context,  
             "http://www.eclipse.org/emf/2002/Ecore/OCL",  
             "AtMostTwoLoans",  
             MEMBER__AT_MOST_TWO_LOANS__EEXPRESSION,  
             Diagnostic.ERROR,  
             DIAGNOSTIC_SOURCE,  
             0);  
}
```

Similarly in **BookImpl** you will find the declaration of a cached delegate and the dynamic invocation that provokes the first time compilation.

```
protected static final EOperation.Internal.InvocationDelegate
    IS_AVAILABLE__EINVOCATION_DELEGATE = ((EOperation.Internal)
        TutorialPackage.Literals.BOOK__IS_AVAILABLE).getInvocationDelegate();

public boolean isAvailable() {
    try {
        return (Boolean)
            IS_AVAILABLE__EINVOCATION_DELEGATE.dynamicInvoke(this, null);
    }
    catch (InvocationTargetException ite) {
        throw new WrappedException(ite);
    }
}
```

The OCL expression for the invocation delegate may be found in **TutorialPackageImpl.createPivotAnnotations()**.

```
addAnnotation
    (getBook__IsAvailable(),
     source,
     new String[] {
         "body", "loans->size() < copies"
     });
```

4.1.10.2. API Invariants

The invariants we have used so far do not contribute to the class API.

If you want to have fine grain control of which validations are performed, perhaps because in some incremental context not all are appropriate, you may use the operation form of an invariant.

```
class Book
{
    operation sufficientCopies(diagnostics : ecore::EDiagnosticChain,
        context : ecore::EMap<ecore::EJavaObject,ecore::EJavaObject>) : Boolean
    {
        body: library.loans->select(book=self)->size() <= copies;
    }
    attribute name : String;
    attribute copies : Integer;
    property library#books : Library;
}
```

Note that the operation must have a Boolean return (true for valid) and diagnostics and context arguments.

4.1.11. Summary

To illustrate how to work with the OCL and Ecore as models we have

- Created an Ecore meta-model using the OCLinEcore text editor
- Created a dynamic model instance from that meta-model
- Enriched the meta-model with embedded OCL
- Used the embedded OCL while validating the model
- Queried the model using the Interactive OCL Console.
- Evaluated OCL embedded in the meta-model in the Console.

To use OCL and Ecore as generated Java models we have

- Generated Java that exploits the embedded OCL.

4.2. Complete OCL tutorial

This tutorial has been refreshed for Eclipse 2021-06; Eclipse 4.20, EMF 2.26, OCL 6.15.0.

- The graphical styling of some screenshots may be slightly out of date.

4.2.1. Overview

In this example you will

- Get an Overview of the Complete OCL language
- Load a Complete OCL document into a third party application
- Enhance Ecore validation for derived properties
- Validate an Ecore model using additional Complete OCL validation
- Enhance UML validation
- Validate a UML model using additional Complete OCL validation
- Enhance Xtext validation
- Validate an Xtext grammar using additional Complete OCL validation

4.2.2. Complete OCL Utility

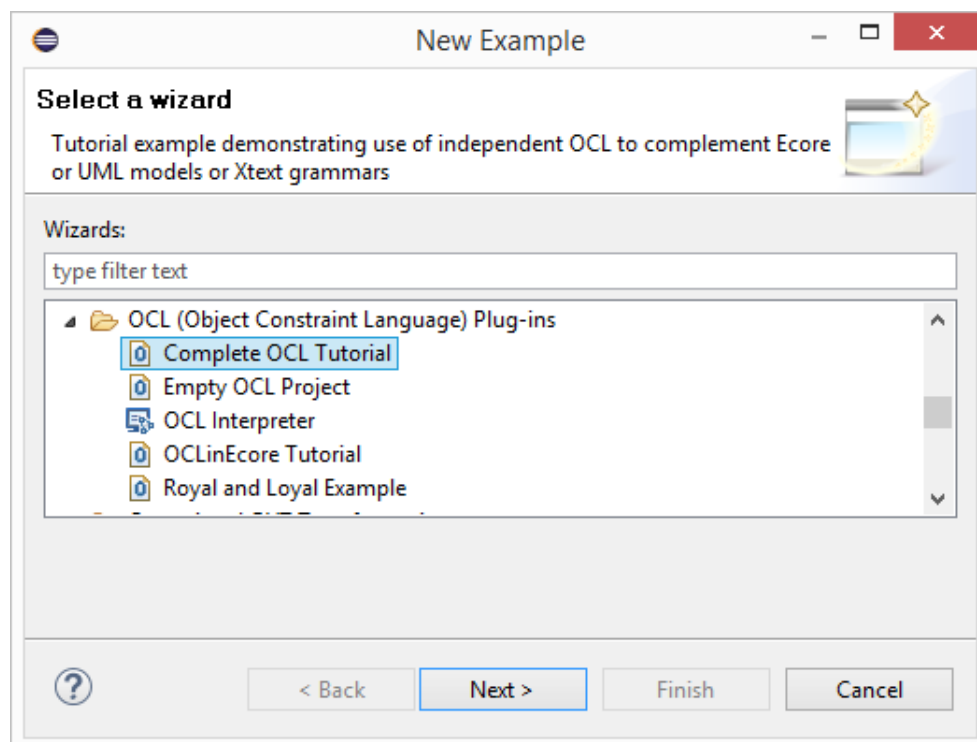
By itself, OCL is almost useless, since without any models to operate on, the constraints cannot achieve a great deal.

The simplest way to make OCL useful is to embed OCL expressions within a model to enrich the basic structural characteristics of a model with more complex behavior. OCLinEcore provides this capability for Ecore models. Papyrus provides comparable capabilities for UML models.

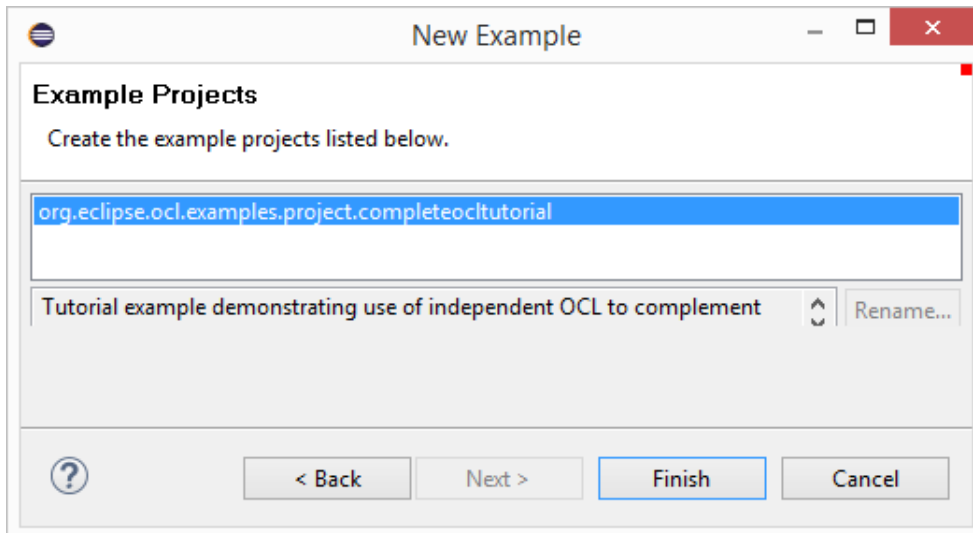
This tutorial introduces the Complete OCL language which may be used to provide a self-standing document that complements a pre-existing meta-model.

4.2.3. Load Complete OCL Tutorial Example Project

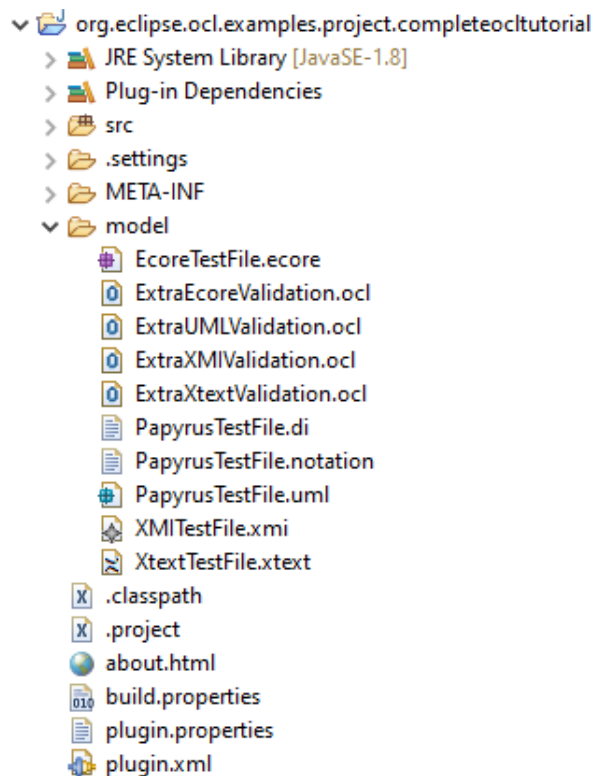
All the material for this tutorial is available as part of the CompleteOCLTutorial Example project that you may load by selecting **New** then **Example...** using the right button context menu of the Project Explorer. This should give the **New Example** dialog in which you can select the **OCL (OCL Constraint Language) Plugins** and the **Complete OCL Tutorial** and then **Next**.



Then **Finish**.



If you do not see these example projects, follow the [Instructions for installing the OCL Editors](#). The resulting project has a few test files.



4.2.4. Complete OCL Language Overview

The Complete OCL language is described in detail in the [Complete OCL](#) section of this documentation. In this tutorial we will provide just a brief overview of the language. If not already open, double click on **ExtraEcoreValidation.ocl** to show the following text that provides examples of many important aspects of the Complete OCL syntax.

```

import ecore : 'http://www.eclipse.org/emf/2002/Ecore#/'

package ecore

context EModelElement
/**
 * Declare a helper operation to map an ok/warning verdict to ok/error.
 */
def: asError(verdict : Boolean) : Boolean = if verdict then true else null endif

/**
 * Extra validation for EReference and EAttribute.
 */
context EStructuralFeature

/**
 * Declare a helper property to determine whether an EStructuralFeature has an OCL derivation.
 */
def: hasDerivation : Boolean =
  eAnnotations->select(source.startsWith('http://www.eclipse.org/emf/2002/Ecore/OCL'))->notEmpty()

/**
 * If a feature has an OCL derivation, it should be transient; otherwise it is not executed.
 */
inv DerivationIsTransient: hasDerivation implies transient

/**
 * If a feature has an OCL derivation, it must be volatile;
 * otherwise the cached value suppresses execution.
 */
inv DerivationIsVolatile: asError(hasDerivation implies volatile)

/**
 * If a feature has an OCL derivation, it should not also have a default value.
 */
inv DerivationIsUninitialized: hasDerivation implies defaultValue.ocIsUndefined()

/**
 * Extra validation for just EReference.
 */
context EReference

/**
 * If a feature has an OCL derivation, it should not compete with built-in containment.
 */
inv DerivationIsNotComposed: asError(hasDerivation implies not containment)

/**
 * If a feature has an OCL derivation, it should be not waste time resolving proxies.
 */
inv DerivationDoesNotResolveProxies: hasDerivation implies not resolveProxies

/**
 * If a feature has an OCL derivation and an opposite,
 * the opposite should also have an OCL derivation
 */
inv DerivationWithOppositeHasOppositeDerivation:
  hasDerivation and eOpposite <> null implies eOpposite.hasDerivation

endpackage

```

4.2.4.1. import declarations

The import statement is a serious omission from the OMG specification, since without it, any attempt to align the Complete OCL constraints with external models relies on implementation-specific magic. The import statement is therefore an extension that the Pivot-based Eclipse OCL prototypes for a future OCL specification revision.

Zero or more import statements may be present to specify the URIs of external model elements and optionally alias names for those elements. In the example:

```
import ecore : 'http://www.eclipse.org/emf/2002/Ecore#/'
```

`http://www.eclipse.org/emf/2002/Ecore` specifies the URI of the Ecore metamodel and `#/` is the fragment URI navigating to the root element which is the Ecore package. The `ecore` specifies

an alias for this package, which happens to be the same as the name of the package. Within the Complete OCL document, the imported model element may be referred to by its alias.

When using the Ecore and UML bindings, the Java API support for using Complete OCL documents requires implementation-specific magic; the imported models must be loaded into the package registry by the invoking code. Import statements are not used.

Prior to the Juno release, import statements were not understood and so there was a usage conflict between Pivot and Ecore/UML bindings. Preparation of a Complete OCL document using the Xtext editor, or usage with Pivot model and Xtext parser required import statements. But re-use with the Ecore and UML LPG parser required the import statements to be removed.

Since Juno, the LPG parser ignores the import statements, so they may be left in.

4.2.4.2. package context declaration

A package context declaration may bracket declarations that complement model elements within the complemented package.

```
package ecore
...
endpackage
```

This specifies that additional Complete OCL declarations will complement the pre-existing declarations of the `ecore` package.

Multiple package context declarations may be used to complement multiple packages.

The package context declaration may be omitted if subsequent classifier context declarations have a fully qualified name identifying the package.

4.2.4.3. classifier context declaration

A classifier context declaration introduces declarations that complement subsequent model elements within the complemented classifier.

```
context EModelElement
```

The classifier context is terminated by a `context` or an `endpackage`.

4.2.4.4. feature definitions

Additional operations and properties may be defined for use within the Complete OCL document. These features may be used as if they were part of the complemented meta-model.

```
def: asError(verdict : Boolean) : Boolean =
  if verdict then true else null endif

def: hasDerivation : Boolean = eAnnotations->select(source.startsWith(
  'http://www.eclipse.org/emf/2002/Ecore/OCL' ) )->notEmpty()
```

A definition starts with the new feature name, then the parameters for operations and the feature type followed by an OCL expression that evaluates the operation or the property.

For properties such as `hasDerivation` there is very little difference between a property definition `hasDerivation` and a parameter-less operation definition `hasDerivation()`. The property definition and usage is two characters shorter and may seem more natural. The operation definition has the advantage that it can be overloaded in derived classes.

4.2.4.5. class invariants

Invariants may be imposed on a complemented meta-model. The invariant comprises the name of the invariant followed by an OCL expression that evaluates true when the invariant is satisfied.

```
inv DerivationIsTransient: hasDerivation implies transient
```

These invariants are executed when a model is validated in an application that has loaded the complementing Complete OCL document. The significance of this is explained in [OCL->Load Document Menu Action](#).

The readability of constraints can be significantly enhanced by the use of let-variables or the re-use, as above, of the `hasDerivation` helper property.

4.2.4.6. custom messages

Eclipse OCL supports two extensions to invariants that allow the validation failure messages and severities to be customized.

```
inv DerivationIsVolatile(  
  "volatile" must be specified for derived feature ' + self.toString():  
  asError(hasDerivation implies volatile)
```

The invariant name may be followed by a parenthesized OCL expression that computes a String to be used as the validation failure message.

The severity of a validation failure may be controlled by the non-true value evaluated by the invariant expression.

- a `false` return indicates a warning severity
- a `null` return indicates an error severity
- an `invalid` return indicates a fatal severity

See [Custom Validation Messages](#) for more details.

4.2.4.7. operation and property context declarations

Complete OCL also allows an incomplete operation or property declaration in the complemented meta-model to be completed.

- initial value expressions or derived value constraints may be specified for properties.
- body expressions and precondition/postcondition constraints may be specified for operations.

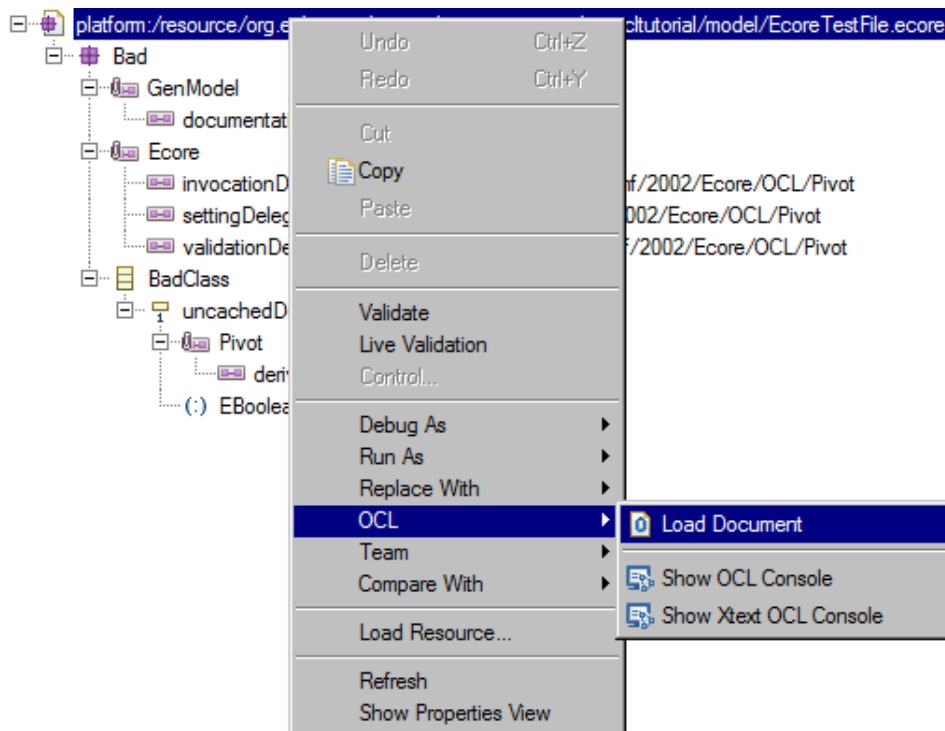
These facilities are of limited use since OCLinEcore avoids the need for incomplete meta-models.

4.2.5. OCL->Load Document Menu Action

The major disclaimer in the above is that the Complete OCL only complements the complemented meta-model in applications that have loaded the Complete OCL.

Prior to the Juno release, this meant that Complete OCL was only usable in custom Java applications since no standard modeling applications would load the complementing document.

The **OCL->Load Document** menu action enables a Complete OCL document to be loaded into a wide variety of applications.



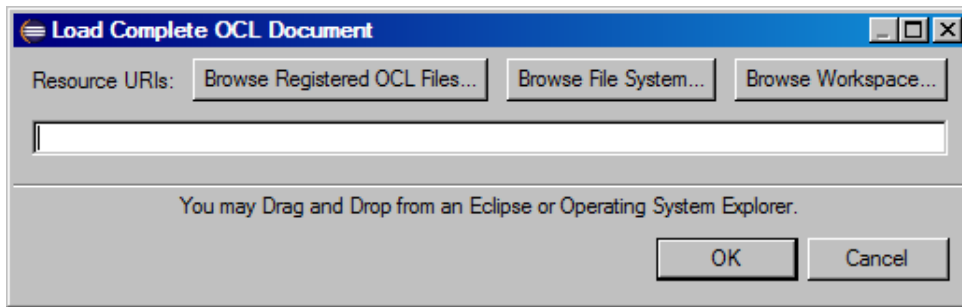
The **OCL->Load Document** menu action is added to the right button menu of applications with a ResourceSet accessible from the current selection.

It has been observed that the extra menu action is not always immediately available, so if you do not see it, hit **Esc** to cancel the menu, select something corresponding to a model object and right click again.

Since Mars, suitable applications are

- an editor generated from an Ecore meta-model
 - the Sample Ecore Editor
 - the UML Model Editor
 - the Papyrus Model Editor
 - your model editor
- an editor generated by Xtext
 - the Xtext Editor
 - the MWE2 Editor
 - the OCLinEcore Editor
 - your DSL editor

The **OCL->Load Document** menu action activates the **Load Complete OCL Document** dialog in which you can browse Registered Complete OCL Documents, the File system or the Workspace for one or more Complete OCL documents to load, or often more conveniently you can just Drag and Drop them from an Operating System Explorer or an Eclipse Explorer.



After clicking **OK** the documents load.

Behind the scenes, it is necessary to install global wrappers around all complemented packages. These wrappers are sensitive to the ResourceSet for which complementing has been requested and so although this incurs a small performance penalty for use of the complemented packages in other applications, it should not affect the functional behavior of other applications.

4.2.6. Example Complete OCL complements for Ecore

The Sample Ecore Editor has acquired many useful validation rules, so that for many usages just invoking **Validate** is quite sufficient. But what if it isn't? Perhaps you have some style conventions that you wish to apply. Perhaps the built-in rules are not sufficient.

Prior to Juno and the **OCL->Load Document** capability, your only choice would be to check out the Ecore Editor and create a custom variant. Now you can use Complete OCL to extend the Sample Ecore Editor.

We will revisit the **ExtraEcoreValidation.ocl** document that we have just examined and use it to rectify inadequate checking of derived properties by the Sample Ecore Editor. The document provides six invariants, at least three of which detect problems that were encountered by users during the Indigo release cycle.

4.2.6.1. DerivationIsVolatile

The EMF code generation templates have a simple treatment of `volatile`. Non-volatile variables have an associated field which is returned by the `get` operation. This overrides any derivation that might be supplied.

```
inv DerivationIsVolatile: asError(hasDerivation implies volatile)
```

We therefore want to diagnose that if an `EStructuralFeature` has a derivation then the volatile declaration is also present to avoid the derivation being ignored.

This problem is so serious that the basic expression is wrapped in the `asError` operation to convert the default `true / false` okay/warning severity into the `true / null` okay/error severity.

4.2.6.2. DerivationIsTransient

The EMF code generation templates have a similarly simple treatment of `transient`. Non-transient variables will be serialized as part of a model save. This is not usually appropriate since the derived value is redundant and can be recomputed when the model is loaded again.

```
inv DerivationIsTransient: hasDerivation implies transient
```

We therefore want to diagnose that a derivation is not serialized because of a default non-transient declaration.

4.2.6.3. DerivationIsNotComposed

Composition is handled directly by EMF and it is not clear that it is appropriate to define an alternate meaning of composition. It is pretty certain that EMF will not permit an alternate semantics.

```
inv DerivationIsNotComposed: asError(hasDerivation implies not containment)
```

We therefore want to diagnose if a derivation is attempting to specify alternate composition semantics and report an error if this occurs.

4.2.6.4. DerivationWithOppositeHasOppositeDerivation

Opposites are also handled directly by EMF, but it is possible to replace this functionality. However if the forward functionality is replaced, it is very unlikely that EMF's default reverse functionality will be appropriate.

```
inv DerivationWithOppositeHasOppositeDerivation:
  hasDerivation and eOpposite <> null implies eOpposite.hasDerivation
```

We therefore want to diagnose that a derivation that redefines the forward semantic of opposite also redefines the corresponding reverse semantics.

4.2.6.5. DerivationIsUninitialized

An initial value for a property may be specified as a simple default value or as a derived expression.

```
inv DerivationIsUninitialized:
  hasDerivation implies defaultValue.oclIsUndefined()
```

We want to diagnose the occlusion of the derived expression by a default value.

4.2.6.6. DerivationDoesNotResolveProxies

Derived expressions are not references.

```
inv DerivationDoesNotResolveProxies:
  hasDerivation implies not resolveProxies
```

We can therefore diagnose whether the EMF proxy resolution logic is not suppressed.

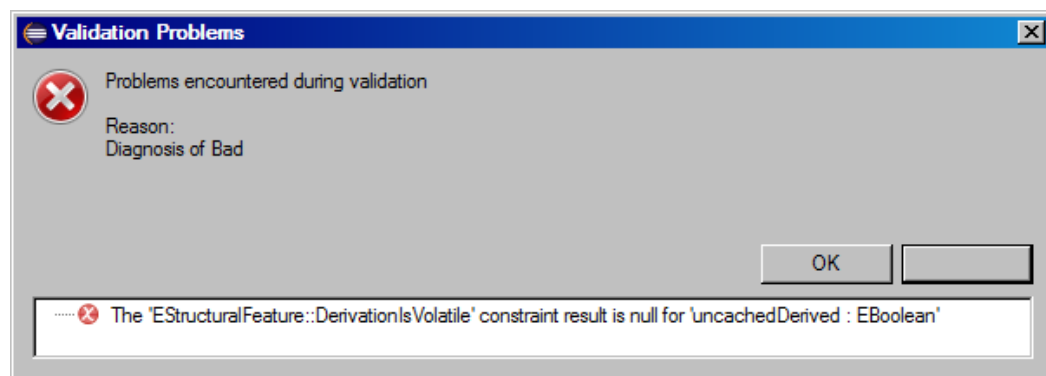
4.2.7. Validating Ecore with additional Complete OCL

In the [previous section](#) we described additional Complete OCL validation constraints to detect problems with inadequate Sample Ecore diagnosis of derived properties. We will now apply those constraints to a test file.

Select **EcoreTestFile.ecore** and use the right button menu to **Open With->Sample Ecore Model Editor**. This is probably the default for double-clicking with the left button, but if you open with the OCLinEcore editor the required validation will not work (in Juno).

Now right click within the Sample Ecore Editor pane as described in [OCL->Load Document Menu Action](#) and load **ExtraEcoreValidation.ocl**. An additional Resource is shown in the editor tree.

Select a model element such as the **Bad** package and use the right button menu to invoke **Validate**.



This shows an error. Depending on the order in which the constraints are evaluated, you may also see one or two warnings. You should use the [Validity View](#) to see all failures.

If we now open **EcoreTestFile.ecore** with the OCLinEcore editor we can see that the **transient** and **volatile** keywords are indeed missing.

```

package Bad : pfx =
  'platform:/resource/org.eclipse.ocf.examples.project.completeocltutorial/model/Bad.ecore'
{
  class BadClass
  {
    attribute uncachedDerived : Boolean { derived }
    {
      derivation: true;
    }
  }
}

```

4.2.8. Editing the Complete OCL

You may edit the Complete OCL to experiment with alternate constraints or messages.

However the Complete OCL complements the meta-model and EMF does not support live modification of meta-models. It is therefore necessary to restart the Sample Ecore Editor and Reload the modified Complete OCL document in order to exploit the changes.

A solution for this may occur in a future release.

4.2.9. Example Complete OCL complements for UML

The extension of the Sample Ecore Editor validation described in [Validating Ecore with additional Complete OCL](#) is applicable to any tree editor generated by EMF tooling.

The **ExtraUMLValidation.ocf** file provides a very simple style check that class names start with an upper case letter.

```

import uml : 'http://www.eclipse.org/uml2/4.0.0/UML#/'

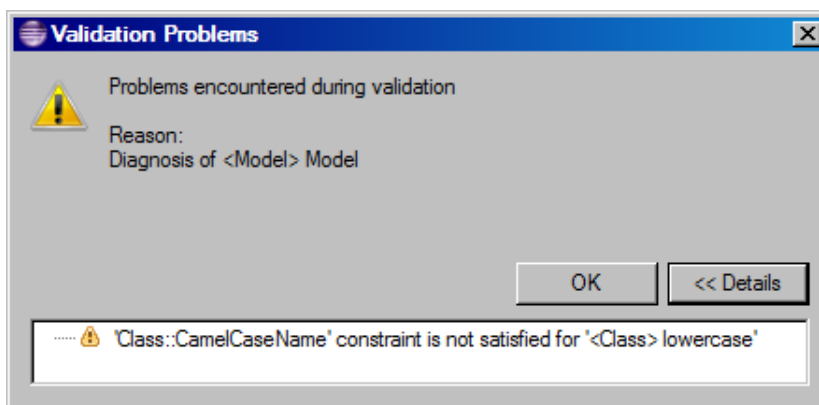
context uml::Class

/**
 * The first letter of a classname should be uppercase.
 */
inv CamelCaseName: name.at(1)=name.at(1).toUpperCase()

```

The UML meta-model is imported and an invariant is specified for the Class classifier which is fully qualified to avoid the need for a surrounding package context declaration.

You may open the **PapyrusTestFile.uml** with the UML Model Editor, load the **ExtraUMLValidation.ocf**, select the **Model** and then **Validate** in the same way as for the Ecore example.



Unfortunately the Papyrus UML editor does not use the EValidator framework and so loading Complete OCL documents into Papyrus fails to enhance validation capabilities. To use additional Complete OCL functionality, you may load and validate in the UML Model Editor, then start the Papyrus editor which will then show the problem markers on diagram elements. Alternatively you may use [Validity View](#) concurrently with Papyrus.

4.2.10. Example Complete OCL complements for Xtext

Xtext editors use EValidator and so a Complete OCL document may be loaded into an Xtext editor, including Xtext itself, to provide enhanced validation.

The **ExtraXtextValidation.ocl** file provides some demonstration style checks.

```
import 'http://www.eclipse.org/2008/Xtext#/'

package xtext

context ReferencedMetamodel
inv NoAnonymousImports: alias <> null

context Action
inv NoActions : false

context ParserRule
inv CamelCaseName : name.matches('[A-Z][A-Za-z]*')

context xtext::TerminalRule
inv UpperName : name = name.toUpperCase()

endpackage
```

The Xtext root package is imported and within the package declaration context for the **xtext** package, invariants are supplied for four classes. These are all just examples of how constraints may use the Xtext model. It is not suggested that users should use all of these constraints for real grammars.

4.2.10.1. NoAnonymousImports

```
context ReferencedMetamodel
inv NoAnonymousImports: alias <> null
```

This invariant diagnoses whether any import statements omit the `as xxxx` model name.

4.2.10.2. NoActions

```
context Action
inv NoActions : false
```

This invariant diagnoses whenever an `{xxx}` action statement is used.

4.2.10.3. CamelCaseName

```
context ParserRule
inv CamelCaseName : name.matches('[A-Z][A-Za-z]*')
```

This invariant verifies that the name of a parser rule starts with an upper case letter and uses only letters.

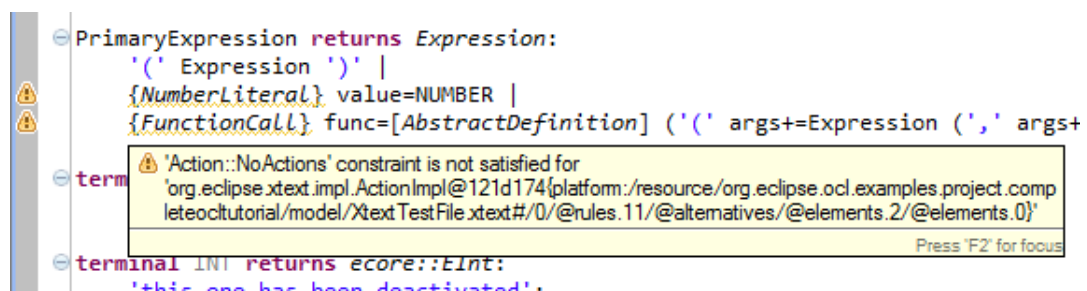
4.2.10.4. UpperName

```
context xtext::TerminalRule
inv UpperName : name = name.toUpperCase()
```

This invariant verifies that the name of a terminal rule is uppercase.

You may open the **XtextTestFile.xtext** with the Xtext Editor, load the **ExtraXtextValidation.ocl** and then **Validate** in the same way as the Ecore example.

The additional validations appear as warning markers in the editor.



Unfortunately Xtext does not have a nice `toString()` method for its Concrete Syntax tree so the descriptions of erroneous elements are a little inelegant.

You may edit the Xtext test file to delete the “as.ecore” in the import statement and see that the additional Complete OCL constraints are contributing to the ongoing functionality of the editor.

4.2.11. Complete OCL Editor

The Complete OCL editor is invoked automatically for an existing or new *.ocl file. You can create an empty file using either **New->File** or a partial content file using **New->Other...** followed by **OCL** and **Complete OCL File**. The editor is Xtext-based and so has most of the facilities that you find in many other Eclipse editors.

4.2.12. Royal and Loyal Example

The Royal and Loyal Example was first provided by Jos Warmer and Anneke Kleppe in *The Object Constraint Language: Getting Your Models Ready for MDA* and has subsequently been used in many tutorials. The example provides substantial examples of Complete OCL and Essential OCL. The models are available by invoking **New->Example...->OCL (Object Constraint Language) Plugins**.

4.2.13. Summary

To illustrate how to work with Complete OCL we have

- Examined the Complete OCL language
- Examined constraints to rectify inadequate Ecore validation of derived features
- Loaded Complete OCL constraints to enhance validation of an Ecore model
- Loaded Complete OCL constraints to enhance validation of a UML model
- Loaded Complete OCL constraints to enhance validation of an Xtext grammar

4.3. Safe navigation tutorial

This tutorial demonstrates the new safe navigation facilities of Eclipse Mars; Eclipse 4.5, EMF 2.11, OCL 6.0.

- Some screenshots may be slightly out of date.

4.3.1. Overview

In this example you will

- learn about navigation hazards
- switch on safe navigation validation
- use safe navigation to eliminate hazards
- use null free declarations to avoid many safe navigation hazards

4.3.2. References

This tutorial continues the [OCLinEcore tutorial](#).

4.3.3. Evaluation hazards

Evaluation of OCL expressions can give invalid results for internal problems

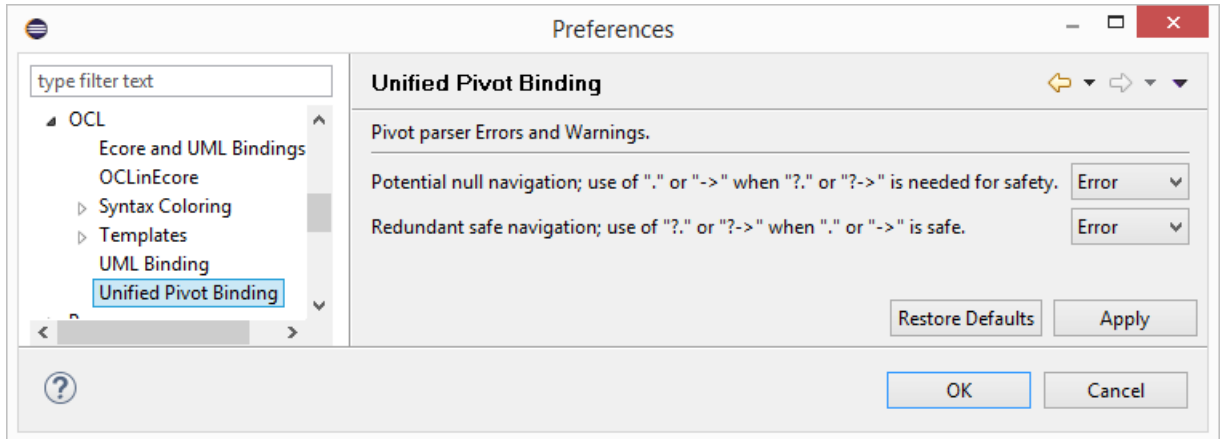
- divide by zero
- index out of bound for an Ordered Collection
- most navigations of an operation or property from a null source

In this tutorial we will show how to eliminate the hazards of unsafe navigation from null.

4.3.4. Enable Safe Navigation Diagnosis

Safe navigation is too new and experimental to be enabled by default. You must therefore enable it explicitly by selecting the **OCL->Unified Pivot Binding** settings from the workspace **Window->Preferences**. You may alternatively set project-specific preferences from Project property pages.

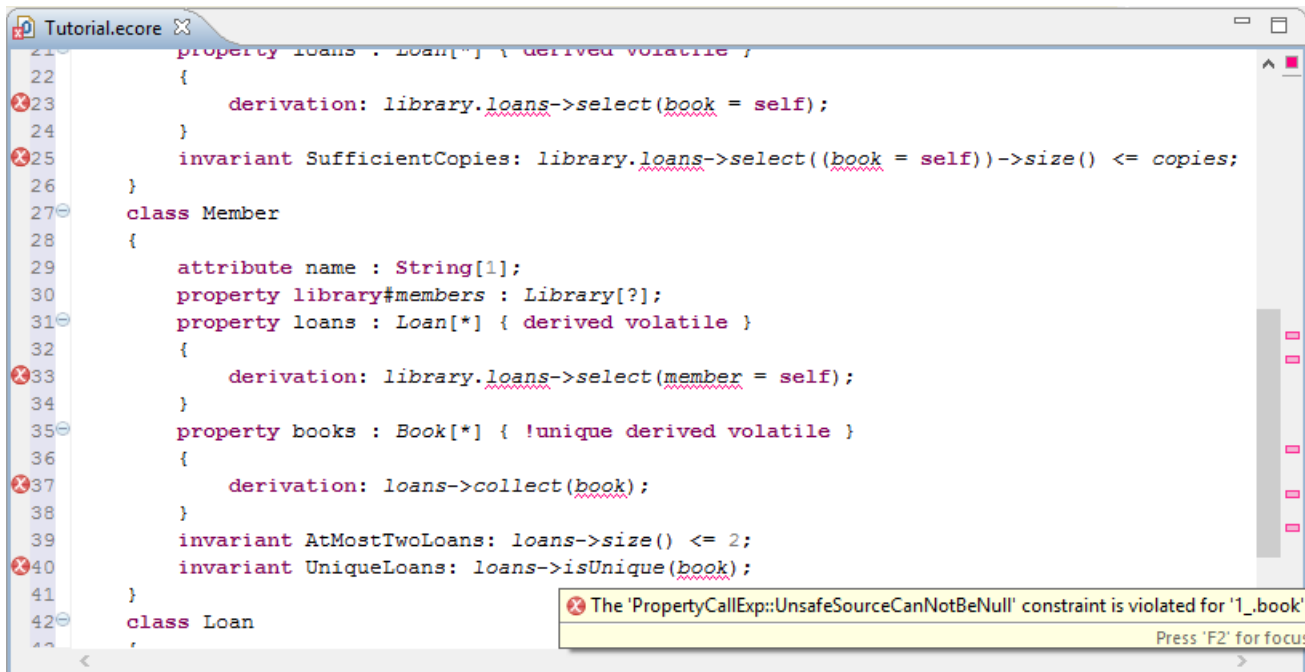
Change the **Potential null navigation** and **Redundant safe navigation** to **Error** (or warning).



4.3.5. Safe Navigation Diagnosis

We will continue the OCLinEcore tutorial, which you may jump to the end of by **New ->Example... ->OCL Plugins ->OCLinEcore Tutorial**.

Select **Tutorial.ecore** and open with the **OCLinEcore Editor**. 8 errors appear on 5 lines.



A bit depressing; 5 out of 7 OCL lines have hazards on a long standing example. The problems arise wherever a null is permitted.

Non-collection values may be null whenever the multiplicity is implicitly or explicitly **MyType[?]**, which permits either an instance of MyType or null. The alternative **MyType[1]** prohibits a null value. The example metamodel is comparatively good with many properties such as **Loan::book** defined as **Book[1]**. However **Loan::date** is **Date[?]** which seems unwise; why should a Loan have an unknown Date? **Book::library** is correctly **Library[?]** since there is no reason why Books may not found in Bookshops or Homes.

We will examine the two errors after expanding short forms.


```

    derivation: self.library.loans->select(loan : Loan[?] | loan.book = self)
  }
  invariant SufficientCopies

```

✖ The 'PropertyCallExp::UnsafeSourceCannotBeNull' constraint is violated for

`self.library.loans` violates the `UnsafeSourceCannotBeNull` constraint because the source, `self.library`, can be null as a consequence of the `library[?]` multiplicity.

Collection values, which are almost the raison d'être of OCL, are a disaster safe-navigation-wise. Any OCL collection may contain a null value and so any OCL iteration may have a null iterator. Consequently the implicit iterator is typed as `Loan[?]` and the source of `loan.book` is also unsafe.

4.3.6. Safe Navigation Operators

Languages such as Groovy have introduced a safe navigation operator to mitigate problems with null navigation. It is proposed that OCL 2.5 will do so too. Eclipse OCL provides a prototype implementation.

OCL provides two navigation operators

- the object navigation operator `"."`
- the collection navigation operator `"->"`.

Safe navigation adds

- the safe object navigation operator `"?."`
- the safe collection navigation operator `"?->"`.

The safe object navigation operator replaces any null navigation by `null`. Where `a` is an object value, `a?.b` is therefore equivalent to

```
let a' = a in if a' <> null then a'.b else null endif
```

The safe collection navigation operator eliminates all null terms from collection sources. `a?->b` is therefore equivalent to

```
a->excluding(null)->b
```

The safe implicit collection navigation operator similarly eliminates all null terms from collection. Where `a` is a collection value, `a.b` is therefore equivalent to

```
a->excluding(null)->collect(b)
```

We may use these operators to make the warnings go away.

```
derivation: library?.loans?->select(book = self);
```

The first replacement for `library?.loans` is reasonable. The `library` really can be null and so, if it is null, the shorthand execution is `null->select(book = self)`. Use of a collection operator on a non-collection object such as `null` causes `oclAsSet()` to be invoked which for `null` gives giving an empty set. Therefore `null.oclAsSet()->select(...)` selects elements from an empty set ensuring that the loans from a null library are an empty collection.

The second replacement for `loans?->select` makes the problem go away, but in practice requires almost every collection navigation operator to be prefixed lexically by `"?"` and operationally by an `exclude(null)`.

4.3.7. Null-free Collections

OCL and UML support four permutations of ordered/not-ordered, unique/not-unique to give useful Collection behaviors.

OCL unfortunately allows any collection to contain null, even though null collection elements are undesirable in almost all applications, and as we have just seen safe, navigation imposes a redundant `exclude(null)` on many collection accesses.

The need for `exclude(null)` can be eliminated if OCL collections can be declared to be null-free, potentially giving 8 rather than 4 possible collection behaviors.

UML and Ecore declarations of collections such as `MyType[2..*] {ordered}` support bounds, whereas Complete OCL supports nested collections such as `Set(Sequence(MyType))`. UML alignment for OCL 2.5 supports nested bounded collections such as `Set(Sequence(MyType[*]) [+])`; a Set of one or more Sequences of zero or more MyTypes.

We can extend this notation by suffixing an element multiplicity following each collection multiplicity so that each element may be

- non-null, explicitly [...|1]
- implicitly or explicitly null/not-null [...|?]

It is not useful to have null loans so we can change the multiplicity of `Library::loans` to `Loan[*|1]`; zero or more Loan objects where each loan is not-null.

```

5  class Library
6  {
7      attribute name : String[1];
8      property books#library : Book[*] { composes };
9      property loans : Loan[*|1] { composes };
10     property members#library : Member[*] { composes };
11 }
12 class Book
13 {
14     operation isAvailable() : Boolean[?]
15     {
16         body: loans->size() < copies;
17     }
18     attribute name : String[1];
19     attribute copies : Integer[1];
20     property library#books : Library[?];
21     property loans : Loan[*|1] { derived volatile }
22     {
23         derivation: library?.loans?->select(book = self);
24     }
25     invariant Suf:
26 }

```

The 'IteratorExp::SafeSourceCanBeNull' constraint is violated for 'self.library?.loans?->select(book = self)'

The problem with the iterator is now replaced by one with the iteration. The `SafeSourceCanBeNull` constraint is now violated because the source `library?.loan` cannot provide null elements as a consequence of the `[==|1==]*` multiplicity. Note that the extended multiplicity is shown in messages and hover text to assist in understanding null-ness.

Revert back to `loans->select` and the new problem goes away; changing the multiplicity to declare a null-free collection makes the original expression safe without an additional safe navigation operator.

4.3.8. Declaring Null-free Collections in Ecore

We have just seen an extension to the multiplicity syntax so that in OCLinECore a null-free collection may be declared by the `[...|1]` extended per-element multiplicity.

Ecore does not support null-free collections and so behind the scenes this is represented by an `EAnnotation`.

```

<eStructuralFeatures xsi:type="ecore:EReference" name="loans" ordered="false"
  upperBound="-1" eType="//Loan" containment="true">
  <eAnnotations source="http://www.eclipse.org/OCL/Collection">
    <details key="nullFree" value="true"/>
  </eAnnotations>
</eStructuralFeatures>

```

4.3.9. Declaring Null-free Collections in UML

UML does not support null-free collections and so an OCLforUML profile is introduced to remedy this and other deficiencies.

A **Collection** stereotype may be applied to a **TypedElement** such as a **Parameter** or **Property** so that the `Collection::isNullFree` property defines the required null-free-ness.

Applying a stereotype to all collection properties and parameters is a little tedious and may be avoided by instead applying the **Collections** stereotype to **Classes** or even **Packages**. The null-free-ness is determined by looking first for a **Collection** stereotype, then searching the container hierarchy for the nearest **Collections** stereotype.

A single **Collections** stereotype application on a **Package** is sufficient to declare all its collections null-free. This is often appropriate, however if any collections can contain nulls, the package-level **Collections** stereotype must be overridden for each **TypedElement** where the collection may contain a null.

4.4. Code Generation tutorial

This tutorial has been refreshed for Eclipse 2021-06; Eclipse 4.20, EMF 2.26, OCL 6.15.0.

- The graphical styling of some screenshots may be slightly out of date.

The direct OCL to Java Code generator has matured significantly from its experimental functionality for the Juno release. It is now the recommended approach.

In this tutorial we will continue the OCLinEcore tutorial and show how to get a direct Java representation of the Ecore model avoiding the need for run-time compilation.

4.4.1. Load OCLinEcore Tutorial Example Project

All the material for this tutorial is available as part of the OCLinEcore Example project that you may load by selecting **New** then **Example...** using the right button context menu of the Project Explorer. This should give the **New Example** dialog in which you can select the **OCL (OCL Constraint Language) Plugins** and the **OCLinEcore Tutorial**.

4.4.2. Direct code

In [Generating Java Code](#) we saw how to create a genmodel and how to generate code from it that realizes OCL as text strings in the Java implementation files. These text strings are lazily compiled at run-time.

Whether to generate OCL as text strings for interpretation or to convert directly to Java is determined by the Code Generation Mode. This may be configured using the project property or workspace preference as described in [Code Generation Mode](#). So use **Window->Preferences->OCL** to change the **Realisation of OCL embedded in Ecore models** setting to **Generate Java code in *Impl classes**.

Now open **Tutorial.genmodel**, select the root **Tutorial** resource and invoke **Generate Model Code** to (re)generate the Java code. This will take somewhat longer as additional work items show that the OCL is being compiled and that Xtend templates are generating additional Java code.

Note that you must close **Tutorial.genmodel** while changing the Code Generation Mode.

You may also need to delete the autogenerated ***Impl** files if you change from one mode of generation to another.

That is all there is to it. Your model code is now 100% Java; no OCL parsing is needed at run-time.

If you see errors related to undefined `...__DIAGNOSTICCHAIN_MAP`, you need to edit your `*.genmodel` to make sure that the **Model->Operation Reflection** option on the overall **GenModel** is set true.

4.4.3. Using a GenAnnotation

Changing the default genmodel setting is a little dangerous since the change will affect any other genmodel activities you perform. It is therefore advisable to reset the workspace preference setting to its default and use a **GenAnnotation** to embed the setting in the genmodel.

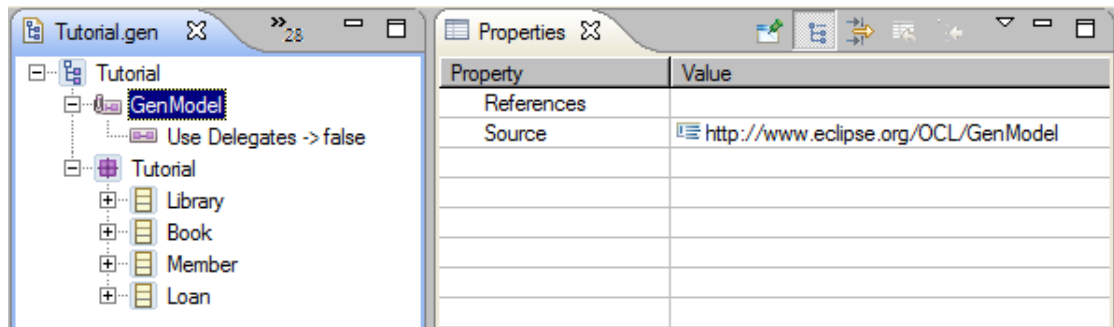
The easiest way to create the **GenAnnotation** that ensure direct code generation regardless of workspace or project preferences, is to paste the following three lines into your genmodel just above the **foreignModel** or **genPackages** element.

```
<genAnnotations source="http://www.eclipse.org/OCL/GenModel">
  <details key="Use Delegates" value="false"/>
</genAnnotations>
```

Of course, if you want to enforce delegation you should set the value to `true`.

If you don't like cutting and pasting into XMI files, you can achieve the same effect with the GenModel editor by:

- Enable annotation display using **Generator->Show Annotations**
- Invoke **Annotate** from the right button context menu of the genmodel root element
- Use the **Properties View** to set the GenAnnotation source to `http://www.eclipse.org/OCL/GenModel`
- Invoke **Add Detail** from the right button context menu of the GenAnnotation
- Use the **Properties View** to set the Detail key to `Use Delegates`
- Use the **Properties View** to set the Detail value to `false`



A further **Use Null Annotations** GenAnnotation may be used to control whether `@NonNull` and `@Nullable` annotations are emitted in the generated code.

```
<genAnnotations source="http://www.eclipse.org/OCL/GenModel">
  <details key="Use Delegates" value="false"/>
  <details key="Use Null Annotations" value="true"/>
</genAnnotations>
```

4.5. Debugger tutorial

This tutorial has been updated for Eclipse Mars: Eclipse 4.5, EMF 2.11, OCL 6.0.

- Some screenshots may be slightly out of date.

In this tutorial we will continue the [OCLinEcore tutorial](#) and show how to use the [OCL debugger](#) to debug:

- constraints typed manually in the Console View
- embedded OCLinEcore validation failures from the Validity View
- Complete OCL validation failures from the Validity View

4.5.1. Load OCLinEcore Tutorial Example Project

The material for the first two parts of this tutorial is available as part of the OCLinEcore Example project that you may load by selecting **New** then **Example...** using the right button context menu of the Project Explorer. This should give the **New Example** dialog in which you can select the **OCL (OCL Constraint Language) Plugins** and the **OCLinEcore Tutorial**.

The material for the third parts of this tutorial is available as part of the CompleteOCL Example project that you may load in a similar way.

4.5.2. The OCL Debugger

The OCL debugger is a customization of the Eclipse debugger framework, so most of its functionality should present few surprises to those familiar with the Java debugger.

There is:

- a Stack View that shows the current line number in nested Evaluation Environments
- a Variables View in which local and intermediate variables can be re-examined
- an Editor in which the source is highlighted to show the next AST node to be evaluated

- an Outline in which the source is shown in tree form
- a Breakpoints View in which breakpoints can be controlled

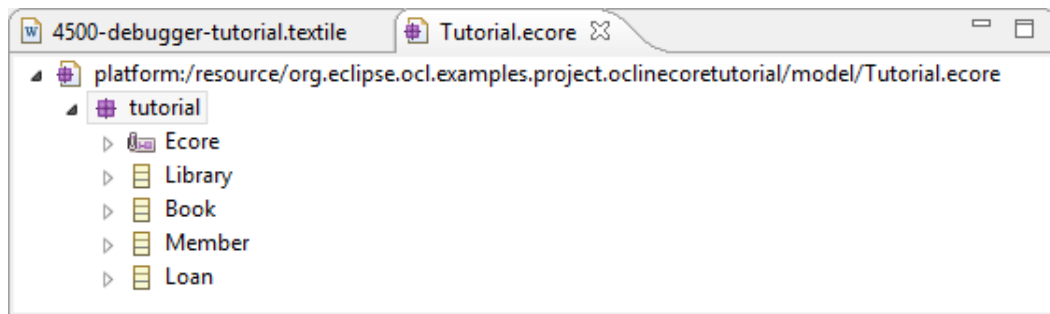
We will demonstrate some of these facilities by debugging a simple example.

4.5.3. Very Simple Debug session

We will debug the execution of the OCL expression **self.name** on an EPackage.

4.5.3.1. Starting the debugger

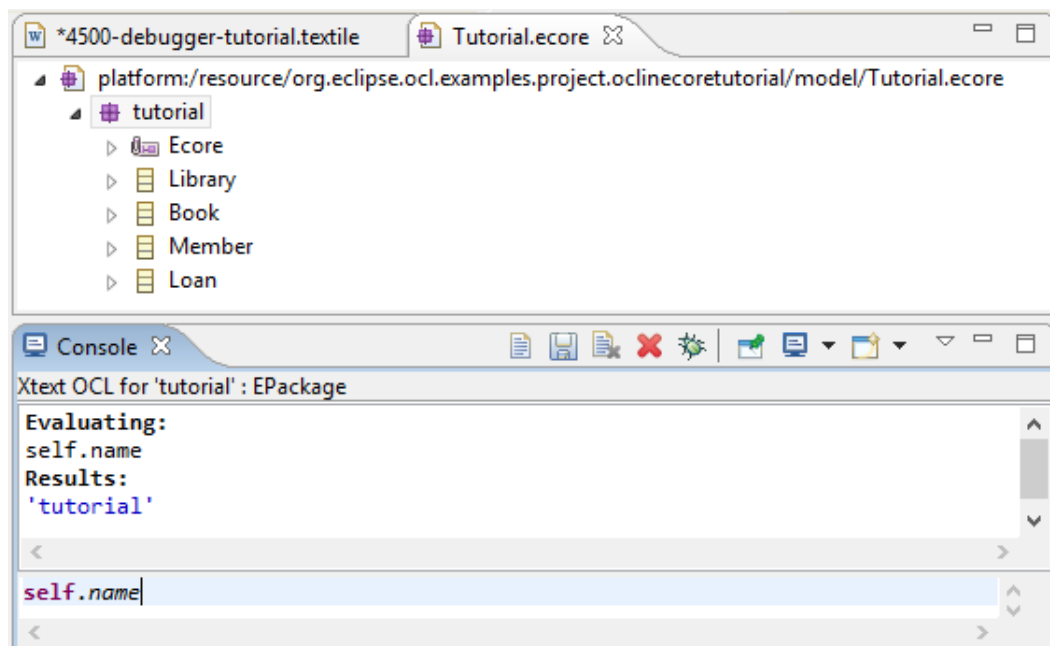
Double click on **model/Tutorial.ecore** to open the model and expand the top entry to show the EPackage.



If the model opens with another editor, close it, and open with the Sample Ecore Editor by selecting **model/Tutorial.ecore** and then **Open With->Sample Ecore Model Editor** from the context menu.

Select the **tutorial** EPackage and invoke **OCL->Show Xtext OCL Console** from the context menu. (Wait a second or two.)

At the bottom of the Console window type **self.name**, then hit the Enter key. Then hit the Page Up key to redisplay your entry.



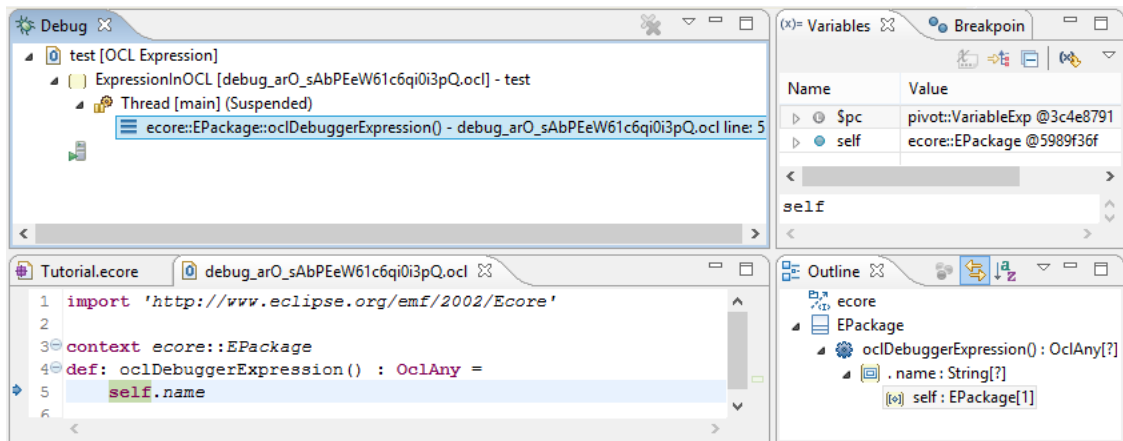
The Console runs an evaluation automatically after hitting Enter and shows the evaluation result: **'tutorial'**.

The Console View provides the two pieces of information necessary to run the OCL debugger:

- an EObject to be used as OCL's **self**; the Console shows the current selection just below its tool bar
- an OCL expression to execute

Start the debugger by clicking the debug icon in the Console View tool bar. (Wait a second or two.)

The debugger perspective should appear automatically. If it doesn't, you can open the Debug perspective manually by invoking **Window->Perspective->Open Perspective->Debug** from the Eclipse menu bar.



A Complete OCL document is created automatically to encapsulate the OCL expression inside as an additional operation for the type of the **self** object. This document is shown in the editor; it is read-only. The stack display shows the context as line 5 of **oclDebuggerExpression()** in the synthesized Complete OCL document.

Select the **oclDebuggerExpression()** line in the stack display; **self** is highlighted in the Complete OCL document, since the next evaluation to perform is to evaluate the VariableExp AST node that performs the self access.

The Variables View shows two variables.

- **self** is the OCL self object
- **\$pc** is a synthetic variable representing the current Program Counter

The Outline View displays a slightly trimmed OCL Abstract Syntax tree; you may choose to close this view. In a future release it may change to support breakpoints. The view shows

- an **Import** for **ecore**
- a **Class** named **EPackage** containing
- an **Operation** named **oclDebuggerExpression** containing
- an **ExpressionInOCL** whose **OwnedBody** is a **PropertyCallExp** for **name** and whose source is
- a **VariableExp** for **self**.

The outline shows fuller type signatures to assist in debugging.

4.5.3.2. Exploring Variables

The Variables View provides an ability to drill down arbitrarily to examine the data available to your program.

The left column of the display presents the name of a variable and may be expanded to navigate to parts of the data referenced by the variable. Part name displays are currently shown 0-based, rather than 1-based as in OCL.

The right column variously displays the type of parts that can be expanded and the values of those that cannot. An OCL syntax is used so Strings appear in single quotes and Collections use names such as OrderedSet.

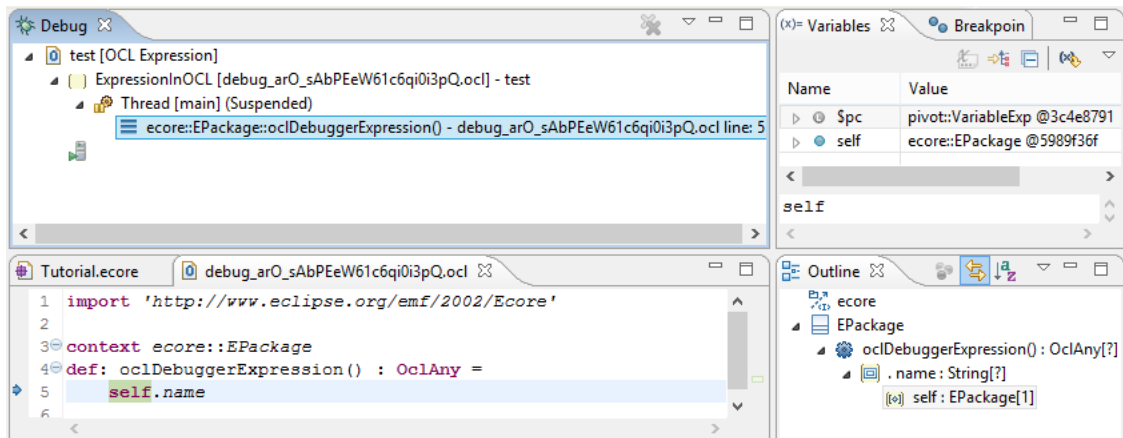
The bottom line shows a textual rendering of the selected variable. For many types of data a helpful rendering is available. For others the fallback is to the default Java toString() functionality. The text can be customized by

- the **org.eclipse.ocl.pivot.utilities.getText()** method if the object implements **Labelable**
- the **LabelUtil.QUALIFIED_NAME_REGISTRY** if an **org.eclipse.ocl.pivot.label_generator** extension point has a registration for the objects' class

Click on the expand/collapse icon to the left of **\$pc** to expand it and allow inspection of the OCL AST. A VariableExp is next to execute and its **\$pc.referredProperty** or **\$pc.type** may be examined to see more program detail.

Click on the expand/collapse icon to the left of **self**, which is an **ecore::EPackage**, to expand it and shows its fields such as **name** which is **'tutorial'**.

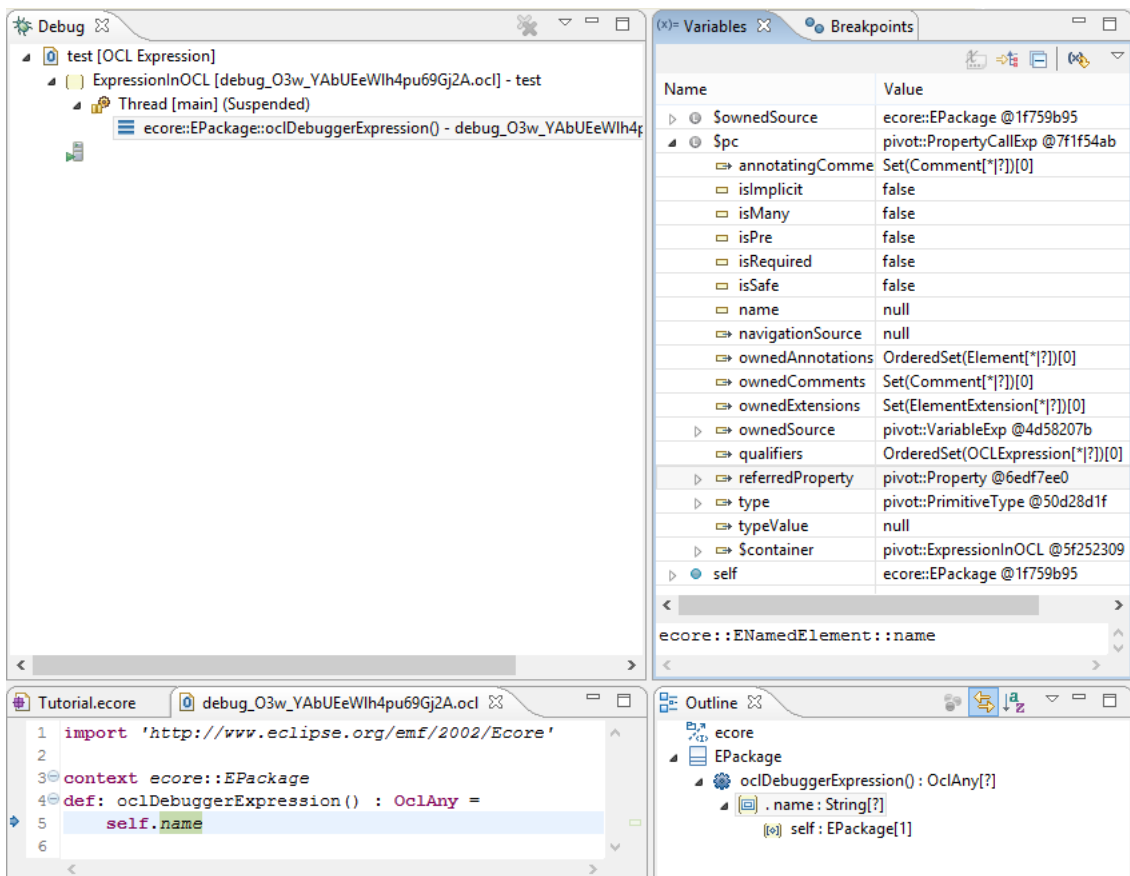
Click on the expand/collapse icon to the left of **self.eClassifiers** to show the four classifiers.
Select **self.eClassifiers[1]** so that the bottom line display shows that the second is named Book.



The Variables View provides more insight that the Sample Ecore Properties View, so you may find it convenient to use a trivial OCL debugger session using **self** as the OCL expression to browse arbitrary model data.

4.5.3.3. Stepping Execution

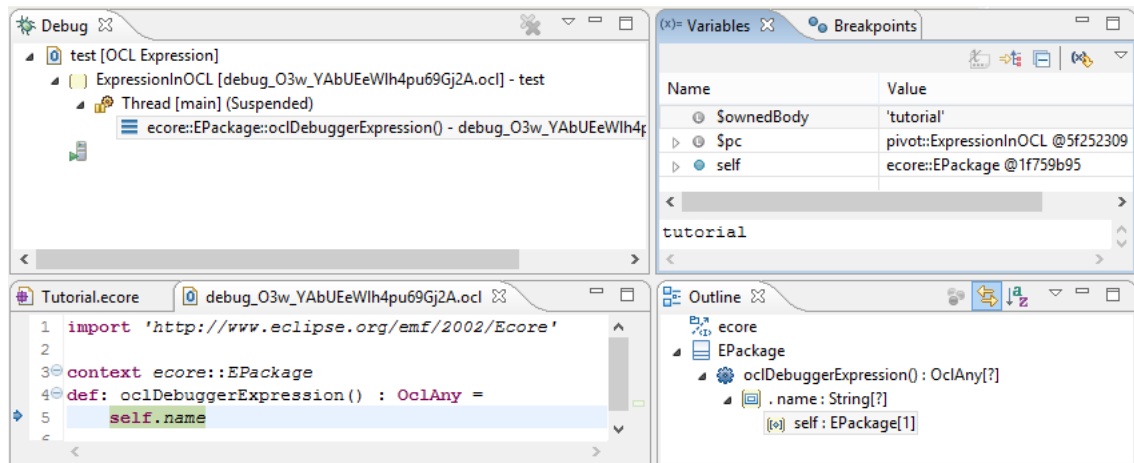
Click F5 or the **Step Into** icon to advance execution by one AST node evaluation.



The editor now highlights **.name**; **\$pc** shows a **PropertyCallExp** as the next execution. **\$pc.referredProperty** shows that it is **ecore::ENamedElement.name**.

An additional synthetic variable **\$ownedSource** shows the result of the **self** evaluation that forms the source term of the **PropertyCallExp**. As expected this is the same as **self**.

Click F5 or the **Step Into** icon again to advance execution by a further AST node evaluation.

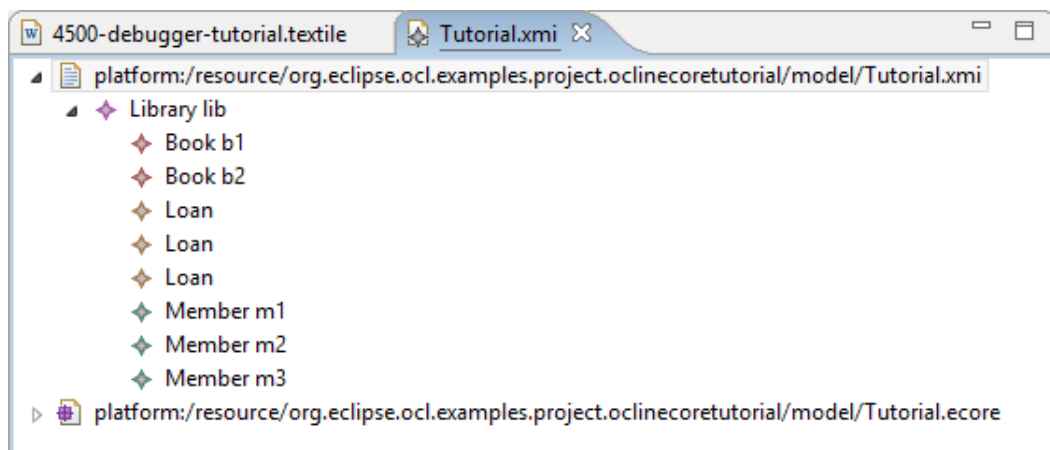


The whole of **self.name** is highlighted and **\$pc** shows that the overall ExpressionInOCL is about to be evaluated. The synthetic **\$ownedBody** for its input shows that **self.name** evaluated to **'tutorial'**.

4.5.4. Debugging a Validation failure

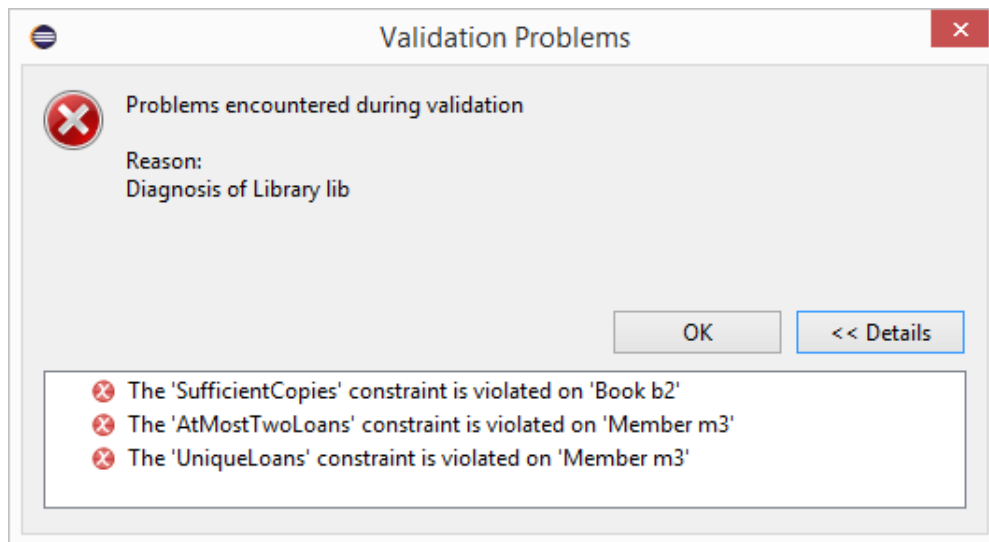
OCL is useful for elaborating models with additional well-formedness rules, but when these fail it can be difficult to understand why a failure occurred, particularly if the bug is in the OCL rather than the model. We will now show how the OCL debugger can be used to debug a validation failure.

Double click on **model/Tutorial.xmi** to open the model, and expand the top two entries to show some detail.



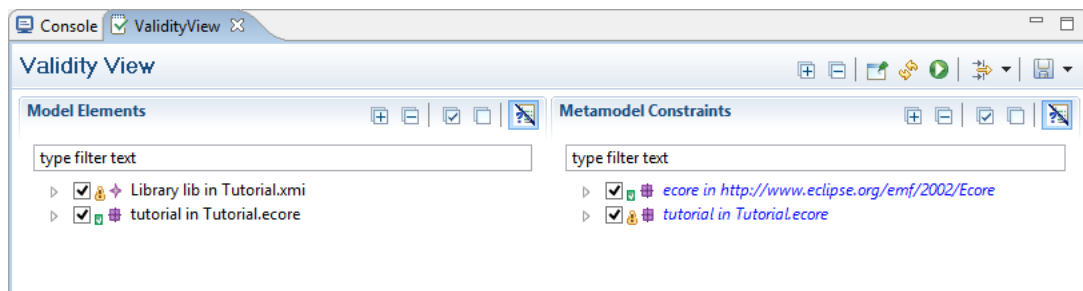
If the model opens with another editor, close it, and open with the Sample Reflective Ecore Model Editor by selecting **model/Tutorial.xmi** and then **Open With->Sample Reflective Ecore Model Editor** from the context menu.

Select the first line and invoke **Validate** from the context menu. (Wait a second.) Optionally click on Details.



These error messages provide insufficient precision to really understand the problems, so click **OK** to dismiss the popup then select **Book b2**, which has an error, and invoke **OCL->Show Validity View** to provide more insight.

If the Validity View shows question marks rather than red/green/amber status decorations, Click the Run icon in the Validity View tool bar.

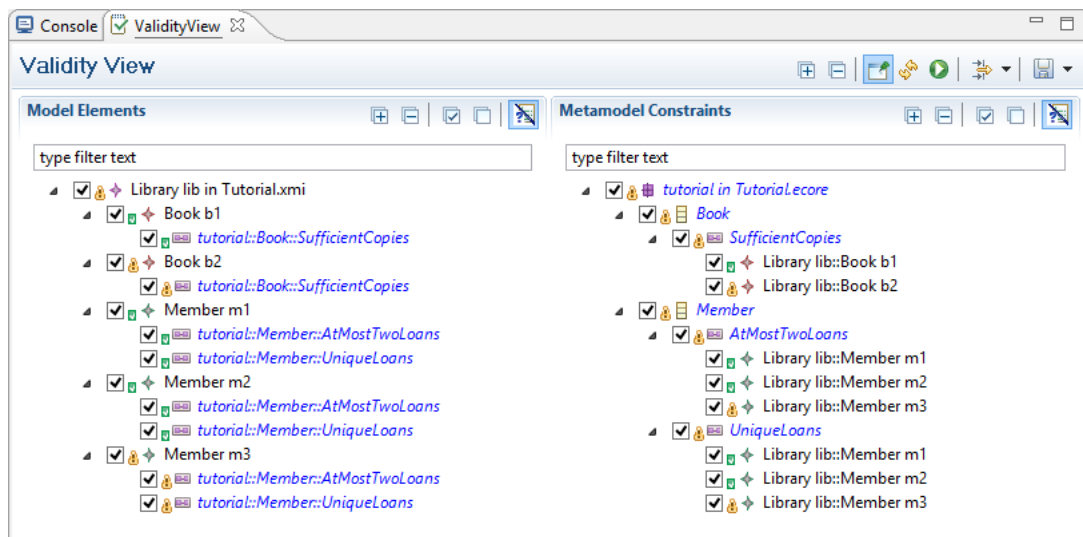


Click the **Pin** icon in the Validity View tool bar to avoid thrashing whenever you change mouse selection.

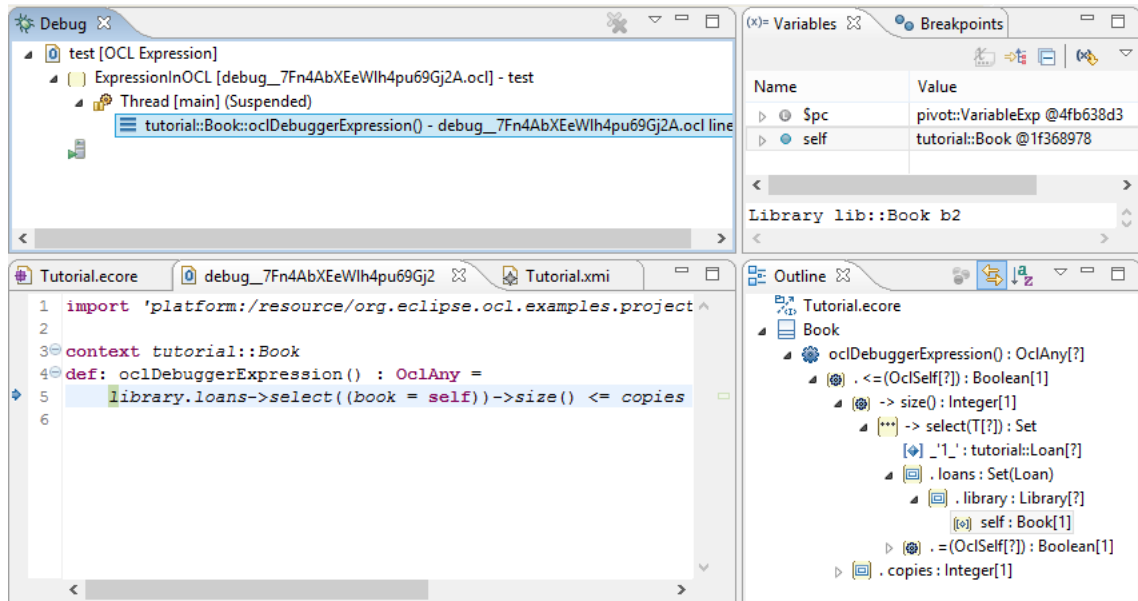
Uncheck the top **ecore** line in the Metamodel Constraints since we are not interested in the successful Ecore metamodel constraints just those in the **tutorial** metamodel.

Similarly uncheck the bottom **tutorial** line in the Model Elements since we are not interested in the successful metamodel, just those in the tutorial model.

Click on the + tool bar icon so that the detail is shown.



We will now debug the failure of the **tutorial::Book::SufficientCopies** on the **Library lib::Book b2** model element. Select either of the leaf warnings, that is either the **tutorial::Book::SufficientCopies** child of **Book b2** in the left hand pane, or the **Library lib::Book b2** child of **SufficientCopies** in the right hand pane, and invoke **Debug Single Enabled Selection**. Wait a second or two and the debugger starts. If it doesn't, open the Debugger perspective manually.

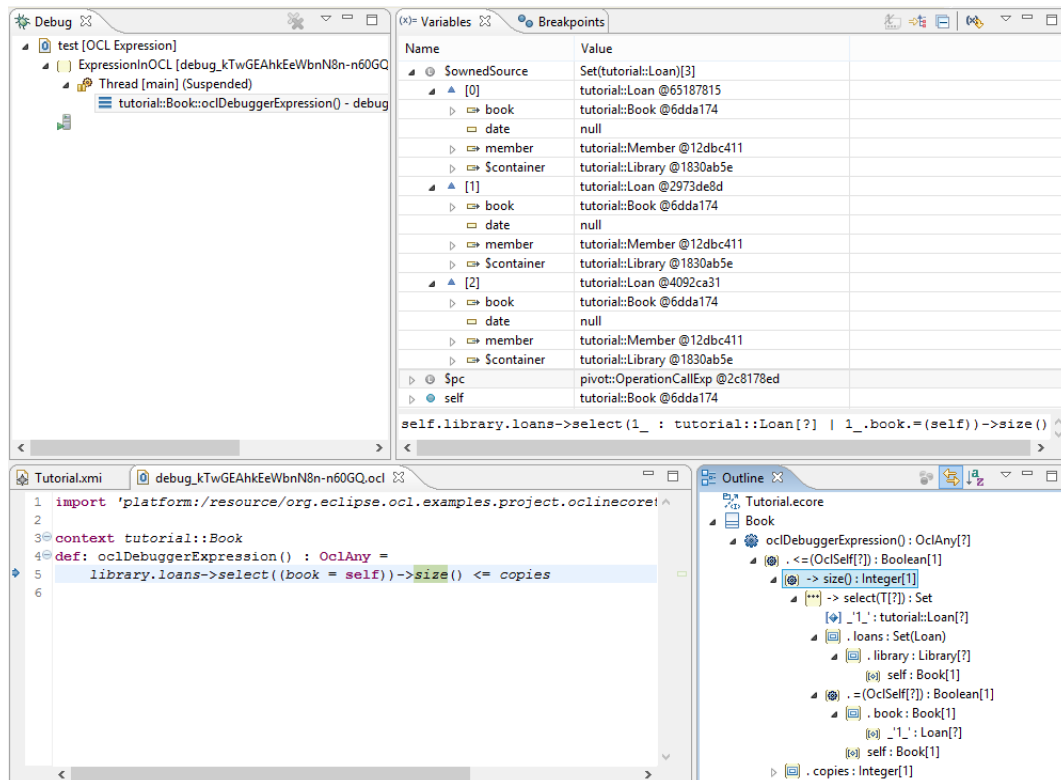


Select the **oclDebuggerExpression()** stack line. The debugger shows **library.loans->select((book = self))->size() <= copies** with **l** highlighted as the next execution. The outline shows that the **VariableExp** for **self** is next to execute. The **library** in the source code is a shorthand for **self.library** so highlighting **l** is an approximation to highlighting the invisible **source**, in front of **library**. **\$pc** in the Variables View also shows a **VariableExp** for **self** as the next instruction.

Click F5 or **Step Into** and **\$pc** advances and the editor highlight changes to **library**.

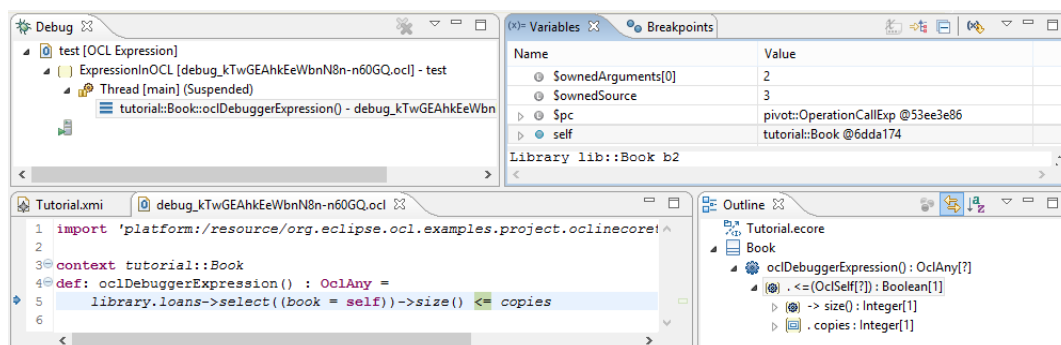
Click F5 or **Step Into** a few more times and the highlight will show the iteration within the **select** body, allowing each state of each element to be examined to determine why the exhibited behavior occurs.

Continue to Click F5 or **Step Into** until **->size()** is highlighted.



Expanding **\$ownedSource** in the Variables View shows the Set of three selected Loans each of which has the same book as self.

Click F5 or **Step Into** three more times until **<=** is highlighted.



We can now see that the **\$ownedSource**, left hand side, of the comparison is 3 and the **\$ownedArguments[0]** right hand side is 2. A further step and we see the result as **\$ownedBody** demonstrating why the validation failed.

4.5.5. Debugging Complete OCL validation failure

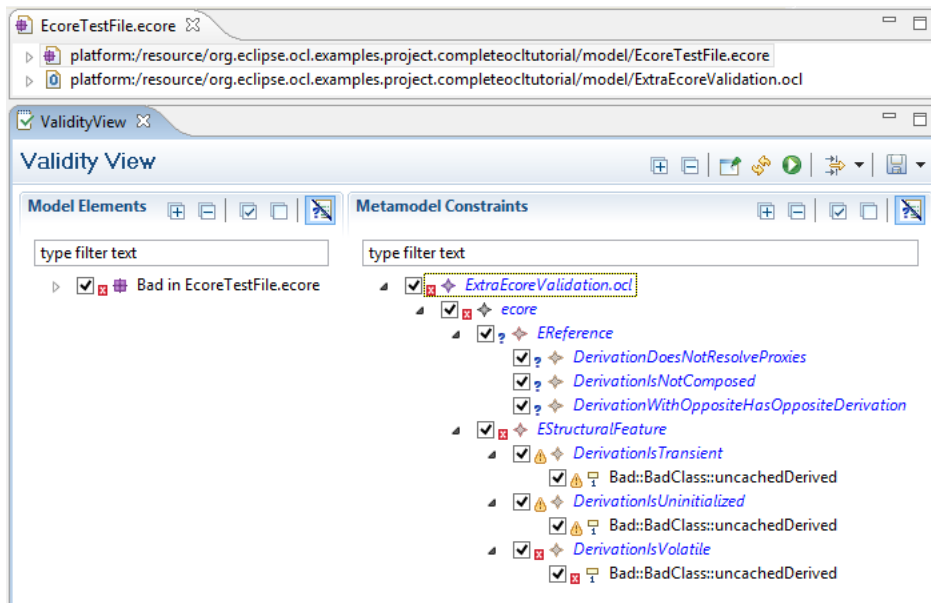
The two preceding examples displayed their source text in a synthesized Complete OCL document.

In this example we debug a failure for which the OCL is already available in a Complete OCL document. Open the **model/EcoreTestFile.ecore** from the [Complete OCL tutorial](#) project using the Sample Ecore Editor.

Within the Ecore editor use **OCL->Load Document** and then drag and drop **model/ExtraEcoreValidation.ocl** and click **OK** to dismiss the pop up.

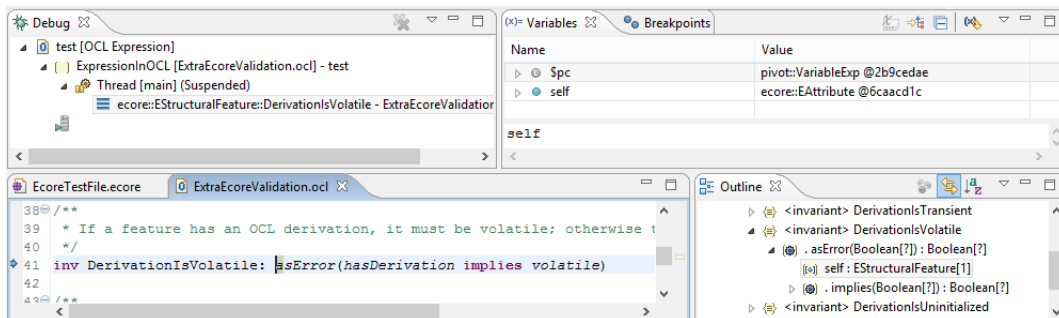
Again within the Ecore editor use **OCL->Show Validity View** to see the constraint/element pairs. *If the Validity View was already visible, close it and re-show it since in Mars addition of a Complete OCL document fails to refresh correctly.*

In the Validity View, uncheck the **ecore** Metamodel Constraint contributions retaining just the **ExtraEcoreValidation.ocl** contribution. Click the plus icon in the **Metamodel Constraint** tool bar to expand all entries.



Select the bottom right **BadClass** model element below the **DerivationIsVolatile** constraint and invoke **Debug Single Enabled Selection** from the context menu (wait a second or two). The debugger should start, if not open the Debugger perspective manually.

*In Mars, select the **DerivationIsVolatile** stack line to refresh the selection.*



Both **asError** and **hasDerivation** are OCL-defined so as you step you successively navigate into the defined property and operation.

4.5.6. Console experiments

While debugging, the original OCL expression from the Console is presented in a Complete OCL editor. This editor is readonly so you cannot edit it to correct mistakes or to experiment.

You may however safely use the OCL Console to perform further experiments. Select a suitable self object in the Variable View and cut and paste to prepare your experimental OCL expression.

In Mars, Console selections cannot be Collections so you are unfortunately restricted to single objects.

4.5.7. Longer range stepping

In the examples above we have only used F5 or **Step Into**.

In principle the tedious stepping through an iteration can be avoided by F7 or **Step Return** which should terminate on the popped evaluation environment at the end of the iteration. *This facility has not been adequately tested in Mars.*

If you arrange for some line breaks in your source text you can use F6 or **Step Next** to proceed until the line number advances. *This facility has not been adequately tested in Mars.* Line breaks can be added in the OCL Console using Shift and Enter together.

4.5.8. Break points

When debugging OCL from Complete OCL documents, the original document is a suitable source for the debugger and so line breakpoints can be set. *This facility has not been adequately tested in Mars*

4.6. Validation tutorial

This tutorial has been updated for Eclipse Mars: Eclipse 4.5, EMF 2.11, OCL 6.0.

- Some screenshots may be slightly out of date.

The standard EMF validation facilities are very useful for avoiding model errors and work well when the models are correct or at least nearly correct. In this tutorial we show how the [Validity View](#) can provide greater insight into what works and what doesn't.

We will show how to

- identify all constraints applicable to a particular model element
 - show the constraint text
 - show the validation status
- identify all model elements constrained by a particular constraint
 - show the constraint text
 - show the validation status
- filter the displayed model elements and constraints
 - by name
 - by status
 - by model
 - by metamodel
- launch an OCL debugger for a particular model element and constraint

4.6.1. Load Complete OCL Tutorial Example Project

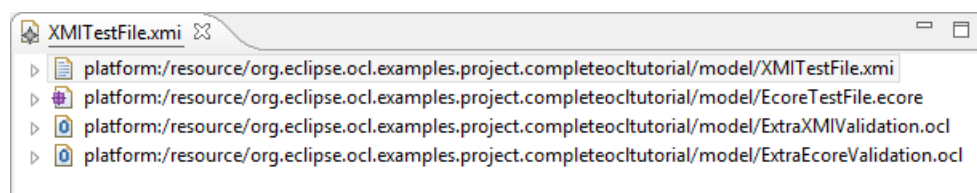
The material for this tutorial is available as part of the Complete OCL Example project that you may load by selecting **New** then **Example...** using the right button context menu of the Project Explorer. This should give the **New Example** dialog in which you can select the OCL (OCL Constraint Language) Plugins and the Complete OCL Tutorial.

4.6.2. Load Test Model

Double click on **model/XMITestFile.xmi** to open the model and expand the top entry to show the EPackage.

If the model opens with another editor, close it, and open with the Sample Reflective Ecore Editor by selecting **model/Tutorial.ecore** and then **Open With->Sample Reflective Ecore Model Editor** from the context menu.

Within the editor invoke **OCL->Load Document** to load **model/ExtraEcoreValidation.ocl** and again to load **model/ExtraXMIVValidation.ocl**



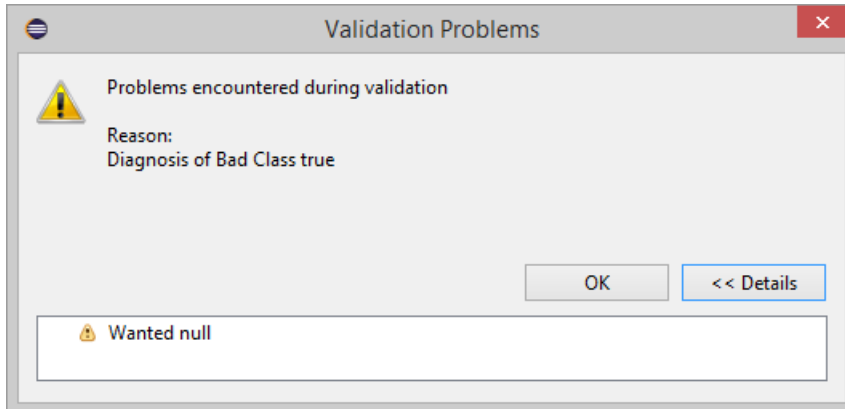
Your source ResourceSet now contains four resources

- the XMITestFile.xmi model
- the EcoreTestFile.ecore metamodel

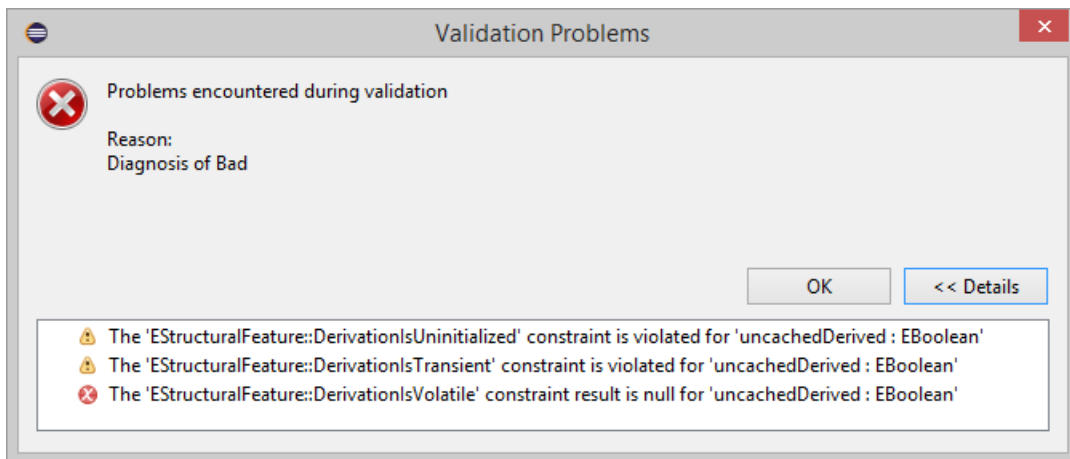
- the ExtraXMIVValidation.ocl additional model validation rules
- the ExtraEcoreValidation.ocl additional metamodel validation rules

4.6.3. EMF Validation

Select the **XMITestFile.xmi** and invoke **Validate** from the context menu. Click **OK** to dismiss.



Select the **EcoreTestFile.ecore** and invoke **Validate** from the context menu. Click **OK** to dismiss.



The above results clearly show problems, but not necessarily all the problems and do not show what was actually done. Sometimes validation of a model element terminates prematurely once an error has been reported. On other occasions some constraints are not run and so no corresponding errors are detected.

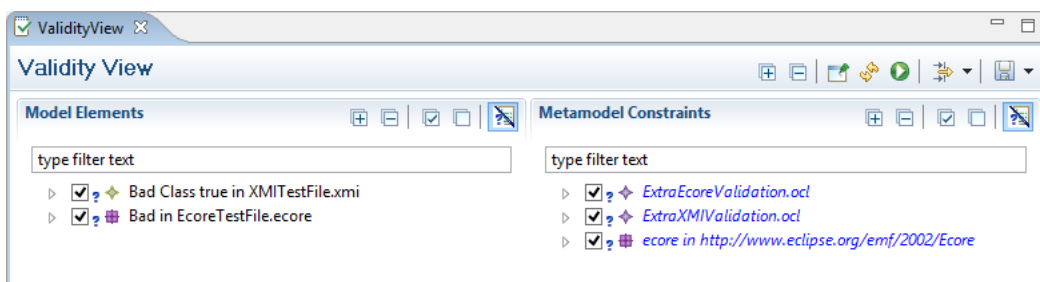
The above limitations are not a problem, when everything is working well, but when you have a misunderstanding as to what is being validated, a bad day can get very much worse.

4.6.3.1. Validity View Validation

Select **OCL->Show Validity View** from the editor context menu.

The left hand pane shows the root model elements in a similar way to the Sample Reflective Ecore Editor.

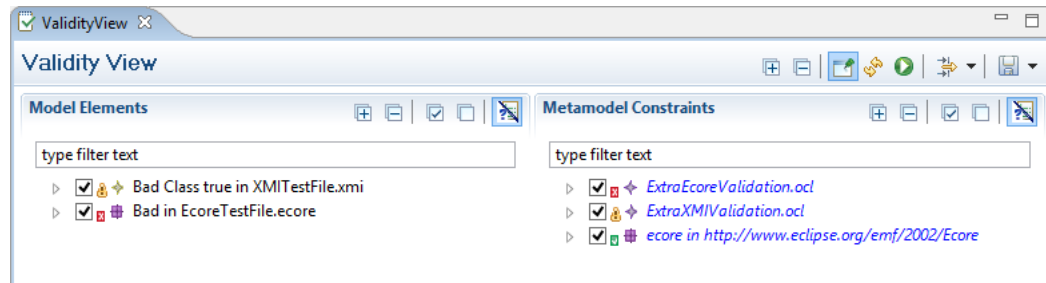
The right hand pane shows the root metamodel constraint sources.



Each may be expanded using the control at the start of each line or the more general controls in the tool bars.

Important tip: click the pin icon in the Validity Model tool bar to stop the Validity View chasing your mouse selections.

You may now obtain the more detailed validation results by clicking on the green Run icon in the main Validation View tool bar.



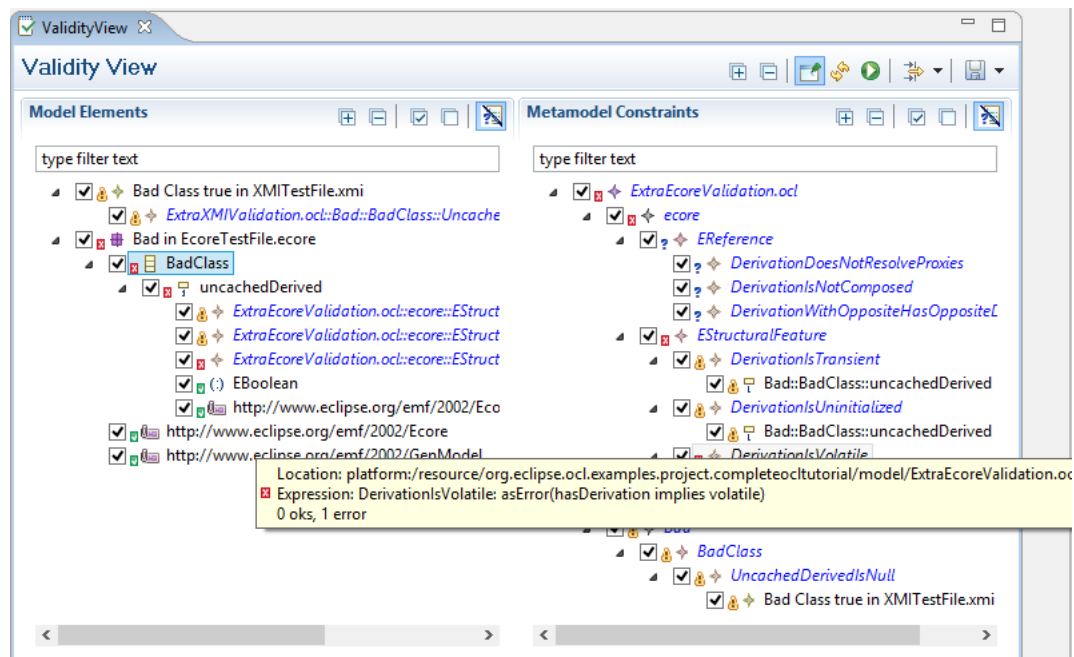
Use the hover text to see how many validations have been rounded up into each root display.

4.6.3.2. Filtering by Root Models

There are 34 results in total, which is more than we want to look at, even for this very small model.

The **ecore** in <http://www.eclipse.org/emf/2002/Ecore> root constraint is contributing 30 successes without problem, so we ignore it by unchecking the enable checkbox preceding it.

The model is so simple that we can now expand it completely. Click on the + expand icons.



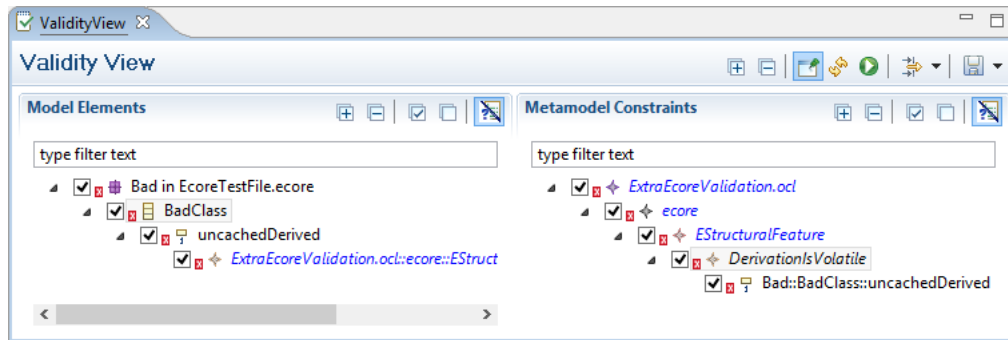
In the left hand pane, the black text labels show the hierarchy of model elements. At the leaves in blue italic text are the constraints applicable to the model element.

In the right hand pane, the blue italic labels show the hierarchy of constraints. At the leaves in black text are the constrained model elements.

You can hover over constraints to see the details and invoke **Show In Editor** to navigate to them.

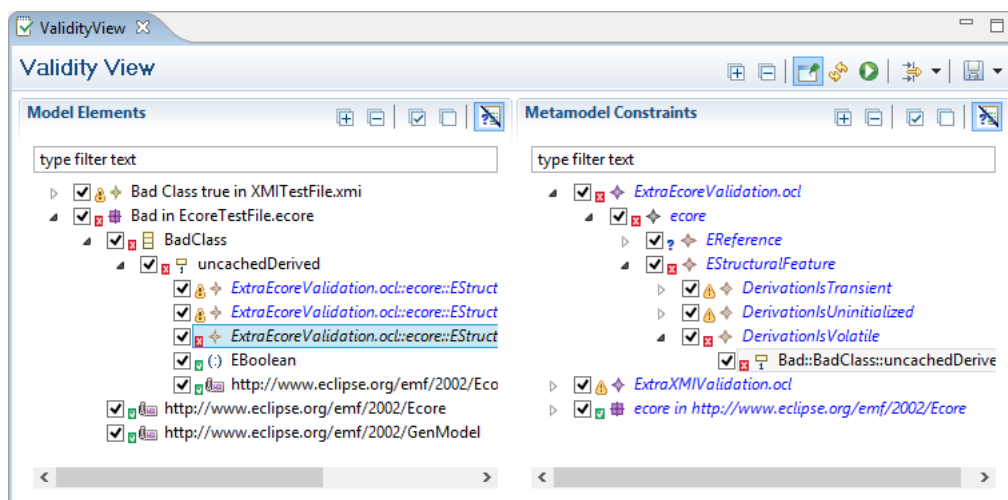
4.6.3.3. Filtering by Status

The many successes are often of limited interest, so we may concentrate on Errors by invoking **Show all Errors** from the Filtering pull down towards the right of the main Validation View tool bar.



Having found an error of interest we can see it in context.

- Select the **Bad::BadClass::uncachedDerived** error in the Constraints pane
- remove the **Show all Errors** filtering using the Filtering pull down
- enable the view of all constraints by clicking the tick icon in the Model Constraint pane tool bar.



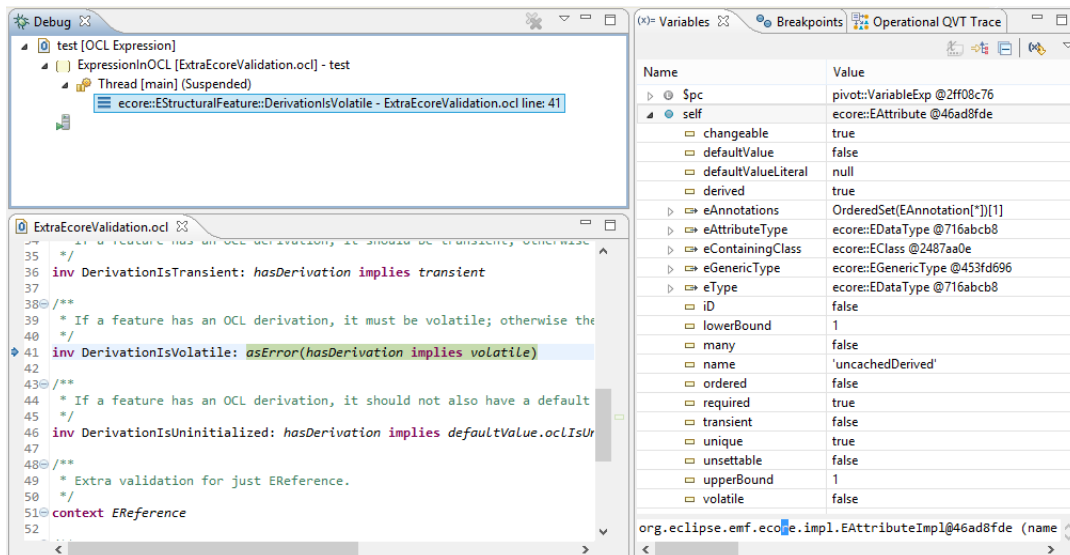
This shows that the constraint is validated five times with one error, two warnings and two successes.

Double clicking on the erroneous child constraint makes the constraint visible in the right hand pane, showing that the constraint is only applied to this one model element.

4.6.3.4. Debugging constraints

Maybe it's time for some debugging. Select the leaf constraint below a model element, or the leaf element below a constraint and invoke **Debug Single Enabled Selection** to start the OCL debugger to step through the problematic constraint on the problematic model element. (Select the debugger perspective explicitly if it doesn't open automatically.)

Use of the OCL debugger is described in the [Debugger Tutorial](#).



4.7. Working with Classic OCL

4.7.1. Overview

This tutorial illustrates the various services provided by the Classic Eclipse OCL implementation.

4.7.2. References

This tutorial assumes that the reader is familiar with the Eclipse extension point architecture. There is an abundance of on-line help in Eclipse for those unfamiliar with extension points.

To see the complete source code for the examples shown in this tutorial, install the [OCL Interpreter Example](#) plug-in into your workspace.

Other references:

- For an environment in which to test the OCL expressions that you will create in this tutorial, install the [Library Metamodel](#) example.
- [OCL 2.0](#) specification.

4.7.3. Parsing OCL Expressions

The first responsibility of the OCL interpreter is to parse OCL expressions. One of the purposes of parsing an expression is to validate it: if it can be parsed, it is well-formed (the parser automatically validates the expression against the semantic well-formedness rules).

The main entrypoint into the OCL API is the [OCL](#) class. An OCL provides an autonomous OCL parsing environment. It tracks all constraints that are parsed in this environment, including the definitions of additional operations and attributes. The `OCL.newInstance()` factory method is used to create a new OCL with an `EnvironmentFactory` that provides the binding to a particular metamodel (Ecore or UML). In this tutorial, we will use the Ecore binding.

To parse a query expression, we will use the [OCLHelper](#) object, which provides convenient operations for parsing queries and constraints (intended for processing constraints embedded in models).


```

boolean valid;
OCLExpression<EClassifier> query = null;

try {
    // create an OCL instance for Ecore
    OCL<?, EClassifier, ?, ?, ?, ?, ?, ?, Constraint, EClass, EObject> ocl;
    ocl = OCL.newInstance(EcoreEnvironmentFactory.INSTANCE);

    // create an OCL helper object
    OCLHelper<EClassifier, ?, ?, Constraint> helper = ocl.createOCLHelper();

    // set the OCL context classifier
    helper.setContext(EXTLibraryPackage.Literals.WRITER);

    query = helper.createQuery("self.books->collect(b : Book | b.category)->asSet()");

    // record success
    valid = true;
} catch (ParserException e) {
    // record failure to parse
    valid = false;
    System.err.println(e.getLocalizedMessage());
}

```

The example above parses an expression that computes the distinct categories of Books associated with a Writer. The possible reasons why it would fail to parse (in which case a `ParserException` is thrown) include:

- syntactical problems: misplaced or missing constructs such as closing parentheses, variable declarations, type expressions, etc.
- semantic problems: unknown attributes or operations of the context type or referenced types, unknown packages, classes, etc.

4.7.4. Parsing OCL Constraints

OCL is primarily intended for the specification of *constraint*s. Unlike queries, there are a variety of different kinds of constraints used in different places in a model. These include classifier invariants, operation constraints, and attribute derivation constraints. The `OCLHelper` can parse these for us.

Let's imagine the confusion that arises from a library that has more than one book of the same title (we are not intending to model copies). We will create an invariant constraint for `@Book@s` stipulating that this is not permitted:

```

Constraint invariant = null;

try {
    // set the OCL context classifier
    helper.setContext(EXTLibraryPackage.Literals.LIBRARY);

    invariant = helper.createInvariant(
        "Library.allInstances()->forall(b1, b2 | b1 <> b2 implies b1.title <> b2.title)");
} catch (ParserException e) {
    // record failure to parse
    System.err.println(e.getLocalizedMessage());
}

```

Parsing constraints differs from parsing query expressions because they have additional well-formedness rules that the parser checks. For example, an invariant constraint must be boolean-valued, an attribute derivation constraint must conform to the type of the attribute, and such constructs as `@pre` and `oclIsNew()` may only be used in operation post-condition constraints.

4.7.5. Evaluating OCL Expressions and Constraints

More interesting than parsing an OCL expression or constraint is evaluating it on some object. The [Query](#) interface provides two methods for evaluating expressions. Queries are constructed by factory methods on the OCL class.

- [Object evaluate\(Object\)](#)

evaluates the expression on the specified object, returning the result. The caller is expected to know the result type, which could be a primitive, `EObject`, or a collection. There are variants of this method for evaluation of the query on multiple objects and on no object at all (for queries that require no "self" context).

- [boolean evaluate\(Object\)](#)

This method evaluates a special kind of OCL expression called a *constraint*. Constraints are distinguished from other OCL queries by having a boolean value; thus, they can be used to implement invariant or pre/post-condition constraints. There are variants for checking multiple objects and for selecting/rejecting elements of a list that satisfy the constraint.

In order to support the `allInstances()` operation on OCL types, the OCL API provides the

[setExtentMap\(Map<CLS, ? extends Set<? extends E>> extentMap\)](#) method. This assigns a mapping of classes (in the Ecore binding, `EClass`es) to the sets of their instances. By default, the OCL provides a dynamic map that computes the extents on demand from the contents of a `Resource`. An alternative extent map can be found in [org.eclipse.ocl.ecore.opposites.ExtentMap](#). We will use a custom extent map in evaluating a query expression that finds books that have the same title as a designated book:

```

// create an extent map
Map<EClass, Set<? extends EObject>> extents = new HashMap<EClass, Set<? extends EObject>>();
Set<Book> books = new HashSet<Book>();
extents.put(EXTLibraryPackage.Literals.BOOK, books);

// tell the OCL environment what our classifier extents are
ocl.setExtentMap(extents);

Library library = EXTLibraryFactory.eINSTANCE.createLibrary();

Book myBook = EXTLibraryFactory.eINSTANCE.createBook();
myBook.setTitle("David Copperfield");
books.add(myBook);

// this book is in our library
library.add(myBook);

Writer dickens = EXTLibraryFactory.eINSTANCE.createWriter();
dickens.setName("Charles Dickens");

Book aBook = EXTLibraryFactory.eINSTANCE.createBook();
aBook.setTitle("The Pickwick Papers");
aBook.setCategory(BookCategory.MYSTERY_LITERAL);
books.add(aBook);
aBook = EXTLibraryFactory.eINSTANCE.createBook();
aBook.setTitle("David Copperfield");
aBook.setCategory(BookCategory.BIOGRAPHY_LITERAL); // not actually, of course!
books.add(aBook);
aBook = EXTLibraryFactory.eINSTANCE.createBook();
aBook.setTitle("Nicholas Nickleby");
aBook.setCategory(BookCategory.BIOGRAPHY_LITERAL); // not really
books.add(aBook);

dickens.addAll(books); // Dickens wrote these books
library.addAll(books); // and they are all in our library

// use the query expression parsed before to create a Query
Query<EClassifier, EClass, EObject> eval = ocl.createQuery(query);

Collection<?> result = (Collection<?>) eval.evaluate(dickens);
System.out.println(result);

```

The same Query API is used to check constraints. Using the library and extents map from above and the constraint parsed previously:

```

eval = ocl.createQuery(constraint);

boolean ok = eval.check(library);

System.out.println(ok);

```

4.7.6. Implementing Content Assist

The `OCLHelper` interface provides an operation that computes content-assist proposals in an abstract form, as [Choice](#) s. An application's UI can then convert these to JFace's `ICompletionProposal` type.

Obtaining completion choices consists of supplying a partial OCL expression (up to the cursor location in the UI editor) to the `OCLHelper::getSyntaxHelp\(ConstraintKind, String\)`, `java.lang.String`) method. This method requires a `ConstraintKind` enumeration indicating the type of constraint that is to be parsed (some OCL constructs are restricted in the kinds of constraints in which they may be used).

```

helper.setContext(EXTLibraryPackage.Literals.BOOK);

List<Choice> choices = helper.getSyntaxHelp(
    ConstraintKind.INVARIANT,
    "Book.allInstances()->excluding(self).");

for (Choice next : choices) {
    switch (next.getKind()) {
        case OPERATION:
        case SIGNAL:
            // the description is already complete
            System.out.println(next.getDescription());
        case PROPERTY:
        case ENUMERATION_LITERAL:
        case VARIABLE:
            System.out.println(next.getName() + " : " + next.getDescription());
            break;
        default:
            System.out.println(next.getName());
            break;
    }
}

```

A sample of the output looks like:

```

author : Writer
title : String
oclIsKindOf(typespec : OclType)
oclAsType(typespec : OclType) : T
...

```

The choices also provide the model element that they represent, from which a more sophisticated application can construct appropriate JFace completions, including context information, documentation, etc.

4.7.7. Working with the AST

The OCL Interpreter models the OCL language using EMF's Ecore with support for Java-style generic types. The bindings of this generic Abstract Syntax Model for Ecore and for UML substitutes these metamodels' constructs for the generic type parameters, plugging in the definitions of the "classifier", "operation", "constraint", etc. constructs of the OCL vocabulary. These bindings, then, support persistence in or as an adjunct to Ecore and UML models.

For processing the abstract syntax tree (AST) parsed from OCL text, the API supplies a [Visitor](#) interface. By implementing this interface (or extending the [AbstractVisitor](#) class, which is recommended), we can walk the AST of an OCL expression to transform it in some way. This is exactly what the interpreter, itself, does to evaluate an expression: it just walks the expression using an evaluation visitor. For example, we can count the number times that a specific attribute is referenced in an expression:

```

helper.setContext(EXTLibraryPackage.Literals.BOOK);

OCLExpression<EClassifier> query = helper.parseQuery(
    "Book.allInstances()->select(b : Book | b <> self and b.title = self.title)");

AttributeCounter visitor = new AttributeCounter(
    EXTLibraryPackage.Literals.BOOK__TITLE);

System.out.println(
    "Number of accesses to the 'Book::title' attribute: " + query.accept(visitor));

```

where the visitor is defined thus:

```

class AttributeCounter extends AbstractVisitor<Integer,
    EClassifier, EOperation, EStructuralFeature, EEnumLiteral,
    EParameter, EObject, EObject, EObject, Constraint> {
    private final EAttribute attribute;

    AttributeCounter(EAttribute attribute) {
        super(0); // initialize the result of the AST visitation to zero
        this.attribute = attribute;
    }

    protected Integer handlePropertyCallExp(PropertyCallExp<EClassifier, EStructuralFeature,
        Integer sourceResult, List<Integer> sourceResults) {
        if (callExp.getReferredProperty() == attribute) {
            // count one
            result++;
        }

        return result;
    }
}

```

4.7.8. Serialization

Because the OCL expression AST is a graph of EMF objects, we can serialize it to an XMI file and deserialize it again later. To save our example expression, we start over by initializing our OCL instance with a resource in which it will persist the environment and in which we will persist the parsed expression. The key is in the persistence of the environment: OCL defines a variety of classes on the fly by template instantiation. These include collection types, tuple types, and message types. Other elements needing to be persisted are additional operations and attributes that may be defined in the local environment.

```

// create a resource in which to store our parsed OCL expressions and constraints
Resource res = resourceSet.createResource(
    URI.createPlatformResourceURI("/MyProject/myOcl.xmi", true);

// initialize a new OCL environment, persisted in this resource
ocl = OCL.newInstance(EcoreEnvironmentFactory.INSTANCE, res);

// for the new OCL environment, create a new helper
helper = OCL.createOCLHelper();

helper.setContext(EXTLibraryPackage.Literals.BOOK);

// try a very simple expression
OCLExpression<EClassifier> query = helper.createQuery("self.title");

// store our query in this resource. All of its necessary environment has
// already been stored, so we insert the query as the first resource root
res.getContents().add(0, query);

res.save(Collections.emptyMap());
res.unload();

```

To load a saved OCL expression is just as easy:

```

Resource res = resourceSet.getResource(
    URI.createPlatformResourceURI("/MyProject/myOcl.xmi", true),
    true;

@SuppressWarnings("unchecked")
OCLExpression<EClassifier> query = (OCLExpression<EClassifier>) res.getContents().get(0);

System.out.println(ocl.evaluate(myBook, query));

```

In the snippet above, we used the OCL's convenience method for a one-shot evaluation of a query. Looking at the contents of the XMI document that we saved, we see that the `self` variable declaration is not

owned by the query expression, but is, rather, free-standing. The `ExpressionInOCL` metaclass solves this problem by providing properties that contain context variable declarations, including `self` and (in the context of operations) operation parameters.

```
<?xml version="1.0" encoding="ASCII"?>
<xmi:XMI xmi:version="2.0" xmlns:xmi="http://www.omg.org/XMI" xmlns:xsi="http://www.w3.org
  <ocl.ecore:PropertyCallExp xmi:id="_897fVPfmEduCQ48h829a5g">
    <eType xsi:type="ocl.ecore:PrimitiveType" href="http://www.eclipse.org/ocl/1.1.0/oclstd
    <source xsi:type="ocl.ecore:VariableExp" xmi:id="_897fVvfmEduCQ48h829a5g" name="self" :
      <eType xsi:type="ecore:EClass" href="http://www.org.eclipse/ocl/examples/library/ext
    </source>
    <referredProperty xsi:type="ecore:EAttribute" href="http://www.org.eclipse/ocl/example
  </ocl.ecore:PropertyCallExp>
  <ocl.ecore:Variable xmi:id="_897fUvfmEduCQ48h829a5g" name="self">
    <eType xsi:type="ecore:EClass" href="http://www.org.eclipse/ocl/examples/library/extli
  </ocl.ecore:Variable>
</xmi:XMI>
```

4.7.9. Summary

To illustrate how to work with the OCL API, we

- Parsed and validated OCL expressions and constraints.
- Evaluated OCL query expressions and constraints.
- Obtained content-assist suggestions for the completion of OCL expressions.
- Transformed an OCL expression AST using the *Visitor* pattern.
- Saved and loaded OCL expressions to/from XMI resources.

4.8. Extensions (in the Unified/Pivot OCL prototype)

This section highlights some of the OCL extensions prototyped by the Pivot OCL.

4.8.1. Models

The Abstract Syntax classes and interfaces are autogenerated from `Pivot.ecore` using standard EMF tooling. `Pivot.ecore` is auto-generated by custom QVTo transformations from OMG's UML.xmi and prototype OCL.uml models. This gives some degree of UML alignment.

The Standard Library is defined by `OCL-2.5.oclstdlib` for which an `OCLstdlib` Xtext editor is available. The library is therefore modelled.

The Concrete Syntax classes and editors are also autogenerated from `Ecore.modell` using standard EMF tooling. Autogeneration of the `Ecore` models from UML models is still work in progress.

The grammars are defined by Xtext models.

The run-time Value classes and interfaces are partially generated from `Values.ecore`. Full auto-generation is still work in progress.

There is also a model of the code generation intermediate.

4.8.2. XMI

The abstract syntax models are fully persistable as standard XMI using the `*.oclas` file extension. `Pivot.oclas` and `OCL-2.5.oclas` models form part of the Eclipse OCL distribution.

The problem of interchange of synthetic types such as `Sequence(String)` is solved by an orphan package in which a singleton copy of every singleton is maintained.

The problem of Complete OCL's open classes allowing additional features is solved by `CompleteModel/CompletePackage/CompleteClass` additions to the abstract syntax so that a `CompleteClass` may aggregate many ordinary Classes; one from the primary user (UML/Ecore) model, any number of further (Complete OCL or `OCLstdlib`) over;ays.

The problem of references to unnavigable opposites is solved by an `OppositePropertyCallExp` class.

The problem of references to modelled Iterations is resolved by adding a `referredIteration` property to `IterateExp/IteratorExp`.

The problem of references to Stereotype properties is resolved by normalizing the UML representation to exploit regular Class/Property usage.

The problem of references to Association properties is resolved by normalizing the UML representation to exploit regular Class/Property usage.

4.8.3. Templates

In OMG OCL, types such as `Sequence(String)` magically associate `String` and an ill-defined concept of `T`. In UML and consequently the UML-aligned pivot OCL, `String` is a `TemplateParameter` for which further classes such as `TemplateParameterSubstitution` define bindings. The use of magic `T` for library classes is generalized to arbitrary user classes and operations; just like UML. Template types of course conform and since in OCL all values are immutable a `Set(Integer)` is conformant to a `Set(Real)` and a `Set(OclAny)`. This can be slightly surprising since typos may not lead immediately to type errors, rather an expression with inferred `OclAny` errors. Use the hover text to inspect your expression types.

4.8.4. Extensibility

The Pivot OCL is extended by the Eclipse QVTd project to support QVTc and QVTr. The models are therefore extensible, but not readily so. Rather too much Java programming is required. True extensibility and in particular a modular OCL Standard Library is still work in progress.

4.8.5. Operation Overloading

The buck passing between UML and OCL in regards to operation overloading is resolved in the Pivot OCL by implementing a Java-style dynamic dispatch to the most derived implementation with a matching signature.

4.8.6. Stereotypes

The UML specification hints in regards to `base_XXX` and `extension_XXX` properties are followed through in conjunction with an `ElementExtension` class to model the instance of a Stereotype. Typesafe stereotype navigation is therefore possible without resorting to the proprietary `getXXX` Java API of Eclipse UML2.

4.8.7. Safe Navigation

The UML `[1]` and `[?]` multiplicities are exploited to distinguish nullable and non-null objects and diagnose unsafe navigations. To make this useful an extension to null-free collections is possible by defining e.g. `Set(String[*|1])` as a Set of String with unbounded `[*]` collection multiplicity and never-null `[1]` element multiplicity. The additional `?.` and `"?->"` safe navigation operators avoid null hazards. See [Safe Navigation in OCL](#) for more details.

4.8.8. Reflection

In the Pivot OCL the `oclType()` library method has a `pivot::Class` return type allowing further navigation to make reflective access to the user metamodel.

4.8.9. Lambda Expressions

OCL has always had hidden lambda expressions in order to define iterator bodies. The Pivot OCL reifies these so that the Standard Library uses a templated `LambdaType` as part of its modelling. Variables and Parameters may use `LambdaType` and so offer full lambda expression capability.

4.8.10. Map(K,V)

The Map type provides a familiar functionality comprising a set of keys with associated values.

Like all other OCL types, the Map type is immutable; there are therefore no **put** or **set** operations, rather a new Map may be created by **including** a key-value pair together with an old Map.

The content of a Map may be accessed using **at**, which returns invalid for an unknown key in the same way as an ordered collection returns invalid for an unknown index.

A Map may be created explicitly using the new Map Literal Syntax. Thus **Map(Integer,String){1 <- 'one',2 <- 'two'}** creates a Map of Integer to String with **'one'** bound to **1** and **'two'** bound to **2**. The type **(Integer,String)** parameterisation can be omitted. **null** but not **invalid** values are permitted as keys and values.

The new **collectBy** iteration may be used to construct a map from a collection or map. The iterators of the **collectBy** define the keys and the value of the body of defines the values. For instance **Sequence{1..10}->collectBy(i | i+i)}** builds a map from the values 1 to 10 to the even values 2 to 20.

Most standard collection iteration operations are available for Maps using the map keys as the (primary) iterator. A secondary value iterator may be specified using the new binds-to syntax. Thus **Map{1<-1,2<-4,3<-9}->reject(k<-v | k = 2 or v = 9)}** defines a reject iteration over the three entry map, with a primary iterator **k** over the set of keys and a secondary co-iterator **v** over the values bound to each key. The body causes the second entry with key 2, and the third entry with value 9 to be rejected leaving just a one entry map.

4.8.10.1. Details

The OCL metamodel is extended by a MapLiteralExp and MapType. A new abstract IterableType captures the iterable commonality of CollectionType and MapType without making map a collection.

The OCL standard library defines the new Map operations and the new Collection::collectBy iteration.

The OCL syntax is extended by the MapLiteralExp syntax and the binds-to co-iterator syntax for all iterators.

The OCL run-time is extended by a MapValue and an abstract IteravleValue to capture the commonality with CollectionValue.

4.9. Installing the Eclipse OCL Examples and Editors

These instructions have been updated for Eclipse Mars; Eclipse 4.5, EMF 2.11, OCL 6.0.

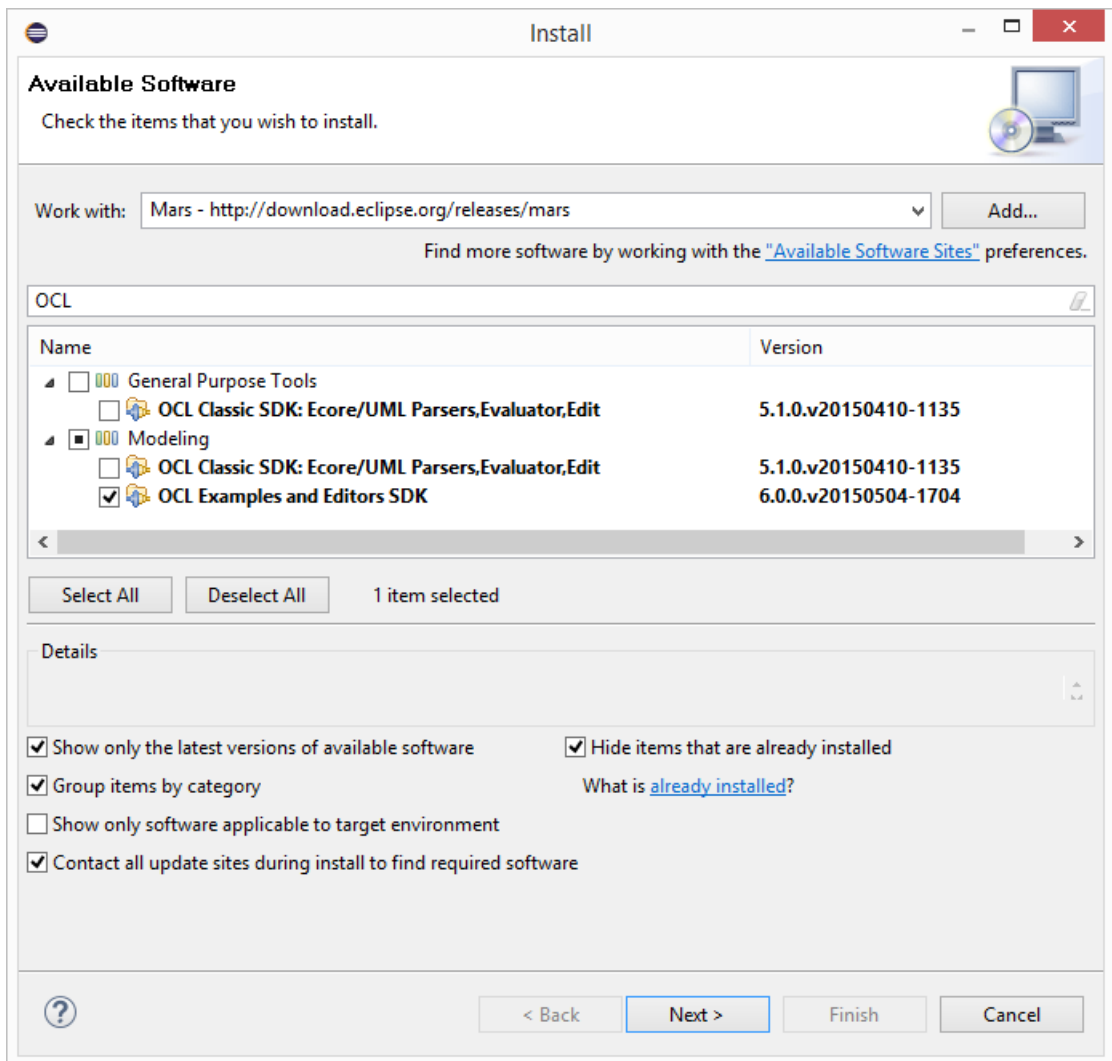
- Some screenshots may be slightly out of date.

The OCL User Interface (console, editors, debugger and validity view) is not part of the core OCL functionality included in the Eclipse Modeling Tools Package, so although you may have OCL installed and be able to read this tutorial via the **Help->Help Contents->OCL Documentation**, you may not have the OCL examples installed.

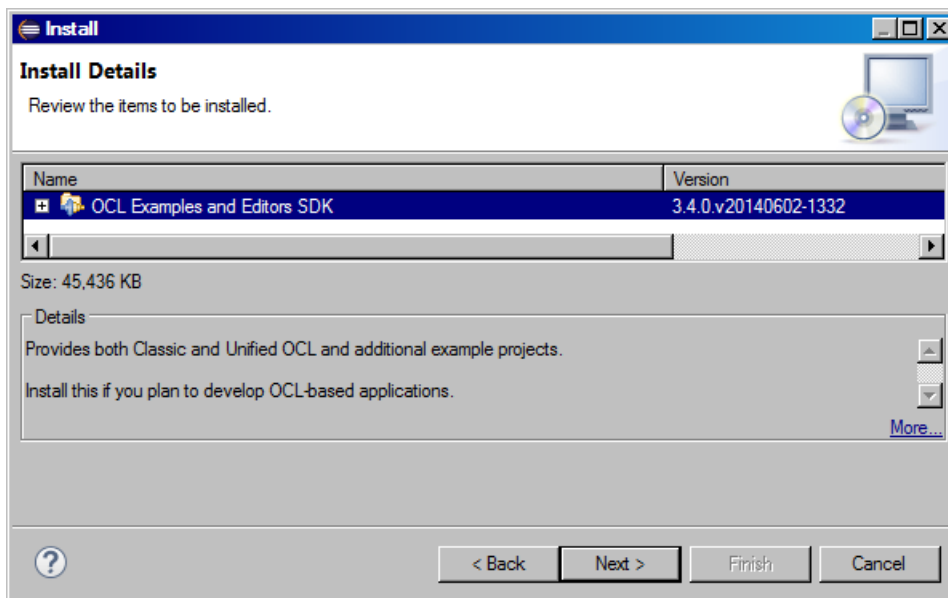
An easy way to test whether you have the OCL Examples installed is to right click on a *.ecore file and see whether **OCLinEcore Editor** appears in the **Open With** submenu.

If OCL is not installed at all, or if just the examples are not installed, the following installation step will automatically install the OCL Examples and all required projects such as **EMF**, **UML2**, **MWE2**, **Xpand** and **Xtext**.

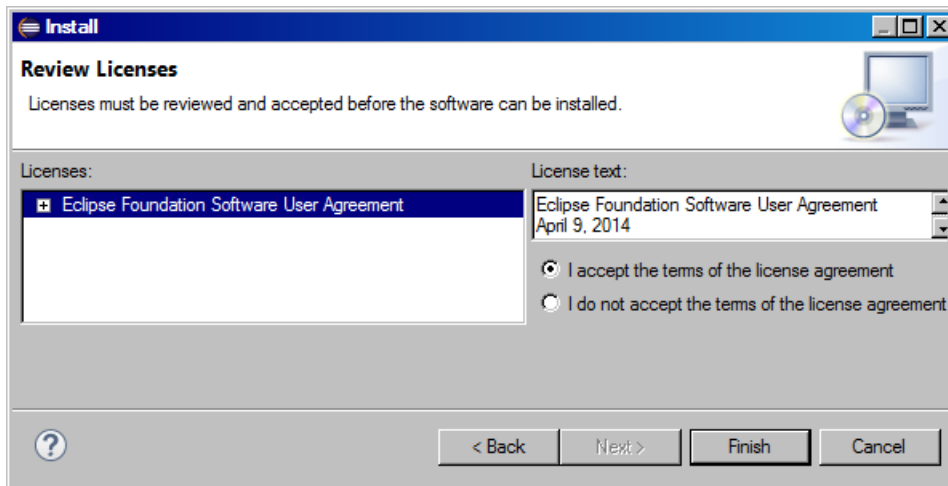
Left-click on **Help** in the Eclipse menu-bar then left-click on **Install New Software...** and select the **Luna** – <http://download.eclipse.org/releases/luna> update site from the pull-down menu to **Work with** and be patient while the available updates are identified. Then type **OCL** in the filter text, click on the expand item preceding the **Modeling** category and then check **OCL Examples and Editors SDK**.



Select **Next**.



Select **Next** again and read the license agreement. Set to accept it.



Select **Finish** and be patient while the software is downloaded and installed. Select **Restart Now** when prompted to do so.

4.9.1. Troubleshooting

Eclipse Modeling Projects have a large number of classes and so require a large amount of PermGen space on a Sun JVM. If you are using default Eclipse startup settings you are liable to encounter `OutOfMemoryExceptions`. Therefore follow the advice in [How do I start Eclipse](#) and set `XX:PermSize` to at least 64M, either on your Eclipse command line, or your Eclipse shortcut or in the **eclipse.ini** adjacent to **eclipse.exe**. If you are using a 64 bit machine or plan to use graphical modeling tools such as Papyrus or Sirius, 128M is almost certainly necessary.

Chapter 5. Examples

5.1. Royal and Loyal Example Project

The RoyalAndLoyal example project provides a substantial example of a Complete OCL document complementing an independent Ecore meta-model.

This is the standard example used in many OCL texts and courses. It was first produced as part of the *The Object Constraint Language Second Edition* by Jos Warmer and Anneke Kleppe.

This example may be used to explore a wide variety of OCL syntaxes and their presentation in the Complete OCL editor.

You may install the example by selecting **Example...** from the **New** menu, then selecting **Royal and Loyal Example** under the **OCL (Object Constraint Language) plugins**.

Open **RoyalAndLoyal.ecore** with the OCLinEcore editor to explore the Ecore metamodel. Note how the Outline can be alphabeticized and so provide a useful overview. The outline very similar to the conventional Sample Ecore Editor tree view.

Open **RoyalAndLoyal.ocl** with the CompleteOCL editor to explore the OCL. Note how the full AST can be explored in the Outline.

5.2. Empty Example Project

The Empty example project creates an empty project with a Java class path set up to assist in the use of OCL.

This assistance is not really necessary now that the editors are based on Xtext and now that an XMI representation is not automatically saved in a **bin** directory.

The OCL editors can be used wherever Ecore editors can be used.

It is not necessary for a project to have a Java nature.

It is not necessary for a project to have an Xtext nature. If you add an Xtext nature, your OCL files will be built automatically when other files in the project or its dependencies change. This can significantly clutter the Problems View if you have problems with your OCL, and may significantly increase build times.

5.3. OCLinEcore Tutorial Example Project

The OCLinEcore Tutorial project provides the conclusion of the [OCLinEcore Tutorial](#) and the material for the [Getting Started](#) quick introduction.

The project provides an example of OCL embedded in Ecore that is also used by the [Code Generation Tutorial](#) and [Debugger tutorial](#).

5.4. Complete OCL Tutorial Example Project

The Complete OCL Tutorial project provides examples for the [Complete OCL Tutorial](#).

The project provides examples Complete OCL documents that complement Ecore, UML, Xtext and XMI.

5.5. OCL Interpreter Example

5.5.1. Introduction

This example illustrates the usage of the generic OCL Parser API to parse and evaluate OCL query expressions and constraints within the SDK. It demonstrates how to author OCL expressions and evaluate them against elements of library model instances, or against Ecore and UML elements. For Ecore and UML models, a further option of parsing (not evaluating) model-level (M1 in the OMG modeling stack) constraints is available.

5.5.2. References

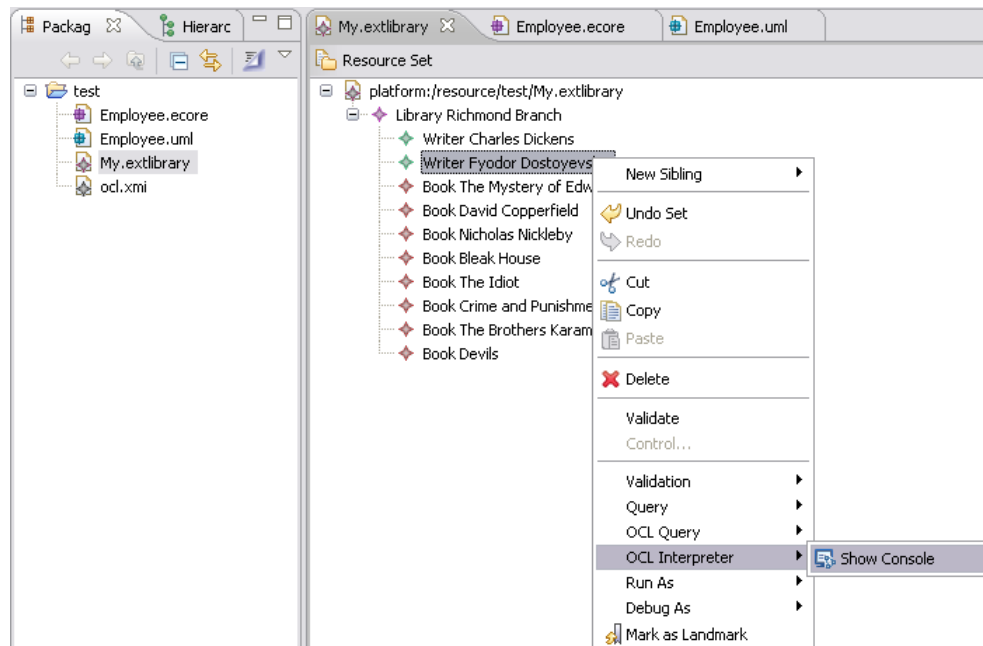
Please refer to the document [Object Constraint Language Examples Overview](#) for reviewing the library meta-model used as the basis for demonstrating the capabilities in this example.

5.5.3. Description

This example plug-in is named `org.eclipse.emf.ocl.examples.interpreter`. This plug-in contributes the OCL Interpreter menu to the library editor's main menu and context menu. The menu has one item:

- Show Console: Opens the interactive OCL console.

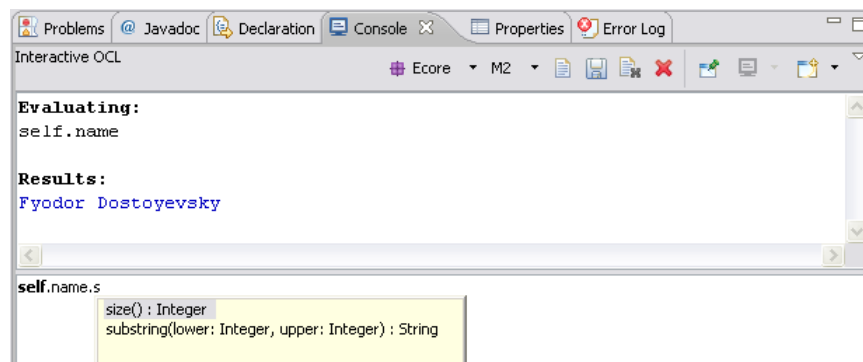
Please refer to the tutorial [OCL Interpreter Tutorial](#) for reviewing the code samples within this example.



The bottom field in the console accepts OCL expressions (comments supported). You can press **Enter** to evaluate on the currently selected element. You can press **Ctrl+Enter** or **Shift+Enter** to insert a newline. The top field shows the output and errors. The console can be cleared by the **Eraser** button and closed by the **X** button.

Because the EXTLibrary model is based on the Ecore metamodel, ensure that the Ecore metamodel is selected in the console's tool bar. Also ensure that the M2 modeling level is selected, as EXTLibrary is not a metamodel, so instances of it are not models. Thus, the OCL expressions that we create will target the Ecore meta-model, as the model of the EXTLibrary model.

Content-assist is automatically activated on typing any of " .", " ->", " ::", and " ^". Also, Ctrl+Space can be used to invoke content-assist at any time.



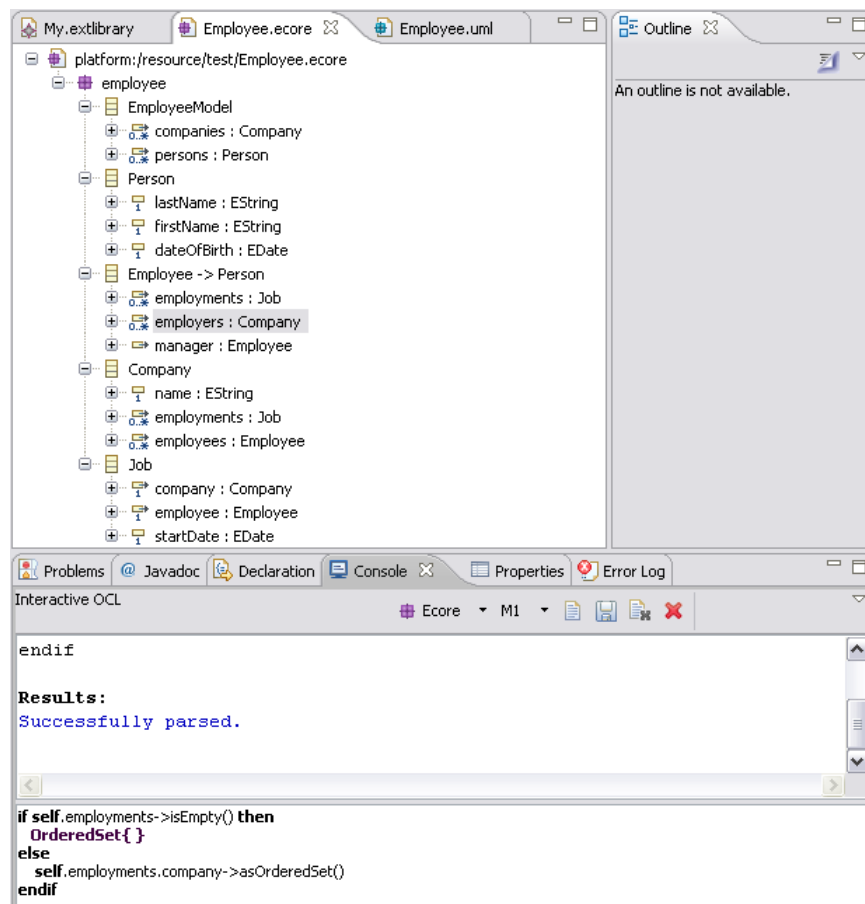
5.5.4. Support for Ecore and UML Models

The OCL Console contributes an **OCL->Show OCL Console** menu action to the Ecore and UML editors (for *.ecore and *.uml models). These actions automatically select the appropriate metamodel in the console.

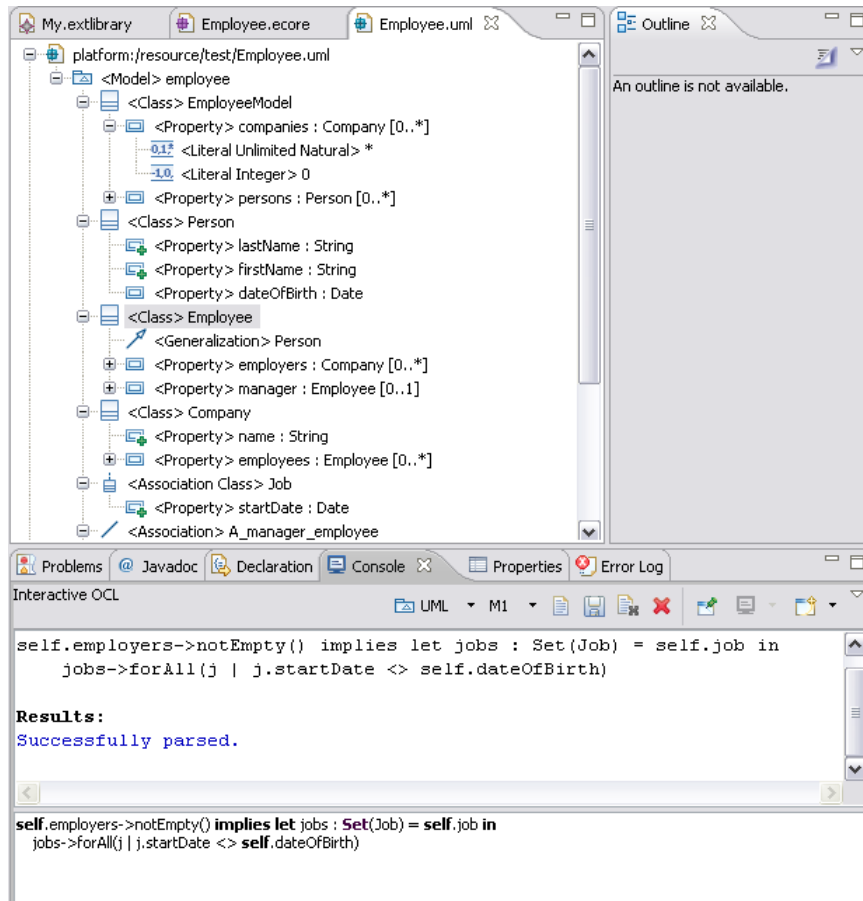
For both Ecore and UML, parsing constraints at the M1 (model) level is supported. This implements a scratch pad for developing OCL constraints in the context of:

- classifiers, for invariant constraints
- operations, for pre/post condition constraints and body expressions
- attributes, for initial-value and derivation constraints

The console infers the kind of constraint from the selected element; in the case of an operation, it assumes a post-condition constraint as these constraints support a superset of the syntax for pre-conditions and body expressions.



The figure above shows the parsing of a derivation constraint on an Ecore property (an EStructuralFeature).



The figure above shows the parsing of an invariant constraint on a UML classifier (a Class). Note that UML can model the Job as an association class; a roughly equivalent Ecore model is more verbose.

5.5.5. Example Code

Refer to the code in this example if you need to:

- parse, validate and evaluate OCL queries and constraints on EMF model elements
- implement content-assist for OCL constraints in your model editor

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Chapter 6. Classic Ecore/UML Programmers Guide

The Ecore/UML Programmers Guide describes the ways in which the Ecore or UML bindings of Eclipse OCL can be used from Java programs.

The Ecore binding has been available since Eclipse OCL 1.0.0 (Callisto). The UML binding was added in 1.1.0 (Europa). Both will remain for as long as necessary. Examples quality prototypes of the new UML-aligned Pivot binding were first available in 3.1.0 (Indigo). The Pivot binding became the preferred binding in 6.0.0 (Mars). The Pivot binding is described in a separate [Pivot Programmers Guide](#).

The OCL Parser/Interpreter provides an implementation of the [Object Constraint Language 2.4](#) specification for EMF-based metamodels and models. It offers OCL constraint and query parsing and evaluation, model-based validation, and provides an infrastructure for content assist in textual editors.

The following features are supported in the current version:

- Classifier invariant constraints
- Operation precondition and postcondition constraints and body conditions
- Property constraints (initial-value and derivation)
- Attribute and operation definitions (def: expressions)
- Package context declaration
- Basic values and types
- Collection types
- Navigation of attributes and association ends
- Operation invocation
- Iteration expressions (all standard iterators)
- Let expressions
- If expressions
- Tuples
- Message expressions, including unspecified values
- Operations predefined by OCL: `allInstances()`, `oclIsKindOf()`, `oclIsTypeOf()`, `oclAsType()`, `oclIsNew()`
- Escape syntax for illegal names: type, operation, attribute, etc. names that correspond to OCL reserved words can be escaped in the standard fashion using a leading underscore ('_'). In addition, names that contain spaces or tabs can be escaped by enclosing them in double-quotes (""); this is non-standard). e.g., `self.ownedRule->forAll(c : Constraint | c._context = self)`

The above constructs are supported by the parser for parsing and for evaluation, with the exception of the `oclIsNew()` operation and message expressions. All of the above are supported for both Ecore and UML models. The following are supported by default for UML (both in parsing and evaluation):

- Navigation of non-navigable association ends (including those that are owned by the association)
- Qualified association end navigation
- Navigation to association classes, including source qualifiers
- Operations predefined by OCL: `oclIsInState()`

The following features are provided in addition to the OCL specification:

- String case conversion operations: `toUpper()`, `toLower()`
- Support for comparison (<, <=, etc.) and sorting of any java `Comparable`s of conformant types
- Transitive closure of associations: `closure(expr : OCLExpression)` iterator
- Navigation of “hidden” opposites of references specified in Ecore models using a `Property.oppositeRoleName` annotation with source <http://schema.omg.org/spec/>

MOF/2.0/emof.xml on the forward reference, producing an `OppositePropertyCallExp` expression

The OCL implementation is defined in plug-ins for convenient deployment in Eclipse, but as is the case for EMF, it can also be used stand-alone. The plug-ins are partitioned thus:

- `org.eclipse.oc1`: the core parsing, evaluation, and content assist services. Definition of the OCL Abstract Syntax Model and Environment API. These APIs are generic, independent of any particular metamodel (though using Ecore/EMF as the meta-meta-model).
- `org.eclipse.oc1.ecore`: implementation of the Ecore metamodel environment, binding the generic Environment and AST APIs to the Ecore language. Provides support for working with OCL constraints and queries targeting Ecore models.
- `org.eclipse.oc1.uml`: implementation of the UML metamodel environment, binding the generic Environment and AST APIs to the UML language. Provides support for working with OCL targeting UML models.

Please refer to the [OCL Interpreter Tutorial](#) for review of the code samples.

6.1. Parsing Constraints and Queries

The OCL parser provides two APIs for parsing constraint and query expressions. The [OCLHelper](#) interface is designed primarily for parsing constraints and query expressions embedded in models, such as Ecore or UML models. The [OCL](#) class serves as the main entrypoint into the parsing API but also implements the parsing of [OCL documents](#), for example from text files. In both cases, the concept of `Environment` is crucial.

6.1.1. The OCL Environment

The following diagram shows the core of the `Environment` API, that clients of the OCL parser interact with:



The [OCL](#) class is a generic type; its type parameters represent the various metaclasses of the metamodels that OCL works with in the UML/MOF family of OMG specifications. For example, `<C>` represents the Classifier concept, `<O>` the Operation concept, etc. See the discussion of [metamodels supported by OCL](#) for details of the mappings. The same type parameter names are used consistently throughout the OCL APIs to represent the same metaclasses.

The OCL class defines instances of autonomous OCL parsing and evaluation environments. It has a single root [Environment](#) created by an [EnvironmentFactory](#) implementation for a particular EMF-based metamodel. The OCL environment consists, conceptually, of the model that is to be constrained together with all of the constraints and additional operations and attributes defined (via OCL) for the purpose of formulating constraints.

Environment s nest. Usually the root environment has no correlation to an element in the model, or it may correspond to some `Package` providing a default namespace (called a package context).

Alternatively, it may contain one or more nested environments defining package namespaces. A package context contains one or more classifier contexts, which in turn can contain operation and/or attribute contexts. Whereas the purpose of a package context is primarily to assist in the look-up of named model elements, the classifier, operation, and attribute contexts have deeper meaning.

A classifier context defines the type of the `self` variable in OCL constraints and queries. By itself, it is the context for invariant constraints for the context classifier. Additionally, as the parent context for operation and attribute constraints, it indicates the classifier in which context an operation or attribute constraint applies; this may be the classifier that defines these features, or it may inherit them from some more general classifier.

An Environment may contain named [Variable](#)s to which OCL expressions can refer. The most common of these is `self`. Others include the parameters defined by an operation (and its `result`), in the case of an operation context. The OCL API even allows clients to add variables, in code, to define “global” names.

6.1.2. Creating an OCL Environment

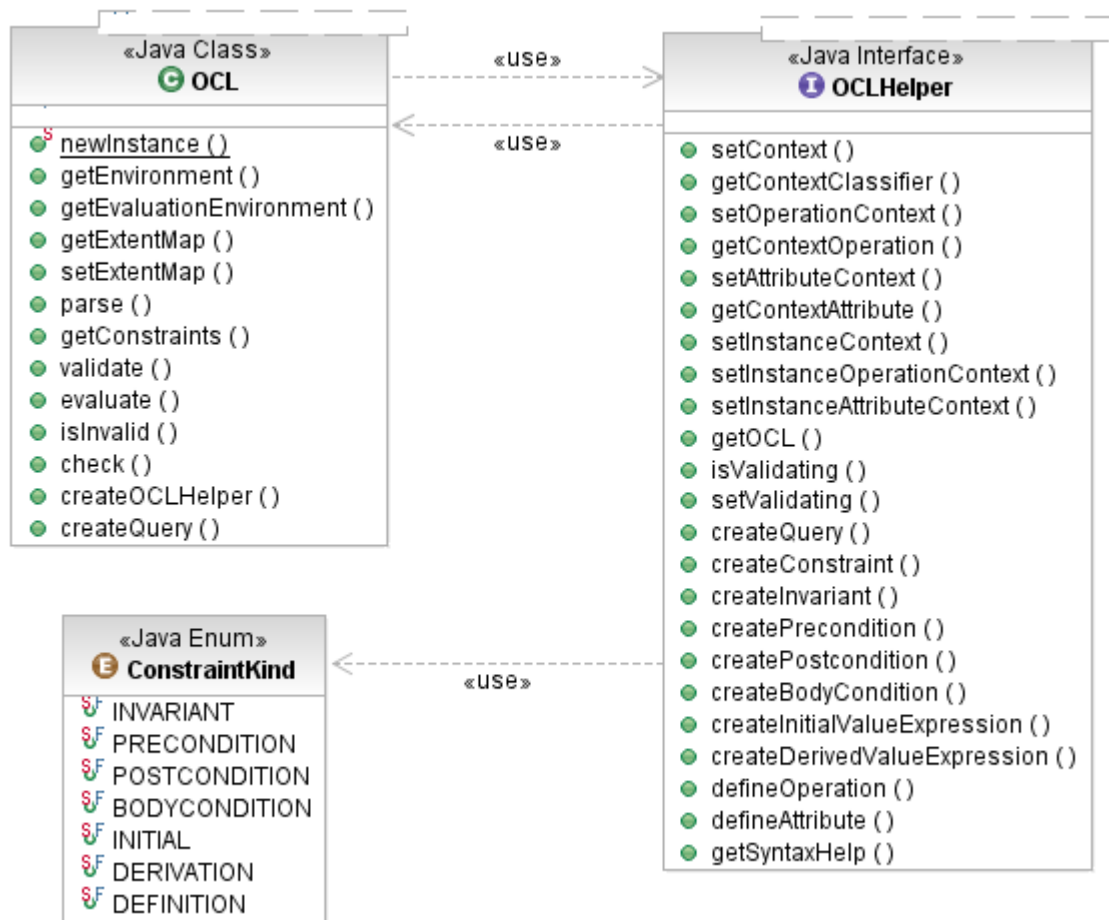
The static factory methods on the OCL class are used to create instances. It is a good practice to re-use the same OCL instance for all parsing and evaluation of constraints and queries on a model while that model is loaded (usually in some `ResourceSet` in an editor). Using the shared environment factory for the Ecore [metamodel](#), we can create an OCL environment suitable for parsing OCL constraints on any Ecore model and evaluating them on instances of the model:

```
// create an OCL instance for Ecore
OCL ocl = OCL.newInstance(EcoreEnvironmentFactory.INSTANCE);
[Text for cut and paste]
```

Several of the type parameters in the OCL generic type signature are useful mostly within the OCL API. We leave them, here, as wildcards.

6.1.3. The OCL Helper

From an OCL instance, we can create a helper object with which to parse constraints and additional operation/attribute definitions. This [OCLHelper](#) stores all of the instantiations of OCL template metaclasses (such as [CollectionType\(T\)](#) and [TupleType](#) and additional operation/attribute definitions in the root environment of the OCL that created it. This ensures that all of these constructs are available for reuse in subsequent parsing.



The OCLHelper is primarily designed for parsing constraints and query expressions embedded in models, providing the following API for that purpose:

- `createQuery()`: parses a query expression
- `createConstraint()`: parses a constraint of a given `ConstraintKind`
- `createInvariant()`: convenience for invariant constraints
- `createPrecondition()`: convenience for pre-condition constraints
- `createPostcondition()`: convenience for post-condition constraints
- `createBodyCondition()`: convenience for body conditions
- `createInitialValueExpression()`: convenience for attribute initial values
- `createDerivedValueExpression()`: convenience for attribute derived values
- `defineOperation()`: convenience for additional operation definitions
- `defineAttribute()`: convenience for additional attribute definitions

Different kinds of constraints require different context environments. The `setContext()`, `setOperationContext()`, and `setAttributeContext()` methods create the appropriate nested `Environment@s` in the host `@OCL` instance's root environment.

The result of parsing a query expression is an [OCLExpression](#), an instance of the [Abstract Syntax Model](#). The result of parsing a constraint is an instance of the `Constraint` metaclass defined by the OCL's [target metamodel](#).

```
// create an OCL helper object
OCLHelper<EClassifier, EOperation, EStructuralFeature, Constraint> helper =
    ocl.createOCLHelper();

// set the OCL context classifier
helper.setContext(EXTLibraryPackage.Literals.LIBRARY);

Constraint invariant = helper.createInvariant(
    "books->forAll(b1, b2 | b1 <> b2 implies b1.title <> b2.title)");

OCLExpression<EClassifier> query = helper.createQuery(
    "books->collect(b : Book | b.category)->asSet()");
\[Text for cut and paste\]
```

Ecore does not define a Constraint metaclass, so the OCL [binding](#) for Ecore supplies one.

6.1.4. Operation and Attribute Contexts

In the case of constraints on operations or attributes, the context consists of two elements: the constrained operation/attribute and a classifier in the context of which the constraint is to apply. This accounts for the possibility that a classifier defines constraints on inherited features. As an example, consider the `EModelElement::getEAnnotation(EString)` operation and `EReference::eReferenceType` property in the Ecore metamodel. These can be constrained as follows:

```
EOperation oper = null;
for (EOperation next : EcorePackage.Literals.EMODEL_ELEMENT.getEOperations()) {
    if ("getEAnnotation".equals(next.getName())) {
        oper = next;
        break;
    }
}

// define a post-condition specifying the value of EModelElement::getEAnnotation(EString)
// This operation environment includes variables representing the operation
// parameters (in this case, only "source : String") and the operation result
helper.setOperationContext(EcorePackage.Literals.ECLASS, oper);
Constraint body = helper.createPostcondition(
    "result = self.eAnnotations->any(ann | ann.source = source)");

// define a derivation constraint for the EReference::eReferenceType property
helper.setAttributeContext(
    EcorePackage.Literals.EREFERENCE,
    EcorePackage.Literals.EREFERENCE__REFERENCE_TYPE);
Constraint derive = helper.createDerivedValueExpression(
    "self.eType->any(true).oclAsType(EClass)");
\[Text for cut and paste\]
```

6.2. Evaluating Constraints and Queries

In [Parsing Constraints](#), we saw how to use the `OCLHelper` API for parsing OCL constraints and query expressions. Parsing constraints is very interesting in itself, but we can also make OCL come alive in our applications by evaluating these constraints. For this, OCL provides a `Query` API.

6.2.1. The OCL Query

Like the `OCLHelper` for parsing constraints, the OCL facade object provides [Query](#) objects for evaluating constraints and query expressions.



The Query encapsulates an [EvaluationEnvironment](#) providing the run-time values of context variables to the OCL interpreter. These context variables are set and retrieved using the following methods:

- `add(String, Object)`: adds a name-value binding for a variable
- `replace(String, Object)`: replaces an existing variable binding
- `remove()`: removes a variable binding
- `getValueOf(String)`: obtains a variable value

The context variables of primary interest are `self` and, in operation constraints, the variables corresponding to its parameters. The `EvaluationEnvironment` API is also used to supply values for “global” variables added to the parsing Environment by the client.

Another important consideration in the evaluation environment is the `allInstances()` operation, which obtains the entire extent of a classifier. For data types, this is a simple problem: the extent of an `Enumeration` is well defined and the extents of other kinds of `DataType`s are undefined. For `Class` extents, the `EvaluationEnvironment` provides support for an extent map, mapping classes to the sets of their instances, as determined by the client. A client sets the extent map using the [OCL.setExtentMap\(\)](#) method. The default extent map, if none is provided by the client, lazily computes the extent of a class from the `EMFResource` containing the context element of the evaluation. An alternative extent map can be found in [org.eclipse.oclecore.opposites.ExtentMap](#).

So, after optionally setting values of context variables (other than `self`; the Query takes care of this) and an extent map, simply construct a query and use it to evaluate the expression or check the constraint:

```
OCL ocl = OCL.newInstance(EcoreEnvironmentFactory.INSTANCE);
OCLHelper<EClassifier, ?, ?, Constraint> helper = ocl.createOCLHelper();

helper.setContext(EXTLibraryPackage.Literals.LIBRARY);
Constraint invariant = helper.createInvariant(
    "books->forAll(b1, b2 | b1 <> b2 implies b1.title <> b2.title)");
OCLExpression<EClassifier> query = helper.createQuery(
    "books->collect(b : Book | b.category)->asSet()");

// create a Query to evaluate our query expression
Query queryEval = ocl.createQuery(query);

// create another to check our constraint
Query constraintEval = ocl.createQuery(invariant);

List<Library> libraries = getLibraries(); // hypothetical source of libraries

// only print the set of book categories for valid libraries
for (Library next : libraries) {
    if (constraintEval.check(next)) {
        // the OCL result type of our query expression is Set(BookCategory)
        @SuppressWarnings("unchecked")
        Set<BookCategory> categories = (Set<BookCategory>) queryEval.evaluate(next);

        System.out.printf("%s: %s\n", next.getName(), categories);
    }
}
```

[\[Text for cut and paste\]](#)

One of the advantages of the Query API is that a query's evaluation environment can be reused for multiple evaluations, as above. The extent of any classifier is only computed once. For convenience, however, in situations where only a single evaluation is required, the OCL class provides shortcuts:

```
// check a single library
Library lib = getLibrary(); // hypothetical source of a library

// check whether it satisfies the constraint
System.out.printf("%s valid: %b", lib.getName(), ocl.check(lib, invariant));
```

[\[Text for cut and paste\]](#)

The Query API also provides methods that work on multiple elements. The first example, above, could be written more succinctly as:

```
// only print the set of book categories for valid libraries
for (Library next : constraintEval.select(libraries)) {
    @SuppressWarnings("unchecked")
    Set<BookCategory> categories = (Set<BookCategory>) queryEval.evaluate(next);

    System.out.printf("%s: %s\n", next.getName(), categories);
}
```

[\[Text for cut and paste\]](#)

6.3. Parsing OCL Documents

As we saw in the [Parsing Constraints and Queries](#) topic, the OCL parser provides an [OCLHelper](#) API for parsing constraints embedded in models. OCL also permits constraints to be specified in a text document, as an adjunct to the model. In this case, the concrete syntax for context declarations indicates the context of constraints, equivalent to their placement in models.

As an example, consider the following Complete OCL document: "

```
import 'platform:/resource/org.eclipse.emf.examples.library/model/extlibrary.ecore'

package extlibrary

context Library
-- get all books with a title in a library and its branches (recursively)
def: getBooks(title : String) : Set(Book) =
    books->select(b | b.title = title)->asSet()->union(
        branches.getBooks(title)->asSet())

context Book
-- the library containing a book
def: library : Library = Library.allInstances()->any(books->includes(self))

-- book titles are unique within their library branch (and its sub-branches)
inv unique_title: not library.oclIsUndefined() implies
    library.getBooks(title) = Set{self}

endpackage
```

[\[Text for cut and paste\]](#)

The *import* on the first line is an extension supported by the Complete OCL editor for use with the Pivot meta-model. The *import* is ignored by the parsers for the Ecore or UML bindings, which assume that the relevant metamodels have been registered in either the global EPackage.Registry or the local EPackage.Registry passed to the EnvironmentFactory..

6.3.1. The OCL Input

The [OCLInput](#) class encapsulates an OCL document. An input can be created from a string or an input stream.



Given an OCLInput, simply ask an OCL to parse it: "


```
EPackage.Registry registry = new EPackageRegistryImpl();
registry.put(EXTLibraryPackage.eNS_URI, EXTLibraryPackage.eINSTANCE);
EcoreEnvironmentFactory environmentFactory = new EcoreEnvironmentFactory(registry);
OCL ocl = OCL.newInstance(environmentFactory);

// get an OCL text file via some hypothetical API
InputStream in = getInputStream("/model/parsingDocumentsExample.ocl");

Map<String, Constraint> constraintMap = new HashMap<String, Constraint>();

// parse the contents as an OCL document
try {
    OCLInput document = new OCLInput(in);

    List<Constraint> constraints = ocl.parse(document);
    for (Constraint next : constraints) {
        constraintMap.put(next.getName(), next);

        OCLExpression<EClassifier> body = next.getSpecification().getBodyExpression();
        System.out.printf("%s: %s\n", next.getName(), body);
    }
} finally {
    in.close();
}
```

[\[Text for cut and paste\]](#)

6.3.2. Accessing the Constraints

The OCL returns the list of constraints if they were successfully parsed. They are retained by the OCL (available via the `getConstraints()` method at any time), and in particular, any definitions of additional operations or attributes are available for subsequent constraint parsing. Any number of OCL documents may be parsed by the same OCL instance, combined also with constraints parsed by OCLHelpers. All of these constraints are retained by the OCL environment.

```
Library library = getLibrary(); // get library from a hypothetical source
```

```
OCLHelper<EClassifier, ?, ?, Constraint> helper = ocl.createOCLHelper();
```

```
// use the constraints defined in the OCL document
```

```
// use the getBooks() additional operation to find a book
helper.setContext(EXTLibraryPackage.Literals.LIBRARY);
OCLExpression<EClassifier> query = helper.createQuery(
    "getBooks('Bleak House')->asSequence()->first()");
```

```
Book book = (Book) ocl.evaluate(library, query);
System.out.printf("Got book: %s\n", book);
```

```
// use the unique_title constraint to validate the book
System.out.printf("Validate book: %b\n",
    ocl.check(book, constraintMap.get("unique_title")));
```

[\[Text for cut and paste\]](#)

The source for these examples may be found in the `org.eclipse.oclecore.tests` plugin in `model/parsingDocumentsExample.ocl` and in `src/org/eclipse/ocl/ecore/tests/DocumentationExamples.java`.

6.4. OCL Relationship to Metamodels

The OCL implementation provides support for models defined using either the Ecore or the UML metamodel (as implemented by the Eclipse EMF and UML2 projects), and an [extensibility API](#) that allows additional EMF-based metamodels to be plugged in.

The direct and indirect coupling of the Ecore and UML2 meta-models to Ecore makes exact compliance with the OMG specification very difficult, particularly in the area of reflection. Eclipse OCL is therefore migrating to a new potentially 100% OMG compliant Pivot metamodel that hides the differences between OMG's UML and

EMOF and Eclipse's UML and Ecore. The Pivot binding is described in the [Pivot Programmers Guide](#).

The OCL API implements support for different target metamodels via the [EnvironmentFactory](#) interface. An implementation of this interface binds the metamodel's metaclasses to the generic type parameters of the [OCL](#) class. The metamodel-specific [Environment](#) implementation constructed by this factory implements the reflection capability required by OCL to discover the elements of the model being constrained and the relationships between them.

6.4.1. The Ecore Metamodel Binding

An OCL binding for the Ecore metamodel is provided by the `org.eclipse.ocl.ecore` plug-in. It is best suited to parsing and evaluating OCL constraints on Ecore models. Evaluation of constraints is supported on instances of the EMF-generated Java API (Ecore as the source for the genmodel) and on dynamic EObjects.

As is illustrated by most of the examples in this documentation, the Ecore binding is provided by the [EcoreEnvironmentFactory](#) class. By default, the Ecore environment uses the static `EPackage` registry to look up package names. It can also be supplied with an alternative package registry (for example, one local to a `ResourceSet`) but it will always use the static registry as a backup. Aside from the package registry, the Ecore environment factory maintains no state. So, when the shared registry is to be used, the static `EcoreEnvironmentFactory.INSTANCE` is most practical.

The Ecore binding for OCL provides the following capabilities, reflecting the subset of Ecore's modeling constructs with respect to UML:

Capability	Parse	Evaluate
Classifier invariant constraints	Y	Y
Operation precondition and postcondition constraints and body conditions	Y	N
Property constraints (initial-value and derivation)	Y	Y*
Attribute and operation definitions (def: expressions)	Y	Y
Package context declaration	Y	n/a
Basic values and types, mapped from the standard EDataTypes to OCL's primitive types	Y	Y
Collection types	Y	Y
Navigation of attributes and references	Y	Y
Operation invocation	Y	Y
Iteration expressions (all standard iterators)	Y	Y
Let expressions	Y	Y
If expressions	Y	Y
Tuples	Y	Y
Message expressions, including unspecified values	Y	N
Operations predefined by OCL: <code>allInstances()</code>	Y	Y
Operations predefined by OCL: <code>oclIsKindOf()</code> , <code>oclIsTypeOf()</code> , <code>oclAsType()</code>	Y	Y

Operations predefined by OCL: Y oclIsNew()	N
@pre expressions Y	N
* derivation only	

Ecore metamodel capability matrix

Because Ecore does not define analogues of some of the UML metaclasses required by the OCL Abstract Syntax Model, the Ecore binding defines these on its behalf, in the `platform:/plugin/org.eclipse.oclc.ecore/model/OCLEcore.ecore` metamodel. These include:

- `Constraint`: the model of an OCL constraint (when the language is OCL)
- `CallOperationAction`: used in the model of message expressions
- `SendSignalAction`: used in the model of message expressions
- `ExpressionInOCL`: it is this metaclass's general class `OpaqueExpression` that Ecore does not define. It is elided in the Ecore binding
- `State`: Ecore provides no behavior modeling capabilities. The Ecore binding simply substitutes `EObject`

For applications that work exclusively with the Ecore binding for OCL, the `org.eclipse.oclc.ecore` package defines a subclass of the OCL class that supplies all of the generic type parameter bindings to simplify typing (in the absence of type aliasing in Java). It also provides Ecore-specific convenience factory methods for the OCL, itself, and narrows the return type of the factory methods for the `OCLHelper` and `Query` interfaces. These specialized interfaces likewise supply the generic type parameter bindings for Ecore.

6.4.2. The UML Metamodel Binding

An OCL binding for the UML metamodel is provided by the `org.eclipse.oclc.uml` plug-in. It is best suited to parsing and evaluating OCL constraints on UML models. Evaluation of constraints is supported on instances of the UML2-generated Java API (UML as the source for the `genmodel`), on dynamic `EObjects` (using an Ecore model created by the UML-to-Ecore converter), and on `InstanceSpecification` elements in the UML model.

The UML binding is provided by the [UMLEnvironmentFactory](#) class. By default, the UML environment factory and all of the environment contexts that it creates use a private `ResourceSet` to look up the corresponding UML model(s) against which OCL constraints are parsed.

- It is the client's responsibility to ensure that the UML model is loaded in the resource set used by the UML environment factory instance.

The UML environment factory can alternatively be initialized with a resource set of the client's choosing. Ordinarily, the UML environment uses its resource set's local `EPackage` registry to look up EMF-generated `EPackage` names corresponding to UML models. A custom package registry may be provided by the client if necessary.

The UML binding for OCL provides the following capabilities:

Capability	Parse	Evaluate
Classifier invariant constraints	Y	Y
Operation precondition and Y postcondition constraints and body conditions	Y	N
Property constraints (initial-value Y and derivation)	Y	Y*
Attribute and operation Y definitions (def: expressions)	Y	Y
Package context declaration	Y	n/a
Basic values and types	Y	Y+

Collection types	Y	Y
Operation invocation	Y	Y-
Navigation of attributes and references	Y	Y
Navigation of non-navigable association ends (including those that are owned by the association)	Y	Y
Qualified association end navigation	Y	Y=
Navigation to association classes, including source qualifiers	Y	Y=
Iteration expressions (all standard iterators)	Y	Y
Let expressions	Y	Y
If expressions	Y	Y
Tuples	Y	Y
Message expressions, including unspecified values	Y	N
Operations predefined by OCL: <code>allInstances()</code>	Y	Y
Operations predefined by OCL: <code>oclIsKindOf()</code> , <code>oclIsTypeOf()</code> , <code>oclAsType()</code>	Y	Y
Operations predefined by OCL: <code>oclIsInState()</code>	Y	N
Operations predefined by OCL: <code>oclIsNew()</code>	Y	N
@pre expressions	Y	N
* derivation only		
+ OCL defines the Real primitive type that is missing from UML, but not a LiteralReal		
- with InstanceSpecifications, only where body constraints are defined		
= only with InstanceSpecifications		

UML metamodel capability matrix

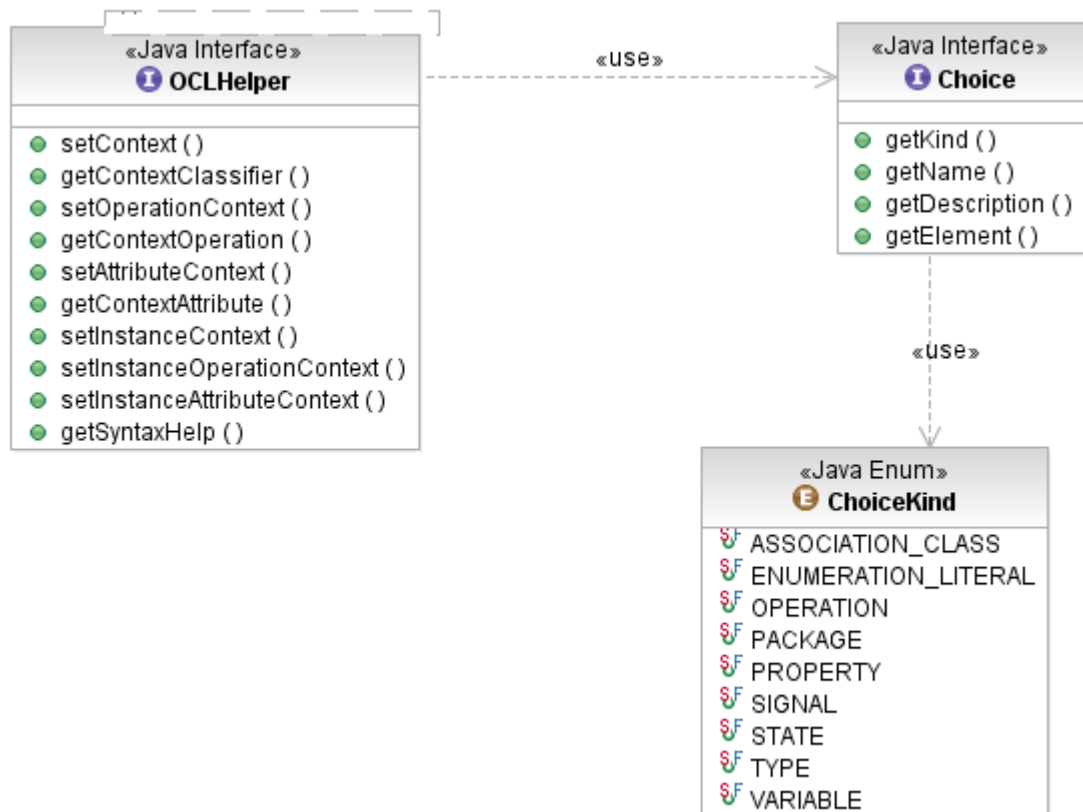
A special case of the UML environment's support for dynamic EObjects, mentioned above, is stereotype applications. The Eclipse UML2 component uses dynamic EMF in the implementation of stereotype applications, by converting UML Profiles to EPackage s. Constraints parsed in the context of a UML Stereotype can be evaluated on applications (instances) of that stereotype or on model elements to which the stereotype is applied. This applies only to UML models, themselves, as instances of the UML metamodel (stereotyping is only available in the UML metamodel).

For applications that work exclusively with the UML binding for OCL, the `org.eclipse.oc1.uml` package defines a subclass of the OCL class that supplies all of the generic type parameter bindings to simplify typing (in the absence of type aliasing in Java). It also provides UML-specific convenience factory methods for the OCL, itself, and narrows the return type of the factory methods for the OCLHelper and Query interfaces. These specialized interfaces likewise supply the generic type parameter bindings for UML.

6.5. Content Assist Support

The Content Assist facilities described here are used by the Interactive OCL Console. They are not used by the new Xtext-based Editors or the Interactive Xtext OCL Console.

The [OCLHelper](#) API provides support for content-assist in rich editors, by parsing partial OCL expressions and supplying completion suggestions. The `List<Choice> getSyntaxHelp(ConstraintKind, String)` operation returns a list of suggestions for the next token to follow the end of the expression fragment.



The [Choice](#) objects returned by the helper include some convenient text strings (name and description) to formulate basic JFace content-assist proposals. Each choice also carries a reference to the element that it represents, the kind of element indicated by the `ChoiceKind` enumeration, for a more sophisticated content assist that might include context information, documentation, etc. as in Eclipse JDT. The list of choices depends in part on the kind of constraint expression that is to be completed, as for example, the `oclIsNew()` operation is only permitted in operation post-conditions.

```
helper.setContext(EXTLibraryPackage.Literals.BOOK);

List<Choice> choices = helper.getSyntaxHelp(ConstraintKind.INVARIANT,
    "Book.allInstances()->collect(author)->");

for (Choice next : choices) {
    switch (next.getKind()) {
        case OPERATION:
        case SIGNAL:
            // the description is already complete
            System.out.println(next.getDescription());
        case PROPERTY:
        case ENUMERATION_LITERAL:
        case VARIABLE:
            System.out.println(next.getName() + " : " + next.getDescription());
            break;
        default:
            System.out.println(next.getName());
            break;
    }
}
```

6.5.1. Syntax Completion Choices

The computation of Choices is supported for the following tokens, which may be used by a client as auto-assist triggers:

Token	Completion choices
.	Features applicable to the type of the expression to the left of the dot, or its element type if it is a collection. association classes (in the UML environment only)
->	Collection operations and iterators
::	Packages, types, enumeration literals, and states (in the UML environment only)
^	Operations and signals (in the UML environment only)
^^	In other situations, the choices the current context variables and implicit references to features of the <code>self</code> variable. For example, if the input is something like <code>" "</code> or <code>"self.isOrdered"</code> and <code>"</code>

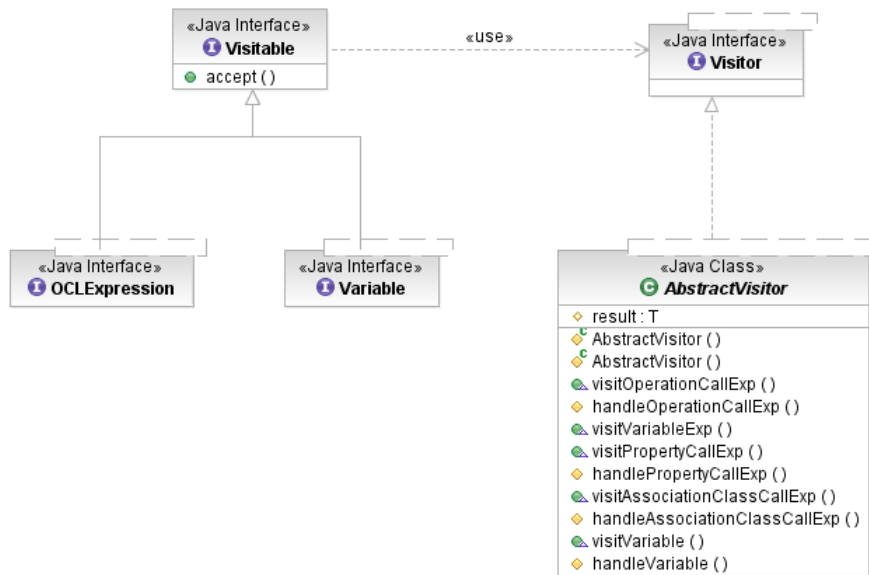
Content-assist triggers

The completion of partially specified identifiers is also supported, by backtracking to look for one of these triggering tokens. This supports interactively narrowing the choices while the content-assist window is active.

```
choices = helper.getSyntaxHelp(ConstraintKind.POSTCONDITION,
    "self.author.oclls");
```

6.6. OCL Abstract Syntax Model

The OCL Abstract Syntax Model is defined by the [OCL Language 2.4 specification](#). We will not attempt to describe this model, here. However, the Eclipse implementation of OCL defines some extensions to this model that provide additional services. The most important of these is support for the *Visitor* design pattern.



6.6.1. The Visitable and Visitor Interfaces

All of the metaclasses in the Abstract Syntax Model (nodes in the AST) that can be visited implement the [Visitable](#) interface. It defines a single operation `accept(Visitor)`. This method delegates to the appropriate `visitXyz(Xyz)` method of the [Visitor](#). The direct implementors of the Visitable interface are the `OCLExpression` and those metaclasses of the Expressions package that do not conform to `OCLExpression`:

- `Variable`
- `CollectionLiteralPart`
- `TupleLiteralPart`
- `ExpressionInOCL`

This last is not defined in the Expressions package because it pertains to the placement of OCL in Constraint elements in models.

The OCL parser, internally, defines a few implementations of visitors, including a `ValidationVisitor` for validating OCL expressions and an [EvaluationVisitor](#) for evaluating OCL expressions.

6.6.2. Implementing a Visitor

The best way to implement a visitor is to extend the [AbstractVisitor](#) class. It provides a `result` variable of the generic type parameter type `T` to store the result computed by the visitor (optional) and a convenient pattern of selective method overrides to process only those nodes of interest for the task at hand.

The `AbstractVisitor` provides implementations of all of the `visitXyz()` interface methods that simply return the current `result` value. Furthermore, for any internal nodes of the syntax tree (such as `OperationCallExp` and `IfExp`), the `visitXyz()` methods recursively visit the child nodes, feeding the results of those descents into a `handleXyz()` method that the subclass can override to compute some result from the child results.

Thus, a subclass needs only to selectively override the default implementations of `visitXyz()` methods for leaf tree nodes and `handleXyz()` methods for non-leaves. For example, to find all variables that are declared but never used:

```

OCLExpression<Classifier> expr = getExpression(); // hypothetical source of an expression

Set<Variable<Classifier, Parameter>> variables = expr.accept(
    new AbstractVisitor<Set<Variable<Classifier, Parameter>>,
        Classifier, Operation, Property, EnumerationLiteral,
        Parameter, State, CallOperationAction, SendSignalAction, Constraint>(
            new HashSet<Variable<Classifier, Parameter>>()) { // initialize the result

        @Override
        protected Set<Variable<Classifier, Parameter>> handleVariable(
            Variable<Classifier, Parameter> variable,
            Set<Variable<Classifier, Parameter>> initResult) {

            result.add(variable);

            return result;
        }

        @Override
        public Set<Variable<Classifier, Parameter>> visitVariableExp(
            VariableExp<Classifier, Parameter> v) {

            result.remove(v.getReferredVariable());

            return result;
        }
    });

Set<String> varNames = new HashSet<String>();
for (Variable<?, ?> next : variables) {
    varNames.add(next.getName());
}

System.out.println("Unused variables: + " varNames);

```

6.6.3. The OppositePropertyCallExp Extension

In Ecore models, a reference may have defined an `opposite` reference, usually owned by the class that is the type of the forward reference. An opposite reference has several, often undesirable or even prohibitive, implications on the class owning it:

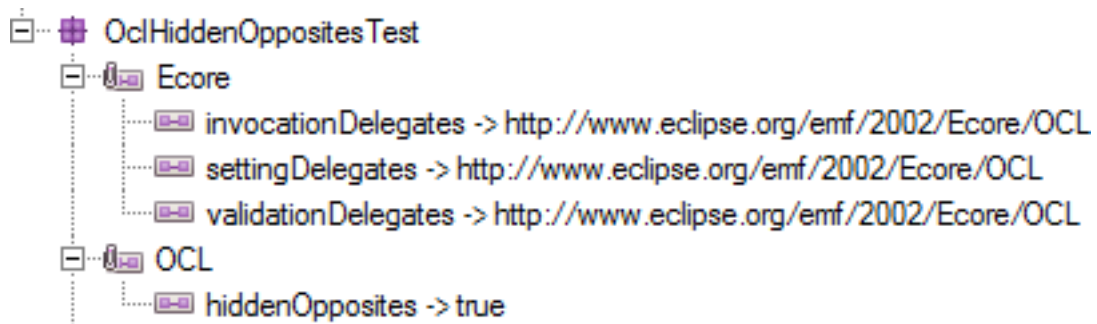
- A getter and, for settable features with upper multiplicity 1, a setter will be added, requiring the class to know the class owning the forward reference. This would create cyclic component references if the two classes lived in different components and would therefore not be possible.
- The default serialization format and usually the storage format for non-default model stores changes to include the opposite reference.

Yet, particularly for expressing constraints over the instance models it is often instrumental to be able to navigate such forward references also in reverse. The `OppositePropertyCallExp` class which inherits from `NavigationCallExp` and is sibling of `PropertyCallExp` allows for this reverse navigation in OCL. It points to the forward reference, and its semantics are to navigate this reference in reverse.

To allow for convenient creation of such expressions in the OCL concrete syntax, the standard property call syntax, such as `self.x` can be used, where `x` is not the name of a forward reference on `self`'s class but rather an annotated name on a reference using `self`'s class or any of its base classes as its type. To enable this feature, use the special environment factory class `EcoreEnvironmentFactoryWithHiddenOpposites` when initializing the OCL environment, e.g., by passing such an object to the `OCL.newInstance(...)` method.

The name for the reverse navigation can be specified by an [EAnnotation](#) with source `http://schema.omg.org/spec/MOF/2.0/emof.xml` and with details key `Property.oppositeRoleName`. The details value contains the name by which the “hidden” opposite can be referred to in OCL expressions.

If OCL delegates are to be used, the standard EPackage annotations with `invocationDelegate`, `settingDelegate` and `validationDelegate` details for the <http://www.eclipse.org/emf/2002/Ecore> source must be augmented as shown by a further `hiddenOpposites` detail for the <http://www.eclipse.org/emf/2002/Ecore/OCL> source.



This additional annotation causes the `EnvironmentFactory` functionality for the EPackage to be provided by an instance of the `EcoreEnvironmentFactoryWithHiddenOpposites` class which uses the `DefaultOppositeEndFinder` class will be used for finding and navigating the hidden opposites. More substantial customisation is possible by specifying an `environmentFactoryClass` detail with the fully qualified name of a derived `EcoreEnvironmentFactory` that provides a constructor taking an `EPackage.Registry` argument. Note, that the class specified must be visible by your Ecore model's bundle.

6.7. Customizing the Environment

An application that integrates OCL may find it advantageous to provide its users with an enhanced OCL environment, to simplify their task of formulating OCL constraints and queries. For example, an application might define additional “primitive” operations on the OCL standard data types that are pertinent to its domain, or “global” variables that inject useful objects into the user's context. It is also possible to customize the way “hidden” opposites are looked up and navigated, specifically to allow reverse navigation across Ecore references that have no opposite defined.

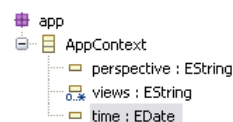
6.7.1. Defining Global Variables

Consider an application that allows end-users to specify conditions, using OCL, to filter the objects that are shown in the user interface. Given a sufficiently rich model (expressed in Ecore or UML) of the objects that the UI presents, many conditions can be expressed entirely in terms of this model. However, some queries might depend on state of the application, itself, not the data: which perspective is active, whether some view is showing, or even the time of day. These are not characteristics of the objects that the user wishes to filter.

Such an application might, then, choose to define application-specific variables that a filter condition can query: `app$perspective`, `app$views`, `app$time`. Or, perhaps a single variable `app$`, that has properties that a condition can access:

```
-- filter out OCL files in the Web Development perspective
self.extension = 'ocl' and app$.perspective = 'Web Development'
```

To do this, we define a small Ecore model of our application context, e.g.:



Then, in the code that parses a user's filter condition:


```

OCL<?, EClassifier, ?, ?, ?, ?, ?, ?, ?, Constraint, EClass, EObject> ocl;
ocl = OCL.newInstance(EcoreEnvironmentFactory.INSTANCE);

OCLHelper<EClassifier, ?, ?, Constraint> helper = ocl.createOCLHelper();
helper.setContext(MyPackage.Literals.FILE);

// create a variable declaring our global application context object
Variable<EClassifier, EParameter> appContextVar =
    ExpressionsFactory.eINSTANCE.createVariable();
appContextVar.setName("app$");
appContextVar.setType(AppPackage.Literals.APP_CONTEXT);

// add it to the global OCL environment
ocl.getEnvironment().addElement(appContextVar.getName(), appContextVar, true);

List<Constraint> conditions = new ArrayList<Constraint>();

// parse the user's filter conditions
for (String cond : getFilterConditions()) {
    conditions.add(helper.createInvariant(cond));
}

// apply the filters
applyFilters(conditions);

```

The body of our hypothetical `applyFilters()` method must bind this context variable to a value. In this case, the value can be computed when we apply the filters:

```

AppContext appContext = AppFactory.eINSTANCE.createAppContext();

// hypothetical workbench utilities
appContext.setPerspective(WorkbenchUtil.getCurrentPerspective());
appContext.getViews().addAll(WorkbenchUtil.getOpenViewIDs());
appContext.setTime(new Date());

List<Query<EClassifier, EClass, EObject>> queries =
    new ArrayList<Query<EClassifier, EClass, EObject>>(constraints.size());

for (Constraint next : constraints) {
    Query<EClassifier, EClass, EObject> query = ocl.createQuery(next);

    // bind the variable value
    query.getEvaluationEnvironment().add("app$", appContext());

    queries.add(query);
}

filter(queries); // applies these filters to the current objects
                // by evaluating the OCLs on them.

```

6.7.2. Defining Helper Operations in Java

OCL allows the definition of additional operations and attributes using `def`: expressions. This is very convenient for the formulation of constraints, but what if the operation that we need is something like a regex pattern match?

```

class Person
inv valid_ssn: self.ssn.regexMatch('\d{3}-\d{3}-\d{3}') <> null

```

We might try to define this using OCL, as an additional operation on the OCL Standard Library's `String` primitive type:

```

class String
def: regexMatch(pattern : String) : String =
    -- ???

```

The operations available in the OCL Standard Library simply are not sufficient to express the value of this operation, which should return the substring matching a regex pattern or null if the pattern does not match. We need to implement this operation in Java. We can do that by creating a custom Environment that knows how to look up this operation, and an EvaluationEnvironment that knows how it is implemented.

First, let's start by defining a specialization of the [EcoreEnvironment](#). The constructor that is used to initialize the root environment of an OCL instance will add our regexMatch additional operation to the String primitive type. The constructor that is used to create nested environments copies the operation from its parent.

```
class MyEnvironment extends EcoreEnvironment {
    EOperation regexMatch;

    // this constructor is used to initialize the root environment
    MyEnvironment(EPackage.Registry registry) {
        super(registry);

        defineCustomOperations();
    }

    // this constructor is used to initialize child environments
    MyEnvironment(MyEnvironment parent) {
        super(parent);

        // get the parent's custom operations
        regexMatch = parent.regexMatch;
    }

    // override this to provide visibility of the inherited protected method
    @Override
    protected void setFactory(
        EnvironmentFactory<EPackage, EClassifier, EOperation,
        EStructuralFeature, EEnumLiteral, EParameter, EObject,
        CallOperationAction, SendSignalAction, Constraint, EClass, EObject>
        factory) {
        super.setFactory(factory);
    }

    // use the AbstractEnvironment's mechanism for defining
    // "additional operations" to add our custom operation to
    // OCL's String primitive type
    private void defineCustomOperations() {
        // pattern-matching operation
        regexMatch = EcoreFactory.eINSTANCE.createEOperation();
        regexMatch.setName("regexMatch");
        regexMatch.setEType(getOCLStandardLibrary().getString());
        EParameter parm = EcoreFactory.eINSTANCE.createEParameter();
        parm.setName("pattern");
        parm.setEType(getOCLStandardLibrary().getString());
        regexMatch.getEParameters().add(parm);

        // annotate it so that we will recognize it
        // in the evaluation environment
        EAnnotation annotation = EcoreFactory.eINSTANCE.createEAnnotation();
        annotation.setSource("MyEnvironment");
        regexMatch.getEAnnotations().add(annotation);

        // define it as an additional operation on OCL String
        addOperation(getOCLStandardLibrary().getString(), regexMatch);
    }
}
```

Next, we will define the corresponding specialization of the [EcoreEvaluationEnvironment](#) that will know how to evaluate calls to this custom operation:

```
class MyEvaluationEnvironment extends EcoreEvaluationEnvironment {
    MyEvaluationEnvironment() {
        super();
    }

    MyEvaluationEnvironment(
        EvaluationEnvironment<EClassifier, EOperation, EStructuralFeature,
        EClass, EObject> parent) {
        super(parent);
    }

    public Object callOperation(EOperation operation, int opcode,
        Object source, Object[] args) {
        if (operation.getEAnnotation("MyEnvironment") == null) {
            // not our custom regex operation
            return super.callOperation(operation, opcode, source, args);
        }

        if ("regexMatch".equals(operation.getName())) {
            Pattern pattern = Pattern.compile((String) args[0]);
            Matcher matcher = pattern.matcher((String) source);

            return matcher.matches()? matcher.group() : null;
        }

        throw new UnsupportedOperationException(); // unknown operation
    }
}
```

Finally, we define a specialization of the [EcoreEnvironmentFactory](#) that creates our custom environments:

```
class MyEnvironmentFactory extends EcoreEnvironmentFactory {
    public Environment<EPackage, EClassifier, EOperation, EStructuralFeature,
        EEnumLiteral, EParameter, EObject, CallOperationAction,
        SendSignalAction, Constraint, EClass, EObject> createEnvironment() {
        MyEnvironment result = new MyEnvironment(getEPackageRegistry());
        result.setFactory(this);
        return result;
    }

    public Environment<EPackage, EClassifier, EOperation, EStructuralFeature,
        EEnumLiteral, EParameter, EObject, CallOperationAction,
        SendSignalAction, Constraint, EClass, EObject>
        createEnvironment(Environment<EPackage, EClassifier, EOperation,
            EStructuralFeature, EEnumLiteral, EParameter, EObject,
            CallOperationAction, SendSignalAction, Constraint, EClass,
            EObject> parent) {
        if (!(parent instanceof MyEnvironment)) {
            throw new IllegalArgumentException(
                "Parent environment must be my environment: " + parent);
        }

        MyEnvironment result = new MyEnvironment((MyEnvironment) parent);
        result.setFactory(this);
        return result;
    }

    public EvaluationEnvironment<EClassifier, EOperation, EStructuralFeature,
        EClass, EObject> createEvaluationEnvironment() {
        return new MyEvaluationEnvironment();
    }

    public EvaluationEnvironment<EClassifier, EOperation, EStructuralFeature,
        EClass, EObject> createEvaluationEnvironment(
        EvaluationEnvironment<EClassifier, EOperation, EStructuralFeature,
        EClass, EObject> parent) {
        return new MyEvaluationEnvironment(parent);
    }
}
```

Now, we can use our environment to parse the kind of expression that we were looking for:

```
OCL<?, EClassifier, ?, ?, ?, ?, ?, ?, ?, Constraint, EClass, EObject> ocl;
ocl = OCL.newInstance(new MyEnvironmentFactory());

OCLHelper<EClassifier, ?, ?, Constraint> helper = ocl.createOCLHelper();
helper.setContext(MyPackage.Literals.PERSON);

// double the '\\' to escape it in a Java string literal
Constraint validSSN = helper.createInvariant(
    "self.ssn.regexMatch('\\d{3}-\\d{3}-\\d{3}') <> null");

Person person = getPersonToValidate();

System.out.printf("%s valid SSN: %b%n", person, ocl.check(person, validSSN));
```

6.7.3. Selecting a Package Lookup Strategy

When package names are provided in OCL expressions, e.g., when representing types in an `oclIsKindOf` call, these names are looked up using a specific strategy. By default, the lookup proceeds starting at the parsing context, traversing up the package hierarchy. If the package name cannot be resolved this way, for the Ecore binding a lookup is performed in the `EPackage.Registry`. By default, the package name provided is compared to the names of the packages that are contained as values in the registry.

In rare cases there may be ambiguous package names. For example, if an OCL expression is to be parsed using a classifier from the OCL AST metamodel as its context, the context package is `ocl::ecore`. If such an expression is trying to reference a type from the EMF Ecore package with package name `ecore`, the EMF Ecore package is hidden by the lookup happening relative to the context package. Instead of the EMF Ecore package, the `ocl::ecore` package will be found.

Such an ambiguity can be resolved by using a dedicated `EPackage.Registry` which registers the otherwise ambiguous packages with a special “URI” that represents a simple alias name for the package. In order to force the OCL parser to look up packages by those alias names, an option needs to be set on the OCL environment, as follows:

```
Registry r = new EPackageRegistryImpl();
r.putAll(EPackage.Registry.INSTANCE);
r.put("EMFEcore", EcorePackage.eINSTANCE);
r.put("OCLEcore", org.eclipse.oclc.ecore.EcorePackage.eINSTANCE);
OCL ocl = OCL.newInstance(new EcoreEnvironmentFactory(r));
((EcoreEnvironment) ocl.getEnvironment()).setOption(
    ParsingOptions.PACKAGE_LOOKUP_STRATEGY,
    ParsingOptions.PACKAGE_LOOKUP_STRATEGIES.
        LOOKUP_PACKAGE_BY_ALIAS_THEN_NAME);
Helper helper = ocl.createOCLHelper();
helper.setContext(
    org.eclipse.oclc.ecore.EcorePackage.eINSTANCE.getOCLExpression());
org.eclipse.oclc.ecore.OCLExpression expr = helper.createQuery(
    "self.oclcIsKindOf(EMFEcore::EClassifier) and not
    self.oclcIsKindOf(OCLEcore::OCLExpression)");
```

In the example above, two packages with ambiguous simple names (EMF Ecore package and OCL Ecore package, both with simple name `ecore`) are added with alias names `EMFEcore` and `OCLEcore`, respectively. The package lookup strategy is then set to `LOOKUP_PACKAGE_BY_ALIAS_THEN_NAME` which allows OCL expressions to reference the packages by their aliases, as in `self.oclcIsKindOf(EMFEcore::EClassifier)` and not `self.oclcIsKindOf(OCLEcore::OCLExpression)`.

Note, that the use of a delegating registry (constructor `EPackageRegistryImpl(EPackage.Registry)`) does not work because a registry initialized this way does not forward the call to `values()` which would be required by the OCL package lookup implementation. Instead, if the packages registered with the default registry are required, they need to be copied to a new registry using `putAll` as shown above.

6.7.4. Customizing Hidden Opposite Lookup and Navigation

The default [EcoreEnvironmentFactory](#) produces environments which can find references that have an annotation with source <http://schema.omg.org/spec/MOF/2.0/emof.xml> that have a detail with key `Property.oppositeRoleName`. In the class that is the type of the reference, and all its subclasses, for OCL this annotation defines an otherwise “hidden” opposite property which can be used in OCL expressions. This can be convenient when it is not possible or desirable to define an explicit opposite reference, e.g., because the class that would have to own the opposite reference can’t easily be modified or the serialization of that class must not be changed.

The logic used to find these “hidden” opposites and to navigate them is provided by implementations of the [OppositeEndFinder](#) interface. By default, the `EcoreEnvironmentFactory` uses the [DefaultOppositeEndFinder](#) implementation. It performs the lookup of annotated references by maintaining a cache based on the Ecore package registry. Successful navigation of those “hidden” opposites requires an [ECrossReferenceAdapter](#) to be registered for the containment hierarchy or the resource or resource set that should be used as the scope of the navigation.

Obviously, [ECrossReferenceAdapter](#) has a significant downside: it responds to “hidden” opposite navigation requests only based on what has so far been loaded by EMF. If the set of resources held by an underlying EMF storage system contains more resources than have so far been loaded into the resource set, non-loaded content from that storage system won’t be considered by the `ECrossReferenceAdapter`. Given a store with reasonable search capabilities it is desirable to take advantage of these capabilities also to perform reverse navigation of those “hidden” opposites. To achieve this, a specific implementation of the [OppositeEndFinder](#) interface can be provided. It may be

a specialization of [DefaultOppositeEndFinder](#), e.g., when the reference lookup based on the Ecore package registry is sufficient and only the navigation behavior shall be redefined:

```
class MyOppositeEndFinder extends DefaultOppositeEndFinder {
    MyOppositeEndFinder(EPackage.Registry registry) {
        super(registry);
    }

    @Override
    public Object navigateOppositeProperty(EStructuralFeature property, Object target) {
        Collection<Object> result = null;
        EObject eTarget = (EObject) target;
        // do something clever, e.g., using your underlying store's query facility or
        // the new EMF Query2 component (incubation)
        // ...
        return result;
    }
}
```

With this, OCL can be instantiated using the custom opposite end finder as follows:

```
OCL ocl = OCL.newInstance(new EcoreEnvironmentFactoryWithHiddenOpposites(
    EPackage.Registry.INSTANCE, new MyOppositeEndFinder()));
...
```

With this, when the use of a property in an OCL expression cannot be resolved to an attribute or reference, the opposite end finder is asked to look for a correspondingly-named "hidden" opposite. Navigation across this "hidden" opposite will then call the `navigateOppositeProperty` method on `MyOppositeEndFinder`.

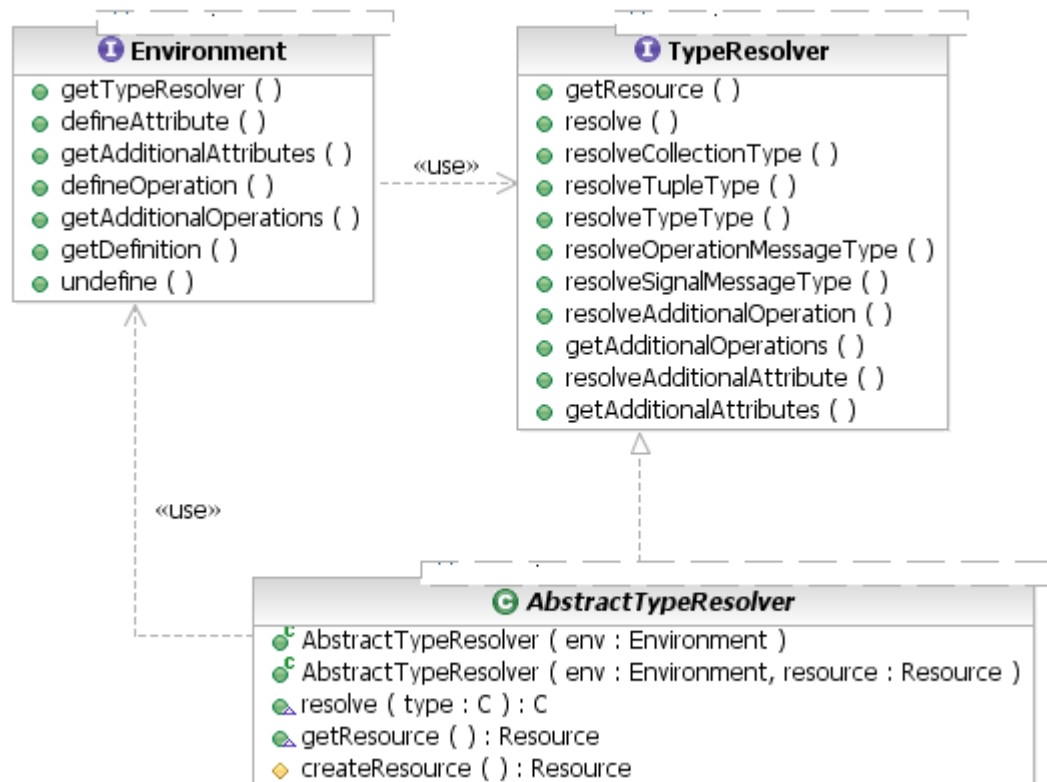
6.8. OCL Persistence

The Eclipse OCL component implements the OCL Abstract Syntax model as an EMF-based metamodel. Thus, parsed OCL expressions and constraints can be serialized, for example in XMI documents. The OCL 2.4 specification is unclear about how the serialization of expressions should look (this will be solved in the next OCL 2.5 specification), especially where references to demand-created types are concerned. This topic discusses the approach taken by the Eclipse OCL component to provide a practical solution to this problem.

6.8.1. The Type Resolver

OCL defines a number of template metaclasses, including the `CollectionType` metaclass and its specializations, `MessageType`, and `TupleType`. In all of these cases, OCL specifies that these templates are instantiated as needed in the OCL environment, and that only one instance of a template exists for any given combination of template arguments. For example, only one `OrderedSet(String)` exists and it is created on the occasion when it is first needed. Likewise, the `OclMessage` type for invocations of the `EModelElement::getEAnnotation(EString)` operation and the `Tuple{a : String, b : EClass}` type.

The problem is, that the OCL Specification does not indicate how expressions that reference such demand-created types can be persisted, because it does not define what should own these types. A similar problem exists for additional operations and attributes defined in OCL via `def : expressions`. The [TypeResolver](#) API is responsible for the demand-creation of these types and for their persistence.



Every [Environment](#) has a [TypeResolver](#) that persists demand-created types and additional features. For a client that doesn't require persistence, the [TypeResolver](#) will create a [Resource](#) with the dummy `ocl://` scheme (no resource factory is provided for this scheme).

A client that does require persistence of OCL expressions and these demand-created elements should provide a specific resource in which to store them, either via the [OCL](#) class's `newInstance(EnvironmentFactory, Resource)` factory method or via the [EnvironmentFactory](#) interface's `load(Resource)` method.

```

Resource modelResource = getResourceSet().getResource(
    URI.createPlatformResourceURI("/models/My.ecore", true), true);

// persist demand-created types etc. in my model resource
OCL<?, EClassifier, ?, ?, ?, ?, ?, ?, ?, Constraint, EClass, EObject> ocl;
ocl = OCL.newInstance(EcoreEnvironmentFactory.INSTANCE, myResource);

// use the OCL to parse constraints, store them in the Ecore model,
//   and save everything together in one resource for a consistent,
//   self-contained OCL environment
...

```

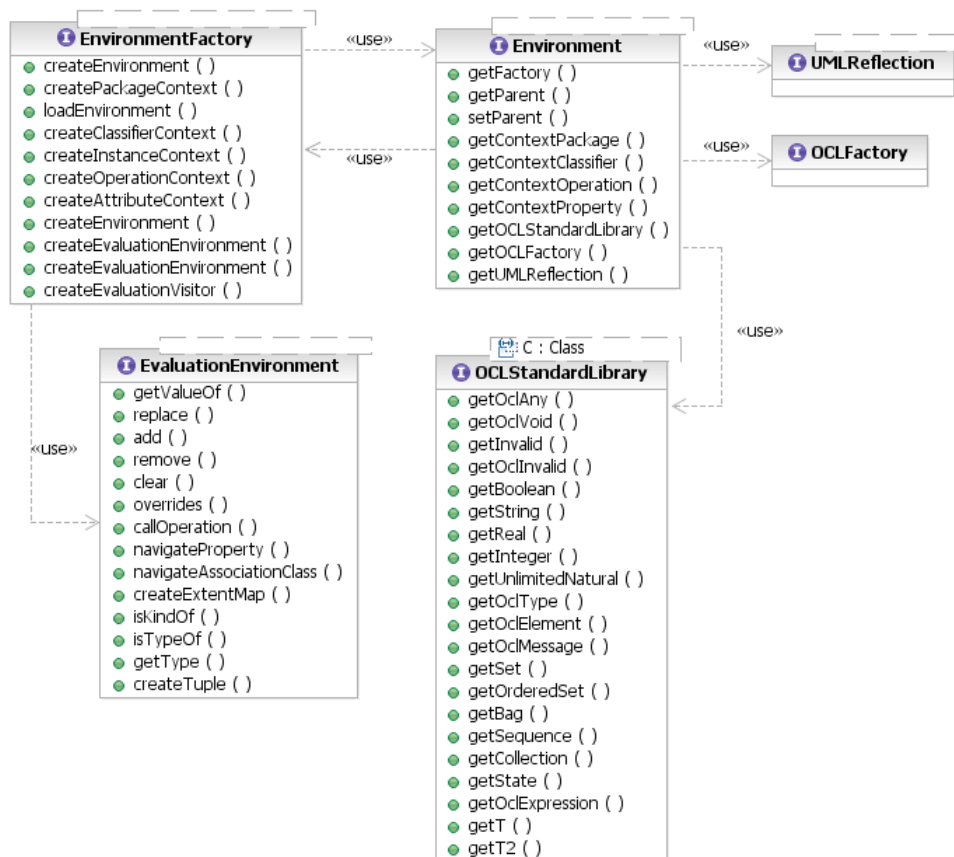
The [AbstractTypeResolver](#) class creates packages in which to store the different elements that it creates: collection types, message types, tuple types, and additional operations and attributes. These last are owned by classes that “shadow” the classifiers in which context they are defined, in the manner by which the OCL specification's adaptation for EMOF indicates that operations are to be “owned” by EMOF `DataType`s.

An environment implementation can customize the way these demand-created elements are stored, by choosing different packages or using some other strategy altogether. Or, using the default [TypeResolver](#) implementation, a client of the OCL parser can find the demand-created objects in the resolver's resource and relocate them as needed.

6.9. Creating Metamodel Bindings

The Eclipse OCL component provides a generic specification of the OCL Abstract Syntax Model plus bindings for two popular Eclipse metamodels: Ecore and UML. Users of the OCL API can likewise create bindings for their metamodels, to integrate OCL with their modeling languages.

The [Environment](#) interface has a generic type signature with several parameters, representing the metamodeling constructs required by OCL, that it borrows from UML, EMOF, and the other metamodels that it targets. The Javadoc for that interface defines the mappings, and the same type parameter names are used consistently throughout the OCL API.



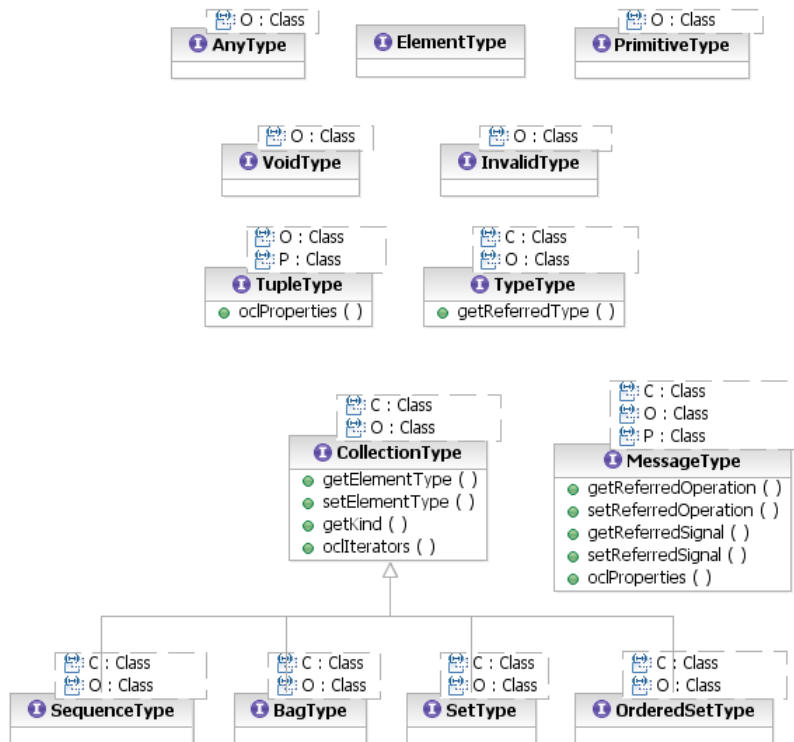
To provide a metamodel binding, a client must provide implementations of the following interfaces:

- `Environment` and `EnvironmentFactory`, supplying suitable substitutions for the generic type parameters. Note that not all of these are actually required; for example, Ecore does not have the concept of `State`, so it just substitutes `EObject`
- `EvaluationEnvironment` for accessing properties of run-time instances of models
- `UMLReflection` for introspecting models (instances of the target metamodel)
- `OCLStandardLibrary`, providing the instances of the metamodel's `Classifier` metaclass that implement the OCL Standard Library types
- `OCLFactory`, providing a factory for all of the metaclasses of the Abstract Syntax Model

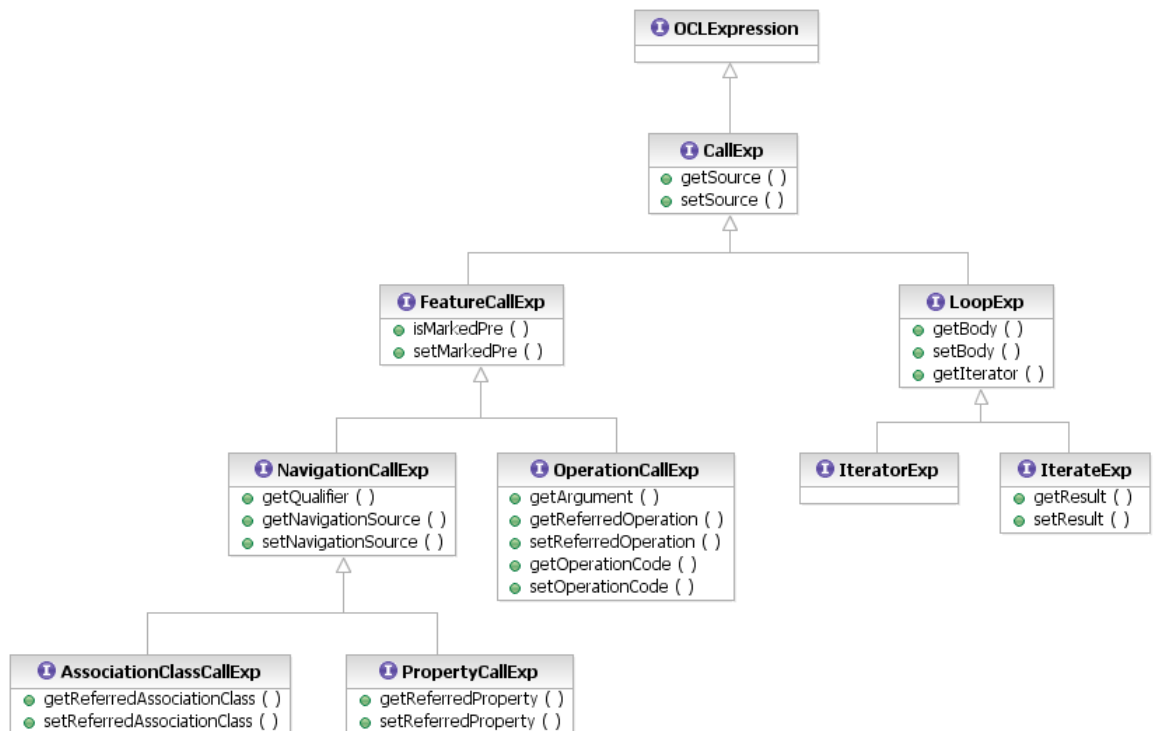
This last item, above, necessitates furthermore that the metamodel binding provide a concrete specialization of the Abstract Syntax Model (in its entirety) that mixes in the target metamodel's correspondents of the UML `Classifier` and `TypedElement` metaclasses. The former is required to provide compatibility of the metaclasses in the OCL `Types` package with the target metamodel's type system. The latter is required for compatibility of the metaclasses in the OCL `Expressions` package with the target metamodel's typed elements.

6.9.1. The OCL Abstract Syntax Model

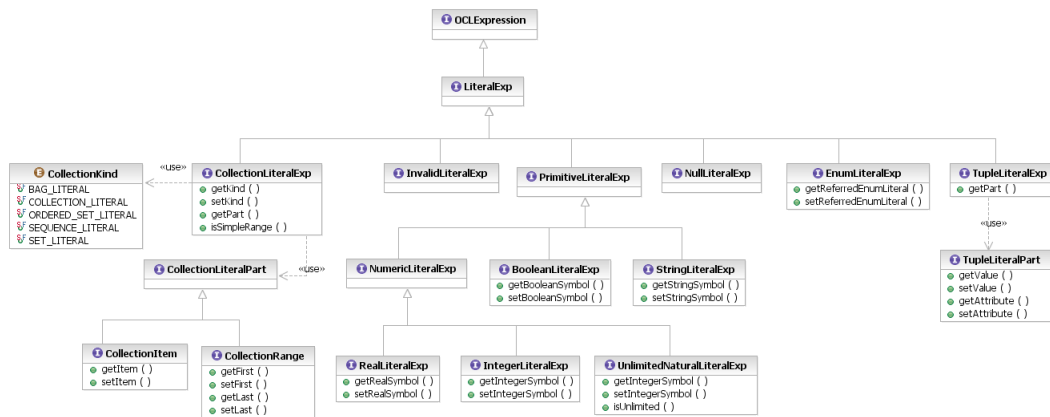
The following diagram summarizes the metaclasses of the OCL `Types` package:



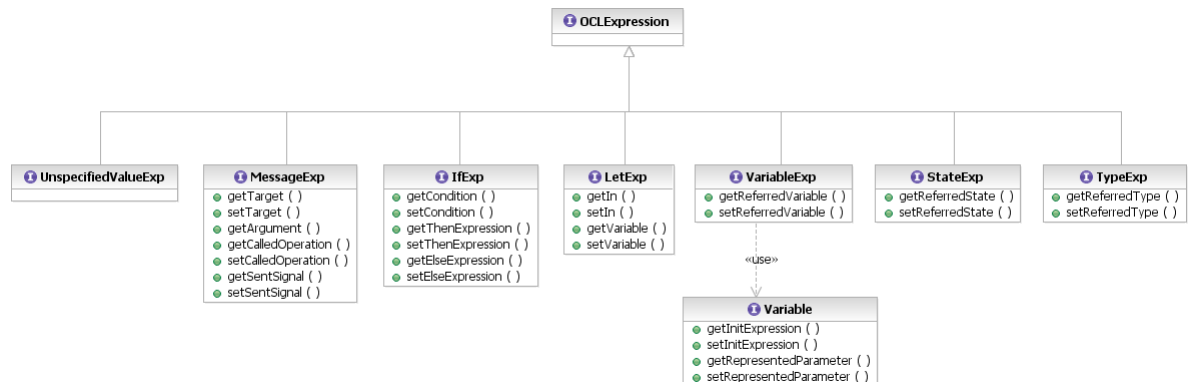
The following diagram summarizes the call expression metaclasses of the OCL Expressions package:



The following diagram summarizes the literal expression metaclasses of the OCL Expressions package:



The following diagram summarizes the remaining metaclasses of the OCL Expressions package:



6.10. Incrementally Re-Evaluating OCL Expressions Using the Impact Analyzer

When Ecore metamodels use many OCL invariants and the models constrained by these invariants grow large, re-evaluating the invariants becomes a performance challenge. As OCL expressions can navigate freely across resource boundaries, changes to a model element in one resource can easily affect invariants for model elements in other resources. To reliably catch all invalidated constraints after a change it would be necessary to re-evaluate all invariants on all their context objects regardless their resource. This does not scale sufficiently well.

The [ImpactAnalyzerFactory](#) interface allows tool builders to efficiently determine a much smaller set of model elements on which re-evaluation of expressions is necessary after a change.

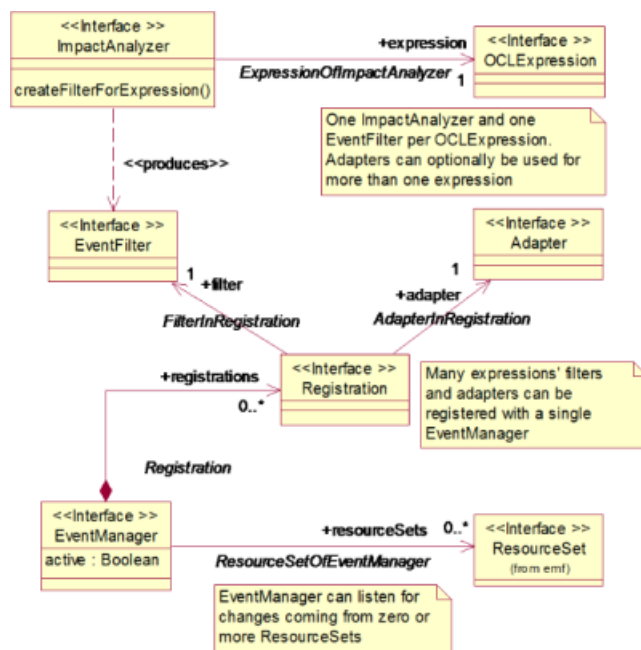
Given an [OCL expression](#), the factory can be used to create an impact analyzer for a single expression as follows:

```
final OCLExpression e = ...;
final ImpactAnalyzer impactAnalyzer =
    ImpactAnalyzerFactory.INSTANCE.createImpactAnalyzer(
        e,          // the expression to re-evaluate incrementally
        false,      // whether to re-evaluate when new context objects appear
        OCLFactory.INSTANCE);
```

The impact analyzer obtained this way can create a change notification filter which can then be used to register for notifications that indicate a change which may affect the value of the expression. Consider the following example:

```
ResourceSet myResourceSet = ...;
EventFilter filter = impactAnalyzer.createFilterForExpression();
EventManager eventManager =
    EventManagerFactory.eINSTANCE.getEventManagerFor(myResourceSet);
eventManager.subscribe(filter, new AdapterImpl() {
    public void notifyChanged(Notification notification) {
        Collection<EObject> valueMayHaveChangedOn =
            impactAnalyzer.getContextObjects(notification);
        for (EObject eo : valueMayHaveChangedOn) {
            // ... perform some re-evaluation action of e for context eo here
        }
    }
});
```

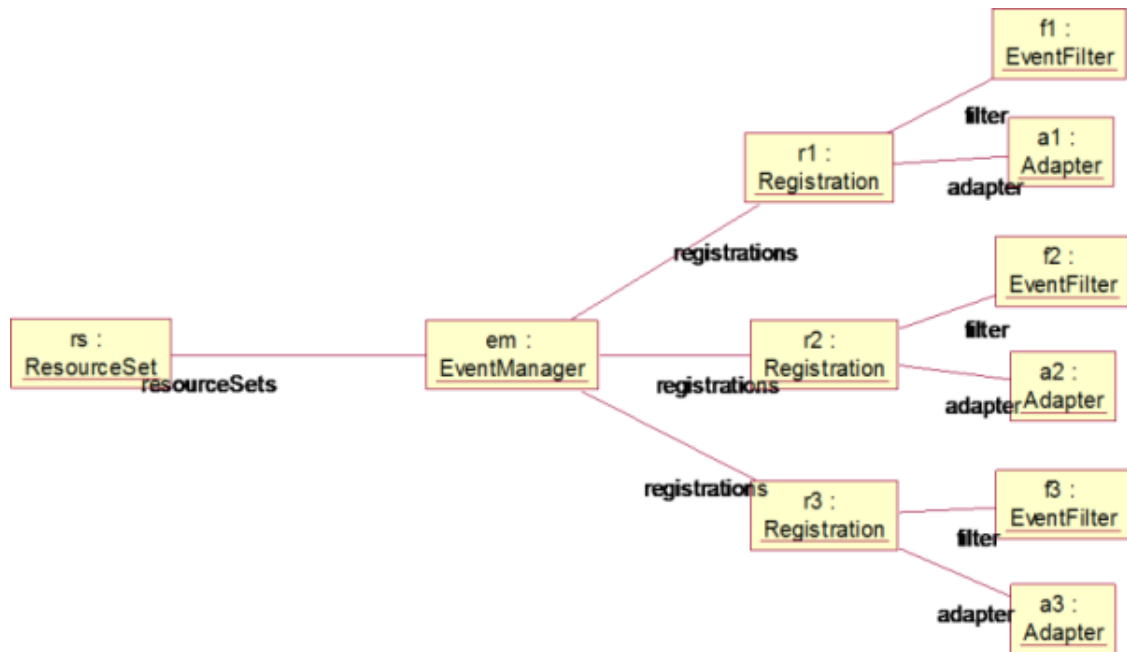
The event manager can be used to register the event filters of several OCL expressions with their respective adapters. The adapters for different expressions do not have to be distinct but may optionally be shared. The following figure shows how the classes relate, as a UML class diagram:



For each OCL expression a new impact analyzer is used. The event filters produced by them can be registered with the same event manager. The following figure shows a typical instance collaboration diagram in UML notation.

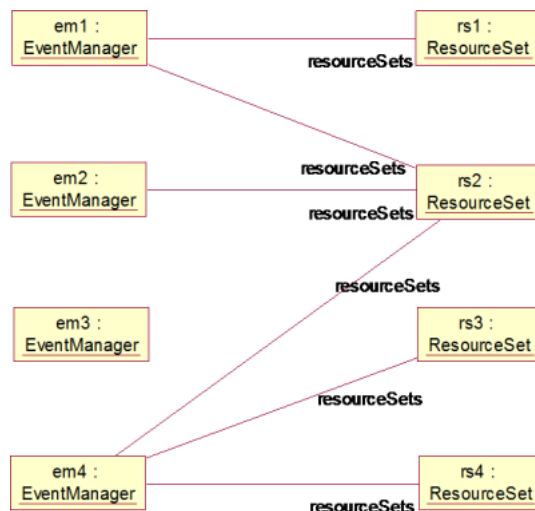


The [event manager factory](#) and the [event managers](#) it produces lay the scalable foundation for the re-evaluation process. Even if it has to manage many subscriptions, its performance does not degrade as it would if the change notification filters were evaluated one after the other. With this it becomes possible to register many OCL expressions for change impact analysis as shown above. The figure below shows a typical default configuration of an event manager, as a UML instance collaboration diagram.



The event manager in the figure is configured to listen to the change events coming from anything inside the resource set. In this example it is shown with three different event filters, each coming with its own adapter handling those change notifications matches by the respective filter.

As described in more detail in the Javadoc, event managers may be re-used, temporarily deactivated and new ones may be created specifically upon request. This way it is possible to have several event managers, e.g., listening for changes during different phases of a model's life cycle without having to create and initialize the event managers again and again. Also, an event manager is not restricted to listen to the changes of exactly one resource set. The following figure shows a not so typical configuration, again as a UML instance collaboration diagram.



6.10.1. Using the Impact Analyzer in EMF Editors

The `org.eclipse.oc1.examples.impactanalyzer.ui` package provides experimental support for embedding the impact analyzer in EMF editors. Adding the lines

```
@SuppressWarnings("unused") // not read; just used to avoid GC
private Revalidator revalidator; // from collecting re-validator
```

to the field declarations of an editor class, and adding the lines

```
revalidator = new Revalidator(editingDomain, OCLFactory.INSTANCE,
    DefaultOppositeEndFinder.getInstance(),
    MyMetamodelEcorePackage.eINSTANCE);
```

at the end of the editor class's `createModel()` method turns on this experimental support for the respective editors. Consequently, changes in the editor's `ResourceSet` will trigger the re-evaluation of the affected invariants on the set of context objects determined by the impact analyzer. Error markers of successfully validated constraints will be removed, markers for invalid constraints are produced. As is obvious also from the `examples` part of the package name, this is not yet production-ready code. It may change or disappear without notice.

6.10.2. Algorithm Outline

The basic idea on which the impact analyzer's algorithm is based is this: take the EMF change notification and see which elementary subexpressions, such as property call expressions, are immediately affected by the change. From these pairs of `(subexpression, model element)` it is possible to walk the expression tree and navigate "backwards" from the model element to the candidates for the `self` variable for which the subexpression may evaluate to the model element indicated by the notification. Recursive operation calls and general `->iterate(...)` expressions complicate matters and lead to a recursive algorithm for the impact analysis.

It is permissible to use calls to OCL-specified operations. The impact analyzer will trace changes considering the called operation's body expression.

The use of `allInstances` inside an expression may be nasty for analyzing the impact of a change because then it may no longer be possible to trace the change back to the possible values for `self`. In those cases the impact analyzer will simply "give up" and return a collection of all instances of the expression's context type and its subtypes.

6.10.3. Impact Analyzer Configuration, Scopes

The impact analyzer can be created in several different configurations as explained in detail in the [Javadocs](#). Particularly noteworthy is the relationship between the [OppositeEndFinder](#) and the way an `allInstance` expression is evaluated. Both depend on a notion of lookup scope. EMF does not provide any particular rules or conventions in this regard other than assuming that what has been loaded into a `ResourceSet` is what tools can see. While this is a working procedure for forward navigation, it doesn't help in defining a scope for `allInstances` and reverse navigation when there is no explicit opposite property.

For this purpose, Eclipse OCL has introduced the [OppositeEndFinder](#) interface through which reverse navigations of references and `allInstances` lookups can be performed. Its default implementation is based on the EMF default which is to consider the contents of a `ResourceSet` the universe. Other implementations are possible, however, such as one that uses EMF Query2 to perform the necessary lookups.

A default OCL evaluator will always use the current `ResourceSet` to determine the set of all instances of a type. If a client has used an opposite end finder that implements a certain lookup strategy then the default `allInstances` evaluation is most likely inconsistent with the scope definitions of that opposite end finder. To avoid such problems, a [specific OCL factory](#) can create OCL instances that ensure consistency between opposite navigation and `allInstances` evaluation.

Other configuration options (see [ActivationOption](#)) concern the specific algorithm used for tracing back from a change notification to the set of context objects for which the expression may have changed its value. The default selection has proven to be the fastest for a set of benchmarks. However, mileage may vary, and we'd like to encourage users to experiment also with the non-default configurations.

6.11. Delegates

EMF provides three delegation mechanisms that enable functionality not directly supported by EMF to be delegated to a technology that can support it.

- a [Validation Delegate](#) supports checking additional invariants on an `EClassifier`
- a [Setting Delegate](#) supports getting an initial or derived computed value for an `EStructuralFeature`
- an [Invocation Delegate](#) supports the execution of a function defined by an `EOperation` and also
- a [Query Delegate](#) supports the execution of a function not defined by an `EOperation`

When you use the [OCLinEcore](#) editor, the required EAnnotations to support delegation are provided automatically. This section provides sufficient detail to allow them to be maintained manually using the Sample Ecore Editor or Java code.

These EAnnotations ensure that delegates can be used for both genmodeled and reflective models. The use of genmodel to generate Java classes for your metamodel has significant performance benefits for modeling, but currently makes little difference for OCL execution. The use of genmodel has the disadvantage that you must install the Java classes and so the user of the Java classes must run in a different Eclipse or standalone session to the developer. Conversely, using reflective models allows both developer and user to share the same Eclipse session.

6.11.1. GenModel Settings

There is one GenModel setting that needs to be correctly set to ensure that OCL within generated Java classes can successfully be invoked by itself. Make sure that support for reflective operation invocation is generated by setting the `Operation Reflection` option to `true`.

6.11.2. OCL Delegate URIs

Each application implementing delegation has an associated Delegate URI, which is

- `http://www.eclipse.org/emf/2002/Ecore/OCL` for the classic evaluator
- `http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot` for the Pivot evaluator

Only the `http://www.eclipse.org/emf/2002/Ecore/OCL` was available in the Helios release and so the Helios release of the OCLinEcore editor used that URI.

The OCLinEcore editor uses the Pivot metamodel which is more accurate and OMG compliant and so in the Indigo release, the OCLinEcore editor uses the `http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot` URI and converts all incoming usage of `http://www.eclipse.org/emf/2002/Ecore/OCL` URI to `http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot`.

As described in [The two Eclipse OCLs](#) the Pivot evaluator uses an intermediate Pivot model to hide Ecore and UML2 and so allow full OMG-compliance. The Pivot evaluator is only available when the OCL Examples and Editors feature has been installed as described in [Installation](#).

The OCL Delegate URIs are registered using the

- `org.eclipse.emf.ecore.invocation_delegate`
- `org.eclipse.emf.ecore.setting_delegate`
- `org.eclipse.emf.ecore.query_delegate`
- `org.eclipse.emf.ecore.validation_delegate`

extension points.

6.11.3. Standalone Initialization

The initialization code for standalone usage of EMF delegates is given in the [Standalone](#) section.

6.11.4. Invocation Delegates

An invocation delegate is invoked to execute the body of an EOperation. An invocation delegate must be registered for the EPackage of the EClassifier of the EOperation.

The EPackage registration is provided by an EAnnotation on the EPackage

- `source = http://www.eclipse.org/emf/2002/Ecore`
 - `key = invocationDelegates`
 - `value = OCL-Delegate-URI`

The invocation delegate is provided by an EAnnotation on the EOperation

- `source = OCL-Delegate-URI`
 - `key = body`
 - `value = OCL-expression`

The *OCLE-expression* is evaluated to provide the EOperation value with the containing EClassifier as the *self* context object and the EParameters accessible as parameters from OCL. The return type of the *OCLE-expression* must conform to the return type of the EOperation.

6.11.5. Setting Delegates

A setting delegate is invoked to provide the initial or derived value of an EStructuralFeature. A setting delegate must be registered for the EPackage of the EClassifier of the EStructuralFeature.

The EPackage registration is provided by an EAnnotation on the EPackage

- source = `http://www.eclipse.org/emf/2002/Ecore`
 - key = `settingDelegates`
 - value = `OCLE-Delegate-URI`

The setting delegate is provided by an EAnnotation on the EStructuralFeature

- source = `OCLE-Delegate-URI`
 - key = `derivation`
 - value = `OCLE-expression`

The *OCLE-expression* is evaluated to provide the EStructuralFeature value with the containing EClassifier as the *self* context object. The result type of the *OCLE-expression* must conform to the type of the EStructuralFeature.

An initial rather than derivation value may be specified. The initial is ignored if a derivation is also specified.

6.11.6. Validation Delegates

A validation delegate is invoked to provide additional validation of an EClassifier. A validation delegate must be registered for the EPackage of the EClassifier for which the EClassifier provides any Ecore invariants or Ecore constraints. Both Ecore constraints and invariants constrain an EClassifier, the difference is that an Ecore invariant is realised by an EOperation and so an Ecore invariant may be re-used by modeling environments that may wish to selectively check or re-check constraints.

The EPackage registration is provided by an EAnnotation on the EPackage

- source = `http://www.eclipse.org/emf/2002/Ecore`
 - key = `validationDelegates`
 - value = `OCLE-Delegate-URI`

All Ecore constraints must be listed in an EAnnotation on the EClassifier

- source = `http://www.eclipse.org/emf/2002/Ecore`
 - key = `constraints`
 - value = `constraintName1 constraintName2 constraintName3`

The validation delegate for each Ecore constraint is provided by a further EAnnotation on the EClassifier

- source = `OCLE-Delegate-URI`
 - key = `constraintName`
 - value = `OCLE-expression`

The validation delegate for each Ecore invariant is provided by an EAnnotation on the EOperation

- source = `OCLE-Delegate-URI`
 - key = `body`
 - value = `OCLE-expression`

The *OCLE-expression* is evaluated to validate the EClassifier with the EClassifier as the *self* context object. The result type of the *OCLE-expression* must be Boolean.

6.11.7. Validation Messages

When a validation fails EMF generates a default diagnostic of the form The '*constraintName*' is violated on '*constrainedObject*'.

If the [OCLinEcoreEObjectValidator](#) or [CompleteOCLEObjectValidator](#) are used a custom message may be supplied using an additional EAnnotation on the EClassifier.

- `source = OCL-Delegate-URI`
 - `key = constraintName $message`
 - `value = OCL-expression`

The *OCL-expression* is evaluated to produce the custom message with the EClassifier as the `self` context object. The result type of the *OCL-expression* must be String.

The severity of the diagnostic can also be customized by exploiting the four values of the Boolean value of the constraint evaluation.

- `true` indicates successful validation
- `false` indicates unsuccessful validation with warning severity
- `null` indicates unsuccessful validation with error severity
- `invalid` indicates a failure to perform validation (error severity)

6.11.8. Query Delegates

A query delegate is invoked to evaluate a parameterized query on a EObject for which there is no corresponding EOperation. A query delegate is registered to install this query and allow its compiled form to be cached. The delegate may then be invoked as many times as required for compatible context objects and parameters.

This facility enables an EMF application to execute OCL without declaring or instantiating any OCL classes.

The query delegate registration is analogous to direct use of `OCL.newInstance().createHelper().createQuery()`

The query delegate execution is analogous to `OCL.evaluate()`

6.12. Ecore/UML Standalone Configuration

If you use Eclipse OCL within Eclipse you should find that the appropriate registrations are provided for you automatically by the plugin registration mechanisms.

However if you use Eclipse OCL outside Eclipse, for instance in JUnit tests, you must provide the corresponding registrations in your code.

6.12.1. Ecore

For the Ecore metamodel, the required registrations should be provided by invoking `org.eclipse.ocl.ecore.OCL.initialize(ResourceSet)`.

This may be invoked with a null argument to install the registrations in the global `EPackage.Registry`. This is not normally recommended, but since this is for your application, the integrity of the global registry is your responsibility.

It is normally recommended to install the registrations solely for use in your own `ResourceSet` and to pass that to the initialize routine.

This initialization ensures that `*.ecore` is understood.

If you want to use EMF delegates to dispatch OCL, the required registrations may be provided by `org.eclipse.ocl.ecore.delegate.OCLDelegateDomain.initialize(ResourceSet)`.

This may be invoked with a null argument to install the registrations in the global `EPackage.Registry` rather than a specified local registry.

6.12.2. UML

For the UML metamodel, the required registrations should be provided in a similar way by invoking `org.eclipse.ocl.uml.OCL.initialize(ResourceSet)`.

This initialization ensures that `*.uml` is understood that `http://www.eclipse.org/ocl/1.1.0/oclstdlib.uml` is known and that standard pathmap: locations are resolvable. It also invokes


```
org.eclipse.uml2.uml.resources.util.UMLResourcesUtil.init(ResourceSet)
```

to ensure that all Eclipse and OMG UML namespaces and extensions are registered..

6.12.3. Classpath

A precise Java 5 classpath for the current release may be obtained as a diagnostic output near the end of the console output of the [Jenkins Ecore Classpath](#) or [Jenkins UML Classpath](#) jobs.

6.12.4. Xtext Editors

The Xtext Editors use the Pivot binding and so their initialization is described in “Pivot Standalone Configuration”#PivotStandalone.

The Xtext editors may be used with the Ecore or UML bindings in so far as the Complete OCL editor provides a *.ocl document that may be parsed by the LPG parser, and the OCLinEcore editor provides embedded OCL that may be executed by either evaluator.

Chapter 7. Unified or Pivot Programmers Guide

The Unified or Pivot Programmers Guide describes the ways in which the Pivot binding Eclipse OCL can be used from Java programs.

The Pivot binding was first available as an examples quality prototype in 3.1.0 (Indigo). The Pivot binding became the preferred binding in 6.0.0 (Mars). The older Ecore and UML bindings are described in a separate [Ecore/UML Programmers Guide](#).

The OCL Parser/Interpreter provides an implementation of the [Object Constraint Language 2.4](#) specification for EMF-based metamodels and models. It offers OCL constraint and query parsing and evaluation, model-based validation, and provides an infrastructure for content assist in textual editors.

The following features are supported in the current version:

- Classifier invariant constraints
- Operation precondition and postcondition constraints and body conditions
- Property constraints (initial-value and derivation)
- Attribute and operation definitions (def: expressions)
- Package context declaration
- Basic values and types
- Collection types
- Navigation of attributes and association ends
- Operation invocation
- Iteration expressions (all standard iterators)
- Let expressions
- If expressions
- Tuples
- Message expressions, including unspecified values
- Operations predefined by OCL: `allInstances()`, `oclIsKindOf()`, `oclIsTypeOf()`, `oclAsType()`, `oclIsNew()`
- Escape syntax for illegal names: type, operation, attribute, etc. names that correspond to OCL reserved words can be escaped in the standard fashion using a leading underscore ('_'). In addition, names that contain spaces or tabs can be escaped by enclosing them in double-quotes (""); this is non-standard). e.g., `self.ownedRule->forall(c : Constraint | c._context = self)`

The above constructs are supported by the parser for parsing and for evaluation, with the exception of the `oclIsNew()` operation and message expressions. All of the above are supported for both Ecore and UML models. The following are supported by default for UML (both in parsing and evaluation):

- Navigation of non-navigable association ends (including those that are owned by the association)
- Qualified association end navigation
- Navigation to association classes, including source qualifiers
- Operations predefined by OCL: `oclIsInState()`

The following features are provided in addition to the OCL specification:

- String case conversion operations: `toUpper()`, `toLower()`
- Support for comparison (<, <=, etc.) and sorting of any java `Comparable`s of conformant types
- Transitive closure of associations: `closure(expr : OCLEExpression)` iterator
- Navigation of “hidden” opposites of references specified in Ecore models using a `Property.oppositeRoleName` annotation with source `http://schema.omg.org/spec/MOF/2.0/emof.xml` on the forward reference, producing an `OppositePropertyCallExp` expression

The OCL implementation is defined in plug-ins for convenient deployment in Eclipse, but as is the case for EMF, it can also be used stand-alone. The plug-ins are partitioned thus:

- `org.eclipse.oc1.pivot`: the neutral Pivot model, interfaces, Standard Library and evaluator.
- `org.eclipse.oc1.examples.codegen`: the OCL to Java code generator.
- `org.eclipse.oc1.examples.debug...`: the extensible debugger.
- `org.eclipse.oc1.examples.validity`: the Validation View.
- `org.eclipse.oc1.xtext...`: Xtext editors.

7.1. OCL Environment

The Pivot-based Eclipse OCL maintains significant amount of working state to cache aspects of the user metamodels and models.

The OCL working meta-state used for OCL parsing and analysis comprises at least a `CompleteEnvironment`, `CompleteModel`, `EnvironmentFactory`, `MetamodelManager`, `Orphanage` and `StandardLibrary`.

The additional OCL working state for OCL execution comprises an `Executor` and a `ModelManager`.

7.1.1. OCL Implementation Problem

Eclipse OCL exploits the Eclipse Modeling Framework (EMF) and so has to comply with EMF APIs. Unfortunately the most basic EMF API `getXXX()` to access the feature `xxx` provides no ability to pass any OCL working state to an OCL implementation of `getXXX()`. There is also no ability to create or destroy the OCL working state before and after a sequence of activities for which the OCL requirement of model invariance is satisfied.

7.1.2. OCL adapters pre-2021-03

Prior to the 2021-03 (6.14.0) release, the OCL working meta-state was lazily created on demand and eventually garbage collected. The working meta-state was persisted by use of an `EnvironmentFactoryAdapter` to attach the state to the `ResourceSet` containing the user model / metamodel. The state could be recovered by a hierarchical search of the user model's containment hierarchy. The OCL facade supports multiple usage of the state via a share count so that GC only kicks in once all usage is done. A `WeakOCLRef` provides another mechanism for sharing.

The OCL working state is similarly maintained via `ResourceSet` adapters and also by an entry in the validation context of the EMF `validate()` API.

The above approaches work for straightforward usage. But...

When OCL invariants or getters are executed from an installed model, there is no `ResourceSet` and so the user's OCL context is not available. Rather a special global OCL working meta-state is used; it ignores any `Complete` OCL contributions from the user's application.

Models shared between applications are isolated by careful use of `ValidationAdapters` to identify which OCL is involved.

Multi-threaded applications may successfully share the working state provided the user has resolved all other threading hazards.

Applications using multiple OCLs such as one reference OCL for an old-way, and another experimental OCL for a new way, may successfully use distinct adapters.

However from a developer's perspective it's all very fragile and complicated and metamodel schizophrenia is always waiting for an opportunity to bite.

Avoiding leakage with EMF applications is quite hard since a single reference from one of the global registries can easily lock everything into memory,

Identifying when the user model analysis in the working state can be re-used and when it must be recomputed is hard since there is no mechanism for a user to delimit the duration of model invariance.

Investigation of a bug in the implicit opposites underpinning a stereotype in a static UML profile revealed that the analyses supporting *allInstances* and *implicitOpposites* was very very pessimistic and consequently very inefficient.

The major use cases for OCL applications are model validation and model transformation. For the latter, the transformation tool can easily initialize the OCL state prior to transformation and clean up afterwards. For the former case, a massive performance improvement is possible if the one working state can be re-used throughout the model validation.

7.1.3. OCL per Thread post-2021-03

For the 2021-03 (6.14.0) release a new approach is taken. The OCL working state is referenced by a thread local variable making discovery easy and cleanup inherent in the demise of the thread. Lazy creation is fairly easy too.

There is no need for a special global OCL context with defective capabilities; the `GlobalEnvironmentFactory` and its `INSTANCE` is obsolete.

But, by default multi-threaded applications have a distinct OCL working state per-thread, which may be beneficial or inefficient. If the programmer is able to manage thread safety, then the `ThreadLocalExecutor.set` API may be used to share the same OCL state on more than one thread. NB the current OCL code has some synchronizations that may help with thread safety but overall there is no guarantee of thread safety.

But, multi-OCL applications cannot have more than one active OCL per-thread.

One variation of the multi-OCL use case was prevalent in the OCL JUnit tests where one OCL processed a reference model while another OCL processed an application model. The solution for interleaved usages is to invoke `OCL.deactivate` or `ThreadLocalExecutor.detachEnvironmentFactory` to suspend one OCL before `OCL.activate` or `ThreadLocalExecutor.attachEnvironmentFactory` resumes another OCL. The multiple OCLs can therefore co-exist till eventually `OCL.dispose()` cleans up.

Another variation of the multi-OCL use case was prevalent in the QVTd JUnit tests where one main extended OCL processed an application model while a nested OCL validated/serialized intermediate results. The same `deactivate/activate` solution again ensures that only one OCL is active.

The use of concurrent OCLs on the same thread is diagnosed and results in a log message such as *Concurrent EnvironmentFactory instances inhibit local thread Executor passing* forcing the code to fall back on the old adapter based approach. The solution, as described above, is to use `deactivate/activate` to eliminate the concurrent activity.

But, whereas the old approach was very pessimistic creating a new OCL working state far too often, the thread-based OCL state must be invalidated by invoking `ThreadLocalExecutor.reset()` whenever the user models are changed in any way that might undermine the OCL assumption that models do not change. (This change could be automated using EMF's `TrackingModificationAdapters` but the cost is considered too high compared to a manual reset).

But, there is currently no support for sharing the UI thread across many `IWorkbenchPart`. i.e. if two views both use OCL on the UI thread, the state of one view may confuse the other. Fortunately OCL activity such as validation is generally delegated to a worker thread avoiding the confusion and guaranteeing a new OCL per usage.

The adapters associated with the old approach are now obsolete but remain for now as legacy/compatibility clutter. They will be removed in a future release.

7.2. Validators

When using the Pivot metamodel, there are two specialized validators available to support integration of OCL in to a larger Ecore environment.

7.2.1. OCLinEcoreEObjectValidator

Unfortunately, in the Indigo release, EMF does not support this customization and so must be activated by explicitly using an `EValidator` that is aware of the `ValidationDelegateExtension` extended API. This is available by using the `OCLinEcoreEObjectValidator`, which you may install globally by:

```
EValidator.Registry.INSTANCE.put(null, new OCLinEcoreEObjectValidator());
```

or more selectively by adjusting the inheritance of the `Validator` class generated by EMF from (for a model of a Company):

```

import org.eclipse.emf.ecore.util.EObjectValidator;

/**
 * <!-- begin-user-doc -->
 * The <b>Validator</b> for the model.
 * <!-- end-user-doc -->
 * @see company.CompanyPackage
 */
public class CompanyValidator extends EObjectValidator {

to

import org.eclipse.ocl.xtext.oclinecore.validation.OCLinEcoreEObjectValidator;

/**
 * <!-- begin-user-doc -->
 * The <b>Validator</b> for the model.
 * <!-- end-user-doc -->
 * @see company.CompanyPackage
 * @generated not
 */
public class CompanyValidator extends OCLinEcoreEObjectValidator {

```

Note the **@generated not** that indicates that the class interface is manually defined. Do not use **@generated NOT** since that indicates that the whole class is manually defined.

7.2.2. CompleteOCLEObjectValidator

The CompleteOCLEObjectValidator is used to enable Complete OCL documents to participate in the validation processing of an Xtext editor.

The APIs for merging Complete OCL and Ecore as intermediate Pivots and then migrating the Pivot back to Ecore are experimental.

7.3. The Pivot Evaluator

The Pivot evaluator is a complete reimplement of the classic evaluator to exploit experience and the Pivot metamodel

- numeric growth beyond 32/64 bits is accommodated
- equal numbers are equal regardless of type
- templated types are supported
- library operations are modeled and extensible
- oclType() returns a Class offering full reflection without loss of static typing
- optimised virtual function dispatch tables
- code generation to Java

The APIs of the two evaluators are very similar since Ecore compatibility is very important. For basic OCL evaluation, users should not notice any functional difference between the two evaluators. The Pivot evaluator is generally between 2 and 5 times faster as well as being more accurate. The code generated evaluation may be a further 20 times faster.

7.3.1. The Evolving Pivot Value System

The classic evaluator uses Ecore and Java library representations such as EObject, Integer, String and Set directly for evaluation. This avoids conversion costs but incurs OCL accuracy challenges for numeric equality and growth.

The Juno release of the Pivot evaluator use polymorphic Value representations such as EObjectValue, IntegerValue, StringValue and SetValue. This avoids the OCL accuracy difficulties but requires wrapper objects and incurs conversion costs wherever a compatible Ecore API is in use.

The IntegerValue and RealValue classes avoid the equivalence and accuracy problems of Integer and Double by implementing Object.equals(Object) with OCL semantics.

The costs of the polymorphic Boolean, String and EObject wrappers became apparent when testing the code generator and so the Kepler and Luna releases use a hybrid representation. Unboxed values (the natural Ecore and Java representation) are used wherever OCL and Java have compatible semantics, that is for Boolean, String, null, invalid/exception and EObjects that are not Types. Boxed polymorphic value representations are used wherever OCL and Java semantics differ, that is for IntegerValue, RealValue, CollectionValue, TupleValue and TypeValue. This avoids unnecessary conversion costs, but requires many instanceof tests to compensate for the lack of Value polymorphism. When generating code, static analysis can often eliminate many of the instanceof cases and so the hybrid representation is faster.

7.3.2. The Pivot Value System

Every value has a unique type identity supervised by the `IdManager` class. This unique identity can be shared by multiple OCL applications that may have distinct type systems as a result of Complete OCL complements.

Every value has a type that is determined from its type identity by a type-system-specific `IdResolver` instance, which also supports conversion between boxed and unboxed value representations.

7.3.2.1. Value Conversions

The values are managed by a `ValueFactory` which provides many utility methods such as `ValueFactory.valueOf(Object)` for creating a `Value` from a naked Java object. The reverse conversion from a value to a naked Java object may be performed by `Value.asObject()` with methods in derived value classes providing stronger type returns.

7.3.2.2. Polymorphic Integers

The `IntegerValue` interface has a family of `IntIntegerValueImpl`, `LongIntegerValueImpl` and `BigIntegerValueImpl` realizations that use Java types internally but support numeric growth where necessary without imposing the overheads of `BigInteger` on the vast majority of mundane usages. The wrapping of `int` in `IntegerIntValueImpl` is very comparable to the wrapping of `int` in `java.lang.Integer` so there is little performance or representation cost.

This enables the Pivot evaluator to handle unlimited integers as specified by the OMG OCL specification.

Prior to the Juno release the handling of greater than 32 bit integers in the classic evaluator was suspect. The Juno release enhances support to allow for 64 bit integers but makes no provision for greater than 64 bit evaluations.

7.3.2.3. Polymorphic Collections

The `CollectionValue` interface has multiple implementations for `Bag`, `OrderedSet`, `Sequence` and `Set` with implementations that observe OMG OCL semantics.

The classic implementation uses Java collections directly, which unfortunately means that the Java semantics for equality is used. Consequently the classic evaluator incorrectly evaluates `Set{1,1.0}->size()` as 2.

Using a distinct hierarchy of collection classes opens up opportunities for smart operation, such as in-place update for collections that are rendered redundant by a calculation.

The classic implementation creates a new collection at every opportunity.

7.3.2.4. Polymorphic Objects

The `ObjectValue` interface has an implementation for `EObject` and further implementations for more specialized objects such as types.

The Pivot evaluator can be used on alternate data models by providing an alternate `ObjectValue` to wrap an alternative form of data object.

The classic implementation uses `EObject` directly, which makes use of non-`EObject` data models rather hard.

7.3.3. The Pivot Evaluator Type System

The Pivot Evaluator uses a very lightweight type system so that alternate implementations can be used.

For compiled evaluation, a dispatch-table based implementation is used.

For OCL compilation, a UML-aligned representation of the combined UML, OCL, library and user type systems is used.

The classic implementation uses either UML or Ecore meta-models directly, with Ecore as the meta-meta-model. Consequently there was no support for `oclType()`. Reflection was available in the non-OMF Ecore domain, so the meta-meta-class is “EClass” rather than “Class”.

7.3.4. The Pivot Evaluator Implementation System

The Pivot evaluator may be used in an interpreted form similar to the classic evaluator. In this form the evaluator performs a tree-walk over the Abstract Syntax Tree of the OCL expression. Languages that extend OCL may extend this tree-walk by implementing the relevant visitor evaluations for additional AST nodes.

A partially optimized code generator is available for the Pivot evaluator for which the code generator walks the AST at compile-time. The code generator may be extended to support code generation for languages that extend OCL. See the QVTi code generator in the QVTd project as an example.

7.3.5. Polymorphic Implementations

The OCL Standard Library comprises packages of classes with one class per library feature, each class implementing the polymorphic implementation interface.

Provision of additional library function therefore requires

- provision of the Java class for the library feature
- declaration of the library feature

Library features (properties, operations and iterations) are declared in a Standard Library model that identifies the invocation signature and binds it to a Java implementation.

```
type Collection(T) : CollectionType conformsTo OclAny {
    operation asSet() : Set(T) =>
        'org.eclipse.ocl.examples.library.collection.CollectionAsSetOperation';

    iteration exists(i : T | body : Lambda T() : Boolean) : Boolean
        => 'org.eclipse.ocl.examples.library.iterator.ExistsIteration';
    iteration exists(i : T, j : T | body : Lambda T() : Boolean) : Boolean
        => 'org.eclipse.ocl.examples.library.iterator.ExistsIteration';
```

The extract from `/org.eclipse.ocl.pivot/model/OCL-2.5.oclstdlib` shows the declaration of the `Collection` type as a templated type with a `T` parameter. The `Collection` type conformsTo (extends/inherit/generalizes) the `OclAny` type and is an instance of the `CollectionType` meta-type.

The `asSet` operation takes no arguments and returns a `Set(T)`, a set of the collection template type. The declaration is bound to `org.eclipse.ocl.pivot.library.collection.CollectionAsSetOperation` which is the Java class name of the implementation.

The `exists` iteration has two overloads, taking one or two iterators of the collection template type. The iteration body is a lambda expression operating on a collection template element with no additional arguments to return a Boolean value. The iteration also returns a Boolean value. The same Java implementation class is used for both one and two argument forms.

The corresponding implementations in the classic evaluator were mostly inlined within the `EvaluationVisitorImpl.visitOperationCallExp` method and so were difficult to extend.

The corresponding declarations in the classic evaluator were partially modeled in **oclstdlib.ecore** or **oclstdlib.uml**, although in practice an equivalent manually code model initialization is used. The type declarations used by the parser and analyzer are independently coded and do not support iterations as modeled concepts.

7.4. Pivot Standalone Application

The functionality of Eclipse OCL is primarily available via the Eclipse IDE where functionality such as editors are readily supported.

The underlying functionality is available to programmers who may use the API from IDE or standalone applications.

Additionally the execution and validation sub-tools are useable via the standalone application described in this section.

While the standalone application can be used as an interactive command line facility, the intended usage is to support automated usage from scripts or tools. Interactive users will generally find the IDE more appropriate.

7.4.1. Installation and Invocation

After following the usual procedure for installing Eclipse OCL [Installation](#) the plugins folder of your installation folder contains all the required JAR files so that you may use a verbose invocation such as:

```
"E:\Program Files\Java\jdk-11.0.13\bin"\java.exe -classpath "
E:\Tools\Eclipse\4.20\plugins\com.google.guava_30.1.0.v20210127-2300.jar;
E:\Tools\Eclipse\4.20\plugins\com.google.inject_5.0.1.v20210324-2015.jar;
E:\Tools\Eclipse\4.20\plugins\javax.inject_1.0.0.v20091030.jar;
E:\Tools\Eclipse\4.20\plugins\org.antlr.runtime_3.2.0.v201101311130.jar;
E:\Tools\Eclipse\4.20\plugins\org.apache.log4j_1.2.15.v201012070815.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.core.resources_3.15.0.v20210521-0722.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.core.runtime_3.22.0.v20210506-1025.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.emf.common_2.22.0.v20210319-0732.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.emf.ecore_2.24.0.v20210405-0628.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.emf.ecore.edit_2.13.0.v20190822-1451.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.emf.ecore.xmi_2.16.0.v20190528-0725.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.emf.edit_2.16.0.v20190920-0401.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.equinox.app_1.5.100.v20210212-1143.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.equinox.common_3.15.0.v20210518-0604.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.equinox.preferences_3.8.200.v20210212-1143.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.equinox.registry_3.10.200.v20210503-1606.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl_3.16.100.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.common_1.8.700.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.examples.emf.validation.validity_2.15.0.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.examples.standalone_2.7.400.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.pivot_1.15.0.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.uml_5.15.0.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.xtext.base_1.15.0.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.xtext.completeocl_1.15.0.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.xtext.essentialocl_1.15.0.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.xtext.markup_1.15.0.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.xtext.oclinecore_1.15.0.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.ocl.xtext.oclstdlib_1.15.0.v20210609-1442.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.osgi_3.16.300.v20210525-1715.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.osgi.services_3.10.100.v20210324-0936.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.xtext_2.25.0.v20210301-0843.jar;
E:\Tools\Eclipse\4.20\plugins\org.eclipse.xtext.util_2.25.0.v20210301-0843.jar"
org.eclipse.ocl.examples.standalone.StandaloneApplication help
```

Typing the path and version corrected text above is pretty painful so you may prefer to use the wildcard capabilities introduced with Java 6.

```
"E:\Program Files\Java\jdk-11.0.13\bin"\java.exe -classpath "E:\Tools\Eclipse\4.20\plugins\
org.eclipse.ocl.examples.standalone.StandaloneApplication help
```

The java preamble as in the help examples above is shown as ocl for further examples in this section.

7.4.2. Help command

The `help` command shown in the examples above prints out the syntax and some description for the available commands.

```
ocl help
```

7.4.3. Execute command

The `execute` command supports execution of one or more OCL queries reporting parsed queries and/or results in textual or XML form.

A default execution such as

```
ocl execute -query "2+3"
```

just returns a textual serialization of the result to the console.

```
5
```

This may be redirected to a file by the `-output` option, or formatted more deterministically as text or XML by the `-exporter` option and filtered by the `-hide` options. A context (self) may be specified for the evaluation by the `-self` option.

NB. The `execute` command has not been optimized to support performance testing. Consequently any attempts to instrument it will find that the measured time is dominated by JVM warm up time, classpath analysis and OCL environment initialization. The JVM costs can be reduced by specifying multiple queries per `execute`. The classpath costs can be reduced by pruning all unnecessary JARs from the classpath and avoiding all usage of files.

-query ocl-query

The required and optionally repeatable `-query` token specifies one or more OCL queries to be evaluated.

-self self-uri

The optional `-self` token specifies a model element to be used as the context for the OCL queries. The model element may be identified using a fragment URI with an absolute, relative or Eclipse platform resource.

```
-self E:\Development\Chital\Workspace\_OCL_StandaloneExecutionTests__testStandaloneExecutionTests
-self ../git/org.eclipse.ocl/tests/org.eclipse.ocl.examples.xtext.tests/models/standalone/
-self platform:/resource/org.eclipse.ocl.pivot/model/Pivot.ecore#/Boolean
-self platform:/resource/org.eclipse.ocl.pivot/model-gen/Pivot.oclas#/0/pivot/Class
```

If `-self` is omitted, `self` evaluates to null.

-output file-name

The optional `-output` token redirects the command output to the specified file name. If omitted the output is directed to the console.

-exporter none|text|model

The optional `-exporter` token specifies whether there should be no, or textual or XML output. The textual output is suitable for simple values, but can be confusing for complex output such as collections of maps. The XML model output is appropriate for a precise intelligible but verbose output; it is an extension of the Pivot OCL Abstract Syntax comprising a literal expression that evaluates to the result value. An additional `ElementLiteralExp` with a `referredElement` property supports the representation of a value such as `self`. The verbosity of the output can be tamed by the `-hide` tokens.

The text output typically echoes the query and shows the result.

```
Query : 2+3
Result: 5
```

The `Result:` is replaced by an `@Error:` if parsing or execution fails.

If `-hideQuery` is specified, the `Result:` is also hidden.

The XML model output typically echoes the query and shows the result in both textual and XML forms.

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE queries:QueryModel [
<!ENTITY _0 "http://www.eclipse.org/ocl/2015/Library.oclas">
]>
<queries:QueryModel xmi:version="2.0"
  xmlns:xmi="http://www.omg.org/XMI"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:pivot="http://www.eclipse.org/ocl/2015/Pivot"
  xmlns:queries="http://www.eclipse.org/ocl/2022/Queries"
  xsi:schemaLocation="http://www.eclipse.org/ocl/2015/Pivot java://org.eclipse.ocl.pivot.
    http://www.eclipse.org/ocl/2022/Queries java://org.eclipse.ocl.pivot.queries.QueriesP
  xmi:id="AAAAA" name="log_testStandaloneExecution_execute_model_echo_all.xml"
  externalURI="file:/C:/Users/ed/ocl-6-17-0/ws/_OCL_StandaloneExecutionTests__testStanda
    /log_testStandaloneExecution_execute_model_echo_all.xml"
  xmiidVersion="1">
  <results query="2+3" result="5">
    <expression type="pivot:PrimitiveType &_0;#tYtCd">
      <ownedBody xsi:type="pivot:OperationCallExp" name="+
        type="pivot:PrimitiveType &_0;#tYtCd" referredOperation="&_0;#iA+ir">
          <ownedSource xsi:type="pivot:IntegerLiteralExp"
            type="pivot:PrimitiveType &_0;#tYtCd" integerSymbol="2"/>
          <ownedArguments xsi:type="pivot:IntegerLiteralExp"
            type="pivot:PrimitiveType &_0;#tYtCd" integerSymbol="3"/>
        </ownedBody>
        <ownedContext xsi:type="pivot:ParameterVariable" name="self"
          type="pivot:VoidType &_0;#7u3MH"/>
      </expression>
      <value xsi:type="pivot:IntegerLiteralExp" integerSymbol="5"/>
    </results>
  </queries:QueryModel>
```

Additional value/errors explain parsing or execution failures.

-hideASQuery

The `-hideASQuery` suppresses all `results/expression` elements from the XML output.

-hideASResult

The `-hideASResult` suppresses all `results/value` elements from the XML output.

-hideASResult

The `-hideASTypes` suppresses all `type` elements from the XML output, which may give an over 50% saving in file size.

-hideQuery

The `-hideQuery` suppresses all `results/query` attributes from the XML output, or the Query line and `@Result:` prefix from the textual output.

-hideResult

The `-hideResult` suppresses all `results/result` elements from the XML output.

If both `-hideASResult` and `-hideResult` are specified, the evaluation is suppressed so the results indicate just the success or failure of query parsing.

7.4.4. Validate command

The `validate` command supports validation of a model using OCL constraints defined in one or more OCL files.

A minimal command requires a model to validate and some constraints to apply.

```
ocl validate -model Model.ecore -rules Rules.ocl
```

The validation results are sent to the console but may be redirected by the `-output` token using a raw text, HTML or XML formatting according to the `-exporter` selection.

-model file-name

The `-model` token specifies the file name in which the model to be validate is stored.

-rules file-name

The required `-rules` token specifies one or more OCL documents that define constraints to be validated. A text file enumerating many OCL document files may also be specified.

-output file-name

The optional `-output` token redirects the command output to the specified file name. If omitted the output is directed to the console.

-exporter html|model|text

The optional `-exporter` token specifies whether there should be textual or HTML or XML output. The textual output is used as the default.

-using all|java|ocl|uml

A sub-selection of the validation may be specified by choosing just one or more of the embedded Java, OCL or UML constraints.

7.5. Pivot Standalone API Configuration

If you use Eclipse OCL within Eclipse you should find that the appropriate registrations are provided for you automatically by the plugin registration mechanisms.

However if you use Eclipse OCL outside Eclipse, for instance in JUnit tests, you should initialize the appropriate language support using at least one of.

```
org.eclipse.oc1.xtext.completeocl.  
    CompleteOCLStandaloneSetup.doSetup(); // *.ocl  
org.eclipse.oc1.xtext.essentialocl.  
    EssentialOCLStandaloneSetup.doSetup(); // *.essentialocl  
org.eclipse.oc1.xtext.oclinecore.  
    OCLinEcoreStandaloneSetup.doSetup(); // *.ecore, *.oclinecore  
org.eclipse.oc1.xtext.oc1stdlib.  
    OCLstdlibStandaloneSetup.doSetup(); // *.oc1stdlib
```

Failure to initialize language support usually results in one of the following diagnostics.

```
No OCL Standard Library content available  
No 'XXX' type in the OCL Standard Library
```

If you want to use UML models, the optional functionality must be activated.

```
org.eclipse.oc1.pivot.uml.UMLStandaloneSetup.init(); // *.uml
```

The following initializations that were once recommended should happen automatically.

```
org.eclipse.oc1.pivot.OCL.initialize(resourceSet);  
org.eclipse.oc1.pivot.uml.internal.es2as.  
    UML2AS.initialize(resourceSet);  
org.eclipse.oc1.pivot.model.OCLstdlib.install();  
org.eclipse.oc1.pivot.internal.delegate.  
    OCLDelegateDomain.initialize(resourceSet);  
org.eclipse.oc1.pivot.internal.resource.  
    StandaloneProjectMap.getAdapter(resourceSet);
```

These are elaborated on below.

7.5.1. Models

For the Pivot metamodel, the required registrations should be provided by invoking `org.eclipse.oc1.pivot.OCL.initialize(ResourceSet)`. This initialization ensures that `*.ecore` is understood.

If *.uml support is also required, invoke `org.eclipse.oc1.pivot.uml.internal.es2as.UML2AS.initialize(ResourceSet)` as well. This initialization ensures that *.uml is understood and that standard pathmap: locations are resolvable. It also invokes `org.eclipse.uml2.uml.resources.util.UMLResourcesUtil.init(ResourceSet)` to ensure that all Eclipse and OMG UML namespaces and extensions are registered.

7.5.2. OCL Standard Library

If you want to use the default OCL Standard Library you should invoke `org.eclipse.oc1.pivot.model.OCLstdlib.install()` which installs a compiled shareable form of `/org.eclipse.oc1.pivot/model/OCL-2.5.oc1stdlib`.

If you want to use an alternate library examine the code for the standard installation above, and if you want to compile your library examine the `/org.eclipse.oc1.examples.build/src/org/eclipse/ocl/examples/build/GenerateOCLstdlibModel.mwe2` launcher for the `/org.eclipse.oc1.examples.build/src/org/eclipse/ocl/examples/build/xtend/GenerateOCLstdlibXtend.xtend` Xtend template.

Note that the library is extensible and importable so you may import your own library that in turn imports the standard library.

If you neglect to install an OCL Standard Library, you get the error “No OCL Standard Library content available”. If you provide a custom library that fails to meet the minimal requirements of defining the basic library types (e.g. Boolean, Set, Tuple) and methods (e.g. `OclAny::“=”`) you get an error such as “No 'Boolean' type in the OCL Standard Library”.

7.5.3. Pivot Delegates

If you have textual OCL embedded within Ecore models you need to register the EMF delegates so that EMF gets, calls or validates dispatch the embedded OCL to the OCL delegates. The required registrations may be provided by `OCLDelegateDomain.initialize(ResourceSet)` from the `org.eclipse.oc1.pivot.internal.delegate` package.

This may be invoked with a null argument to install the registrations in the global `EPackage.Registry` rather than a specified local registry.

If you neglect to register delegates before generated EMF classes are initialized, you may get an NPE or an error of the form “An exception occurred while delegating evaluation of the ...”

7.5.4. Xtext Parsers

If you want to be able to convert any textual form of OCL to its internal pivot form you need to initialize the relevant parser.

*.ocl Complete OCL documents are initialized by `CompleteOCLStandaloneSetup.doSetup()`.

*.oclinecore metamodels are initialized by `OCLinEcoreStandaloneSetup.doSetup()`

*.oc1stdlib OCL Standard Library definitions are initialized by `OCLstdlibStandaloneSetup.doSetup()`.

*.ecore, *.essentialocl, *.uml files or general use of the query API is initialized by `EssentialOCLStandaloneSetup.doSetup()`.

Each of the above ensures that everything that it requires is installed. The various set ups can be found in one of the following packages:

```
org.eclipse.oc1.xtext.completeocl.  
org.eclipse.oc1.xtext.essentialocl.  
org.eclipse.oc1.xtext.oclinecore.  
org.eclipse.oc1.xtext.oc1stdlib.
```

7.5.5. platform:/plugin and platform:/resource URIs

If you want to be able to use `platform:/plugin/...` or `platform:/resource/...` URIs in a standalone configuration you need to configure the EMF package and URI map registries appropriately.

This is a costly activity that involves scanning the classpath and exploiting the content of any plugin.xml and MANIFEST.MF files that are found.

```
org.eclipse.ocl.pivot.internal.resource.StandaloneProjectMap.getAdapter(resourceSet);
```

creates a StandaloneProjectMap to cache all the scan results, initializes the ResourceSet and installs itself as an adapter on the ResourceSet so that it can be retrieved again if needed. Users are strongly recommended to ensure that a single StandaloneProjectMap is shared by all clients and so avoid incurring the classpath scan cost more than once.

(The StandaloneProjectMap has no OCL-specific functionality; it just cures a major problem in the standalone usage of EMF.)

7.5.6. Classpath

If your standalone environment supports OSGI bundles, as will be the case when you use Eclipse to launch a JUnit test or a transformation, the required plugin dependencies are easily configured in the MANIFEST.MF using JDT quick fixes, or the Manifest editor.

For a totally standalone Java launch, you must identify the exact spelling of each JAR that you require and identify it on your Java classpath. The Eclipse JARs may be found in the plugins folder adjacent to your eclipse.exe. So you may need org.eclipse.ocl.common_1.0.0.v20120516-1543.jar amongst many others. The required JARs can be recursively determined by looking at the Class Not Found Exceptions from the Java launch and locating the plugin with a similar name prefix. This is very tedious and has to be repeated each time you upgrade, so don't do it. Use OSGI. However if you must, the following dependency trees may provide some clues.

The dependency tree for the basic parsing and evaluation is:

```
org.eclipse.ocl.common
  org.eclipse.ocl.pivot
    org.eclipse.ocl.xtext.base
      org.eclipse.ocl.xtext.essentialocl
        org.eclipse.ocl.xtext.completeocl
          org.eclipse.ocl.xtext.oclinecore
            org.eclipse.ocl.xtext.oclstdlib
```

Additionally the UI requires

```
org.eclipse.ocl.common.ui
  org.eclipse.ocl.examples.markup
    org.eclipse.ocl.examples.markup.ui
      org.eclipse.ocl.xtext.essentialocl.ui
        org.eclipse.ocl.xtext.completeocl.ui
          org.eclipse.ocl.xtext.oclinecore.ui
            org.eclipse.ocl.xtext.oclstdlib.ui
              org.eclipse.ocl.examples.xtext.console
                org.eclipse.ocl.pivot.ui
```

You may also need the Xtext, EMF, MWE, Orbit plugins and their dependencies

```
com.google.guava
com.google.inject
org.apache.log4j
org.eclipse.emf.common
  org.eclipse.emf.ecore
    org.eclipse.emf.codegen
      org.eclipse.emf.ecore.xmi
org.eclipse.xtext
  org.eclipse.xtext.common.types
    org.eclipse.xtext.common.types.ui
  org.eclipse.xtext.ui
    org.eclipse.xtext.ui.shared
  org.eclipse.xtext.util
```

7.6. Pivot Thread Safety

OCL is declarative and side effect free and so particularly suitable for execution on multiple threads, provided all shared context is maintained in ways that avoid inter-thread conflicts.

The classic Ecore-based OCL evaluation makes no attempt to guarantee thread safety and some of the more recent functionality involving EMF delegate caches is very suspect for multiple thread usage. So if you want thread safety use the Pivot-based evaluation.

The thread safety of interpreted Pivot evaluation is similarly suspect, however the much faster code generated evaluation is designed for thread safety.

7.6.1. Code Generated Evaluation

The code-generated evaluator is intended to be thread-safe; all shared objects update their caches within relatively fine-grained synchronized regions. However there are a number of class static variables that are not synchronized and might therefore experience at best a redundant multiple initialization and at worst an assumed uniqueness violation. Thread safe code must therefore invoke:

```
org.eclipse.occl.pivot.utilities.ValueUtil.initAllStatics()
```

to ensure eager initialization of unsynchronized class variables. This routine is itself synchronized and so may be safely invoked on all threads, if it is not practical to invoke it solely from just a startup thread.

It is not permissible to modify any part of any OCL object, array or collection.

Application code should not assume that the getter for a protected final field is invoked internally and so should not attempt to modify behavior by overriding it.

7.6.1.1. Design Notes

Loose miscellaneous static fields are initialized by `ValueUtil.initAllStatics()`.

Most non-static fields are `@NonNull` and final eliminating thread hazards. However lazy caches cannot be avoided and these require manual review. Caches shared across OCL invocations use Weak references to avoid leakage.

`ElementIds` are unique and shared across OCL evaluations and so `IdManager` maintains a hierarchy of synchronized caches for distinct forms of `ElementId`. Some `ElementIds` such as `TemplateParameterId` are subject to two-phase construction (constructor followed by `install`). It is assumed that a half-constructed `ElementId` will not be made visible to other threads.

Values are optionally shared and so `ValueUtil` has a few loose statics for simple values such as `FALSE`, and a synchronized cache for integers in the range -256 to 1024.

`EvaluatorIterationManagers` do not currently permit forking of iterations to multiple threads and may malfunction if application code does so.

7.6.2. Interpreted Evaluation

This is not considered thread-safe. Superficial consideration suggests that the EMF delegate dispatching in particular needs careful attention.

7.6.3. OCL Analysis

The Xtext-based functionality is only thread-safe in so far as Xtext imposes strict main/worker thread disciplines. It is very unlikely that activating additional worker threads will give satisfactory results.

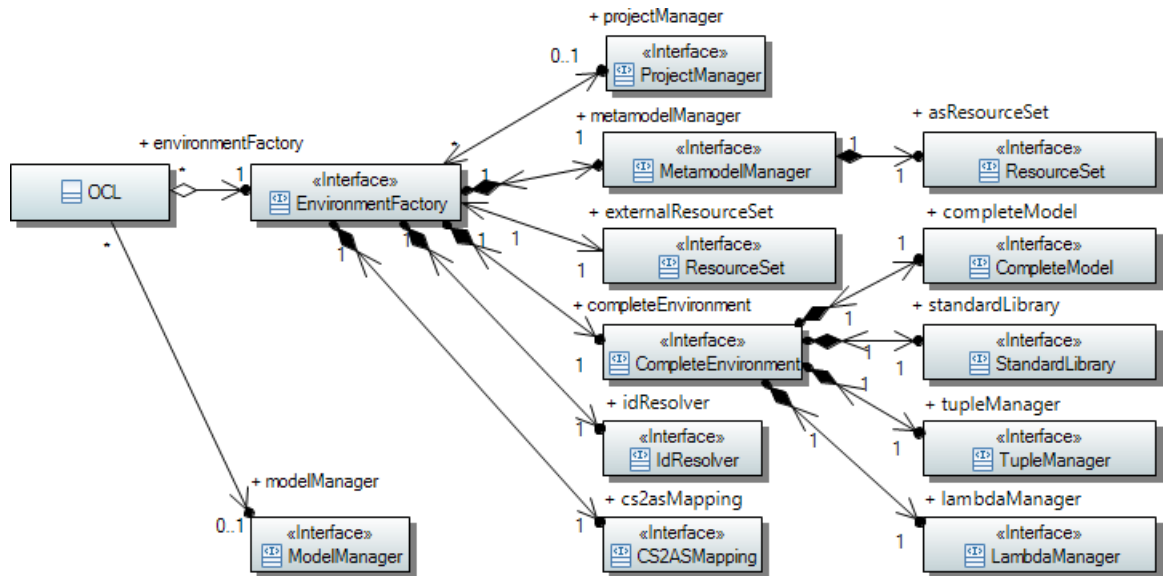
7.7. Parsing Constraints and Queries

This section may be contrasted with the corresponding [Parsing Constraints and Queries](#) for the Ecore binding to see examples of the changes needed to migrate from the Ecore binding to the Pivot binding.

The OCL parser provides two APIs for parsing constraint and query expressions using the [OCL](#) Facade.

7.7.1. The OCL Facade

The [OCL](#) class provides both a Facade and a Handle for the various objects that support different aspects of OCL parsing and evaluation.



The OCL class is a simple type.

There is no need for the many template parameters that parameterize the equivalent OCL class for the Ecore/UML bindings.

Behind the scenes, OCL instances share an `EnvironmentFactory` that creates and owns the primary support objects and provides an API to create these and other important artefacts.

The `ProjectManager` supports the discovery of metamodels to resolve URI references.

- `OCL.NO_PROJECTS` is a very lightweight `ProjectManager` supporting access only to those models known to the external `ResourceSet`.
- `OCL.CLASS_PATH` is a heavyweight `ProjectManager` supporting access to models registered with plugins on the Java classpath.

The external `ResourceSet` is a potentially user-supplied `ResourceSet` to manage the external metamodels such as Ecore or UML models or Xtext Concrete Syntax models.

The external metamodels are converted to the normalized Pivot representation under control of the `MetamodelManager` which maintains the normalized representation in an Abstract Syntax as `ResourceSet`.

A merged view of the normalized metamodels is provided by the `CompleteModel` under control of the `CompleteEnvironment` that also supervises a `StandardLibrary`, `TupleManager` and `LambdaManager` for more specialized aspects of the merge. The `CompleteEnvironment` API supports synthesis of Collection and Map types.

Access to the normalized representations from diverse contexts, in particular from generated Java code, requires an ability to discover the merged representation of e.g. the **Boolean** type from the minimal concept of a **Boolean** type-id. The `IdResolver` performs the id-to-object conversion.

When Pivot models are derived from Xtext source text, a Concrete Syntax representation is converted to the normalized Abstract Syntax. The `CS2ASMapping` tracks the equivalences in this conversion so that tooling can reverse the navigation to discover appropriate text to highlight in a source editor for an underlying model element.

The OCL handle may also reference a `ModelManager`. This is used to identify objects during evaluation of operations such as `allInstances()`.

7.7.2. OCL Handles

The static factory methods of the OCL class are used to create new instances. These are suitable for parsing OCL constraints on any Ecore or UML model and evaluating them on instances of the model.

If you already have models loaded in a `ResourceSet`, you may activate OCL functionality by creating a new OCL instance specifying that OCL should exploit that `ResourceSet`.

```
// create an OCL instance exploiting an externally supplied ResourceSet
ResourceSet myResourceSet = new ResourceSetImpl();
/* ... */
OCL ocl = OCL.newInstance(myResourceSet);
```

[\[Text for cut and paste\]](#)

Alternatively you may leave the OCL instance to create the ResourceSet.

```
// create an OCL instance exploiting registered models on the Java classpath
OCL ocl = OCL.newInstance(ProjectManager.CLASS_PATH);
ResourceSet resourceSet = ocl.getResourceSet();
```

[\[Text for cut and paste\]](#)

It is good practice to invoke `dispose()` explicitly to release all OCL-related Resource references promptly rather than rely on garbage collection.

```
// ensure that resources are released
ocl.dispose();
```

[\[Text for cut and paste\]](#)

When repeated parsing and evaluation occurs on a model, it is very beneficial to re-use rather than re-create the underlying OCL support objects. This is easily achieved in simple scenarios by re-using the OCL instance directly. In more complex scenarios the handle behavior of an OCL instance can be exploited to create multiple handles for diverse usages each of which is disposed when complete. The dispose of the underlying OCL support occurs when the final handle disposes.

7.7.3. Class Context

Parsing an OCL expression requires a classifier to define the type of `self`. This is passed to `createInvariant()`, which enforces a Boolean result type, or to `createQuery()`, which allows any result type.

The result of parsing a query expression or a constraint is an [ExpressionInOCL](#), an instance of the [Abstract Syntax Model](#).

```
EClass contextEClass = EXTLibraryPackage.Literals.LIBRARY;
ExpressionInOCL invariant = ocl.createInvariant(contextEClass,
    "books->forAll(b1, b2 | b1 <> b2 implies b1.title <> b2.title)");
ExpressionInOCL query = ocl.createQuery(contextEClass,
    "books->collect(b : Book | b.category)->asSet()");
```

[\[Text for cut and paste\]](#)

7.7.4. Operation and Property Contexts

In the case of constraints on operations or properties, the context consists of two elements: the constrained operation/property and a classifier that defines the type of `self` while parsing the OCL. The classifier is deduced as the container of the operation or property. These can be constrained as follows:

```
// define a post-condition specifying the value of EModelElement::getEAnnotation(EString).
// This operation environment includes variables representing the operation
// parameters (in this case, only "source : String") and the operation result
EOperation contextEOperation = NameUtil.getENamedElement(
    EcorePackage.Literals.EMODEL_ELEMENT.getEOperations(), "getEAnnotation");
ExpressionInOCL body = ocl.createPostcondition(contextEOperation,
    "result = self.eAnnotations->any(ann | ann.source = source)");

// define a derivation constraint for the EReference::eReferenceType property
EReference contextEReference = EcorePackage.Literals.EREFERENCE__REFERENCE_TYPE;
ExpressionInOCL derive = ocl.createQuery(contextEReference,
    "self.eType->any(true).oclAsType(EClass)");
```

[\[Text for cut and paste\]](#)

7.7.5. Errors

The preceding examples are simplified by the assumption that there will be no parsing errors. In practice `ParserExceptions` should be caught and handled in an appropriate way by the application.

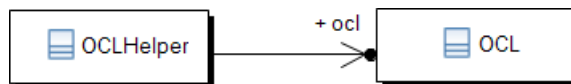

```
// syntax errors such as bad text or semantic errors such as bad names throw a ParseException
try {
    ocl.createInvariant(contextEClass, "books->forall(true)");
}
catch (ParseException e) {
    /*e.printStackTrace();*/
}
```

[\[Text for cut and paste\]](#)

7.7.6. The OCL Helper

The Ecore/UML bindings for OCL provide an `OCLHelper` class to assist in creating queries. A similar class is available with the Pivot binding for compatibility although it is largely redundant since the OCL class can be used directly. An `OCLHelper` will give a small performance benefit for multiple parses but not as much as direct use of an underlying `ParserContext` or a structuring multiple queries in a Complete OCL document.

From an OCL instance, we can create a helper object with which to parse constraints and additional operation/attribute definitions.



The `OCLHelper` is primarily designed for parsing constraints and query expressions embedded in models, providing the following API for that purpose:

- * `createQuery()`: parses a query expression
- * `createConstraint()`: parses a constraint of a given `ConstraintKind`
- * `createInvariant()`: convenience for invariant constraints
- * `createPrecondition()`: convenience for pre-condition constraints
- * `createPostcondition()`: convenience for post-condition constraints
- * `createBodyCondition()`: convenience for body conditions
- * `createDerivedValueExpression()`: convenience for attribute derived values

Different kinds of constraints require different context environments. The `setContext()`, `setOperationContext()`, and `setAttributeContext()` methods create the appropriate nested `Environment`s in the host OCL instance's root environment.

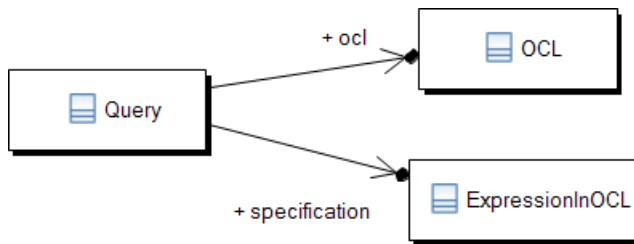
The Ecore/UML bindings variously produce a `Constraint` or `OCLExpression` result. A `Constraint` has too much context and an `OCLExpression` too little. An `ExpressionInOCL` produced by the Pivot binding is just right.

7.8. Evaluating Constraints and Queries

In [Parsing Constraints](#), we saw how to use the OCL Facade to parse a textual OCL constraint or query expressions to give its `ExpressionInOCL` compiled representation. Parsing constraints is interesting, but evaluating them using the [Query](#) API is much more useful.

7.8.1. The OCL Query

The [Query](#) class wraps the minimal `ExpressionInOCL` parse result to provide evaluation capabilities.



The Query encapsulates an [EvaluationEnvironment](#) providing the run-time values of context variables to the OCL interpreter. These context variables are set and retrieved using the following methods:

- `add(TypedElement, Object)`: adds a TypedElement-to-value binding
- `replace(TypedElement, Object)`: replaces an existing binding
- `remove(TypedElement)`: removes a binding
- `getValueOf(TypedElement)`: obtains a binding value

.bq The Ecore/UML binding of Eclipse OCL used String rather than TypedElement to support name-to-value bindings. The use of TypedElement rather than String avoids whereby the same name refers to multiple Variables depending on context. .p

The context variables of primary interest are `self` and, in operation constraints, the variables corresponding to its parameters.

An important consideration for OCL evaluation is the `allInstances()` operation, which obtains the entire extent of a classifier. For data types, this is a simple problem: the extent of an Enumeration is well defined and the extents of other kinds of DataTypes are undefined. For Class extents, the OCL handle references a [ModelManager](#) that provides access to the user's models. The default [PivotModelManager](#) lazily computes the extent of a class from the EMF ResourceSet containing the context element of the evaluation.

So, after optionally setting values of context variables (other than `self`; the Query takes care of this) and an extent map, simply construct a query and use it to evaluate the expression or check the constraint:

```

OCL ocl = OCL.newInstance(OCL.CLASS_PATH);
ResourceSet resourceSet = ocl.getResourceSet();

ExpressionInOCL invariant = ocl.createInvariant(EXTLibraryPackage.Literals.LIBRARY,
    "books->forAll(b1, b2 | b1 <> b2 implies b1.title <> b2.title)");
ExpressionInOCL query = ocl.createQuery(EXTLibraryPackage.Literals.LIBRARY,
    "books->collect(b : Book | b.category)->asSet()");

// create a Query to evaluate our query expression
Query queryEval = ocl.createQuery(query);

// create another to check our constraint
Query constraintEval = ocl.createQuery(invariant);

List<Library> libraries = getLibraries(resourceSet); // hypothetical source of libraries

// only print the set of book categories for valid libraries
for (Library next : libraries) {
    if (constraintEval.checkEcore(next)) {
        // the OCL result type of our query expression is Set(BookCategory)
        @SuppressWarnings("unchecked")
        Set<BookCategory> categories = (Set<BookCategory>) queryEval.evaluateUnboxed(next);

        debugPrintf("%s: %s\n", next.getName(), categories);
    }
}

```

[\[Text for cut and paste\]](#)

7.8.2. Object representations

The example above uses `evaluateUnboxed()` so that the return value is unboxed and so compatible with the Classic Ecore/UML OCL binding.

The Pivot binding of OCL supports three distinct Java representations.

- boxed for internal use
- unboxed for traditional API compatibility
- Ecore for Ecore API compatibility

OCL	Unboxed	Ecore	Boxed
Boolean	Boolean	Boolean	Boolean
String	String	String	String
Integer	Integer/Long/ BigDecimal	Integer/Long/ BigDecimal	IntegerValue
Real	Float/Double	Float/Double	RealValue
Object	EObject	EObject	EObject
Type	EClassifier	EClassifier	TypeValue
null	null	null	null
invalid	InvalidValueException	InvalidValueException	InvalidValueException
Collection	Collection	EList	CollectionValue
Bag	Bag	EList	BagValue
Sequence	List	EList	SequenceValue
OrderedSet	OrderedSet	EList	OrderedSetValue
Set	Set	EList	SetValue

The boxed representation is used wherever the Java semantics of `Object.equals(Object)` is different to the OCL semantics of `OclAny::_=''(OclAny)`.

The unboxed representation is used when a similar representation to the Ecore/UML binding is required.

The Ecore representation is used for all interchange with Ecore `EStructuralFeature` values or `EOperation` arguments and returns.

7.8.3. Multiple Evaluations

One of the advantages of the Query API is that a query's evaluation environment can be reused for multiple evaluations, as above. The extent of any classifier is only computed once. For convenience, however, in situations where only a single evaluation is required, the OCL class provides shortcuts:

```
// check a single library
Library lib = getLibrary(resourceSet); // hypothetical source of a library

// check whether it satisfies the constraint
debugPrintf("%s valid: %b\n", lib.getName(), ocl.check(lib, invariant));
```

[\[Text for cut and paste\]](#)

7.8.4. Succinct Evaluations

The Query API also provides methods that work on multiple elements. The first example, above, could be written more succinctly as:

```
// only print the set of book categories for valid libraries
for (Library next : constraintEval.selectEcore(libraries)) {
    @SuppressWarnings("unchecked")
    Set<BookCategory> categories = (Set<BookCategory>) queryEval.evaluateUnboxed(next);

    debugPrintf("%s: %s\n", next.getName(), categories);
}
```

[\[Text for cut and paste\]](#)

7.9. Parsing OCL Documents

As we saw in the [Parsing Constraints and Queries](#) topic, the [OCL](#) Facade provides an API for parsing OCL expressions embedded in models as constraints.

The OCL specification defines a Complete OCL text document with which a UML (or Ecore) metamodel may be completed by providing many complementary constraints and expressions. In this case, the concrete syntax for context declarations indicates the context of constraints, equivalent to their placement in models.

As an example, consider the following Complete OCL document:

```
import 'http://org.eclipse/emf/examples/library/extlibrary.ecore/1.0.0'

package extlibrary

context Library
-- get all books with a title in a library and its branches (recursively)
def: getBooks(title : String) : Set(Book) =
    books->select(b | b.title = title)->asSet()->union(
        branches.getBooks(title)->asSet())

context Book
-- the library containing a book
def: library : Library = Library.allInstances()->any(books->includes(self))

-- book titles are unique within their library branch (and its sub-branches)
inv unique_title: not library.ocIsUndefined() implies
    library.getBooks(title) = Set{self}

endpackage
```

[\[Text for cut and paste\]](#)

7.9.1. The OCL Input

The Pivot binding provides a UML-aligned representation and so a Complete OCL document can be parsed to provide a similar Resource to that derived from a UML or Ecore metamodel. A Root contains a Model which contains Packages and Classes. The complementing Resource from the Complete OCL document is independent of the similarly structured complemented Resource of the completed metamodel.

The Pivot binding uses an Xtext parser with a UML-aligned output. The input text is therefore specified by a URI and loaded by the Xtext parser to create a Concrete Syntax Resource. This may then be converted to the Pivot Abstract Syntax Resource. The Abstract Syntax Resource has a conventional Model, Package, Class, Operation hierarchy in order to provide a coherent composition context for the Constraints.

The elements of the independent complementing and complemented Resources are merged within CompleteClasses and CompletePackages of the CompleteModel managed behind the OCL facade.

There are therefore two Class objects named **Library**, one for each Resource. The objects are distinct in so far as they belong to different resources, which can be separately serialized, and in so far as they may appear distinct to OCL expressions that use reflective access. However they are logically merged and the CompleteEnvironment provides utility methods that allow the multiple objects to be accessed as a merged object.

The Ecore binding provided an OCLInput class to supervise the OCL source text, and the result of parsing the document was a List<Constraint>.p.

The Complete OCL document is a textual Resource with an associated text tooling. The OCL facade provides an API to load a Resource from a given URI.

```
// Create an EPackage.Registry for just the EXTLibraryPackage
EPackage.Registry registry = new EPackageRegistryImpl();
registry.put(EXTLibraryPackage.eNS_URI, EXTLibraryPackage.eINSTANCE);

// Create an OCL that creates a ResourceSet using the minimal EPackage.Registry
OCL ocl = OCL.newInstance(registry);
ResourceSet resourceSet = ocl.getResourceSet();

// get an OCL text file via some hypothetical API
URI uri = getInputURI("/model/parsingDocumentsExample.ocl");

// parse the contents as an OCL document
Resource asResource = ocl.parse(uri);
```

[\[Text for cut and paste\]](#)

7.9.2. Traversing the Constraints

The parsed resource can be traversed in the same way as other EMF resources.

```
// accumulate the document constraints in constraintMap and print all constraints
Map<String, ExpressionInOCL> constraintMap = new HashMap<String, ExpressionInOCL>();
for (TreeIterator<EObject> tit = asResource.getAllContents(); tit.hasNext(); ) {
    EObject next = tit.next();
    if (next instanceof Constraint) {
        Constraint constraint = (Constraint)next;
        ExpressionInOCL expressionInOCL = ocl.getSpecification(constraint);
        if (expressionInOCL != null) {
            String name = constraint.getName();
            if (name != null) {
                constraintMap.put(name, expressionInOCL);
                debugPrintf("%s: %s\n", name,
                    expressionInOCL.getOwnedBody());
            }
        }
    }
}
```

[\[Text for cut and paste\]](#)

7.9.3. Accessing the Constraints

The contents of the Complete OCL document contribute to a CompleteModel that merges all the contributions. The contributions can therefore be used as if defined in a primary metamodel.

```
Library library = getLibrary(resourceSet); // get library from a hypothetical source

// use the constraints defined in the OCL document

// use getBooks() from the document in another query to find a book
ExpressionInOCL expression = ocl.createQuery(EXTLibraryPackage.Literals.LIBRARY,
    "getBooks('Bleak House')->asSequence()->first()");

Book book = (Book) ocl.evaluate(library, expression);
debugPrintf("Got book: %s\n", book);

// use the unique_title constraint to validate the book
boolean isValid = ocl.check(book, constraintMap.get("unique_title"));
debugPrintf("Validate book: %b\n", isValid);
```

[\[Text for cut and paste\]](#)

7.9.4. Using the Constraints to Validate a Model

The standard EMF validation makes use of an EValidatorRegistry that maps the URI of an EPackage to the derived EValidator that provides the constraints applicable to the EPackage. If we want to exploit additional constraints defined in a Complete OCL document, we must extend the underlying EValidator. The ComposedValidator enables multiple EValidator to be

composed and to behave as a single EValidator. `ComposedEValidator.install()` replaces the single EValidator by a composite initially containing just the replaced EValidator. A `CompleteOCLEObjectValidator` provides the additional validation of the given uri and EPackage.

```
// Register an additional EValidator for the Complete OCL document constraints
ComposedEValidator newEValidator = ComposedEValidator.install(EXTLibraryPackage.eINSTANCE);
newEValidator.addChild(new CompleteOCLEObjectValidator(
    EXTLibraryPackage.eINSTANCE, uri, ocl.getEnvironmentFactory()));

// Validate the entire Resource containing the library
Resource resource = library.eResource();
MyDiagnostician diagnostician = new MyDiagnostician();
Diagnostic diagnostics = diagnostician.validate(resource);

// Print the diagnostics
if (diagnostics.getSeverity() != Diagnostic.OK) {
    String formattedDiagnostics = PivotUtil.formatDiagnostics(diagnostics, "\n");
    debugPrintf("Validation: %s\n", formattedDiagnostics);
}
```

[\[Text for cut and paste\]](#)

The standard Diagnostician does not directly support validation of a Resource. `MyDiagnostician` remedies this deficiency and provides a `SubstitutionLabelProvider` that provides slightly better labels within OCL diagnostics.

```
public class MyDiagnostician extends Diagnostician
{
    @Override
    public Map<Object, Object> createDefaultContext() {
        Map<Object, Object> context = super.createDefaultContext();
        context.put(EValidator.SubstitutionLabelProvider.class,
            new LabelSubstitutionLabelProvider());
        return context;
    }

    public BasicDiagnostic createDefaultDiagnostic(Resource resource) {
        return new BasicDiagnostic(EObjectValidator.DIAGNOSTIC_SOURCE, 0,
            EMFEditUIPlugin.INSTANCE.getString(
                "_UI_DiagnosisOfNoObjects_message", new String[]{"1"}),
            new Object[]{resource});
    }

    public Diagnostic validate(Resource resource) {
        BasicDiagnostic diagnostics = createDefaultDiagnostic(resource);
        Map<Object, Object> context = createDefaultContext();
        for (EObject eObject : resource.getContents()) {
            validate(eObject, diagnostics, context);
        }
        return diagnostics;
    }
}
```

[\[Text for cut and paste\]](#)

The source for these examples may be found in the `org.eclipse.ocl.examples.xtext.tests` plugin in `model/parsingDocumentsExample.ocl` and in `src/org/eclipse/ocl/examples/test/xtext/PivotDocumentationExamples.java`.

7.10. OCL Relationship to Metamodels

The Pivot-based OCL implementation provides indirect support for models defined using either the Ecore or the UML metamodel (as implemented by the Eclipse EMF and UML2 projects), and an [extensibility API](#) that allows additional EMF-based metamodels to be plugged in. The indirection through the UML-aligned Pivot metamodel makes OMG compliance much easier and decouples the implementation from particular bindings. Support for an alternate concrete metamodel representation is therefore comparatively simple.

The OCL API implements support for different target metamodels via the [EnvironmentFactory](#) interface. An implementation of this interface binds the metamodel's metaclasses to the generic type parameters of the [OCL](#) class. The metamodel-specific [Environment](#) implementation constructed by this factory implements the reflection capability required by OCL to discover the elements of the model being constrained and the relationships between them.

7.10.1. The Pivot Metamodel Binding

The preliminary OCL binding for the Pivot metamodel has been provided since the Indigo release by the `org.eclipse.ocl.examples.pivot` plug-in. This has been promoted to `org.eclipse.ocl.pivot` in the Mars release.

The Pivot metamodel prototypes resolutions of the following problems in the OCL 2.4 specification

- UML-alignment
- OCL Standard Library model
- XMI interchange
- Complete OCL implementability

The support for an OCL Standard Library model enables large parts of the OCL specification to be captured by models. This makes the behavior mutable and extensible through definition of alternate or extended library models. (The corresponding Ecore and UML bindings have an Ecore representation of the library but much of its functionality is directly implemented and so immutable.)

The Pivot metamodel is auto-generated by a package merge of

- selected parts of the UML metamodel
- additional OCL packages
- implementation-specific packages

The implementation-specific packages provide

- Visitors throughout the entire metamodel (OCL **and** MOF)
- Ecore extensions

It is anticipated that the performance advantages of a uniform compliant metamodel, without the complexities of the templates from the `org.eclipse.ocl` plugin, will outweigh the initial overhead of converting an Ecore or UML metamodel to Pivot form. Once this has been demonstrated, the direct Ecore and UML metamodels will be deprecated.

The Pivot binding is provided by the [PivotEnvironmentFactory](#) class. For compatibility, as a default, the Pivot environment uses the static `EPackage` registry to look up package names. This default is deprecated since the domain of `allInstances()` may be very large when many models are registered. It should therefore be supplied with an alternative package registry (for example, one local to a `ResourceSet`) for relevant metamodels. The static registry is then used as a backup for package lookups, but not for `allInstances()`. The Pivot environment factory maintains the Pivot models associated with

- Ecore metamodels in use
- UML metamodels in use
- Library models in use
- Concrete Syntax source models
 - `OCLinEcore` (rather than Ecore)
 - Complete OCL
 - OCL Standard Library

The Pivot binding for OCL will provide the full capabilities of the UML binding, but at present only the Ecore facilities have been tested. The Pivot binding has the additional ability to support extensions to the library.

For applications that work exclusively with the Pivot binding for OCL, the `org.eclipse.ocl.pivot` package defines an OCL class that provides similar facilities to the corresponding Ecore and UML binding equivalents.

The Pivot metamodel is used by Eclipse OCL for:

- all Xtext editors; editing, parsing, analysis and validation
- the Xtext OCL console; editor and evaluation
- EMF delegates using the <http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot> URI
- explicit use of the Pivot metamodel from Java

The Pivot metamodel is not used by Eclipse OCL for:

- OCL console editing and evaluation
- EMF delegates using the <http://www.eclipse.org/emf/2002/Ecore/OCL/LPG> URI
- [Impact Analyzer](#).
- explicit use of the Ecore or UML bindings from Java

EMF delegates using the <http://www.eclipse.org/emf/2002/Ecore/OCL> virtual URI are redirected to either <http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot> or <http://www.eclipse.org/emf/2002/Ecore/OCL/LPG> by the setting of the “Executor targeted by the default OCL delegate” preference setting, which defaults to <http://www.eclipse.org/emf/2002/Ecore/OCL/LPG> for compatibility.

Note that the Indigo and Juno OCLinEcore editor uses the <http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot> URI and so uses the [Pivot Evaluator](#), whereas the Helios OCLinEcore editor used the <http://www.eclipse.org/emf/2002/Ecore/OCL> URI and so the Ecore evaluator. A file using the <http://www.eclipse.org/emf/2002/Ecore/OCL> URI will automatically be upgraded to the <http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot> URI when edited using the Indigo or Juno OCLinEcore editors.

In Kepler, Luna and Mars, the OCLinEcore editor preserves any existing delegate URI selection. The new “Preferred executor requested for OCL constraints” preference determines the URI when no previous setting is available. This defaults to <http://www.eclipse.org/emf/2002/Ecore/OCL/Pivot> for backwards compatibility.

7.11. Ids

The `ElementId` hierarchy provides the simplest base level of metamodel representation. The `ElementIds` feature

- identity
- uniqueness
- thread-safety
- predictability
- hashcodes

Every primary hierarchical metamodel object such as a `Package`, `Type`, `Operation` or `Property` has a globally unique identity established by the package-class-feature path.

Auxiliary metamodel object such as a `TemplateParameter`, `TuplePart` or `List-of-Parameter` have a locally unique identity supporting fast matching of tuples or single lookup for operation parameters.

7.11.1. Id Equality

`ElementIds` are unique, whereas metamodel elements are not; there may be many meta-models in many applications all with their own `Boolean PrimitiveTypeImpl` instances. The equivalence of these elements may be established rapidly since each returns the same `TypeId.BOOLEAN` singleton from `PrimitiveTypeImpl.getTypeId()`.

7.11.2. IdManager

Uniqueness of `ElementIds` is enforced by the various `getXxxId` methods of the single `IdManager.INSTANCE`. These methods are synchronized to ensure thread safety. Child hierarchical objects are similarly mediated by their parent.

7.11.3. CollectionTypeId

`CollectionTypeIds` are a degenerate form of specialization/generalization with a single template parameter. The template parameter is declared explicitly in generalizations.

7.11.4. TupleTypeid

TupleTypes are self-contained, that is all external template parameter references with the part types are bindings of a specialized tuple type whose generalization replaces those external references by the template parameters of the generalization.

For instance given a declaration

```
Set(A)::op(B)() : Tuple(a:A, b:Bag(B), c:B)
```

`Tuple(a:A, b:Bag(B), c:B)` is the (A,B) specialization of the `Tuple(T1,T2)(a:T1,b:Bag(T2),c:T2)` generalization.

7.11.5. LambdaTypeid

LambdaTypes are self-contained in the same way as tuples with specializations of generalizations.

7.11.6. ParameterIds

A `ParameterIds` identifies an ordered list of typeid suitable for identifying an operation's parameter list by a single object and hashcode.

A `ParameterIds` has no knowledge of its parent `Operation` and so `ParameterIds` are reused whenever the typeid list arises. Note that collection typeIds are always `collectionTypeIds`, so there is no need for multiplicities. The residual optional existence is not subject to overloading and is ignored in `ParameterIds`.

LambdaTypes reuse `ParameterIds` to capture the extended type list comprising the typeids of context-type, result-type then parameter-types.

7.11.7. TuplePartId

A `TuplePartId` identifies a part of a `Tuple`. It has a name, typeid and index. The index is the part position in the set of parts in a parent tuple alphabetically sorted by name. It provides efficient access to a slot position in a tuple representation.

A `TuplePartId` has no knowledge of its parent `Tuple` and so `TuplePartIds` are reused whenever the same combination of name, typeid and index arise.

7.11.8. TemplateParameterId

A `TemplateParameterId` identifies a template parameter in the ordered list of template parameters in a parent templateable element. It has just an index in the parent list. For debugging purposes a `TemplateParameterId` has a name such as \$0 or \$1.

A `TemplateParameterId` has no knowledge of its parent templateable element and so only a couple of `TemplateParameterIds` ever exist. Three are statically defined as `TypeId.T_1`, `T_2`, `T_3`.

`TemplateParameterId` has no knowledge of whether it is a type or value parameter. Pragmatically a `TemplateParameterId` extends a `TypeId`. (This design decision may need revision.)

7.11.9. Code Generation

Since the `ElementIds` are predictable and unique, code generation can assign them for computation once in static variables so that large parts of the costs of model element location can be performed at compile time. At class load time it is only necessary to construct/share the `ElementId` object. At run-time the `ElementId` provides a hashcode to provide rapid lookup.

Chapter 8. API Reference

8.1. Javadoc

The Javadoc for Eclipse OCL 2020-06 (6.12.0) APIs may be found by following the [OCL 2020-06 \(6.12.0\) API Reference](#) link.

8.2. Extension points

There is one extension point, but it is no longer clear that it has any useful functionality. Please consider it deprecated.

[Extension Points Reference](#).

Chapter 9. Building the OCL Project

This section contains some details on the way in which the OCL project is built. This should only be of interest to users creating extension of the project.

The interactive build facilities may be found in the `org.eclipse.ocl.examples.build` plugin. The “Generate OCL All” launch invokes all the sub-generators for models and editors.

The documentation build uses the “OCL Documentation” Ant external launch; see `org.eclipse.ocl.doc/libs/Readme.txt` for prerequisites. The build populates the `help/html/manual` folders whose content should be committed to GIT to ensure that the regular build uses the updated documentation. Publishing `ocl.pdf` is an option that can be selected when performing a final Jenkins release build.

The Javadoc build uses the “Run OCL Javadoc using Ant directly” Ant external launch. The build populates the `javadoc` folder which should not be committed to GIT. Generating and publishing the javadoc is an option that can be selected when performing a final Jenkins release build.

The distribution build facilities uses the `Maven pom.xml` in the `org.eclipse.ocl.releng.tycho` plugin. The “Build OCL Distribution - Nightly” replicates the Jenkins build locally differing only the absence of the final signing. The build populates the `org.eclipse.ocl.releng.build-site` plugin

9.1. OOMPH

There is an `org.eclipse.ocl.oomph/setups/ocl.setup` that users may find helpful to create a development workspace, but the setup is not used by the developers and so may be stale.

9.2. Maven Central and `repo.eclipse.org`

Eclipse projects, such as OCL, use Maven in the form of Tycho that adds support for Eclipse working practices such as the P2 repositories.

There is no official support for provision of releases via Maven central and few projects provide it. When you find an Eclipse project on Maven Central be aware that it was probably provided by a well-meaning but misguided Maven user without knowledge or approval of the Eclipse project. It is almost certain that that user will neglect to provide updates and so it is just about guaranteed that what you find is very stale.

Eclipse provides an `http://repo.eclipse.org` for use by Maven users and some projects publish there. However there is no standard support for `http://repo.eclipse.org` and it appears that this approach is going obsolete. Attempts to offer OCL via `http://repo.eclipse.org` have foundered.

9.3. Maven and Gradle

Some enthusiastic users have succeeded in using Maven directly and even Gradle. Anyone interested is recommended to read

[Maven and Complete OCL usage](#)

[Gradle usage](#)

Further contributions from users are welcome.

9.4. GenModel GenAnnotations

The automated generation of models that form part of the OCL tooling exploits a number of GenAnnotations to influence the auto-generated code.

9.4.1. `http://www.eclipse.org/OCL/GenModel` GenAnnotation Source

```
<genAnnotations source="http://www.eclipse.org/OCL/GenModel">
  <details key="Use Null Annotations" value="true"/>
</genAnnotations>
```

This GenAnnotation is also used by regular OCL code generation

9.4.1.1. Use Delegates

If the *Use Delegates* key is present and has a *true* value `genModel` will generate code for OCL expressions that delegates to the run-time interpreter, rather than generating Java code.

9.4.1.2. Use Null Annotations

If the *Use Null Annotations* key is present and has a *true* value the generated code will have *@NonNull* and *@NotNull* annotations.

9.4.2. <http://www.eclipse.org/OCL/GenModel/ToString>

```
<genAnnotations source="http://www.eclipse.org/OCL/GenModel/ToString">
  <details key="org.eclipse.ocl.examples.codegen.cgmodel.CGElement"
    value="return &lt;%org.eclipse.ocl.examples.codegen.analyzer.CG2StringVisitor%>.toString(this);"/>
</genAnnotations>
```

By default EMF generates a *toString()* method that identifies all attribute values. This cannot be suppressed, only circumvented.

If the <http://www.eclipse.org/OCL/GenModel/ToString> GenAnnotation is present the default is changed to use an inherited implementation, which must be specified somewhere.

Specific implementations of *toString* may be provided as the values of detail entries whose key is the qualified name of the interface class. Imports may be encoded with the implementation by enclosing the fully qualified name in *<% . . . %>*.

9.4.3. <http://www.eclipse.org/OCL/GenModel/Visitor>

```
<genAnnotations source="http://www.eclipse.org/OCL/GenModel/Visitor">
  <details key="Root Visitor Class" value="org.eclipse.ocl.pivot.util.Visitor"/>
  <details key="Derived Visitor Class" value="org.eclipse.ocl.pivot.util.Visitor"/>
  <details key="Visitable Interface" value="org.eclipse.ocl.pivot.util.Visitable"/>
  <details key="Visitable Classes" value="org.eclipse.ocl.pivot.Element"/>
</genAnnotations>
```

The *accept* method for an hierarchical visitor pattern may be woven into the code using the <http://www.eclipse.org/OCL/GenModel/Visitor> genAnnotation.

The implementation for class XXXX in the root package is

```
@Nullable R accept(@NonNull RootVisitorClass<R> visitor) {
  return visitor.visitXXXX(this);
}
```

The implementation for class XXXX in the derived package is

```
@Nullable R accept(@NonNull RootVisitorClass<R> visitor) {
  return (R) (DerivedVisitorClass<?>)visitor.visitXXXX(this);
}
```

The direct cast to the derived type assumes that the caller has ensured that the visitor in use supports the visitor interfaces for all objects in use.

The null annotations or omitted unless null annotations have been enabled.

9.4.3.1. Root Visitor Class

The fully qualified name of the visitor class must be specified as the value of the *Root Visitor Class* detail. This class defines the argument type of the *accept* method.

9.4.3.2. Derived Visitor Class

The fully qualified name of the derived visitor class must be specified as the value of the *Derived Visitor Class* detail. This detail may be omitted for the root package.

9.4.3.3. Visitable Interface

The fully qualified name of the visitable interface must be specified as the value of the *Visitable Interface* detail. It's mandatory for the root package.

9.4.3.4. Visitable Classes

An *@Override* annotation is generated for all implementations. This leads to an error where the implementation is not an override. The space-separated fully qualified names of all classes for which the *accept* is not an override must be specified as the value of the *Visitable Classes* detail.

9.4.3.5. Implementation Details

The support for accept is in `templates/model/Class/insert.javajetinc` where the appropriate code is generated into the implementation file with help from `OCLBuildGenModelUtil`.

9.4.4. <http://www.eclipse.org/OCL/GenModel/CopyAndPaste>

```
<genAnnotations source="http://www.eclipse.org/OCL/GenModel/CopyAndPaste">
  <details key="org.eclipse.oc1.xtext.markup.FigureElement"
    value="model/FigureElement.javacopy"/>
</genAnnotations>
```

EMF allows custom code to be added to classes using an `@Generated` NOT comment annotation or no annotation at all. These additions are preserved during regeneration, but may be lost if the file is deleted and regenerated.

As an alternative, custom contributions may be pasted into class implementation files by specifying a detail entry whose key is the qualified interface name of the class to be customised and whose value is the project-relative name of a file providing text to be copied and pasted.

The copied text should be tab indented so that it matches the tab indentation of the auto-generated code.

The copied text may reference types that may need importing by encoding the fully qualified name in `<%...%>`.

The customization files are conventionally given a `*.copyjava` file name and are placed in the `model` folder alongside the `*.genmodel`.

9.4.4.1. Implementation Details

The support for copy and paste is in `templates/model/Class/insert.javajetinc` where the referenced text is copied into the implementation file with help from `OCLBuildGenModelUtil`.

9.4.5. Implementation Details

9.4.5.1. `org.eclipse.oc1.examples.build`

The `org.eclipse.oc1.examples.build` plugin hosts the build-time functionality that does not need to bloat the distribution.

Modified JET templates are in the `templates` folder which `.jetproperties` prefixes to the template path. The `.project` has an `org.eclipse.emf.codegen.jet.IJETNature` nature and builder so that the custom JET templates are automatically built to the `jet-gen` source folder. The `.project` similarly has an `org.eclipse.xtext.ui.shared.xtextNature` nature and builder so that the Xtend templates are automatically built to the `xtend-gen` source folder. Both these generated source folders are excluded from source control, since they are 100% auto-generated and they do not form part of the distribution.

Custom JET templates are declared by `OCLBuildGenModelGeneratorAdapterFactory` which creates a `OCLBuildGenClassGeneratorAdapter` that replaces the normal reference to `org.eclipse.emf.codegen.ecore.templates.model.Class` by `org.eclipse.oc1.examples.build.templates.model.Class`.

The custom build functionality is installed by the `GenModelSetup` workflow component,

Appendix A. Glossary

EMF	Eclipse Modeling Framework
OCL	Object Constraint Language
OMG	Object Management Group
QVT	Query View Transformation
RTF	Revision Task Force
UML	Unified Modeling Language