The Amsterdam Manifesto on OCL

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September 1999

Abstract

In November 1998 the authors participated in a two-day workshop on the Object Constraint Language (OCL) in Amsterdam. The focus was to clarify issues about the semantics and the use of OCL, and to discuss useful and necessary extensions of OCL. Various topics have been raised and clarified. This manifesto contains the results of that workshop and the following work on these topics. Some of the results are already incorporated in the new OCL specification 1.4 [OCL1.4]. Some others will be incorporated in the next version and some of the proposed extensions are elaborated further and published appropriately.

1 Overview of OCL

The Object Constraint Language (OCL) is a textual specification language, designed especially for the use in the context of diagrammatic specification languages such as the UML [Booch98]. Due to the two-dimensional nature of diagrams, their perception is much easier for humans than linear text. As furthermore software systems tend to be some of the most complex things that humans ever developed, it is quite natural to use diagrams to denote views of software systems. The UML offers several kinds of diagrams, dedicated to describe different aspects of a system, such as structure, interaction, state based behaviour or deployment. However, when regarding the UML diagrams as a language, it turns out that the diagram-based UML is limited in its expressiveness. Although the UML is powerful and covers many important situations, it is often not sufficient to describe certain important constraints. Using natural language on the one hand introduces freedom of misinterpretations and on the other hand gives tools no chance to cope with it.

Therefore the Object Constraint Language was introduced as a textual add-on to the UML diagrams. OCL is deeply connected to UML diagrams, as it is used as textual addendum within the diagrams, e.g. to define pre- and postconditions, invariants, or transition guards, but also uses the elements defined in the UML diagrams, such as classes, methods and attributes. The following example taken from ... shows some important features of the OCL and how to apply them in class diagrams.

(Jos could you copy and paste an example here, it may have been published already elsewhere)

OCL has syntactic similarities to Smalltalk [Ref]. OCL could also be given a Java/C++-like syntactic flavour without affecting the usefulness of OCL. Syntactic flavour is to a large extent a matter of taste. However, more important are the concepts within the language. Here we name the most important features of OCL. Please, be reminded that this manifesto is not an introduction to OCL, this can be found in [Warmer99]:

- Tight integration with the UML notation
- Pure specification language without operational elements
- Basic types like Boolean, Integer, Float
- Container types Collection, Bag, Sequence, and Sets with appropriate operators
- The full typesystem also includes the types induced by class definitions within UML
- Navigation expressions to navigate along associations with various multiplicities
- Boolean operators to allow full propositional logic
- Existential and universal quantifiers over existing sets of objects
- Specifications are (to a large extent) executable and can therefore be used as assertions when animating the UML diagrams or generating code

OCL is a specification language that tries to mediate between the practical users needs and the theoretical work that has been done in that area. In particular much of the theoretical work was done in the areas of algebraic specification languages, such as Spectrum [Broy93-1, Broy93-2], CIP [Bauer85], ACT ONE [Ehrig85], ACT TWO [Ehrig90], TROLL [Conrad92, Hartmann94, Jungclaus91], logic systems such as HOL [Gordon93, Paulson94], LCF [Gordon79, Regensburger94]. Other theoretical work worth mentioning is on model based specification techniques such as Z [Spivey88, Spivey89] and VDM [Jones90], functional programming languages such as Gofer [Jones93], Haskell [Hudak92] and ML [Paulson91], and also the data base query languages such as SQL [ref].

The best ideas from these areas, such as navigation expressions or container types as abstract data types, have been taken and combined into a language that is dedicated to software engineers. OCL does not only have a syntax similar to Smalltalk, but also provides expressive operator names to increase readability of OCL constraints.

The current status of OCL is as follows:

- The official OCL specification in version 1.3 has been published by the OMG together with the UML specification in version 1.3.
- A parser for OCL specifications, written in Java is available at:

  http://www.software.ibm.com/ad/ocl

A note on the degree on formality: There exist several degrees of formality of a notation [Rumpe98]. If the syntactic shape of a notation is precisely defined, e.g. for OCL a grammar is given, then the syntax is formalised. However, based on the syntax the meaning of the notation has still to be defined. Or can we understand the meaning of Java constructs from the Java grammar (without knowing at least similar languages)?

OCL does currently not have a formally defined meaning and can therefore only be regarded as semi-formal. Due to the tight connection of OCL with the UML diagrams, the definition of a formal syntax for OCL must be based on a formal semantics for the UML. This is a difficult task.

2 Contents of this Paper

The manifesto documents the results of a two-day workshop held in Amsterdam discussing various topics and issues of the OCL. Therefore the manifesto is to some extent a collection of the results discussed in that workshop. The results have been classified roughly in four groups:

- bug fixes,
- clarifications,
- extensions, and
- applications.

Some of the issues discussed below do not fall clearly into one of these categories, but belong to several groups. E.g. it is sometimes necessary to propose an extension in order to fix a bug in the language. The following four chapters are structured along this four groups. Each discussed topic corresponds to one section. Therefore, the table of contents gives quite a useful overview.

Another hot topic of the workshop was the question, how to get OCL used. The suggestions and results from that discussion are not included in this manifesto.

3 Bug fixes of the language

3.1 Remove direct type

In UML 1.1 the standard operation “oclType” would result in the type of an object. Because objects can have multiple types, this operation was ill defined. In UML 1.3 this operation has been removed. The operations “oclIsTypeOf” and “oclIsKindOf” can be used instead.

3.2 Adaptation of OclAny

OCL provides a special type, called “OclAny”. This type is meant to be a common supertype of all types. This includes the basic types, such as Boolean, types defined in UML diagrams, like Flight, and collection types, like Set(Flight). In particular Set(OclAny) is again a type included in OclAny. Although, there are type systems dealing with such a situation, these type systems rather complex. Also for practical purposes this complication is not necessary.

To remedy this situation, the type OclAny was adapted in UML 1.3 to include only the basic types of OCL and the types defined within the UML diagrams. In particular, none of the collection types, e.g. Set(Flight) or Sequence(Boolean), are subtypes of OclAny. It is still possible to build and work with Set(OclAny), but this type is not included in OclAny. Please note, that there is also no inclusion in the other direction, although elements of OclAny could be regarded as one element sets, bags, or sequences as in OBJ [Goguen92].

The adaptation of OclAny leads to an improved and simplified type system. Using this fix of the type system and ignoring the two meta-types OCLexpression and OCLtype, we get a strong type system in the sense, that type checking can be done within the parser.

3.3 "allInstances" considered dangerous

The definition of “allInstances” is problematic. It is unclear in what context all instances should be taken. It is much better style and much clearer to make sure that any collection of objects is only reached by navigation.

The following paragraph has been added to the UML 1.3 OCL specification to warn users of the potential pitfalls of using allInstances.

NB: The use of *allInstances* has some problems and its use is discouraged in most cases. The first problem is best explained by looking at the types like Integer, Real and String. For these types the meaning of *allInstances* is undefined. What does it mean for an Integer to exist? The evaluation of the expression *Integer.allInstances* results in an infinite set and is therefore undefined within OCL. The second problem with *allInstances* is that the existence of objects must be considered within some overall context, like a system or a model. This overall context must be defined, which is not done within OCL. A recommended style is to model the overall contextual system explicitly as an object within the system and navigate from that object to its containing instances without using *allInstances*.

4 Clarifications of the syntax and semantics of OCL

4.1 Boolean operators and undefined expressions in OCL

OCL provides the following operators with Boolean arguments and/or results:

=, not, and, or, xor, implies, if-expression.

This section presents informal definitions of the operators, aimed at users of OCL. The definitions are intended for incorporation into the next release of the definition of OCL. It in fact turns out that also the given definitions are intended to give an intuitive explanation, the characterisation of an operation through truth-tables and through reduction to know operations, as used below, is a fully precise definition.

The definitions are presented in two parts. First, the meanings of the operators are given using truth tables and equations. Then there is a short discussion of the use of Boolean operators within OCL constraints.

In UML, and hence in OCL, the type Boolean is an enumeration whose values are “false” and “true”, and a Boolean expression is one that evaluates to a Boolean value.

In what follows, b, b1 and b2 are expressions of type Boolean.

4.1.1 The = operator

Two Boolean expressions are equal if they have the same value. The following table defines the equality operator. Thus equality can be used, for instance, to denote the equivalence of two properties.

b1	b2	b1 = b2
false	false	true
false	true	false
true	false	false
true	true	true

4.1.2 The not operator

The not operator is defined by the following table.

b	not b
true	false
false	true

4.1.3 The and operator

The and operator is commutative, so that

(b1 and b2) = (b2 and b1)

It is defined by the following two equations.

false and b = false

true and b = b

Applying the above commutativity rule to the equations, we get:

b and false = false

b and true = b

and therefore the following table holds:

b1	b2	b1 and b2
false	false	false

false	true	false
true	false	false
true	true	true

4.1.4 The or operator

The or operator is also commutative, so that

(b1 or b2) = (b2 or b1)

It is defined by the following two equations.

false or b = b

true or b = true

Once again, it is possible to apply the commutativity rule to the defining equations to produce two more equations:

b or false = b

b or true = true

and a truth table:

b1	b2	b1 or b2
false	false	false
false	true	true
true	false	true
true	true	true

4.1.5 The xor operator

The xor operator (“exclusive or”) holds if exactly one of its arguments holds. It is therefore similar to the or operator, but excludes the case that both arguments are true. The xor operator is commutative, so that

(b1 xor b2) = (b2 xor b1)

It is defined in terms of the and, or and not operators.

b1 xor b2 = (b1 or b2) and not (b1 and b2)

4.1.6 The implies operator

The implies operator allows us to formalize statements of the following kind:

“if b1 is true then b2 must also be true (but if b1 is false we don't say anything about b2)”.

Such a statement can be formalized by the OCL expression

b1 implies b2

which constrains b2 to be true whenever b1 is true. The implies operator is defined by the following equations:

false implies b = true

true implies b = b

It follows that the expression “b1 implies b2” can be false **only** when b1 is true and b2 is false.

4.1.7 The if-expression

An if-expression takes the form

if b then e1 else e2 endif

in which b is a Boolean expression and e1 and e2 are OCL expressions of compatible types. If b is true, the value of the whole expression is e1. If b is false, the value of the whole expression is e2.

In contrast to an if statement in procedural languages, an if expression has a value. Therefore the else clause is always necessary. The resulting type of the if-expression is the least type T such that the types of both argument expressions e1 and e2 conform to that type. (See also the type conformance rules of OCL).

Here is a small example. Assume that count is an integer variable and x is a real variable. The literals 100 and 0 are integers. The if-expression

if (count <= 100) then x/2 else 0

has type real (because e1 and e2 are of type real and integer, respectively, and integer conforms to real). The value of the whole expression is x/2 if count<=100. The value of the whole expression is the real number zero if count>100.

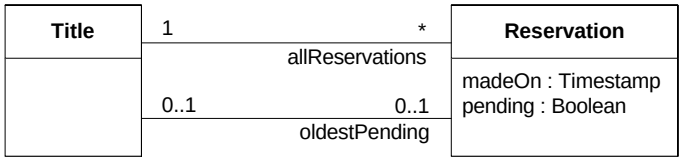
4.1.8 Boolean operators and undefined expressions

The meanings of the Boolean operators have been presented in the preceding subsections. The meanings have been chosen to support the intuitions of those who write and read OCL constraints. Sometimes it is necessary to write expressions of the form

“if b1 is true, b2 should also be true”

even though we know that “b2” has no meaning when “b1” is false.

Here is an example, based on a fragment of a model of a library system, which has two

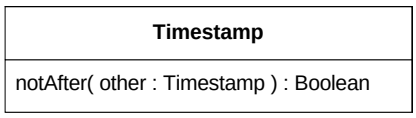


associations between class Title and class Reservation.

To reserve a title means to put in a request to borrow any copy with that title. A reservation object is created as part of the act of reserving a title. If one or more of the reservations for a particular title is pending then there must be an “oldestPending”, which is the reservation that

is next in line to be satisfied when a copy with the right title becomes available. (If there are no pending reservations, there is no “oldestPending” reservation, and “allReservations” captures only historical information.)

There is also a Timestamp class, and we are interested in one of its methods.



The “notAfter” query returns true if the receiver is a timestamp that is at the same time as, or earlier than, the “other” timestamp.

Here is an invariant to define the intended meaning of the “oldestPending” association. The OCL definition includes a comment to explain the formal part.

```
t : Title
        t.allReservations->select(pending)->isEmpty implies
                t.oldestPending->isEmpty
and
        t.allReservations->select(pending)->notEmpty implies
                ( t.oldestPending->notEmpty and
                        t.allReservations->select(pending)->forall( r |
                                t.oldestPending.madeOn.notAfter(r) ) )
-- In the context of a title t
--      if there are no pending reservations for t (check by selecting
--      the pending ones and seeing if the resulting set is empty) then
--              there is no oldest pending reservation
-- and
--      if there are some pending reservations for t then
--              there must be an oldest pending and
--                      for all reservations, r, that are pending for t,
--                              the timestamp showing when the oldest pending
--                              reservation was made is NOT after the timestamp of r
```

More loosely, the invariant says that, if there are some pending reservations, there must an oldest one, and this oldest one has the property that there is not an even older one. The specification intentionally doesn't say which is the oldest pending reservation out of two with equal time stamps.

The example was chosen to illustrate how the definitions of the Boolean operators avoid a problem with expressions that have no defined meaning.

In the very last line of the formal version of the invariant, what does the subexpression “t.oldestPending” mean when there are no pending reservations? The intuition behind the formal specification is that, when there are no pending reservations, there is no “oldest pending” reservation, so the question is irrelevant. To support this intuition, the “implies”

operator is defined so that “a implies b” is true whenever “a” is false - we do not need to examine “b”.

However, the formal logic underpinning OCL does assign a “virtual value” to “b”. This value is neither true nor false, “undefined”. As a consequence the Boolean type does have three values, “true”, “false”, and “undefined” and the Boolean operations need to be defined on “undefined” as well. Fortunately, we can use this special value to describe the desired behavior of our operations. We e.g. can define that “false implies undefined” is true (the formal logic is known as Kleene logic). Please note, that the value “undefined” was an invention of semantics modelers (formalists) to get their understanding of the semantics of a logic like OCL right. The technique of introducing virtual values was very successful, and is nowadays often used to model certain situations, like “nil” models the absence of an object to navigate to.

As the example concerning reservations illustrates, modelers usually do not need to consider “undefined” values explicitly. They model them out by carefully exploiting definitions such as “false implies b is true, for any expression b that has type Boolean”. As a result, most of the time, modelers can choose freely to work with any one of these three informal pictures of what Boolean expressions mean when they have subexpressions that cannot be given a value:

operators such as “and” and “implies” are evaluated by a process that stops as soon as the answer is knowable (for example, when either of b1 or b2 in “b1 and b2” is found to be false)

Boolean expressions can have the values false, true or undefined, and the rules for evaluating the operators take care of undefined values by including such rules as “false and undefined = false”

All Boolean expressions are either true or false, but, because the modeler has (deliberately) under-specified an expression, it might not be possible to determine which. However, rules such as “false and b = false” mean that, even if “b” is underspecified, so that its value is not known, the value of “false and b” is still known (its value is false).

When a modeller does need full, formal definitions of the Boolean operators, for example, to construct formal proofs, such definitions are available.

4.2 Clarify the meaning of recursive definitions

Recursion always occurs, if an element refers to its own definition while being defined. Functions and methods can be recursive. Famous examples are the faculty function

fac(n) = if (n==1) then return(1) else return(n* **fac**(n-1));

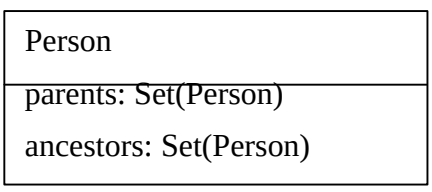
or list traversals as e.g. used in container classes:

list.**length**() { if (list.elem==NIL) then return(0) else return 1 + **length**(list.next); }

But structures may also be recursive, for example by including an attribute in a class that refers to the class itself (used in list implementations) or to a superclass (used in part-whole-structures). Also OCL constraints may use recursive definitions, like the following:

```
context: Person
ancestors = parents->union(parents.ancestors)
```

Which is defined in the context of the following class:

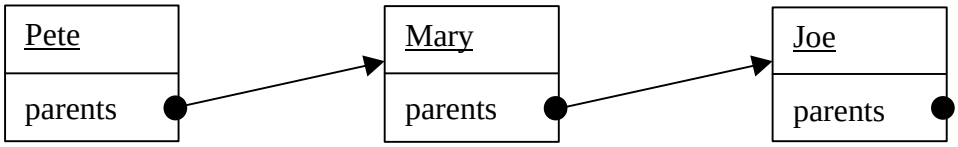


In the above constraint ancestors is meant to be the transitive closure of the relation defined by parents. Reading the constraint as a functional program, then we actually have defined what we desired to.

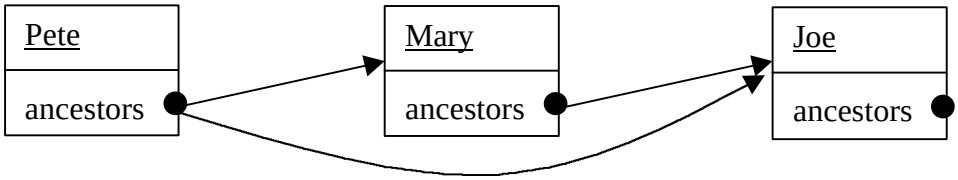
When dealing with recursive specifications instead of programs, then there are typically more than one solutions. This can be easily seen regarding the OCL constraint

a = a*a - 4*a + 6

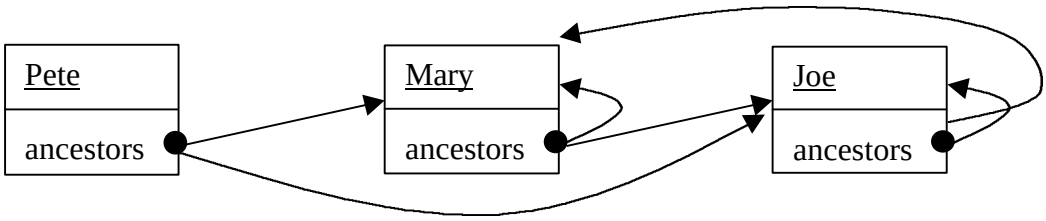
This is not a valid mathematical definition for a, but a binomial equation with two solutions (a=2 or a=3). Both are valid and none is preferable. The same situation arises with the ancestors. Let's look at the following object structure, where Joe is Mary's dad and Pete's grandpa:



The desired solution is covered by the following object structure (disregarding the parents attribute):



But there are more solutions to the ancestor constraint as shown in the following object structure:



It demands that Mary and Joe are both ancestors of each other and themselves. Through checking the constraint on the ancestors attribute, we find out both shown object diagrams are valid structures. And there are a lot more.

Fortunately, there is a unique characterisation of all possible object structures that furthermore distinguishes one solution from all others. The first object structure shown, is contained in all others, in the sense that each solution must contain at least the link from Pete to Mary, from Pete to Joe and from Mary to Joe. This solution is "minimal" and therefore corresponds to the "minimal fixpoint" and is identical to what we get, if "executing" the ancestor definition.

Unfortunately, such a minimal solution does not always exist, sometimes there are several ones, sometimes none at all. Even worse, it may be difficult to find out, whether a recursive definition has a unique solution. For example the equation about a from above does have two solutions, but none of it can be preferred in the domain-theoretic sense. This is also reflected, if you try to "execute" the equation, by iterative application. The row

$a_{n+1} = a_n * a_n - 4 * a_n + 6$

starting with, say a_n=0, leads to a limit of +∞.

It may, furthermore, happen that the modeller does not want to get the minimal solution. Consider a specification, where Person stands for computer nodes, “parents” is replaced by “TCP-connection” and “ancestors” is the transitive closure of all “connections”, describing to whom a connection can be made. Then the constraint tells us, that connection includes all TCP-connection, but in case other kinds of connections exist, we want to add additional connections later.

By the way, these considerations have been explored fully with the fixpoint theory. Fixpoint techniques, like the one provided by Kleene [Kleene54] and Tarski [Tarsky52] give an unambiguously defined semantics for recursive definitions. If fixpoint theory is familiar, then you know about the results discussed above. If not, then just accept the results presented here, as you probably don’t want to bother with the technical issues here. From first order logic languages, we know how to deal with that situation. There are two approaches possible, both have their merits and problems.

One approach is to use “loose semantics”: Only the constraints are valid that are explicitly given or can be derived from given constraints. No implicit “minimal solution” semantics is used, when recursive equations occur. If a minimal solution is desired, a special keyword or stereotype is to be added to the constraint. The keyword could be “executable” or “operational” to give a hint to the operational semantics of recursive definition.

Another approach is to use the minimal solution as default and provide a keyword, like “loose” to indicate that any solution is possible.

Although the first approach is somewhat cleaner, as it does not add implicit constraints, the second one is probably more practical. We opt to include both kinds of keywords to allow to explicitly mark which kind of semantics is to be used.

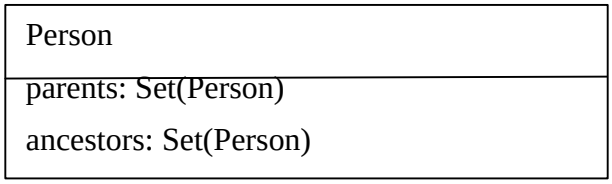
Some technical remarks on recursion:

Recursion can be more complicated through involvement of several elements, like in

```
context: Person
grandancestors = parents.ancestors;
ancestors = parents->union(grandancestors)
```

where the recursion is mutually dependent between ancestors and grandancestors, but not direct. But the standard keywords can be extended to such cases.

The nature of first order logic languages does not allow to uniquely characterize a minimal solution. This is only possible by adding second order principles, such as induction or term generation of the specified elements. Usually introducing special keywords (like the ones proposed above) provides such principles. Fortunately, OCL has the natural numbers and their induction principle built in and therefore provides the necessary techniques. It is a bit awkward, but the minimal solution can be specified through using natural numbers and explicitly mimicking induction over natural number n:




```
context: Person
ancestors-up-to(n) =
     if (n==1) then parents else
           parents->union(parents.ancestors-up-to(n-1))
Nat->forall(n | ancestors-up-to(n) = ancestors-up-to(n+1)
```

```
                implies ancestors = ancestors-up-to(n) )
```

The use of an appropriate keyword is absolutely preferred.

From our experience using OCL for specification, we found that recursive situations frequently occur. Particular sources are recursive data structures (lists, containers, part-wholes, directory structures, hierarchical, and graph-containing structures). Usually recursion of OCL constraints is accompanied with the existence of an association circle in the class diagrams. When one or several associations form a circle, building paths through them can lead to recursive structures.

4.3 Use path concept only for packages

The UML and OCL specification uses a double colon "::" to denote pathnames. This used e.g. for denoting Classes in other packages as with "Packagename::Classname". The same construct has been used in OCL to denote the use of a redefined feature. Because this uses the same notation for something else than a pathname, it was considered to make the specification less consistent.

In UML 1.3 the use of "::" to access redefined features has been removed. Instead, one has to use the "oclAsType" operation to cast an object to its supertype and then access the redefined feature.

4.4 Other subjects that should be clarified

During our meeting we discussed other subjects in the OCL standard that needed clarification. However, until September 1999 we did not have the opportunity to discuss them further and include a clarification in this manifesto. The subjects were:

- Explain navigation paths like "a.b.c" without flattening
- Precisely define the scope of invariants
- Type expressions in OCL

5 Extensions to OCL to make it more useful

5.1 New operator "oclIsNew" for postconditions

5.1.1 Rationale:

One of the most common ways to denote the existence of new objects was the use of "allInstances". Because this operation is not well-defined (see section 3.3) there should be another way to denote that an instance has been created. The operation "oclIsNew" has been added to the OclAny type for this purpose.

5.1.2 Syntax:

The syntax of "oclIsNew" in UML 1.3 is as follows:

```
object.oclIsNew : Boolean
```

5.1.3 Semantics:

In UML 1.3 the operation "oclIsNew" can only be used in a post condition. It evaluates to true if the *object* is created during performing the operation. I.e. it didn't exist at precondition time.

5.2 New operator “isUnique”

5.2.1 Rationale:

In practice one often wants to ensure that the value of an attribute of an object is unique within a collection of objects. The isUnique operation gives the modeler the means to state this fact. This operator is not part of the OCL 1.3 version.

5.2.2 Syntax:

```
collection->isUnique(expr : OclExpression) : Boolean
```

5.2.3 Semantics:

The isUnique operation returns true if “expr” evaluates to a different value for each element in the collection, otherwise the result is false.

More formally:

```
collection->isUnique(expr : OclExpression)
```

is identical to

```
collection->forAll(e1, e2| if e1 <>e2 then e1.OCLexpression <>
e2.OCLexpression )
```

5.2.4 Example usage:

```
context: LoyaltyProgram
serviceLevel->isUnique(name)
```

Note that the definition precludes expressions like self.isUnique(serviceLevel.name) and serviceLevel.isUnique(availableServices.description).

5.3 Add a “let” statement to define local variables and functions

5.3.1 Rationale:

For larger constraints it is cumbersome and error prone to repeat identical sub expressions. The possibility to define a local variable within a constraint solves this problem.

Sometimes a sub-expression is used more than once in a constraint. The *let* expression allows one to define a variable, which can be used in the constraint.

5.3.2 Syntax:

The syntax of a Let expression is as follows:

```
context Person inv:
let income : Integer = self.job.salary->sum in
if isUnemployed then
    income < 100
else
    income >= 100
endif
```

5.3.3 Semantics:

The variable defined in a let statement can be used within the OCL expression. The value of the expression is substituted for the variable. Because semantically nothing can change during evaluation of a constraint, it is not necessary to define whether the expression at the left hand side is evaluated once at the start, or at each occurrence in the OCL expression.

5.4 Introduce a read-only modifier for attributes[1]

5.4.1 Rationale

In current UML, attributes are either public, protected, or private. These modifiers constrain visibility of attributes to foreign classes, sublasses and to other methods of the same class. Whenever an attribute is visible, it can be both read and changed. Sometimes, it is useful to constrain the visibility to be readable, but not changable. For example, current time, a counter, or a reference to certain objects could be readonly to the environment, but writable to the own methods. Currently such values must be private and used through (rather expensive) method access. We therefore introduce the concept of a readonly-modifier in combination with private and protected.

5.4.2 Syntax

public read attributename

public read protected write attributename

protected read attributename

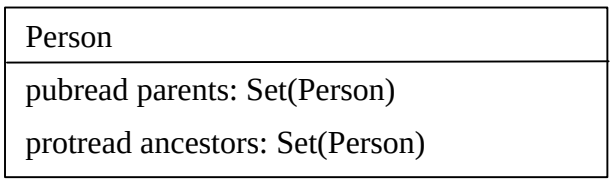
5.4.3 Semantics

In addition to the existing three modifiers, we introduce the above given modifier combinations with the following meaning:

- public read — read access is public, write is private (!)
- public read protected write — read access is public, write is protected
- protected read — read access is protected, write is private

Write access is always at least as constrained as read access. The three variants, where the write access is more constrained than the read access, is covered above. Shortcuts, like “pubread”, “protread” and “protwrite” are possible.

5.4.4 Example usage:



[1] Note, that this is actually a proposal for extending UML.

5.5 Constant declarations for object properties

5.5.1 Rationale

Some properties of objects never change. Marking them to show this allows for some additional checking, e.g. such properties can never be mentioned as changing in a postcondition, and also allows for more reasoning to be done over the object model.

5.5.2 Syntax

```
context: object
constant <attribute>
constant <query()>
constant <rolename>
```

5.5.3 Semantics

Where an attribute or query has been declared as constant, no postcondition can be specified which implies any change to the value of that attribute or query, unless the postcondition also states that the object to which that attribute or query is applied is new.

Where an association end (role name) has been declared as constant, no postcondition can be specified which implies any change to the collection of objects denoted by that role name, unless the postcondition also states that the object to which that role name is applied is new.

Note that this declaration relates to the attribute 'changeability' of StructuralFeature (superclass of Attribute), where one of the values is *frozen*. The class AssociationEnd (rolename) has the samen attribute in the UML metamodel, but Operation (query) is lacking this attribute.

5.5.4 Example usage

```
Customer
constant dateOfBirth
```

5.6 Enhance the abilities to define context of OCL specifications

Expressions written in Object Constraint Language (OCL) within a UML model assume a context, depending upon where they are written. Currently the exact nature of this context is not fully defined. Furthermore there is no mechanism for defining the context for OCL expressions in extensions to UML. The authors of this manifesto have written a separate paper [Cook99], which defines the context of OCL expressions, and proposes precise and flexible mechanisms for how to specify this context. This paper will be published in the proceedings of the UML '99 conference.

5.7 Other extensions that were discussed

During our meeting other extensions and improvements were discussed:

- Useful syntactic abbreviations for existing constructs
- Add “effect” definitions (from Catalysis) for postconditions

6 Application of OCL

6.1 Using OCL to define events, operations, and actions

6.1.1 Background and rationale

UML/OCL allows us to specify operations using preconditions and postconditions. Catalysis introduces the idea of joint actions. A key difference between operations and joint actions is that operations are *localized* on a single type, whereas joint actions are localized on two or more types. UML/OCL should explicitly embrace joint actions, and to go even further, allow *events,* which are not localized on any types at all.

Note that there's nothing original here. The ideas presented here come from Syntropy and Catalysis.

6.1.2 Operations

Users of object technology are familiar with the idea of what Smalltalk and Java call a method, C++ calls a member function, Eiffel calls a routine, and UML calls an operation. Those familiar with Syntropy, Fusion, OCL, Eiffel, etc. will know about using preconditions and postconditions to specify the behaviour of an operation.

The general form of an operation specification in OCL is this:

```
Typename::operationName(parameter1 : Type1, ... ): ReturnType
  pre :  parameter1 ...
  post:  result = ...
```

Within the assertions labelled *pre:* and *post:* the term *self* refers to an object of type *Typename*.

Example

In a model of a library, there could be an operation *borrow* on type *Library*, specified along these lines (assume that every library object has a clock object):

```
Libary::borrow( m : Member, c : Copy, d : Date )
        -- Member m borrows copy c to be returned on date d
pre:
     -- The date is in the future
     d > self.clock.today
     ...
post:
     -- There's a new loan object recording that m has borrowed c
     Loans.allInstances -> exists( n | n.isNew & ... )
```

The operation is localized on the library. It is natural to think of the operation *borrow* being called on a library object, or of a library object "receiving" a call to its *borrow* operation. The term *self* in the precondition refers to the library that "receives" the call.

6.1.3 Joint actions

In Catalysis, we can have joint actions. They are joint in the sense that they are localized on two or more types.

Example

The borrow action can be seen as a joint action between a member and a library system.

```
(m : Member, lb : Libary)::borrow( c : Copy, d : Date )
        -- A joint action in which a member and a library system
        -- collaborate in the borrowing of a copy c by the member
        -- from the library, to be returned on date d
pre:
     -- The date is in the future
     d > lb.clock.today
     ...
post:
     -- There's a new loan object recording that m has borrowed c
     Loans.allInstances -> exists( n | n.isNew & ... )
```

Note that the library is now identified by name. The term *self* is no longer unambiguous.

6.1.4 Events

An operation is localized on a single type. A joint action is less localized. We don't need to think of borrowing as an operation on a library. We can think of it as a piece of behaviour that a member and a library collaborate in performing.

We can go further, and have no localization at all. We call a fully de-localized operation an *event*, following Syntropy.

Example

The borrowing of a copy by a member from a library, with a certain return date, can be seen as an event that involves a number of objects. The event has a before state and an after state, but is not done *to* any particular object. Rather, it can affect any of the objects identified in the event's signature, and any object that can be reached from them.

```
borrow( lb : Library, m : Member, c : Copy, d : Date )
        -- An event in which member m borrows copy c from library l,
        -- to be returned on date d
pre:
     -- The date is in the future
     d > lb.clock.today
     ...
post:
     ...
```

There is no receiving object, and nothing for the term *self* to refer to.

More strictly, what is specified above is an event type. Any event occurrence will identify instances of types Library, Member, etc.

6.2 Adding dynamics to OCL

6.2.1 Rationale

Currently OCL expressions state only static requirements. Class invariants are static by nature and even guard conditions, pre- and postconditions express static information. They only constrain changes in the object's state. Although this is very useful, one would often like to express more dynamic constraints.

What can not currently be expressed using OCL is, for instance, what should happen at the exact moment that a condition becomes true. Another example is, the case where one would like to express that although the state of the object is not changed, events must have occurred due to the invocation of the current operation.

6.2.2 Proposed features

Special features need to be introduced in OCL to be able to specify these dynamic constraints. We propose to add two stereotypes for constraints to UML and their syntax to OCL that will support dynamic constraints:

- the **action** stereotype, which indicates a constraint on the triggering of messages, and
- the **called** stereotype, which indicates a constraint that ensures certain messages are send.

To explain these new features the example UML model shown in figure 1 will be used.

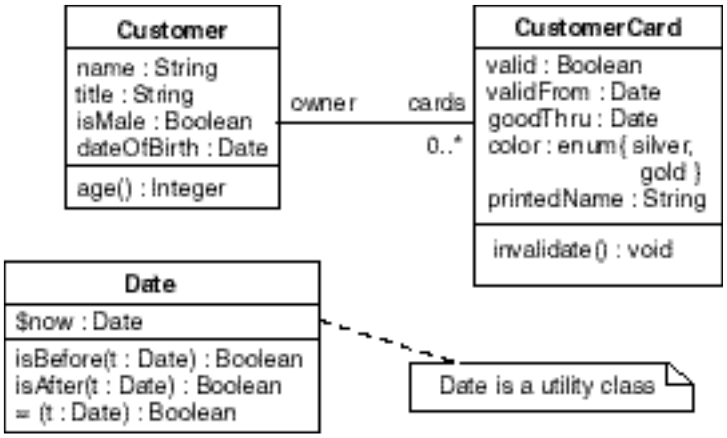


Figure 1

6.2.3 The action stereotype for constraint

An action constraint states that when a Boolean expression becomes true, a list of messages must be send. The constraint can be used to guarantee the sending of the messages, but not the completion of the invoked operations. The messages in the messagelist can only be send to the contextual object or objects navigable from the contextual object.

6.2.3.1 Syntax[2]:

context class **action**:

on booleanExpression **do** messagelist

Where booleanExpression is an OCL expression of the boolean type and messagelist is defined as featureCall (“,” featureCall)* (featureCall as defined in the formal grammar of OCL).

6.2.3.2 Semantics:

To define the semantics of an action constraint we propose that an action constraint has the same semantics as an automatic, conditional transition in a statechart. Figure 2 shows a statechart with the same meaning as the example below.

[2] The syntax we are using here is conform the syntax for defining the context in a document separate from the UML model as described in version 1.3 of the standard.

6.2.3.3 Example usage:

```
context CustomerCard action:
on self.goodThru.isAfter(Date.now) do self.invalidate()
```

6.2.4 The called stereotype for constraint

A called constraint can only be used in the context of an operation. A called constraint states that every time the contextual operation is executed a message or a list of messages is being sent. Again, there is no guarantee that the invoked operations are completed. The messagelist may be included in an if-then-else-clause. The else branch may be empty, in which case the keyword 'else' may be omitted.

6.2.4.1 Syntax:

```
context: class.operation(paramlist): resultType
called: messagelist | if booleanExpression then messagelist [else
messagelist] endif
```

6.2.4.2 Semantics:

The semantics of the called constraint can be defined in terms of sequence diagrams. Stating that a message Y has been send during the execution of an operation X is equal to requiring that in every sequence diagram where operation X is called, this call is followed by message Y. In the case of a conditional message, the call X is followed by a guard and message Y.

6.2.4.3 Example usage:

```
context CustomerCard::invalidate(): void
pre:    -- none
post:   valid = false
called: if valid@pre = true then
           if customer.special then customer.sendPoliteInvalidLetter()
           else customer.sendInvalidLetter()
           endif
        endif
```

6.2.5 Consequences of introducing dynamics

What is described above is a proposal of which the consequences need to be examined. Some of these are:

- Like in pre and postconditions we do need some formalization of the concept 'time'. Perhaps we only need to specify 'moment', 'before' and 'after'.
- There seem to be a relation to the proposed UML action language specification, which we have not yet investigated further.

6.3 Mapping STD to object states using OCL

6.3.1 Rationale

A state machine for a Classifier defined the states in which an instance of the classifier can be in. It is very common to use the state of an object in preconditions, postcondtions and invariants. It is therefore useful to enhance OCL to be able to refer to those states.

6.3.2 Syntax

The standard operation “oclInState” has been added to OclAny.

```
object.oclInState(state : OclState) : Boolean
```

6.3.3 Semantics

Results in true if *object* is in the state *state*, otherwise results in false. The argument is a name of a state in the state machine corresponding with the class of *object*.

The type OclState is used as a parameter got the operation “oclInState”. There are no properties defined on OclState. One can only specify an OclState by using the name of the state, as it appears in a state machine. These names can be fully qualified by the nested states and state machine that contain them.

6.3.4 Using prefaces to customize UML (RM)

((BR: I would suggest, not to include the preface stuff here at the moment. Instead, we should finalize the paper first, and then include it here in a (slightly) adapted, extended or condensed version. Also addenda may be included here ...))

6.4 Explicit import of UML and OCL metamodels used to customize UML (BR)

((BR: mainly in the preface addendum, the remainder of this section is a part currently not used there))

In the above example UML-preface, we have generated OCL expressions as strings. For a thorough treatment, this is not a satisfying approach. Although OCL is not a graphic language, it has an abstract syntax and can therefore be included in the meta-model approach in quite the same way as other UML diagrams are. Figure 9 contains a subset of an OCL preface.

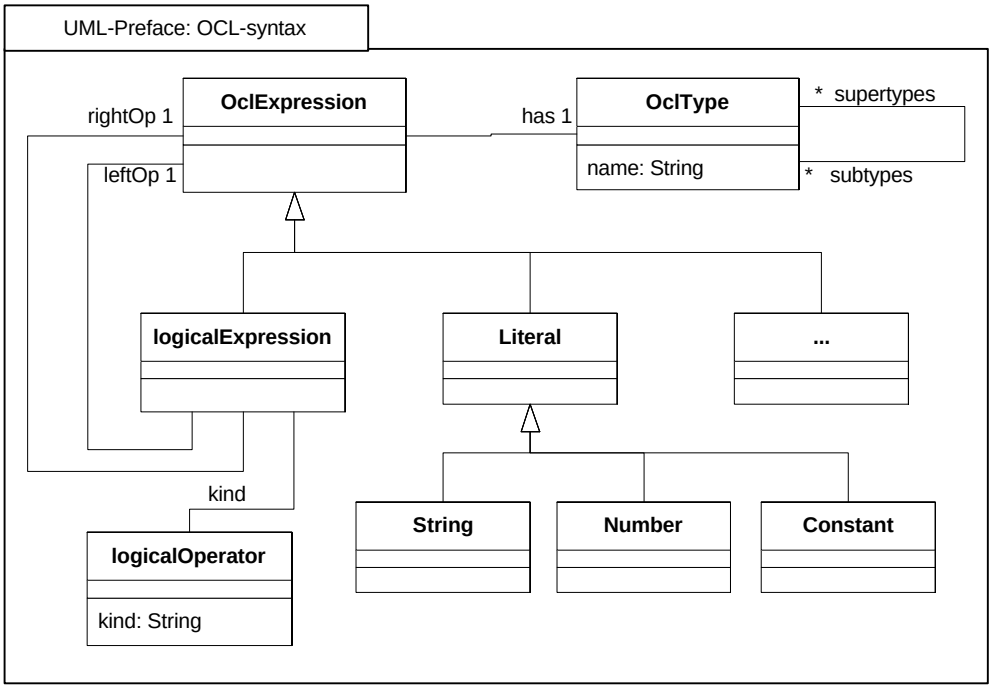


Figure 9. *UML-Preface package for OCL (subset)*

Using the OCL preface allows manipulating OCL expressions in the same way as ordinary class structures. OCL on the meta-level can be used to constrain OCL expressions on the modelling level, without the usual conflicts, which arise when two levels are mixed. In particular, OCL has a strong type system, both on the meta-level and the level below. However, through manipulating OCL expressions on the meta-level, we can easily construct OCL expressions on the modelling level that are not well formed. It is not as easy as it was when using strings, but still e.g. variables may be used that do not exist or are of a wrong type.

To deal with that issue, class "OclExpression" can offer an appropriate query, e.g. "correctExpr()" that discovers well-formedness errors of OCL expressions on the modelling level.

6.5 Other subjects discussed

- Expression placeholders
- Define a basic inference calculus
- How to deal with exceptions in OCL

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