

Analyzing Semantic Properties of OCL Operations by Uncovering Interoperational Relationships

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Motivation

Objective

- Compile Semantic Relationships (Equivalences)
- Initiate Discussions
- Develop an OCL Benchmark (← large Variety of OCL Engines)

Subject

- OCL Collection Operations
- Logic related: **exists**, **forAll**, **one**
- Database related: **reject**, **select**
- Functional Programming related: **collect**

Property of one

$C \rightarrow \text{one}(\dots | e) \equiv$

$C \rightarrow \text{exists}(\dots | e)$ and

$C \rightarrow \text{forAll}(x, y | e_x \text{ and } e_y \text{ implies } x = y)$

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$\text{Set}\{1, 1, 2, 3\} \rightarrow \text{one}(x \mid x < 2) \equiv \text{true}$

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Valid for Bag{1, 1, 2, 3}?

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Relationship Compilation (1)

Kind	Left	Right
Logic	$C \rightarrow \text{exists}(\dots e)$	$\text{not } C \rightarrow \text{forall}(\dots \text{not } e)$
	$C \rightarrow \text{forall}(\dots e)$	$\text{not } C \rightarrow \text{exists}(\dots \text{not } e)$
Set	$C \rightarrow \text{one}(\dots e)$	$C \rightarrow \text{exists}(\dots e)$ and $C \rightarrow \text{forall}(x, y e_x \text{ and } e_y \text{ implies } x = y)$
Set	$C \rightarrow \text{one}(\dots e)$	$C \rightarrow \text{exists}(x e_x \text{ and } C \rightarrow \text{forall}(y e_y \text{ implies } x = y))$
DB related		
Inter-disciplinary		
Collect		

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Set	$C \rightarrow \text{one}(\dots e)$	$C \rightarrow \text{exists}(\dots e)$ and $C \rightarrow \text{forall}(x, y e_x \text{ and } e_y \text{ implies } x = y)$
Set	$C \rightarrow \text{one}(\dots e)$	$C \rightarrow \text{exists}(x e_x \text{ and } C \rightarrow \text{forall}(y e_y \text{ implies } x = y))$
DB related	$C \rightarrow \text{reject}(\dots e)$	$C \rightarrow \text{select}(\dots \text{not } e)$
	$C \rightarrow \text{select}(\dots e)$	$C \rightarrow \text{reject}(\dots \text{not } e)$
Inter-disciplinary	$C \rightarrow \text{exists}(\dots e)$	$C \rightarrow \text{reject}(\dots e) \rightarrow \text{size}() < C \rightarrow \text{size}()$
	$C \rightarrow \text{exists}(\dots e)$	$C \rightarrow \text{select}(\dots e) \rightarrow \text{notEmpty}()$
	$C \rightarrow \text{forall}(\dots e)$	$C \rightarrow \text{reject}(\dots e) \rightarrow \text{isEmpty}()$
	$C \rightarrow \text{forall}(\dots e)$	$C \rightarrow \text{select}(\dots e) = C$
	$C \rightarrow \text{one}(\dots e)$	$C \rightarrow \text{reject}(\dots e) \rightarrow \text{size}() = C \rightarrow \text{size}() - 1$
	$C \rightarrow \text{one}(\dots e)$	$C \rightarrow \text{select}(\dots e) \rightarrow \text{size}() = 1$
Collect	$C \rightarrow \text{exists}(\dots e)$	$C \rightarrow \text{collect}(\dots e) \rightarrow \text{includes}(\text{true})$
	$C \rightarrow \text{exists}(\dots e)$	$C \rightarrow \text{collect}(\dots e) \rightarrow \text{asSet}() \rightarrow \text{one}(e e)$
	$C \rightarrow \text{forall}(\dots e)$	$C \rightarrow \text{collect}(\dots e) \rightarrow \text{excludes}(\text{false})$
	$C \rightarrow \text{forall}(\dots e)$	let $s = C \rightarrow \text{collect}(\dots e) \rightarrow \text{asSet}()$ in $C \rightarrow \text{notEmpty}() \text{ implies } s \rightarrow \text{one}(\text{true}) \text{ and } s \rightarrow \text{one}(e e)$
	$C \rightarrow \text{one}(\dots e)$	$C \rightarrow \text{collect}(\dots e) \rightarrow \text{count}(\text{true}) = 1$

Relationship Compilation (2)

Operation	Iterate Expression
exists	$C \rightarrow \text{exists}(\dots e)$
	$C \rightarrow \text{iterate}(\dots ; r:\text{Boolean} = \text{false} r \text{ or } e)$
forAll	$C \rightarrow \text{forAll}(\dots e)$
one	$C \rightarrow \text{one}(\dots e)$
reject	$C \rightarrow \text{reject}(\dots e)$
select	$C \rightarrow \text{select}(\dots e)$
collect <i>Set, Bag</i> <i>Sequence</i> <i>Sequence</i>	$C \rightarrow \text{collect}(\dots e)$

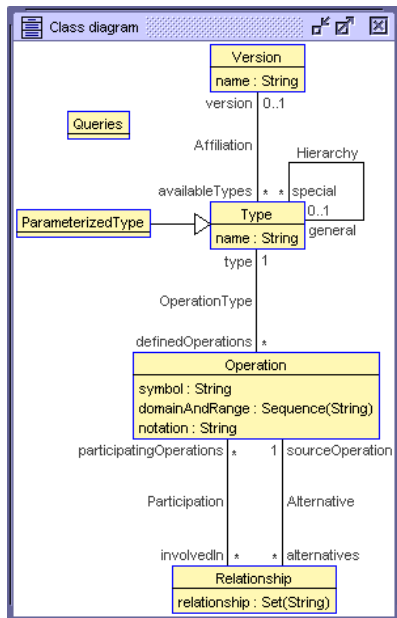
Relationship Compilation (2)

Operation	Iterate Expression
exists	<code>C->exists (... e)</code>
	<code>C->iterate (... ; r:Boolean = false r or e)</code>
forAll	<code>C->forAll (... e)</code>
	<code>C->iterate (... ; r:Boolean = true r and e)</code>
one	<code>C->one (... e)</code>
	<code>C->iterate (... ; r:Sequence (Boolean) = Sequence {false, false} if r->first () then Sequence {true, false} else Sequence {r->last () and e, (r->last () and e) xor (r->last () or e) } endif)->last ()</code>
reject	<code>C->reject (... e)</code>
	<code>C->iterate (elem; r:ct = oclEmpty (ct) if e then r else r->including (elem) endif)</code>
select	<code>C->select (... e)</code>
	<code>C->iterate (elem; r:ct = oclEmpty (ct) if e then r->including (elem) else r endif)</code>
collect	<code>C->collect (... e)</code>
	<i>Set, Bag</i> <code>C->iterate (... ; r:Bag (et) = oclEmpty (Bag (et)) r->including (e)</code>
	<i>Sequence</i> <code>C->iterate (... ; r:Sequence (et) = oclEmpty (Sequence (et)) r->append (e)</code> (also possible <code>r->including (e)</code>)
	<i>Sequence</i> <code>C->iterate (... ; r:Sequence (et) = oclEmpty (Sequence (et)) Sequence {r, Sequence {e}}->flatten ())</code>

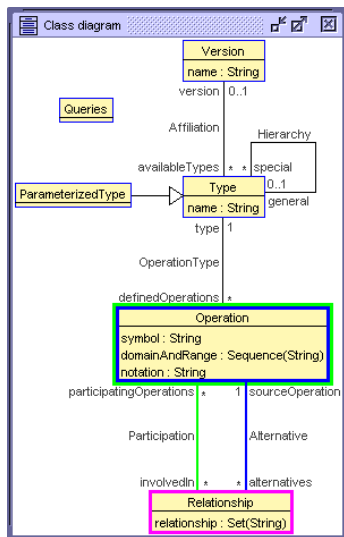
Relationship Warehouse

- Record the Equivalences
- Allow various Queries for different Purposes
- Implementation
 - ▶ Tool: USE (UML-based Specification Environment)
 - ▶ Model: UML Class Diagram
 - ▶ Content: UML Object Diagram
 - ▶ Queries: OCL Expressions

Warehouse Model



Querying the Warehouse



```
q.getRelationshipBySymbolAndParticipating(  
  'one', 'Mark Richters (USE)',  
  'Collection', Set{'select'})
```

```
Set{  
  'X->one(elem : ElemType | Expr) ==  
  X->select(elem : ElemType | Expr)  
  ->size() = 1'  
} : Set(String)
```

Conclusion and Future Work

- Semantic Analysis of OCL Relationships
 - ▶ Proposing Equivalences
 - ▶ Uncovering Assumptions for Equivalences → Modifications of Equivalences
- OCL Benchmark
 - ▶ Many Tools (→ Quality Assurance)
 - ▶ Making General Equivalences Applicable through Concrete Examples
 - ▶ Measuring Execution Times
 - ★ Equivalences
 - ★ Special OCL Terms
(e.g. `Set{1..1000}` → `select ('Square Numbers')`)

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Thank you for your attention!