Aocl : A Pure-Java Constraint and Transformation Language for MDE

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Abstract: OCL is a standard MDE language to express constraints. OCL has been criticized for being too complicated, over-engineered, and difficult to learn. But beneath OCL's complicated exterior is an elegant language based on relational algebra. We call this language $\mathbb{A}_{\text{ocl}}$, which has a straightforward implementation in Java. $\mathbb{A}_{\text{ocl}}$ can be used to write OCL-like constraints and model transformations in Java. A simple MDE tool generates an $\mathbb{A}_{\text{ocl}}$ Java 8.0 package from an input class diagram for $\mathbb{A}_{\text{ocl}}$ to be used.

1 Introduction

A central issue in *Model Driven Engineering* (MDE) is tooling: How can MDE tools be easier to learn, use, and maintain? This is not new: a visionary 2004 paper by (Favre, 2004) raised similar concerns by advocating a rethinking of MDE basics from the ground-up. The *Object Constraint Language* (OCL) (OMG, 2019) has not gone unscathed (Cabot and Gogolla, 2019; Avila et al., 2010; Wilke and Demuth, 2011; Bauerdick et al., 2004; Brucker and et al, 2014; Fuentes et al., 2003; Cadavid et al., 2011).

Unease about OCL's complexity transcends MDE where a simple constraint language for UML class diagrams is needed. For years, researchers in *Software Product Lines* (SPLs) explored generalizations of feature models to admit replicated features, feature attributes, and numerical features (Eichelberger and Schmid, 2015; Czarnecki et al., 2006). Doing so generalizes trees of features (a.k.a., *feature models*) where propositional logic was sufficient to express constraints (Apel et al., 2013), to class diagrams where first-order logic and languages like OCL are required (Czarnecki et al., 2006). Of course, there has been resistance in adopting OCL outright by SPL researchers for the reasons in the first paragraph.

There is also the intellectual challenge to find an alternative to OCL that matches its power but is simple and elegant. Imagine the damage COBOL would have inflicted on programming and Computer Science if we all were required to use it into the 1980s. Any early language is not, nor should be, an absolute endpoint.

Against this backdrop, today's *Object Oriented* (OO) programming languages have made great strides in the last 25 years; Java 8.0 is vastly different than Java 1.0. We demonstrate in this paper that contemporary OO languages now have the functionality to replace specialized languages used in MDE, like OCL and ATL. Our work is simply a next step in the evolution of MDE concepts and tooling.

Where might a replacement or simplification of OCL be found? Researchers with a graduate understanding of classical databases have long recognized the connections between MDE and relational algebra (Karsai et al., 2006). Independently, category theory is a mathematical foundation for MDE; categorical concepts are finding their way into today's MDE tools and texts (Ehrig and et al., 2006; Diskin and Maibaum, 2012; Mabrok and Ryan, 2015). What would result if these foundational lines of thought were unified?

(Freyd and Scedrov, 1990) studied categories with power set domains called *allegories*. (Zieliński et al., 2013) showed how allegories were closely connected to database modeling and query processing. Allegories were noticed by mathematicians but not so by the database and MDE communities.

This paper is not an immediate response to reading these pioneering works on allegories; it took years to understand and integrate these ideas and realize their implications and utility.

To our delight, allegories offer a clean way to express constraints from a relational algebra perspective. Our language, called $\mathbb{A}_{\text{ocl}}$, is pure-Java and is implemented by a Java framework that relies on Java streams, generics, and lambda expressions. Using $\mathbb{A}_{\text{ocl}}$ to write and evaluate model constraints requires an MDE tool to generate a Java 8.0 package for a given class diagram of the target metamodel.

$\mathbb{A}_{\text{ocl}}$ is a pragmatic response to the motivations of this paper. It is a simple, extensible (meaning new operations can be added), pure-Java replacement for OCL. The $\mathbb{A}_{\text{ocl}}$ codebase is $\sim$9K Java LOC and can be prototyped in a few months on any MDE platform.

2 $\mathbb{A}_{ocl}$

2.1 Insights Behind $\mathbb{A}_{ocl}$

Below is the EDD class diagram. It says there are Employees, Departments, and Divisions. Each Emp works in any number of Deps and each Dep employs any number of Emps. Each Dep belongs to a single Div.

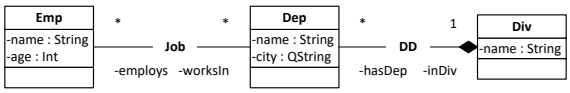


Figure 1: The Emp-Dep-Div or EDD Class Diagram.

Here is a query written in USE OCL (USE, 2019) to find employees in the tool division:

```
Div.allInstances.select(name='tool').hasDep.employs
```

Its meaning is straightforward:

- Div.allInstances produces all Div objects;
- select(name='tool') eliminates Div objects whose name is not tool;
- hasDep produces Dep objects that belong to tool divisions; and
- employs produces Emp objects that work in tool divisions, which is the result of the query.

Written in this way, the connection between relational databases and OCL emerges when a relational algebra analog to this query is written in OO style/syntax:

```
Div.select(name.equals("tool"))
   .hasDep().employs()                                (1)
```

- Div is the table of all Div tuples;
- select(name.equals("tool")) eliminates Div tuples whose name is not tool;
- hasDep() produces the table of Dep tuples that are referenced by qualified Div tuples. In database parlance, this operation is a *right-semijoin* of qualified Div tuples with the entire Dep table (Silberschatz et al., 2006; Wikipedia, 2017); and
- employs() is another right-semijoin that produces the table of Emp tuples that work in qualified departments.

Query (1) could have been written using only relational algebra operations, making explicit the semijoin argument — here an association name — for each right-semijoin:

```
Div.select(name.equals("tool"))
   .rightSemiJoin(hasDep)
   .rightSemiJoin(employs)
```

This is ugly. However, by lifting association role names to their corresponding semijoin operations yields the compact expression (1).

Note: A bit of database sugaring was used in this example. Job is a many-to-many association between Emp and Dep (Fig. 2 a). Classical relational database design, called *normalization*, replaces association Job with an association class Job and two one-to-many associations JobEmp and JobDep (Fig. 2 b) (Elmasri and Navathe, 1999; Silberschatz et al., 2006). In MDE parlance, the transformation of Fig. 2 a to Fig. 2 b is a model refactoring (France et al., 2003).

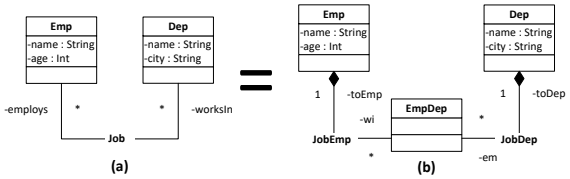


Figure 2: Database Normalization of the Job Association.

Association traversals in (1) and Fig. 2 a are cascading right-semijoins in Fig. 2 b. Written as Java composed methods where A().B() means evaluate A() first, then B():

```
worksIn()  =  wi().toDep()
employs()  =  em().toEmp()
```

That is, worksIn() is a traversal (right-semijoin) from Emp to Dep in Fig. 2 a. In Fig. 2 b, worksIn() is a right-semijoin from Emp to Job via association wi() and then another right-semijoin from Job to Dep via toDep(). Of course, these details can be hidden from end-users.

In a nutshell, ***the essence of OCL is relational algebra written in OO syntax with customized names for right-semijoins.*** We call this language $\mathbb{A}_{ocl}$.

Foundations and Concessions. Our presentation is incomplete in that the theory that inspired $\mathbb{A}_{ocl}$, and which existed long before $\mathbb{A}_{ocl}$ itself, should be presented next. For lack of space and as few in MDE appreciate category theory (and far fewer allegories), the usual theory-then-implementation order is presented in a technical report (Batory and Altoyan, 2019).

2.2 Running Example

We add a recursive association Anc to our EDD diagram, Fig. 3. Now each Emp has a lineage: descendants (children) and ancestors (parents). Traversing the Anc association computes Emps that are grandparents, by expression Emp.parent().parent(), and Emps that are grandchildren, by Emp.child().child().

Class Diagram to Relational Schema Mapping. It is well-known that UML class diagrams can be translated into normalized relational schemas (Elmasri and Navathe, 1999). The **blue** statements in Fig. 4 are EDD

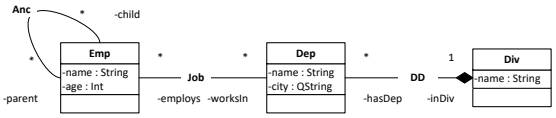


Figure 3: EDD with a Recursive, Lineage Association Anc.

schema declarations in **MDElite** (Batory et al., 2013), the MDE platform used in this paper. The dbase statement declares the EDD database to consist of five tables: Emp, Dep, and Div, along with an association table Job that encodes n:m relationships among Emp and Dep tuples, and an association table Anc that encodes n:m ancestry information among Emp.

The first column of every table is a manufactured identifier id required by **MDElite**. The primary key of tables Emp, Dep, and Div is their name attribute. The manufactured tuple identifier id always serves as a tuple key. All facts, dbase, table, and tuple declarations are written in a Prolog-fact notation.

The Emp table of Fig. 4 has 3 columns: id, name, and age. Column age is of type int; the others default to String. Table Dep has 4 columns: id, name, "city", and inDiv. The first three columns are of type String. "city" means that city values are quoted because they may have blanks (e.g., "New York"). Attribute name has unquoted String values. Column inDiv has legal identifiers of Div tuples as its values.

```
dbase(EDD,[Emp,Dep,Div,Anc,Job]).

table(Emp,[id,name,age:int]).
Emp(p1,don,64).
Emp(p2,karen,57).
Emp(p3,hanna,23).
Emp(p4,alex,18).
Emp(p5,steve,53).
Emp(p6,priscila,28).
Emp(p7,hanna,73).
Emp(p8,kelly,58).
Emp(p9,phyllis,56).

table(Dep,[id,name,"city",inDiv:Div]).
Dep(d1,mens,"Austin",v1).
Dep(d2,womens,"Austin",v1).
Dep(d3,appliances,"Toronto",v2).
Dep(d4,hardware,"Toronto",v2).
Dep(d5,book,"Hamilton",v2).
```

```
table(Div,[id,name]).
Div(v1,clothing).
Div(v2,goods).

table(Anc,[id,parent:Emp,child:Emp]).
Anc(c1,p1,p3).
Anc(c2,p2,p3).
Anc(c3,p1,p4).
Anc(c4,p2,p4).
Anc(c5,p5,p1).

table(Job,[id,employs:Emp,worksIn:Dep]).
Job(w1,p1,d1).
Job(w2,p2,d2).
Job(w3,p3,d2).
Job(w4,p4,d4).
Job(w5,p5,d3).
Job(w6,p6,d2).
Job(w7,p7,d2).
Job(w8,p1,d3).
Job(w9,p8,d5).
Job(w10,p9,d5).
```

Figure 4: An EDD Database Instance.

Object Model to Database Mapping. An EDD model (object diagram) is needed to evaluate queries and constraints. Any EDD model can be translated into a database of tuples for the computed EDD schema, such as Fig. 4. Again, tuples are written as Prolog facts: Emp(p1,don,64) is a Emp tuple where id=p1, name=don, and age=64. The Anc(c1,p1,p3) tuple has id=c1, parent=p1, and child=p3, meaning don is the parent of hanna.

Although this example lacks inheritance hierarchies, $\mathbb{A}_{\text{ocl}}$ supports subclasses/subtables as expected.

Constraints and Queries on EDD. Here are four constraints to enforce on EDD:

(C1) Every Emp has a unique name.
(C2) Every Dep in Toronto employs Emps 19 and older.
(C3) No Div can employ more than 20 Emps.
(C4) Grandparents of workers can not be employed.

And here are five non-trivial and progressively more complicated queries that could be used in constraints or in model-to-model transformations:

(Q1) Find Emps whose name begins with d or p.
(Q2) Find the Divs that have Deps in Austin.
(Q3) List Emps that work in multiple Divs.
(Q4) Print the Div colleagues of priscila.
(Q5) List the id of each Emp (whose parent is also an Emp) with the id of division(s) in which he/she works.

We consider queries in the next section and constraints afterwords.

2.3 $\mathbb{A}_{\text{ocl}}$ Queries

An $\mathbb{A}_{\text{ocl}}$ program is a pure-Java program that imports its allegory package and starts by reading a database, here the EDD model of Fig. 4:

```
import Allegory.EDD.*;
...
Database edd = new Database("EDD.edd.pl");
```

We can immediately write $\mathbb{A}_{\text{ocl}}$ expressions for each query in Section 2.2. Query outputs are posted in Fig. 5.

(Q1) finds employees whose name begins with d or p. Here is Java ($\mathbb{A}_{\text{ocl}}$) code to compute **(Q1)**'s solution:

```
edd.Emp
   .select(e->e.name.startsWith("d") ||
            e.name.startsWith("p"))
   .print();
```

The expression edd.Emp yields the Emp table. The select takes a Java **Predicate** as input, which selects Emp tuples whose name starts with d or p. Then print() displays the select-produced table. Its USE OCL counterpart is:[1]

```
Emp.allInstances
   .select(name.at(1)='d' or
           name.at(1)='p')
```

[1] Following allInstances in some versions of OCL require -> or ()->; our USE OCL is correct.

(Q2) finds divisions that have departments in Austin:

```
edd.Dep
   .select(d->d.city.equals("Austin"))
   .inDiv()
   .print();
```

Deps that are in Austin are identified by select(). Austin Deps are mapped by inDiv() to their Divs, and then printed. Its USE OCL counterpart:

```
Dep.allInstances
   .select(city='Austin')
   .inDiv->asSet
```

(Q3) lists Emps that work in multiple Deps:

```
edd.Emp
   .select(e->e.worksIn().count()>1)
   .print();
```

The select() finds employees that work in more than one department. Its USE OCL counterpart:

```
Emp.allInstances.select(worksIn->size>1)
```

(Q4) prints the division colleagues of priscila:

```
edd.Emp
   .select(e->e.name.equals("priscila"))
   .worksIn().inDiv()
   .hasDep().employs()
   .print();
```

Emp.select() produces an Emp table of priscila tuples. worksIn().inDiv() produces a table of Divs in which priscila works. hasDep().employs() computes the table of Emps that work in those Divs. Its USE OCL counterpart is:

```
Emp.allInstances
   .select(name='priscila')
   .worksIn.inDiv.hasDep.employs->asSet
```

(Q5) lists the id of each employee (whose parent is an employee) with the id of division(s) in which he/she works:

```
DTable Q5 = new DTable("Q5","EmpId","DivId");
edd.Emp
   .select(e->e.parent().exists())
   .forEach(em->em.worksIn().inDiv()
                .forEach(d->Q5.add(em.id,d.id)));
Q5.print();
```

The first line creates a temporary table Q5 with column names EmpId and DivId. The second line selects eligible Emps. The forEach lines compute Q5 tuples (ordered pairs). The last line prints table Q5. Its USE OCL counterpart is:

```
Emp.allInstances
    .select(parent->notEmpty)->
  iterate(e:Emp;
  ed:Set(Tuple(first:Emp,
               second:Set(Div)))=Set{}
  | ed->including(Tuple{first=e,
      second=e.worksIn.inDiv->asSet}))
```

Observations.

- Fig. 5 is the output of $\mathbb{A}_{ocl}$ and USE OCL. Their solutions are identical, albeit different syntax. As these examples showed, $\mathbb{A}_{ocl}$ and OCL expressions are syntactically similar. This is to be expected as both are stream processing languages.
- The methods invoked in the above examples on EDD tuples and tables belong to the generated EDD Java package. The same holds for the EDD constraints we consider next.

Aocl Solutions	USE OCL Solutions
(Q1) Find all employees whose name begins with 'd' or 'p'	
table(Emp,[id,name,age:int]). Emp(p1,don,64). Emp(p6,priscila,28). Emp(p9,phyllis,56).	Set{p1,p6,p9} : Set(Emp)
(Q2) Find the divisions that have departments in Austin	
table(Div,[id,name]). Div(v1,clothing).	Set{v1} : Set(Div)
(Q3) List employees that work in multiple departments	
table(Emp,[id,name,age:int]). Emp(p1,don,64).	Set{p1} : Set(Emp)
(Q4) Print the division colleagues of priscila	
table(Emp,[id,name,age:int]). Emp(p1,don,64). Emp(p2,karen,57). Emp(p3,hanna,23). Emp(p6,priscila,28). Emp(p7,hanna,73).	Set{p1,p2,p3,p6,p7} : Set(Emp)
(Q5) List the ID of each employee (whose parent is an employee) and the ID of division(s) in which he/she works	
table(Q5,[EmpId,DivId]). Q6(p1,v1). Q6(p1,v2). Q6(p3,v1). Q6(p4,v2).	Set{ Tuple{first=p1,second=Set{v1,v2}}, Tuple{first=p3,second=Set{v1}}, Tuple{first=p4,second=Set{v2}} } : Set(Tuple(first:Emp, second:Set(Div)))

Figure 5: $\mathbb{A}_{ocl}$ and USE OCL Solutions to **(Q1)**–**(Q5)**.

- $\mathbb{A}_{ocl}$ follows relational database tradition as tables (sets of tuples) are produced. Tables with duplicates can indeed be produced in $\mathbb{A}_{ocl}$ and by applying a unique() operation, duplicates can be removed. Again, this is standard relational database technology (Elmasri and Navathe, 1999). The Bag, Sequence, Orderedset, and Collection constructs in OCL are clutter from a classical relational database perspective.
- The simplicity of $\mathbb{A}_{ocl}$ syntax relies heavily on Java 8.0 syntax and Java streams. For example, all $\mathbb{A}_{ocl}$ select statements require an iteration variable (e.g., t->) – this is part of Java 8.0 and absent in earlier versions of Java.

2.4 $\mathbb{A}_{ocl}$ Constraints

A special Java class and table operation are used in $\mathbb{A}_{ocl}$ to log constraint violations. ErrorReport is a

Java class whose stateful objects log errors. Table method `error(er,...)` takes an `ErrorReport` object (`er`) and logs a customized error for each tuple of `error()`'s input table. Constraint outputs are posted in Fig. 6.

$\mathbb{A}_{ocl}$ constraint programs begin with the reading of a database and the creation of an `ErrorReport` object:

```
import Allegory.EDD.*;
...
Database    edd = new Database("EDD.edd.pl");
ErrorReport er = new ErrorReport();
```

Constraints can now be written. **(C1)** asserts all employees have unique names:

```
String fmt = "multiple employees have name=%s";
edd.Emp
   .name()
   .duplicates()
   .error(er,fmt,e->e.value);
```

`Emp.name()` produces a single-column `STRINGTable` of `Emp` names that preserves duplicates. `duplicates()` retains one copy of each duplicated tuple in a table and eliminates non-duplicates. An error is logged for each tuple in `STRINGTable`. Its USE OCL counterpart:

```
context Emp inv UniqueName:
Emp.allInstances
   .forAll(e1,e2 | e1.name=e2.name implies e1=e2)
```

(C2) every `Dep` in Toronto hires `Emps` 19 and older:

```
String fmt = "%s illegally hired %s";
edd.Dep
   .select(d->d.city.equals("Toronto"))
   .forEach(d->d.employs()
                .select(ee->ee.age<19)
                .error(er,fmt,e->d.name,e->e.name));
```

For each `Dep` in Toronto, a table of under-aged `Emps` is computed and each violation is logged. Its USE OCL counterpart:

```
context Dep inv EmpAge:
self.select(city='Toronto')
    .employs->forAll(e|e.age>=19)
```

(C3) says no `Div` can employ more than 20 `Emps`:

```
edd.Div
   .select(d->d.hasDep().employs().count()>20)
   .error(er,"%s has >20 workers",d->d.name);
```

Its USE OCL counterpart:

```
context Div inv EmpCount:
self.hasDep.employs->size()<=20
```

(C4) grandparents of workers can not be employed:

```
String fmt = "%s has grandchildren employed";
db.Emp.select(e->e.child().child().exists())
      .error(er, fmt, e->e.name);
```

Its USE OCL counterpart:

```
context Emp inv twoGen:
self.child.child->size() = 0
```

Printing accumulated errors ends a constraint program:

```
er.printEH();
```

(C1), **(C2)** and **(C4)** log errors; **(C3)** does not.

Observations.

- Fig. 6 shows the output of $\mathbb{A}_{ocl}$ and USE OCL queries. The solutions are identical, albeit different syntax. $\mathbb{A}_{ocl}$ errors pin-point their source; USE OCL simply reports `false` when any error is detected, `true` otherwise. The $\mathbb{A}_{ocl}$ reports no errors for **(C3)**, and thus is blank.
- USE OCL and $\mathbb{A}_{ocl}$ constraint expressions are comparable in structure with $\mathbb{A}_{ocl}$ expressions a bit longer due to customized error logging.

Aocl Solutions	USE OCL Solutions
(C1) All Emps must have unique names	
Solution 1: multiple employees have name=hanna Solution 2: Emp(p3..) has non-unique name=hanna Emp(p7..) has non-unique name=hanna	false
(C2) All Deps in Toronto cannot employ Emps younger than 19	
hardware illegally hired alex	false
(C3) No Div can employ more than 20 Emps	
	true
(C4) Grandparents of workers can not be employed	
steve has grandchildren employed	false

Figure 6: Error Log of Constraints **(C1)**–**(C4)**.

2.5 Model-to-Model Transformations

OCL cannot update the model that it examines. By precluding updates, $\mathbb{A}_{ocl}$ could behave similarly. By allowing updates, $\mathbb{A}_{ocl}$ could be used to write model-to-model transformations and be more versatile.

As an illustration, in a few minutes, we coded and executed ATL's **"Families-to-Persons"** example (Jouault, 2007). The Java source for this program is in Fig. 7. (This image is digitally enlargable). We generated $\mathbb{A}_{ocl}$ packages for the `Families` and `Persons` metamodels, and the rest was easy. We do not foresee problems scaling $\mathbb{A}_{ocl}$ to large M2M transformations.

```
package atlexample;

import MDLUtilities.MarqueeIn_1Out;
import Allegory.Person.*;

public class ATLExample {
    static Allegory.Family.Database in;
    static Allegory.Person.Database out;

    public static void main(String... args) {
        // Step 1: standard marquee processing
        MarqueeIn_1Out mark = new MarqueeIn_1Out(ATLExample.class,
                ".family.pl", ".person.pl", args);
        String inputFileName = mark.getInputFileName();

        // Step 2: read the families database and init output database
        in = new Allegory.Family.Database(inputFileName);
        out = new Allegory.Person.Database();

        // Step 3: m2m transformation + print out
        addBoys();
        addFathers();
        addGirls();
        addMothers();
        out.print();
    }

    static void addBoys() {
        in.member
          .select(m->m.sonOf!=null)
          .forEach(m->{
              String fullName = m.firstName+" "+m.sonOf.lastName;
              out.male.add(new male(m.id,fullName)); });
    }

    static void addGirls() {
        in.member
          .select(m->m.daughterOf!=null)
          .forEach(m->{
              String fullName = m.firstName+" "+m.daughterOf.lastName;
              out.female.add(new female(m.id,fullName)); });
    }

    static void addFathers() {
        in.family.forEach(f->{
            String fullName =  f.fatherid.firstName + " " +f.lastName;
            if (out.male.select(m->m.fullName.equals(fullName)).size()==0)
              out.male.add(new male(f.fatherid.id, fullName));});
    }

    static void addMothers() {
        in.family.forEach(f->{
            String fullName =  f.motherid.firstName + " " +f.lastName;
            if (out.female.select(m->m.fullName.equals(fullName)).size()==0)
              out.female.add(new female(f.motherid.id, fullName));});
    }
}
```

Figure 7: $\mathbb{A}_{\text{ocl}}$ Families-to-Persons M2M Transformation.

3 Status

$\mathbb{A}_{\text{ocl}}$ is operational and relies on a Java framework that uses Java generics, lambda functions, and Java streams (MDELite, 2020). An **MDElite** tool called **Meta4** converts a textual specification of a class diagram into a plug-in for the $\mathbb{A}_{\text{ocl}}$ framework. This plug-in defines all classes, tables, and database operations to support an $\mathbb{A}_{\text{ocl}}$ package for that class diagram. For example, a textual specification of the EDD diagram of Fig. 3 is:

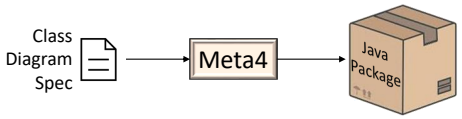
```
classDiagram EDD.

table(Emp,[id,name,age:int]).
table(Dep,[id,name,"city"]).
table(Div,[id,name]).

// continued on next page
assoc Emp employs * -- Dep worksIn *.
assoc Emp parent  * -- Emp  child  *.
assoc Div inDiv   1 -- Dep hasDep  *.

// no inheritance decls in this example
```

From this specification, **Meta4** generates the $\mathbb{A}_{\text{ocl}}$ EDD Java 8.0 package with classes for Emp, Dep, Div tuples and tables, hidden association tables and their tuples, a Java class whose instances are EDD databases and a **MDElite** database schema:



Meta4 itself is a set of M2T tools and parsers, totaling 6100 Java LOC. Java Generic classes that are shared by all $\mathbb{A}_{\text{ocl}}$ packages is 2800 Java LOC. The size of the generated EDD plug-in is 1330 Java LOC. And **MDElite**, the MDE platform on which **Meta4** was built, is 18K Java LOC.

4 The Value Proposition of $\mathbb{A}_{\text{ocl}}$

Must MDE use special-purpose programming and constraint languages like OCL(OMG, 2019), ATL (ATL, 2005), and QVT (OMG, 2016) that require their own compiler and IDE-like infrastructure, when a standard and richer infrastructure that Java 11 provides might suffice? $\mathbb{A}_{\text{ocl}}$'s existence suggests not. Here are additional pros-and-cons:

Pros. Maintaining a custom language, compiler, debugger, refactoring tools, document tools, etc. is a long-term and costly burden that few research efforts can afford. Modern programming languages have come a long way in the last 20 years. Java 11 (2018) is vastly different than Java 1 (1996). The combination of generics (Java 5), lambda expressions and streams (Java 8), with compiler, debugging, documentation, and refactoring support offers a modern programming environment that makes $\mathbb{A}_{\text{ocl}}$ appealing.

Even if OCL and its infrastructure were perfect today, they must be maintained and extended tomorrow. Extending tools that are Java packages, like **Meta4**, is easier and less costly. And replacing arcane languages with custom packages in modern languages can entice more people to the MDE community. It certainly would reduce the long-term burden of MDE tool support and tool education.

Cons. A perceived important down-side of $\mathbb{A}_{\text{ocl}}$ is that it is a platform dependent language rather than a platform *independent* language. So how could a platform dependent language be advantageous? Ans#1: Recall the history of distributed programming. CORBA initially offered a language-independent front-end for multi-platform programming. It has given way to language annotations that bridge the gap (Oracle, 2019), eliminating arcane CORBA languages entirely and replacing them with Java-derivable WSDLs for platform independence. This could be done for MDE. Ans#2: The tools of an area reflect the quality of teaching material. OCL is about 20 years old; Eclipse MDE tools are about 15. They are first generation and should be celebrated for their success. We can

do better now, by reducing ideas that were considered new 20 years ago to well-established Computer Science technologies, making MDE concepts, languages, and tools more elegant, easier to learn, and use.

5 Related Work

Embedding database queries in Java and other languages is common (Meijer et al., 2006). (Cheney et al., 2013) proposed quoting mechanisms for Java to enclose SQL-like queries. (Cook and Wiedermann, 2011) took a broader view, recognizing that quoted blocks of SQL or a subset of Java can provide elegant language support for service oriented architectures and database processing. $\mathbb{A}_{\text{ocl}}$ is an even closer integration where Java packages express database (or relational algebra) computations.

General-purpose tools, like `Xtend` and `Xbase`, integrate DSLs (e.g., OCL constructs) with Java and other languages (XText, 2017). Of course, these tools are necessarily heavier-weight than $\mathbb{A}_{\text{ocl}}$ as $\mathbb{A}_{\text{ocl}}$ is simply a package requiring no language engineering at all.

Another approach implements OCL as a Java package (interpreter) (Eclipse, 2019). OCL queries are submitted as Java Strings to this package (much like SQL strings are submitted to SQL packages for execution). The results are returned as Java objects for subsequent processing. $\mathbb{A}_{\text{ocl}}$ eliminates this middleware approach to express OCL-like queries natively, invoking methods of an $\mathbb{A}_{\text{ocl}}$-generated package for direct execution.

Several projects translated OCL into Java (Shidqie, 2007; Kallel and et al., 2016). These particular projects were completed before Java 8 (2014) was released, where streams and lambda functions first appeared. The translations to Java 7.0 and earlier versions are verbose and not as elegant as their OCL and $\mathbb{A}_{\text{ocl}}$ counterparts.

(Yue and Ali, 2016) compared OCL and Java when writing constraints. Java 7 was used, meaning that the Java code was (as above) more verbose than OCL. Never-the-less, the authors found that participants working with OCL and Java performed equally well, with an edge to OCL when constraints became complicated. $\mathbb{A}_{\text{ocl}}$ should reduce this advantage. A goal was to "find a way to ... offset the investment in terms of training and tool support ... for OCL". $\mathbb{A}_{\text{ocl}}$ does not eliminate this cost, but reduces it to learning a Java package, which is less intimidating.

(Rumpe, 2002) proposed $\ll$`Java`$\gg$`OCL` to (a) adjust OCL syntax closer to that of Java to make it more familiar to Java developers. He examined the OCL meta operations (e.g., `OclAny`, `OclType`, `OclExpression`, `oclAsType`) that we believe are more elegantly handled in Java. His underlying motivation (in our opinion) was similar to that of Yue and Ali (Yue and Ali, 2016): to offset the investment in OCL training.

And finally, (Vaziri and Jackson, 2000) argue that a language like Alloy would be more appropriate than OCL to express constraints, as OCL is "too implementation oriented". Declarative languages always need some escape to code to express certain concepts. $\mathbb{A}_{\text{ocl}}$ is a compromise between too-high and too-low a specification language.

6 Conclusions

$\mathbb{A}_{\text{ocl}}$ is a lightweight, simple, and pure-Java alternative to OCL and special-purpose MDE transformation languages. $\mathbb{A}_{\text{ocl}}$ queries and constraints are syntactically similar (with comparable complexity) to those of OCL. But $\mathbb{A}_{\text{ocl}}$ is more streamlined as it is pure Java, relying on Java syntax and semantics. We believe this will simplify next-generation MDE tooling and teaching – critical problems in their own right.

Modern programming languages are constantly improving. Our experience with Java generics, lambda expressions and streams have convinced us that Java can effectively compete with some of yesterday's special-purpose languages. The trade-off replaces an ecosystem of intertwined special-purpose programming languages with their massive IDE infrastructure (all of which must be maintained) with small Java libraries. We argued that maintaining Java libraries will be more cost effective in the long-run and the maintenance of infrastructure becomes the rightful burden of a small set of language and IDE developers that have the resources for such efforts.

MDE users will also benefit: the cost of entry using well-known modern languages will be lower than it is for out-dated specialized legacy languages.

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