

Towards Synchronizing Relations Between Artifacts in the Java Technological Space

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Organization

1 Introduction

- Background
- Objective

2 Development

- The Metamodels
- The Relations
- The Synchronization

3 Conclusion

4 References

Background

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Models are used in Software Engineering

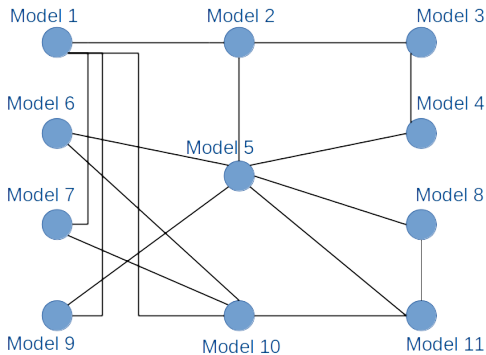


Models are used in Software Engineering

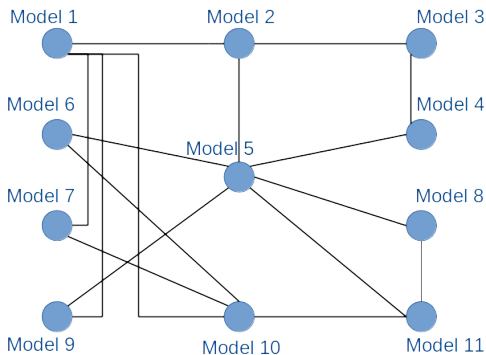


- New needs in industry thrill new methods and paradigms.
- **Model-driven Engineering (MDE):** Software processes are oriented to models.
- One software may have several different models.

Models have to be kept consistent



Models have to be kept consistent



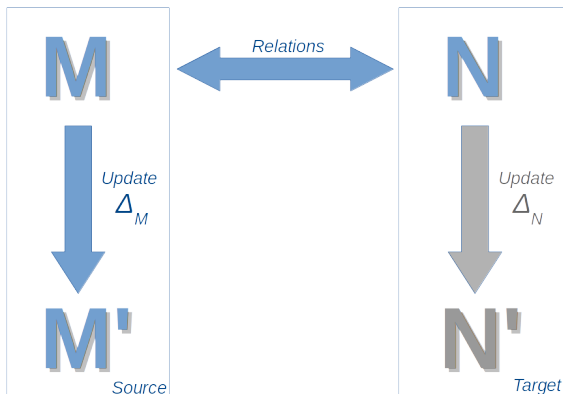
- Models are to be maintained consistent as they evolve.
- This means **models synchronization**.

Model Synchronization in the Network of Models

- For each edge of the network there is a synchronization task.

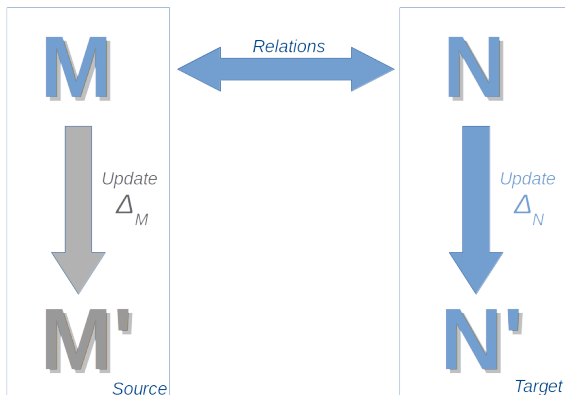
Model Synchronization in the Network of Models

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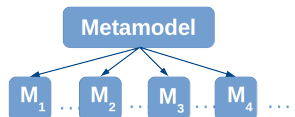


Model Synchronization in the Network of Models

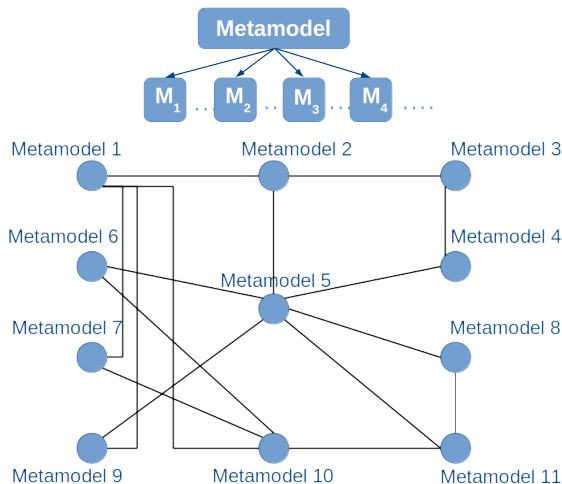
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Relations are written between metamodels



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The problems of the current state-of-the-art

- Definitions of the **metamodels** in literature

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- Definitions of the **relations** in literature

The problems of the current state-of-the-art

- Definitions of the **metamodels** in literature
- Definitions of the **relations** in literature
- Approach able to treat synchronization of **complex technological spaces** with a large number of **tangled** metamodels.

Objective

1 Introduction

■ Background

■ Objective

2 Development

■ The Metamodels

■ The Relations

■ The Synchronization

3 Conclusion

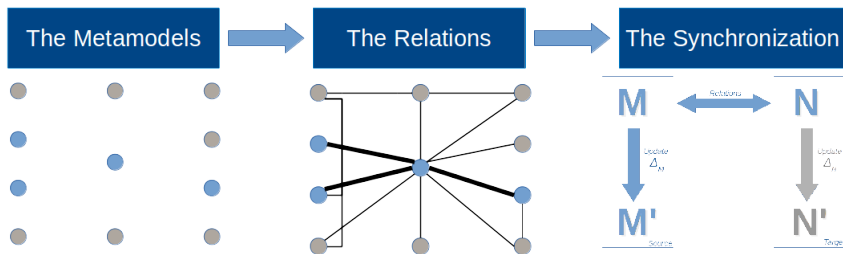
4 References

Three Steps

- Focus on the Java technological space.

Three Steps

- Focus on the Java technological space.



The Metamodels

1 Introduction

- Background
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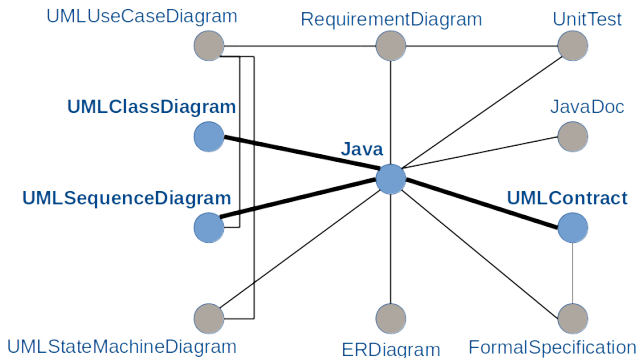
2 Development

- **The Metamodels**
- The Relations
- The Synchronization

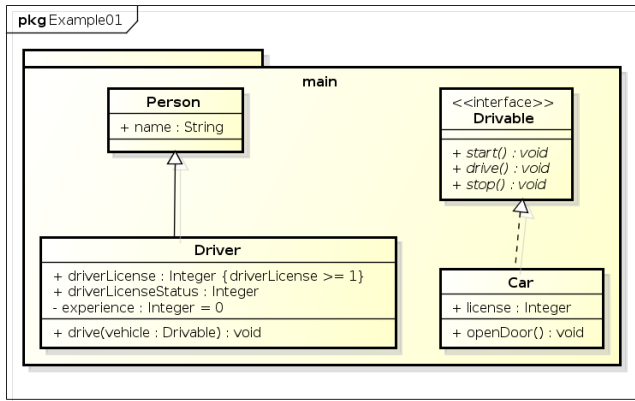
3 Conclusion

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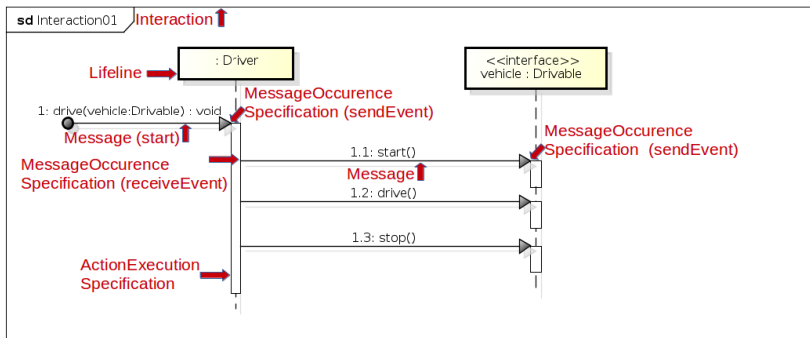
Some Metamodels of the Java Technological Space



UMLClassDiagram Concrete Syntax Example



UMLSequenceDiagram Concrete Syntax Example



UMLContract

- No concrete syntax defined
- Constraints (pre or postcondition or invariant) related to Properties or Operations
 - Opaque Expression (textual definition)
 - Interval

Java Concrete Syntax Example

```

1  package main;
2
3  import de.silvawb.utils.*;
4
5  public class Driver extends Person {
6      /*
7       * Fields
8       */
9      @Inv(constraint = "driverLicense >= 1")
10     public Integer driverLicense;
11     public Integer driverLicenseStatus;
12     private Integer experience = 0;
13
14     /*
15      * Methods
16      */
17     public void checkRep(){
18         assert driverLicense >= 1;
19     }
20     public void driveCheckInvConstraint(Drivable vehicle){
21         assert vehicle != null;
22     }
23     public void driveCheckPreConstraint(Drivable vehicle){
24         assert driverLicenseStatus >= 1;
25     }
26     public void driveCheckPosConstraint(Drivable vehicle){
27
28
29         @Inv(constraint = "vehicle <> null")
30         @Pre(constraint = "driverLicenseStatus >= 1")
31         @Pos(constraint = "experience > experience@pre")
32         @Interaction(interactionSequence = {
33             "start", "drive", "stop",
34         })
35         public void drive(Drivable vehicle){
36             checkRep();
37             driveCheckInvConstraint(vehicle);
38             driveCheckPreConstraint(vehicle);
39
40             vehicle.start();
41             vehicle.drive();
42             vehicle.stop();
43
44             checkRep();
45             driveCheckInvConstraint(vehicle);
46             driveCheckPosConstraint(vehicle);
47         }
48     }

```


The Relations

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Triple Graph Grammar

■ Relations coded by triple graphs

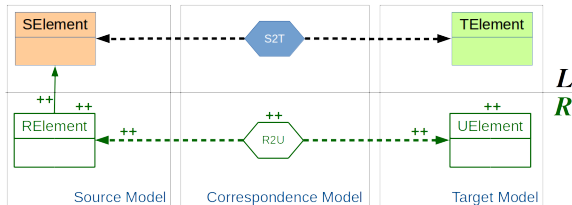


Triple Graph Grammar

■ Relations coded by triple graphs



■ Triple graphs are organized in triple rules $L \rightarrow R$.

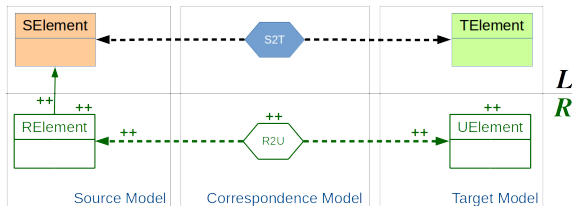


Triple Graph Grammar

- Relations coded by triple graphs



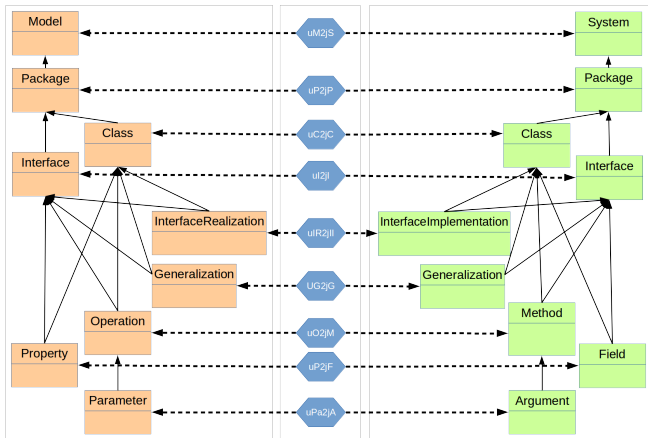
- Triple graphs are organized in triple rules $L \rightarrow R$.



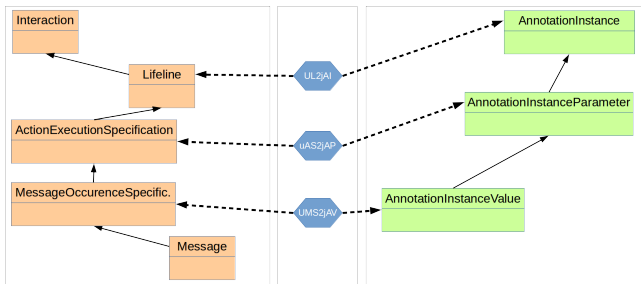
- These triple rules form a triple graph grammar (TGG) for each edge.

The Relations

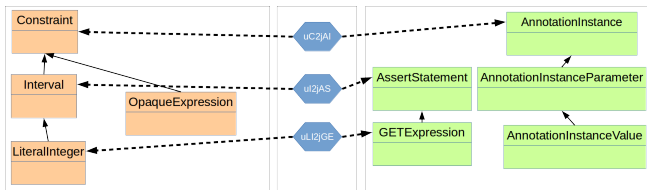
UMLClassDiagram2java



UMLSequenceDiagram2java



UMLContract2java



The Synchronization

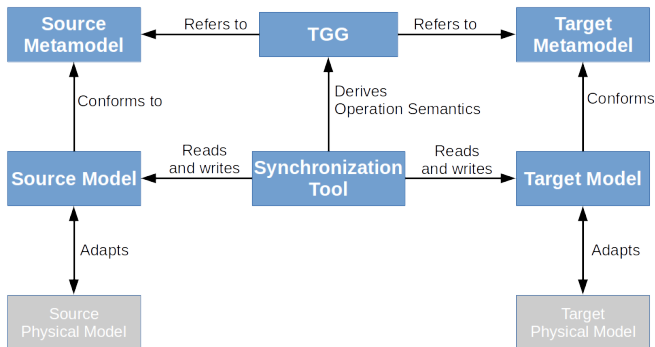
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Synchronization Scheme for Each TGG

- Following scheme for every edge of the network of metamodels

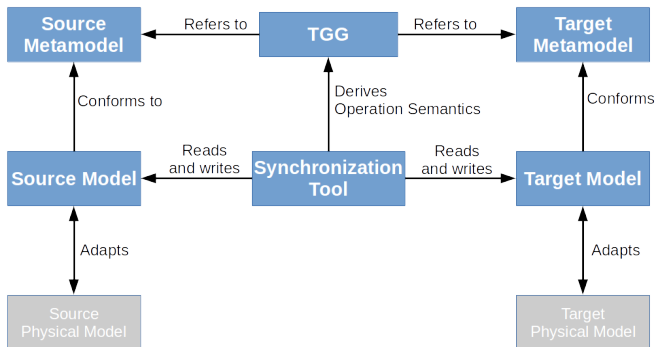
Synchronization Scheme for Each TGG

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Synchronization Scheme for Each TGG

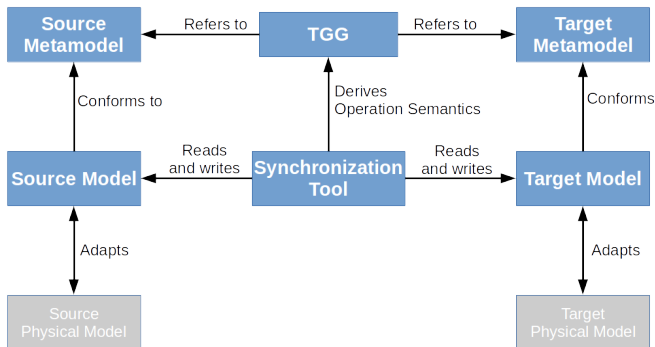
- Following scheme for every edge of the network of metamodels



- Treated separately by state-of-the-art approaches

Synchronization Scheme for Each TGG

- Following scheme for every edge of the network of metamodels



- Treated separately by state-of-the-art approaches
- How to treat the whole network of metamodels?

Synchronization Algorithm for the Network

```

function NETWORK SYNCHRONIZATION( $G, v, v_{new}, \delta_v$ )
    Update  $v$  to  $v_{new}$  in  $G$ 
    for all  $n_i = N(v)$  do
        Synchronize  $n_i$  according to  $v, v_{new}$  and  $\delta_v$ 
        if  $n_i$  was modified then
            Network Synchronization ( $G, n_i, n_{i_{new}}, \delta_n$ )
        end if
    end for
    return  $G$ 
end function

```

Synchronization Algorithm for the Network

function NETWORK SYNCHRONIZATION(G, v, v_{new}, δ_v)

Update v to v_{new} in G

for all $n_i = N(v)$ **do**

Synchronize n_i according to v, v_{new} and δ_v

if n_i was modified **then**

Network Synchronization ($G, n_i, n_{i_{new}}, \delta_n$)

end if

end for

return G

end function

- Supposing only one modification at a time and unidirectional modifications.
- The algorithm always terminates (for G finite without cycles).
- The algorithm is deterministic (for deterministic synchronization).

Conclusion

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Achieved goals

- 1 Metamodel definitions of artifacts from the Java Technological Space
 - Metamodels can be used in future works.
 - Metamodels are not complete.

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 - Exploration of TGGs for defining the relations
 - Evaluation of the definitions through forward transformation
 - Relations are not complete.

Achieved goals

- 1 Metamodel definitions of artifacts from the Java Technological Space
 - Metamodels can be used in future works.
 - Metamodels are not complete.
- 2 Creation of a network of metamodels including the relations' formalizations
 - Exploration of TGGs for defining the relations
 - Evaluation of the definitions through forward transformation
 - Relations are not complete.
- 3 The proposal of an algorithm for network synchronization
 - Novel view of the model synchronization problem
 - Algorithm has very limiting assumptions.

Thank you

Thank you for your attention

References



Krzysztof Czarnecki and Simon Helsen.

Feature-based survey of model transformation approaches.
IBM Systems Journal, 45(3):621–645, 2006.



Zinovy Diskin.

Model synchronization: Mappings, tiles, and categories.
In Generative and Transformational Techniques in Software Engineering III, pages 92–165. Springer, 2011.



Holger Giese, Stephan Hildebrandt, and Stefan Neumann.

Model synchronization at work: keeping sysml and autosar models consistent.
In Graph transformations and model-driven engineering, pages 555–579. Springer, 2010.



Florian Heidenreich, Jendrik Johannes, Mirko Seifert, and Christian Wende.

Jamopp: The java model parser and printer.
Technical report, Fakultät Informatik, Technological University of Dresden, Germany, 2009.



Frank Hermann, Hartmut Ehrig, Fernando Orejas, Krzysztof Czarnecki, Zinovy Diskin, and Yingfei Xiong.

Correctness of model synchronization based on triple graph grammars.
In Model Driven Engineering Languages and Systems, pages 668–682. Springer, 2011.























OMG OMG.

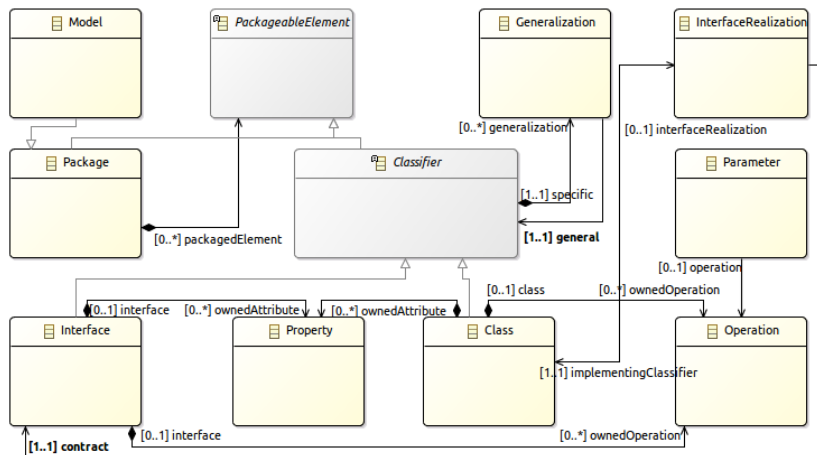
Unified modeling language (omg uml).
Superstructure, 2007.

Appendix

UMLClassDiagram Abstract Syntax Example

- 1 ▼  <Model> Example01
- 2 ▼  <Package> main
- 3 ▼  <Class> Person
- 4  <Property> name : String
- 5 ▼  <Class> Driver
- 6  <Generalization> Person
- 7  <Property> driverLicense : Integer
- 8  <Property> driverLicenseStatus : Integer
- 9 ▼  <Property> experience : Integer
- 10  <Literal String> 0
- 11 ▼  <Operation> drive (vehicle : Drivable)
- 12  <Parameter> vehicle : Drivable
- 13 ▼  <Interface> Drivable
- 14  <Operation> start ()
- 15  <Operation> drive ()
- 16  <Operation> stop ()
- 17 ▼  <Class> Car
- 18  <Property> license : Integer
- 19  <Interface Realization> Drivable
- 20  <Operation> openDoor ()

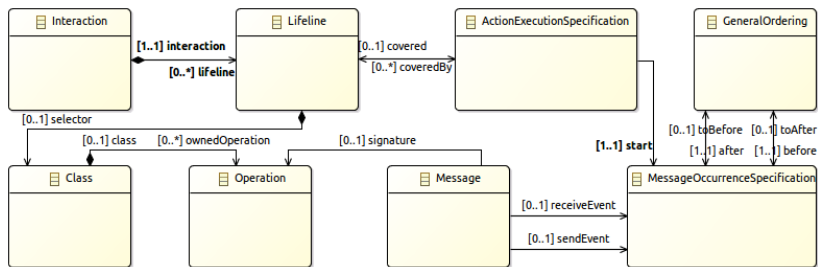
UMLClassDiagram Metamodel














UMLSequenceDiagram Abstract Syntax Example

1	▼ <Model> Example01	12	✚ <Message Occurrence Specification> 1.1 (sendEvent)
2	▼ <Interaction>	13	🔗 <Action Execution Specification> :Drivable (2)
3	📄 <General Ordering> 1 < 1.1	14	✚ <Message Occurrence Specification> 1.2 (receiveEvent)
4	📄 <General Ordering> 1.1 < 1.2	15	✚ <Message Occurrence Specification> 1.2 (sendEvent)
5	📄 <General Ordering> 1.2 < 1.3	16	🔗 <Action Execution Specification> :Drivable (3)
6	👤 <Lifeline> :Driver	17	✚ <Message Occurrence Specification> 1.3 (receiveEvent)
7	👤 <Lifeline> :Drivable	18	✚ <Message Occurrence Specification> 1.3 (sendEvent)
8	🔗 <Action Execution Specification> :Driver	19	📬 <Message> 1: drive(vehicle:Drivable) : void
9	✚ <Message Occurrence Specification> 1 (sendEvent)	20	📬 <Message> 1.1: start() : void
10	🔗 <Action Execution Specification> :Drivable (1)	21	📬 <Message> 1.2: drive() : void
11	✚ <Message Occurrence Specification> 1.1 (receiveEvent)	22	📬 <Message> 1.3: stop() : void

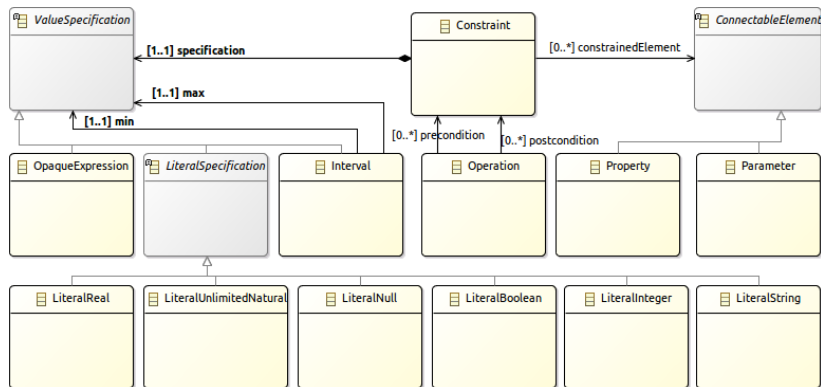
UMLSequenceDiagram Metamodel



UMLContract Abstract Syntax Example

- 1 ▼  <Model> Example01
- 2 ▼  <Package> main
- 3 ▼  <Class> Person
- 4  <Property> name : String
- 5 ▼  <Class> Driver
- 6 ▼   <Constraint> driverLicense >= 1
- 7  <Interval> 1 ..
- 8  <Generalization> Person
- 9  <Property> driverLicense : Integer
- 10  <Property> driverLicenseStatus : Integer
- 11 ▼  <Property> experience : Integer
- 12  <Literal String> 0
- 13 ▼  <Operation> drive (vehicle : Drivable)
- 14 ▼   <Constraint> driverLicenseStatus >= 1
- 15  <Interval> 1 ..
- 16 ▼   <Constraint> vehicle <> null
- 17  <Opaque Expression> vehicle <> null
- 18 ▼  <Constraint> experience > experience@pre
- 19  <Opaque Expression> experience > experience@pre
- 20  <Parameter> vehicle : Drivable
- 21 ▼  <Interface> Drivable
- 22  <Operation> start ()
- 23  <Operation> drive ()
- 24  <Operation> stop ()
- 25 ▼  <Class> Car
- 26  <Property> license : Integer
- 27  <Interface Realization> Drivable
- 28  <Operation> openDoor ()

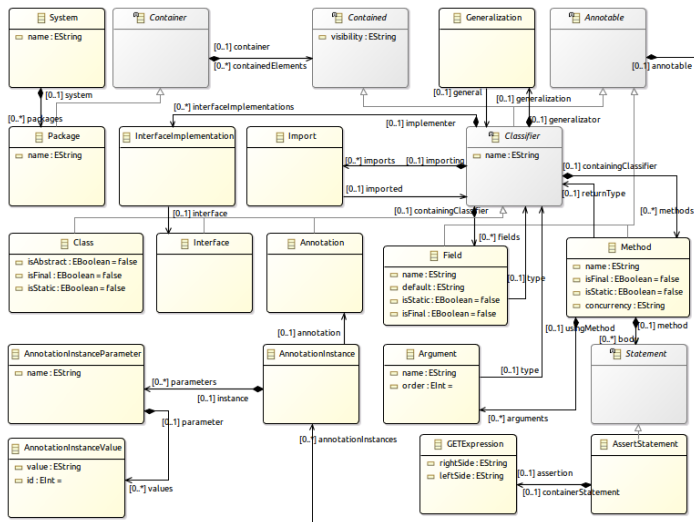
UMLContract Metamodel



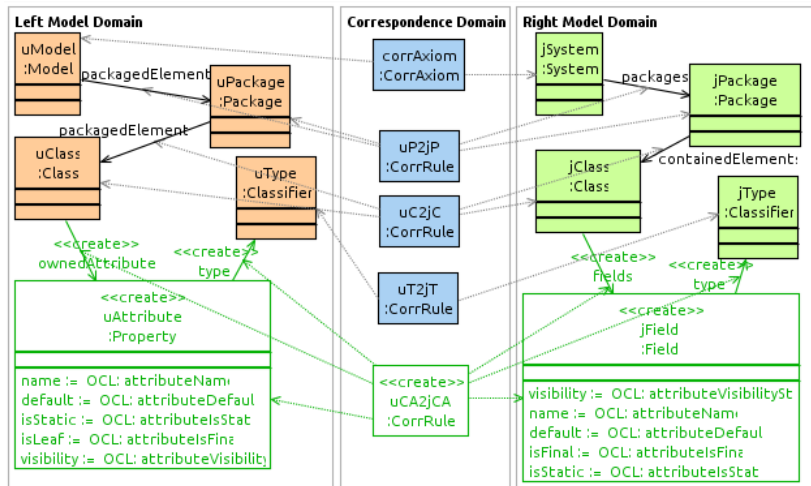
Java Abstract Syntax Example

```
1 ▼ ◆ System Example01
2 ▼ ◆ Package main
3 ▼ ◆ Class Person
4   ◆ Field name
5 ▼ ◆ Class Driver
6   ▼ ◆ Field driverLicense
7     ▼ ◆ Annotation Instance Inv
8       ▼ ◆ Annotation Instance Parameter constraint
9         ◆ Annotation Instance Value driverLicense >= 1
10    ◆ Field driverLicenseStatus
11    ◆ Field experience
12 ▼ ◆ Method drive
13   ▼ ◆ Annotation Instance Inv
14     ▼ ◆ Annotation Instance Parameter constraint
15       ◆ Annotation Instance Value vehicle <= null
16   ▼ ◆ Annotation Instance Pre
17     ▼ ◆ Annotation Instance Parameter constraint
18       ◆ Annotation Instance Value driverLicenseStatus >= 1
19 ▼ ◆ Annotation Instance Pos
20   ▼ ◆ Annotation Instance Parameter constraint
21     ◆ Annotation Instance Value experience > experience@pre
22 ▼ ◆ Annotation Instance Interaction
23   ▼ ◆ Annotation Instance Parameter interactionSequence
24     ◆ Annotation Instance Value start
25     ◆ Annotation Instance Value drive
26     ◆ Annotation Instance Value stop
27   ◆ Argument vehicle
28 ▼ ◆ Method checkRep
29   ▼ ◆ Assert Statement driverLicense >= 1
30     ◆ GET Expression 1
31 ▼ ◆ Method driveCheckInvConstraint
32   ◆ Argument vehicle
33 ▼ ◆ Method driveCheckPreConstraint
34   ◆ Argument vehicle
35   ▼ ◆ Assert Statement driverLicenseStatus >= 1
36     ◆ GET Expression 1
37 ▼ ◆ Method driveCheckPosConstraint
38   ◆ Argument vehicle
39   ◆ Generalization Person
40   ◆ Import de.silvawb.utils.Inv
41   ◆ Import de.silvawb.utils.Pre
42   ◆ Import de.silvawb.utils.Pos
43   ◆ Import de.silvawb.utils.Interaction
44 ▼ ◆ Interface Drivable
45   ◆ Method start
46   ◆ Method drive
47   ◆ Method stop
48 ▼ ◆ Class Car
49   ◆ Field license
50   ◆ Method openDoor
51   ◆ Method start
52   ◆ Method drive
53   ◆ Method stop
54   ◆ Interface Implementation Drivable
```

Java Metamodel



One triple rule for UMLClassDiagram2java



Result of the implementation for UMLClassDiagram2java

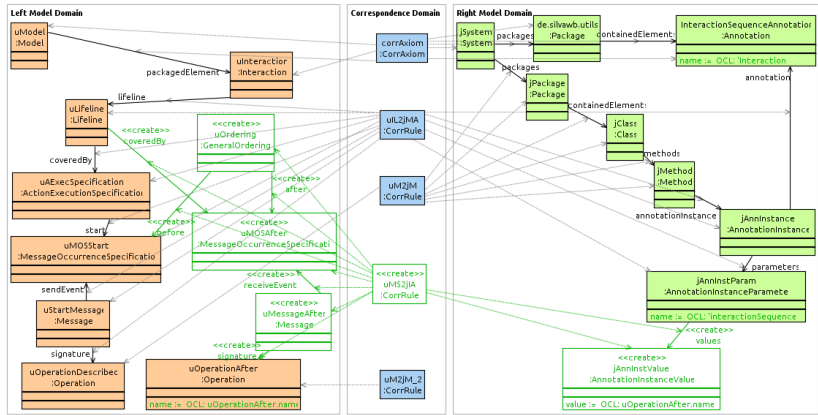
- Forward transformation was applied.

```
1 ▼ <Model> Example01
2 ▼ <Package> main
3 ▼ <Interface> Drivable
4   <Operation> start ()
5   <Operation> drive ()
6   <Operation> stop ()
7 ▼ <Class> Car
8   <Property> license : Integer
9   <Interface Realization> Drivable
10  <Operation> openDoor ()
```



```
1 ▼ System Example01
2 ▼ Package main
3 ▼ Interface Drivable
4   Method start
5   Method drive
6   Method stop
7 ▼ Class Car
8   Field license
9   Method openDoor
10  Interface Implementation Drivable
```

One triple rule for UMLSequenceDiagram2java



Implementation for UMLSequenceDiagram2java

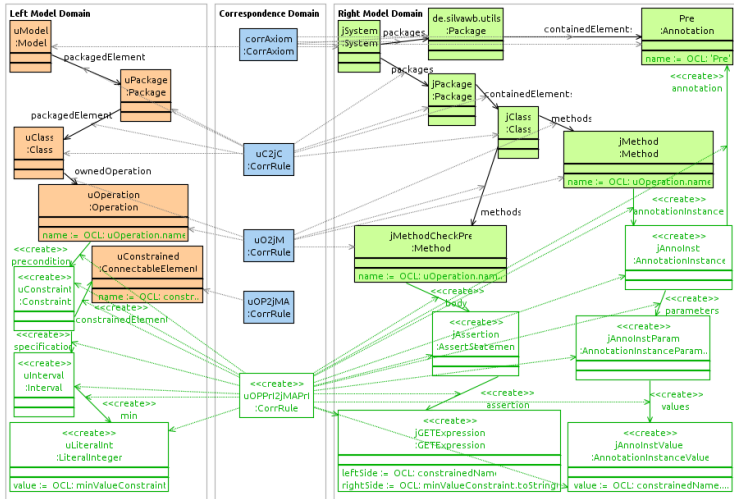
■ Forward transformation was applied.

```
1 ▼ <Model> Example01
2 ▼ <Interaction>
3   <General Ordering> 1 < 1.1
4   <General Ordering> 1.1 < 1.2
5   <General Ordering> 1.2 < 1.3
6   <Lifeline> :Driver
7   <Lifeline> :Driver
8   <Action Execution Specification> :Driver
9   <Message Occurrence Specification> 1 (sendEvent)
10  <Action Execution Specification> :Drivable (1)
11  <Message Occurrence Specification> 1.1 (receiveEvent)
12  <Message Occurrence Specification> 1.1 (sendEvent)
13  <Action Execution Specification> :Drivable (2)
14  <Message Occurrence Specification> 1.2 (receiveEvent)
15  <Message Occurrence Specification> 1.2 (sendEvent)
16  <Action Execution Specification> :Drivable (3)
17  <Message Occurrence Specification> 1.3 (receiveEvent)
18  <Message Occurrence Specification> 1.3 (sendEvent)
19  <Message> 1: drive(vehicle:Drivable) : void
20  <Message> 1.1: start() : void
21  <Message> 1.2: drive() : void
22  <Message> 1.3: stop() : void
23 ▼ <Package> main
24 ▼ <Class> Driver
25   <Operation> drive (vehicle : Drivable)
26 ▼ <Interface> Drivable
27   <Operation> start ()
28   <Operation> drive ()
29   <Operation> stop ()
```



```
1 ▼ ♦ System
2 ▼ ♦ Package de.silvawb.utils
3   ▼ ♦ Annotation Interaction
4     ♦ Field interactionSequence
5 ▼ ♦ Package main
6   ▼ ♦ Class Driver
7     ▼ ♦ Method drive
8       ▼ ♦ Annotation Instance Interaction
9         ▼ ♦ Annotation Instance Parameter InteractionSequence
10           ♦ Annotation Instance Value start
11           ♦ Annotation Instance Value drive
12           ♦ Annotation Instance Value stop
13         ♦ Argument vehicle
14 ▼ ♦ Interface Drivable
15   ♦ Method start
16   ♦ Method drive
17   ♦ Method stop
```

One triple rule for UMLContract2java



Result of the Implementation for UMLContract2java

■ Forward transformation was applied.

```
1 ▼ [Model] Example01
2 ▼ [Package] main
3 ▼ [Class] Driver
4   ▼ [Constraint] driverLicense >= 1
5     [Interval] 1 ..
6   [Property] driverLicense : Integer
7   [Property] driverLicenseStatus : Integer
8   [Property] experience : Integer
9   [Operation] drive (vehicle : Drivable)
10  ▼ [Constraint] driverLicenseStatus >= 1
11    [Interval] 1 ..
12  ▼ [Constraint] vehicle <> null
13    [Opaque Expression] vehicle <> null
14  ▼ [Constraint] experience > experience@pre
15    [Opaque Expression] experience > experience@pre
16  [Parameter] vehicle : Drivable
17 ▼ [Interface] Drivable
18   [Operation] start ()
19   [Operation] drive ()
20   [Operation] stop ()
```



```
1 ▼ [System]
2 ▼ [Package] de.silvawb.utils
3   [Annotation Inv]
4   [Annotation Pos]
5   [Annotation Pre]
6 ▼ [Package] main
7   ▼ [Class] Drive
8     ▼ [Field] driverLicense
9       ▼ [Annotation Instance Inv]
10        ▼ [Annotation Instance Parameter]
11          [Annotation Instance Value] driverLicense >= 1
12        [Field] driverLicenseStatus
13        [Field] experience
14      ▼ [Method] checkRep
15        ▼ [Assert Statement] driverLicense >= 1
16          [GET Expression 1]
17        ▼ [Method] driveCheckPreConstraint
18          [Argument] vehicle
```

```
19   ▼ [Assert Statement] driverLicenseStatus >= 1
20     [GET Expression 1]
21   ▼ [Method] driveCheckPosConstraint
22     [Argument] vehicle
23   ▼ [Method] drive
24     ▼ [Annotation Instance Pos]
25     ▼ [Annotation Instance Parameter]
26       [Annotation Instance Value] experience > experience@pre
27     ▼ [Annotation Instance Pre]
28     ▼ [Annotation Instance Parameter]
29       [Annotation Instance Value] driverLicenseStatus >= 1
30     ▼ [Annotation Instance Inv]
31     ▼ [Annotation Instance Parameter]
32       [Annotation Instance Value] vehicle <> null
33     [Argument] vehicle
34   ▼ [Method] driveCheckInvConstraint
35     [Argument] vehicle
```