

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

1 Introduction

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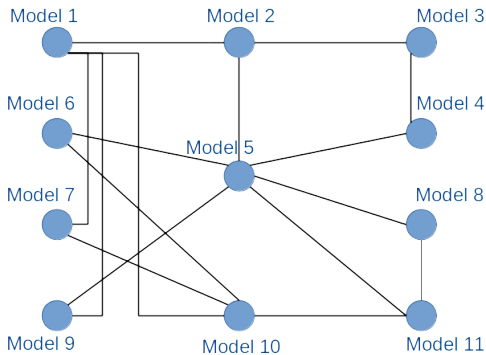
3 Conclusion

4 References

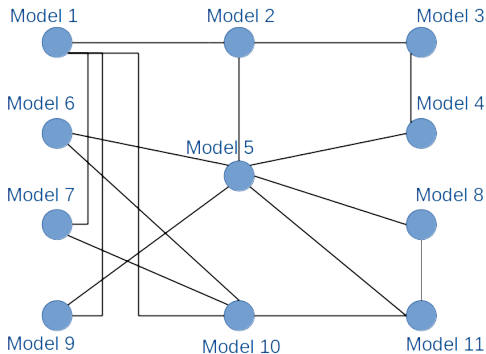
Models are used in Software Engineering

- New needs in industry and academy 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



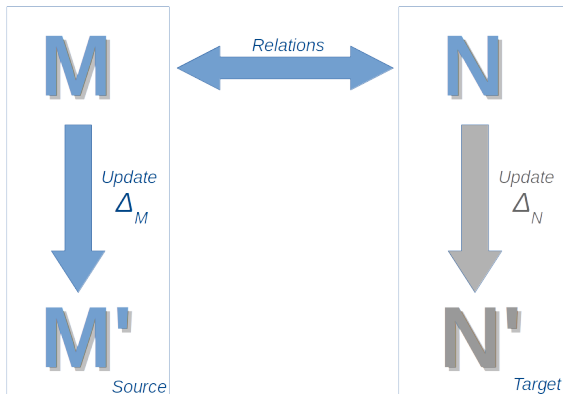
- Models are to be maintained consistent as they evolve.
- This means **models synchronization**.

Model Synchronization in the Network of Models

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

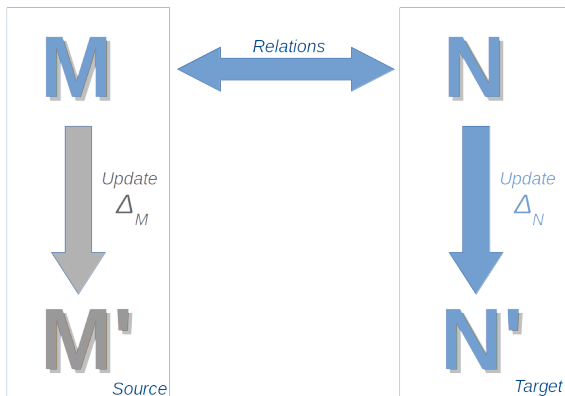
Model Synchronization in the Network of Models

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

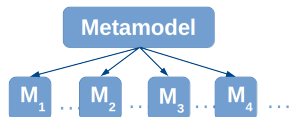


Model Synchronization in the Network of Models

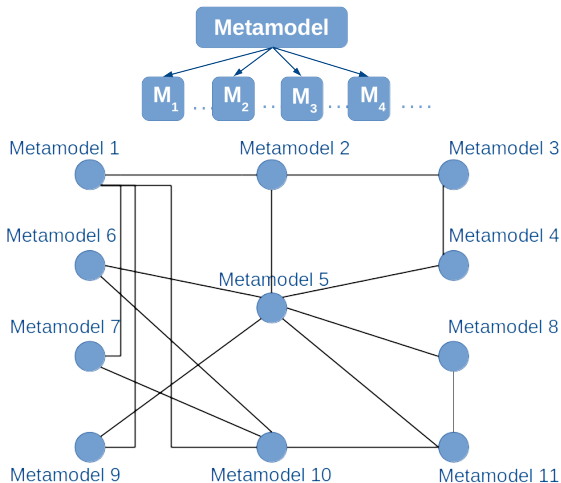
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Relations are written between metamodels



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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

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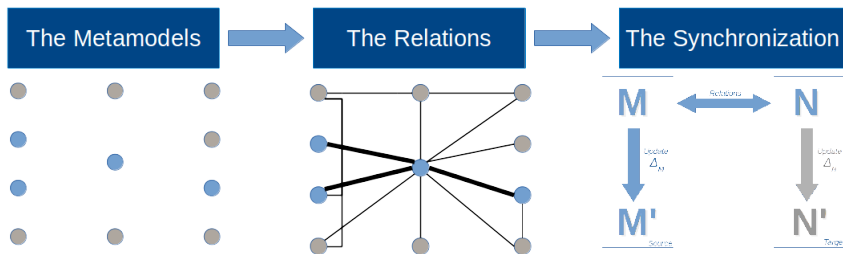
4 References

Three Steps

- Focus on the Java technological space.

Three Steps

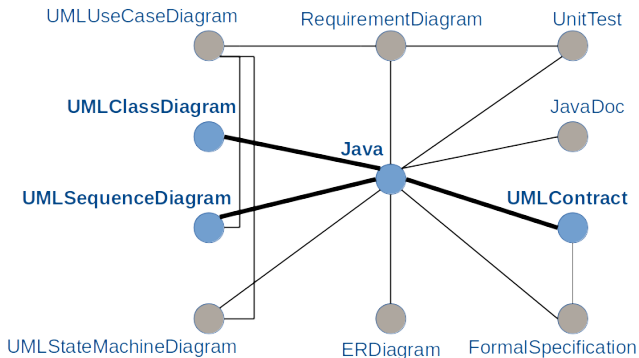
- Focus on the Java technological space.



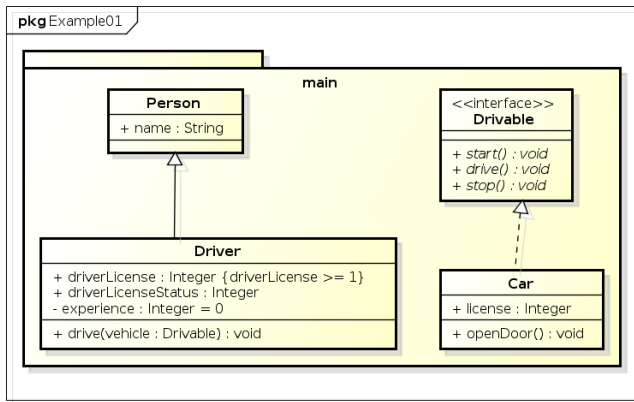
The Metamodels

- 1 Introduction
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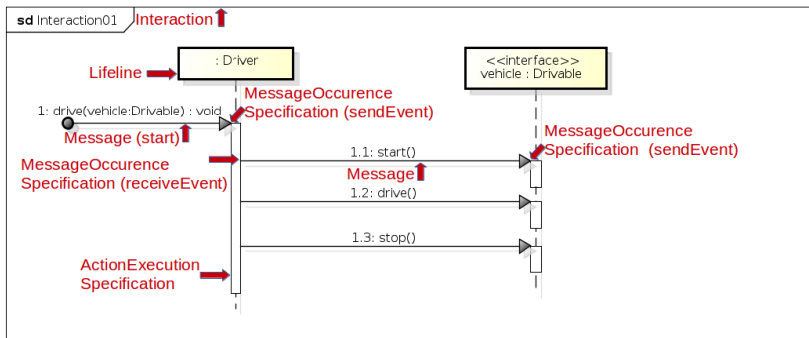
Some Metamodels of the Java Technological Space



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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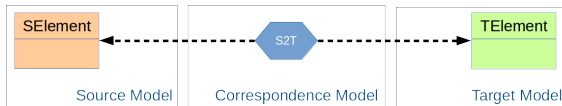
Triple Graph Grammar

■ Relations coded by triple graphs

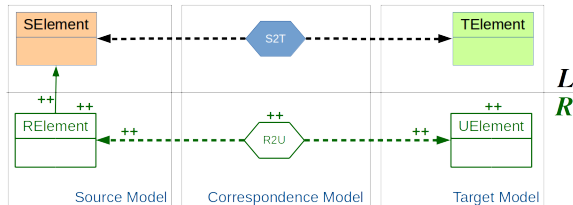


Triple Graph Grammar

■ Relations coded by triple graphs



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

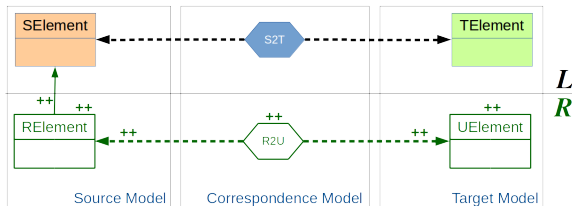


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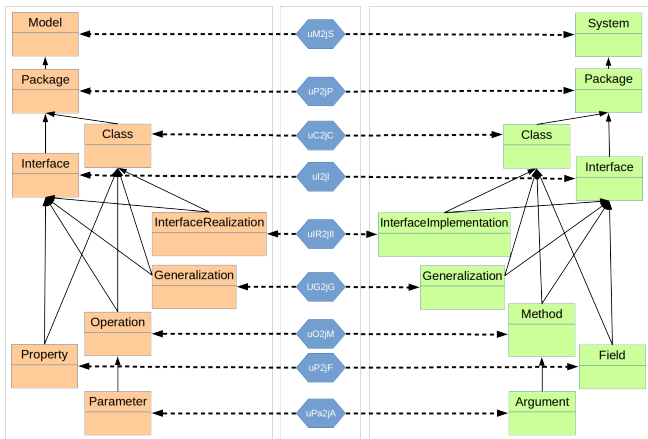
- Triple graphs are organized in triple rules $L \rightarrow R$.



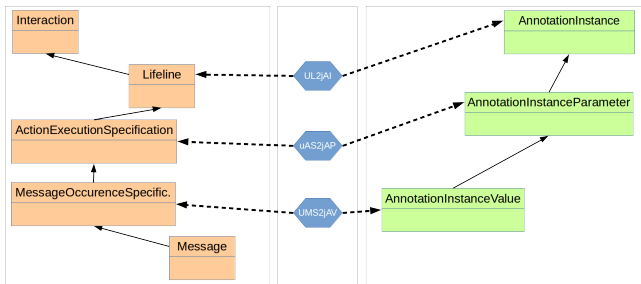
- These triple rules form a triple graph grammar (TGG) for each edge.

The Relations

UMLClassDiagram2java



UMLSequenceDiagram2java



UMLSequenceDiagram2java 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

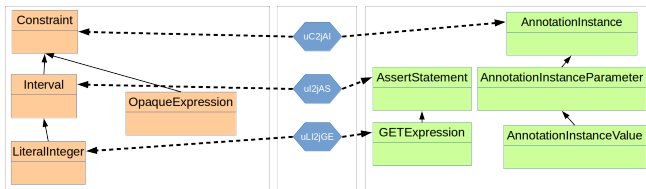
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28
29     @Inv(constraint = "vehicle <> null")
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```

UMLContract2java



UMLContract2java Example

```

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The Synchronization

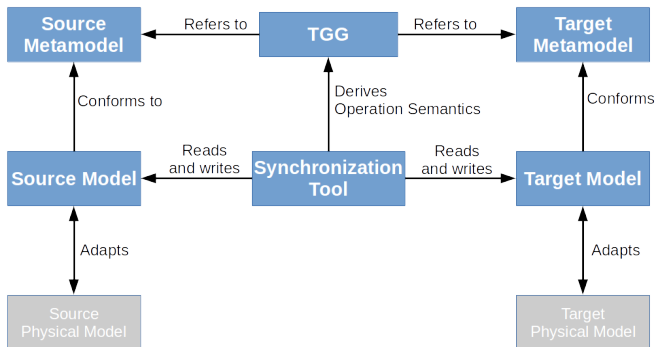
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Synchronization Scheme for Each TGG

- Following scheme for every edge of the network of metamodels

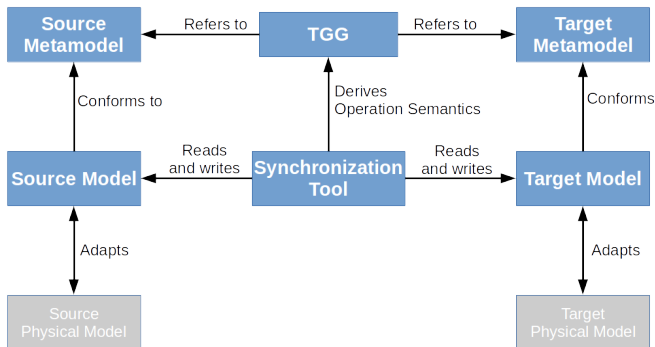
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Synchronization Scheme for Each TGG

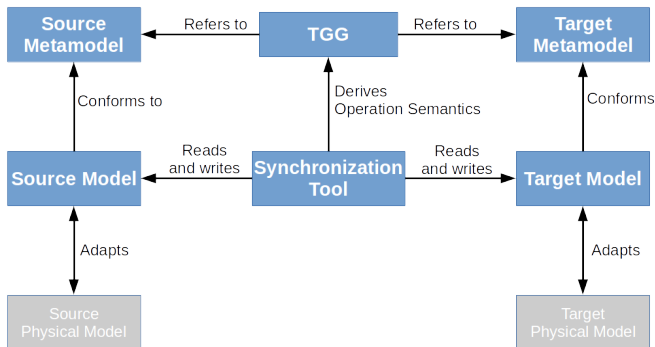
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- Treated separately by state-of-the-art approaches

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
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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.
- 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



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



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Model synchronization: Mappings, tiles, and categories.
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Frank Hermann, Hartmut Ehrig, Fernando Orejas, Krzysztof Czarnecki, Zinovy Diskin, and Yingfei Xiong.

Correctness of model synchronization based on triple graph grammars.
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OMG OMG.

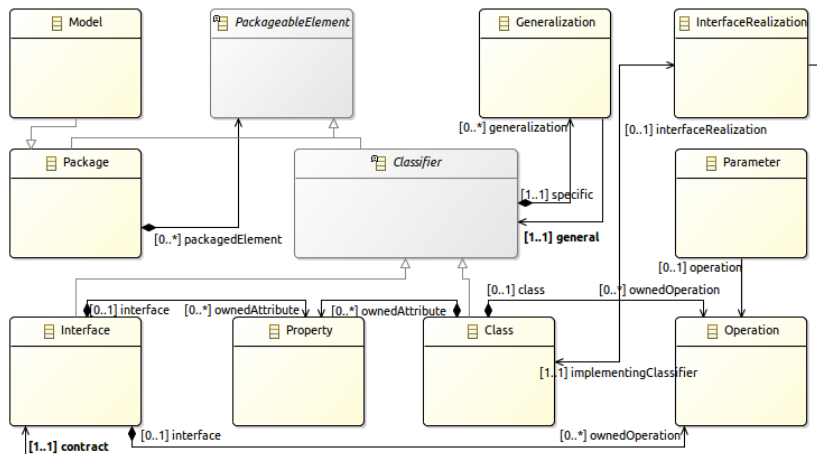
Unified modeling language (omg uml).
Superstructure, 2007.

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 ()

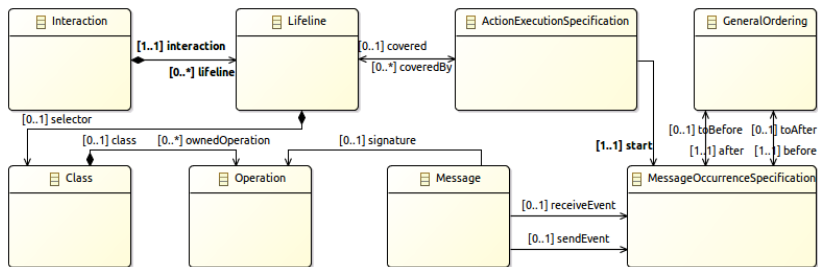
UMLClassDiagram Metamodel
















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

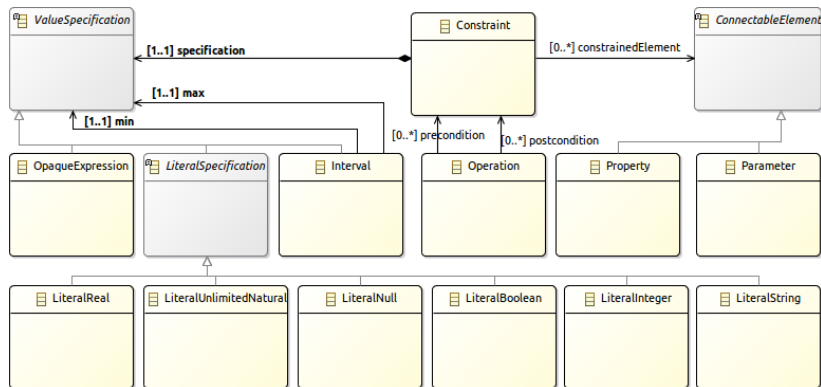
UMLSequenceDiagram Metamodel



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 ()

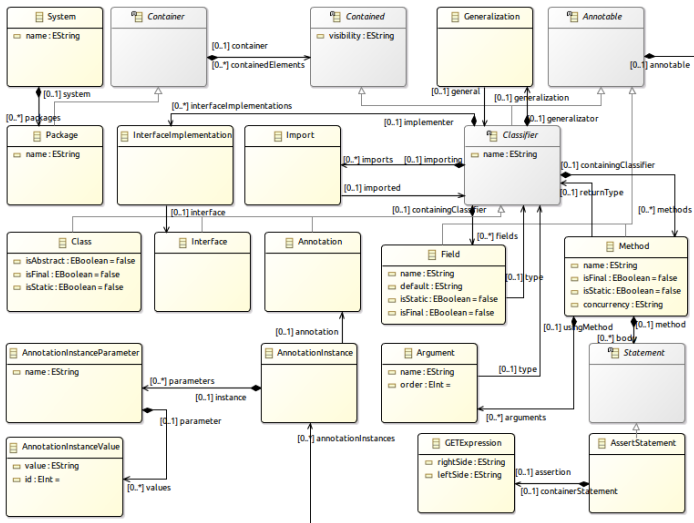
UMLContract Metamodel



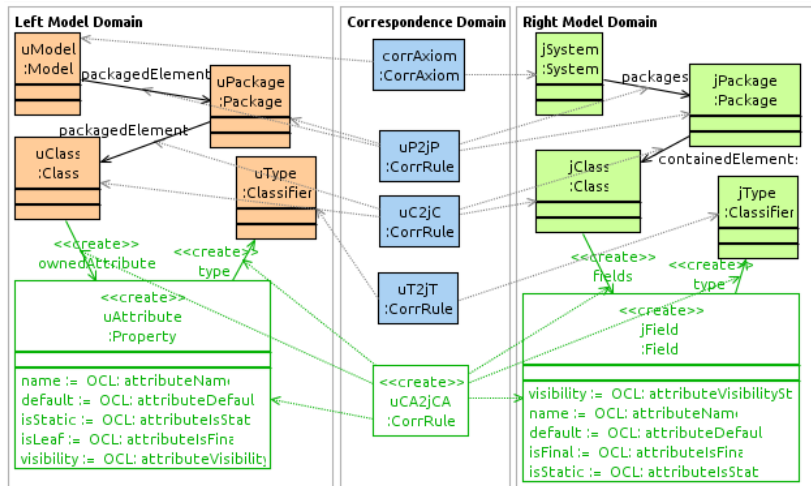
Java Abstract Syntax Example

```
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

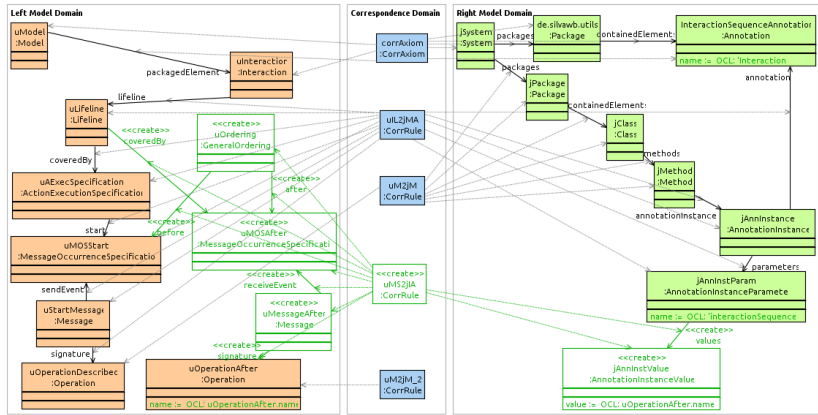
- Forward transformation was applied.

```
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

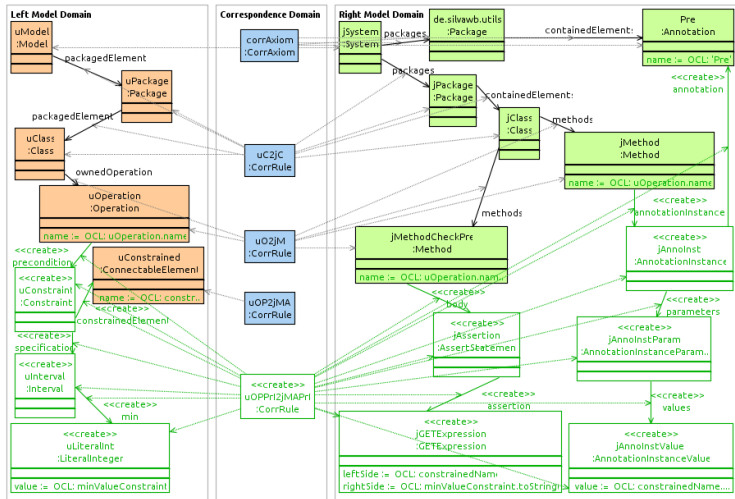
■ Forward transformation was applied.



```
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> :Driverable
8   <Action Execution Specification> :Driver
9   <Message Occurrence Specification> 1 (sendEvent)
10  <Action Execution Specification> :Driverable (1)
11  <Message Occurrence Specification> 1.1 (receiveEvent)
12  <Message Occurrence Specification> 1.1 (sendEvent)
13  <Action Execution Specification> :Driverable (2)
14  <Message Occurrence Specification> 1.2 (receiveEvent)
15  <Message Occurrence Specification> 1.2 (sendEvent)
16  <Action Execution Specification> :Driverable (3)
17  <Message Occurrence Specification> 1.3 (receiveEvent)
18  <Message Occurrence Specification> 1.3 (sendEvent)
19  <Message> 1: drive(vehicle:Driverable) : 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 : Driverable)
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
```