44. Domain-Specific Languages - Modular Metamodels in Reuseware, based on Invasive Composition

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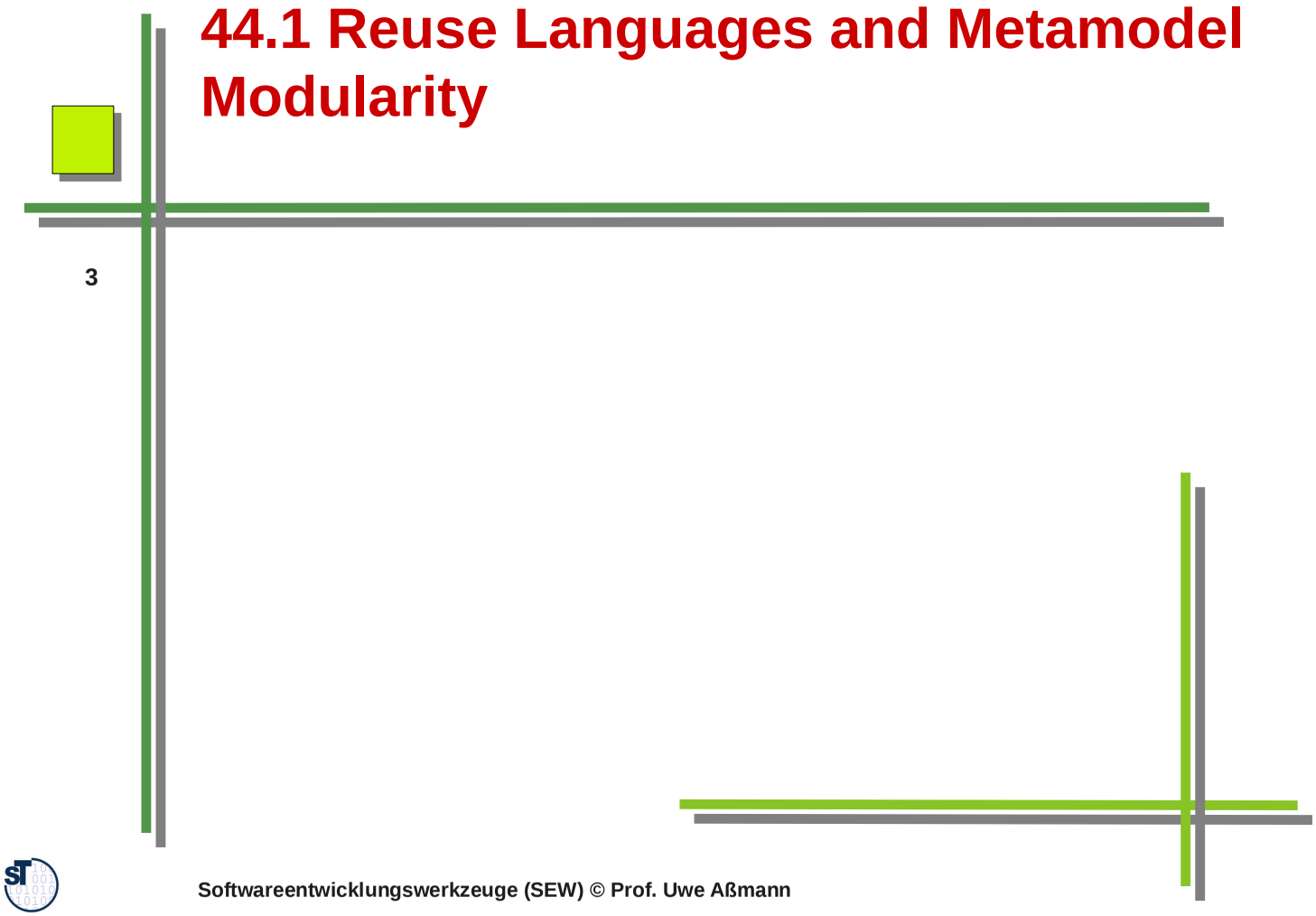
1) The DSL Taipan
2) Reuseware
3) Extending the metamodel of Taipan for modularity
4) Reuseware tool

Obligatory Literature

- [1] Jakob Henriksson, Jendrik Johannes, Steffen Zschaler, and Uwe Aßmann. Reuseware - adding modularity to your language of choice. Journal of Object Technology, 6(9):127-146, 2007. On Language-Independent Model Modularisation,Transactions on Aspect-Oriented Development, 2008
- [2] http://reuseware.org
- [3] http://wiki.eclipse.org/index.php/GMF Tutorial#Quick Start

44.1 Reuse Languages and Metamodel Modularity



44.1 Building Modularisation into Taipan DSL

A reuse (sub-)language is a sublanguage providing modularity

- Languages need modularization concepts to improve reusability and reduce complexity of applications and tools
- Challenges of modularization (on M1):
  - Modularization needs reuse concepts in syntax and semantics
- Requirement for the reuse language on M2:
  - The reuse language itself should be modular, to be composable with other languages
  - The metamodel of a reuse language should be an M2-module
  - Reuse languages requires additional tooling support
- We have already discussed role-based metamodel composition
  - Here we show how to use invasive composition for metamodel components on M2 and their composition
- A metamodel composition system is a composition system for

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Metamodel Composition

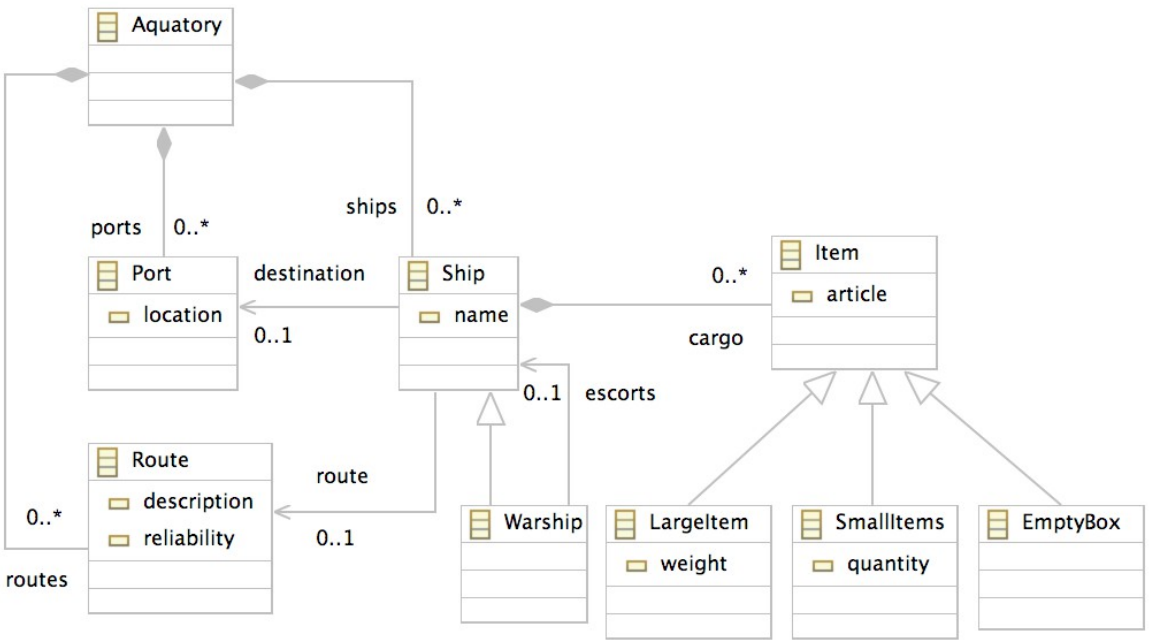
- This chapter presents a toolkit to build reuse languages
  - based on invasive metamodel composition, implemented in the Reuseware toolkit [1][2]
  - Does not influence design of DSL syntax or semantics
    - DSL syntax can be extended at the end
  - Composes modularized models to monolithic models
    - DSL semantics do not require extension
  - Generic tooling can be used with arbitrary DSLs

Building Modularisation into a DSL

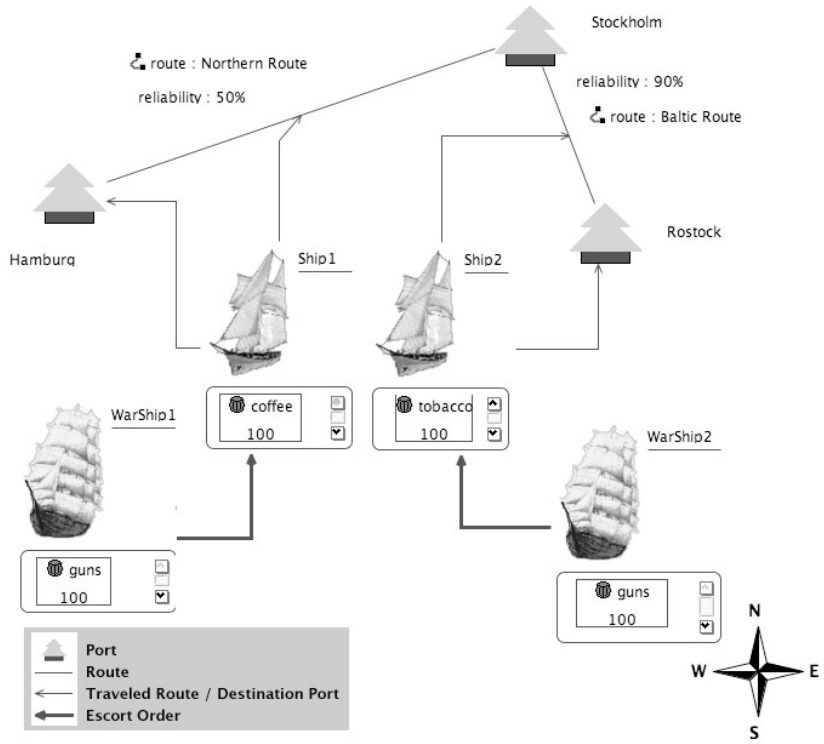
- Reuseware approach
  - Define a ***composition system*** with modularisation concepts (see CBSE course)
  - Composition systems define **component model**
    - E.g., Modules, Packages, Aspects, etc.
  - **Composition techniques**
    - E.g., parameterization, extension, weavings
  - And **composition languages**
    - For the structure in the large
  - Optional: Extend DSL syntax with concepts for variation points
    - Variation points allow definition of templates
  - Define a reuse extension for your DSL
    - Binds the composition system to your DSL
    - E.g., what are the specifics of a module in your DSL, what identifies an aspect, etc.
  - Reuseware can handle modularization in your DSL

Building a DSL: Modularisation – Example

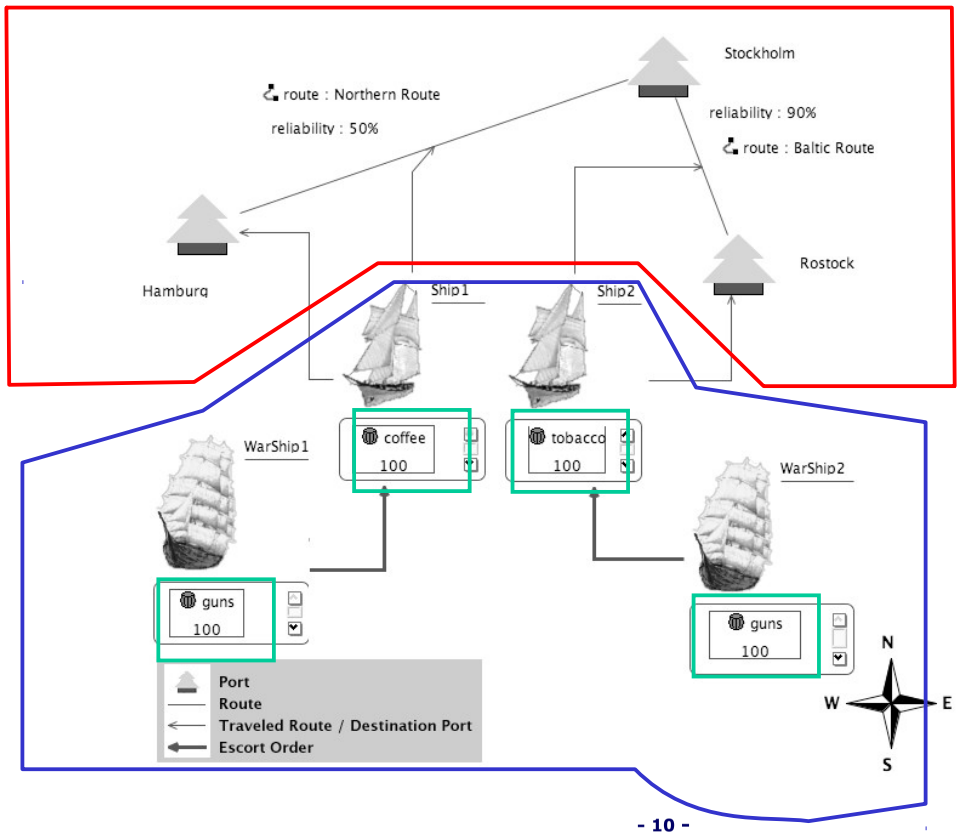
- Taipan DSL[3] for modeling ship fleets (Metamodel excerpt)



A Specification in the Taipan DSL: A Model with Ships



Building a DSL: Modularisation of Metamodel



Different concerns should be separated into model fragments

- **Port model (configuration of ports and routes)**
- **Flotilla model (ships and their relations)**
- **Cargo model (Cargo and its properties)**

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Building a DSL: Modularisation of Metamodel

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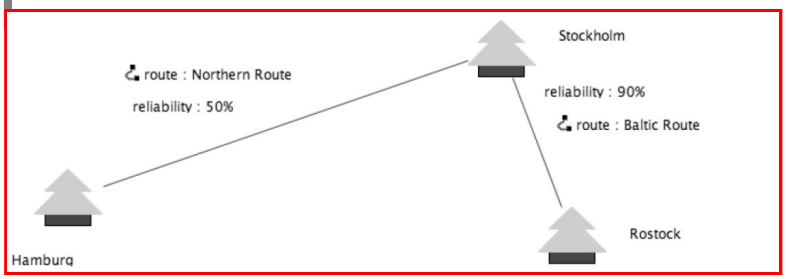

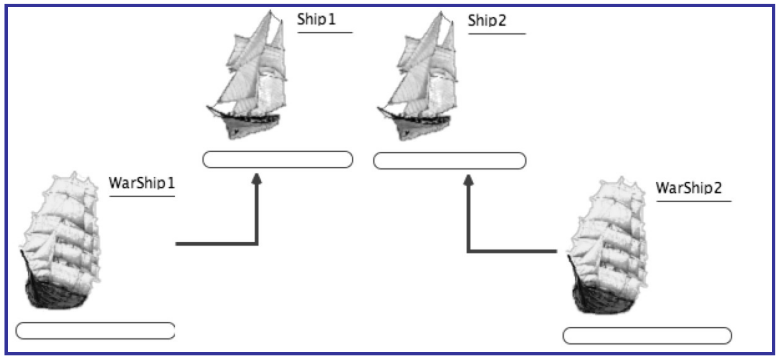

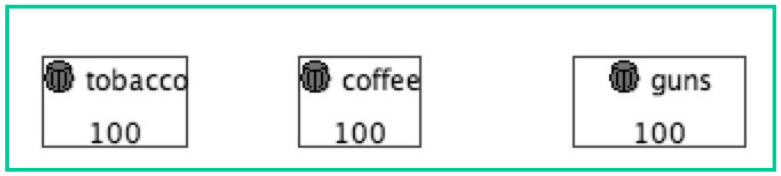

Different concerns should be separated into model fragments

- Port model (configuration of ports and routes)
- Flotilla model (ships and their relations)
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44.2 The Reuseware MetaCASE Tool - Overview

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- **Model fragments** (model snippets) are partial models that may contain variation points
  - Offer a ***Composition Interface***
  - ***Composition Interface*** consists of ***Ports***
  - ***Ports*** point at elements of the model fragment that can be accessed for composition
- Composition Programs
  - Define ***composition links*** between Ports
  - Can be executed to produce a composed model where model fragments are merged at the elements pointed out by the linked Ports

Building a DSL: Reuseware - Overview

- Composition Systems
  - Define modularisation concepts (e.g., Modules, Packages, Aspects)
  - Define relations between modularisation concepts (e.g, an aspect relates to a core)
- Reuse extensions (for DSLs)
  - Define how modularization concepts defined in a composition system are realized in a concrete DSL
  - Define which ports are related to which model elements of a model fragment

Defining Composition Systems with Reuseware

- A composition system defines fragment components with
  - Fragment roles
    - Role a model fragment plays in the modularisation (e.g., aspect or core)
    - Fragment roles collaborate through associations between ports
  - Static ports of a fragment component
    - Defined for one fragment role
    - Each fragment playing the role has to offer the port
  - Dynamic ports
    - Defined for one fragment role
    - Each fragment playing the role can offer several of these ports
  - Contribution Associations
    - Defines that two ports are related
    - Executing a composition link between the two ports will trigger the copying of model elements
  - Configuration Associations
    - Defines that two ports are related
    - Executing a composition link between the two ports will NOT trigger the copying of model elements

ReuseTaipan - a Composition System for the Taipan Metamodel, Specified in Reuseware-FraCL


```
compositionsystem reuseTaipan {

  fragment role TravelSpace {
    static port VehicleContainer;
    dynamic port Routes;
    dynamic port Places;
  }

  fragment role Flotilla {
    static port Vehicles;
    dynamic port RouteSlots;
    dynamic port PlaceSlots;
  }

  contribution Flotilla.Vehicles --> TravelSpace.VehicleContainer;
  configuration Flotilla.RouteSlots --> TravelSpace.Routes;
  configuration Flotilla.PlaceSlots --> TravelSpace.Places;


  fragment role ItemHolder {
    dynamic port ItemSpaces;
  }

  fragment role ItemContainer {
    dynamic port Items;
  }

  contribution ItemContainer.Items --> ItemHolder.ItemSpaces;
}
```


Building a DSL: ReuseTaipan - a Composition System


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compositionsystem reuseTaipan {

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  }

  contribution ItemContainer.Items --> ItemHolder.ItemSpaces;
}
```

A **TravelSpace** offers a place where vehicles can be placed (**VehicleContainer**) and a number of **Routes** and **Places**

Building a DSL: ReuseTaipan - a Composition System


```
compositionsystem reuseTaipan {

  fragment role TravelSpace {
    static port VehicleContainer;
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  }

  fragment role Flotilla {
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}
```

A **Flotilla** offers a set of **Vehicles** and has a number of placeholders for routes **(RouteSlots)** and places **(PlaceSlots)**

Building a DSL: ReuseTaipan - a Composition System


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  fragment role ItemHolder {
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  fragment role ItemContainer {
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```

A **Flotilla** contributes **Vehicles** to a **TravelSpace**'s **VehicleContainer**; a **RouteSlots** can be configured with a **Route**; a **PlaceSlots** can be configured with a **Place**

Building a DSL: ReuseTaipan - a Composition System


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  fragment role ItemContainer {
    dynamic port Items;
  }

  contribution ItemContainer.Items --> ItemHolder.ItemSpaces;
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```

An **ItemHolder** offers different **ItemSpaces**

Building a DSL: ReuseTaipan - a Composition System


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compositionsystem reuseTaipan {

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  fragment role ItemHolder {
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```

An **ItemContainer** contains and offers **Items**

Building a DSL: ReuseTaipan - a Composition System

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}
```

Items can be individually assigned to **ItemSpaces**

44.3 Building a DSL: Extending a Metamodel for Variation

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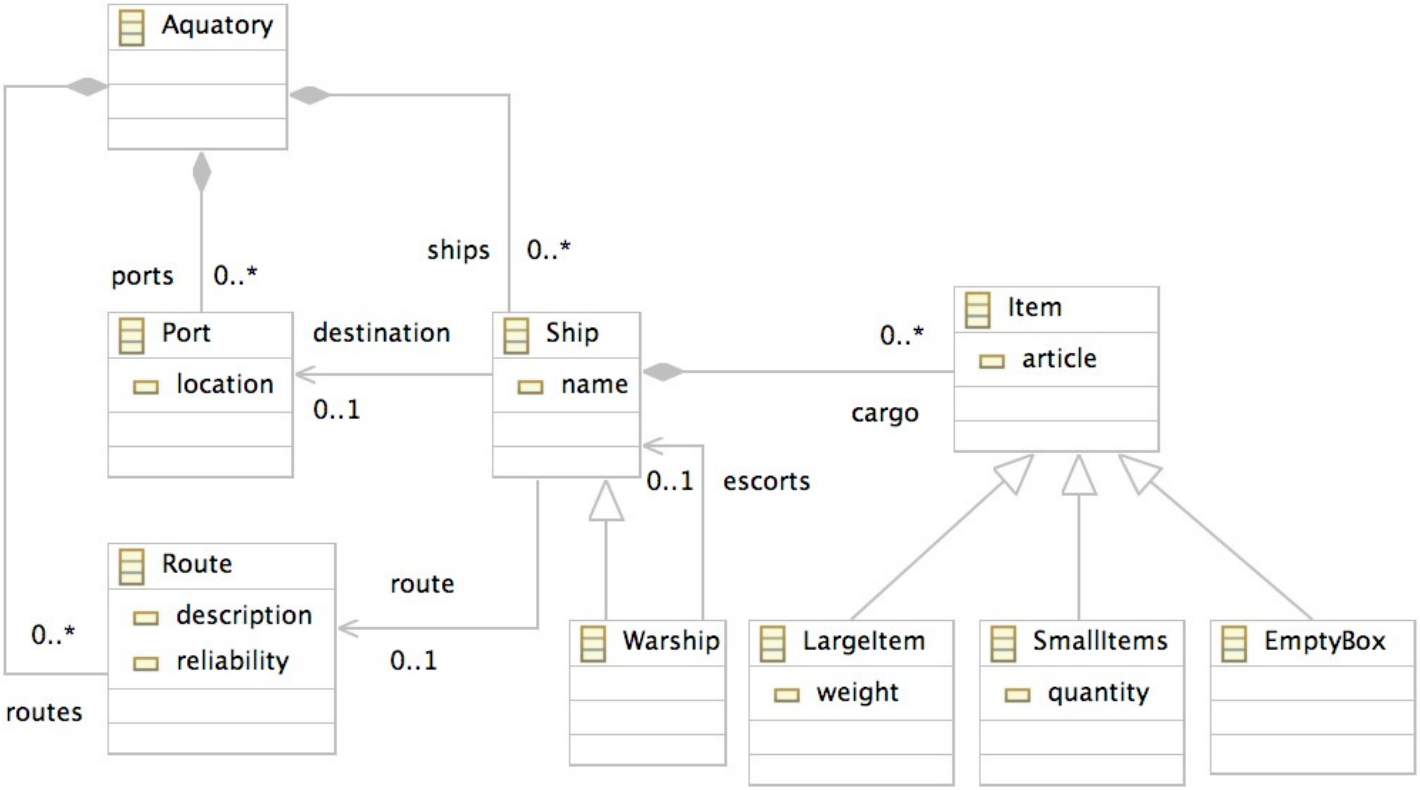
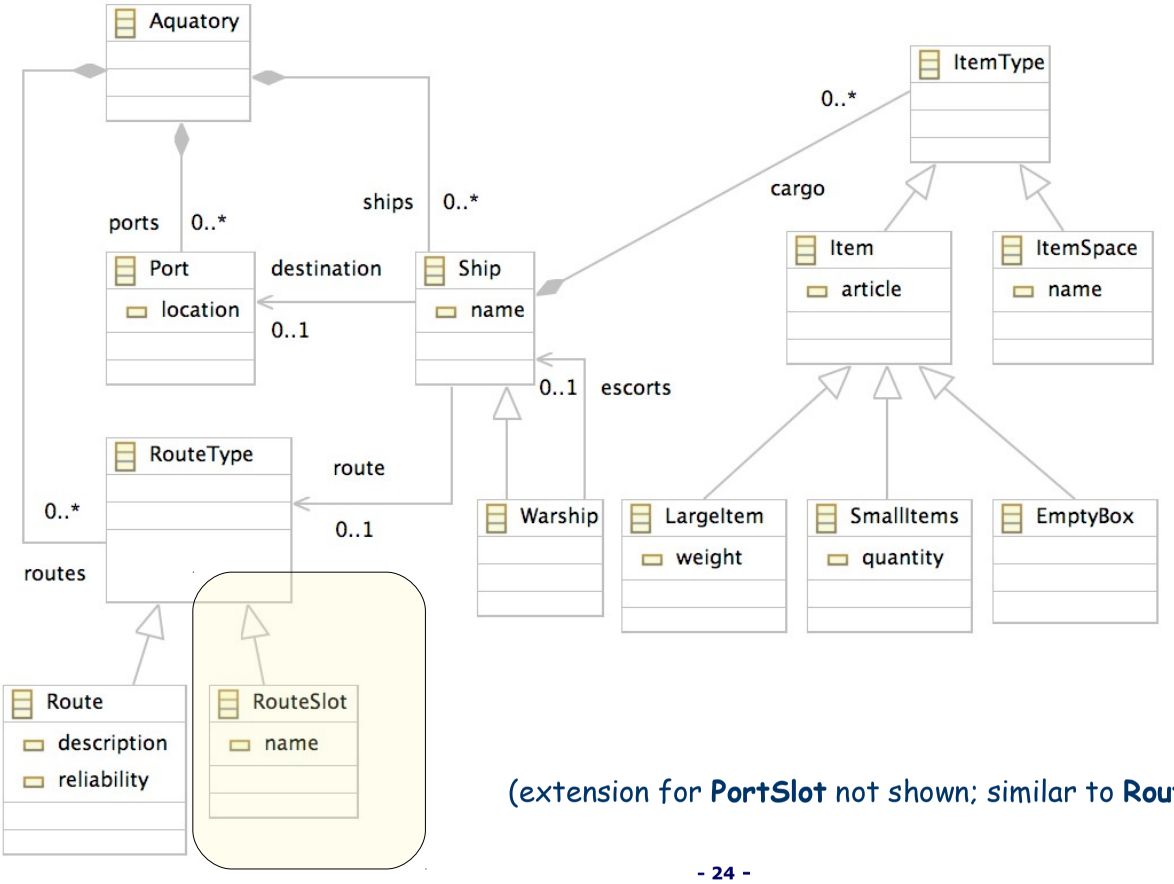
- Three kinds of variation points required in the metamodels
  - RouteSlot
  - PortSlot
  - ItemSpace
- For each kind of variation point we...
  - Introduce a superclass for the metaclass that defines the elements which may replace the variation point
    - e.g., we introduce **RouteType** as a superclass of **Route** in the case of RouteSlot
  - We redirect all references to the metaclass to the new superclass
    - e.g., all references to **Route** are redirected to **RouteType**
  - We introduce a new subclass for the just introduced superclass that represents the variation point. This class needs properties from which a name can be derived.
    - e.g., we introduce **RouteSlot** as a subclass of **RouteType**

The Taipan Metamodel (Rpt.)



Extending the Taipan Metamodel for Variation



(extension for **PortSlot** not shown; similar to **RouteSlot**)

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Building a DSL: Reuseware - Reuse Extensions

- A **reuse extension of a metamodel** is an extended metamodel defining
  - How a composition interface defined by a fragment role (which is defined in a composition system) is linked to the content of a model fragment
  - Each port links to a set of model elements treated as:
    - Prototype: Element that can be copied with its contained elements
    - Anchor: Element that can be referenced by other elements
    - Hook: Variation point where Prototypes can be put
    - Slot: Variation point where Anchors can be put
- Reuseware-CL is a language to define reuse extensions of metamodels
  - to make a metamodel composable

Building a DSL: Binding ReuseTaipan to Taipan DSL

```
reuseextension reuseTaipan implements reuseTaipan
epackages <http://www.eclipse.org/examples/gmf/taipan>
Rootclass TravelSpace {
  fragment role TravelSpace {
    port VehicleContainer {
      Aquatory.ships is hook {}
      Aquatory.ports is hook {}
      Aquatory.routes is hook {}
    }
    port Routes {
      Route is anchor {
        port expr = $self.description$
      }
    }
    port Places {
      Port is anchor {
        port expr = $self.location.concat('Port')$
      }
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

The ReuseTaipan composition system is bound to the Taipan DSL (referred to by the URI of its metamodel)

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  }
  ...
```
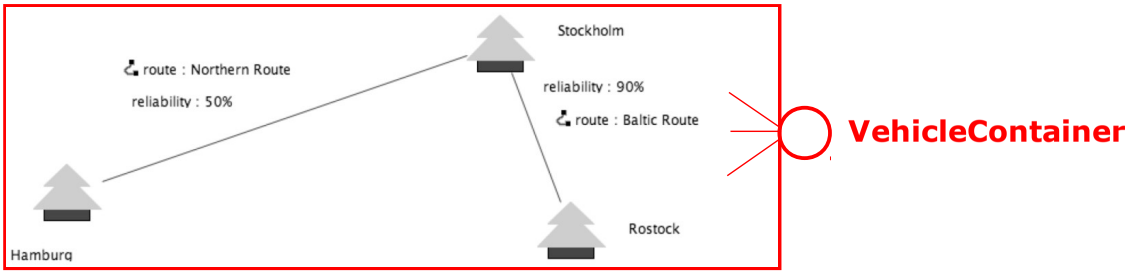
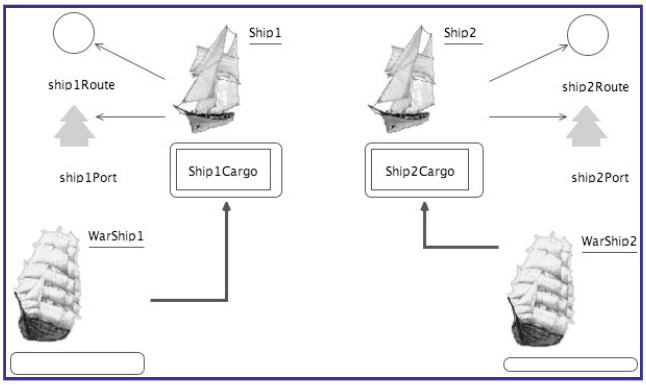
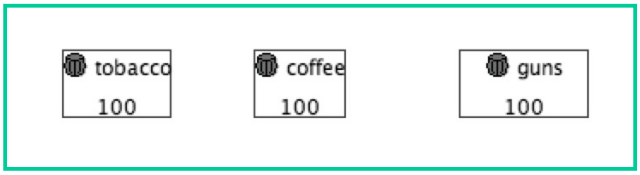
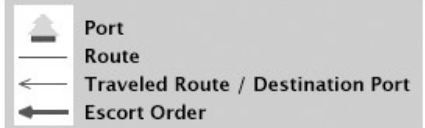

The references **ships**, **ports** and **routes** of the metaclass **Aquatory** all act as hooks accessible through the **VehicleContainer** port

Building a DSL: Binding ReuseTaipan to Taipan DSL









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      Route is anchor {
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      }
    }
    port Places {
      Port is anchor {
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      }
    }
  }

  fragment role Flotilla {
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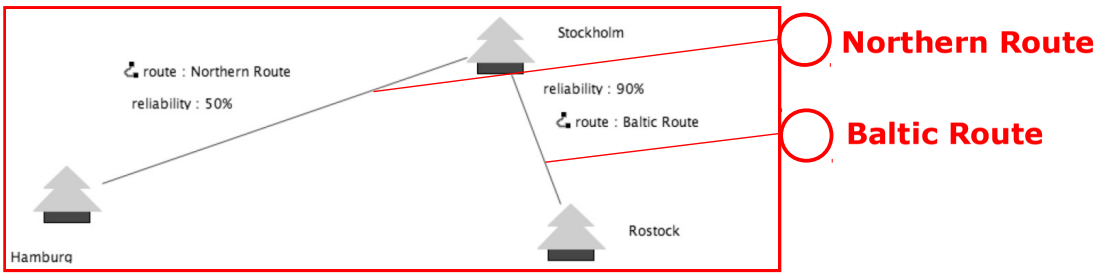
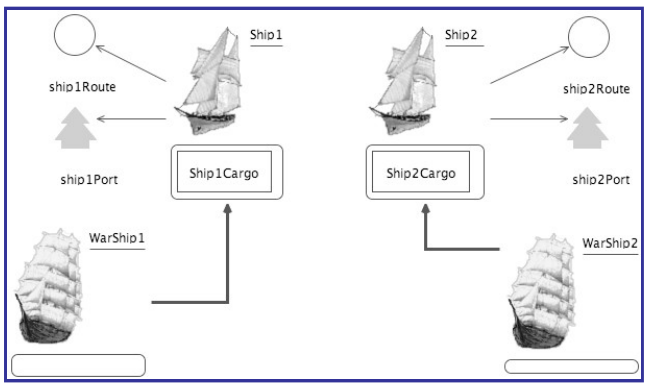
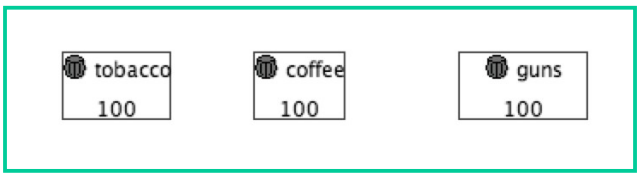
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

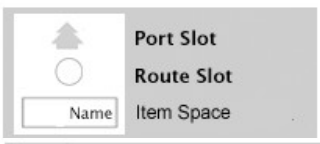
Each **Route** is an anchor accessible through individual ports; the ports are named using the **description** attribute of the **Route** metaclass
(OCL Expression: self.description)

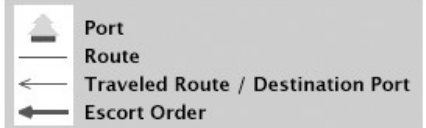
Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components











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    port Routes {
      Route is anchor {
        port expr = $self.description$
      }
    }
    port Places {
      Port is anchor {
        port expr = $self.location.concat('Port')$
      }
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```
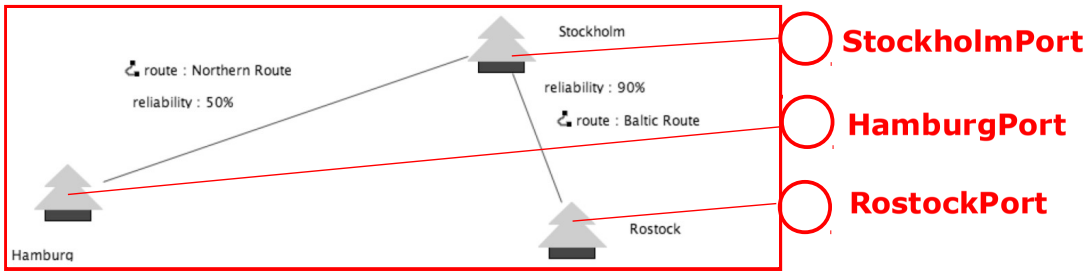
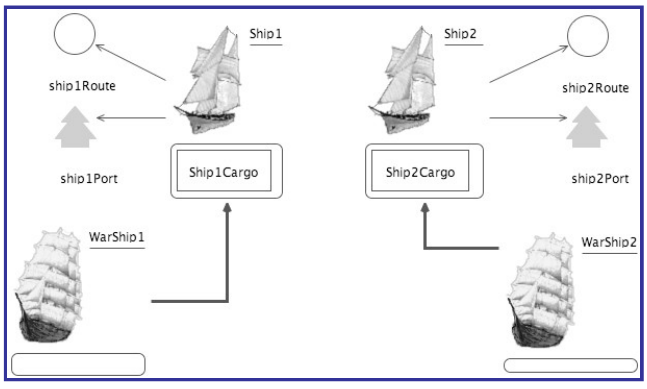
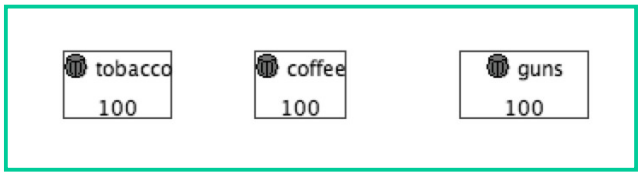
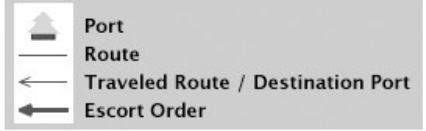

Each **Port** is an anchor accessible through individual ports; the ports are named using the **location** attribute of the **Port** metaclass

Building a DSL: Binding ReuseTaipan to Taipan DSL
Model Components







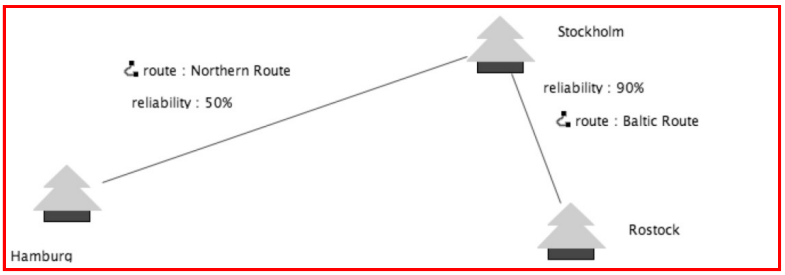


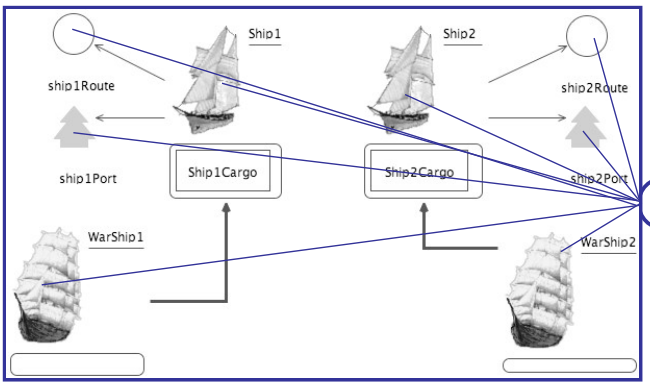
Building a DSL: Binding ReuseTaipan to Taipan DSL

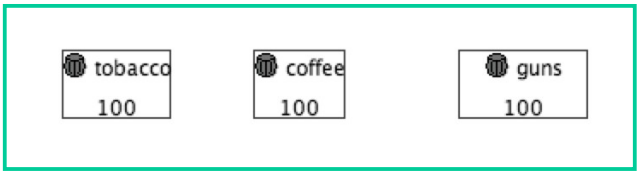
```
reuseextension reuseTaipan implements reuseTaipan
epackages <http://www.eclipse.org/examples/gmf/taipan>
Rootclass TravelSpace {
  fragment role TravelSpace {
    port VehicleContainer {
      Aquatory.ships is hook {}
      Aquatory.ports is hook {}
      Aquatory.routes is hook {}
    }
    port Routes {
      Route is anchor {
        port expr = $self.description$
      }
    }
    port Places {
      Port is anchor {
        port expr = $self.location.concat('Port')$
      }
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

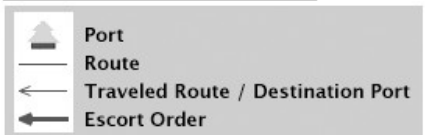
All elements of the references **ships**, **ports** and **routes** of the metaclass **Aquatory** act as prototypes accessible through the **Vehicles** port

Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components









Building a DSL: Binding ReuseTaipan to Taipan DSL

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      Aquatory.routes is prototype {}
    }
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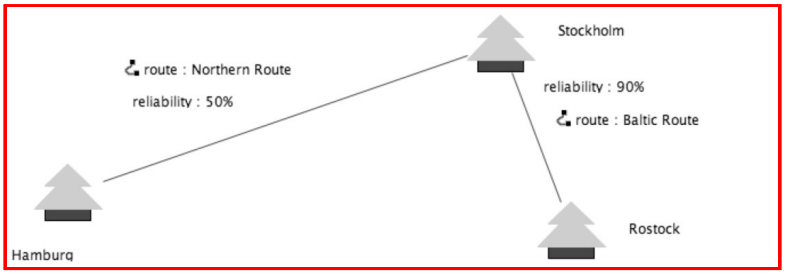
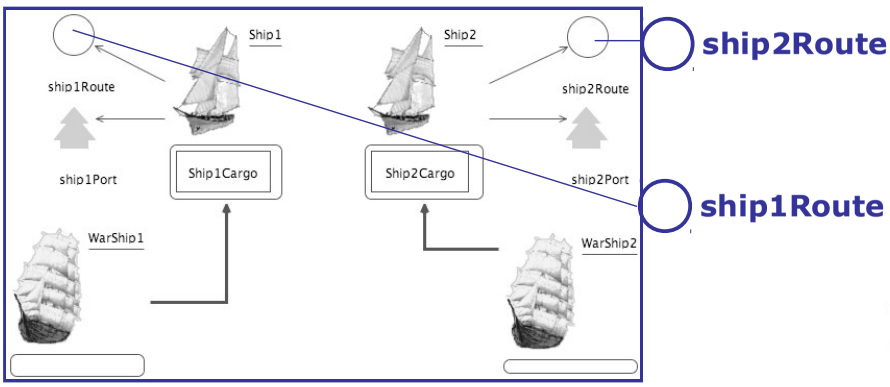
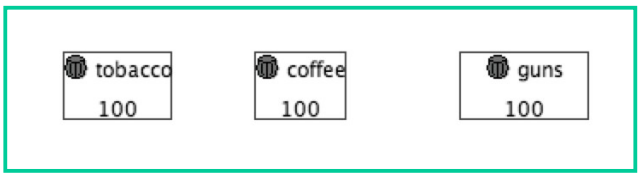
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```

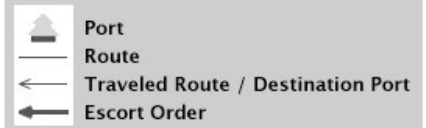
Each **RouteSlot** is a slot accessible through individual ports; the ports are named using the **name** attribute of the **RouteSlot** metaclass

Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components









Building a DSL: Binding ReuseTaipan to Taipan DSL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      Aquatory.ports is hook {}
      Aquatory.routes is hook {}
    }
    port Routes {
      Route is anchor {
        port expr = $self.description$
      }
    }
    port Places {
      Port is anchor {
        port expr = $self.location.concat('Port')$
      }
    }
  }

  fragment role Flotilla {
    port Vehicles {
      Aquatory.ships is prototype {}
      Aquatory.ports is prototype {}
      Aquatory.routes is prototype {}
    }
    port RouteSlots {
      RouteSlot is slot {
        port expr = $self.name$
      }
    }
    port PlaceSlots {
      PortSlot is slot {
        port expr = $self.name$
      }
    }
  }
  ...
```
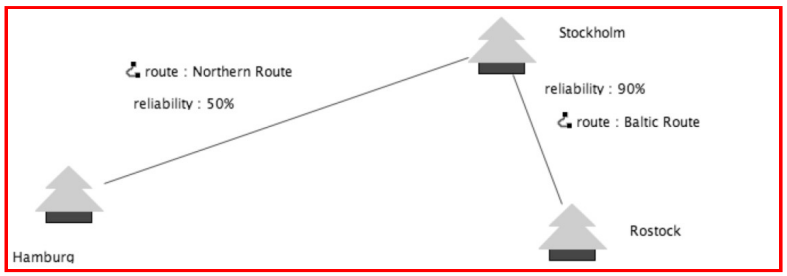
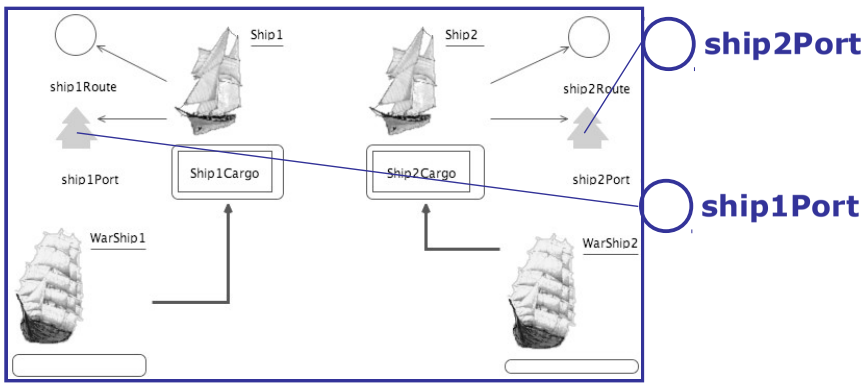
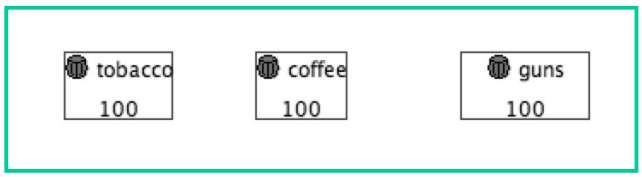
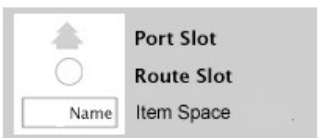

Each **PortSlot** is a slot accessible through individual ports; the ports are named using the **name** attribute of the **RouteSlot** metaclass

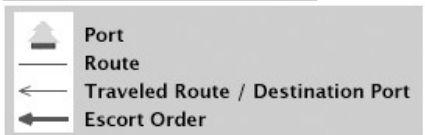
Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components









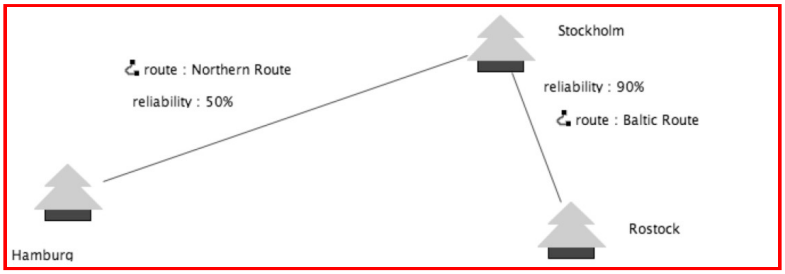


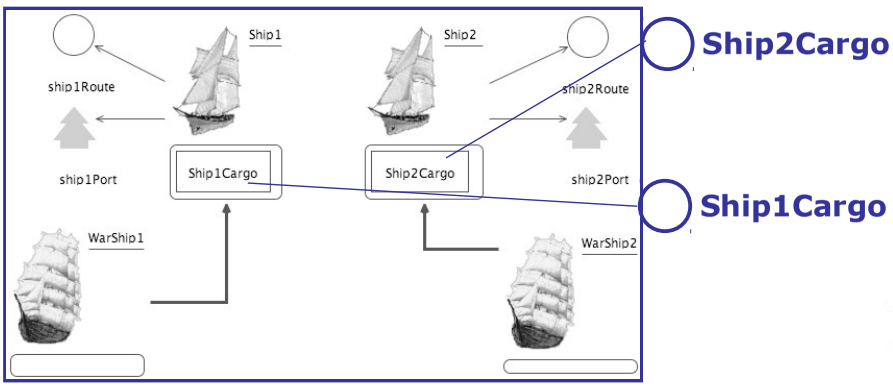
Building a DSL: Binding ReuseTaipan to Taipan DSL


```
...

binding ItemHolder {
  binding ItemSpaces {
    ItemSpace is hook {
      port expr = $self.name$
    }
  }
}

binding ItemContainer {
  binding Items {
    Item is prototype {
      port expr = $self.article$
    }
  }
}
}
```

Each **ItemSpace** is a hook accessible through individual ports; the ports are named using the **name** attribute of the **ItemSpace** metaclass

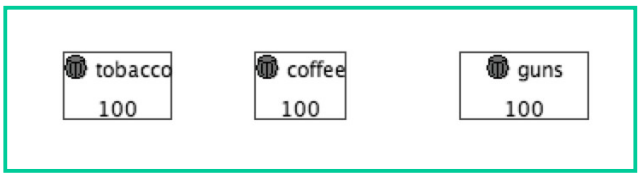
Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components

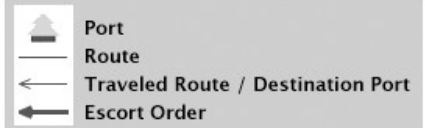




Ship2Cargo

Ship1Cargo



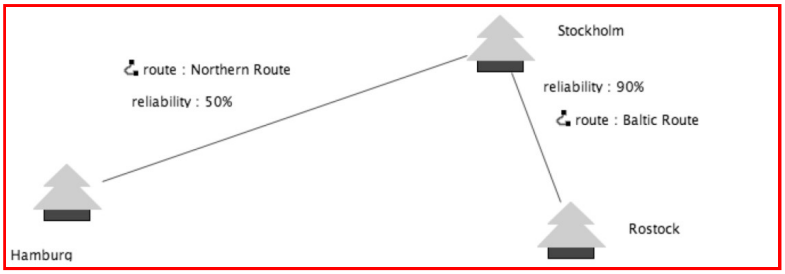


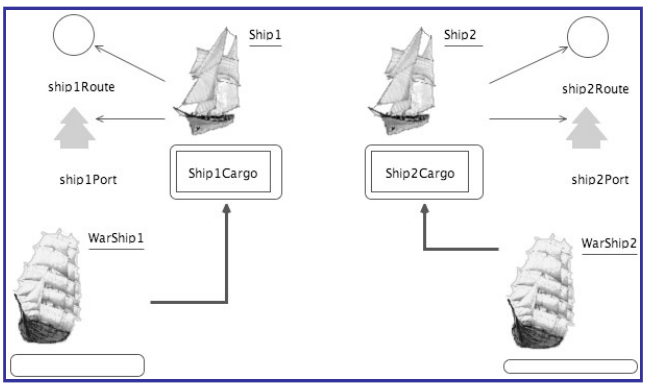
Building a DSL: Binding ReuseTaipan to Taipan DSL

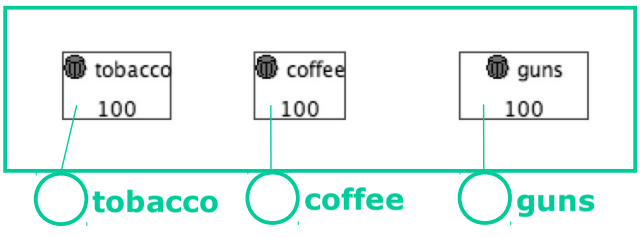

```
...

fragment role ItemHolder {
  port ItemSpaces {
    ItemSpace is hook {
      port expr = $self.name$
    }
  }
}

fragment role ItemContainer {
  port Items {
    Item is prototype {
      port expr = $self.article$
    }
  }
}
}
```

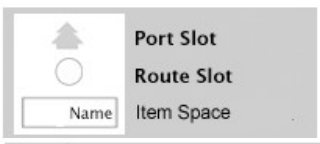
Each **Item** is a prototype accessible through individual ports; the ports are named using the **article** attribute of the **Items** metaclass

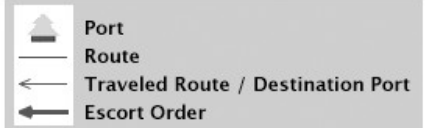
Building a DSL: Binding ReuseTaipan to Taipan DSL Model Components





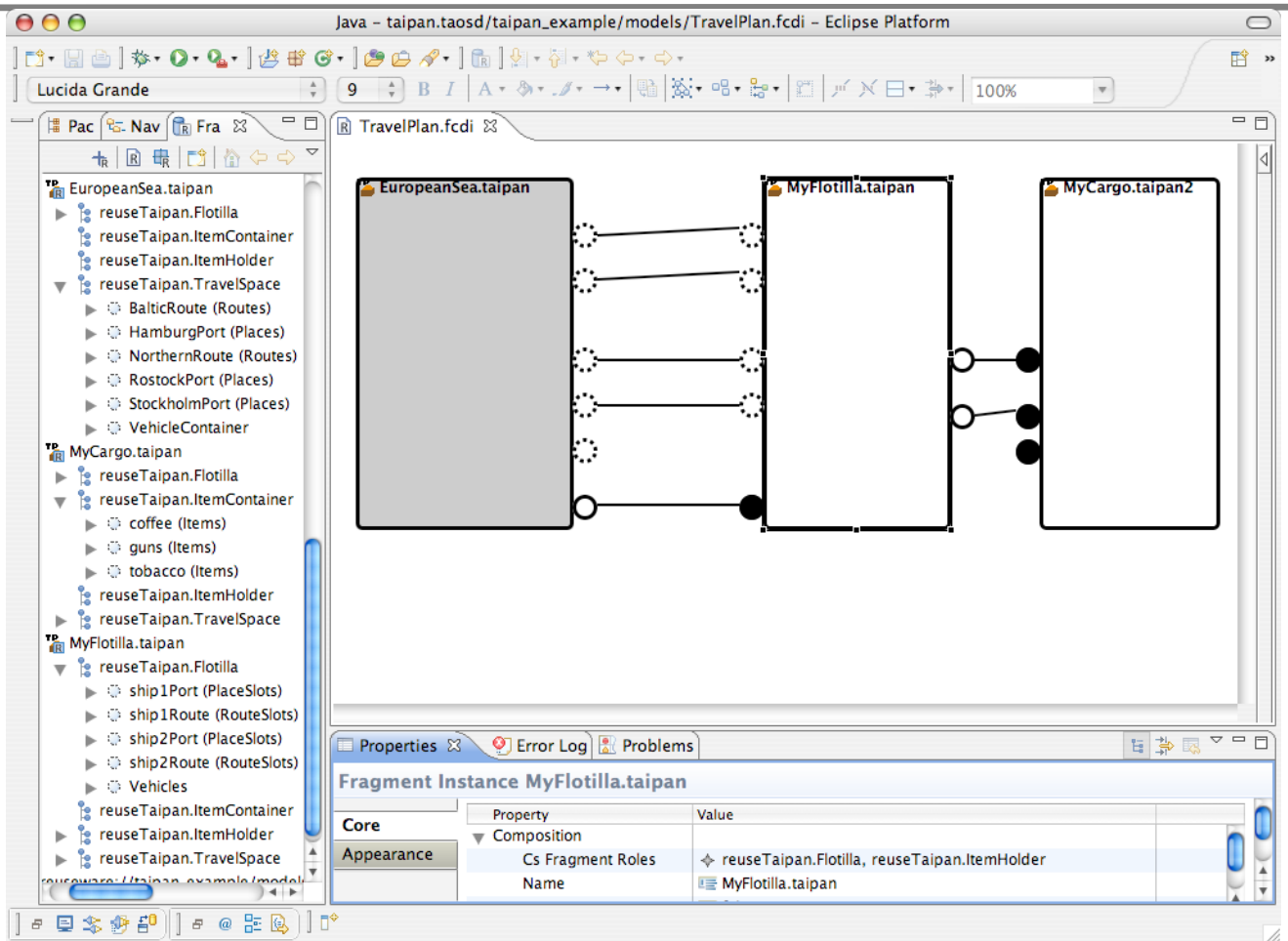




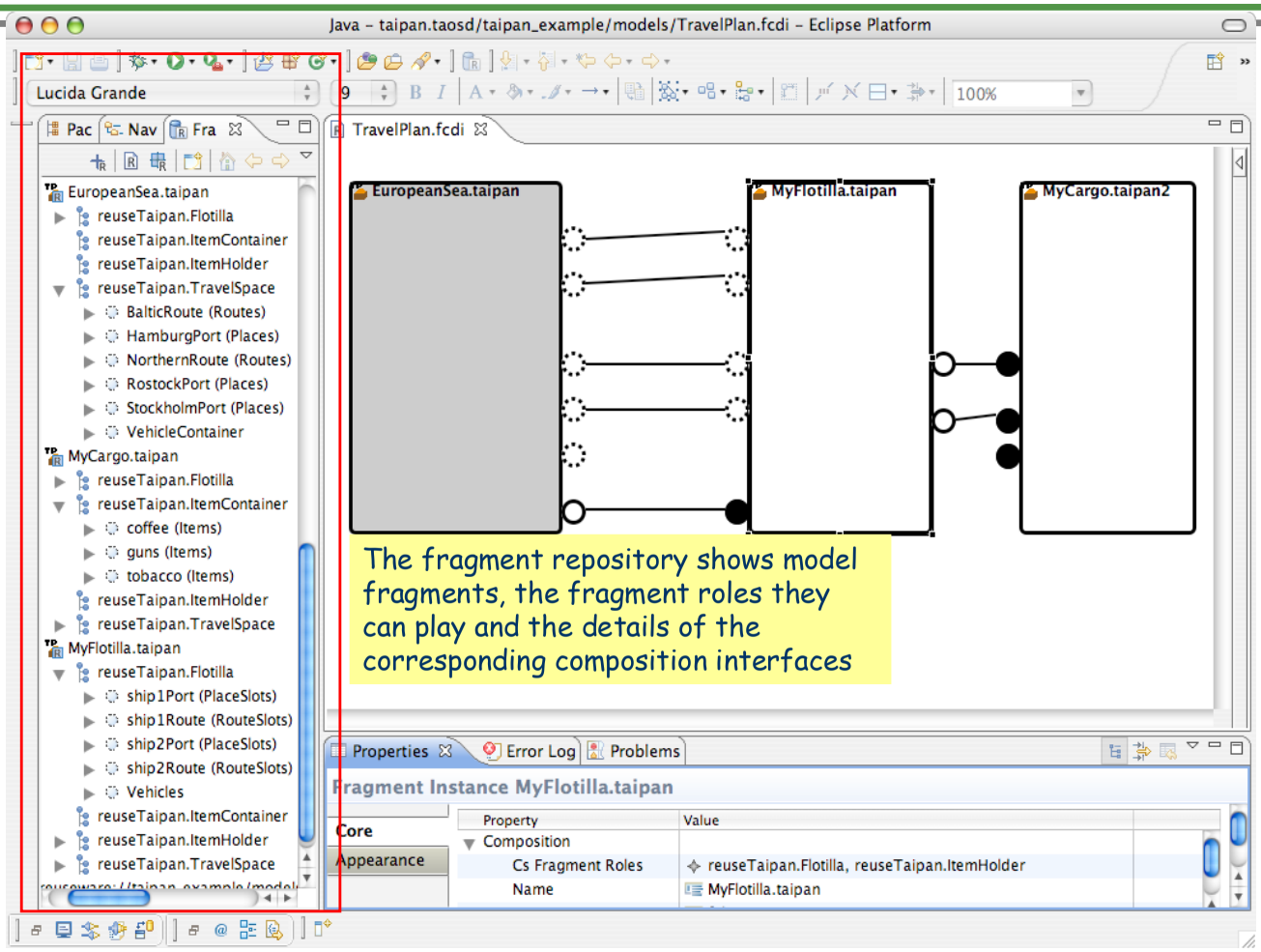


- Fragment Repository
  - Light-weight repository to manage and find reusable model fragments
  - Can instantly be used to build libraries of model fragments designed in a DSL

- Composition Program Editor
  - Independent of composition systems and reuse extensions
  - Can instantly be used to define compositions for the DSL
  - Layout can be customized if desired



Building a DSL: Using Reuseware Tooling with a DSL



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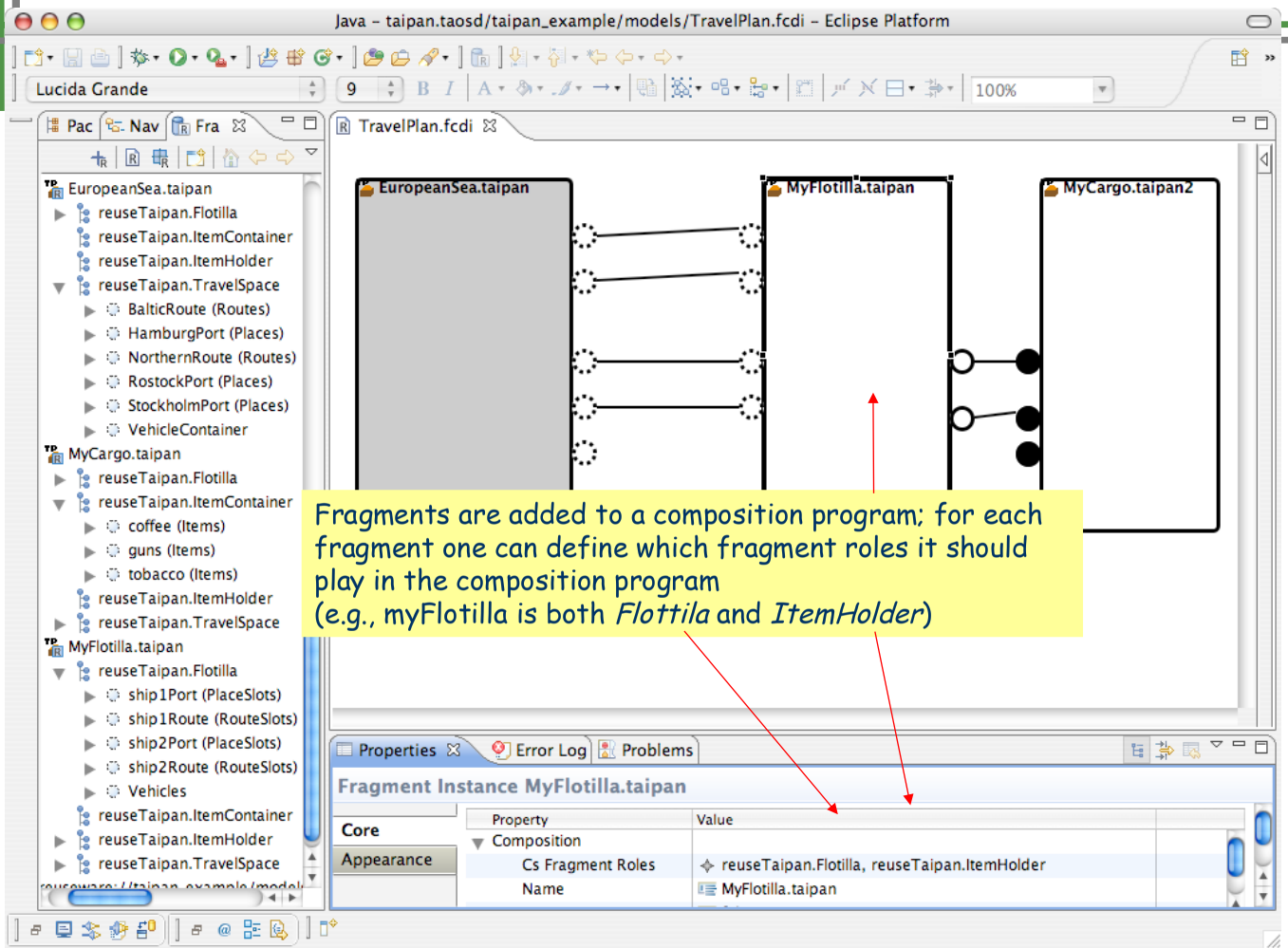

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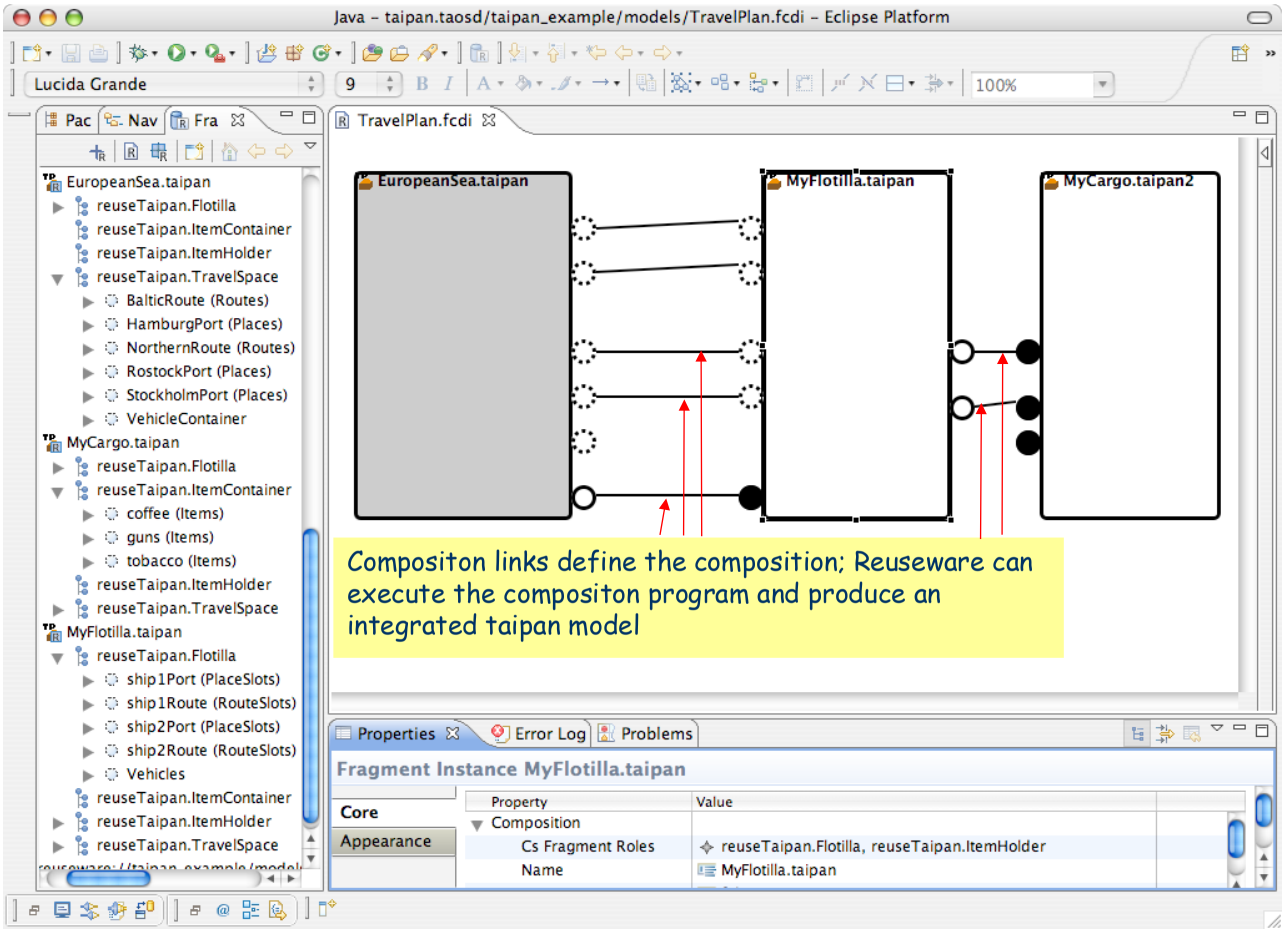

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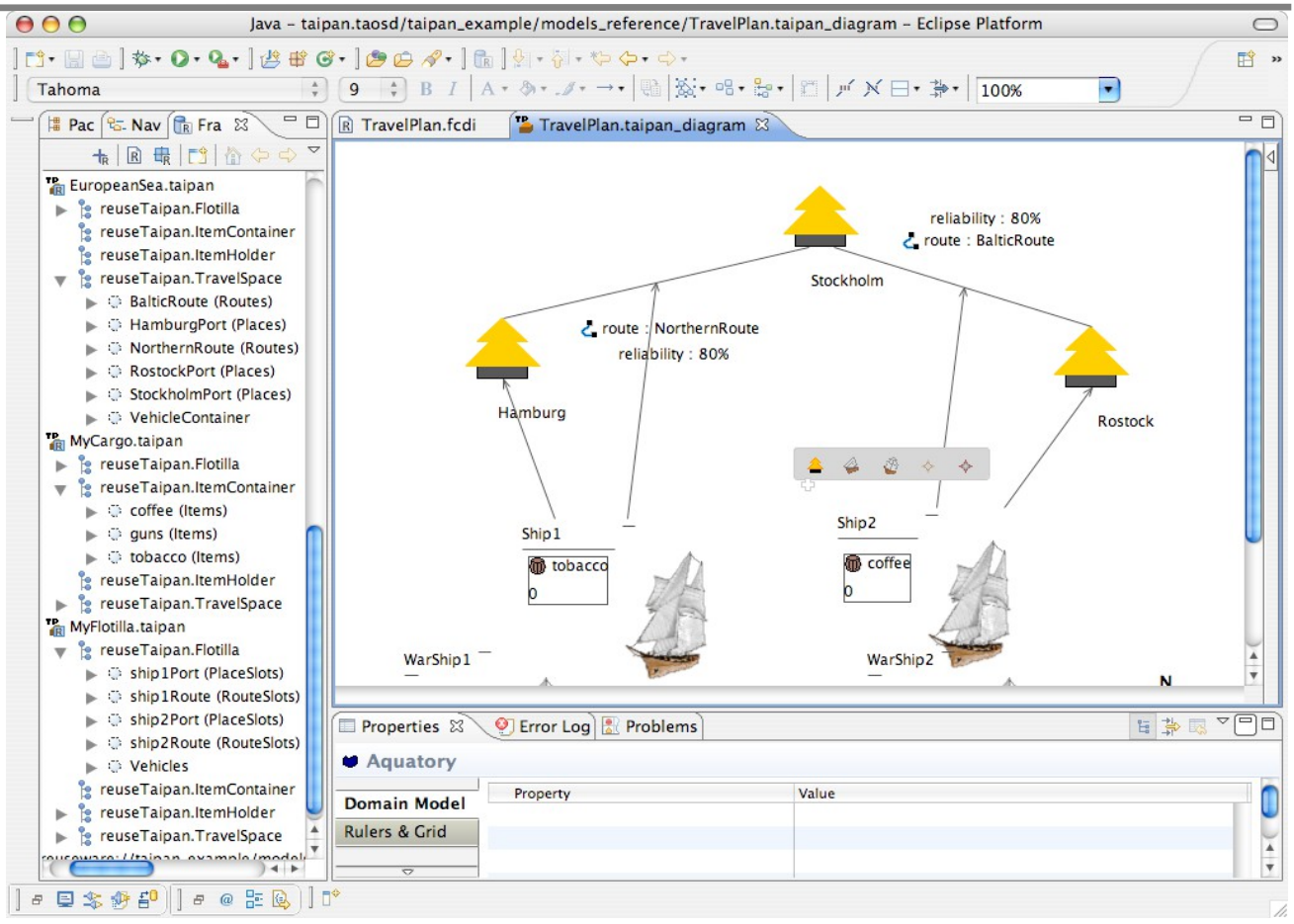

The End

- Reuseware is open source, but also dual licensed, i.e., commercialized by the company www.devboost.de