DSL Best Practices

illustrated with Eclipse Tools

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About me

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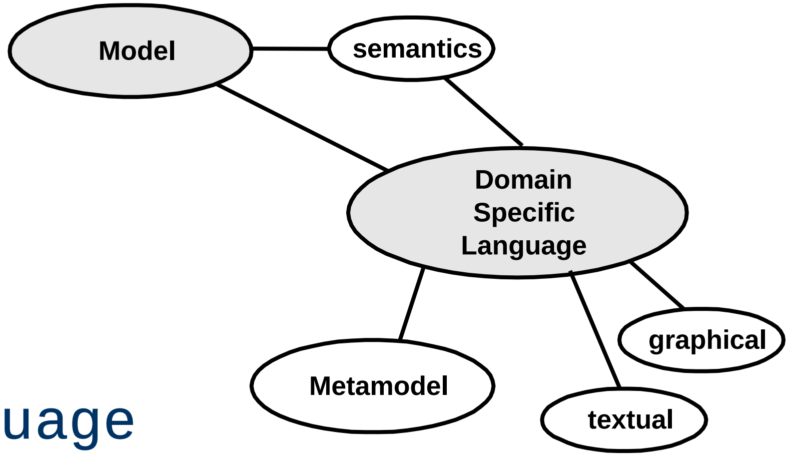
- Independent Consultant
- Based out of Heidenheim, Germany
- Focus on
  - Model-Driven Software Development
  - Software Architecture
  - Middleware

Custom Metamodel

When working with „generic“ languages such as UML, always transform to your own metamodel first

Custom Metamodel

- A **DSL** always consists of
  - Abstract syntax (Metamodel)
  - Concrete syntax
  - Semantics



- If you use a general purpose language (such as UML) on which to build your DSL, **consider it concrete syntax!**

- You should still have a domain-specific metamodel the first step must be a **transformation** from the GP language to the custom metamodel.

Custom Metamodel II

- Why is this important? Basically, because the GP metamodel is typically **very complicated** (UML ☺)
  - Constraint checking can be more specific in a DS metamodel
  - Model modifications are much easier (try to **write** to the UML metamodel!)
  - Subsequent transformation/code generation is also much easier

Take care of your Metamodel

The meta model is the central asset. It will grow over time. Make sure you use appropriate means to model and manage the metamodel.

Take Care of your Metamodel

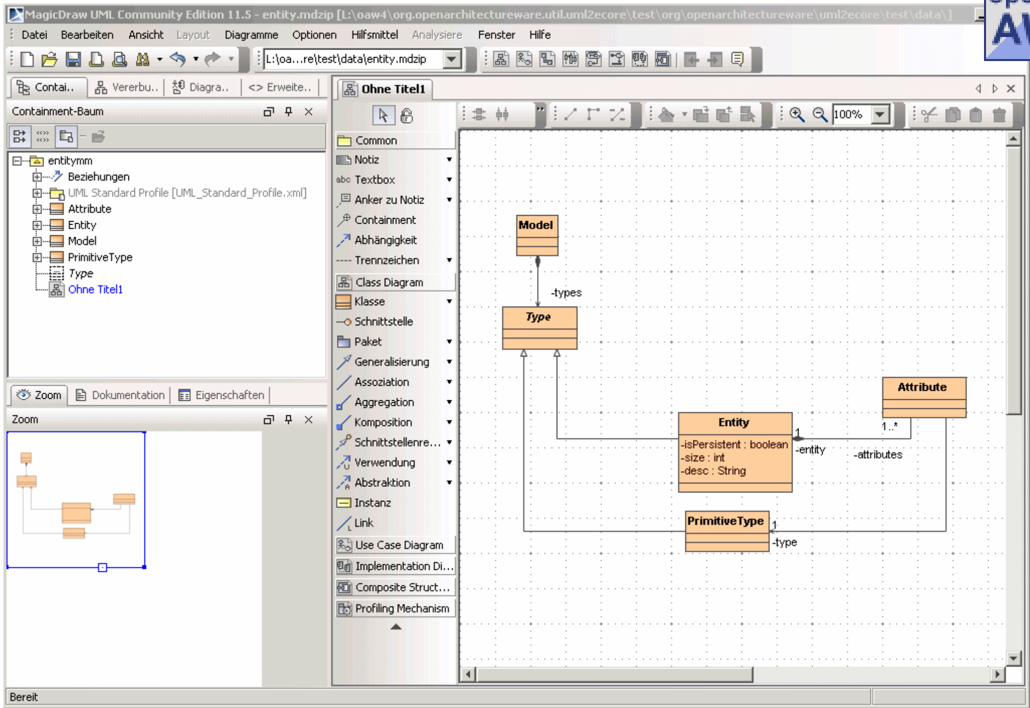
- The meta model is the **central asset** that defines the semantics of your domain and your DSL(s).

- Make sure it is described using a **scalable means**, such as a textual DSL or a UML tool
  - The EMF tree editors don‘t scale!
  - The Ecore Editor provided with GMF also does not really scale...

Take Care of your Metamodel II

- One approach is to use a UML tool (one which supports Eclipse UML2 export) and **transform** the model into an Ecore meta model.

- An alternative is to use a **suitable textual notation** (make sure you can distribute the model over several files...!)



oAW **uml2ecore**

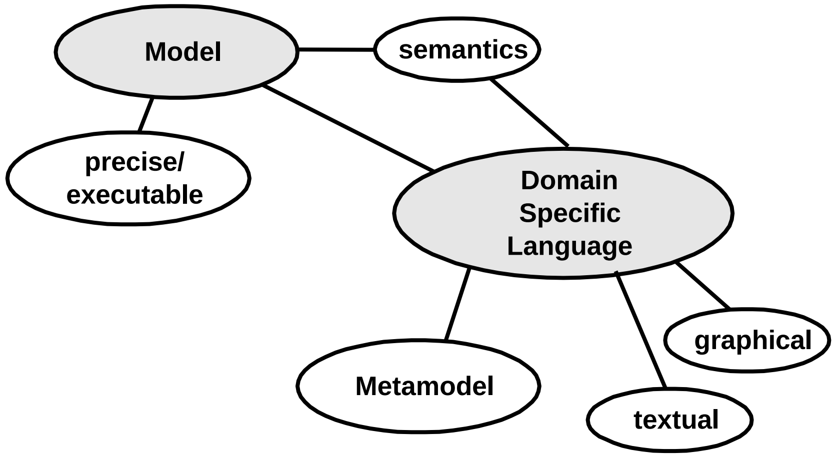
- Ecore File
- Name Management (qualified, namespaces)
- Various constraints

Checks First & Separate

Before you do anything else with the model (transformation, generation) make sure you check constraints – these must not be part of the transformation to avoid duplication

Checks First & Separate

- There‘s no point in **transforming a „buggy“ model** into something else.
- A buggy model is a model where the **constraints** defined as part of the metamodel **do not hold**.



- Make sure you have such constraints!
- Make sure they are **not part of the transformation**:
  - Would make transformation more complicated
  - If you have several transformations from the same model, you‘d need to have the checks several time.
- Make constraint checking a **separate, and early** step in the transformation workflow

Checks First & Separate II

- Here are some examples written in **oAW's Checks language.**

For which elements is the constraint is applicable

exampleFromGMF.oaw | ...eBatchErrors.chk

```
import statemachine2;

context StateMachine ERROR "States must have unique Names" :
    states.typeSelect(State).forAll(s1| !states.typeSelect(State).
        exists(s2| (s1 != s2) && (s1.name == s2.name) ));

context Named if !Transition.isInstance(this) ERROR this.metaType.name+" must be named":
    this.name != null;

context StartState ERROR "no incoming transitions allowed":
    this.inTransitions.size == 0;

context StartState ERROR "start state must have one out transition
    this.outTransitions.size == 1;
```

Error message in case Expression is false

Constraint Expression

ERROR or WARNING

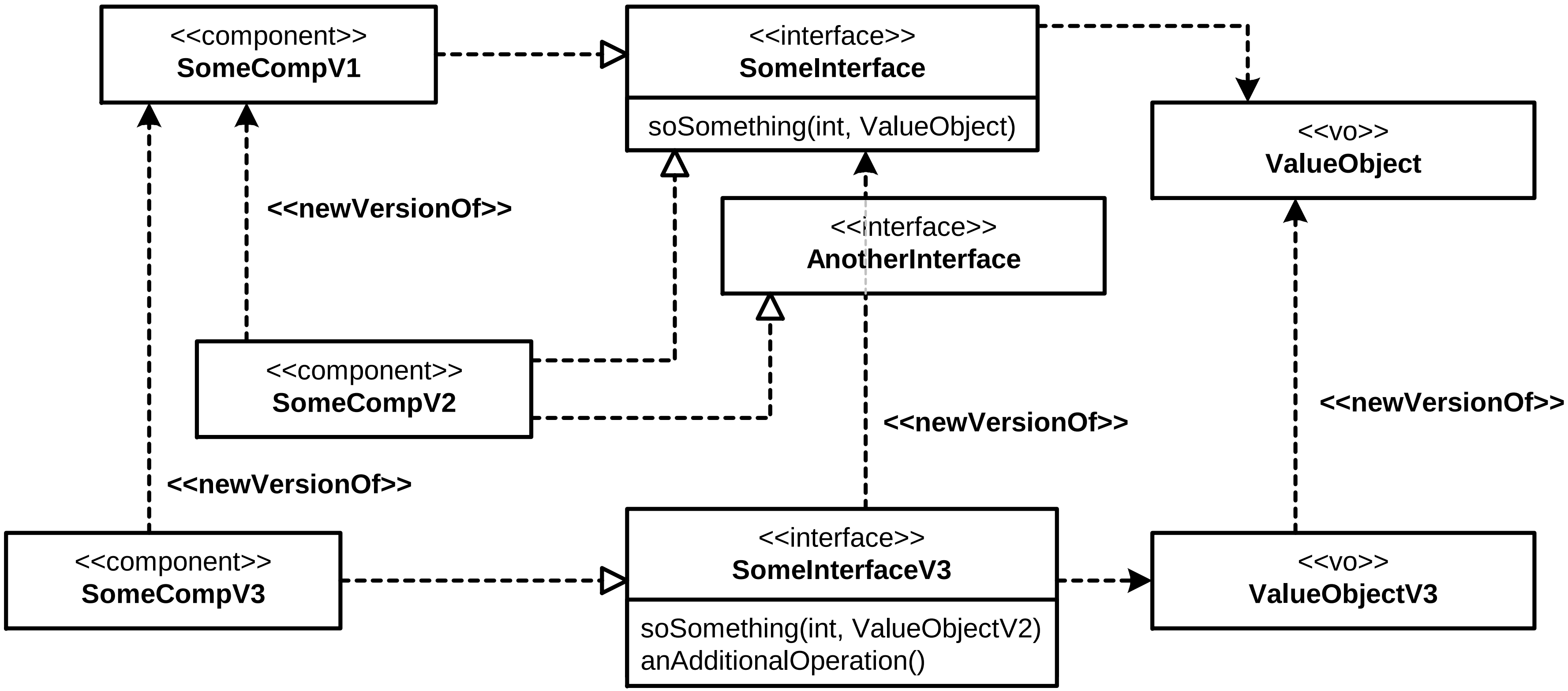
- Note the **code completion** & **error highlighting** ☺

```
unexpected token: n if !Transition.isInstance(this) ERROR this.metaType.n ame+"
    this.name != null;

context StartState ERROR "no incoming transitions allowed":
    this.inTransitions.size == 0;

context S                                               ne out transition":
    this.

context S                                               allowed":
    this.
```

- actions List - AbstractState
- compareTo(Object) Integer - Object
- eAllContents Set - EObject
- eContainer EObject - EObject
- eContents List - EObject
- eRootContainer EObject - EObject
- outTransitions List - AbstractState

Checks First & Separate III

- More complex constraints: Versioning and Evolution

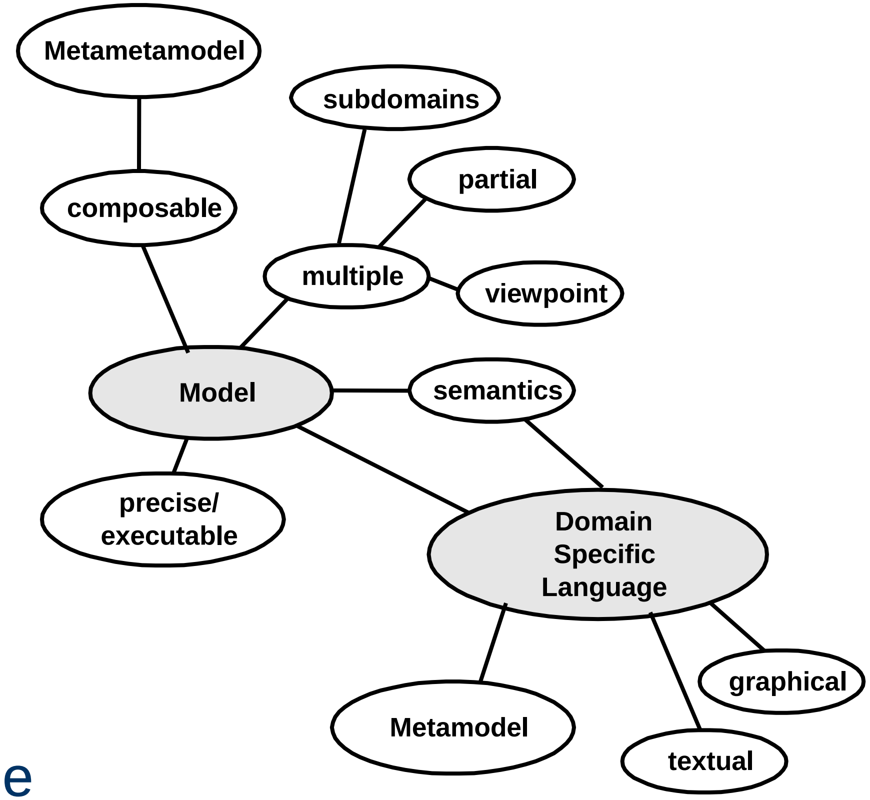


Multiple Viewpoints

Use several models to describe a system from several viewpoints – each viewpoint will have a suitable concrete syntax and metamodel

Multiple Viewpoints

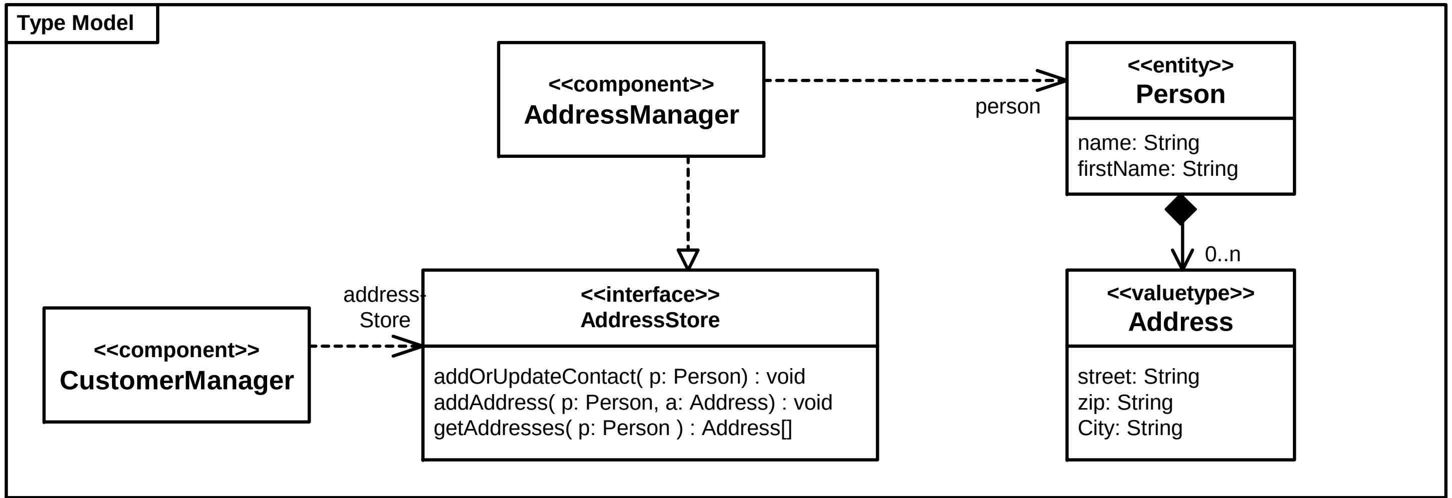
- Complex Systems typically consist of **several aspects, concerns or viewpoints**.
- Often (though not always) these are described by different people at different times in the development process.
- In most cases**, different** forms of **concrete syntax** are suitable for these different viewpoints.



- Therefore, provide **separate models** for each of these viewpoints.

Multiple Viewpoints II: CBD Example

- **Type Model**: Components, Interfaces, Data Types
- **Composition Model**: Instances, "Wirings"
- **System Model**: Nodes, Channels, Deployments



Composition Model

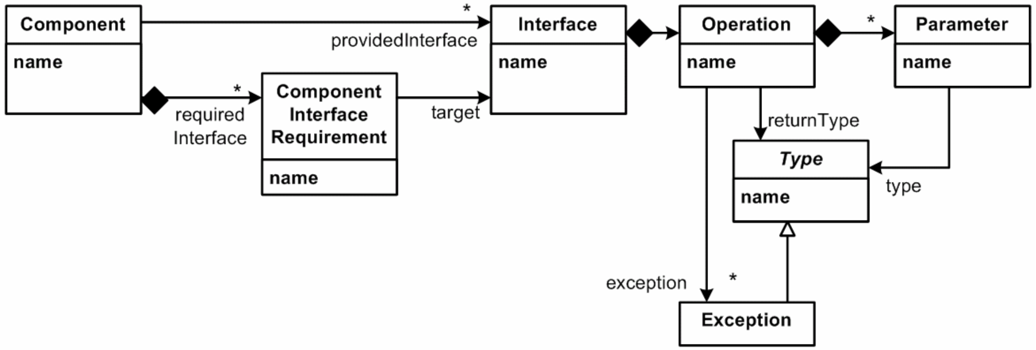
```
<configurations>
  <configuration name="addressStuff">
    <deployment name="am" type="AddressManager">
      <wire name="personDAO" target="personDAO"/>
    </deployment>
    <deployment name="personDAO" type="PersonDAO"/>
  </configuration>
  <configuration name="customerStuff">
    <deployment name="cm" type="CustomerManager">
      <wire name="addressStore" target=":addressStuff:am"/>
    </deployment>
  </configuration>
  <configuration name="test" includes="addressStuff, customerStuff"/>
</configurations>
```

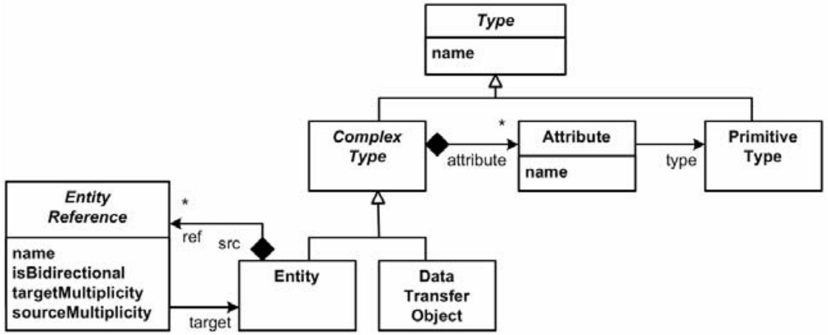
System Model

```
<systems>
  <system name="production">
    <node name="server" type="spring" configuration="addressStuff"/>
    <node name="client" type="eclipse" configuration="customerStuff"/>
  <system>
  <system name="test">
    <node name="test" type="spring" configuration="test"/>
  <system>
</systems>
```

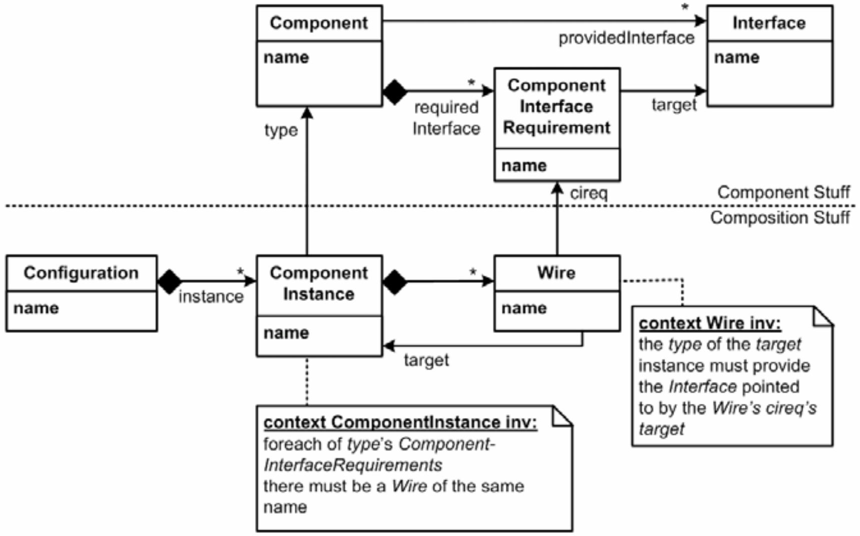
Multiple Viewpoints III: CBD Example Metamodels

Types

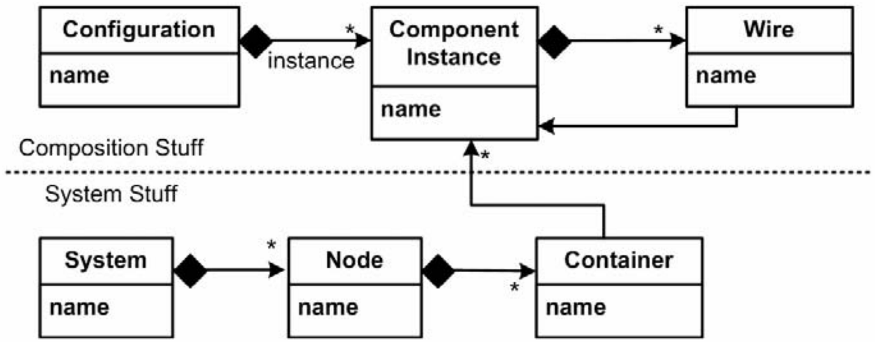




Composition

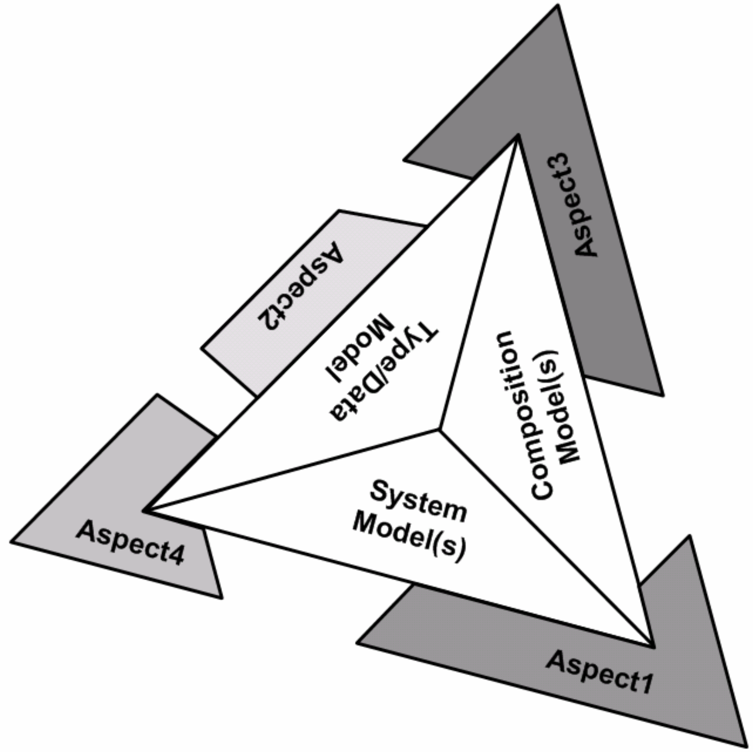


Deployment



Multiple Viewpoints IV: Aspect Models

- Often, the described three viewpoints are not enough, **additional aspects** need to be described.
- These go into **separate aspect models**, each describing a well-defined aspect of the system.
  - Each of them uses a suitable DSL/syntax
  - The generator acts as a weaver
- Typical **Examples** are
  - Persistence
  - Security
  - Forms, Layout, Pageflow
  - Timing, QoS in General
  - Packaging and Deployment
  - Diagnostics and Monitoring



Architecture First

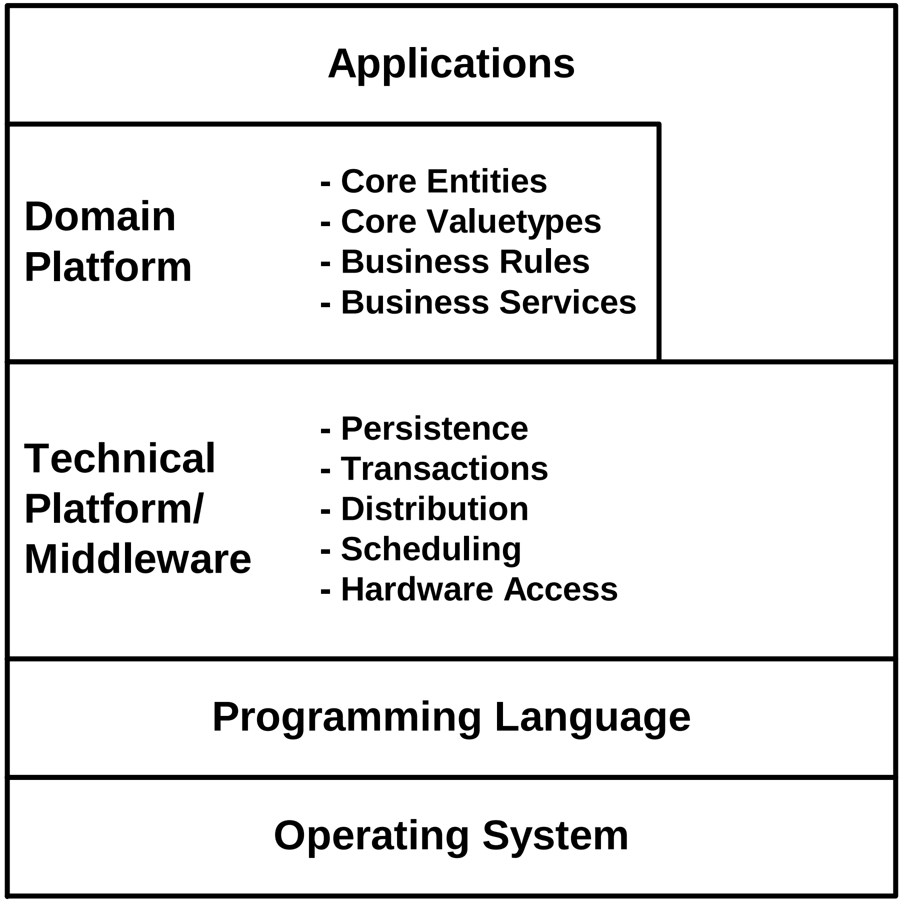
You can generate all the „adaption code“ to run the system on a given platform – you don‘t need to care about these things when implementing business logic

Architecture First

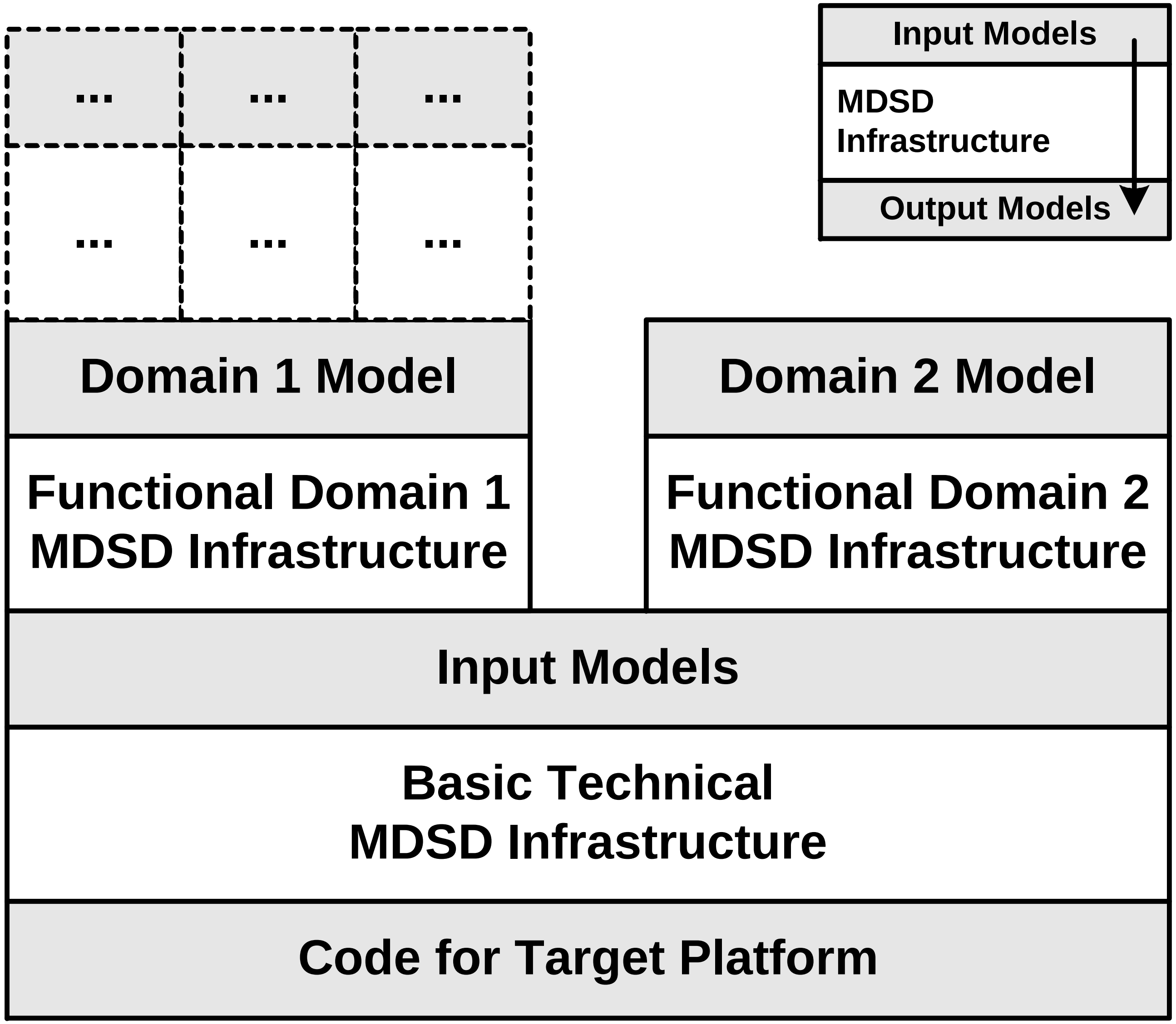
- A successful system is built based on a **well-defined architecture**, often along the lines of the illustration below.

- Various parts/layers of this stack can be generated, or developed with meta-model and generator support.

- Use **Model-2-Model Trans-formations** to implement higher layers based on the abstractions provided by lower layers.



Architecture First II

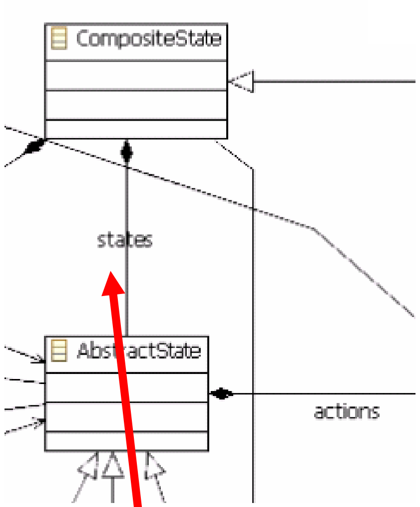


Architecture First III: Generated Stuff

- What can be generated?
  - Base classes for component implementation
  - Build-Scripts
  - Descriptors
  - Remoting Infrastructure
  - Persistence
  - ...

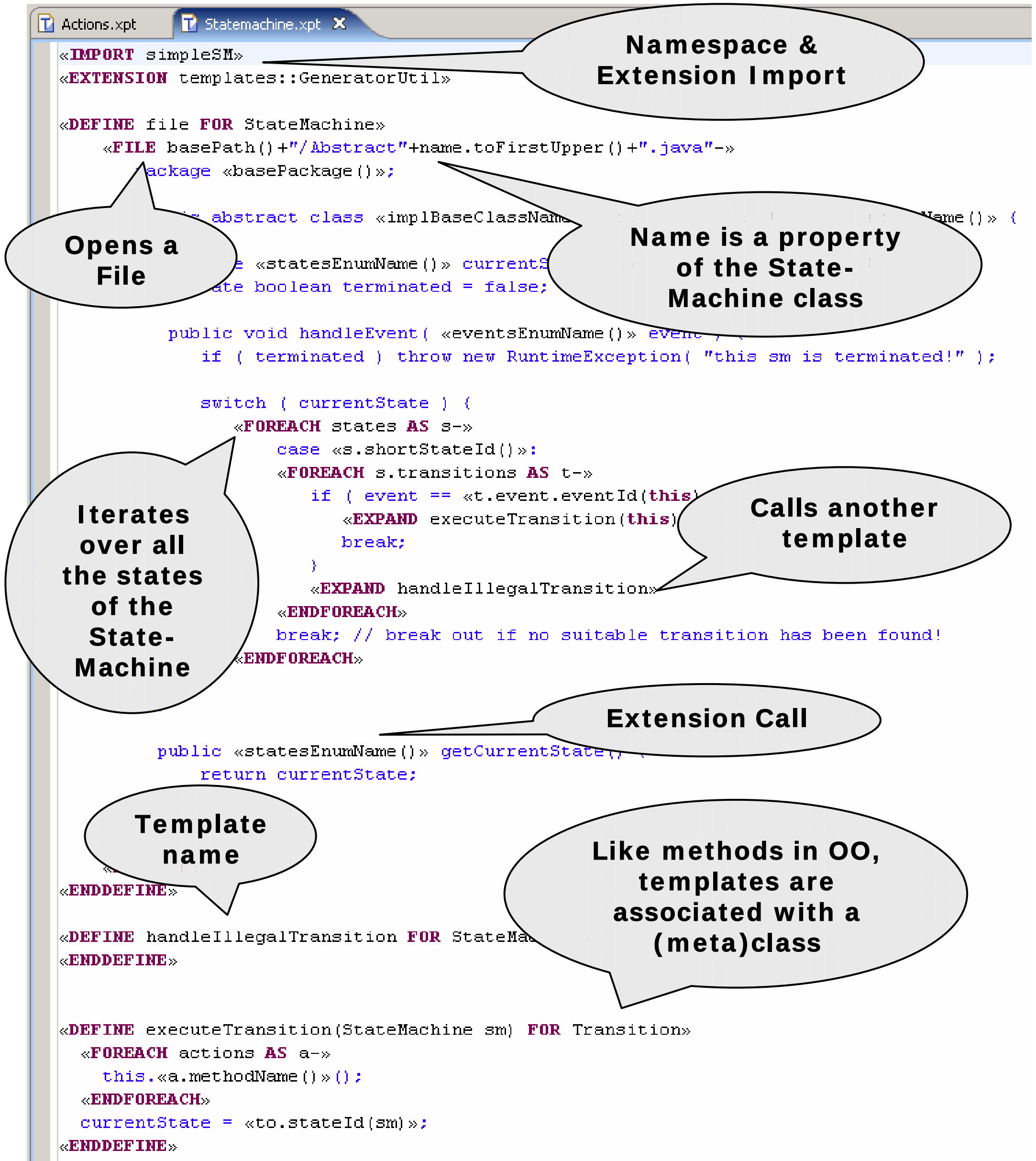
Architecture First IV: Code Generation

- Code Generation is used to **generate executable code** from models.
- Code Generation is **based on the metamodel** & uses **templates** to attach to-be-generated source code.
- In openArchitectureWare, we use a **template language** called **xPand**.
- It provides a number of **advanced features** such as polymorphism, AO support and a powerful integrated expression language.
- Templates can access **metamodel properties** seamlessly




```
«DEFINE SwitchBasedImpl FOR StateMachine»

  «FOREACH states.typeSelect(State) AS s
     public static final int «s.constant
  «ENDFOREACH»
```

Architecture First V: Code Generation



- The **blue text** is generated into the target file.
- The **capitalized words** are xPand keywords
- **Black text** is access to metamodel properties
- DEFINE…END-DEFINE blocks are called **templates**.
- The whole thing is called a **template file**.

Extendible Metamodel

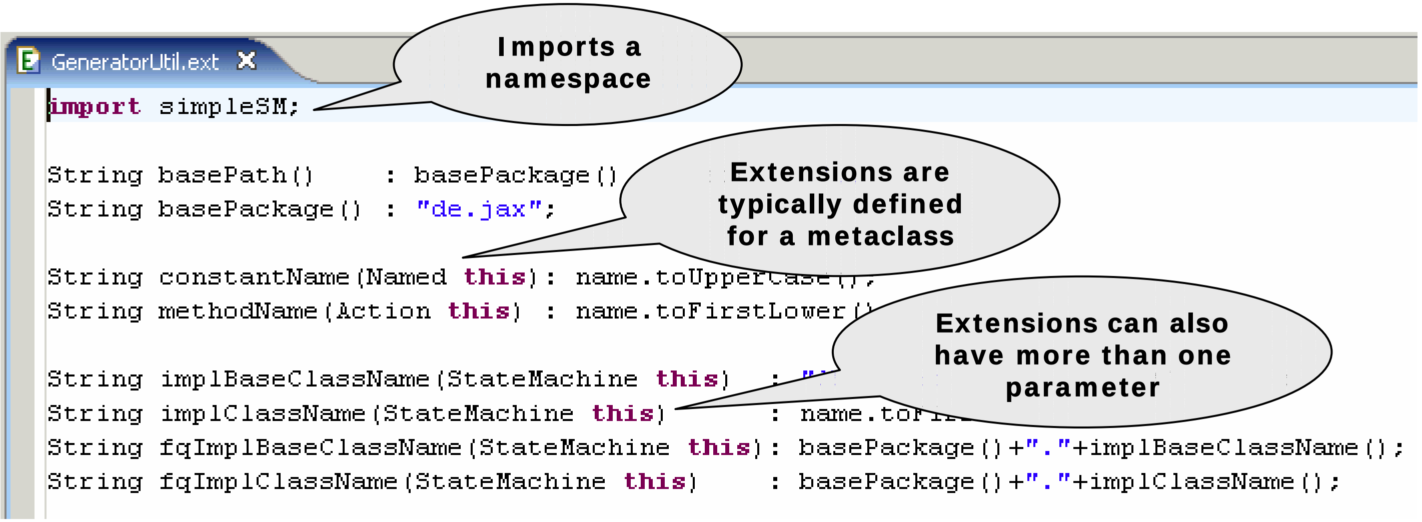
When generating/transforming models, you often need additional properties on your metaclasses, or whole even new metaclasses; make sure you can add them, without touching the metamodel itself!

Extendible Metamodel

- Assume you want to **generate code for Java** from a given model. You'll need all kinds of **additional properties** on your model elements, such as:
  - Class::javaClassName
  - Class::package
  - Class::fileName
- If you add these to your domain metamodel, you'll **pollute the metamodel** with target platform-specific properties.
- This gets even worse if you generate for **several targets** from the same model...
- Therefore allow **metaclasses to be annotated** with additional (derived) properties **externally**.
  - Somewhat like open classes/AOP/C#3.0 extension methods

Extendible Metamodel II

- One can **add behaviour to existing metaclasses** using oAW's **Xtend** language.



- Extensions can be called using **member-style syntax**: *myAction.methodName()*
- Extensions can be used in **Xpand templates, Check files** as well as in other **Extension files**.
- They are imported into template files using the **EXTENSION** keyword

Active Programming Model

You should restrict the freedom of developers …
making the code more consistent and structured.
Help developers write correct code!

Active Programming Model

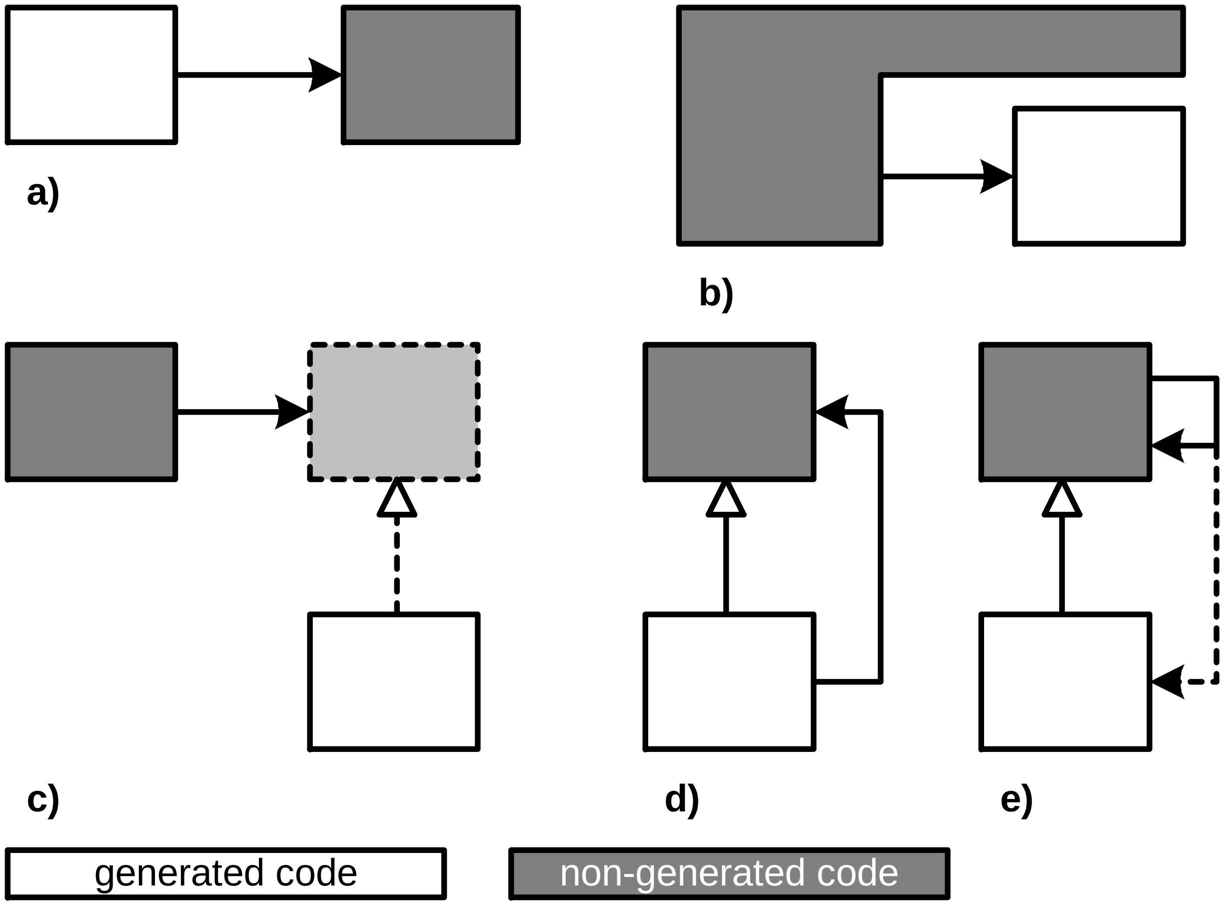
- You want to make sure developers have only **limited freedom** when implementing those aspects of the code that are not generated.
  -> well structured system
  -> keeps the promises made by the models

- An important challenge is thus: How do we combine **generated** code and **manually written** code in a controlled manner (and without using protected regions)?

- **Solution**: Patterns, Recipe Framework

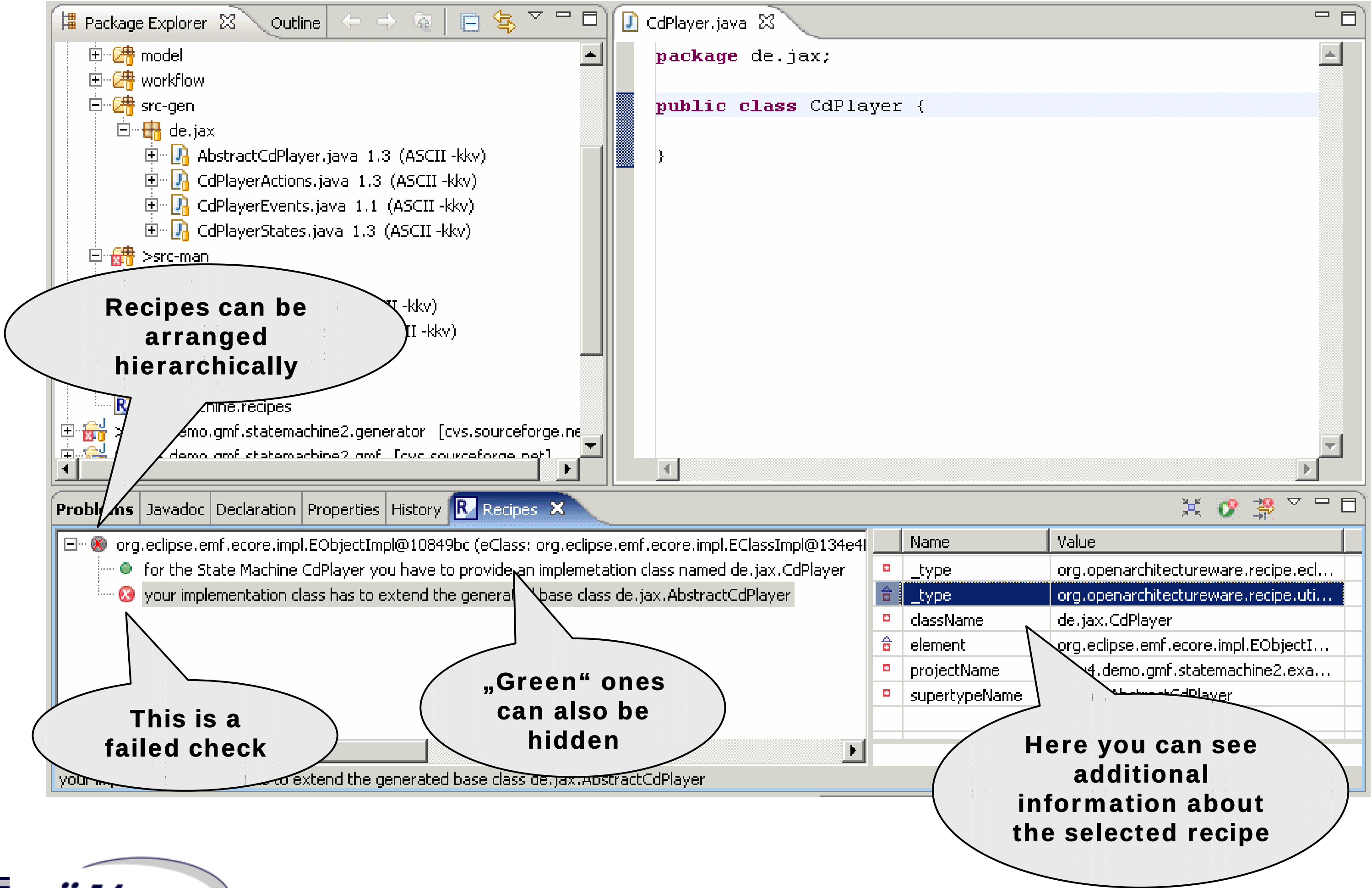
Active Programming Model II: Integration Patterns

- There are various ways of integrating generated code with non-generated code



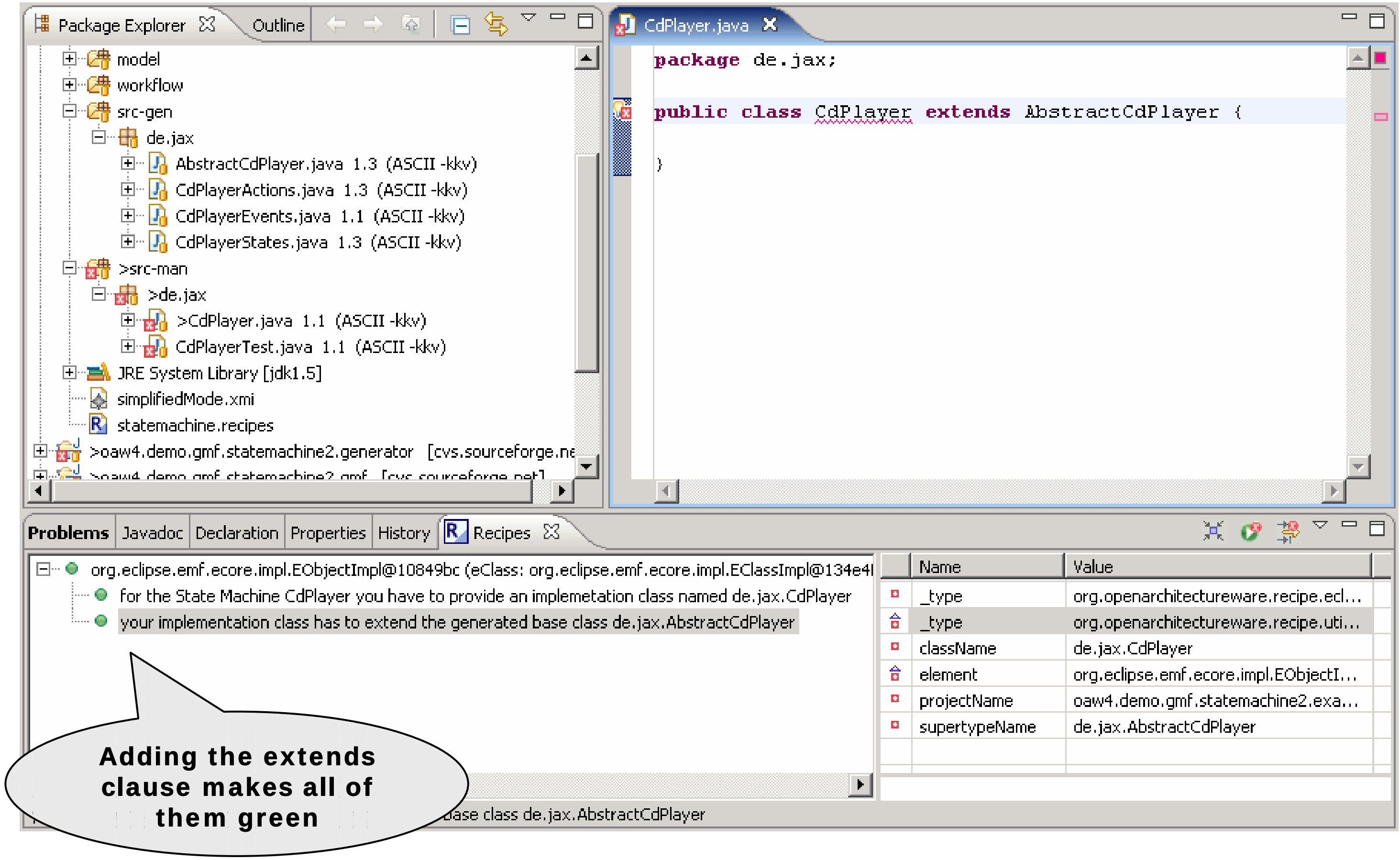
Active Programming Model III: Recipes I

- Here's an error that suggests that I **extend** my manually written class **from the generated base class:**



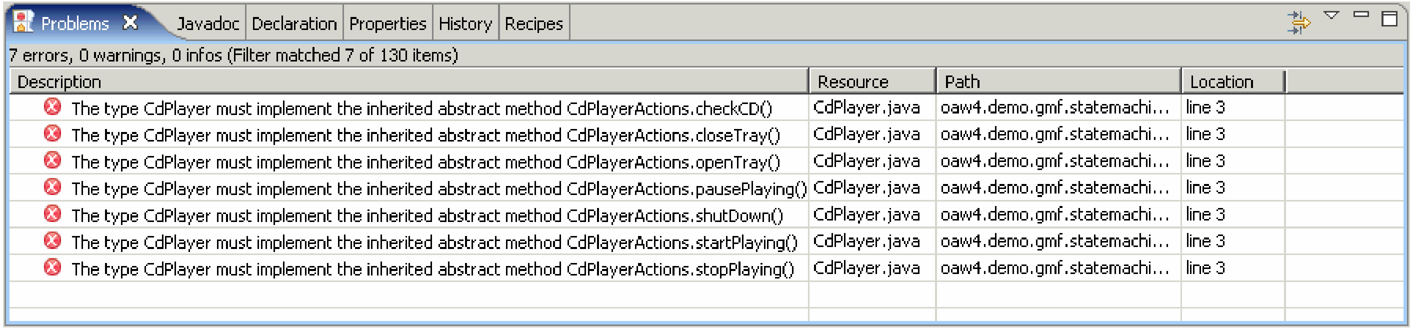
Active Programming Model IV: Recipes II

- I now **add the respective *extends* clause**, & the message goes away – automatically.



Active Programming Model V: Recipes III

- Now I get a number of compile errors because I have to **implement the abstract methods** defined in the super class:



Problems | Javadoc | Declaration | Properties | History | Recipes

7 errors, 0 warnings, 0 infos (Filter matched 7 of 130 items)

Description	Resource	Path	Location
The type CdPlayer must implement the inherited abstract method CdPlayerActions.checkCD()	CdPlayer.java	oaw4.demo.gmf.statemachi...	line 3
The type CdPlayer must implement the inherited abstract method CdPlayerActions.closeTray()	CdPlayer.java	oaw4.demo.gmf.statemachi...	line 3
The type CdPlayer must implement the inherited abstract method CdPlayerActions.openTray()	CdPlayer.java	oaw4.demo.gmf.statemachi...	line 3
The type CdPlayer must implement the inherited abstract method CdPlayerActions.pausePlaying()	CdPlayer.java	oaw4.demo.gmf.statemachi...	line 3
The type CdPlayer must implement the inherited abstract method CdPlayerActions.shutDown()	CdPlayer.java	oaw4.demo.gmf.statemachi...	line 3
The type CdPlayer must implement the inherited abstract method CdPlayerActions.startPlaying()	CdPlayer.java	oaw4.demo.gmf.statemachi...	line 3
The type CdPlayer must implement the inherited abstract method CdPlayerActions.stopPlaying()	CdPlayer.java	oaw4.demo.gmf.statemachi...	line 3

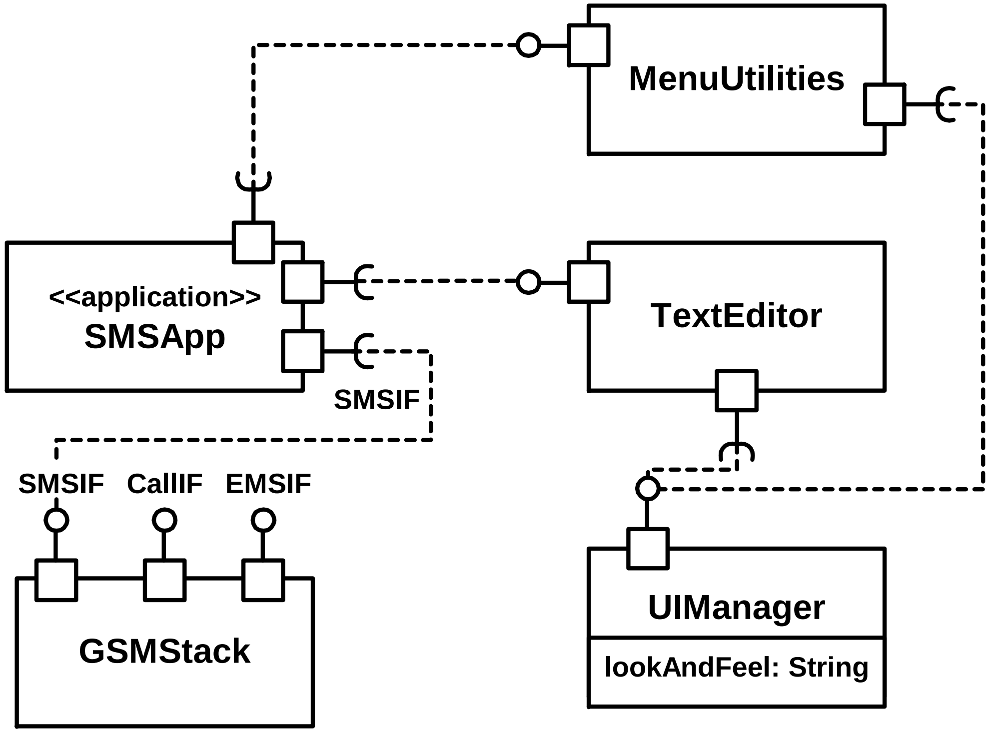
- I finally implement them sensibly, & everything is ok.
- The Recipe Framework & the Compiler have **guided me through the manual implementation steps.**
  - If I didn't like the compiler errors, we could also add recipe tasks for the individual operations.
  - oAW comes with a number of **predefined recipe checks for Java**. But you can also define your own checks, e.g. to verify C++ code.

Managing the Architecture

MDSD can help to make sure an architecture is used consistently and „correctly“ in larger teams

Managing the Architecture

- It is relatively easy check architectural constraints (such as dependencies) **on the level of models**.
- However, if the model analysis tells you that everything is ok (no constraint violations) it must be ensured that the **manually written code does not compromise** the validity of the constraints.
- E.g. how do you ensure that there are no more dependencies in the code than those that are modeled in the model?



Managing the Architecture II

- The programming model shown below is bad:

```
public class SMSAppImpl {
  public void tueWas() {
    TextEditor editor =
            Factory.getComponent("TextEditor");
    editor.setText( someText );
    editor.show();
  }
}
```

- **Problems:**
  - Developers can lookup, use, and thus, depend on whatever they like
  - Developers are not guided (by IDE, compiler, etc.) what they are allowed to access and what is prohibited

Managing the Architecture III

```
public interface SMSAppContext extends ComponentContext {
  public TextEditorIF getTextEditorIF();
  public SMSIF getSMSIF();
  public MenuIF getMenuIF();
}
```

```
public class SMSAppImpl implements Component {
  private SMSAppContext context = null;
  public void init( ComponentContext ctx) {
    this.context = (SMSAppContext)ctx;
  }
  public void tueWas() {
    TextEditor editor = context.getTextEditorIF();
    editor.setText( someText ); editor.show();
} }
```

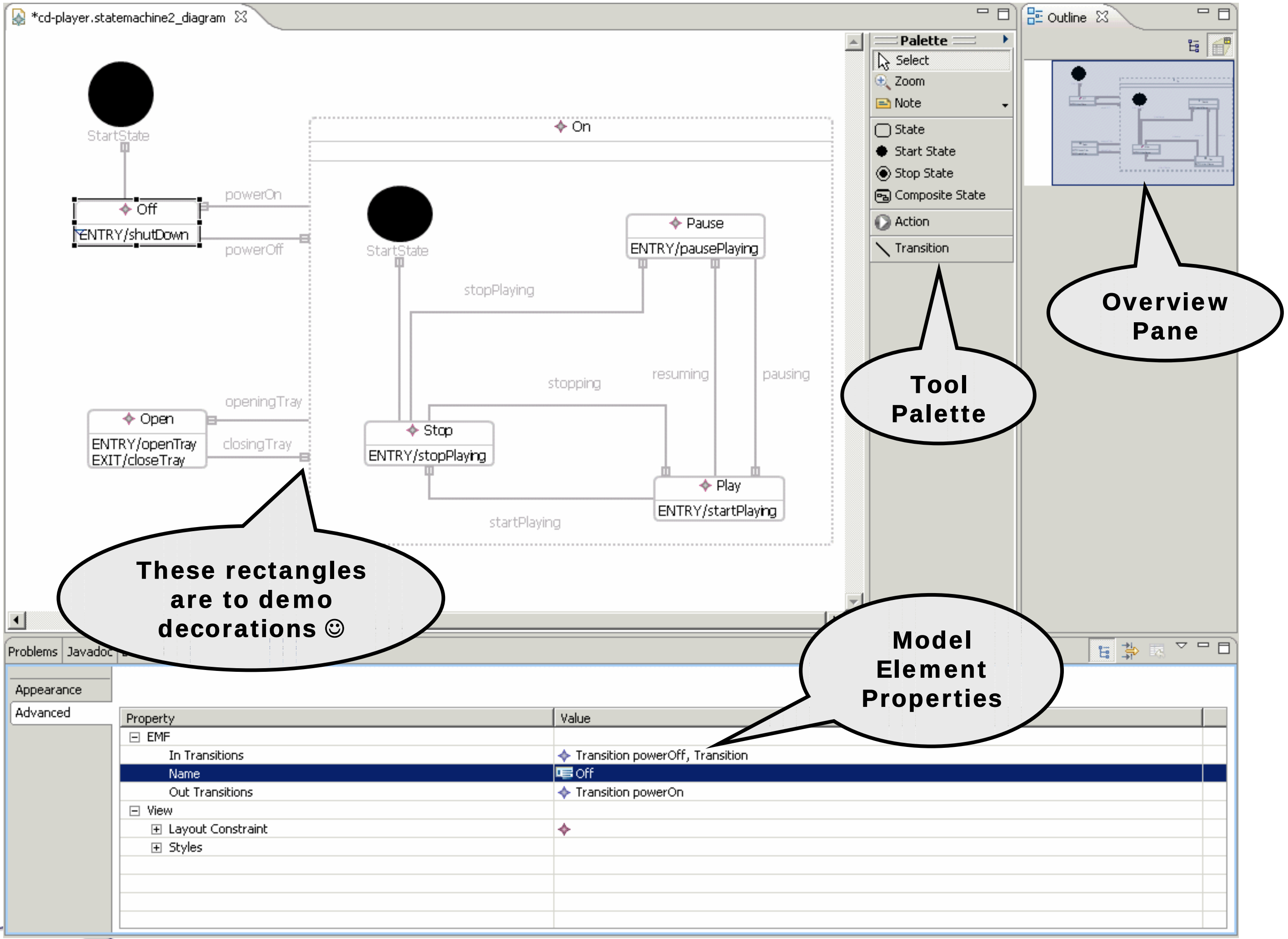
- **Better, because:**
  - Developers can only access what they are allowed to...
  - ... and this is always in sync with the model
  - IDE can help developer (ctrl+space in eclipse)
  - Architecture (here: Dependencies) are enforced and controlled

Graphical vs. Textual Syntax

Textual DSLs are often neglected in the MDSD / MDA space. Graphical DSLs are often ignored in other circles. When do you use which flavour?

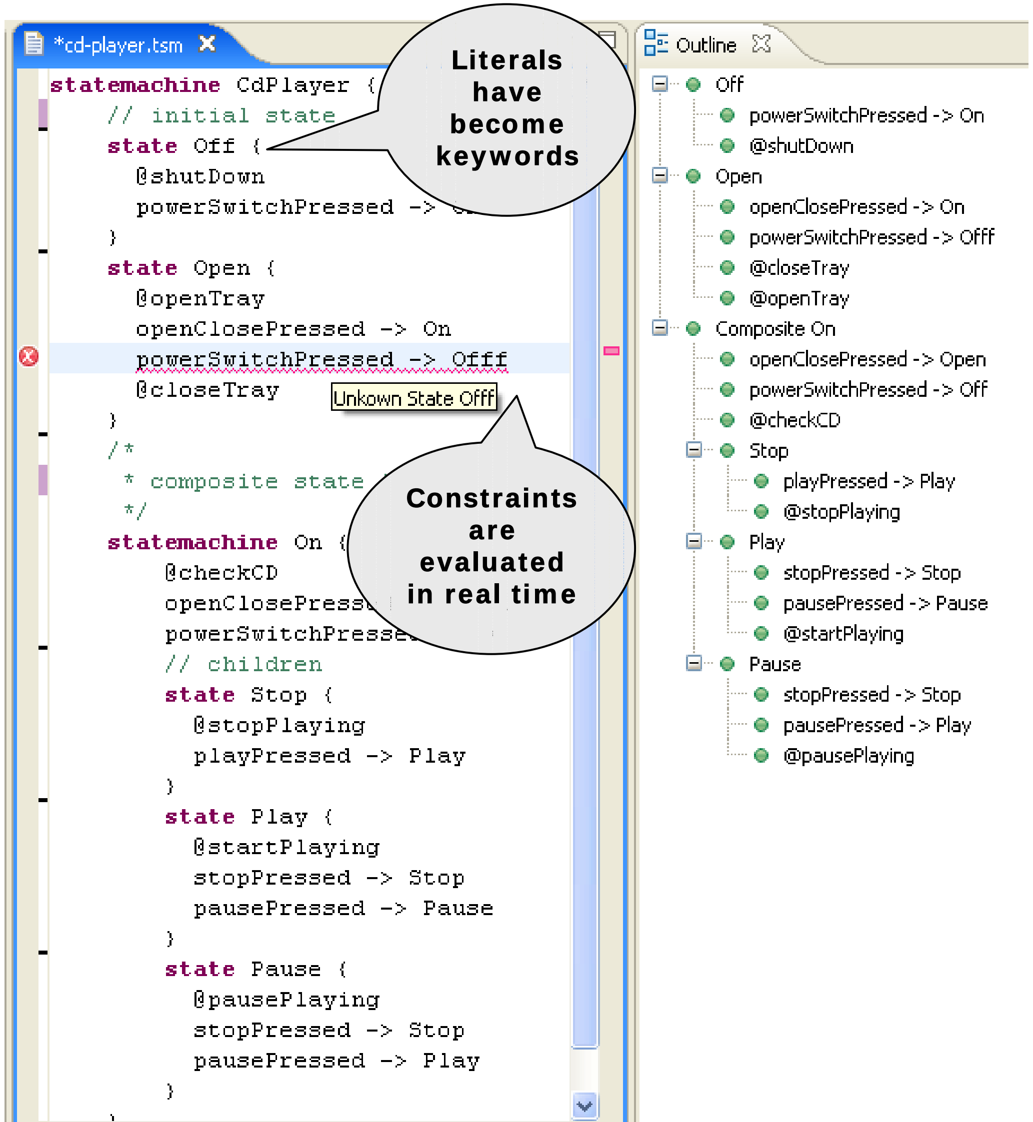
Graphical vs. Textual Syntax

- This is an example of an editor **built with Eclipse GMF**, based on a metamodel for state machines.



Graphical vs. Textual Syntax II

- This is a textual editor for the same metamodel



Graphical vs. Textual Syntax III: Comparison

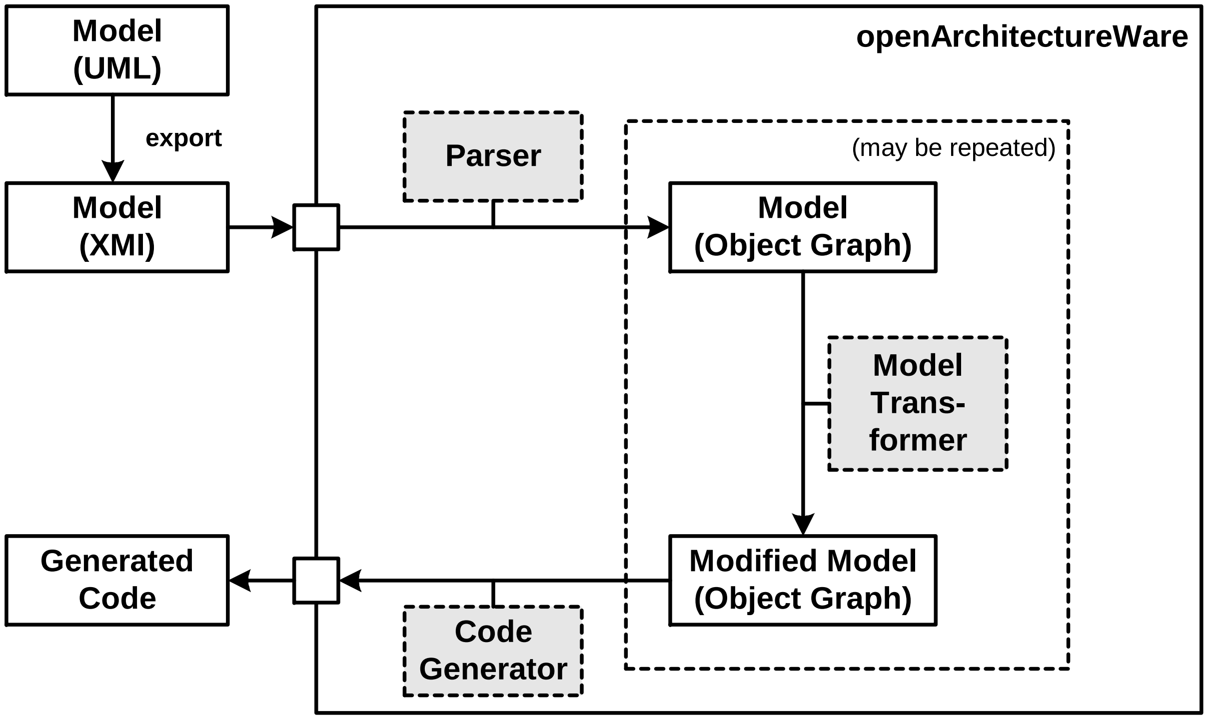
- **Both kinds** of editors...
  - Can be built on the same meta model
  - Can verify constraints in real time
  - Will write ordinary EMF models
- **Graphical Editors**
  - are good to show structural relationships
- **Textual Editors**
  - are better for „algorithmic“ aspects
  - Integrate better with CVS etc. (diff, merge)

Don‘t Duplicate – Transform!

Direct Model-to-Code Transformation is often not enough, since you’ll either have to duplicate stuff into code generation templates or you have to add “obvious” stuff to your models. Neither is desirable.

Don‘t Duplicate – Transform!

- M2M Transformations should be kept **inside the tool**, use them to **modularize the transformation** chain.
  - Never ever modify the result of a transformation manually
- Use **example models** and **model-specific constraints** to verify that the transformation works as advertised.



Don‘t Duplicate – Transform! II

- Consider you want to generate a **state machine implementation for C++ and Java**:
  - You have a model of a state machine,
  - And you have two sets of templates – one for C++, one for Java

- Assume further, that you want to have an ***emergency stop* feature** in your state machines (a new transition from each ordinary state to a special stop state)
  - You can either add it manually to the model (which is tedious and error prone)
  - Or you can modify the templates (two sets, already...!) and hard-code the additional transitions and state.

- Both solutions are not satisfactory.

- **Better Alternative:** Use a Model-Modification to add these transitions and state automatically

Don‘t Duplicate – Transform! III

- The **model modification** shows how to add an dditional state & some transitions to an existing state machine (emergency shutdown)

AddEmergencyShutdown.ext

```
import statemachine2;

extension statemachine2::constraints::Statemachine;

StateMachine modify(StateMachine sm) :
    sm.transitions.addAll(sm.allConcreteStates().createTransition()) ->
    sm.states.add(createShutDown()) ->
    sm;

private create State this createShutDown() :
    setName("EmergencyShutDown");

private create Transition this createTransition(State s) :
    setEvent("Error")->
    setName("Aborting") ->
    setFrom(s) ->
    setTo(createShutDown());
```

Extensions can import other extensions

The main function

„create extensions“ guarantee that for each set of parameters the *identical* result will be returned.

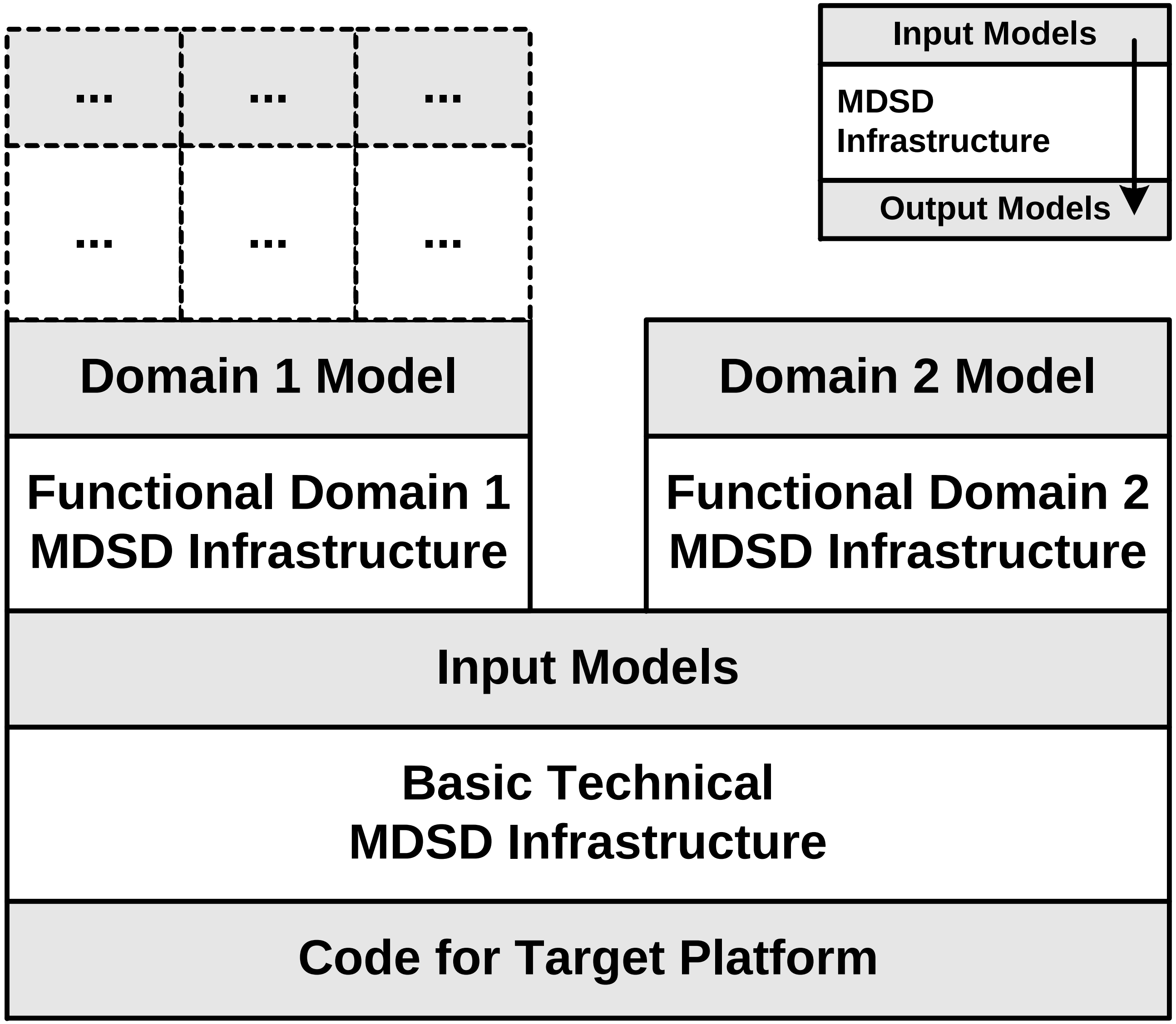
Therefore createShutDown() will always return the same element.

No code generation templates need not be modified for the new feature to work

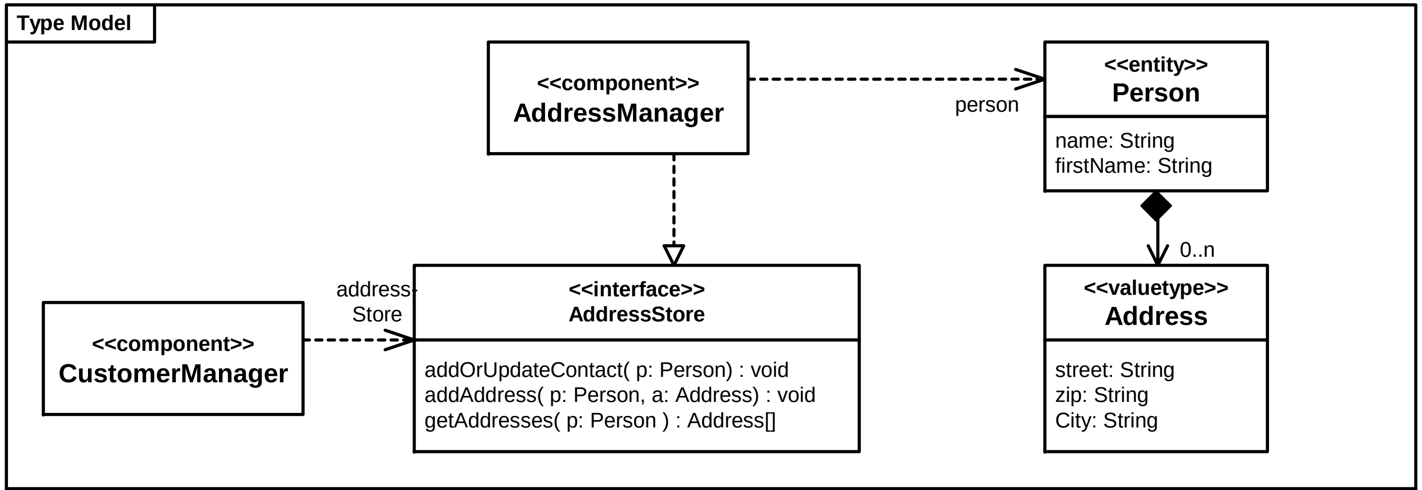
Partitions / Layers / Cascading

Architecture can be nicely layered and architected to be as small an consistent as possible

Partitions / Layers / Cascading



Partitions/Layers/Cascading II

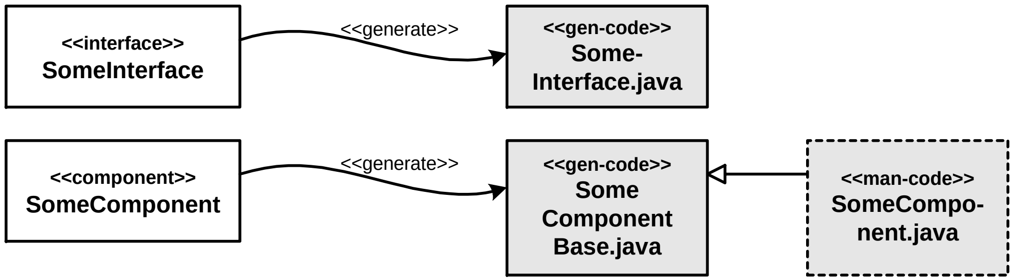


Composition Model

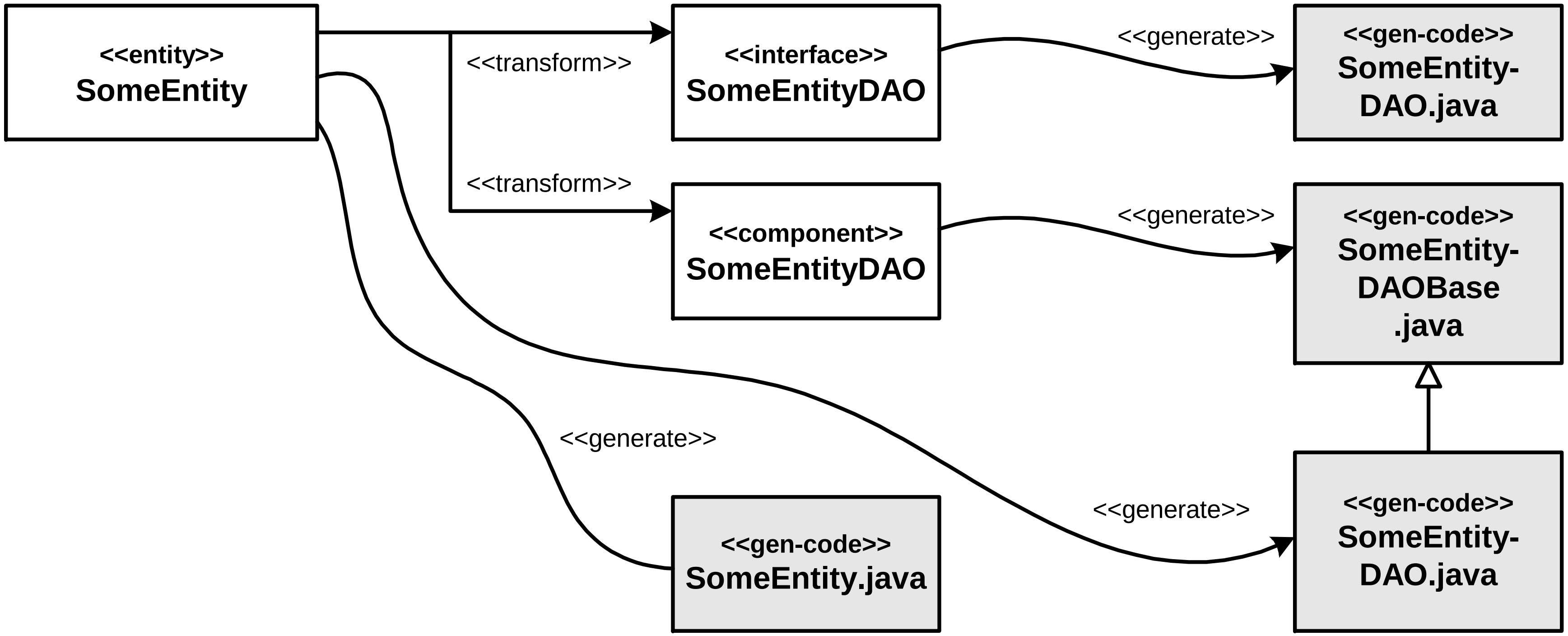
```
<configurations>
  <configuration name="addressStuff">
    <deployment name="am" type="AddressManager">
      <wire name="personDAO" target="personDAO"/>
    </deployment>
    <deployment name="personDAO" type="PersonDAO"/>
  </configuration>
  <configuration name="customerStuff">
    <deployment name="cm" type="CustomerManager">
      <wire name="addressStore" target=":addressStuff:am"/>
    </deployment>
  </configuration>
  <configuration name="test" includes="addressStuff, customerStuff"/>
</configurations>
```

System Model

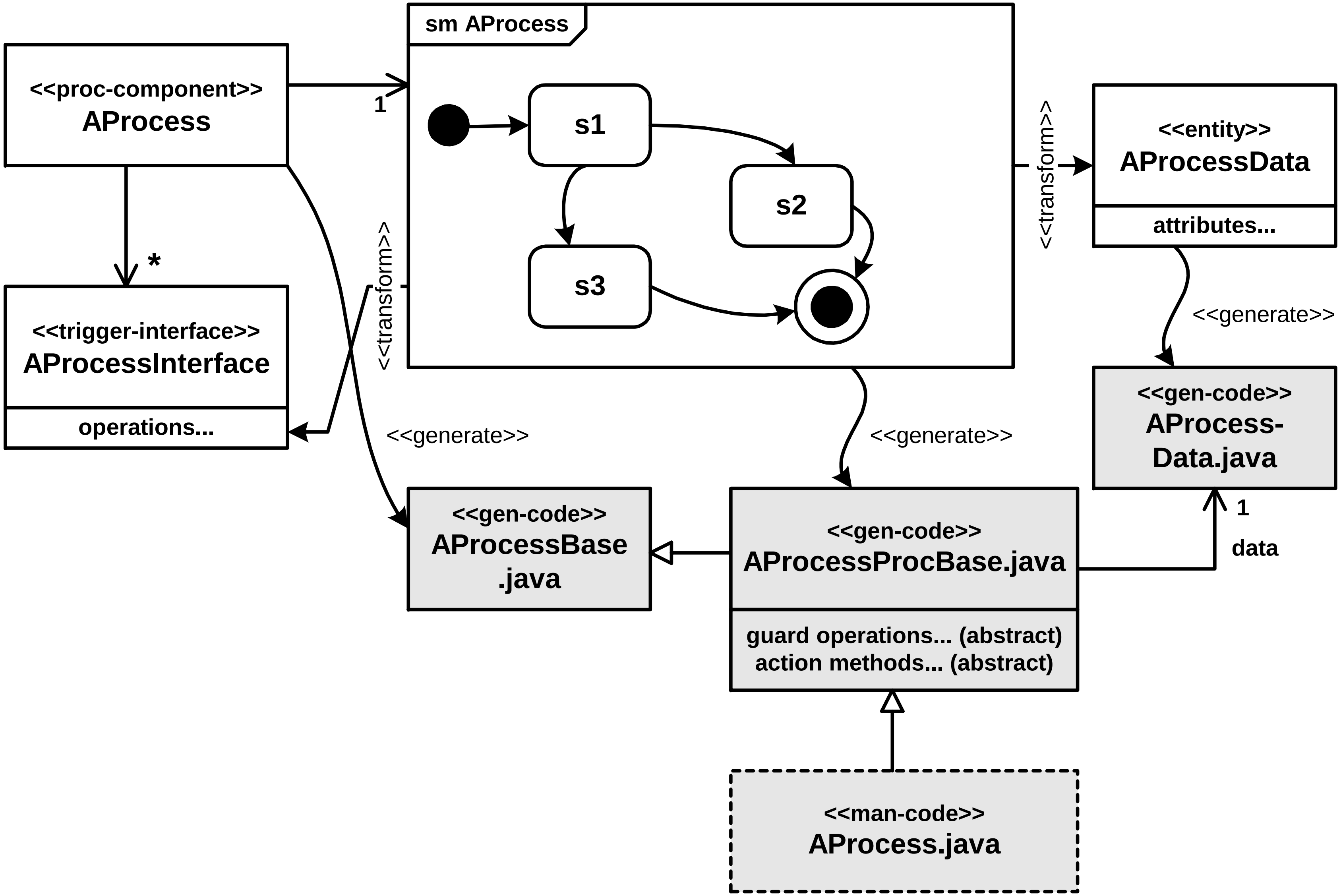
```
<systems>
  <system name="production">
    <node name="server" type="spring" configuration="addressStuff"/>
    <node name="client" type="eclipse" configuration="customerStuff"/>
  <system>
  <system name="test">
    <node name="test" type="spring" configuration="test"/>
  <system>
</systems>
```



Partitions/Layers/Cascading III



Partitions/Layers/Cascading IV

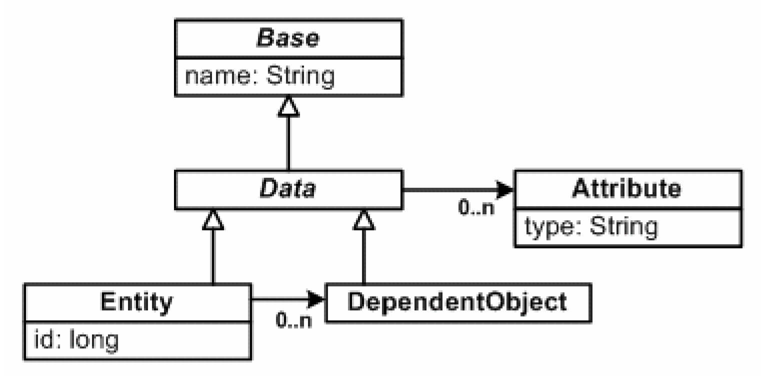


Configuration over Composition

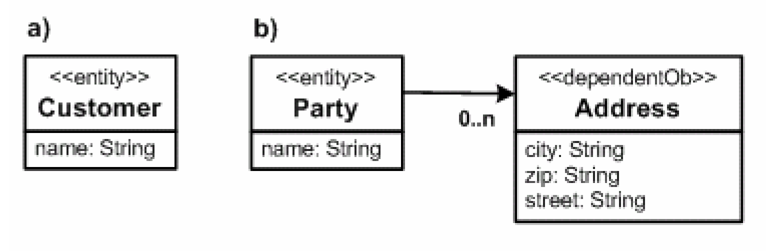
Architecture can be nicely layered and architected to be as small an consistent as possible

Configuration over Composition

- **Structural Variations**
  Example Metamodel



- Based on this sample metamodel,
  you can build a **wide variety of models:**

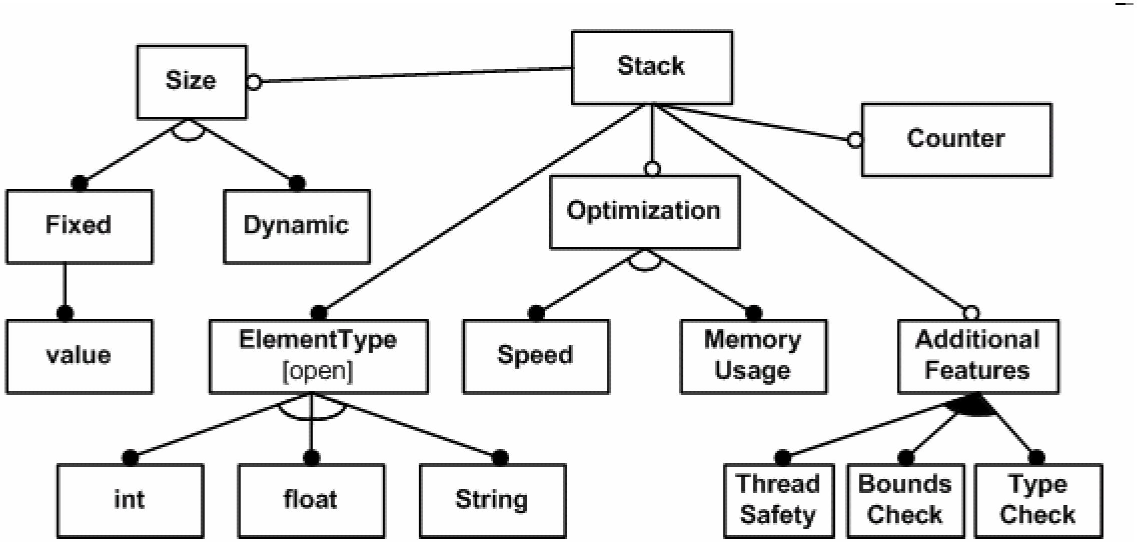


- **Non-Structural Variati**
  Example Feature Models

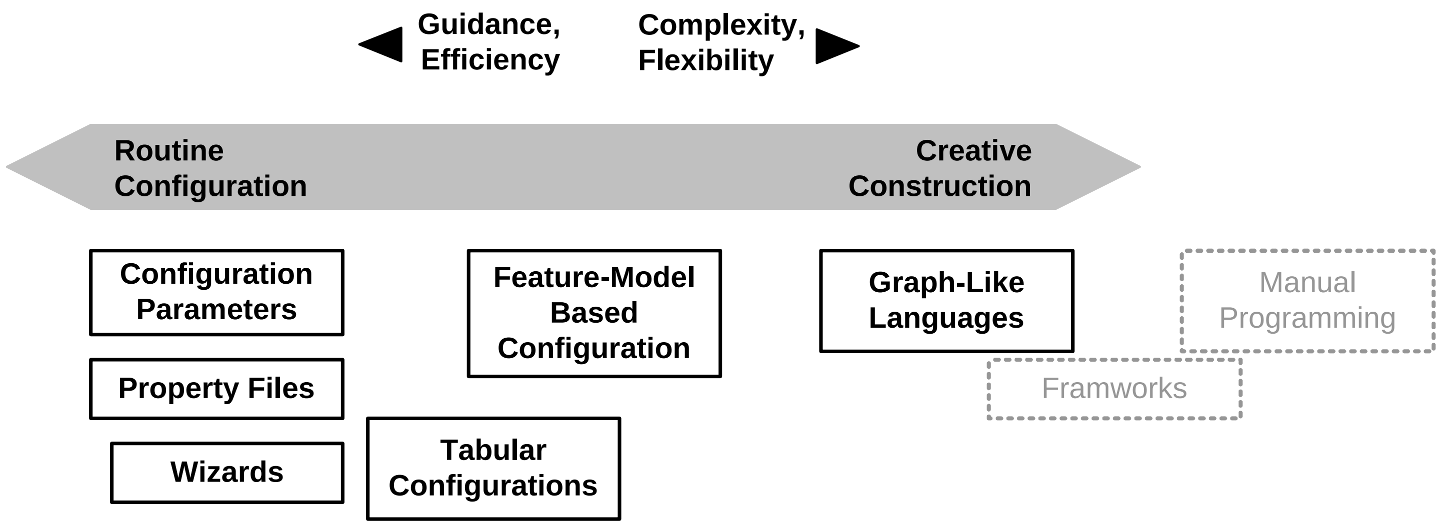
  Dynamic Size, ElementType: int, Counter, Threadsafe

  Static Size (20), ElementType: String

  Dynamic Size, Speed-Optimized, Bounds Check



Configuration over Composition II



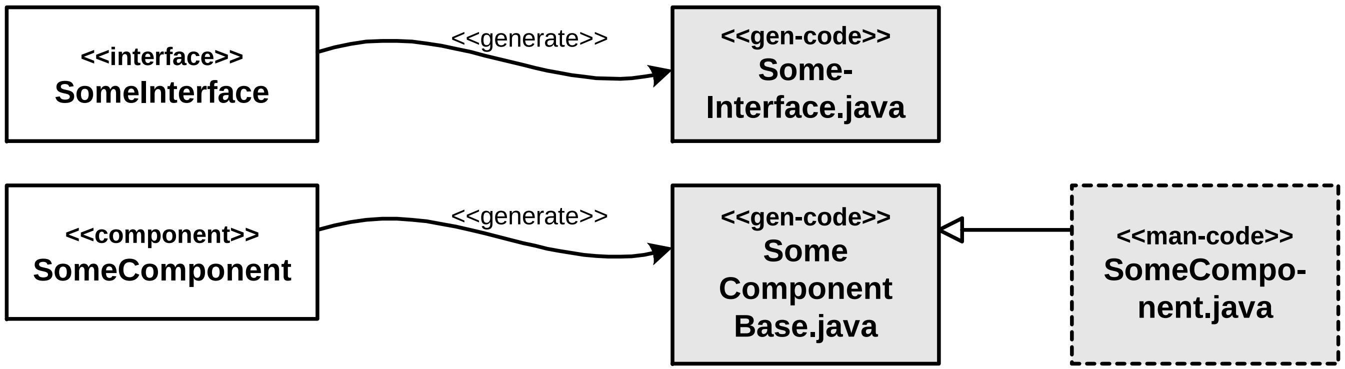
- This slide (adopted from K. Czarnecki) is **important for the selection of DSLs** in the context of MDSD **in general**:
  - The more you can move your DSL „form“ to the configuration side, the simpler it typically gets.
  - We will see why this is especially important for behavior modelling.

Specific Implementation DSLs

Architecture can be nicely layered and architected to be as small an consistent as possible

Specific Implementation DSLs

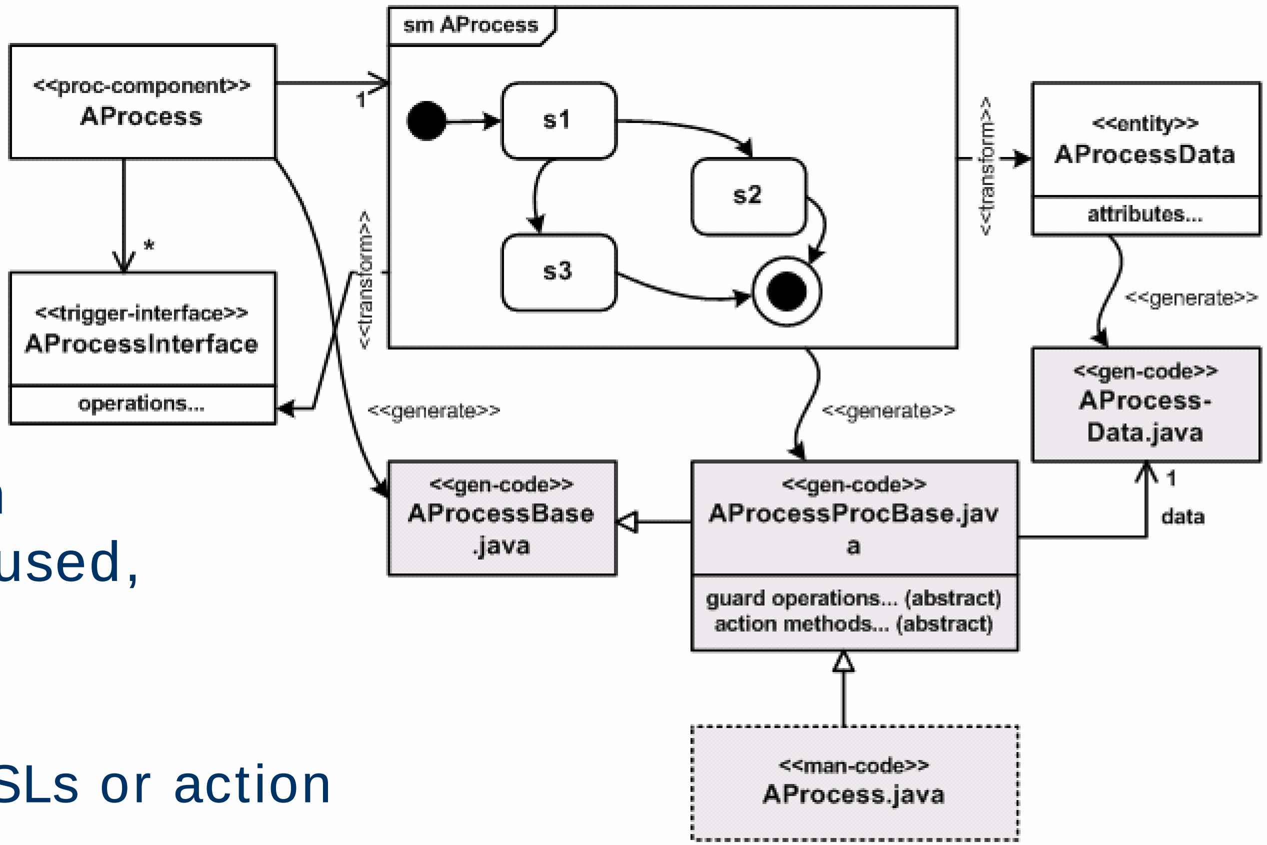
- We have not yet talked about the **implementation code** that needs to go along with components.
  - As a default, you will provide the implementation by a **manually written subclass**



- However, for **special kinds of components** (“component kind” will be defined later) can use different implementation strategies -> **Cascading!**

Specific Implementation DSLs II

- Remember the **example of the process components** from before:



- Various other **implementation stragies** can be used, such as:
  - Rule-Engines
  - “Procedural” DSLs or action semantics

- Note that, here, **interpreters** can often be used sensibly instead of generating code
  -> JRuby, but that’s another talk ☺

Thanks!

Please ask questions!

Some advertisement ☺

- For those, who speak (or rather, read) german:

  Völter, Stahl:

  Modellgetriebene Softwareentwicklung
  Technik, Engineering, Management

  dPunkt, 2005

  www.mdsd-buch.de

- An **very much updated** translation is under way:
  Model-Driven Software Development,
  Wiley, Q2 2006

  www.mdsd-book.org