Model-Driven Product Line Engineering

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This work is supported by

About me

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- Independent Consultant
- Based out of Göppingen, Germany
- Focus on
  - Model-Driven Software Development and DSLs
  - Software Architecture
  - Product Line Engineering

Founder and Editor of Software Engineering Radio – the Podcast for Professional Developers – http://se-radio.net

About AMPLE

- AMPLE == **A**spect-Oriented, **M**odel-Driven **P**roduct **L**ine **E**ngineering
  (buzzwords are important to get funded ☺)
- EU-funded **research project**
- Resulting tooling based on **Eclipse / openArchitectureWare** and is freely available from *eclipse.org/gmt/oaw*
  - Version 4.2 that includes all of these features is current.

About openArchitectureWare

- Well-known (and much used) toolkit for most aspects of **model-driven software development**
- Open Source at Eclipse GMT
  - **integrates** w/Eclipse Modeling projects (eg. EMF, GMF)
  - **Contributes** to various Eclipse Modeling projects (Workflow Engine, Model-to-Text, Textual Modeling Framework)
- Version **4.2** is current, has been released Sept. 2007
- **Some Features:**
  - Constraint Checking, Code Generation, Model-to-Model Transformation
  - OCL-like expression language used throughout the tool
  - Xtext Framework for building textual DSLs and Editors
  - Support PLE in models, generators and transformations via AOP
  - Editors and Debuggers for all those languages integrated in Eclipse

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Product Line Engineering

- The idea of PLE is to not develop software products as single artifacts, but rather to develop a **family of related products** as **efficiently** as possible.

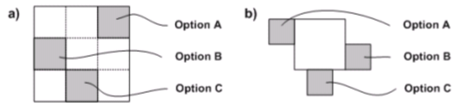
- We consider a **set of programs** to constitute a family whenever it is worthwhile to study programs from the set by **first studying the common properties** of the set and **then determining the special properties of the individual family members.**

Definition by Parnas

Variability Analysis: A central building block for PLE

- **Variability analysis** discovers the variable and fixed parts of a product in a domain. Parts can be
  - Structural or behavioral
  - Functional or non-functional (technical)
  - Modularized or aspectual
- Central challenges wrt. to variabilities are:
  - **Identification:** where are the variabilities, what are the options?
  - **Kind of variability:** see above
  - **Description:** how do I describe the allowed alternatives
  - **Management:** what are the constraints between the various variation points
  - **Implementation:** how do I implement the respective varibility in my software system?

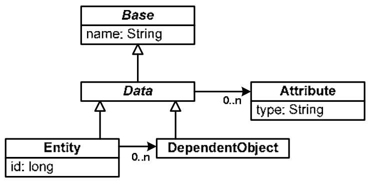
Negative vs. Positive Variability



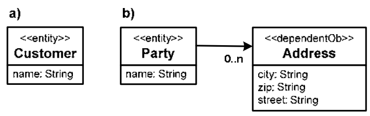
- Negative Variability (a) **takes optional parts away** from an „overall whole“
  - **Challenge:** the „overall whole“ can become really big an unmanageable
- Positive Variability (b) **adds optional parts** to a minimal core.
  - **Challenge:** How to specify where and how to join the optional parts to the minimal core
- **In Practice:** combine both

Structural vs. Non-Structural Variability

- **Structural Variations**
  Example Metamodel



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

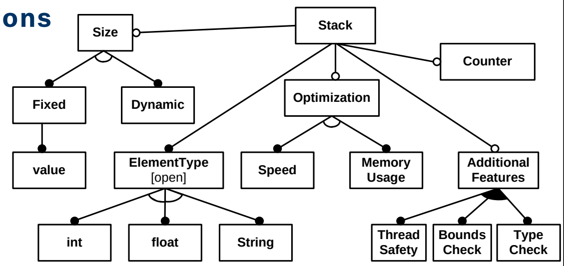


- **Non-Structural Variations**
  Example Feature Models

  Dynamic Size, ElementType: int, Counter, Threadsafe

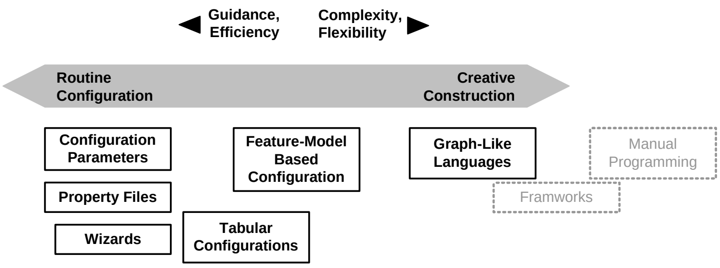
  Static Size (20), ElementType: String

  Dynamic Size, Speed-Optimized, Bounds Check



Routine Configuration vs. Creative Contruction

- The **expressive power** of the language used to bind the variability (select an option) van vary widely



- 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 to the configuration side, the simpler it typically gets.

Managing Variability in Product Lines

Typical Binding Times & Techniques

- For each of the variable features you need to define when you'll bind the feature
  - **modeling time:** DSLs, transformations, generators
  - **source time:** manual programming
  - **Compile time:** function overloading, precompiler, template evaluation, static aspect weaving
  - **deployment/configuration time:** component deployment (impl. for an interface), environment variables
  - **link time:** DLLs, class loading
  - **run time:** virtual functions, inheritance & polymorphism, factory-based instance creation, delegation, meta programming, data driven (tables, interpreters)

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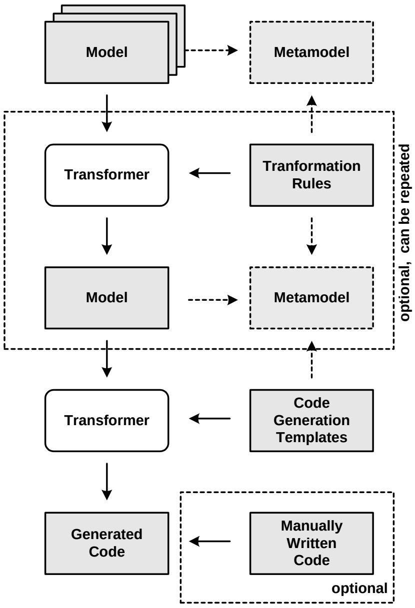
What is MDSD?

- **DSL is defined** for a domain formalizing domain concepts into a custom meta model.
- Developer develops **model(s)** based on DSL
- Using **code generators,** the model is transformed to executable code (interpreters are also possible)
- Optionally, the **generated code is merged** with manually written code.
- One or more **model-to-model transformation steps** may precede code generation.

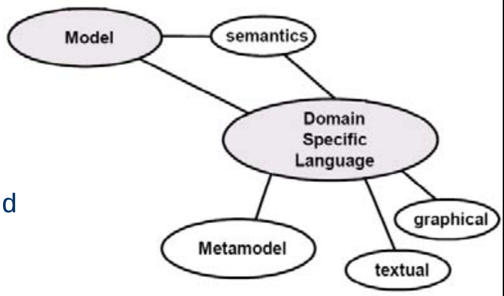


Models & Meta Models

- A model is an **abstraction** of a real world system or concept.
  - It only contains the **aspect** of the real world artifact that is **relevant** to what should be achieved with the model.
  - A model is therefore **less detailed** than the real world artifact.
- MDD models are **precise** and **processable**.
  - **Complete** regarding the abstraction level or viewpoint.
  - The **concepts** used for building the model are actually **formally defined**.
  - The way to do this is to make every **model conform to a meta model**.
- The **meta model** defines the “**terms**” and the **grammar** we can use to build the model.
  - Models are **instances** of their respective meta models.

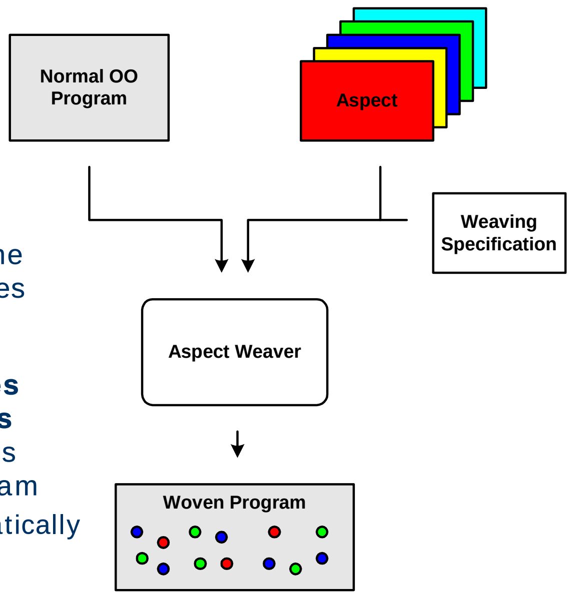
Domain Specific Language

- A Domain Specific Language (DSL) is a **formalism to build models**. It encompasses
  - the **meta model** of the models to be built
  - some textual or graphical (or other) **concrete syntax** that is used to represent ("draw") the models.
- In the context of product line engineering **DSLs are used to bind variabilities**.
  - Consequently, feature diagrams are a special kind of DSL, one that can be used to express *configurative* variability.



What is AOSD?

- Developer develops **program code**
- Developer develops (or reuses) **aspect code**
- Developers specifies the **weaving rules** (defines pointcuts)
- Aspect Weaver **weaves program and aspects together** and produces the „aspectized" program
  - This may happen statically or dynamically



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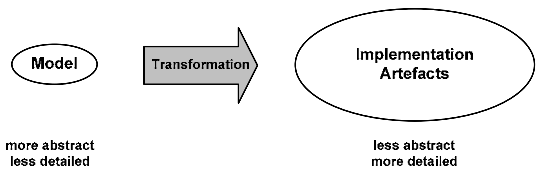
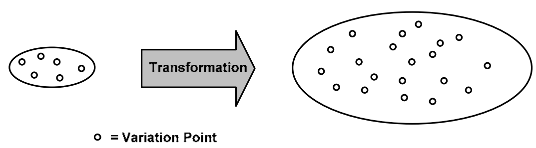
Core idea of MD-AO-PLE

- The challenge of implementing and handling variabilities is **more easily addressed on model level** than on code level
- Models are **more abstract** and hence **less detailed** than code



- Thus, the **variability is inherently less scattered**, making variability management on model level **simpler**!

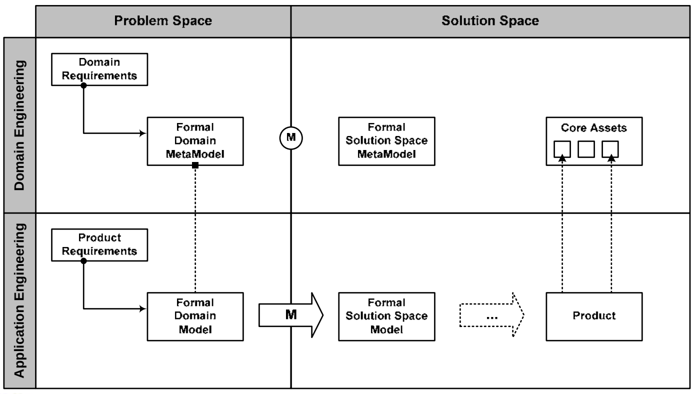


MD-AO-PLE building blocks

- **Variability can be described more concisely** since it is described on model level.
- The **mapping from problem to solution space** can be formally described using model-to-model transformations.
- AO enables the explicit expression and **modularization of crosscutting variability :**
  - In models: **weaving models** and meta models
  - In transformation: **weave variant aspects into transformations** and generators
  - In code: **implement fine-grained** implementation variants.
- Additional benefit: **Fine grained traceability** is supported since **tracing is done on model element level** rather than on the level of artifacts.

MD-AO-PLE Definition and Thumbnail

- **Definition:**
  MDD-AO-PLE uses **models** to describe product lines. **Variants** are defined on model-level. **Transformations** generate running applications. **AO techniques** are used to help define the variants in the models as well as in the transformers and generators.



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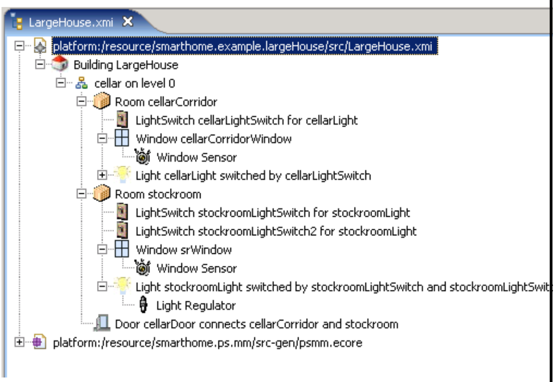
Intro to Case Study

- A **home automation system** called Smart Home.
- In homes you will find a wide range of electrical and electronic **devices**
  - lights
  - thermostats
  - electric blinds
  - fire and smoke detection sensors
  - white goods such as washing machines
  - as well as entertainment equipment.
- Smart Home **connects those devices** and enables inhabitants to monitor and control them from a **common UI**.
- The home network also allows the devices to **coordinate their behavior** in order to fulfill complex tasks without human intervention.

Problem Space Modeling

- The **domain expert** (i.e. a building architect) uses a suitable modeling language for building smart homes.

- Currently, we use a **simple tree editor** for that (based on Exeed, and it is basically an EMF tree view with customized icons and labels)



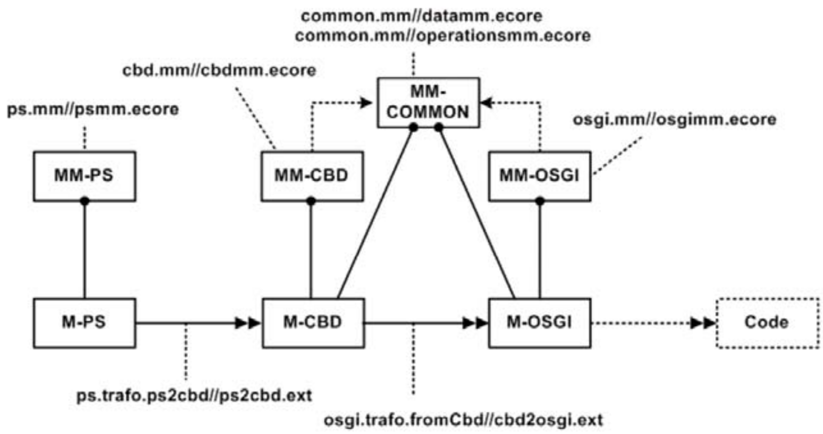
- Note that problem space modeling uses a **creative construction DSL** since describing a Smart Home is not just a matter of “ticking boxes”.

- A more convenient editor will be provided later.

Models and Transformations Overview

- Solution Space is made up of a **component-based architecture** (CBD level) subsequently mapped to OSGi (OSGi-level)

- Various **meta models** desribe all these different levels



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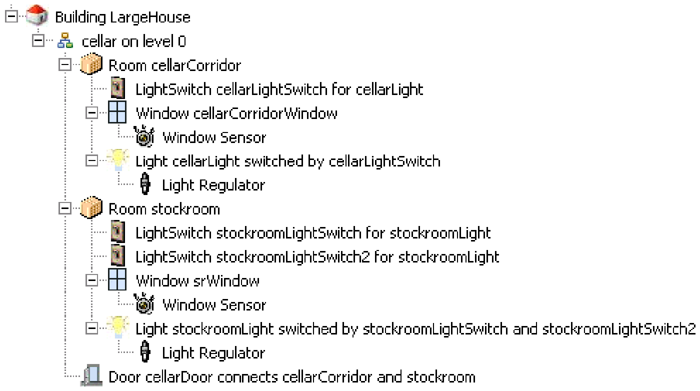
Application Domain to Software Domain Transformation

- We use an M2M transformation to map **from the application domain to the software domain**.
- Here are some examples of what that **transformation has to do:**
  - Lighting:
    - For each light in a room, instantiate a light driver component
    - For each light switch, instantiate a light switch component
    - For each room with lights, instantiate a light controller, that manages lights and the connected switches
  - Windows:
    - For each window, instantiate a window sensor component
- Note how the transformation only **instantiates and connects** software components. The components themselves are pre-built and are available in **libraries**.

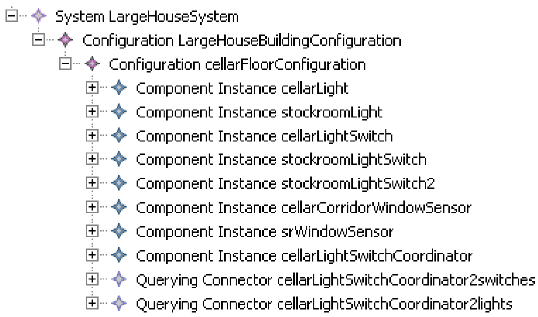
Example House: A Problem Space Model



- A house with only **one level**, and **two rooms**, connected by **doors**.
- The rooms have **windows** as well as **lights** and **light switches**.

Example House: The Transformed CBD Model

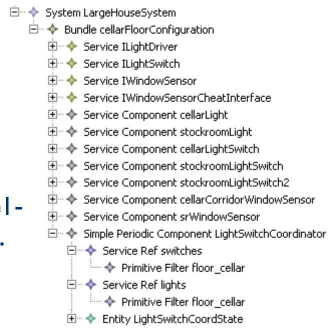
- For each of the lights and switches we have **instances** of driver **components** (the component types are taken from the library)
- We also have a **light switch coordinator** component instance for each floor that has light switches.

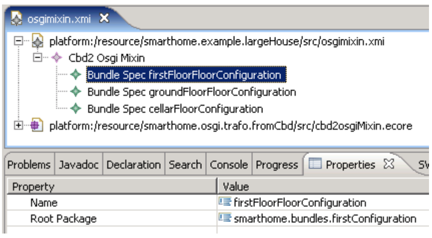


- We use **query based connectors** to connect the coordinator with the lights and the switches.
  - The query dynamically finds all lights and switches for a given floor, dynamically at runtime.
- We also have hierarchical configurations for the building and floors.

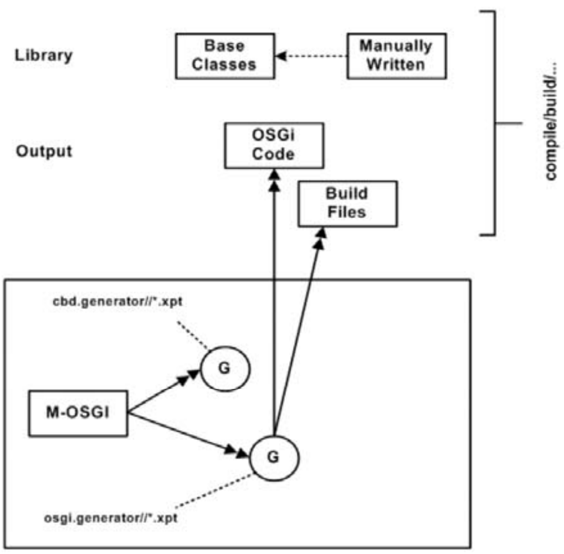
Example House: The Transformed OSGi Model

- Leaf **configurations** have been transformed into **bundles**.
- **Interfaces** (from the Lib!) are now **Services** in this model.
- **Component instances** have become OSGI-level **components** of the appropriate type.
  - Those use ServiceRefs with queries to find the respective provided services at runtime.
- Note how the **mixin model** specifies the root packages for the bundles to enable code generation.





Example House: Code Generation



Example House: Generated Code

- We generate the **OSGi bundle activators** which
  - Instantiate the components deployed in that bundle
  - Register the services of those components
  - Register generated service trackers for each of the component's service refs … using an LDAP expression to dynamically find the provided services
- We generate a **manifest file**
  - including the correct package exports and imports
- We generate an ant **build file** to assemble the bundle JARs
  - JAR will contain OSGI-level code as well as the CBD level code
  - The used libraries know their Eclipse project so we know from where we need to grab the implementation source code
- We generate a **batch file** that runs the OSGi runtime (Knopflerfish) with the correct configuration (xargs-file)

Component Libraries

- Library components are **predefined building blocks** to be used in products. There are three "flavors":
- **Code-Only:** the aspect of the PL that is covered by the library component is not supported by generators,
  - The production process for the product will simply include/link/instantiate/deploy the component if it's required as part of a product.
  - Example: an optional SNMP agent running on a system node
- **Model-Only:** PLA contains generators that can completely generate the component implementation from a model.
  - If the generator changes, the library component's implementation is automatically adapted (since it's regenerated).
  - Example: A reusable business process component specified as a component with an associated state machine
- **Model/Code Mix:** This is necessary if you can represent some aspects of a component via a model, but cannot represent others.

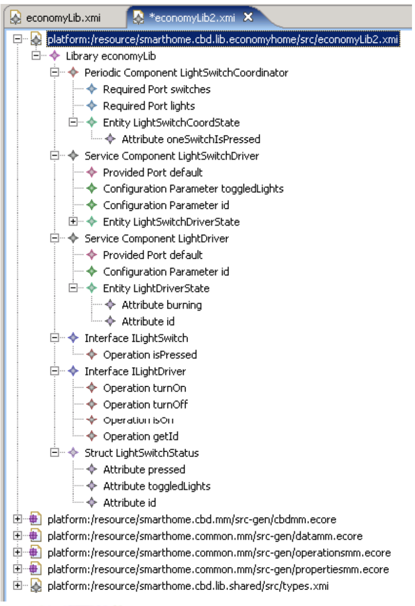
Model/Code Mix: The different levels of code

- There are **two kinds of source code** in the system.
- CBD-level code is **partly generated/partly hand-written.**
  - As the name implies, it does **not depend** on the concrete **implementation technology** (such as OSGi)
  - Base classes (and other skeleton artifacts) are **generated**, the manually written code is **integrated** in well-defined ways
  - This is the way, manually written **business logic** is integrated.
- Implementation-level code is **completely generated**
  - It is **specific** to the concrete **implementation technology**
  - It **wraps** or **uses** the CBD-level code and adapts it to the concrete implementation technology
- The **generation process is separated** into two phases, one for each kind of source code.

EconomyLib: An example library

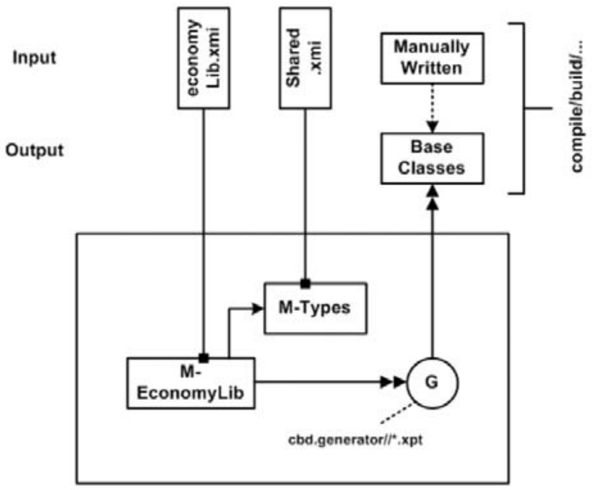
- The EconomyLib library contains pre-built **components**, **interfaces** and **data types** that are needed for building Smart Homes of the *Economy* variety.
- Interfaces and data types are **model-only,** whereas components are **model/code mixed**, because they contain manually written code parts.
- Libraries such as the EconomyLib are **CBD-level code**. There is absolutely nothing in there that is specific to the concrete implementation technology.
- The library comes with a **model file** as well as a **source code directory**.
- Note that this library depends on another library that defines basic primitive types.

EconomyLib: Part of the Model



- The **LightSwitchCoordinator** orchestrates lights and switches
- The **LightSwitchDriver** proxies a light switch
  - The state knows whether the switch is pressed or not
- The **LightDriver** proxies an actual light
  - Its state has an ID and it knows whether it is burning
- **ILightSwitch** is used to query a switch whether it is pressed
- **ILightDriver** can be used to turn a light on or off

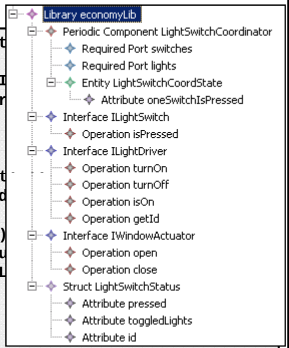
EconomyLib: Generating CBD-Level code



EconomyLib: Manually written code I

- This is the component that **switches lights** based on the status of the switches
- It is a **periodic component**, hence it has only an ***execute()*** operation.
- Note how it uses the ***switchesAll()*** operation to access all the switches it is connected to.

```
package smarthome.eco…witchCoordinat

public class LightSwitchCoordinatorI
      extends LightSwitchCoordinator

  @Override
  public void execute() {
    Collection<LightSwitchStatus> st
         switchesAll().isPressed
    for (LightSwitchStatus status :
      if (hasChanged( status.getId()
        String changedLights = statu
        parseLightsToSwitch(changedL
      }
    }
  }

  private boolean hasChanged(String id, boolean pressed) {
    // is the light switch in another position than
    // last time around?
  }

  private void parseLightsToSwitch(String lights) {
    // find out which lights this switch affects
    // and switch these lights
  }

}
```



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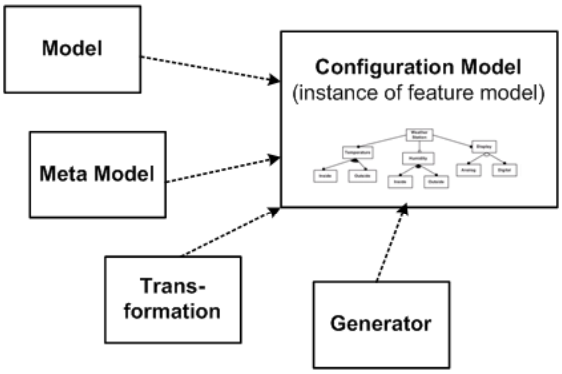
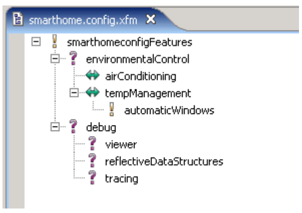
Orthogonal Variability Management

- Orthogonal Variability: all the artifacts of a system **depend on a central configuration** model that describes the variability of those artifacts.
- Here: the “system” is the **MDSD tooling** for developing Smart Homes



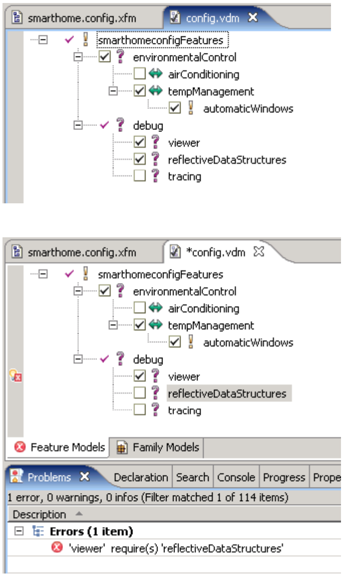
Orthogonal Variability Management II

- oAW comes with a feature that allows domain architecture artifacts to **depend on whether certain features are selected**.
- An API is available that allows to plug in various **feature modeling tools**
  - In the simplest case, that API can be bound to a simple text file that contains a list of selected features.
  - Another binding is available to Pure Systems’ pure::variants tool
- That configuration model **controls various aspects** of the model transformation and code generation process.
  - It is read at the beginning of the workflow and is available globally.
- Currently, we use it for the following **optional features**:
  - Tracing
  - Reflective Data Structures
  - Viewer (UI)
  - Automatic Windows



Orthogonal Variability Management III

- The configuration is done via a **pure::variants variant model** (ps:vdm)
- pure::variants supports the **interactive selection** of features, while **evaluating constraints** and feature relationships to make sure **only valid variants** are defined.
- If a constraint is violated, the model is either automatically corrected, or **an error is shown**.



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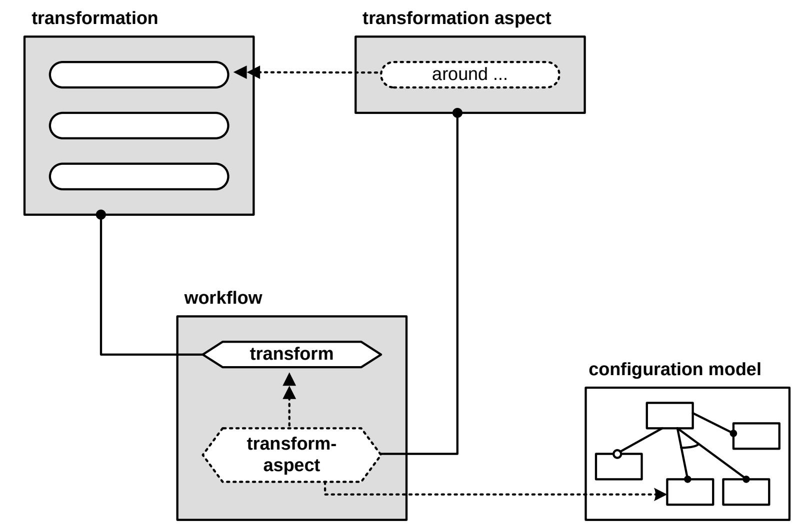
AO for generator artifacts

- Aspect Orientation is used to **encapsulate and "inject" transformation and generator code** that is only necessary for implementing a given feature.
- Transformation and generator aspects are **captured in separate files.**
- These files are only deployed **iff a certain feature is selected** in the configuration model
- The **workflow** ties all these loose ends together.

Optional Feature: Logging

- Logging is simply about writing a stdout **log of the methods called** on Service Components as the system runs.
  - The runtime infrastructure (OSGI-level) supports the use of **interceptors** for any component.
  - Interceptors are available in **libraries** (just as the light switch components and their interface and the primitive types)
  - If the **model configures interceptors** for a given component, the generated activator actually instantiates them, **instantiates a proxy** for each component and **adds the interceptors to that proxy**.
- **In short:** if the feature debug.logging is selected, the transformation from PS to CBD level must make sure that the appropriate interceptor is configured for the components.

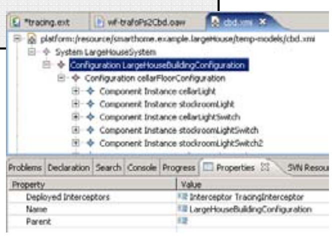
Optional Feature: Logging [Thumbnail]



Optional Feature: Logging, Implementation

- The implementation uses **AO for the model transformation language**. Here is the aspect:

```
// logging. ext
import psmm;
import cbdmm;

extension ps2cbd;

extension org::openarchitectureware::util::stdlib::io;
extension org::openarchitectureware::util::stdlib::naming;

around ps2cbd::transformPs2Cbd( Building building ):
  let s = ctx.proceed(): (
    building.createBuildingConfiguration().
      deployedInterceptors.addAll(
          { utilitiesLib().interceptors.findByName("LoggingInterceptor") }
      ) ->
      s
    );
```



- We **advice** *ps2cbd::transformPs2Cbd*
- We then execute the **original definition** (*ctx.proceed()*)
- Then we **add**, to the top level config, the *LoggingInterceptor*

Optional Feature: Logging, Implementation II

- Remember we only want to have these interceptors in the system **iff the feature *debug.tracing* is selected** in the global configuration model.
- That dependency is expressed in the workflow:

```
<component id="xtendComponent.ps2cbd" class="oaw.xtend.XtendComponent">
  …
</component>

<feature exists="debug.logging">
  <component adviceTarget="xtendComponent.ps2cbd" class="oaw.xtend.XtendAdvice">
    <!-- references tracing.ext, file that contains aspect on prev. slide -->
    <extensionAdvices value="logging"/>
  </component>
</feature>
```

- The stuff inside the <feature>…</feature> tag is only executed **if the respective feature is selected** in the global configuration
- The XtendAdvice component type is an aspect **component for the Xtend component** used for transforming models.

Managing Variability in Product Lines

Optional Feature: Logging, Implementation III

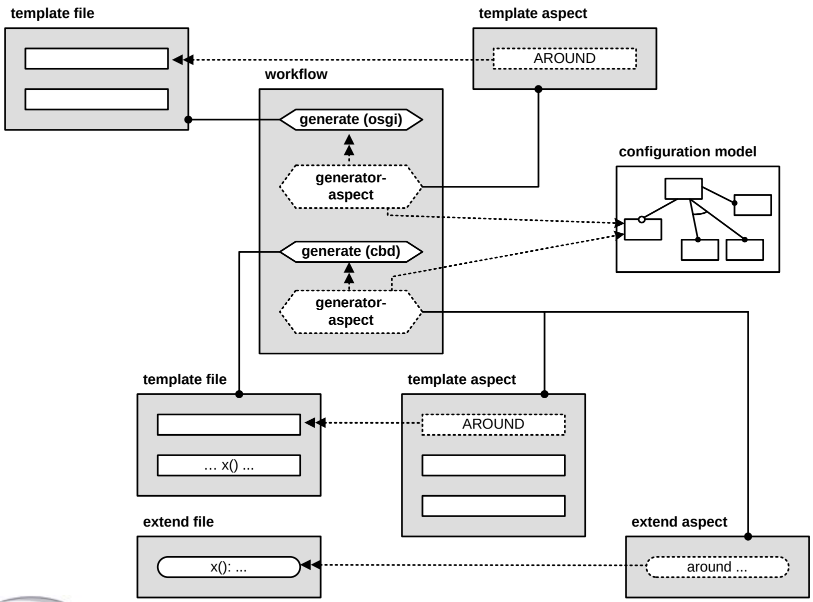
```
<component id="xtendComponent.ps2cbd" class="oaw.xtend.XtendComponent">
  …
</component>

<feature exists="debug.logging">
  <component adviceTarget="xtendComponent.ps2cbd" class="oaw.xtend.XtendAdvice">
    <!-- references tracing.ext, file that contains aspect on prev. slide -->
    <extensionAdvices value="logging"/>
  </component>
</feature>
```

- An Advice component basically takes the sub-elements and adds them to the component **refenced by the *adviceTarget*** attribute.
- In the case here, that target is the one that runs the PS to CBD M2M transformation
- Using this mechanism, the configuration of aspect code (the <extensionAdvices> element is **non-invasive.**

Optional Feature: Component State Viewer

- The viewer UI shown before is not generated. It is a **generic** piece of code that **reflects on the data structures** that it is supposed to render.
- To make this work, the following two additions have to be made to the generated system:
  - The component state data structures must feature a **generated reflection layer**
  - Whenever a component is instantiated in the activator, its **state has to be registered** with the viewer.
- These things are implemented using **generator aspects,** depending on the selection of the **debug.viewer** feature.

Optional Feature: Component State Viewer [Thumbnail]



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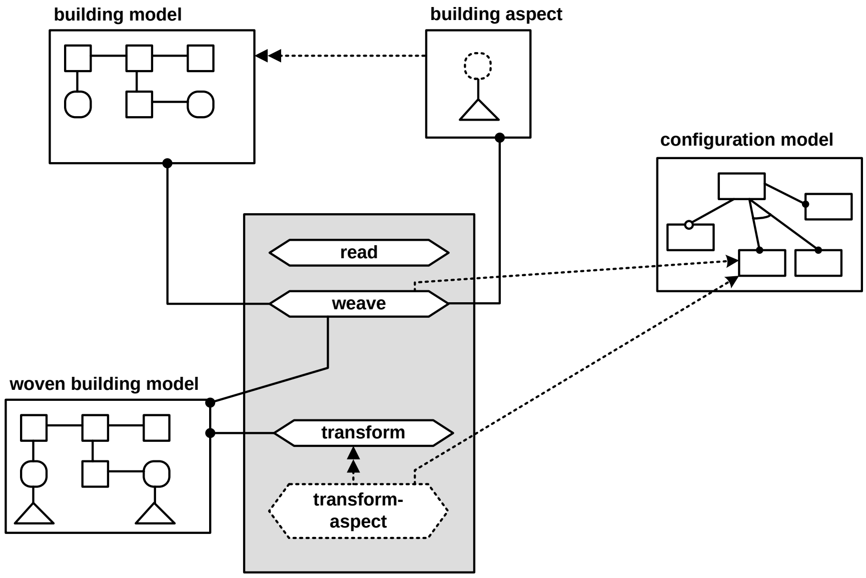
AO on Model Level

- AO Modeling (aka Model Weaving) is about **applying AO techniques** for models and meta models.
- Aspect Models capture the parts of models that **represent elements** necessary for a “implementing” a given **feature**.
- **Pointcut expressions** are used to determine **where and how** those aspect models are “woven” into base models.
- A **model weaver** does the weaving.
- Note that AO modeling is NOT about drawing UML diagrams of AspectJ code… contrary to what some people suggest!

Optional Feature: Automatic Windows [Thumbnail]

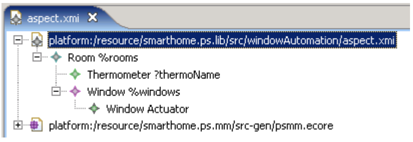


Optional Feature: Automatic Windows

- Automatic windows are an **optional feature on the PS level**.
  - If we have at least one thermometer in a room,
  - We can automatically open the windows if the temperatures are above 25°C average, and close them if we are below 20°C.
  - We also need windows actuators for that
- We want this feature, if the **global configuration model** has the *environmentalControl.tempManagement.automaticWindows* feature selected.
- To implement it,
  - We **weave the necessary elements** into the PS model
  - **Advice the PS to CBD transformation** to consider these additional elements
  - ... and then (for debugging purposes) **write the modified model** to an XMI file.

Optional Feature: Automatic Windows, Implementation

- Here is the **aspect** for the problem space model:

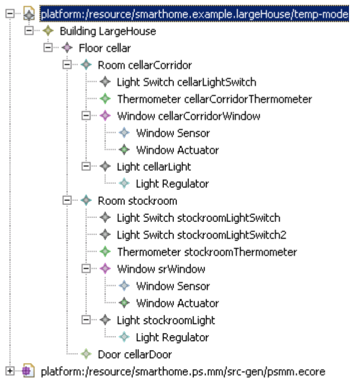


- Here are the **pointcut expressions** used in the aspect model:

```
rooms( Building this ):
        floors.rooms.select(e|e.windows.size > 0) ;
windows( Building this ):
        rooms().windows;
thermoName( Thermometer this ):
        ((Room)eContainer).name.toFirstLower()+"Thermometer";
```

- ***rooms*** returns all the rooms that have windows
- ***windows*** returns the windows in these rooms
- ***thermoName*** calculates a sensible name for the thermo device

Optional Feature: Automatic Windows, Implementation II



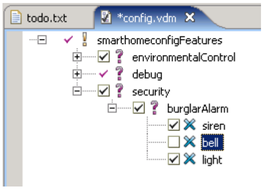
- Here is the result of the example house **after weaving**.
  - The rooms now have a **thermometer** with a suitable name
  - The windows have an **actuator**
- The transformation must now be enhanced to transform those new devices into **instances of software components**.
- Also we need some kind of driver component that **periodically checks the temperature** of all thermometers, calculates the average, and then **opens or closes the windows.**
- This whole additional transformation is **located in a separate aspect transformation file** and is “adviced” into the original transformation.

Optional Feature: Automatic Windows, Implementation III

- Here is the **workflow fragment** that configures all of this:

```
<feature exists="environmentalControl.tempManagement.automaticWindows">

  <!-- the stuff that enhances the M2M transformation -->
  <component adviceTarget="xtendComponent.ps2cbd"
                class="org.openarchitectureware.xtend.XtendAdvice">
    <extensionAdvice value="windowAutomation::extensionAdvices"/>
  </component>

  <!-- this launches the model weaver that adds the aspect to the PS model -->
  <cartridge file="org/openarchitectureware/util/xweave/wf-weave-expr"
    baseModelSlot="psmodel"
    aspectFile="platform:/resource/smarthome.ps.lib/src/windowAutomation/aspect.xmi"
    expressionFile="windowAutomation::expressions"/>

  <!-- and here we write the model for debugging purposes -->
  <component class="org.eclipse.mwe.emf.Writer">
    <useSingleGlobalResourceSet value="true"/>
    <uri value="${dumpFileUriPrefix}/psWithWindowAutomation.xmi" />
    <cloneSlotContents value="true"/>
    <modelSlot value="psmodel" />
  </component>

</feature>
```


Optional Feature: Burglar Alarm



- In the configuration feature model, you can select whether your house should **feature a burglar alarm system**; and if so, which kinds of **alarm devices** it should have.
- There is a library of **pre-built components** for these devices in the *securehome* library project
- The *ps2cbd* transformation
  - Instantiates a **control panel** component (turn on/off)
  - Instantiates the burglar alarm **detection agent**
  - ... **connects** those two ...
  - And then instantiates an instance of each of the **alarm devices** selected in the feature model
  - ... and **connects** those to the agen.

Optional Feature: Burglar Alarm II

- Thumbnail:

- Here is (part of) the code:

```
create System transformPs2Cbd( Building building ):
  …
  hasFeature("burglarAlarm") ? ( handleBurglarAlarm() -> this) : this;

handleBurglarAlarm( System this ):
  let conf = createBurglarConfig(): (
    configurations.add( conf ) ->
    …
    conf.connectors.add( connectSimToPanel( createSimulatorInstance(),
                                            createControlPanelInstance() ) ) ->
    hasFeature( "siren" ) ? conf.addAlarmDevice("AlarmSiren") : null ->
    hasFeature( "bell" ) ? conf.addAlarmDevice("AlarmBell") : null ->
    hasFeature( "light" ) ? conf.addAlarmDevice("AlarmLight") : null
);
```

- Note how we **query the feature model from within the transformation** instead of using aspects to contribute the additional behaviour to the transformation.

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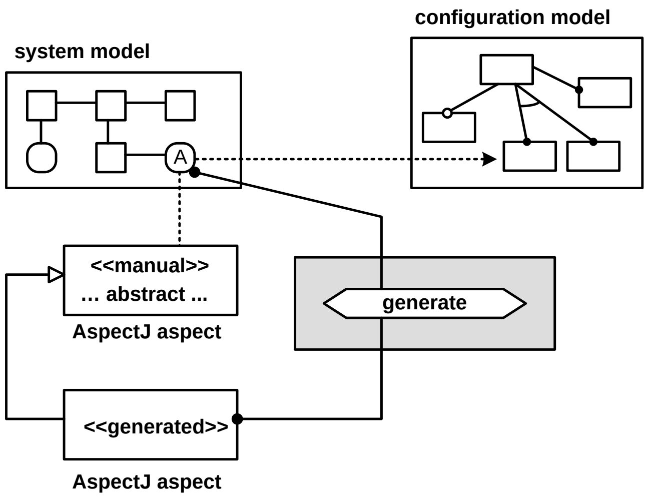
Code Level Aspects

- Sometimes the simplest way to implement variability is to **aspects on code level (AOP)**
- Since we're using Java as the implementation language, we'll use **AspectJ** as the implementation language for code level aspects
- The following challenges must be addressed:
  - A certain aspect shall only be woven iff a certain **feature is selected** in the global configuration model
  - It might be necessary to define (in the models!) **to which joinpoints** an aspect should be woven
- We assume that aspect functionality is **hand-written,** they are available in **libraries.** We distinguish
  - **Complete aspects:** advice and pointcut handwritten, inclusion is optional based on feature configuration
  - **Incomplete aspects:** advice is handwritten, pointcut is generated based on information in the models

Managing Variability in Product Lines

Code Level Aspects [Thumbnail]



Code Level Aspects: Implementation I

- Here is a **sample aspect** (trivialized authentication):

```
public abstract aspect AuthenticationAspect {

    pointcut pc(): call (public * smarthome.ecolib.components..*(..));

    before() : pc() {
        // do some fancy authentication here
    }
}
```

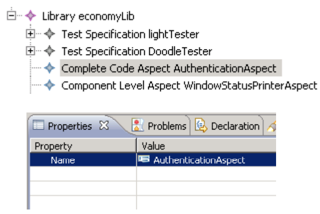
- The aspect contains **all the relevant code** (hence the pointcut is extremely generic) and is completely handwritten
- The aspect is **abstract** to make sure it is **not woven** by default!
- If it **should be woven** (see later for how this is determined) a concrete sub-aspect is automatically generated
  - Which is then grabbed by the weaver and automatically woven

```
public aspect AuthenticationAspectImpl extends AuthenticationAspect {

}
```


Code Level Aspects: Implementation II

- As with interceptors, components and other code-related architectural elements, aspects are **represented in the library model**
  - provides awareness of the generated build file, etc.
  - Allows the use of model-level negative variability (see below)



- Using a **naming convention** (enforced and checked by the recipe framework) the manually written code is associated with the model

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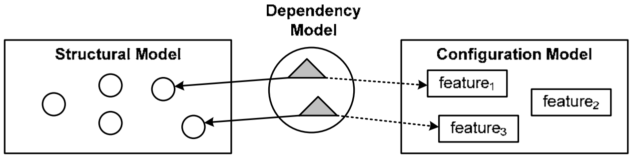
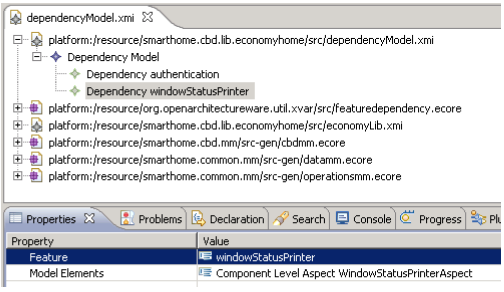
Negative Variability

- In negative variability, **elements of a structural model** are associated with **features in a configuration model**. If that feature is not selected, the respective elements of the structural models are **removed.**
  - The oAW XVar tool does that
- The dependencies between the structural model and the configuration model are **externalized into a dependency model**.
  - This makes sure the meta model of the structural model need not be changed in order to make it “configurable”



Negative Variability for Aspects

- We use negative variability to **remove the aspect definitions** (see previous topic) from the library model if a specific feature is not selected.
- Since the aspect model elements are removed from the model, no **aspect-subclasses are generated**, and hence, no aspect is woven.
- Here is the dependency model:
  - Structural Elements are referenced directly,
  - Features are referenced by name



Negative Variability for Aspects II

- A **cartridge call to the XVar tool** in the API-level code generator workflow configures the structural model.

```
<workflow abstract="true">

    <readConfig uri="${globalConfigurationModel}"/>

    <read
        uri="platform:/resource/smarthome.cbd.lib.economyhome/src/economyLib.xmi"
        modelSlot="ecomodel"/>

    <catridge file="org/openarchitectureware/util/xvar/wf-xvar.oaw"
        dependencyFileUri="platform:/resource/smarthome.cbd.lib.economyhome/src/dependencyModel.xmi"
        baseModelSlot="ecomodel"/>

    <feature exists="dumpCBDAfterXVar">
        <cloneAndWrite uri="temp-models/cbdAfterXVar.xmi"
            modelSlot="ecomodel" />
    </feature>

    <!-- more... -->

</workflow>
```

Customizing Code

- Remember that our libraries contain a **mixture of models and code –** the implementation ("business logic") is implemented manually in Java.
- Hence, if you want to define variants of library components, it is not enough to vary the models (and with it the generated code). You also need to **vary manually written code**.
- Consider making **the lights dimmable**:
  - The interface *ILightDriver* needs an operation *setLightLevel()*
  - The state of the light driver component needs an additional attribute to keep track of the light level
  - And the implementation code needs to change – it needs to implement the optional *setLightLevel()* operation.
- The variability in the models is handled as explained before.

Customizing Code II

- Variable code sections can be marked up using **special syntax**:

```
public class LightDriverImplementation extends LightDriverImplBase {

  @Override
  protected String getIdInternal() {
    return getConfigParamValueForId();
  }

   …

  //# dimmableLights
  @Override
  protected int setLightLevelInternal(int level) {
    state().setEffectiveLightLevel(level);
    return level;
  }
  //~# dimmableLights

}
```

- This piece of code is in a ***.javav* file**
  - Hence it is not compiled
  - It is **customized** into a .java file based on the configuration

Customizing Code III

- Here is the **workflow component** that handles the customization.

```
<workflow abstract="true">

   ...

   <catridge file="org/openarchitectureware/util/xvar/file/wf-xvarfile.oaw"
       sourcePath="platform:/resource/smarthome.cbd.lib.economyhome/src"
       sourceExt="javav"
       genPath="platform:/resource/smarthome.cbd.lib.economyhome/src-gen"
       genExt="java"
       useComments="false"/>

</workflow>
```

- The component
  - looks for *sourceExt*-files in the *sourcePath* directory
  - customizes them,
  - And writes the result to *genExt*-files in the *genPath* directory.

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Summary

- It is essential to **explicitly describe** the variabilities wrt. to the various product in a product line.
- While you can directly map variabilities to implementation code, it is much better to use a model-driven approach and **map the variability to models**
  - because they are more coarse grained and there's less to vary
- **Variant management tools** integrate well with the model-driven tool chain
- Generators, transformation languages and all the other **MDD tooling is mature** and can be used in practice.
  - Advanced tools have sufficient features to build variants of generators, transformations or models based on configuration data in feature models

THANKS!

Resources

- **Videos** of a the full presentation of these slides are at *http://ample.holos.pt/pageview.aspx?pageid=50&langid=1*
- **Papers** on the topic:
  - Product Line Implementation using Aspect-Oriented and Model-Driven Software Development (SPLC 2007) *http://www.voelter.de/publications/index/detail-1395240160.html*
  - Feature-Based Variability in Structural Models (MVSPL 2007) *http://www.voelter.de/conferences/index/detail-1817579497.html*
  - Handling Variability in Model Transf. and Generators (DSM 2007) *http://www.voelter.de/conferences/index/detail-966723965.html*
- **Tooling:** openArchitectureWare 4.2, *eclipse.org/gmt/oaw,* includes 3 hours of tutorial videos
- **AMPLE Project:** *http://ample-project.net*
- **Podcasts** on PLE and MDSD at Software Engineering Radio: http://se-radio.net