IRISA
institut de recherche en informatique et systèmes aléatoires

Triskell Metamodeling Kernel www.kermeta.org
Kermeta

Hyper-Agility: Handling Variability from Design-Time to Runtime

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Outline

- The Need for Hyper-Agility
- From Software Product-Lines (SPL) …
  … to Dynamic Adaptive Systems (DAS)
- (Aspect-Oriented) Modeling of DAS
- Dynamic Adaption with Aspects & Models

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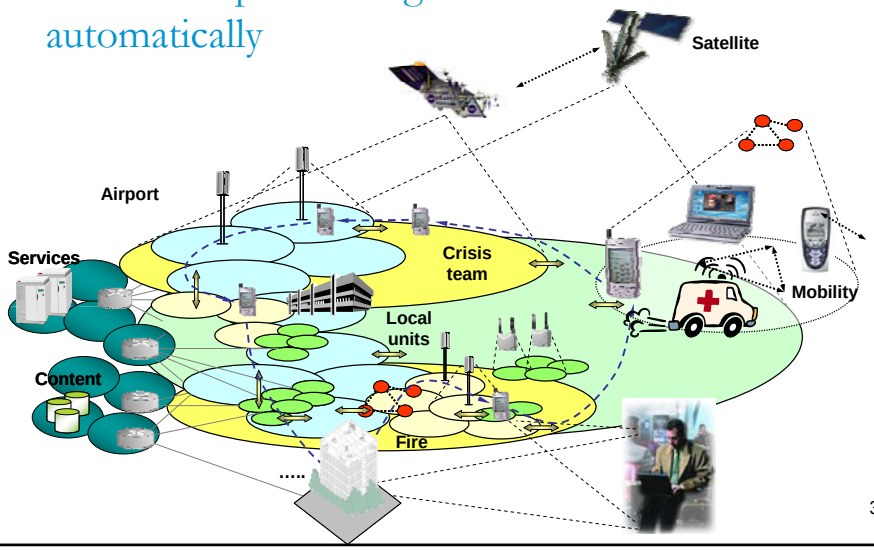
Context aware software systems

- able to adapt to changes in their environments automatically



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Agile Manifesto

- **Manifesto for Agile Software Development**
  - **Individuals and interactions**
    - over processes and tools
  - **Working software**
    - over comprehensive documentation
  - **Customer collaboration**
    - over contract negotiation
  - **Responding to change**
    - over following a plan

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Towards Hyper-Agility

- **Think of it as the Agile Manifesto @ runtime**
  - **Individuals and interactions**
  - **Working software**
  - **Customer collaboration**
  - **Responding to change**

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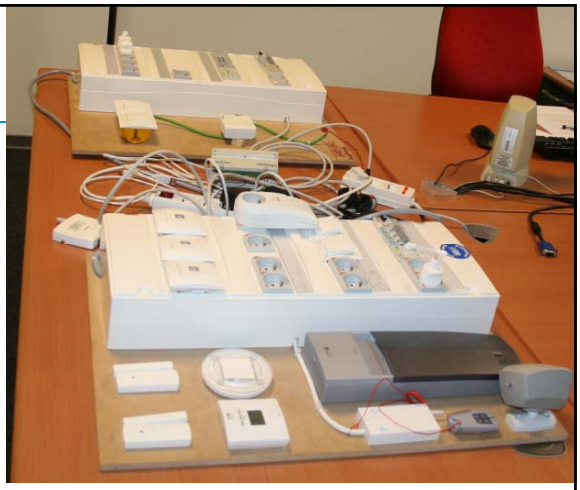
Example Application Domain

- Home-automation to help disabled people stay home
  - Aging society
  - Hospital have limited resources, rooms, etc
    - → Very short stays
  - Long stays very expensive for people and society
  - Houses, flats, etc should be equipped
- How do we produce a program for each of them:
  - Individuals and interactions
  - Working software
  - Customer collaboration
  - Responding to change

Entimid



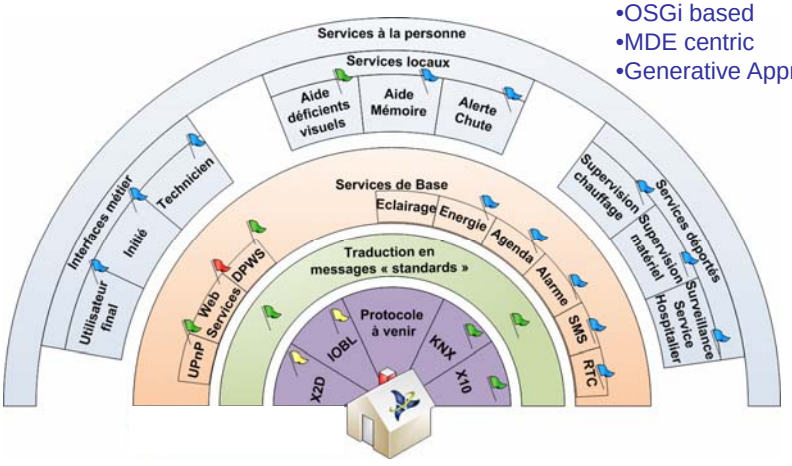
Cf demonstration at « fete de la science »

EnTiMid : Integrating IoS & IoT

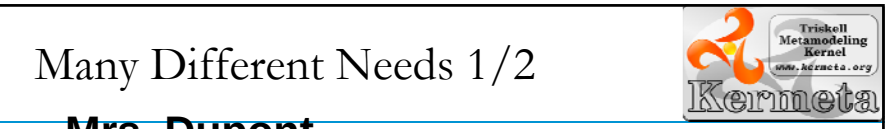
[ServiceWave '09]

Controlling Boiler/Shutters from GoogleAgenda through a browser or an iPhone

- OSGi based
- MDE centric
- Generative Approach



Many Different Needs 1/2



Mrs. Dupont

Picture from http://www.apt-gc.ca

- Living at home
- Motion troubles
- Memory loss
- Speaks French (only)
- Home equiped with :
  - LonWorks (lights)
  - Velux (shutters)

Many Different Needs 2/2

Mr. John Doe

Picture from http://ditwww.epfl.ch

- English student
- Living at home
- He had an accident
- He likes technology
- Wheelchair equipped with remote access for:
  - Lights and shutters (KNX)
  - Multimedia (UPnP)

Their needs

Both

Medical/technical staff should be able to

- Check their health state
- Check home configuration (shutters, lights, heaters…)

Mrs. Dupont

Some daily tasks should be automated (motion troubles) or reminded (memory loss).

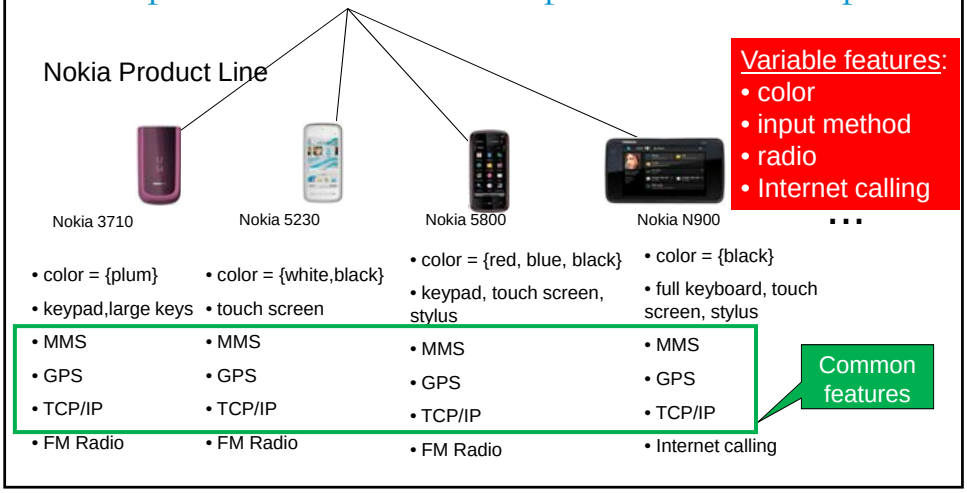
Mr. Doe

Would like to control everything remotely, with a unified protocol

➢ *Software Product Lines (SPL)*

Software Product Lines (SPL)

- Families of related software products
- The products have a *common* part and a *variable* part



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Different variability dimensions

- Protocols
  - Low-level protocols: KNX, X2D, X10, etc
  - High-level protocols: http, UPnP, DPWS, etc
- Devices
  - Lights, heaters, shutters, etc
- Web services
  - GoogleAgenda, skype, WeatherForecast, MSN
  - PaaS: Nurse as a Service, Food Delivery, Ooshop
- Adaptation to handicap/current health state
  - Motion, memory, perception, etc
- ***Dynamic reconfiguration => DAS***

Towards more complex DAS

- Dynamic Adaptive Software (DAS) development:
  - Adaptation logic often embedded into application logic
  - Adaptation logic hard-coded using low-level APIs
  - Readability, maintainability, and communication with other stakeholder not easy
- Exponential growth of possible configurations
  - Convergence with Dynamic Software Product Lines
  - N features, N tending to be larger and larger
    - 2^N potential program configurations, 2^N x (2^N-1) transitions

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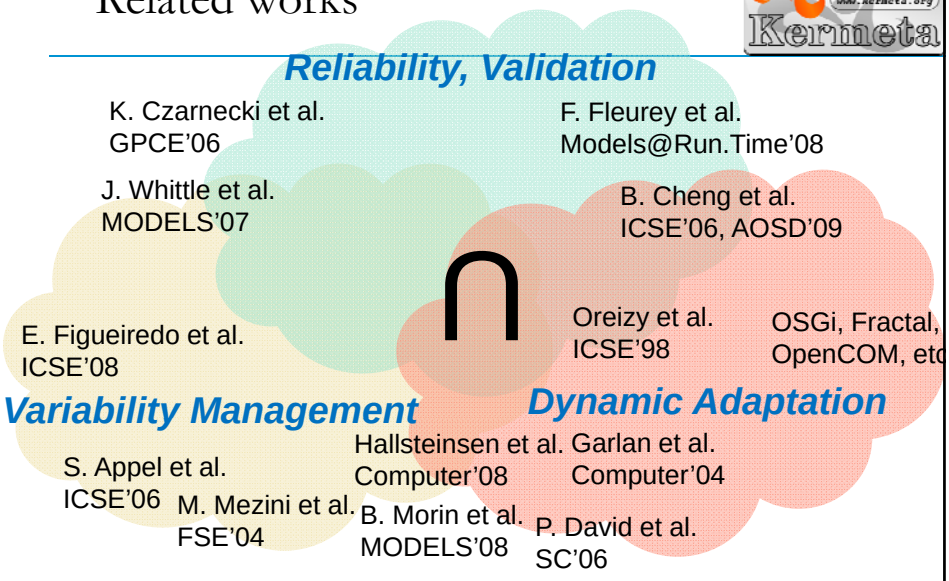
Challenges

- Explosion of the number of possible configurations of Entimid
  - 10^{14} possible configurations! → 10^{28} transitions!
- Dynamic Adaptation
  - Evolution of the handicap
  - Houses should be configured remotely
    - No wires to connect/disconnect in the walls
  - No service interruption
    - Rebooting the system cannot be a solution (lives depend on the system)
- Reliability
  - **Safe migration path**
    from a valid configuration **to another valid configuration**
  - Performance issue (time) not critical

Related works



Validation *VS* Variability management...

- How to validate DAS?
  - Specify everything!
    - all the configurations: $>10^{14}$
    - all the transitions: $\sim 10^{28}$
  - Model checking, code generation

- Problems
  - Explosion: Time consuming, error-prone
  - Evolution of the system (not predicted)
    - Stop all -> Evolve the specifications -> model check -> re-generate -> re-deploy

Validation *VS* **Variability management…**

- How to manage dynamic variability?
  - Do not focus on configurations!
    - Write reconfiguration scripts, encapsulating « features »
  - Depending on the context and/or user needs
    - Choose the most adapted scripts
    - Executes all the selected scripts to dynamically adapt the system
- Problems
  - Scripts written by hand (calls to reconfiguration API)
  - Interactions, dependencies between scripts?
  - Does the configuration (after executing scripts) make sense?
    - Hopefully yes…

Hyper-Agility with a DSPL Approach

- Focus on variability, not on configurations
- Build (derive) configurations when needed
  - JIT, On demand at runtime, caching…
- Validate configurations before actual adaptation
- Automate the reconfiguration process

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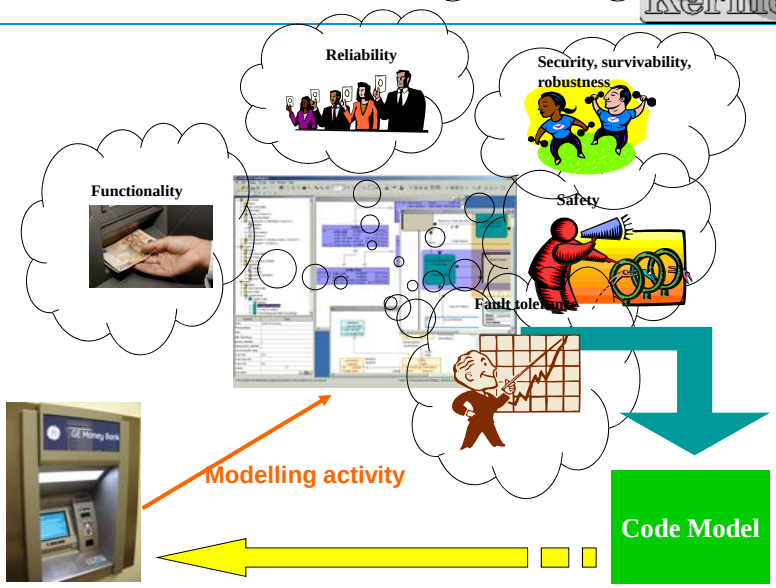
Why modeling: master complexity

- Modeling, in the broadest sense, is the *cost-effective use of something in place of something else for some cognitive purpose.* It allows us to use something that is *simpler*, *safer* or *cheaper* than reality instead of reality for some purpose.
- A model represents reality for the given purpose; the model is an abstraction of reality in the sense that it cannot represent all aspects of reality. This allows us to deal with the world in a simplified manner, avoiding the complexity, danger and irreversibility of reality.

Jeff Rothenberg.

Naive Model Driven Engineering



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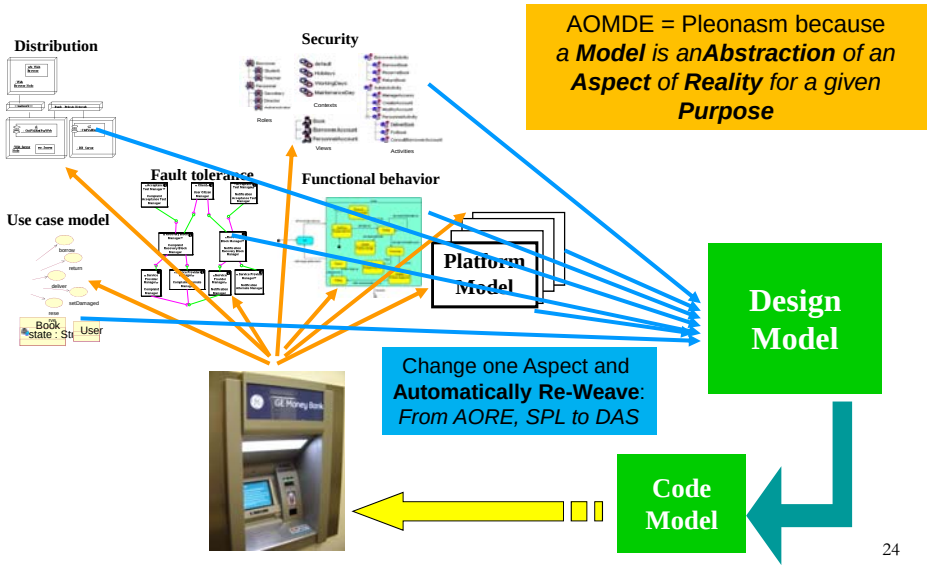
Aspect Oriented Model Driven Engineering



AOMDE = Pleonasm because a ***Model*** *is an* ***Abstraction*** *of an* ***Aspect*** *of* ***Reality*** *for a given* ***Purpose***

Change one Aspect and **Automatically Re-Weave**: *From AORE, SPL to DAS*

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(AO) MDE
=
(AO) Modeling
+
Composition

Why? When? What? Where? How?

AOM: Why?

- Intent of separation of concerns
  - Handle complexity by decomposition
  - (Dynamic) Product line modeling : features and variation points are modeled as separate concerns
  - Reusable aspect models : build models that can be reused in the design of different systems
  - Analyzable concerns : separate the characteristics of a system in order to analyse them separately before building a larger system

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Composition: Why?

- Collaborative development: compose models that have been developed in parallel
- Compose different variants to limit the maintainance cost
- Analyze the result of composition
- Use the result of composition as a new model

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AOMDE: When?

- Separate concerns at different stages
  - Requirements engineering: identify features and cross-cutting concerns from requirement documents
  - Feature modeling: AOM for product derivation 
  - Architecture
  - Design
  - Runtime (for system dynamic adaptation) 
- Implies different techniques for composition

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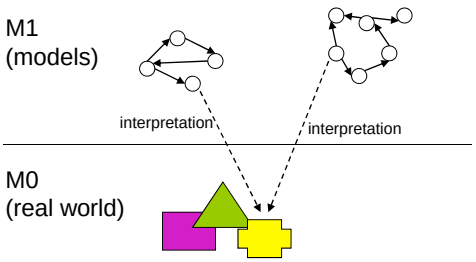
Composition: what?

- Identify the "similar" elements in both models
- Elements are "similar" in two models if they have the same "meaning"



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Composition: what?

- Difficult to establish the interpretation relation for each element in the model
- A little bit easier to compose elements from the same metamodel
  - Only elements that have the same type can have the same interpretation
  - When the models to compose have different metamodels it is necessary to specify interpretation at the meta level

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Composition: where?

- Critical for behavioural models
  - When composing scenario A after B does not mean the same as B after A
- The place where the elements should be composed (joinpoints) can be declared with a pattern language
  - To define predicates (pointcuts) over a model
    - Mata, Smartadapters, RAM

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Composition: how?

- What process to perform on the model to integrate new elements
  - Merge, insert, replace, etc.
- Default strategies in some composition algorithms
  - Match and merge, signature-based
- Experience shows that explicit strategies are often needed
  - Cf. Kermeta/Smartadapters

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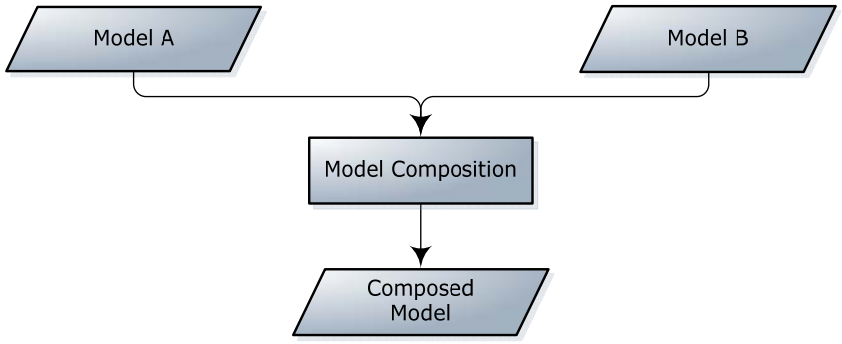
Model Composition - Scheme

- C. Jeanneret « An analysis of model composition approaches ». Masters thesis.



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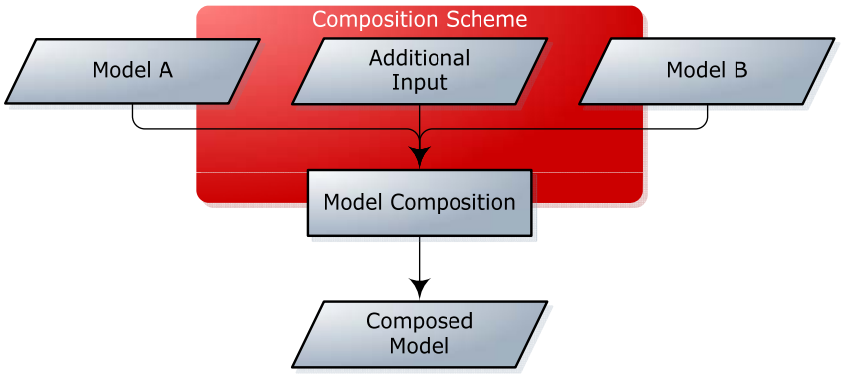
Model Composition - Scheme



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Weaving Aspects: SmartAdapters

- Two-phased:
  1. Detection of the join points

     Uses Kermeta+DROOLS for pattern-matching

     -> yield a list of join point
  2. Generic Composition of the Advice at the level of the join points.
- SmartAdapters: a generic framework for AOM
  - Built with Kermeta (a tool to build tools)
  - Can be adapted to different modeling languages

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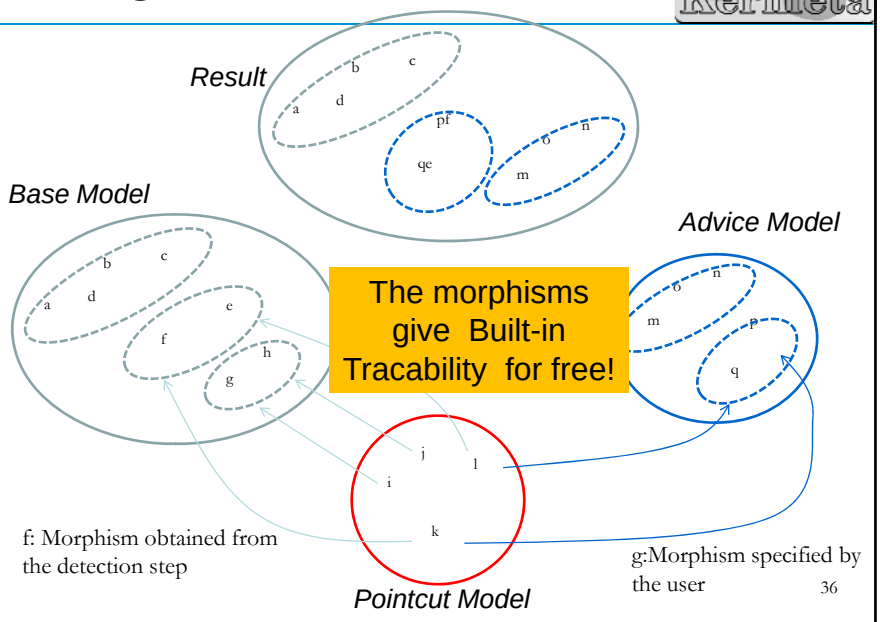
Weaving in AOM



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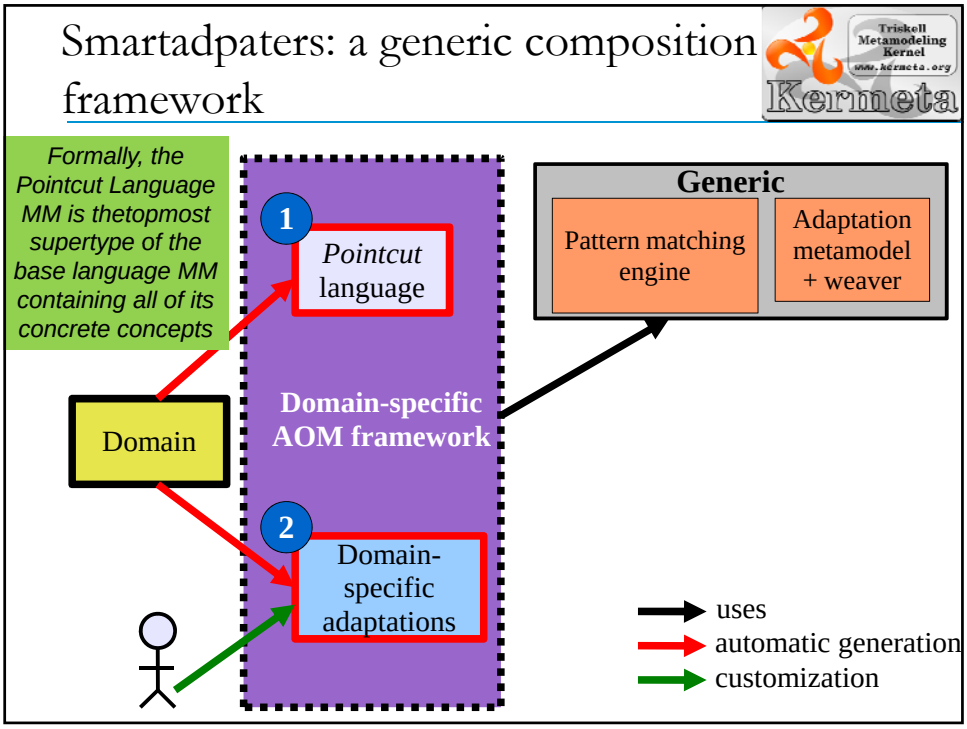
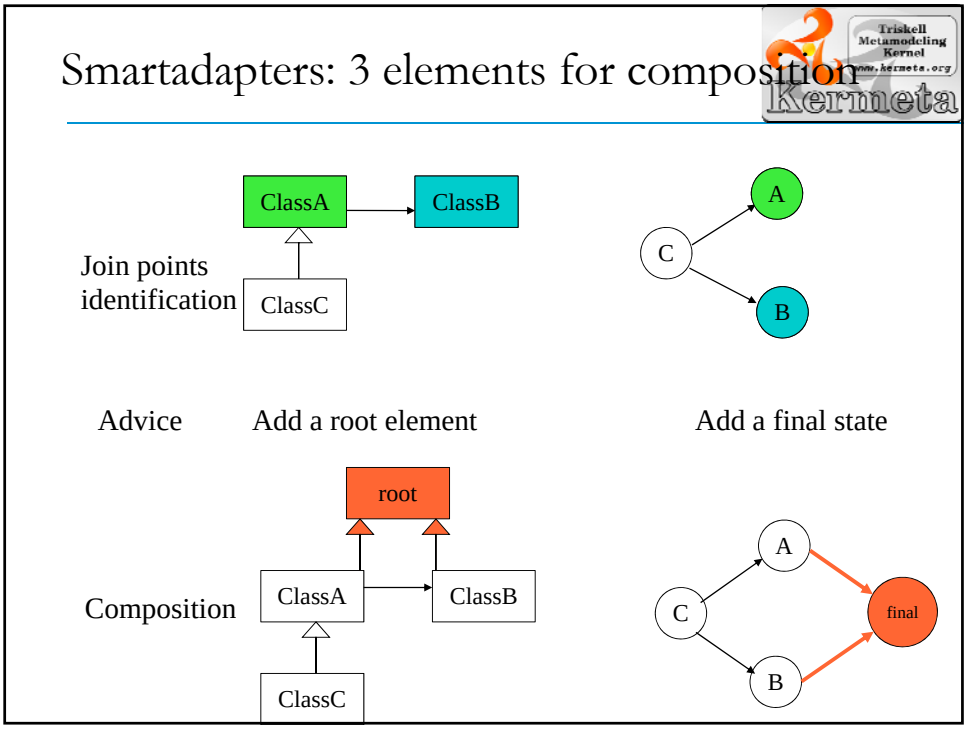
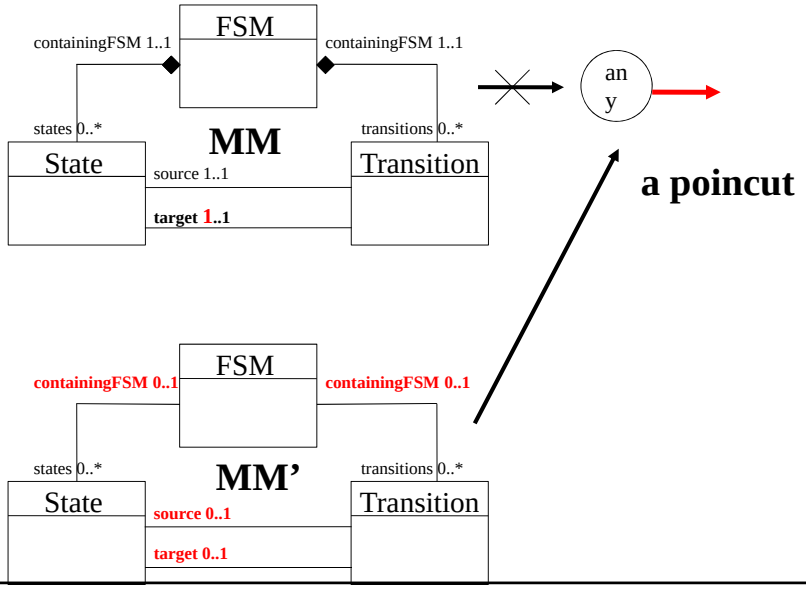
Smartadpaters: a generic composition framework



Smartadapters: 3 elements for composition



Generating the Pointcut Language



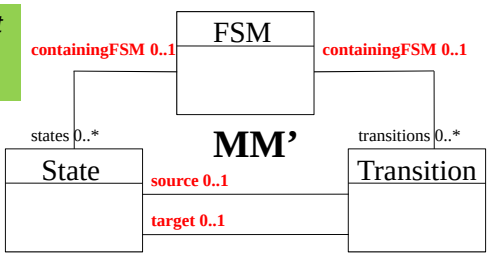
Generating the Pointcut Language

1

MM' == MM except:

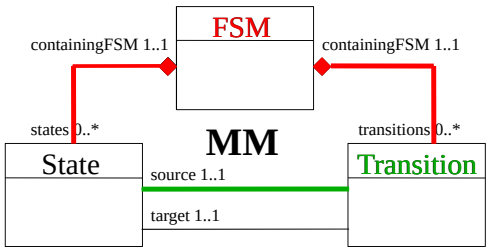
- No invariant or precondition in MM'
- All features are optional in MM' (lower bound:=0)
- No abstract element in MM'

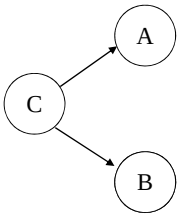
Formally, MM4 is the topmost supertype of MM containing all of its concrete concepts

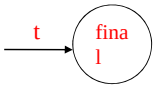


– ***Matching Model Snippets***
R.Ramos, O.Barais and J.M. Jézéquel
accepted at the MoDELS'07 conference,
Sept. 30 to Oct. 5, Nashville, TN, USA

Generating Adaptations







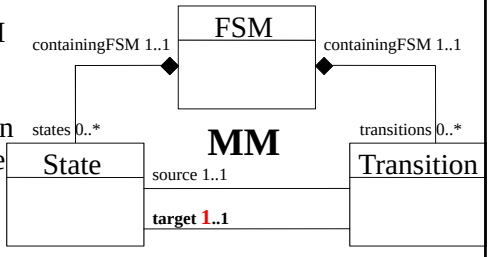
Composing this snippet means:
- adding final and t in the base FSM
- setting the source of t

Generating Adaptations

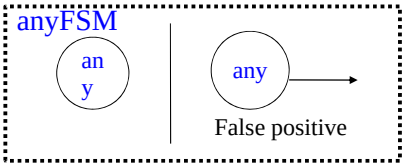
2

- For each metaclass `MyMetaClass` in MM
  - `setMyMetaClass`
  - `unsetMyMetaClass`
  - `createMyMetaClass`
  - `cloneMyMetaClass`

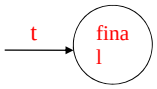
- setFSM unsetFSM createFSM cloneFSM
- setTransition unsetTransition createTransition cloneTransition
- setState unsetState createState cloneState



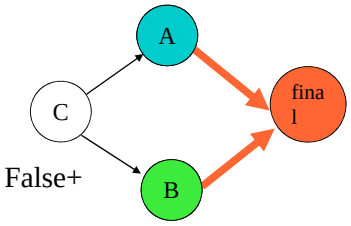
Smartadapters: example



Template
(*pointcut*)



Structure




```
SetFSM
     -aFSM:anyFSM
     -states:{final}
     -transitions:{t}
setTransition
     -aTransition:t
     -aSource:any
     -aTarget:final
makeUnique
     -element:final
```

No aspect/base coupling
protocol = f(template,structure)

Weaving engine

- Load adapter + base model
- Pattern matching : {bindings}
  - Binding : Role (template elt) -> base model element
- For each binding *b* selected by the user
  - Apply the composition protocol
    - Just call `adapter.apply(b)`
      (directly implemented in the adaptation metamodel)
- Save the result

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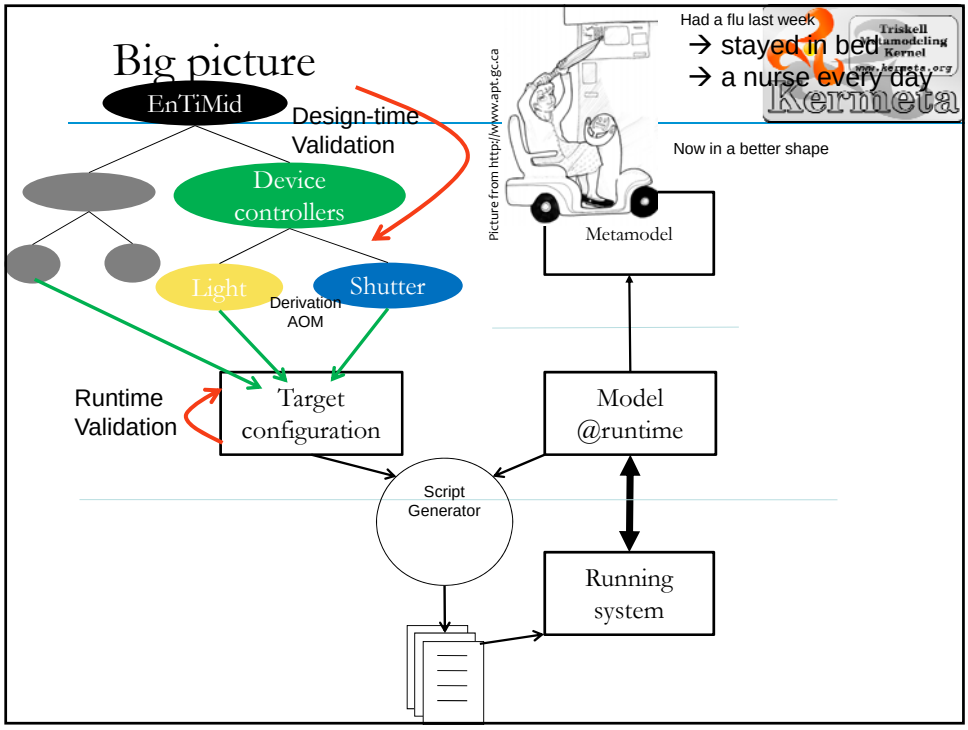

Technical Approach

- Separating the application-specific functionality from the adaptation concerns in the requirements
- Aspect-oriented techniques used to analyse and reconfigure crosscutting features dynamically
- Model driven techniques used to raise the level of abstraction by providing models at runtime, model composition and automatic reconfiguration of platform

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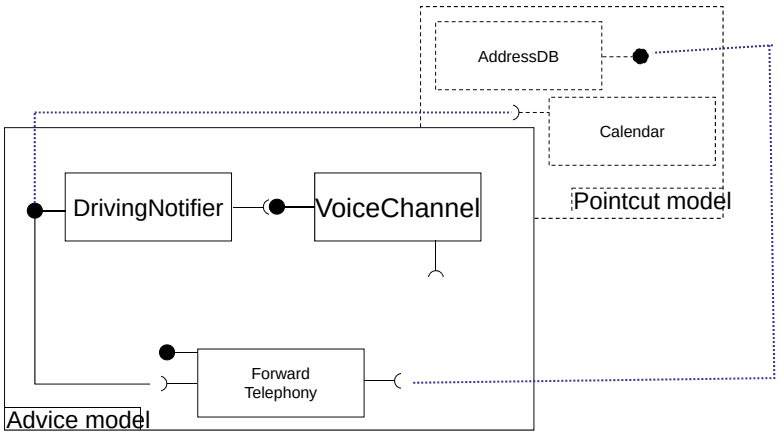
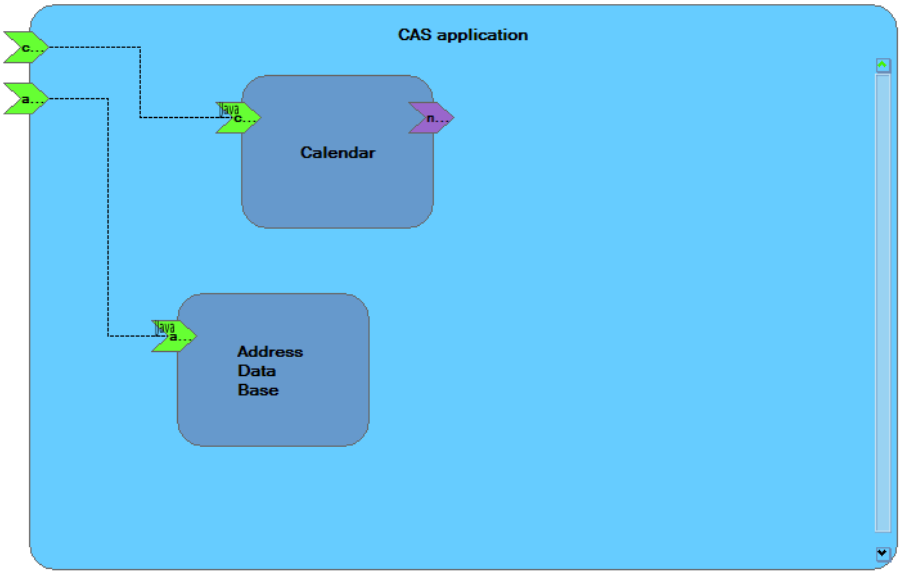
Refining variants (features) with aspect models

- Mandatory elements → Base model
- One variant (leaf feature) → One aspect model
- An aspect model
  - Is a fragment of architecture (What? = advice)
  - Should be easily plugged into the base architecture
    - Where? = pointcut
    - How? = weaving directives

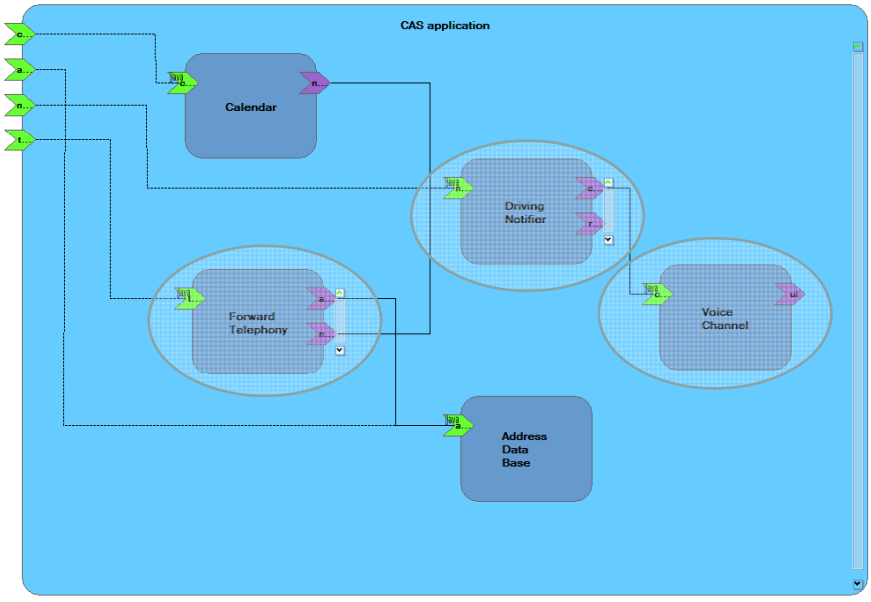
CAS architecture: driving aspect



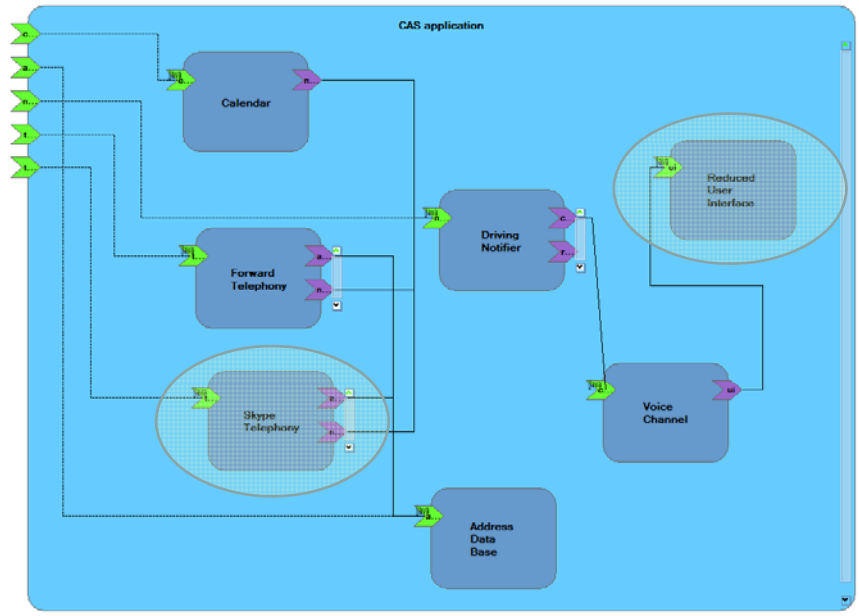
Base Model (Mandatory elements)



Base + Driving Aspect



Base + Driving + SmartPhone



Aspect Weaving and Validation

- N aspects → 2^N possible programs
  - Each aspect can be woven or not
  - However, there are some constraint
- Design-time validation
  - As much as possible, but not always possible due to combinatorial explosion
  - Evolution of requirements, once the system is deployed prevent 100% beforehand validation
- Complemented with runtime validation
  - Invariant checking, simulation, etc
  - Performed on the model, not on the running system
  - Possibly performed outside of the running system

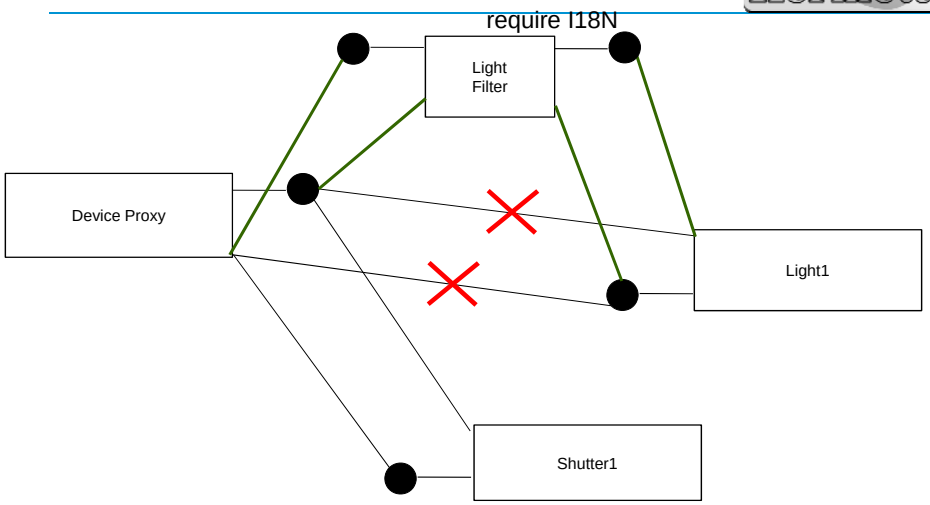
Extensive design-time validation

- Still possible to validate everything, for small systems
  - Produce all the possible configurations by aspect weaving
  - Validate all the configurations
- Discussion
  - Time/resource consuming
  - The number of configurations explodes
  - … but they are automatically generated, by aspect composition
- Not scalable

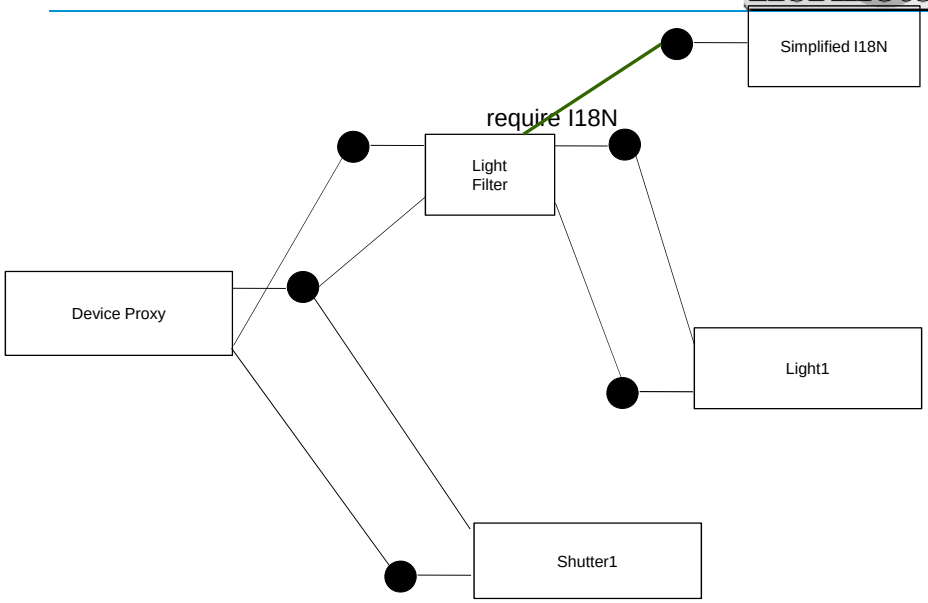
Validation of aspect models

- Aspect-Oriented Modeling
  - Validate the DSPL at design-time
  - Strong theoretical background (graph theory)
  - Modular reasoning
  - → interactions and dependencies detection
    - Using Critical Pair Analysis
  - → weaving order

Two interacting aspects



Two dependent aspects



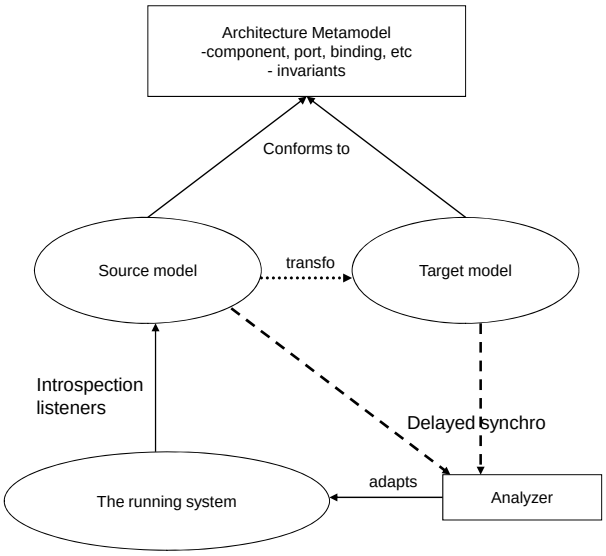
Limitations of CPA

- Critical Pair Analysis has limitations
  - Aspect1, Aspect2 → OK
  - Aspect1, Aspect3 → OK
  - Aspect1, (Aspect2, Aspect 3) → ?
- Need to validate woven configurations
  - At runtime, when they are produced

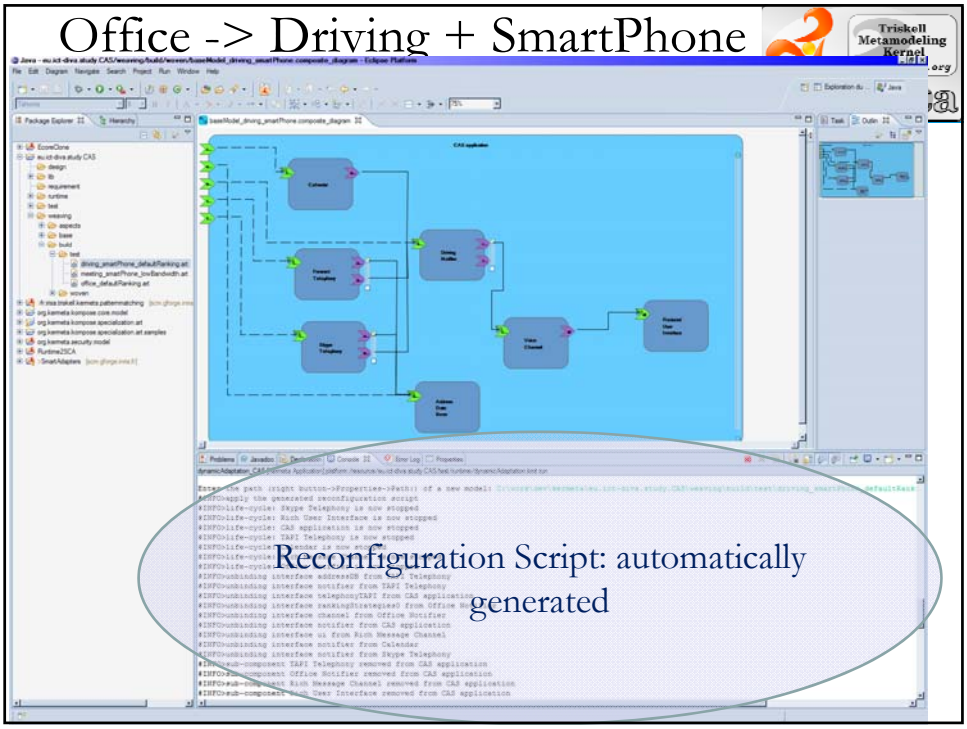
Checking configurations at runtime

- Focus on one configuration
  - Not the whole dynamically adaptive system
- Efficient roll-back
  - The running system is not yet adapted
  - Just discard invalid models
  - Report to user

Generating reconfiguration scripts



Office -> Driving + SmartPhone



Wrap-up

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Handling Variability in DAS

- (D)SPL approach to tame
  - The combinatorial explosion of configurations
  - The quadratic explosion of transitions
- AOM to automatically build configuration
  - Runtime validation before adapting the running system
  - Simple roll-back
- MDE to automate reconfiguration
  - Generation of safe reconfiguration scripts

Models@runtime

- Aspect as variability units raised at the model level
  - No explicit representation of ALL possible configurations
  - Configurations obtained by weaving most adapted aspects on demand at runtime
- MDE for automation of model composition
  - Model Based Validation, Generation of reconfiguration scripts
- Applications
  - DiVA: Airport Crisis Management, CRM
  - Home Automation for Dependent Persons
    - Spin-off from INRIA/U. Rennes to leverage this technology…
      - Morin et al., Models@runtime, IEEE Computer 10/2009
      - Brice Morin, Olivier Barais, Grégory Nain, and Jean-Marc Jézéquel. -- Taming Dynamically Adaptive Systems with Models and Aspects. -- In *31st International Conference on Software Engineering (ICSE'09)*, Vancouver, Canada, May 2009.

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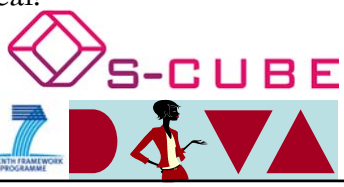
Conclusion

- Aspects to model variability in DAS
- AOMDE is what MDE is really about
- Thanks to Kermeta this is not just meta-bla-bla
  - A tool for building tools for building software
    - Eg an aspect weaver
      - For weaving aspect at runtime to handle safe dynamic adaption of complex system
  - It works for real!



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