Formal Model Transformations in Model Driven Architecture

Alfonso Pierantonio

Software Engineering and Architecture Group

Università degli Studi dell'Aquila
Dipartimento di Informatica
I-67100 L'Aquila
alfonso@di.univaq.it

joint work with Davide Di Ruscio

Roadmap

» Introduction

» What is a Model?

» MDA Primer

» Model Transformations

» Example : Developing data-intensive Web Applications

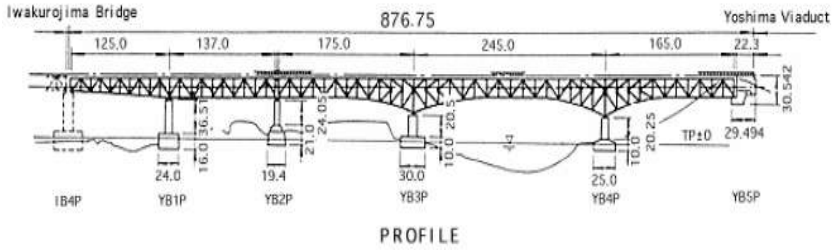
» Conclusions

Introduction

- Model transformations are increasingly gaining attention in different areas of software design and integration
- Model transformation presents intrinsic difficulties
- It requires specialized support in several aspects in order to realize the full potential, for both the enduser and transformation developer [Tratt 04]
- Different proposals have been issued, especially in combination with the QVT RFP [OMG 02]
- Abstract State Machines as a candidate for specifying (and executing) model transformations

What is a Model?

In his work in the seventies H.Stachowiak characterized a model as follows



1. A model has a **purpose**
2. A model describes some **entity** that exists or is intended to exist in the future

Allgemeine Modelltheorie
Herbert Stachowiak
Springer (1973)

What is a Model?

In his work in the seventies H.Stachowiak characterized a model as follows

1. A model has a **purpose**
2. A model describes some **entity** that exists or is intended to exist in the future
3. A model is an **abstraction**, that is, it does not describe details of the entity that are not of interest to the audience of the model

Allgemeine Modelltheorie
Herbert Stachowiak
Springer (1973)

Models | Pros&Cons

- **Pros**
  - Models help us understand a complex problem and its potential solutions through abstraction
  - Characteristics
    - abstract, understandable, accurate, predictive, inexpensive
  - A number of pragmatic qualities
    - improved communication of ideas
    - completeness checks
    - viability in terms of indicators such as cost and estimation
    - test case generation
- Cons
  - Models when used only as documentation, have a limited value since they easily diverge from reality

Models | Pros&Cons

» Pros

> Models help us understand a complex problem and its potential solutions through abstraction

> Characteristics

> abstract, understandable, accurate, predictive, inexpensive

> A number of pragmatic qualities

> improved communication of ideas

> completeness checks

> viability in terms of indicators such as cost and estimation

> test case generation

» **Cons**

> Models when used only as documentation, have a limited value since they easily diverge from reality

MDA | Premise

» Too many platforms and technologies

> Distributed Objects, Components, Web services, etc

> Which technology is the best ?

» Too fast evolution

> Technologies evolve and get obsolete very soon

> Which technology will be out tomorrow?

» How to protect my investment in business logic?

> The business logic has to be as independent as possible from supporting technologies

MDA | Introduction

» Defined by OMG (2000) and based on modeling and automated mappings of models to implementations

» The artifacts are formal models, ie. models that can be understood by computers

» It separates the specification of system functionality from the specification of the implementation on a given technology platform

» Slogan : "Design one, built it on any platform"

> eg. Deutsche Bank intends to retain the design for about 20 years regardless of the different technological changes

MDA | Models

» PIM (Platform Independent Model) is an abstract model independent from any technology

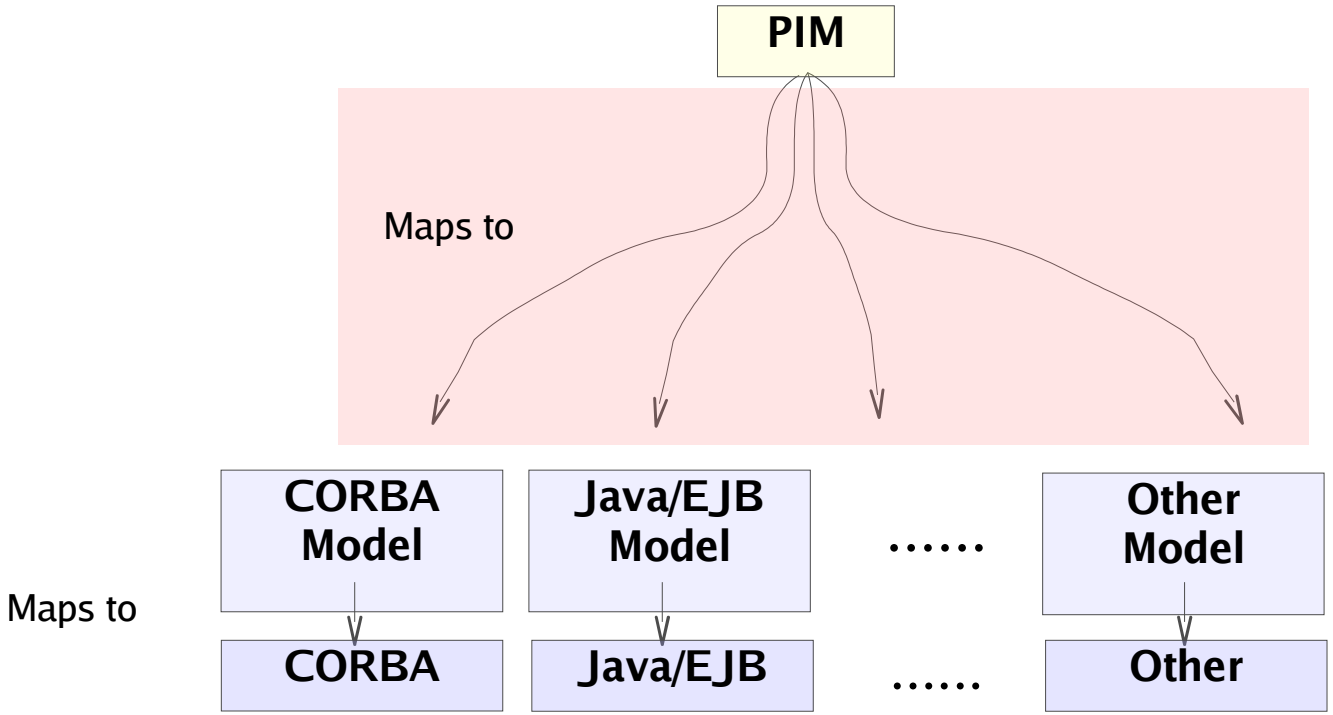
» PSM (Platform Specific Model) specifies how the functionality specified in a PIM is realized on a given platform.

> A PIM is transformed into one or more PSMs

» PIMs and PSMs are expressed in UML profiles or metamodels

» The ultimate goal is to generate the system implementation (among other views) by means of model transformations

Model Transformations



MDA | MOF & UML

» OMG standards which provide a well-established foundation for defining PIMs and PSMs

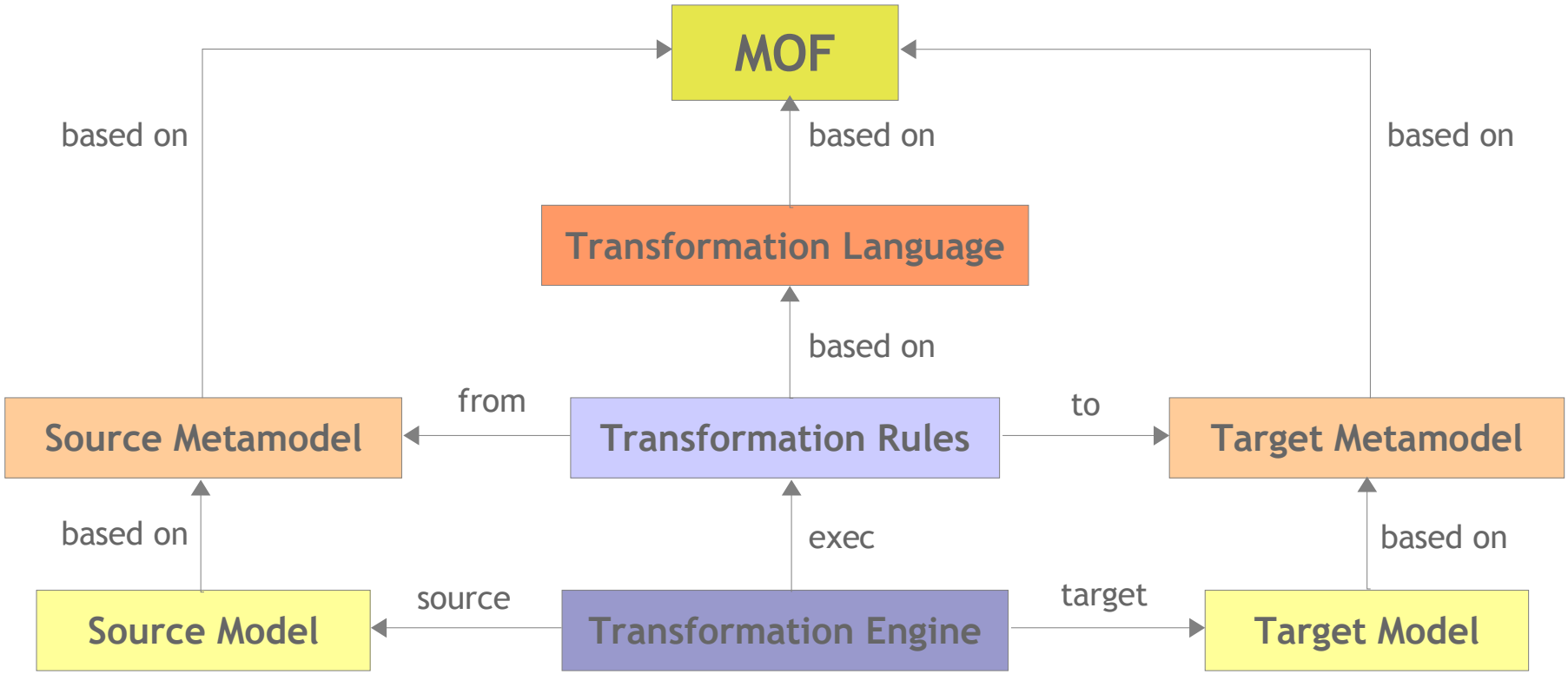
> UML: Unified Modeling Language

> MOF: Meta Object Facility

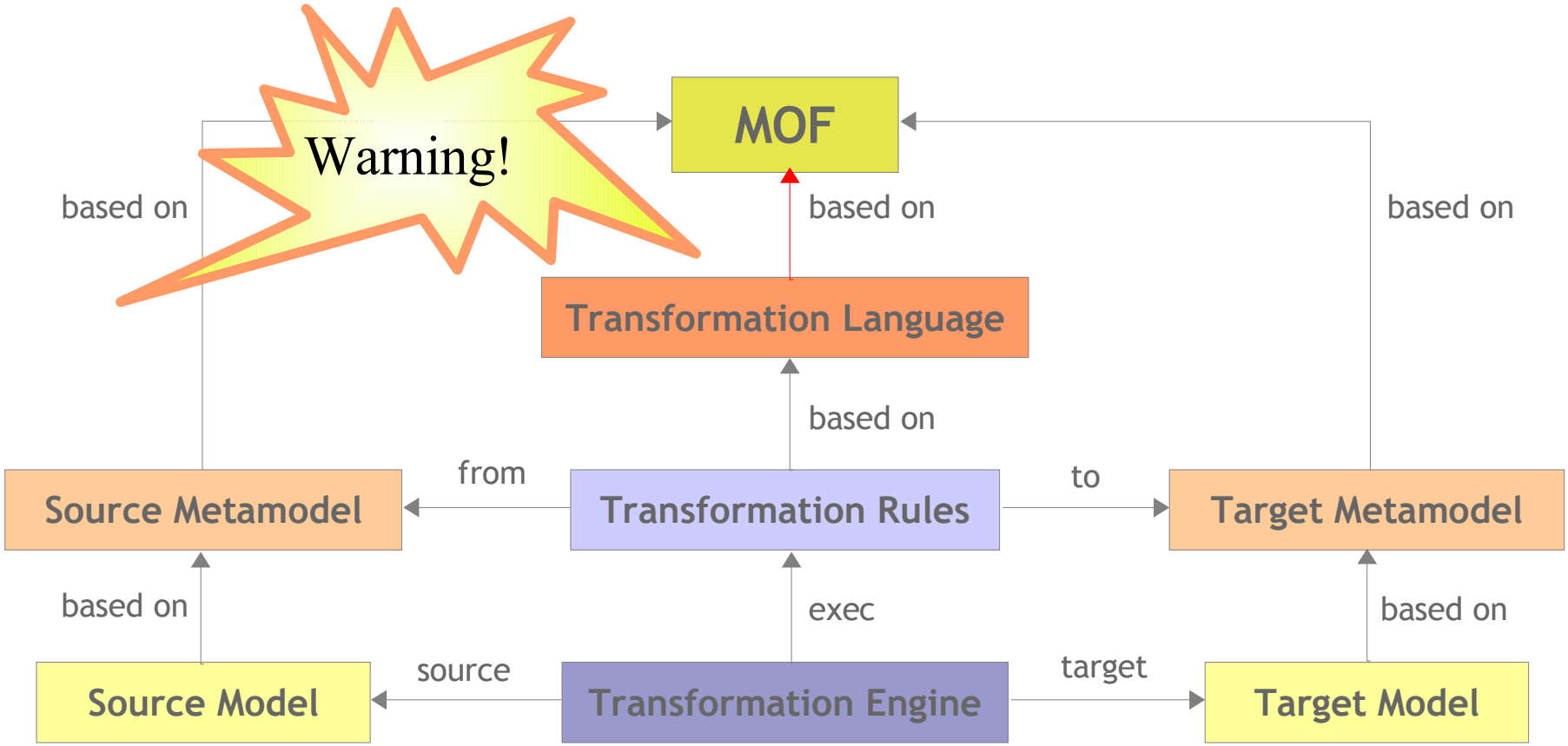
Meta level	MOF terms	Examples
M3	Meta-metamodel	MOF models
M2	Meta-metadata, metamodel	UML Metamodel, UML profiles
M1	Metada, model	UML Models (eg. Class diagrams)
M0	Data	Modeled systems

OMG metamodel architecture

Model Transformations



Model Transformations



Model Transformations | mappings

- **PIM to PIM:** used wen models are enhanced, *refined* or filtered during the development lifcycle without needing any platform dependent information
- **PIM to PSM:** used when a sufficiently refined PIM is projected to the execution infrastructure
- **PSM to PSM:** used for component realization and deployment, generally related to platform dependent model refinement
- **PSM to PIM:** used for mining PIMs from concrete PSMs. Typically called re-engineering and cannot be fully automated, requires renovation tools

Model Transformations | languages

- Declarative vs imperative matching algorithm
- Unidirectional vs bidirectional
  - Unidirectional transformations are usually imperative
  - Bidirectional transformations are usually declarative, potentially subject to unbounded time execution, problems from a practical standpoint
- Stateless vs persistent
  - Stateless transformations generate each time a new instance
  - Persistent transformations perform the minimum alteration to the target model to propagate the changes leaving the rest intact
- Practical approaches tend to be unidirectional and persistent

Abstract State Machines (1)

- Invented by Y.Gurevich and (promoted by) E.Börger
- ASMs tend to bridge the gap between specification and computation by providing more versatile Turing-complete machines
- ASMs is a variant of first-order logic with equality, where the fundamental concept is that functions are defined over a set U and can be changed point-wise
- Ability to simulate algorithms on their natural levels of abstraction without implementing them
- Extended literature on high-level system design and analysis (see [Börger03])

Abstract State Machines (2)

» Systems of finitely many *transition rules* of form

if *Condition* **then** *Updates*

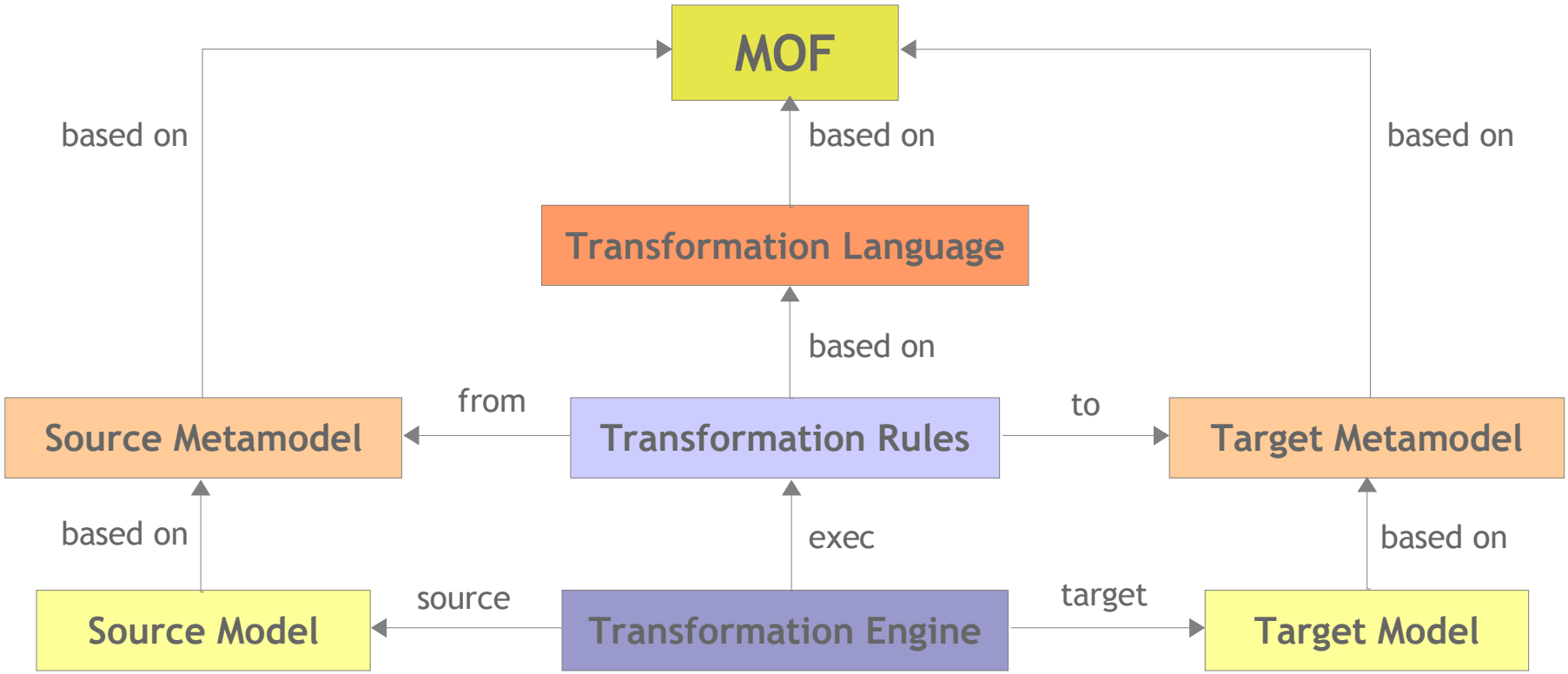
which transform abstract states.

> *Condition:* arbitrary first-order formula without free variables

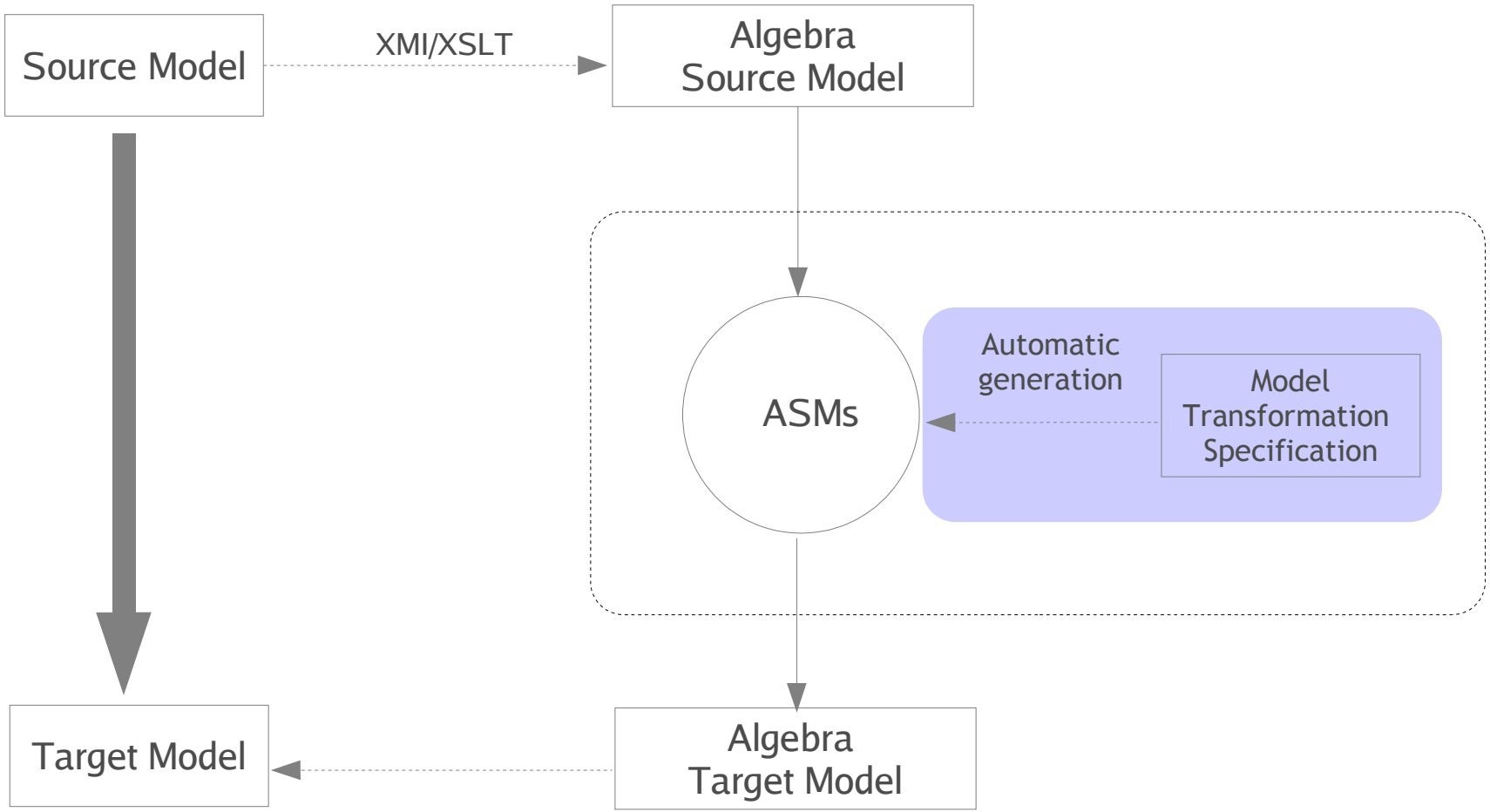
> *Updates:* finite set of function updates of form $f(t_1,\ldots,t_n):=t$ simultaneously executed when *Condition* is true

» A mathematically rigorous form to capture fundamental operational intuitions of computing

Model Transformations



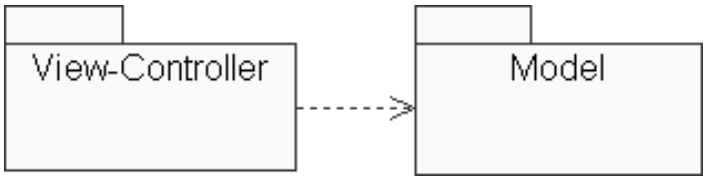
ASM and Model Transformations

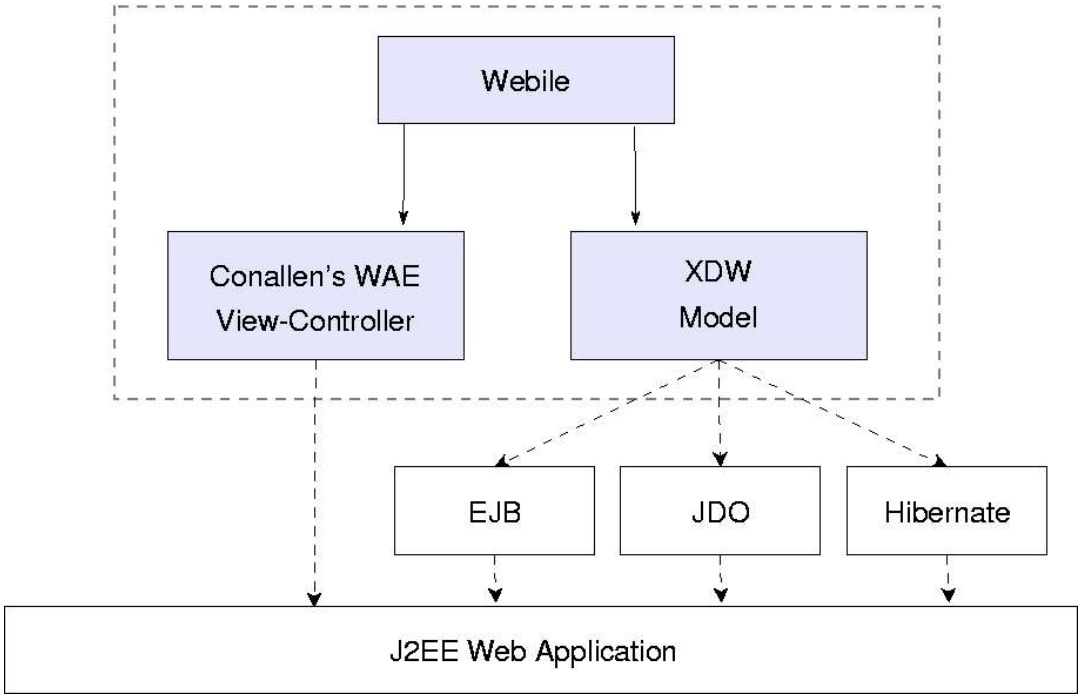


Model Transformation | an example

- Overall architecture
- Source model
  - Conceptual description of a data-intensive Web application
  - The algebraic encoding
- Target model(s)
  - Model-View-Controller complaint platform-specific model
    - Model
    - View-Controller
- A simple ASM transformation rule
  - A structured content (Web page in the source model) is mapped in the MVC design pattern (controller + view)

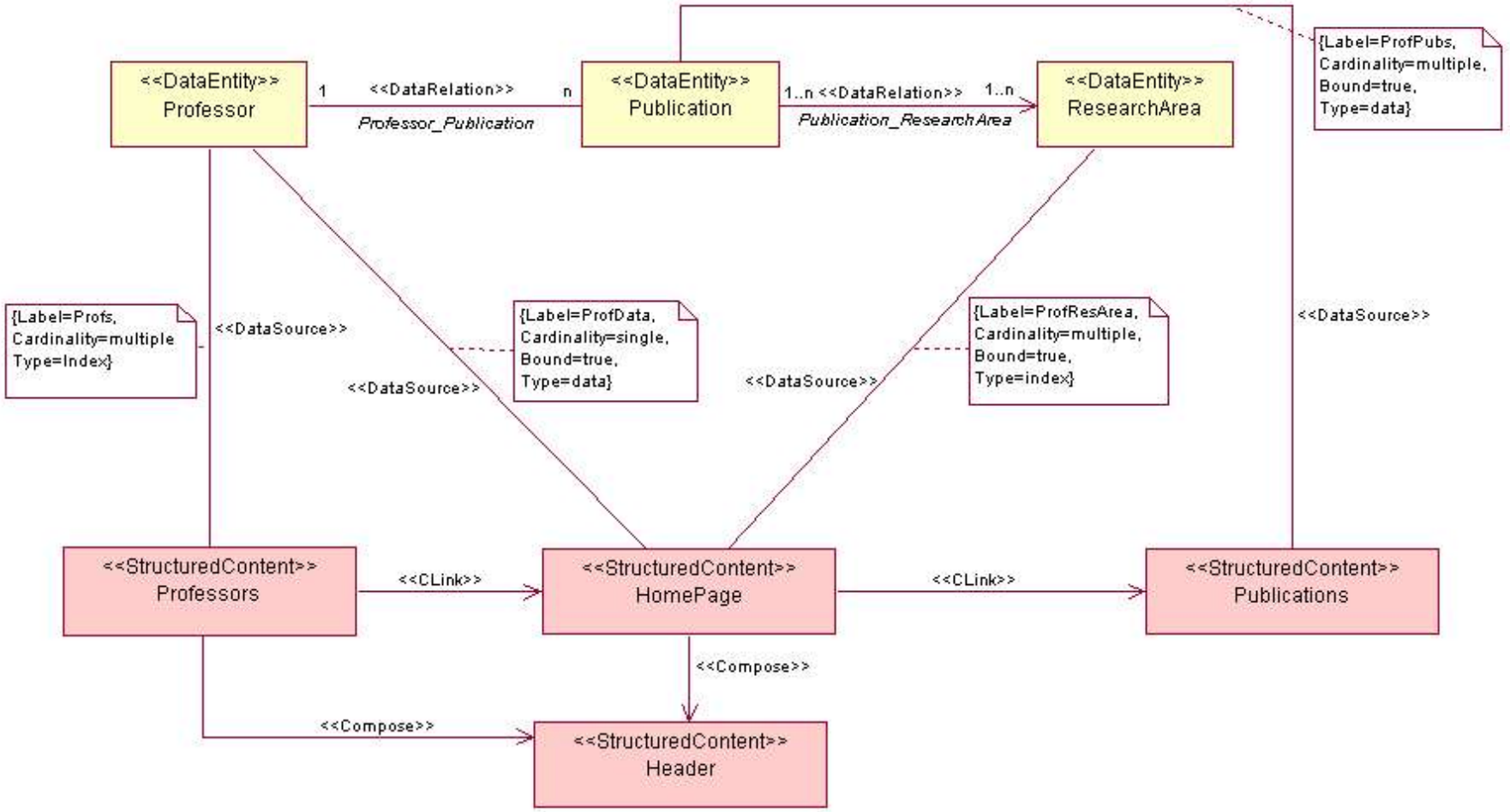
Overall Architecture



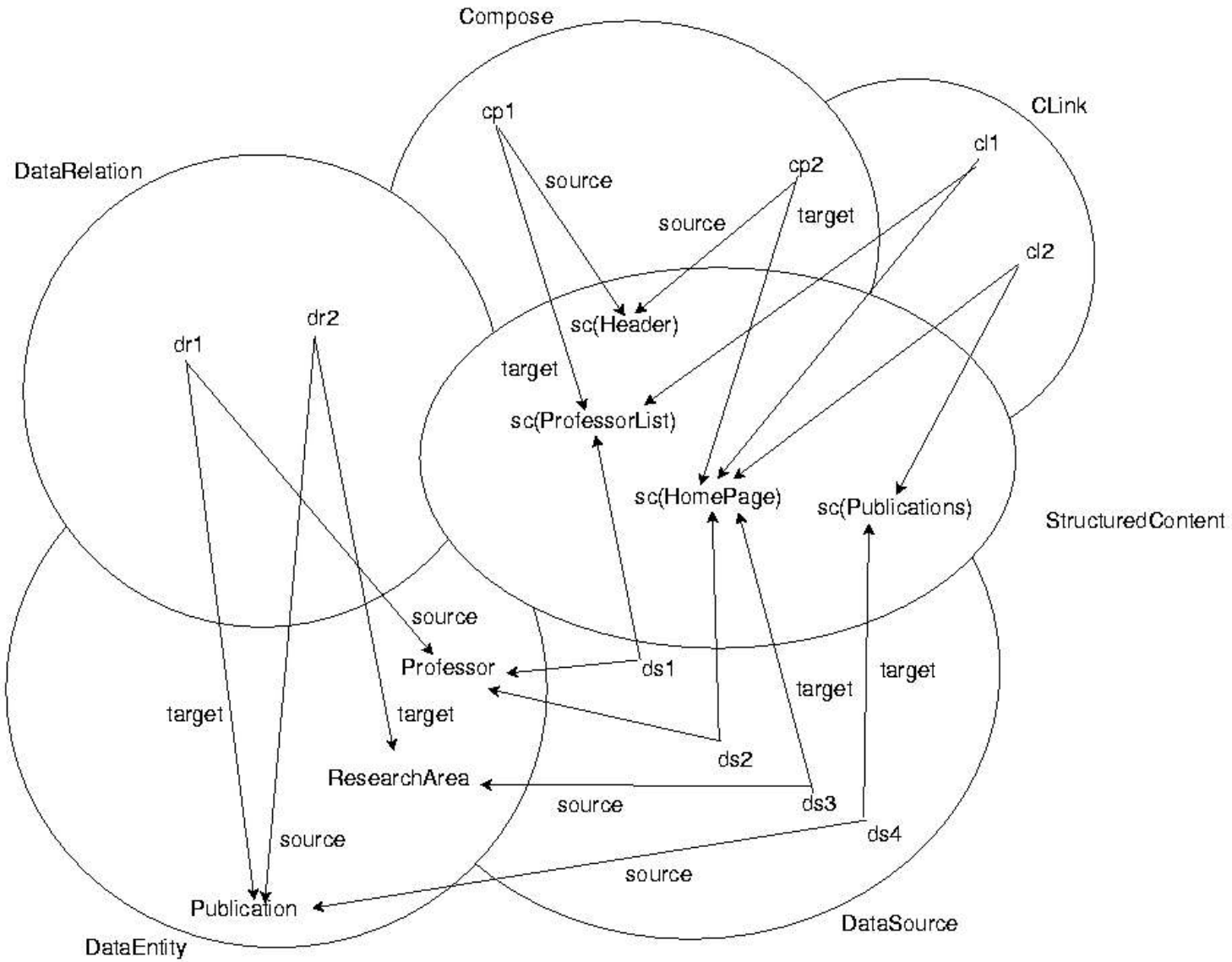


Source Model | conceptual description

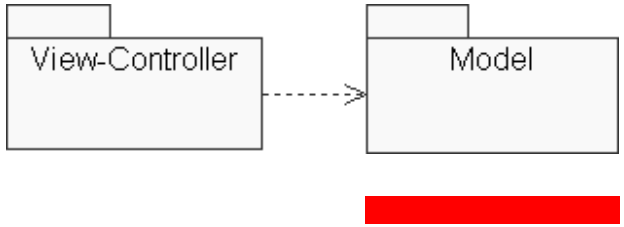
» Webile [IJWET 04] is a UML profile to model data-intensive Web apps

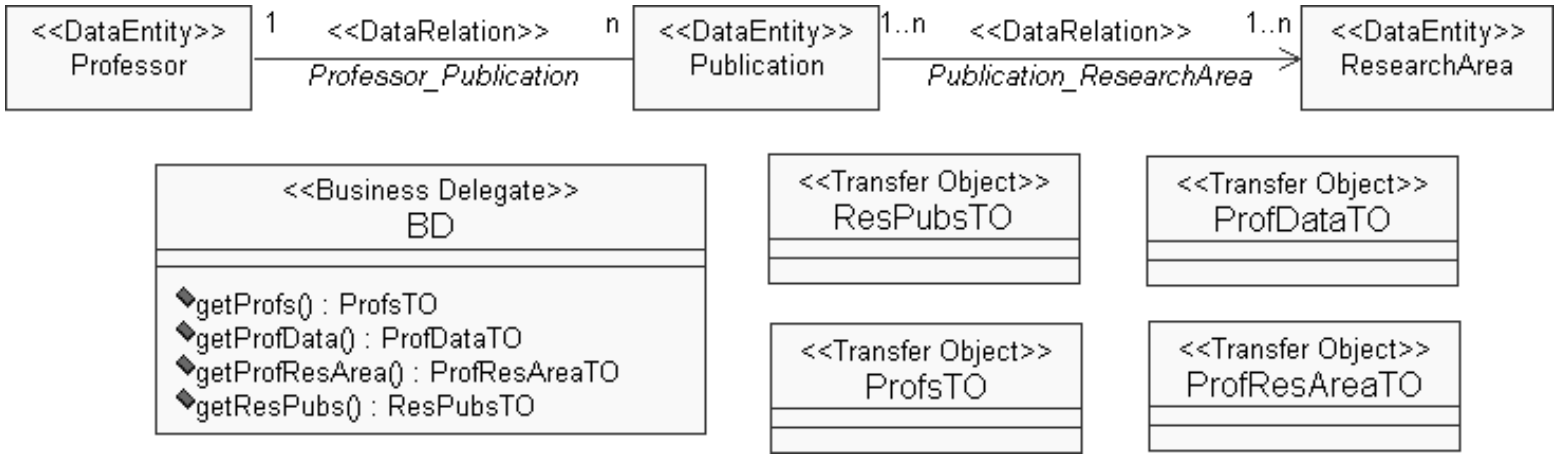


Source Model | algebraic encoding

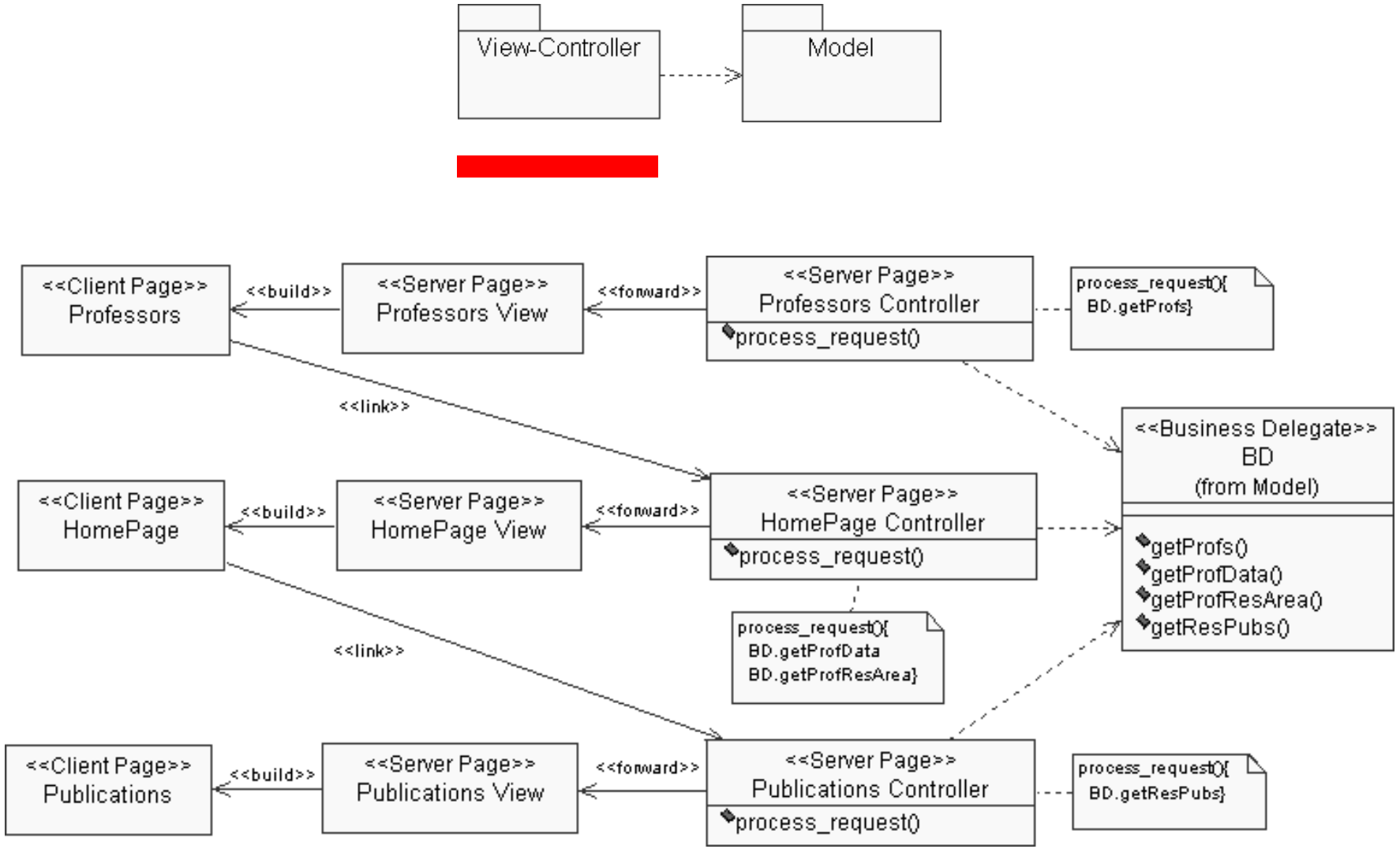


Target Model > *Model (in the sense of MVC)*





Target Model | View-Controller



An ASM rule (1)

```
asm StructuredContent is
  do forall x in StructuredContent
    extend ServerPage with s1,s2 and ClientPage with c and Build with b and
                Forward with r and Use with u
        source(b) := s1
        target(b) := c
        source(r) := s2
        target(r) := s1
        source(u) := s2
        target(u) := bd
        controller(x) := s2
        serverView(x) := s1
        clientView(x) := c

        generatedFrom({s1,s2,c,b,r}) = {x}

    endextend
  enddo
endasm
```

An ASM rule (2)

```
asm StructuredContent is
  do forall x in StructuredContent
    extend ServerPage with s1,s2 and ClientPage with c and Build with b and
           Forward with r and Use with u
        source(b) := s1
        target(b) := c
        source(r) := s2
        target(r) := s1
        source(u) := s2
        target(u) := bd
        controller(x) := s2
        serverView(x) := s1
        clientView(x) := c

        generatedFrom({s1,s2,c,b,r}) = {x}

    endextend
  enddo
endasm
```

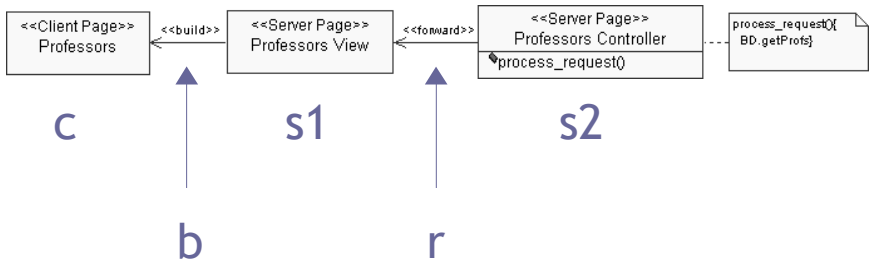
An ASM rule (3)

```
asm StructuredContent is
  do forall x in StructuredContent
    extend ServerPage with s1,s2 and ClientPage with c and Build with b and
           Forward with r and Use with u
      source(b) := s1
      target(b) := c
      source(r) := s2
      target(r) := s1
      source(u) := s2
      target(u) := bd
      controller(x) := s2
      serverView(x) := s1
      clientView(x) := c

      generatedFrom({s1,s2,c,b,r}) = {x}

    endextend
  enddo
endasm
```

For each StructuredContent in the source algebra, creates in the target algebra representatives for the following



An ASM rule (4)

```
asm StructuredContent is
  do forall x in StructuredContent
    extend ServerPage with s1,s2 and
           Forward with r and Use wi
      source(b) := s1
      target(b) := c
      source(r) := s2
      target(r) := s1
      source(u) := s2
      target(u) := bd
      controller(x) := s2
      serverView(x) := s1
      clientView(x) := c

      generatedFrom({s1,s2,c,b,r}) = {x}

    endextend
  enddo
endasm
```

Persistent transformation

Explicit tracking information for change propagation, usually implicit.

Conclusions

- Protecting investment by separating the business model from the supporting technologies
- Model transformations play a key rôle in the OMG's Model Driven Architecture initiative
- Persistent model transformations allow advanced usage scenarios that are currently largely unfeasible [Tratt 04]
- The presented approach to model transformation provides with a flexible, efficient, and practical platform for creating model transformations

Conclusions

- Protecting investment by separating the business model from the supporting technologies
- Model transformations play a key rôle in the OMG's Model Driven Architecture initiative
- Persistent model transformations allow advanced usage scenarios that are currently largely unfeasible [Tratt 04]
- The presented approach to model transformation provides with a flexible, efficient, and practical platform for creating model transformations
- Tool support with

Asmatic