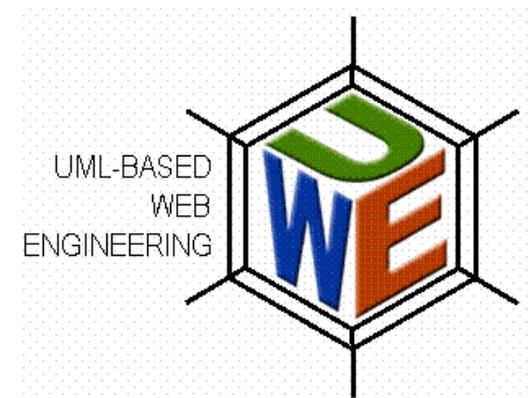# Model-Driven Web Engineering

UWE Approach

Nora Koch

Web Engineering Group

Ludwig-Maximilian-Universität München (LMU)
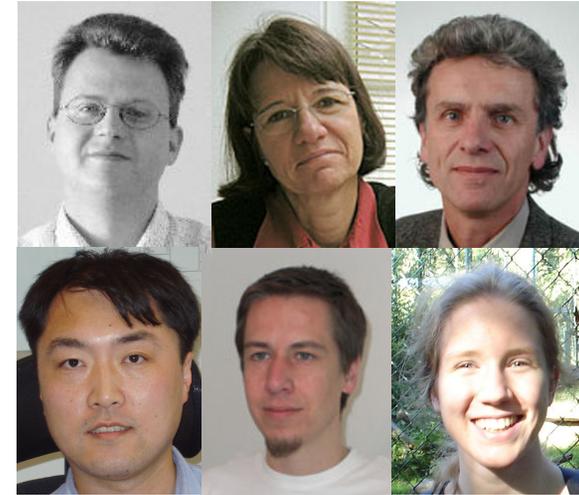
Germany

Madrid, 28.05.2008

Web Engineering Group of LMU

- Current staff
  - Alexander Knapp and Nora Koch
  - Gefei Zhang (PhD student)
  - Christian Kroiß and Marianne Busch (students)
  - Martin Wirsing (head of department)
- Projects
  - UWE
  - MAEWA
  - SENSORIA
- Cooperations
  - Universities of Alicante, Extremadura, Málaga, Sevilla (ES), Milano (IT), Viena & Linz (AT), Lingby (DK), LaPlata (AR)
  - Industry: FAST/Cirquent, S.Co LifeScience
- Other activities
  - ICWE conferences since 2003
  - MDWE workshops since 2005
  - MDWEnet initiative since 2006

Web Engineering

- Software Engineering for the Web domain

- Concept introduced by San Murugesan in 1998

- Definition

  - Web engineering is the application of a systematic and quantifiable approach to cost-effective requirements analysis, design, implementation, testing, operation, and maintenance of high-quality Web software.

  - Web engineering is also the scientific discipline concerned with the study of these approaches.

    Gerti Kappel, Birgit Pröll, Siegfried Reich, Werner Retschitzegger
    Web Engineering (2006)

- Established as own discipline

- Model-Driven Web Engineering relevant topic as many Web engineering approaches follow a model-driven development approach

Outline

- Web Software and Model-Driven Development

- UWE Approach
  - Modelling Language
  - Metamodel
  - Development Process
  - Tool Support

- Outlook

UML-BASED
WEB
ENGINEERING

Web Software & MDD
UWE Approach
Modelling Language
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Development Process
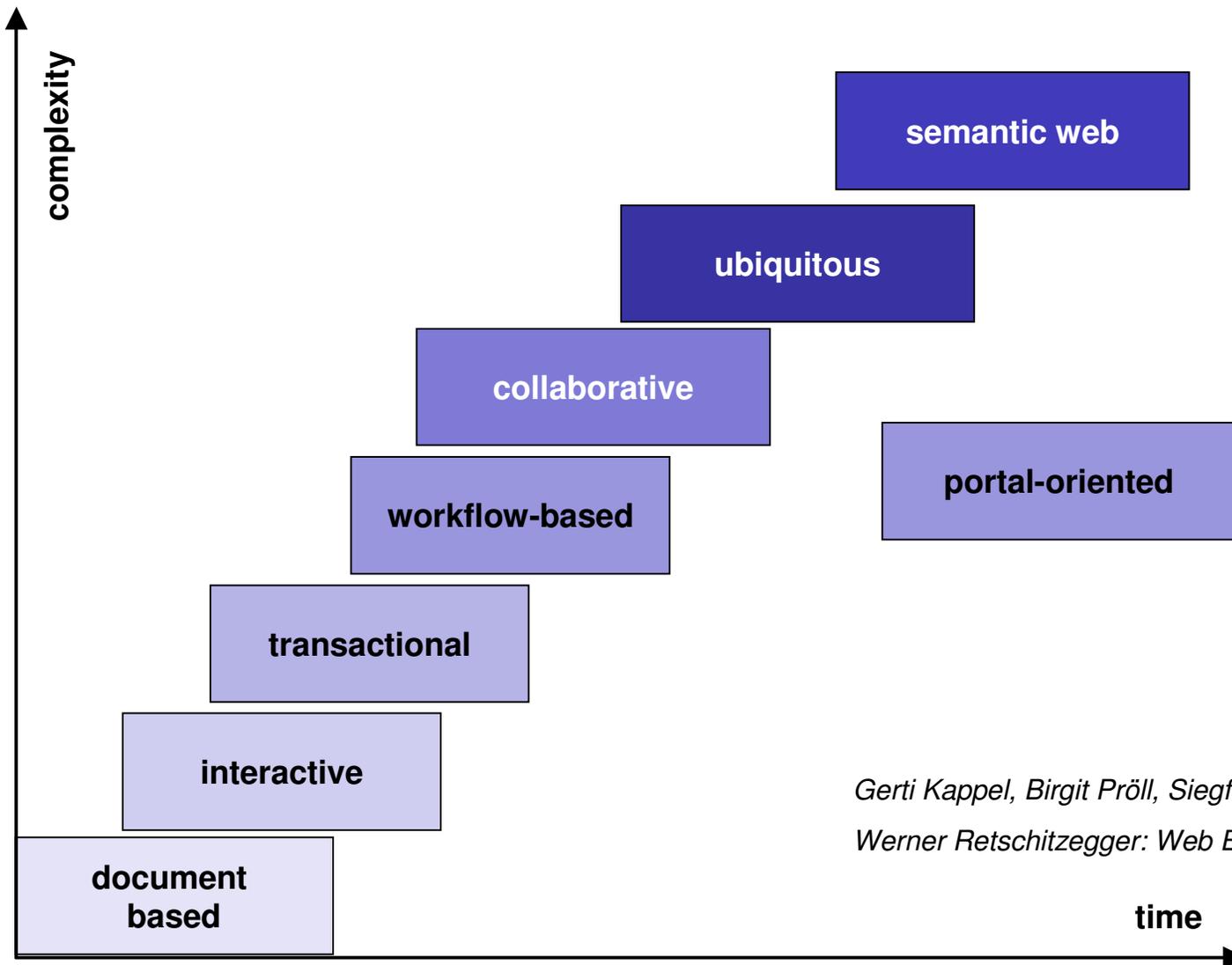Tool Support

LMU
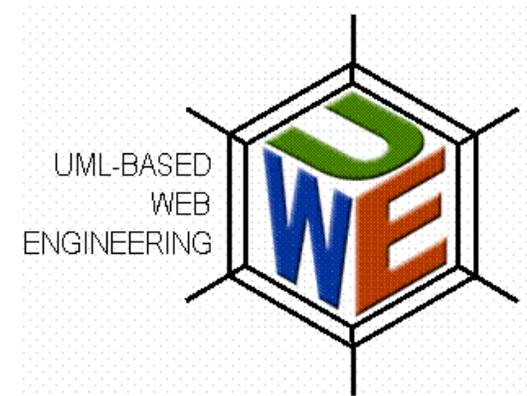
Web Software

Web information system (WIS)

- software system based on client/server technology provides information through a user interface (Web browser). Pages belong to a particular domain name or subdomain on the World Wide Web
    - Web site, homepage, Web portal

- Web application
    - software system that provides Web specific resources such as content and services through a Web browser

- Web service[1]
    - software system designed to support interoperable machine to machine interaction over a network. Web services are frequently just application programming interfaces (API) that can be accessed over a network, such as the Internet, and executed on a remote system hosting the requested services
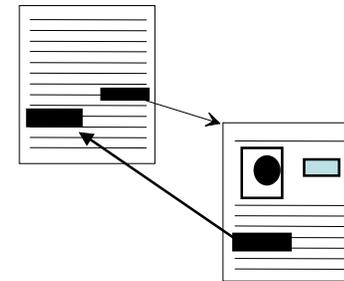
[1]W3C, www.w3.org

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Categories of WIS and Web Applications

complexity ↑

```
                                                    ┌──────────────────┐
                                                    │  semantic web    │
                                                    └──────────────────┘
                                          ┌──────────────────┐
                                          │   ubiquitous     │
                                          └──────────────────┘
                               ┌──────────────────┐
                               │  collaborative   │
                               └──────────────────┘          ┌──────────────────┐
                                                             │ portal-oriented  │
                    ┌──────────────────┐                     └──────────────────┘
                    │  workflow-based  │
                    └──────────────────┘
          ┌──────────────────┐
          │   transactional  │
          └──────────────────┘
     ┌──────────────────┐
     │   interactive    │
     └──────────────────┘
┌──────────────────┐
│    document       │
│     based         │                    time →
└──────────────────┘
```

Gerti Kappel, Birgit Pröll, Siegfried Reich,

Werner Retschitzegger: Web Engineering, (2006)

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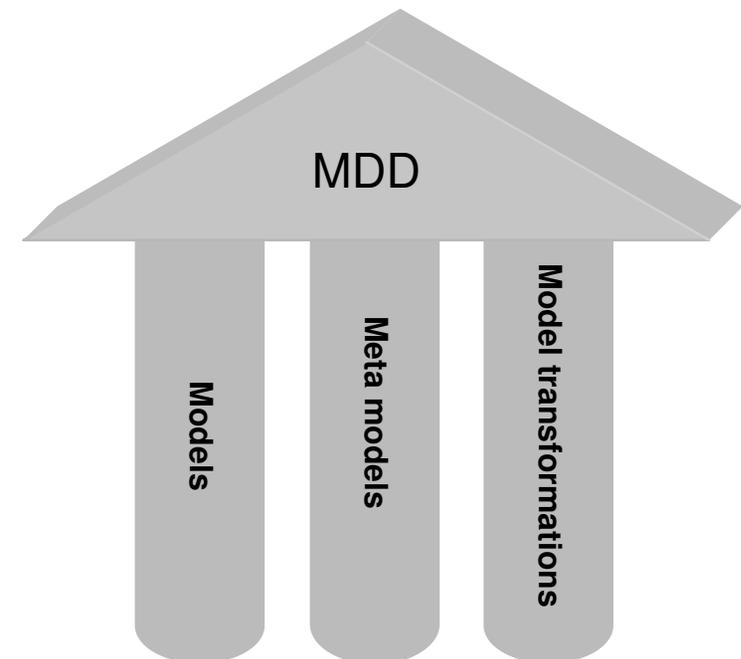
Web Specifics in Engineering

- Hypermedia paradigm
  - nodes & links
  - text & multimedia
- Omnipresent due to the nature of the Web
  - global and permanent availability
  - comfortable and unified access
  - distributed information / services
- Dynamic development
  - incremental number of Web pages
  - continuous improvement of existing Web applications (content, links, layout)
  - offer of new services
  - adaptation required by new Web technologies
- Management aspects
  - multidisciplinary development team
  - inhomogeneous and immature technical infrastructure
  - short product lifecycles → short development cycles
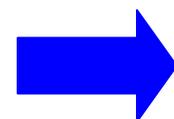
➡ Specific engineering methods for the Web domain

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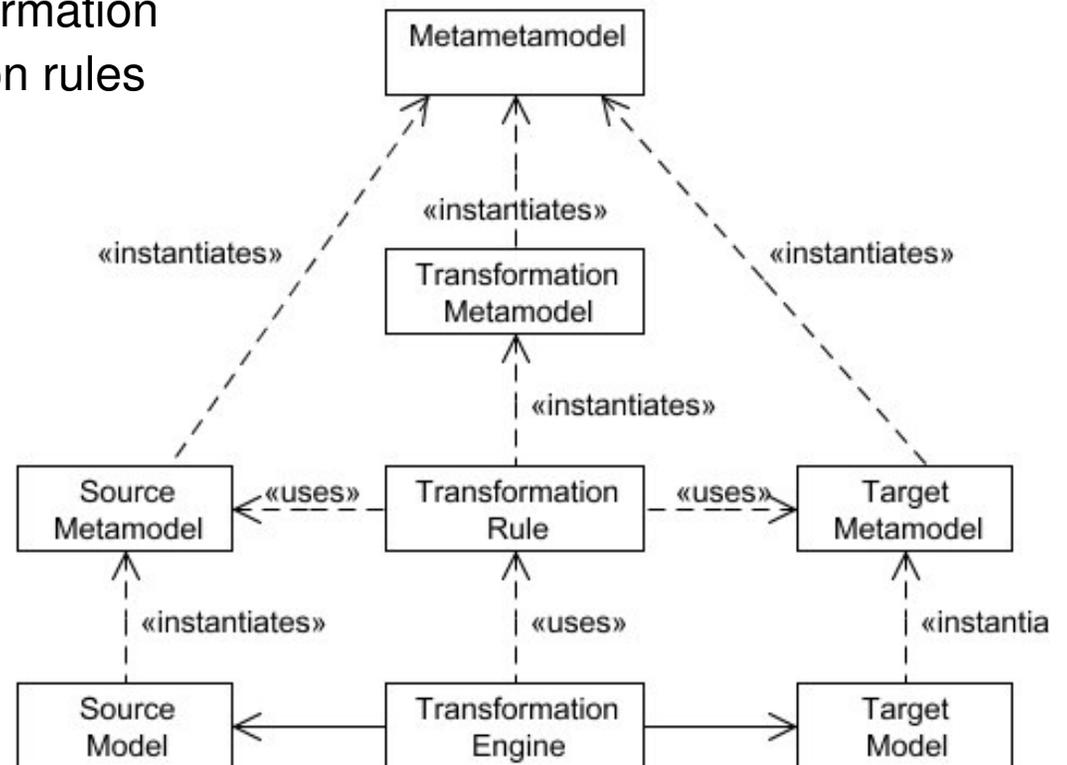
Model-Driven Development

- MDD approaches based on
    - models, metamodels and model transformations

- MDD approaches require languages for
    - specification of models
        - UML, BPMN, …
    - description of metamodels
        - UML, MOF, OCL, …
    - definition of model transformations
        - Java
        - Graph transformations
        - ATL, QVT, …

- Model-Driven Architecture (MDA)
    - computational independent model (CIM)
    - platform independent model (PIM)
    - platform specific model (PSM)

MDD

Models

Meta models

Model transformations

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Model Transformations

- Goal is automatic translation between source and target models

- Translation performed by a transformation engine that executes transformation rules

- Set of rules
  - seen as a model
  - based on a transformation metamodel

- Metamodels are based on a metametamodel

- MDA model transformations
  - CIM2PIM
  - PIM2PIM
  - PIM2PSM

Model transformation pattern (J. Bézivin, 2004)

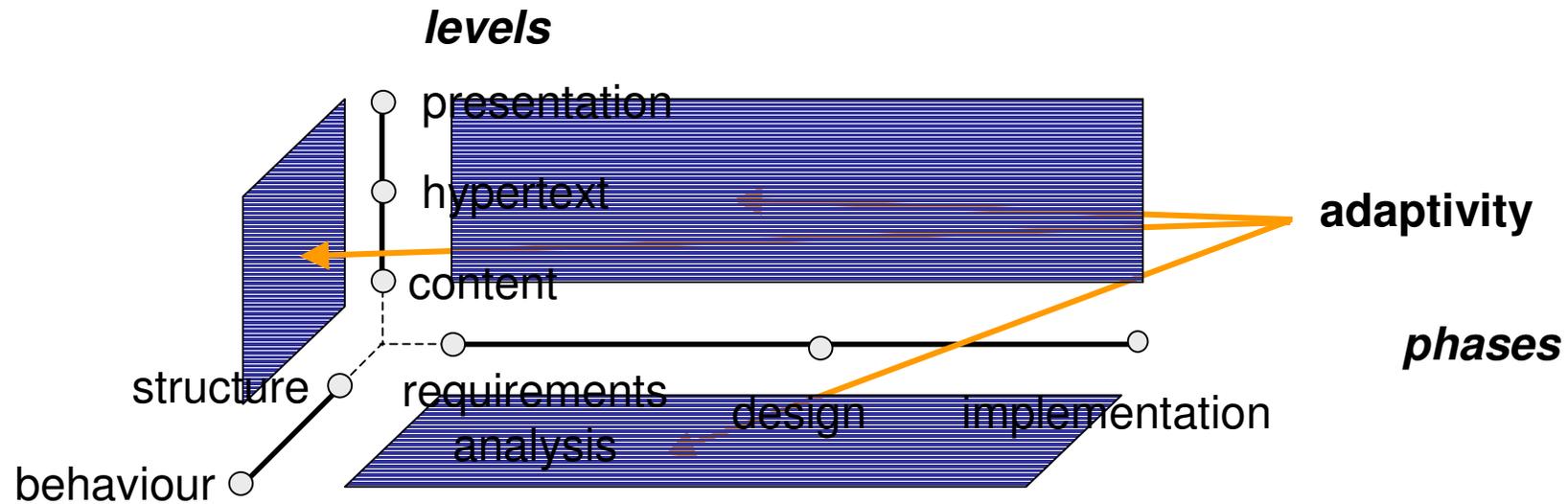**Web Software & MDD**
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Web Engineering Methods

HDM / HDM-lite	Hypertext Design Model
Hera	
NDT	Navigational Development Technique
MIDAS	Hypertext Modeling Method (HM^3)
	Service-Oriented Development Method (SOD-M)
OO-H	Object-Oriented Hypermedia Method
OOHDM	Object-Oriented Hypermedia Design Method
OOWS	Object-Oriented Web Solution
RMM	Relationship Management Methodology
UWE	UML-based Web Engineering
W2000	
WAE / WAE2	Web Application Extension
WebML	Web Modeling Language
WebSA	Web Software Architecture
WSDM	Web Site Design Method

based on
ER   Entity Relationship Model
OMT Object Modeling Technique
UML Unified Modeling Language

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Model-Driven Development in the Web Domain

- Several methods propose building models
  - Hera, MIDAS, OOHDM, OO-H, UWE, WebML, …
  - separation of concerns
    - content
    - navigation
    - presentation
    - business processes
    - adaptation, …
  - similar Web specific modeling elements
  - different notations
- Some methods define metamodels for modelling languages
  - MIDAS, OO-H, UWE, W2000, WebML, …
- Few approaches address model transformations
  - MIDAS, OOWS, UWE, WebSA, …
- Goal of almost all
  - Platform specific models in a late development stage

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UWE in a Nutshell

- Main characteristic is the use of UML for all models
  - "pure" UML whenever possible
  - UML extension for Web specific features: UML profile
- Use of OMG standards, such as UML, MDA, MOF, OCL, XMI, …

- Focuses on systematisation and automatic generation

- UWE comprises
  - a modelling language for the graphical representation of models of Web applications
  - a metamodel for UWE modelling elements
  - a development process
  - tools supporting semi-automatic generation
    - MagicUWE & ArgoUWE editors for the design
    - set of ATL transformations
      - model-to-model and model-to-code transformations
      - set of plugins integrated in eclipse environment

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Dimensions of Web Modelling

levels

presentation

hypertext

content

adaptivity

phases

structure

behaviour

requirements
analysis

design

implementation

aspects

- **Modelling process**
    - information-driven ("content first")
    - presentation-driven ("layout first")
    - functionality-driven ("business processes first")

Source: Kappel et al. Web Engineering, d-punkt (2003)

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Why UML?

- UML is a graphical language for specifying, constructing and documenting software artifacts

- UML is a de facto industry standard and an OMG standard

- UML includes

  - notation

  - diagram types

  - Object Constraints Language (OCL)

  - metamodel

  - well-formedness rules

- UML does not provide a development process

- How expressive is UML for the development of Web applications?

  - UML does not include specific Web model elements

  - UML defines extension mechanisms → UML profiles

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UML Extensions

- **Light weight extension**
  - called a UML profile
  - based on extension mechanisms provided by UML
  - defines stereotypes for new metaclasses
    - domain specific: EJB «bean», «session», «entity», …
    - defined in the UML: «metaclass», «trace», «file», …
  - tagged values for metaattributes
  - OCL constraints for invariants, pre- and postconditions
  - CASE tool support by UML tools

- **Heavy weight extension**
  - different notation
  - other diagram types not defined in the UML
  - need of proprietary CASE tool

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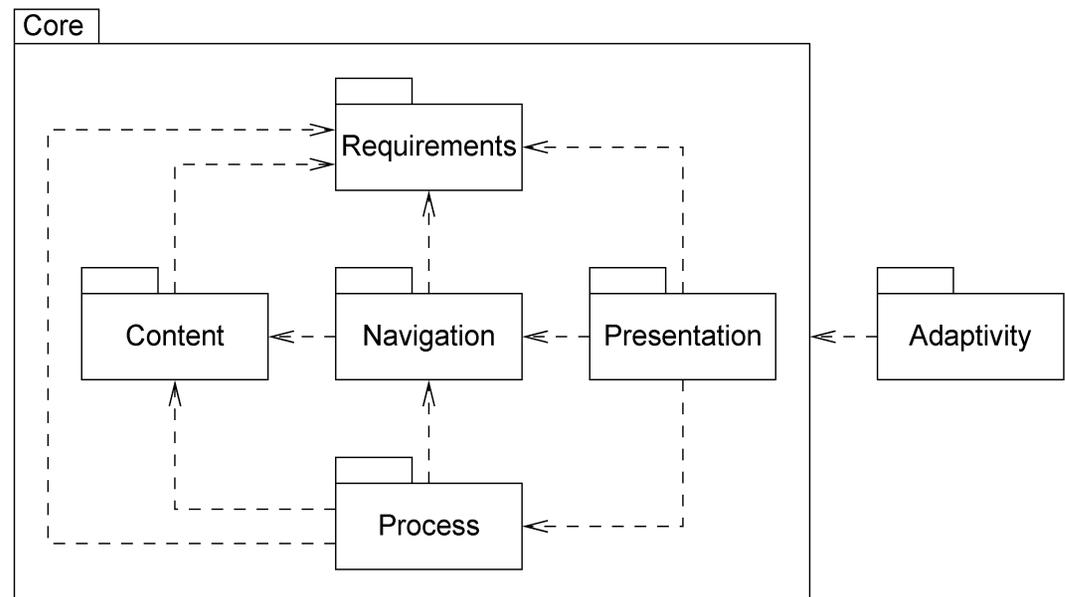# Analysis and Design Models in UWE

- **Analysis models of a Web application**
  - functional requirements are specified by
    - uses cases
    - workflows
  - data (content) requirements are specified by
    - domain models
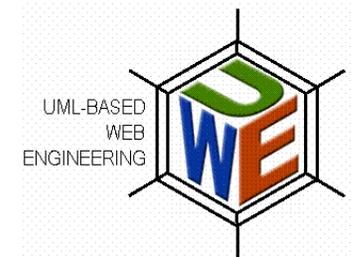
- **Design models of a Web application**

  - information aspects
    - content model
  - hypertext structure and navigation functionality
    - navigation model
  - layout schema
    - presentation model
  - functionality
    - process model
    - adaptivity model

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Core

| Content | Navigation | Presentation | Adaptivity |

Requirements

Process

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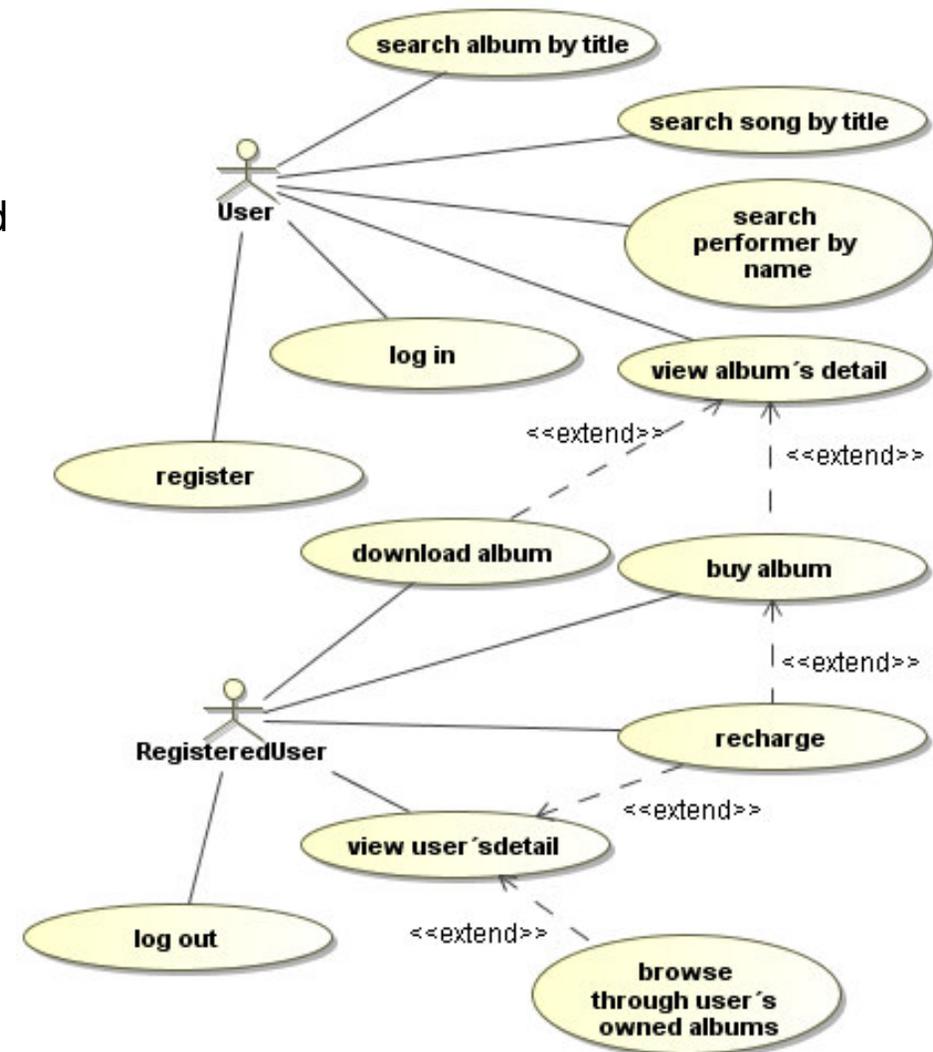# Example: Simple Music Portal

- Inspired by `www.mp3.com`
    - offers albums for downloading
    - contains information about albums, songs and artists
    - this information is available for free
    - registered users can download them
    - for downloading they need to have enough credit on their prepaid account
    - accounts are rechargeable

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Modelling Requirements with UWE

- Graphical visualization by UML use case diagram
  - to model required functionality
  - distinguishes between navigation and process use cases
- Web specific model elements
  (not yet implemented in MagicDraw)

  - «navigation» use cases for browsing tasks
    - browse use cases
    - view use cases
    - search use cases
  - «web process» use cases for other tasks
    - other use cases

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Content Modelling

- ■ Representation of domain information
  - ■ persistent data

- ■ Modelling technique
  - ■ UML class diagram
  - ■ plain UML
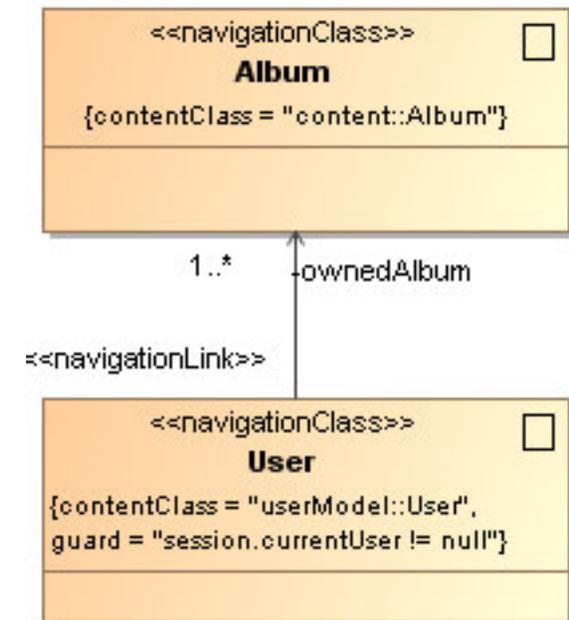 - ■ no additional
    semantics required

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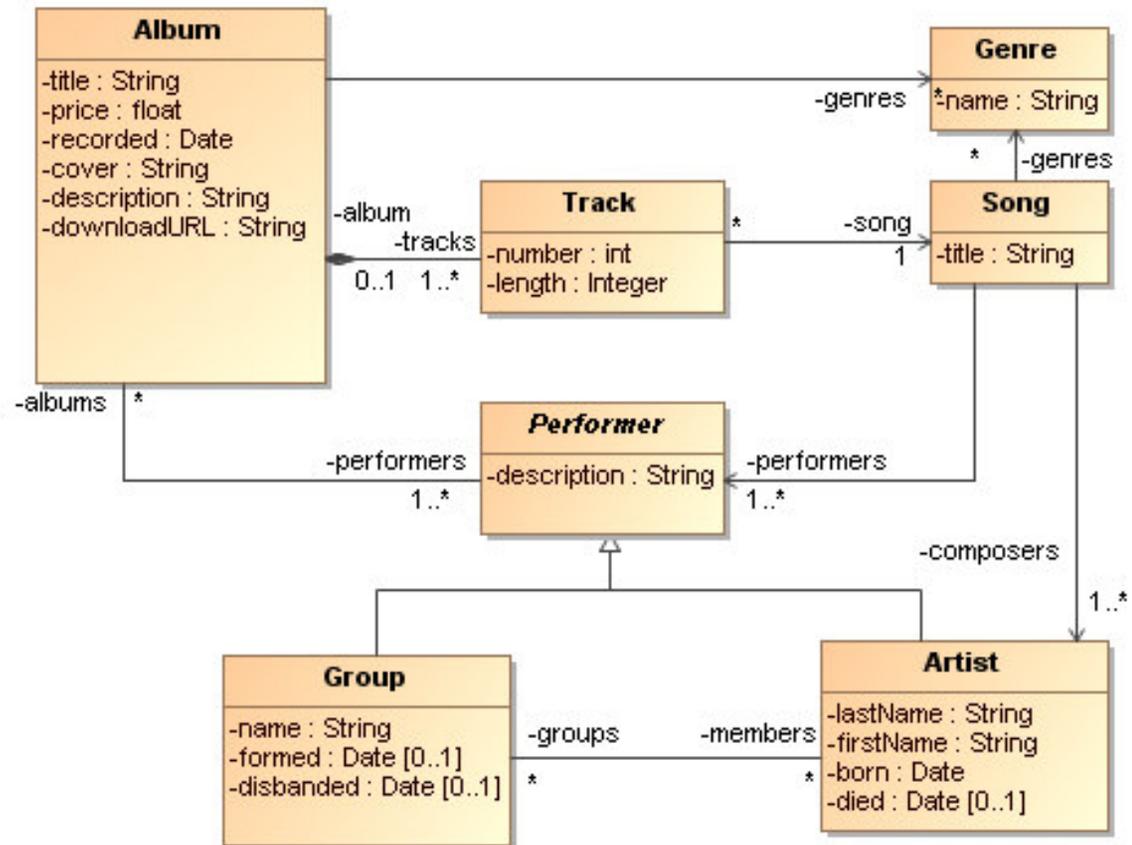
User Model

- Representation of session specific information
  - allows for customization
- Represented as UML class diagram
  - "normal" UML classes
  - Visit object for each session
    - «visitClass»

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Navigation Modelling
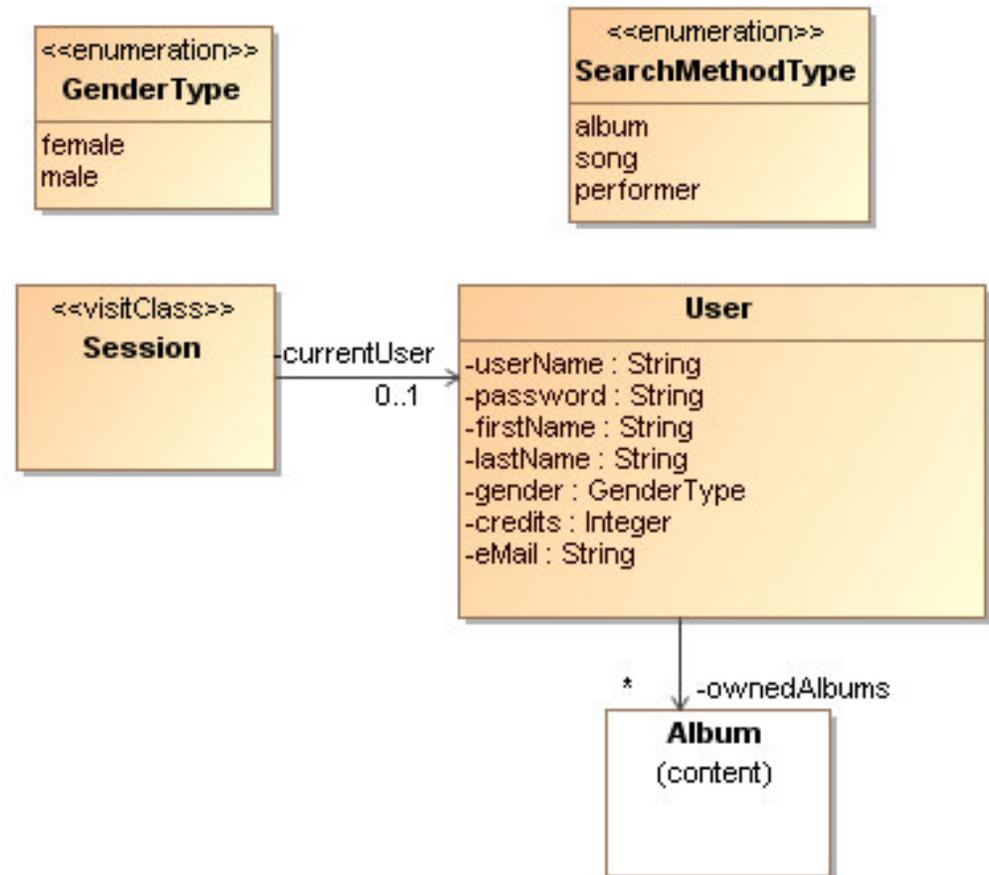
- Goals
  - to represent nodes and links of the hypertext structure
  - to design navigation paths
  - to avoid disorientation and cognitive overload
- Navigation model
  - represented by a UML class diagram
  - uses specific modelling elements for Web concepts
- Basic elements to model the core hypertext structure

  - «navigation class» specifies a hypertext node visited by a user through browsing (related to a content class)

  - «navigation link» specifies a hyperlink used to access the target navigation object from the source navigation object
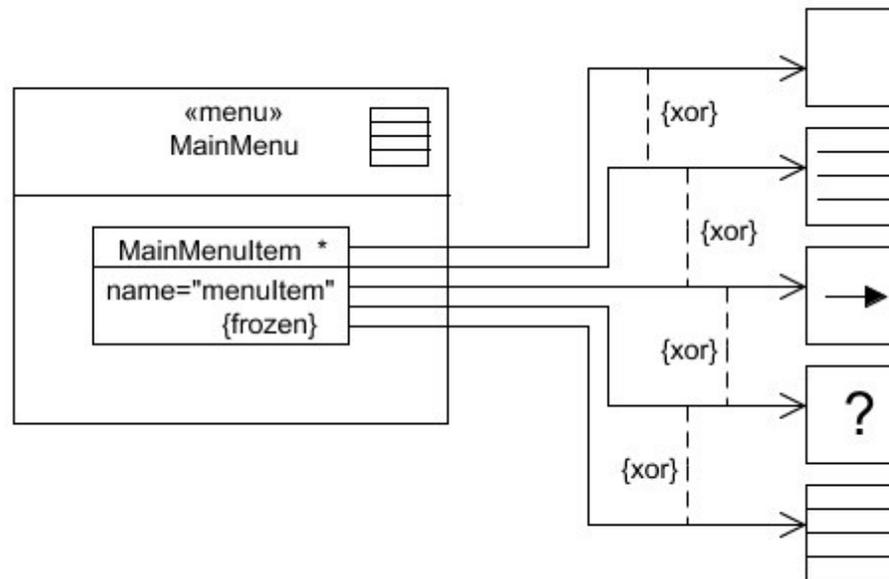
<<navigationClass>>
Album
{contentClass = "content::Album"}

1..* +ownedAlbum

<<navigationLink>>

<<navigationClass>>
User
{contentClass = "userModel::User",
guard = "session.currentUser != null"}

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Access Primitives

- Systematic enhancement of the navigation structure model by
  - «index» for all navigation links which have multiplicity > 1 at the directed association end
  - «menu» for all navigation classes with more than 1 outgoing association
- Design decision to include
  - «guidedTour» instead of index
  - «query» for selection of instances of a navigation class
  - tagged value home to indicate starting point of the application (node without ingoing links)
  - tagged value landmark to indicate that a node is reachable from everywhere (all other nodes include a link to the landmark node)
- Shortcuts for more complex constructs (if represented in UML without extension)

<<index>>	<<query>>	<<menu>>
AlbumIndex	**SearchAlbum**	**MainMenu**
{itemType = "content::Album"}	-title : String	

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Navigation Model Elements: Menu

- **Menus** are used to structure the outgoing links from a node

  - usually associated to a navigation class by composition

  - consists of a set of links to heterogeneous elements, such as indexes, guided tours, queries, instances of navigation classes or other menus
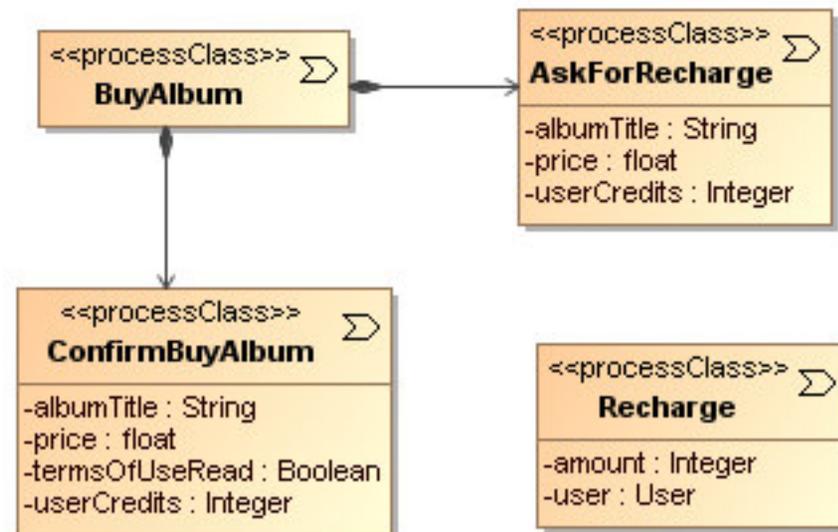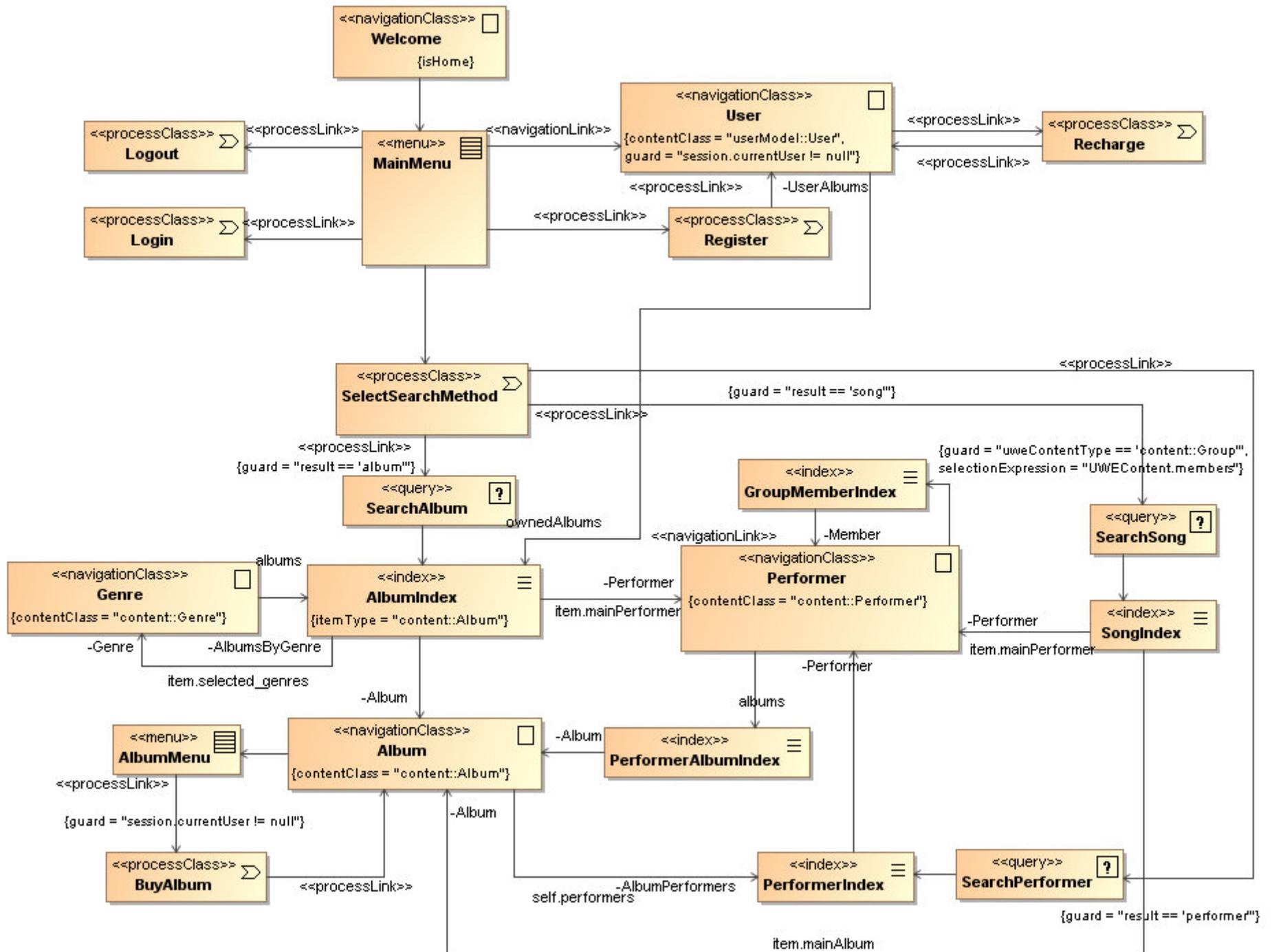
  - UML stereotype: «menu»

- Semantics of menu

Navigation Model

(excerpt)

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Modelling Processes in UWE

- Navigation model of a Web application
  - represents the static information structure accessible to a user of the system
  - specifies browsing (navigation) functionality
- Process model
  - represent the dynamic aspects of a Web application
  - specifies functionality, such as transactions and complex workflows of activities
- Process modelling consists of
  - definition of process classes (for non-navigation use cases)
  - integration of these process classes in the navigation model
  - description of the behaviour through a process flow
    - represented as UML activity diagram

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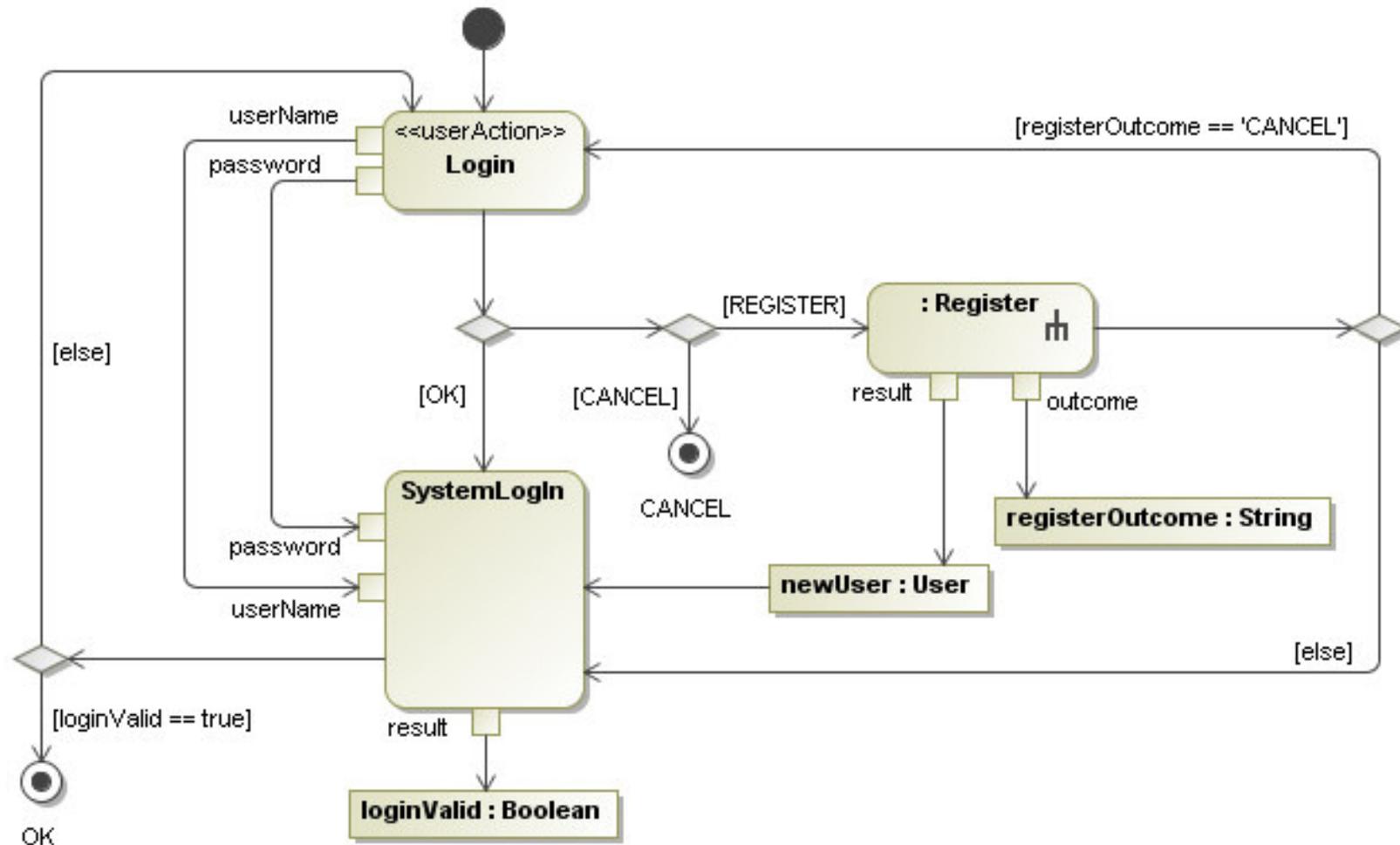Tool Support

Process Elements

- **Process class** represents the process through which the user will be guided in the Web application
    - for complex process that require more than a single class, an additional process model is built
    - UML stereotype: «process class»

- **Process link** is used to model the association between a «navigation class» and a «process class»
    - indicates entry points and exit points of processes within the navigation structure
    - UML stereotype: «process link»

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Modelling the Process Flow

- The behavior of a Web process is defined by the process flow model
    - represented by UML activity diagram
    - result of the refinement of the activity diagram drawn for requirements specification
    - «process class» stereotype
    - optional use of nested activity diagrams

- Process flow consists of
    - flow of execution represented by activity nodes connected by activity edges
    - control nodes that provide flow-of-control constructs, such as decisions and synchronization
    - object nodes that represent data flowing along object flow edges or pins associated to the actions
    - in UML2 the semantic of activities is based on control and data token flows, similar to Petri nets

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Process Model: Login

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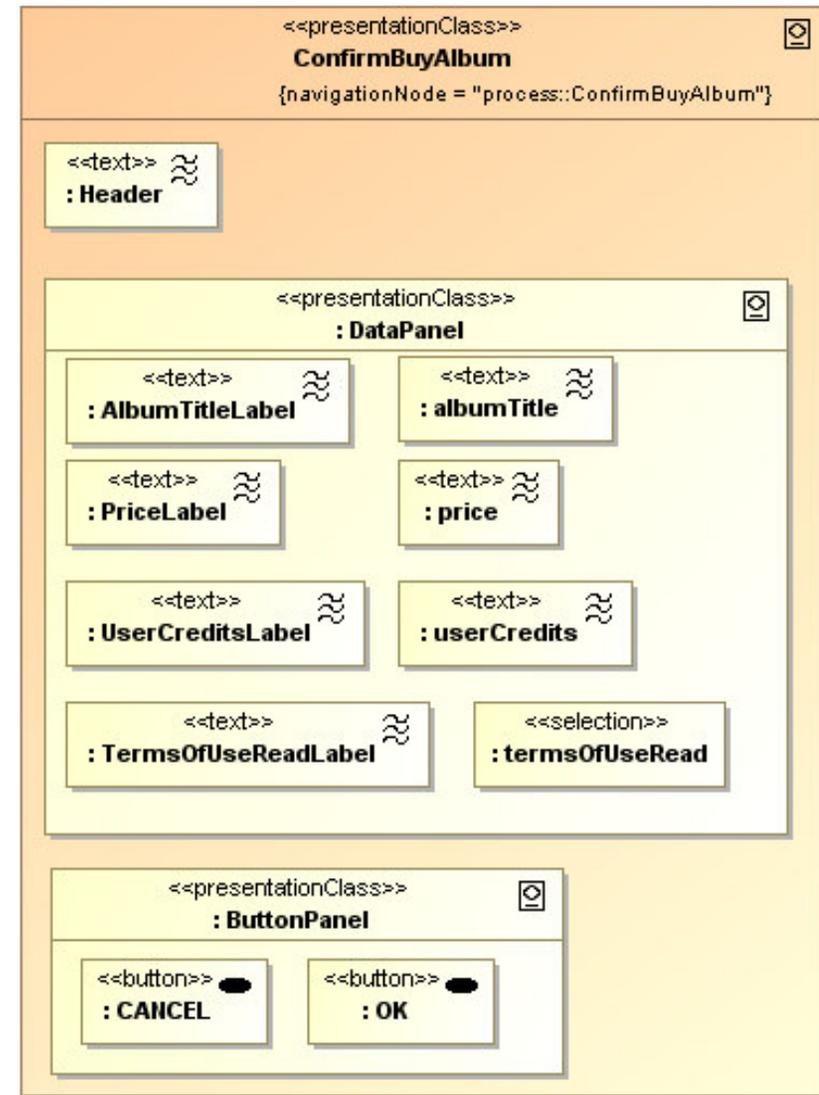
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Modelling Presentation

- Representation of layout for the underlying navigation and process models
  - is an abstract presentation
  - concrete presentation requires specification of additional physical properties of the layout
    - colour, position, …
    - # of columns in table, type of menu, …

- Presentation classes represent Web pages or part of pages
  - composition of user interface elements
  - hierarchical composition of presentation elements

- UML class diagram for the structure of the presentation
  - using UML container notation

- UML interaction diagram (sequence diagrams)
  - used for modelling behaviour of presentation classes (classical UML)

- Alternative: development of a prototype

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Presentation Model Elements

- **Structural presentation elements**

  - **«presentationClass»/ «presentationGroup»:** container of user interface elements representing a logic unit of presentation associated to a navigation class or process class

  - **«presentationPage»:** presentation class at highest level

  - **«presentationAlternatives»:** container for presentation classes which are not shown simultaneously

- **User interface elements**

  - **«anchor»**
  - **«button»**
  - **«text»**
  - **«image»**
  - **«textInput»**
  - **«selection»**
  - **...**

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Adaptive Web Applications

- Adaptation/Customization for
  - user properties: knowledge, tasks, preferences, interests
  - context properties: location (place and time) & platform (HW, SW, network)
- Update of a user model / context model
  - observation of the user behaviour or environment by the system
- Techniques for adaptation
  - content adaptation
    - inserting and removing text/multimedia features
    - content variants
  - navigation adaptation
    - link ordering
    - link annotation
    - link hiding
    - link generation
  - presentation adaptation
    - modality adaptation (audio or text)
    - language selection
    - layout variants (resizing of fonts, images, changing colours)

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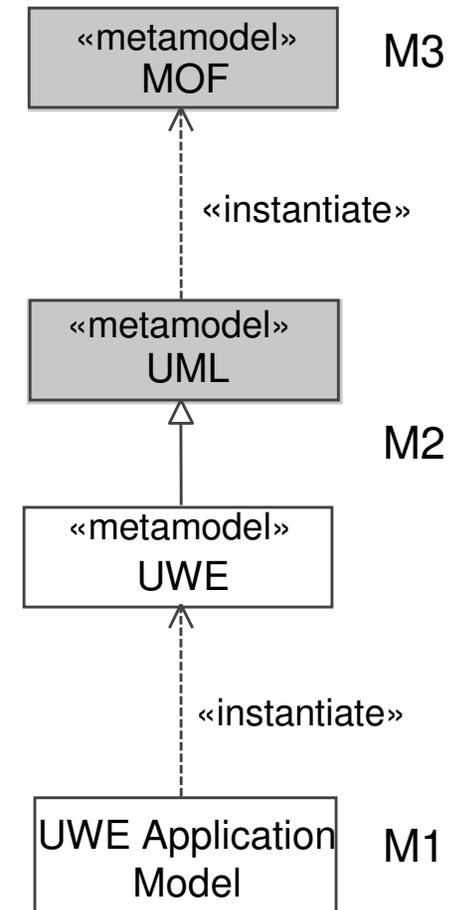Tool Support

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Modelling Adaptivity

- UWE uses a technique called Aspect-Oriented Modelling (AOM)

- Identification of
    - «pointcut» (including conditions)
    - «advice»
- Weaving the result into the web application based on
    - current state of the user model
    - information provided by link traversal
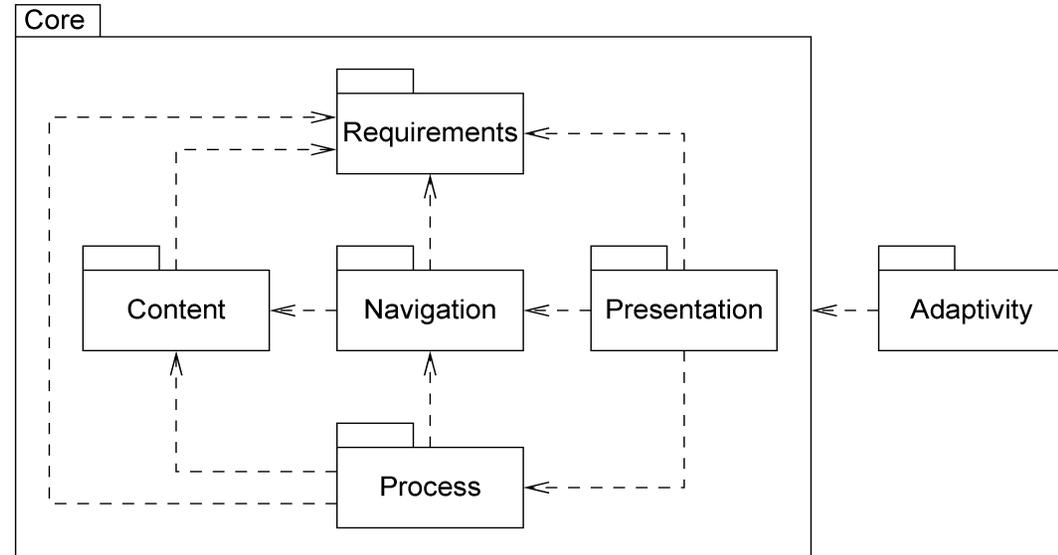- Example: links only visible for registered users to
    - BuyAlbum

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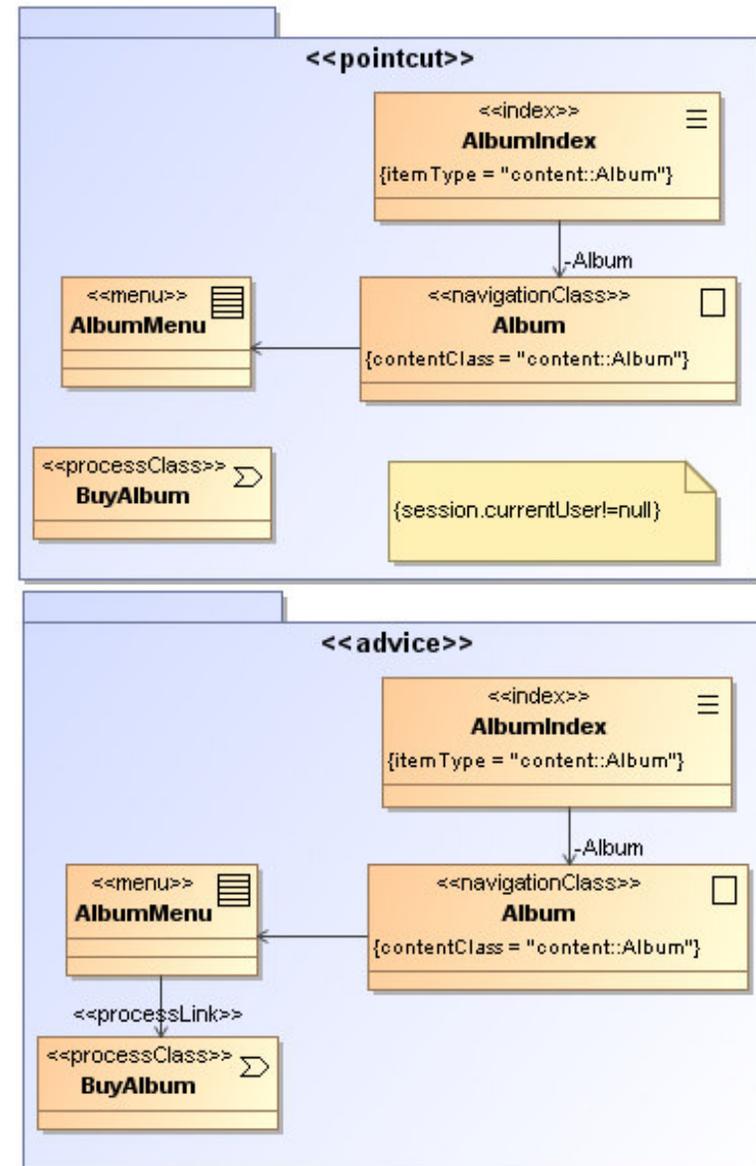
UWE Metamodel

- UWE Metamodel is defined as a conservative extension of UML 2.0
    - model elements of the UML metamodel are not modified
    - all new elements are related by inheritance to at least one model element of the UML
    - use of OCL to specify additional semantics of the new elements
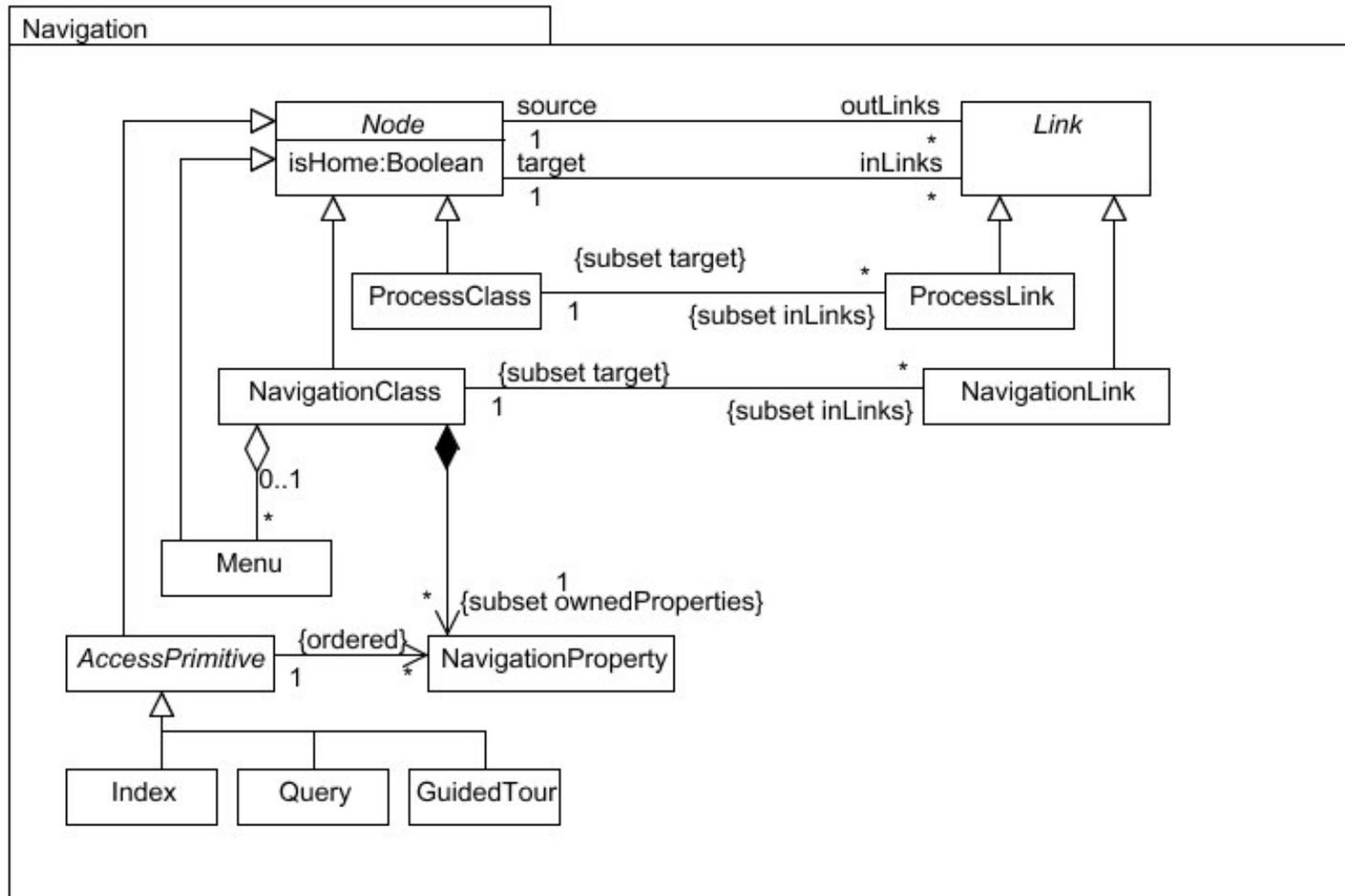   - so-called light-weighed extension of UML

«metamodel»
MOF   M3

⫶ «instantiate»

«metamodel»
UML   M2

«metamodel»
UWE

⫶ «instantiate»

UWE Application   M1
Model

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UWE Metamodel Characteristics

- **UWE metamodel**
  - reflects separation of concerns in the structure of Core
  - shows cross-cutting aspect of adaptation
- **UWE metamodel is profileable**
  - mapping to a UML profile is possible
- **UWE metamodel is MOF compatible**
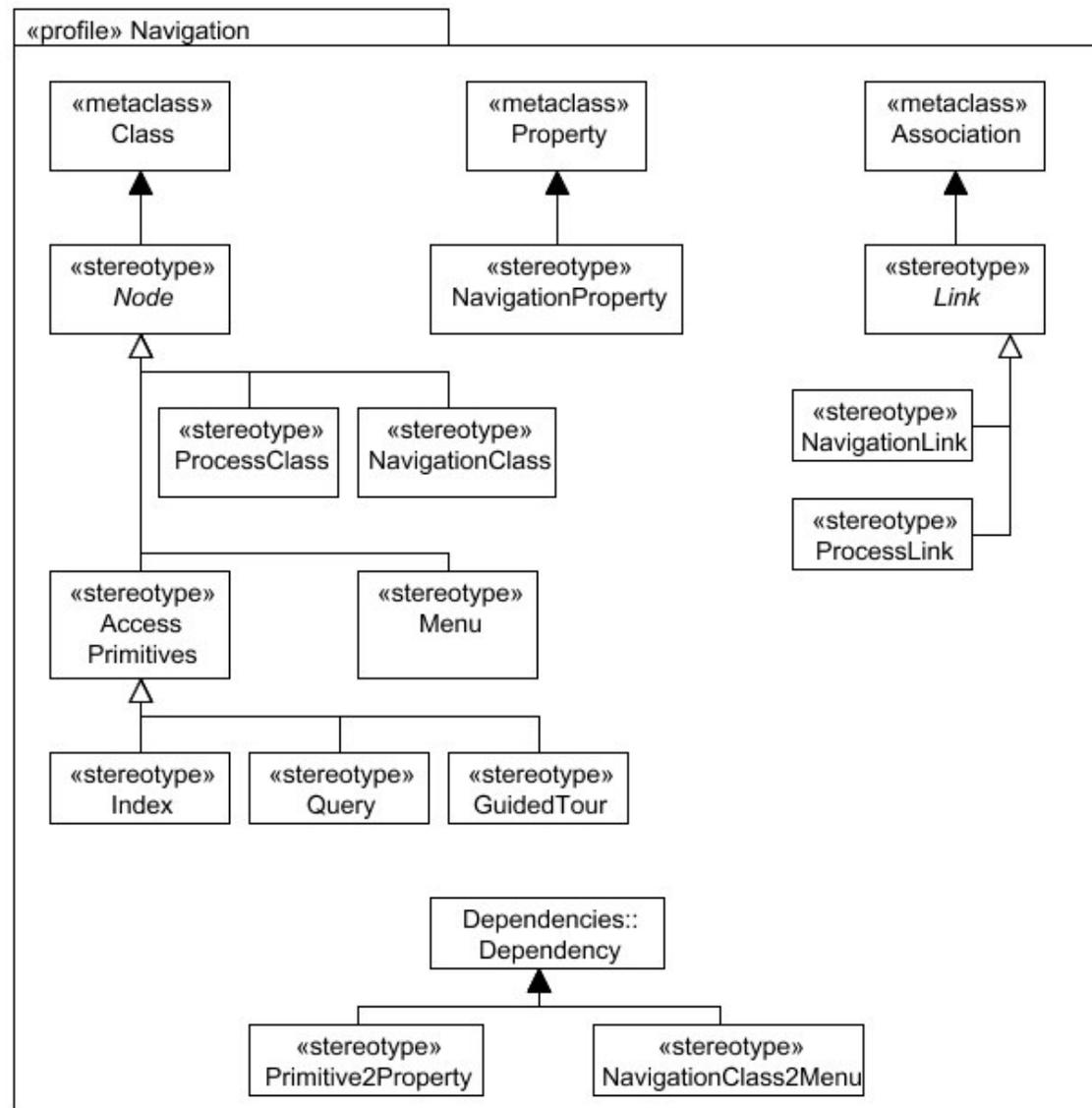 - uses XML metadata interchange format (XMI)

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UWE Metamodel: Navigation

(see stereotypes used in the example)

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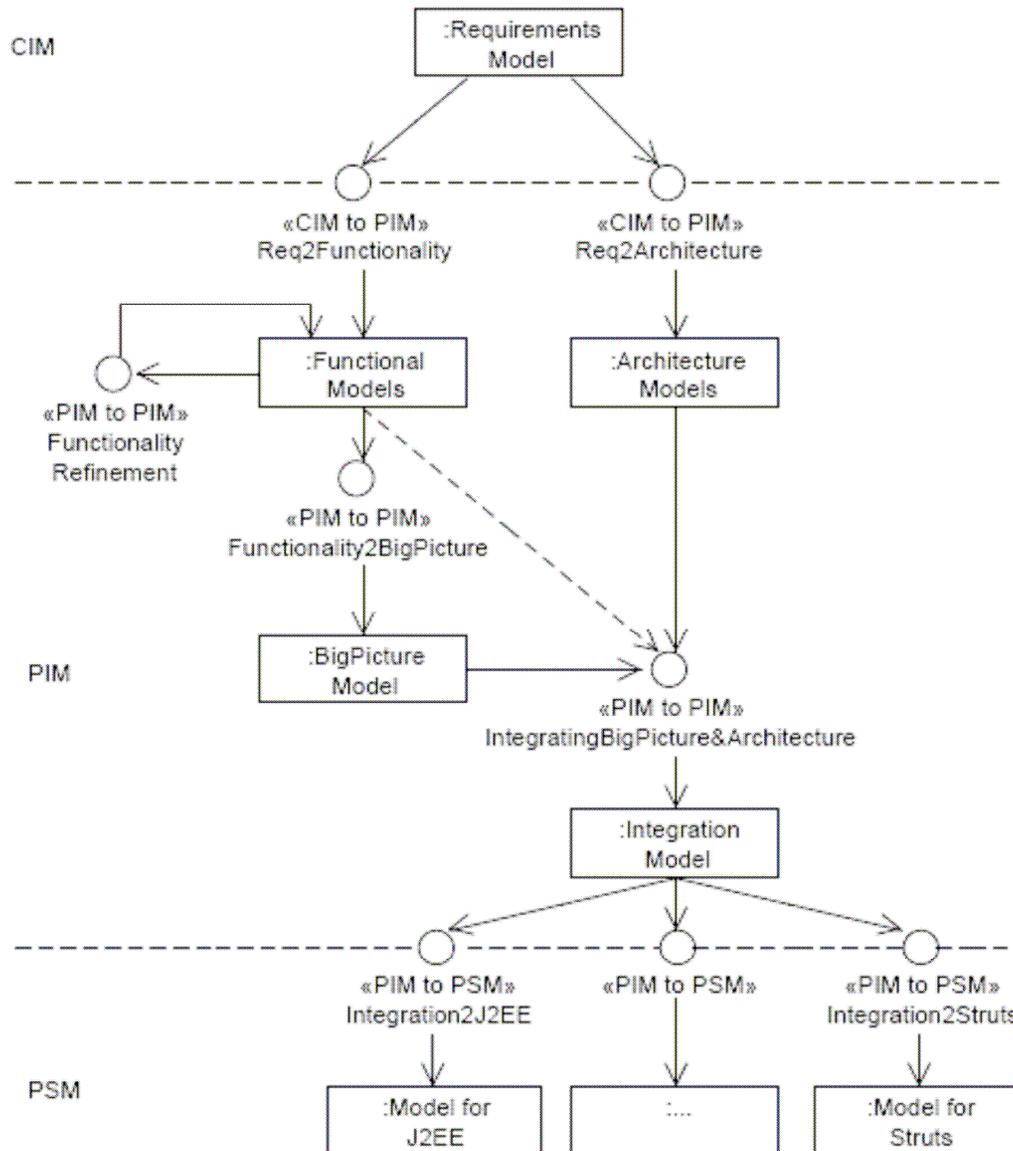Development Process
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UWE Profile: Navigation

- UML stereotypes for Web specific concepts used for the specification of the hypertext structure
- Extends relationships
- UML metaclasses

«profile» Navigation

«metaclass» Class

«stereotype» *Node*

«stereotype» ProcessClass

«stereotype» NavigationClass

«stereotype» Access Primitives

«stereotype» Menu

«stereotype» Index

«stereotype» Query

«stereotype» GuidedTour

«metaclass» Property

«stereotype» NavigationProperty

«metaclass» Association

«stereotype» *Link*

«stereotype» NavigationLink

«stereotype» ProcessLink

Dependencies:: Dependency

«stereotype» Primitive2Property

«stereotype» NavigationClass2Menu

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Model-Driven Process of UWE

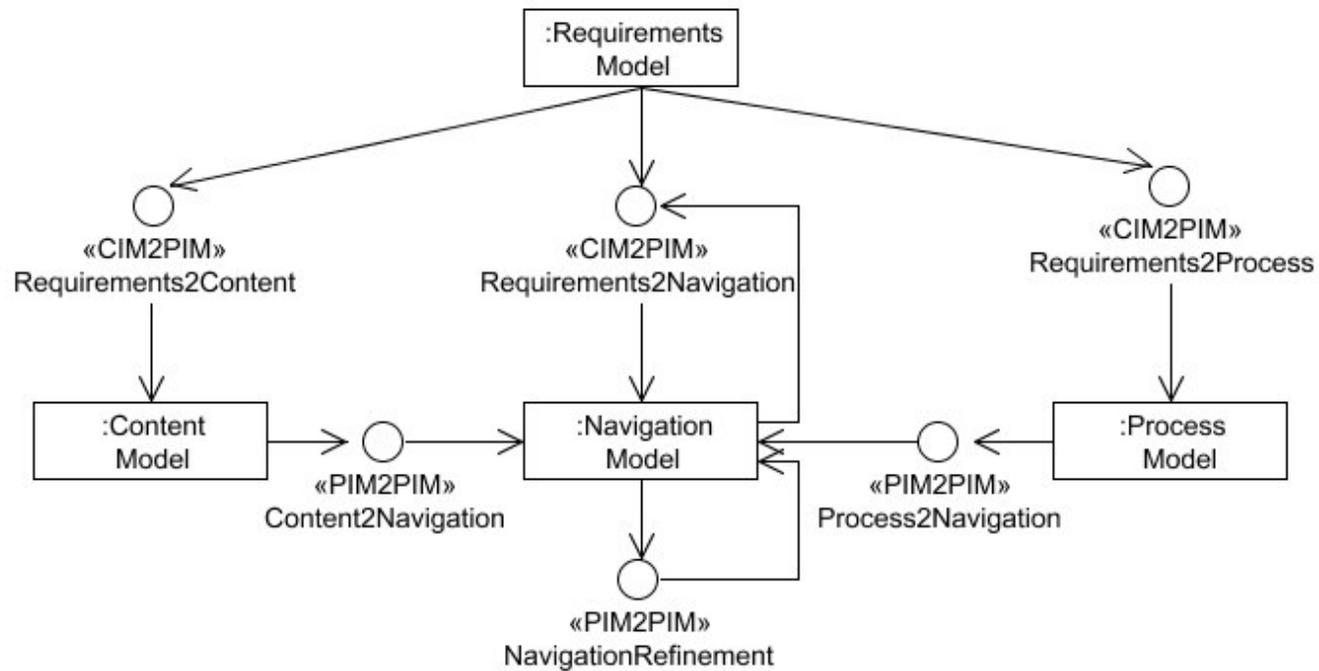- Graphical representation of the process
  - process as UML activity diagram
  - model transformations as stereotyped UML actions
  - models as UML object flow states
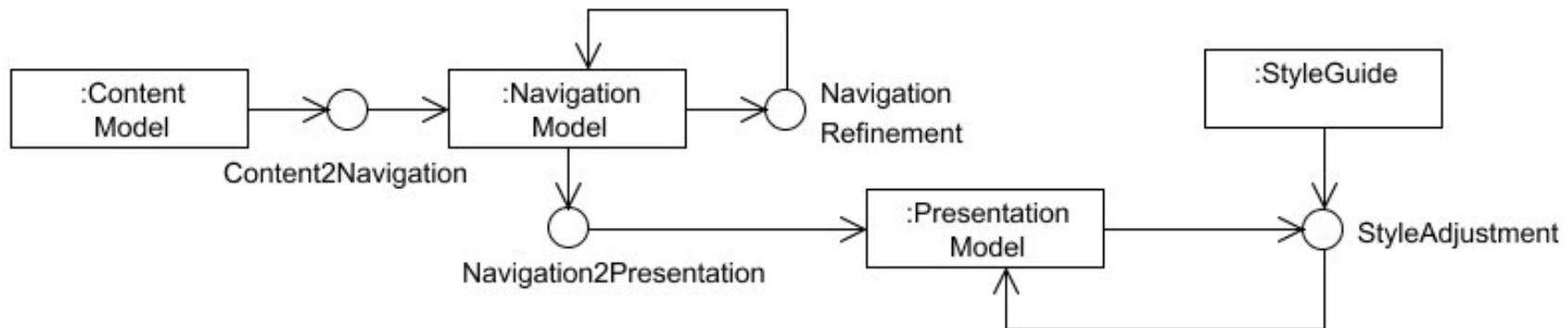 - implicit initial and final state
- Types of models in UWE
  - requirements model (CIM)
  - functional models (PIM)
    - content model
    - navigation model
    - …
  - architecture models (PIM)
  - integration models (PIM)
  - models for J2EE, .Struts (PSM)

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UWE Development Process
Requirements to Functional Models

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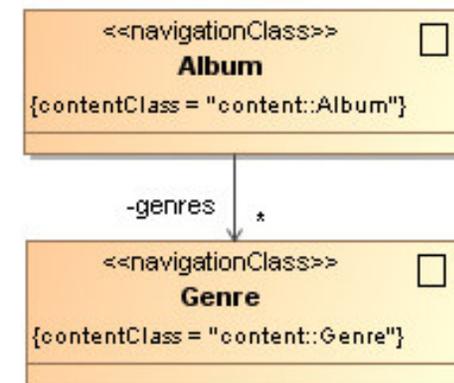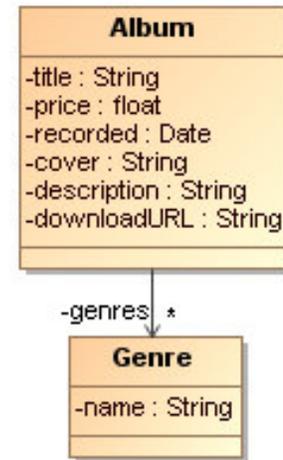Tool Support

Construction of Functional Models

- **UWE metamodel and UWE profile**
  - navigation elements: *navigation class, navigation link, index*, …
  - presentation elements: *presentation class, anchor, image*, …

- **Case tool ArgoUWE/MagicUWE**
  - extension of ArgoUML/MagicDraw
  - provides UWE Profile
  - supports (semi-)automatic execution of transformations

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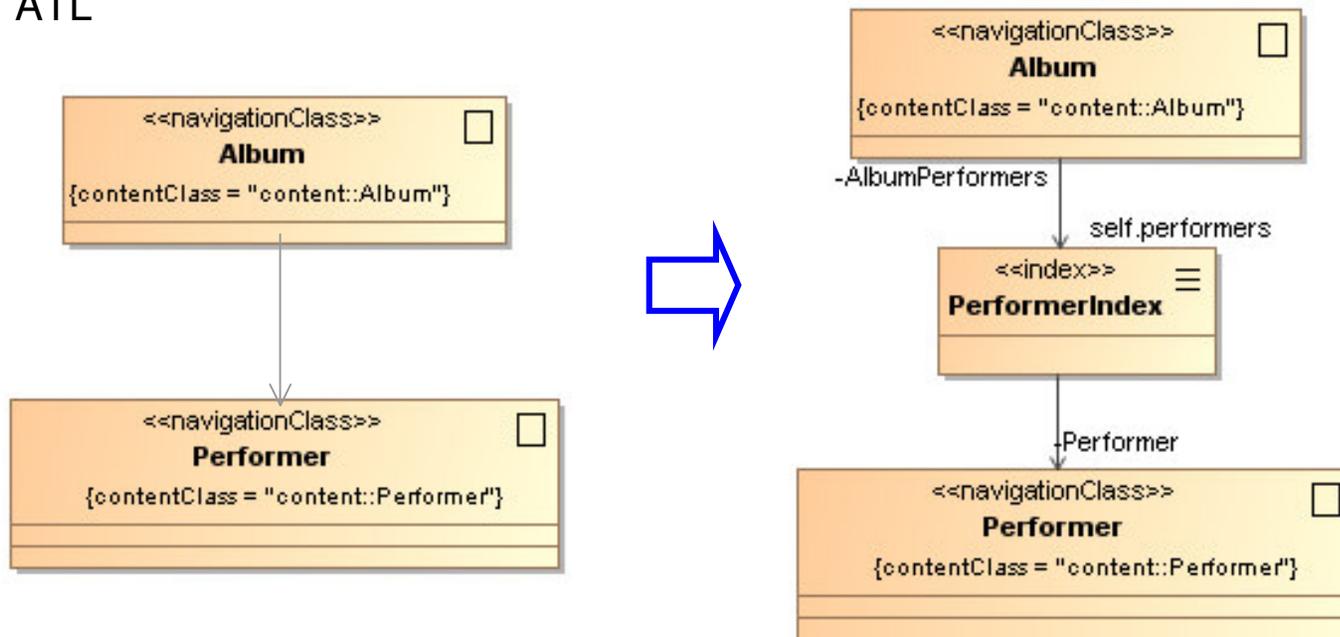# Transformation Content to Navigation

- Content2Navigation
    - generates navigation classes from content classes
    - adds a navigation links based on associations of the content model
- Marking elements
    - identification of classes of the content model that are relevant for the navigation view
    - task performed by designer
- Implementation
    - ArgoUWE/MagicUWE plugin implemented in Java
    - ATL (ATLAS Transformation Language)

Album

-title : String
-price : float
-recorded : Date
-cover : String
-description : String
-downloadURL : String

-genres *

Genre

-name : String

<<navigationClass>>
Album
{contentClass = "content::Album"}

-genres *

<<navigationClass>>
Genre
{contentClass = "content::Genre"}

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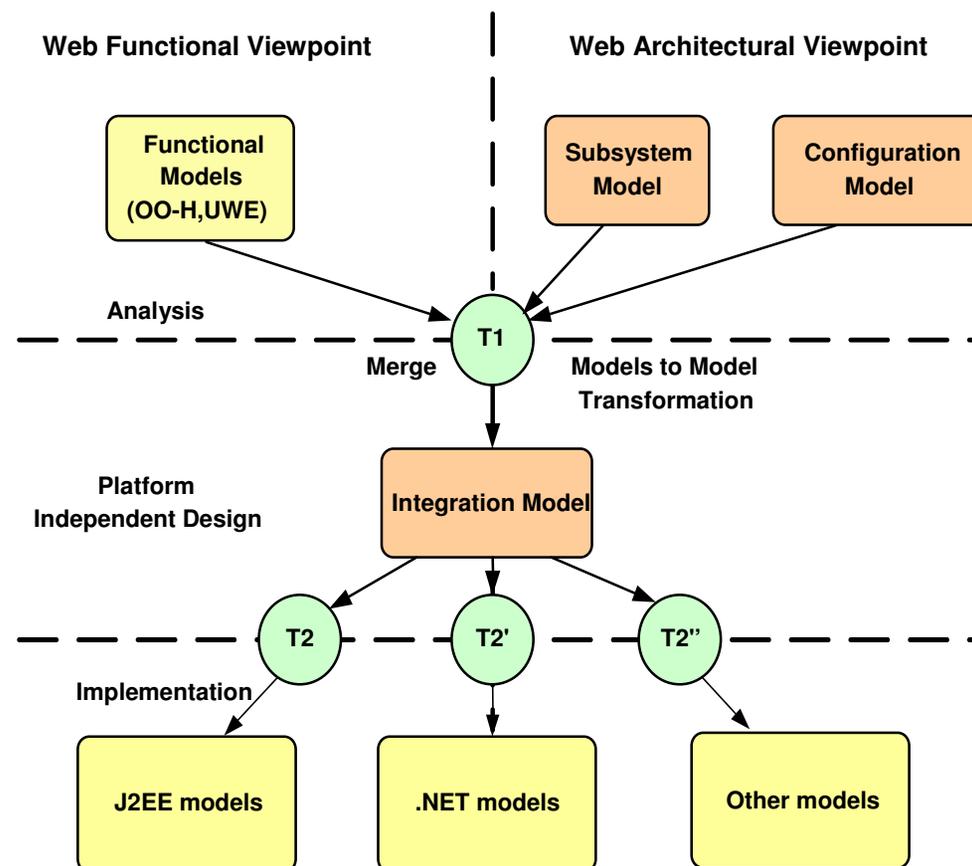Tool Support

Refinement of Navigation Model

- Improvement based on patterns
  - index for associations with multiplicity greater than one at the directed association end
  - menu for navigation classes with multiple outgoing associations
- Implementation
  - Java in ArgoUWE/MagicUWE
  - ATL

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Integration with Architecture Models

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- Web Software Architecture (WebSA) approach*

  - domain specific language for modelling architectural views of Web applications
    - subsystem model
    - configuration model
    - integration model

  - UML profile of architectural modelling elements
    - Web component
    - Web port
    - Web connector
    - server page,
    - etc.

  - model transformations
  - written in QVT-P

Web Functional Viewpoint   **Web Architectural Viewpoint**

Functional Models (OO-H,UWE)   Subsystem Model   Configuration Model

Analysis   T1

Merge   Models to Model Transformation

Platform Independent Design   Integration Model

T2   T2'   T2''

Implementation

J2EE models   .NET models   Other models

Santiago Melía, University of Alicante, PhD Thesis (2007)

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Generating "Big Picture" Model

- Generation of an integrated functional model ("big picture")
  - transformation target UML state machine for integration of content, navigation and process models
  - graph transformation language
  - tool: Attributed Graph Grammar System (AGG)
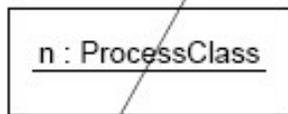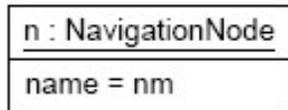 - validation of correctness by model checking

```
┌──────────┐    ┌───────────┐    ┌──────────┐
│ :Content │    │:Navigation│    │ :Process │
│  Model   │    │  Model    │    │  Model   │
└──────────┘    └───────────┘    └──────────┘
        \            │            /
         \           ▼           /
          ──────►   ( )   ◄──────
             «PIM2PIM»
          Functional2BigPicture
                    │
                    ▼
            ┌──────────────┐
            │ :Big Picture │
            │    Model     │
            └──────────────┘
```

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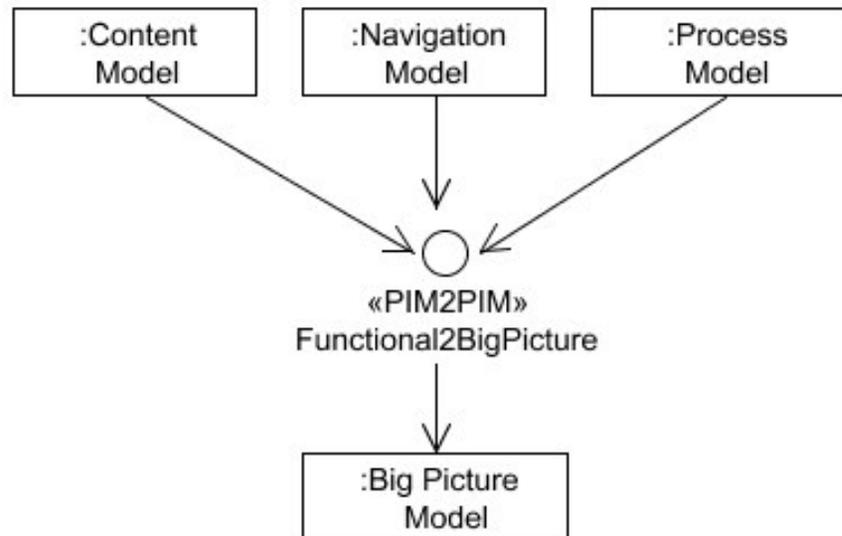
Big Picture: Transformation of Navigation Model

- Capture navigation nodes as states (with parameters for data)

left-hand side pattern

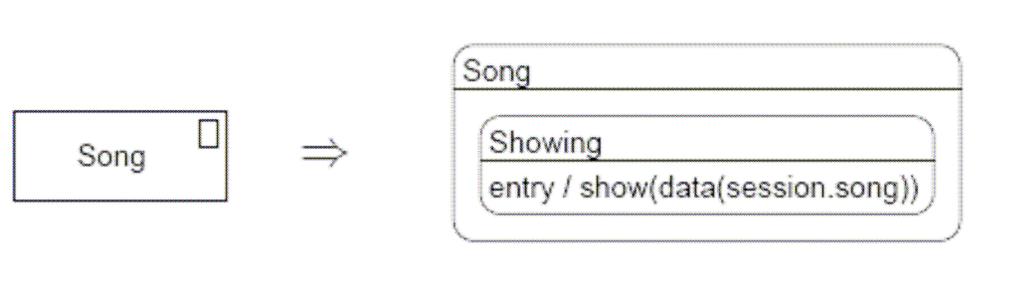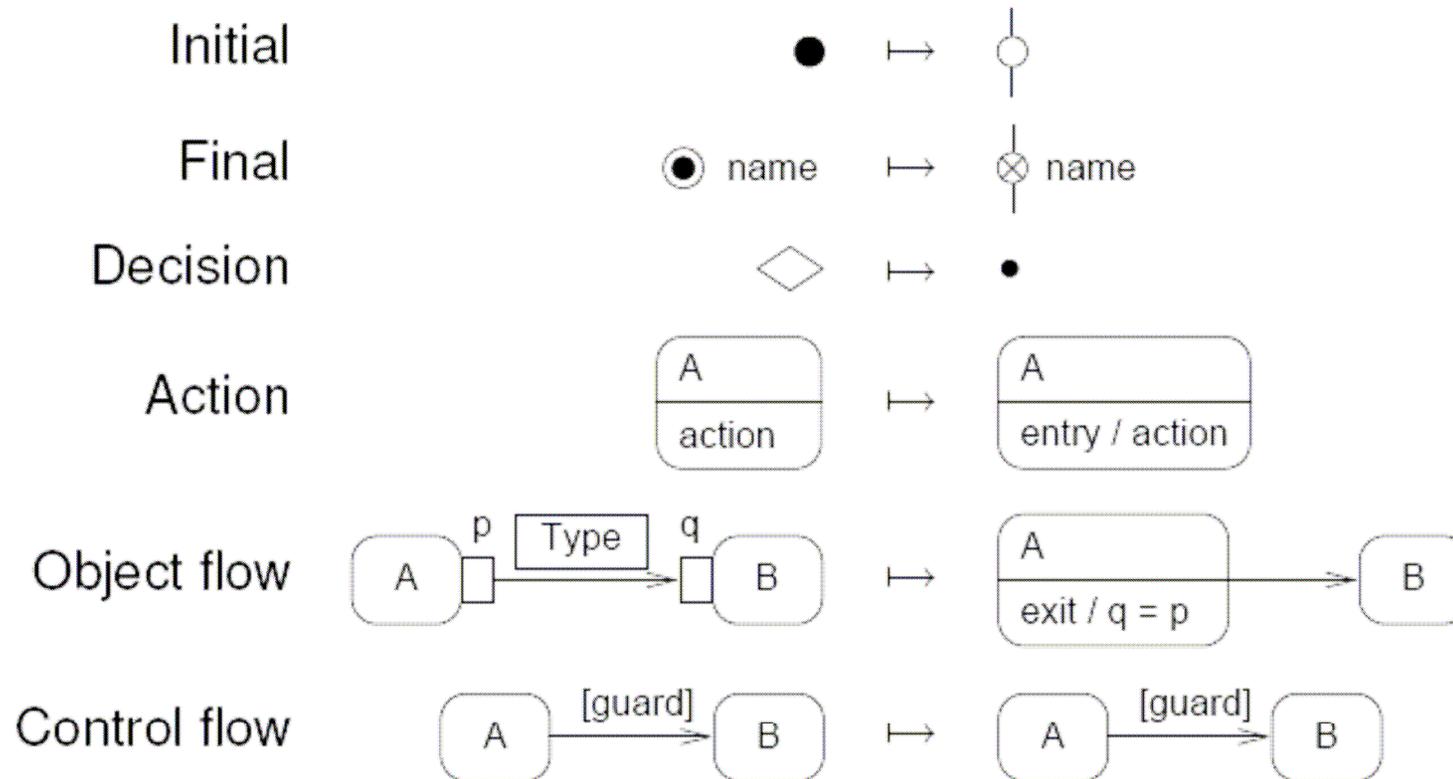| n : NavigationNode |
|---|
| name = nm |

n : ProcessClass

negative application condition

$\Rightarrow$

: State
name = nm
isComposite = true
isHome = isHome(n)
isGuidedTour = isGuidedTour(n)
isContent = isContent(n)

state ◆——— region | : Region |

region ◆

subVertex

: OpaqueBehavior
body = "show(data("+translate(n)+"))"

entry ◆———

Showing : State
isSimple = true
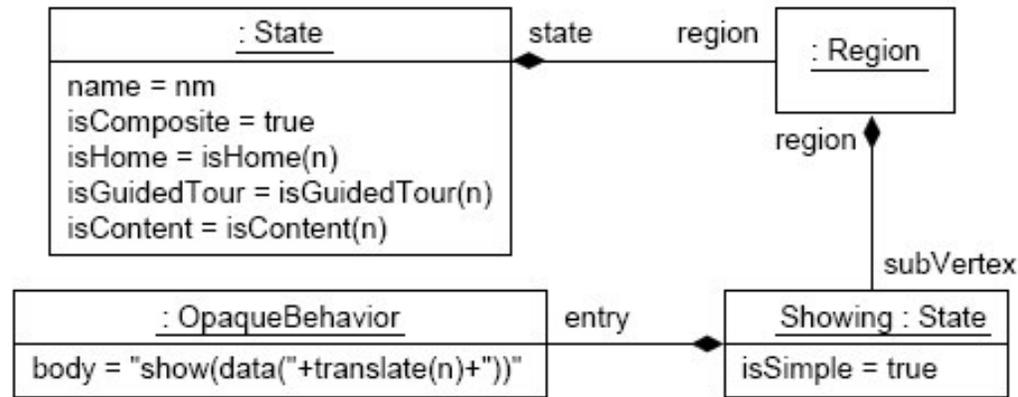
right-hand side

- Example: music portal: transformation for navigation node "song"

Song	☐

$\Rightarrow$

Song
> Showing
> entry / show(data(session.song))

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Big Picture: Transformation of Business Process

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Initial	●	↦ ○
Final	⦿ name	↦ ⊗ name
Decision	◇	↦ ●
Action	A / action	↦ A / entry / action
Object flow	A p [Type] q B	↦ A exit / q = p → B
Control flow	A [guard] → B	↦ A [guard] → B

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Model Validation

- Model transformations for Web applications based on UWE and its UML-based metamodel

- Graph transformations into integrating UML state machine

- Model validation by model checking using Hugo/RT (http://www.pst.ifi.lmu.de/projekte/hugo)

- Automation of transformation process using Attribute Graph Grammars (AGG)

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Generation of Web Applications

- UWE uses a transformational approach
    - to generate data model and presentation layer
    - based on content, navigation structure and presentation models
    - transformation rules from UWE content model to Java beans
    - transformation rules from UWE presentation model to Java Server Pages (JSPs)
- UWE uses an interpretational approach
    - using a virtual machine
    - to interpret the process model (activity diagrams)
    - configuration data for the virtual machine is generated from process and navigation model
- Implemented so far
    - using the Spring framework
    - transformations defined in ATLAS Transformation Language (ATL)

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Model to Code Transformations

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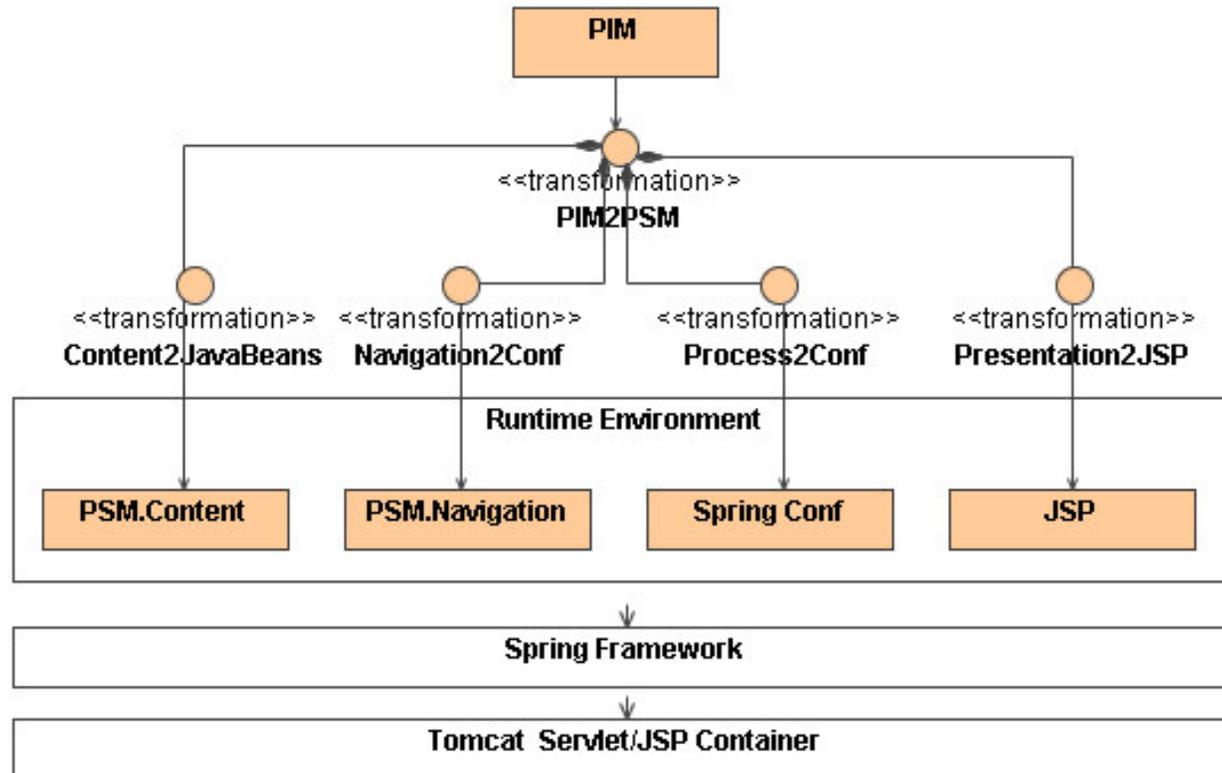
Classification of UWE Model Transformations

Characteristics Transformation	Type	Complexity	Marks	Execution	Techniques
Req2Content	CIM to PIM	simple	WebRE profile	automatic	QVT
Req2Architecture	CIM to PIM	simple	-	manual	-
Content2Navigation	PIM to PIM	simple	navigation relevance	semi-automatic	Java, ATL
NavigationRefinement	PIM to PIM	simple	UWE profile & patterns	automatic	Java
Req2Navigation	CIM to PIM	merge	WebRE profile	automatic	QVT
Navigation2Presentation	PIM to PIM	simple	UWE profile	automatic	Java, ATL
StyleAdjustment	PIM to PIM	merge	style guide	automatic	Java
Functional2BigPicture	PIM to PIM	merge	patterns	automatic	graph trans-formations
Functional&Architecture2 Integration	PIM to PIM	merge	UWE & WebSA profile	automatic	QVT-P
Integration2J2EE	PIM to PSM	merge	patterns	automatic	QVT-P, ATL

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Tool Support for UWE

- Goal

  - support of UWE notation for design of Web applications

  - separation of concerns (navigation, process, presentation,…)

  - implementation of UWE development process allowing for semi-automatic model generation

  - support of model validation checking models consistency

  - code generation

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ArgoUWE & MagicUWE

- **Extension of ArgoUML**
  - advantages
    - open source UML CASE tool
    - easy extension of design critics feature for checking model consistency
    - XMI output as basis for code generation
  - disadvantages
    - still based on UML 1.x
    - inherited usability problems
  - Plugin for ArgoUML 0.16

- **Extension of MagicDraw**
  - advantages
    - based on UML 2
    - UML profile definition support
    - XMI output
  - disadvantages
    - commercial tool
    - distribution of UML profile
  - Plugin for MagicDraw 15.0

- **Plugins for other CASE tools**
  - Rational Software Modeller
  - interest in further extensions supporting UWE notation and model transformations

MagicUWE

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Development Environment

- Eclipse based
  - PIM2PIM transformations (ATL)
  - PIM2PSM & PSM2Code (ATL)
  - written in ATL
- Spring Framework
- Java Server Pages

Evolution of UWE

	Modelling Language	Metamodel	Development Process	Tool support
Current Status	UML profile for content, navigation, process, abstract presentation, adaptation	Conservative extension of UML metamodel (light-weight) and profileable	Different languages for model transformations	CASE tool ArgoUWE, Eclipse plugins Spring JSP
Ongoing Work	Extension for concrete presentation, requirements and services	Evolving to include modelling elements for concrete presentation and services	Model transformation language ATL	Plugin for MagicDraw Eclipse plugins JSF
Future Work	Extension for Web 2.0	Evolving to include modelling elements for Web 2.0	Model transformation language QVT (if standardized)	Plugins for other CASE tools Editors for development environment

Vision for Model-Driven Web Engineering

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Literature
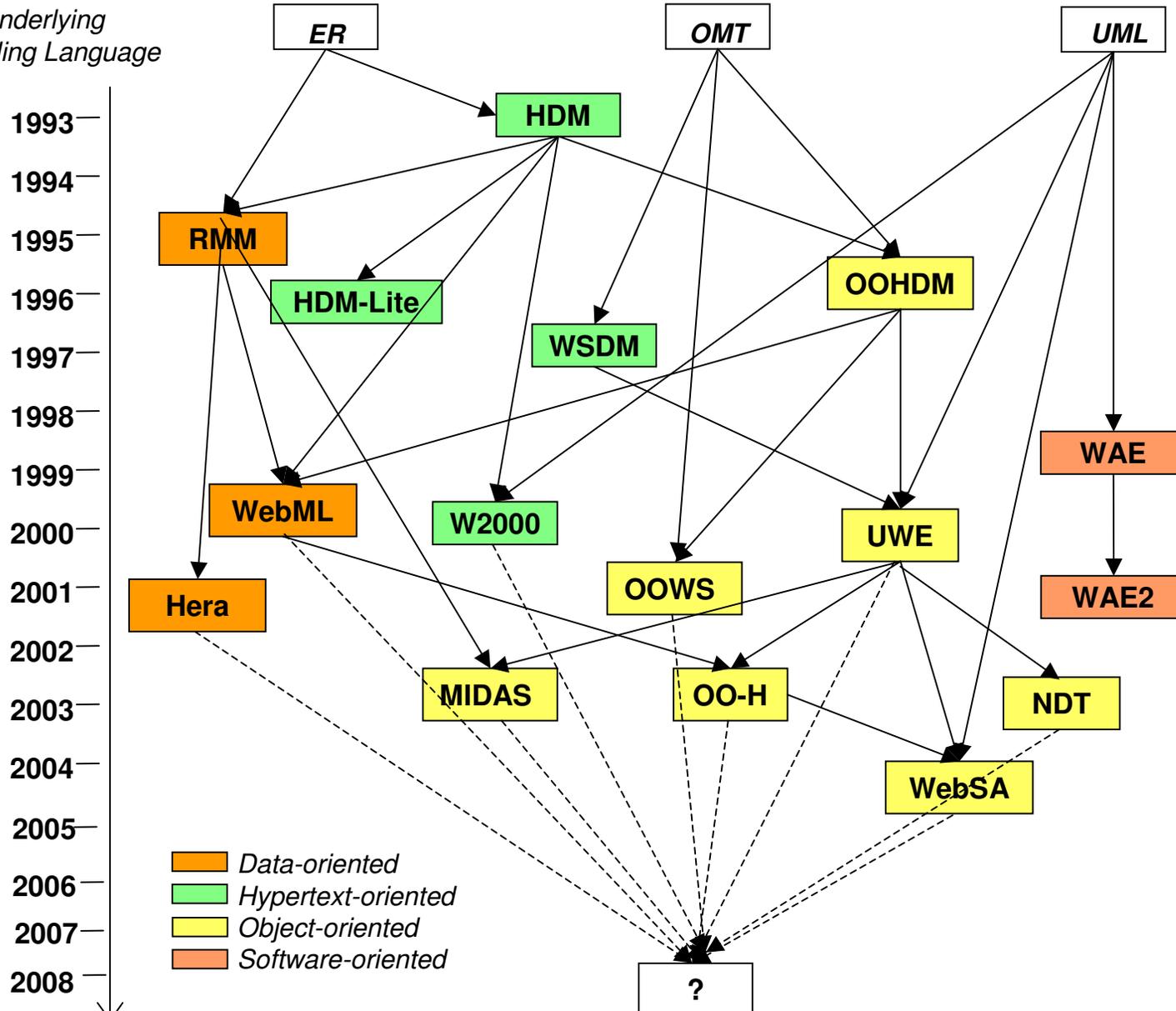
- **Web Engineering: Modelling and Implementing Web Applications**

  G. Rossi, O. Pastor, D. Schwabe, L. Olsina (eds.), Springer (2008).

- **Web Engineering: Systematic Development of Web Applications**

  Gerti Kappel, Birgid Pröll, Siegfried Reich, Werner Retschitzegger (eds.)

  dpunkt-verlag (German version), 2003,

  John Wiley & Sons (English version), 2006.

- **Model-Driven Generation of Web Applications in UWE**

  Andreas Kraus, Alexander Knapp and Nora Koch

  3rd International Workshop on Model-Driven Web Engineering (MDWE 2007), Como, Italy

- **Metamodelling the Requirements of Web Systems**

  María José Escalona and Nora Koch

  2nd International Conference on Web Information Systems and Technologies (WebIST'06), Setubal, Portugal, pages 310-317. INSTICC, 2006.

- **Modelling Adaptivity with Aspects**

  Hubert Baumeister, Alexander Knapp, Nora Koch and Gefei Zhang

  5th International Conference on Web Engineering (ICWE 2005), Sydney, Australia, LNCS 3579, 406-416, 2005.
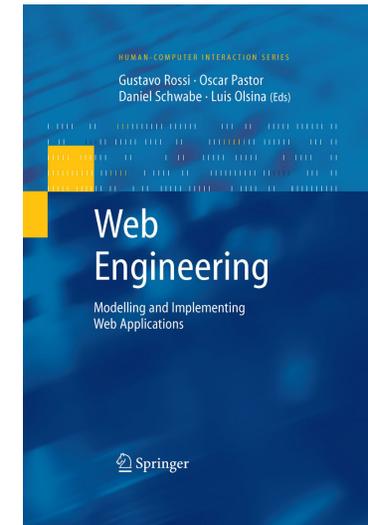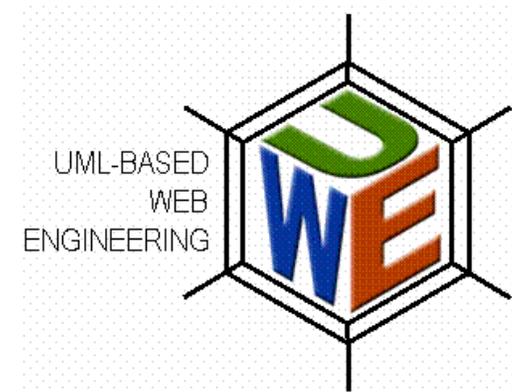
Muchas gracias!

Nora Koch
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