Object-Oriented Connector-Component Architectures

H. Ehrig[1] B. Braatz[1] M. Klein[1,2] F. Orejas[2]
S. Pérez[2] E. Pino[2]

[1]Institut für Softwaretechnik und Theoretische Informatik
Technische Universität Berlin
Berlin, Germany

[2]Departament de Llenguatges i Sistemes Informàtics
Universitat Politècnica de Catalunya
Barcelona, Spain

Formal Foundations of Embedded Software and Component-Based Software Architectures
Edinburgh, 9th April 2005

Outline

Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

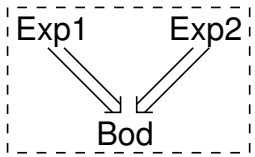
Generic Architecture Framework

- Framework for Connector-Component Architectures
- Generic w. r. t.
  - Specification / Modeling Techniques
  - Transformations / Refinements
  - Embeddings / Inclusions
- Existing Instantiations (FESCA 2004):
  - Petri Nets
  - CCS Process Algebra
- New Instantiation:
  - Object-Oriented Specifications / UML Models

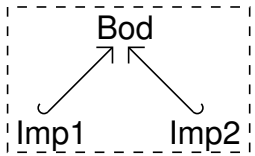
Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

Structure of Components and Connectors

Component as Computation Unit
- *Exports* specify Provisions
- *Body* specifies Realization
- Connected by *Transformations*



Connector as Coordination Unit
- *Imports* specify Requirements
- *Body* specifies Coordination
- Connected by *Embeddings*

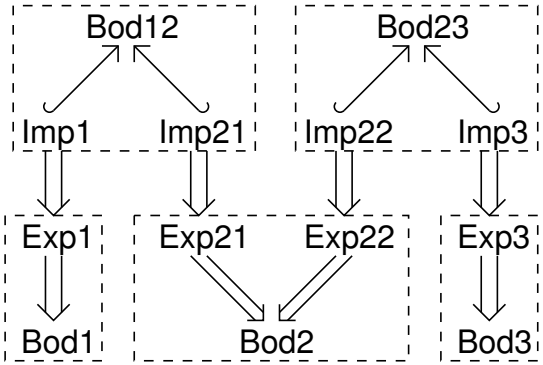


Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

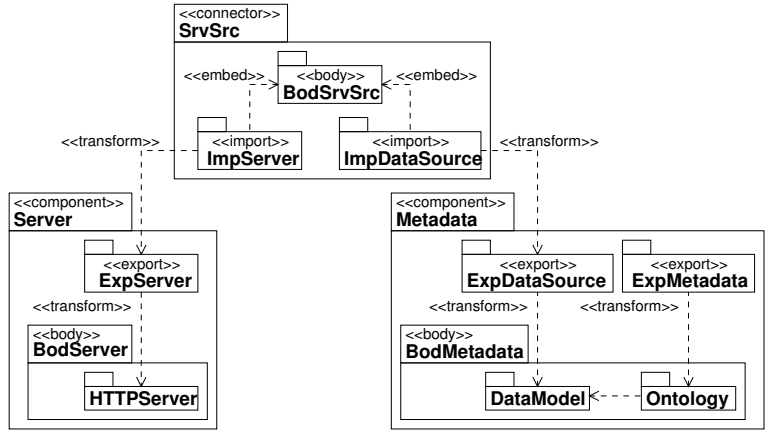
Connector-Component Architectures

Architecture Diagrams:

- Components and Connectors
- Transformations from Imports to Exports



Example Package Architecture



Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

Parallel Extension Property

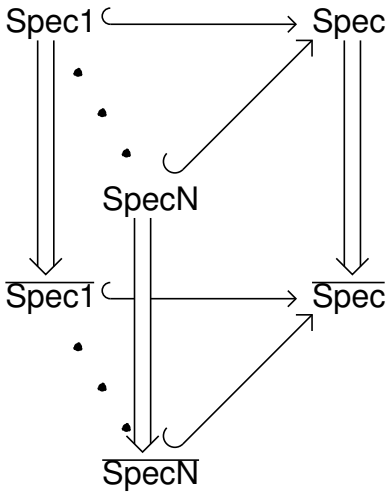
Requirement by the Generic Framework:

Family of Embeddings

and

Family of *Consistent* Transformations

$\Rightarrow$ *Extension* of Transformations along Embeddings

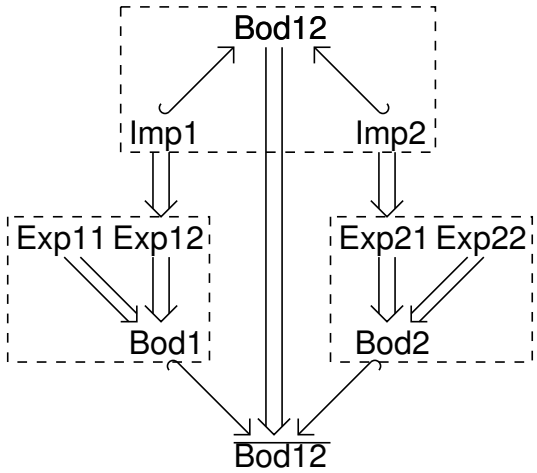


Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

Composition of Components

Connector combining Components

Composed Body by Parallel Extension



Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

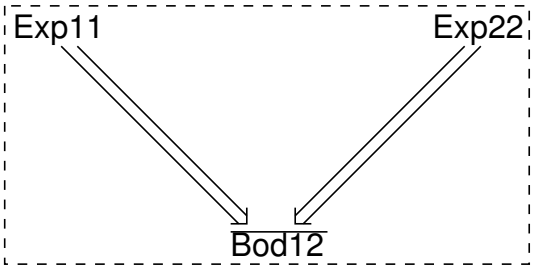
Composition of Components

Connector combining Components

Composed Body by Parallel Extension

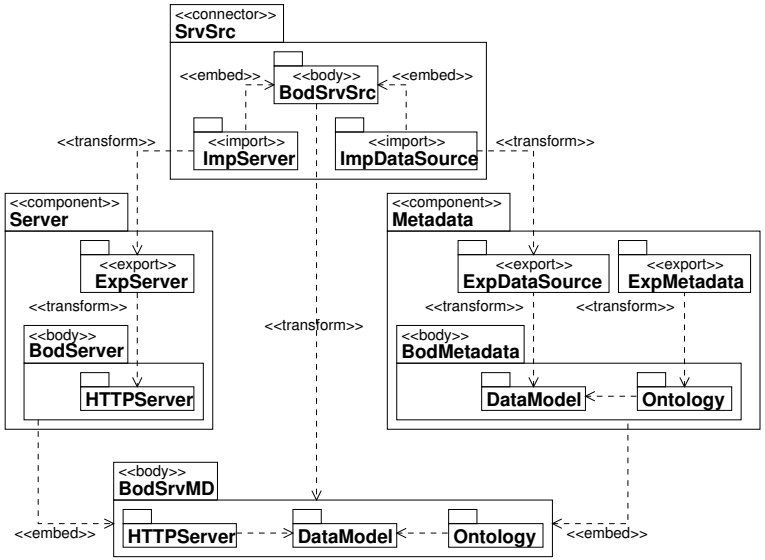
Connected Parts Removed

Composition of Transformation and Embedding



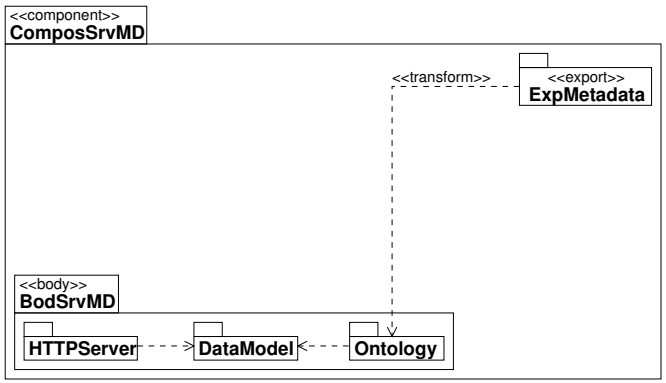
⇒ Single Composed Component

Composition of the Example



Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

Composition of the Example



Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

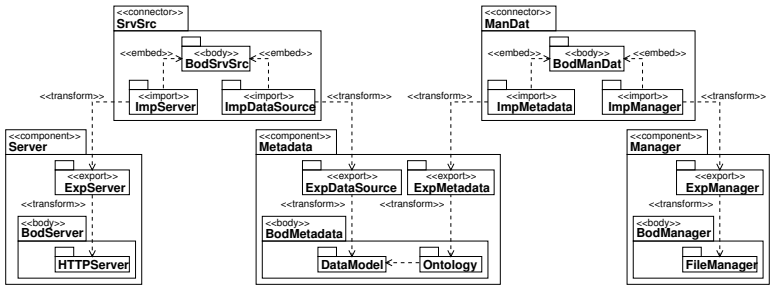
Architecture Semantics / Main Results

Valid for all Instantiations of the Framework
(Only dependent on Parallel Extension Property)

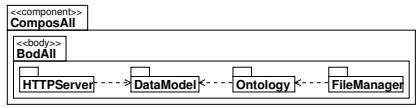
- Semantics of Architectures:
  Single Component derived by Iterated Composition
- Connectors gradually removed by Composition
  ⇒ Iterated Composition terminates
  ⇒ Existence of Semantics
- Compatibility/Associativity of Composition
  ⇒ Local Confluence of Composition
  ⇒ Uniqueness of Semantics

Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

Semantics of Example Architecture



Semantics of Example Architecture



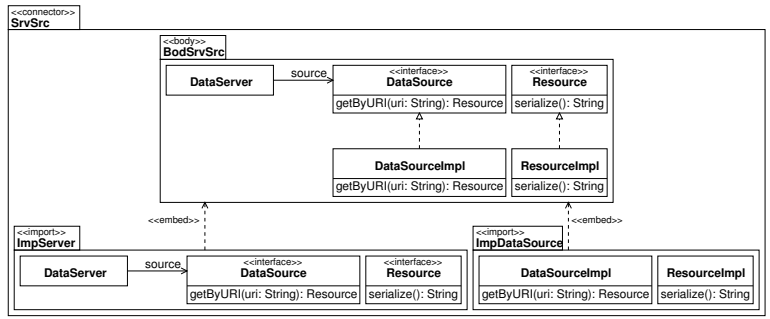
Instantiation to UML

Instantiations of Architecture Framework must provide:

- Class of Specifications
  ⇒ Packages containing UML Diagrams
- Transformations and Embeddings
  ⇒ Refinements and Inclusions of UML Diagrams
- Consistency of Transformations and Embeddings
  ⇒ Parallel Extension Property

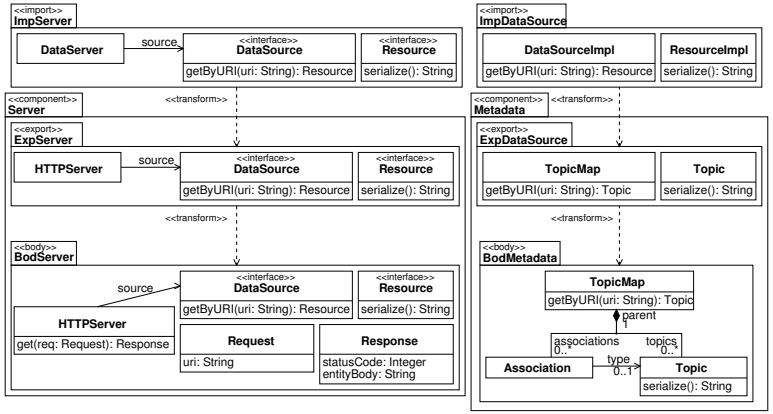
Embeddings of Class Diagrams

- Identification of Classes to be realized in different Components
- No Renamings – just Inclusions



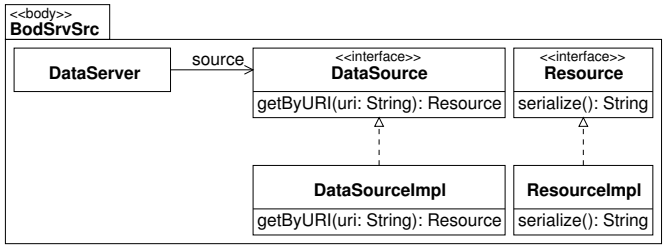
Transformations of Class Diagrams

- Realization of Classes by Addition of Methods and Properties
- Renamings possible (except Interfaces)



Extension Property for Class Diagrams

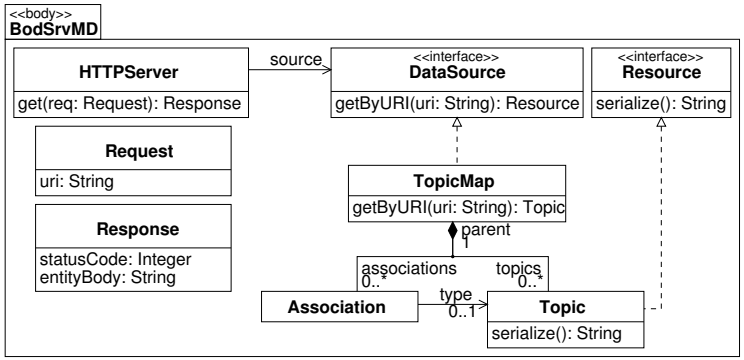
- Consistency:
  - Boundary of Embeddings preserved
  - Common Parts transformed identically
- Extension by Transformations in larger Context



Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

Extension Property for Class Diagrams

- Consistency:
  - Boundary of Embeddings preserved
  - Common Parts transformed identically
- Extension by Transformations in larger Context



Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

Sequence Diagrams

- Considering Sets of Scenarios
- Embeddings:
  - Inclusion of each Scenario in the Source into some Scenario of the Target
- Transformations:
  - Translation of Names according to Class Diagram Transformation
  - Refinement of Lifelines by Sets of Lifelines (Decomposition)
  - Refinement of Messages by (Sub-)Scenarios
- Consistency of Transformations and Embeddings:
  - Boundary of Embeddings preserved
  - Common Parts transformed identically

$\Rightarrow$ Extension of Sequence Diagram Transformations

Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

State Machines

- Considering State Machines assigned to Classes or Methods
- Embeddings:
  - Inclusion of State Machines, such that visible Traces are preserved
- Transformations:
  - Translation of Names according to Class Diagram Transformation
  - States may be renamed and given Substructure
  - Possible Traces enhanced
- Consistency of Transformations and Embeddings:
  - Boundary of Embeddings preserved
  - Common Parts transformed identically

$\Rightarrow$ Extension of State Machine Transformations

Thank You!

Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion

Conclusion

Summary:

- Theoretical Framework based on Parallel Extension Property
- New Application of Architecture Framework to UML (FESCA 2004: Instantiations to CCS and Petri Nets)
- Universal Connectors for Common Architecture Styles

Future Work:

- Transformation/Refinement Concept for Further Techniques
- Application of Graph Transformation to UML

Object-Oriented Connector-Component Architectures
Ehrig, Braatz et al.
Generic Architecture Framework
Connector-Component Architectures
Composition by Extension
Architecture Semantics
Instantiation to UML
Class Diagrams
Sequence Diagrams and State Machines
Conclusion