TECHNISCHE UNIVERSITÄT DRESDEN

DRESDEN concept

Ringvorlesung GRK „Role-based Software Infrastructures (RoSI)", funded by DFG
https://rosi-project.org

Development, Deployment, and Runtime of Context-Aware Software Systems

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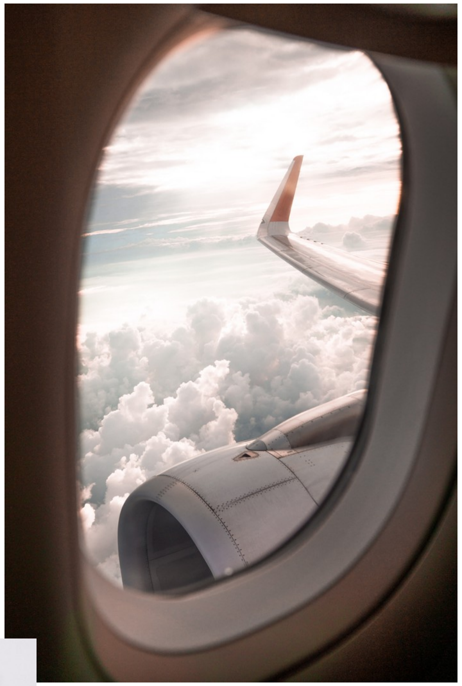
Version 0.4, WS 19/20 10/3/19

Welcome to RoSI!

- „ever-changing contexts“
  - Mobility
  - Personalization
  - Resource availablity
- How to realize
  - Adaptation to change of context?
  - Context polymorphism?



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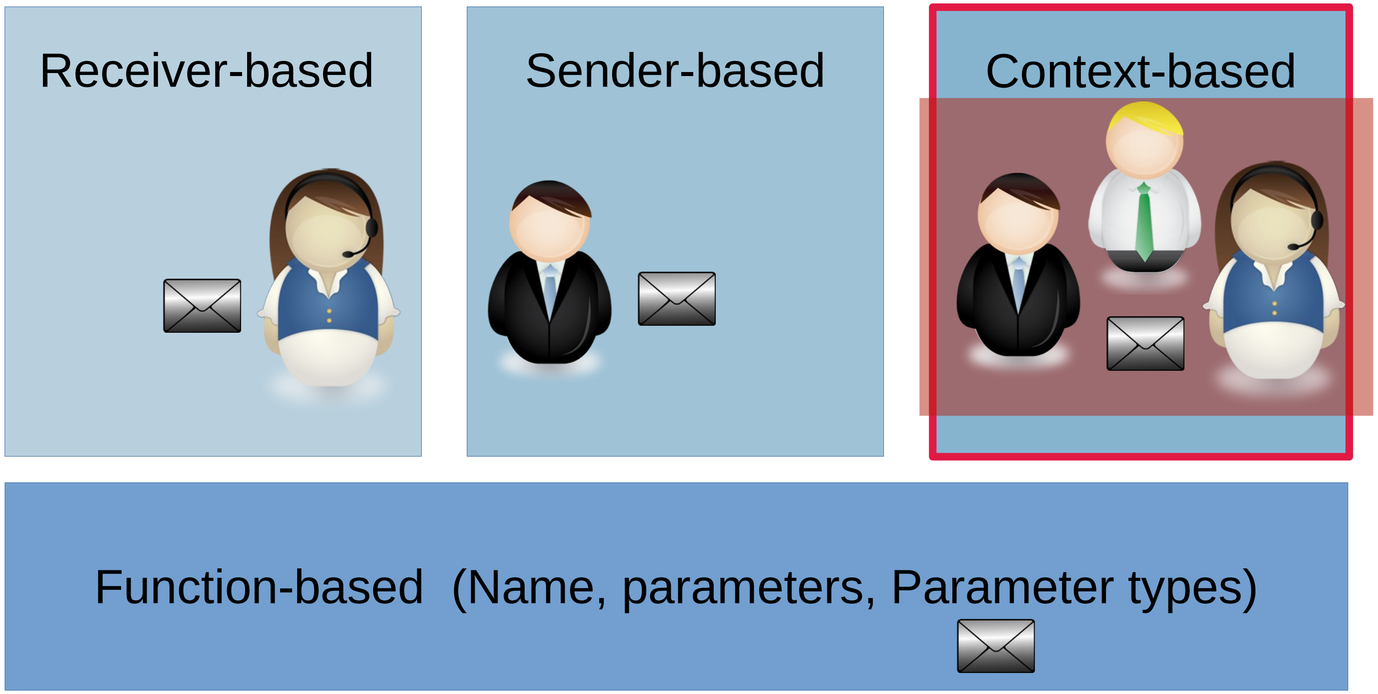
Multi-Dimensional Dispatch for Multi-Polymorphism

- How is the semantics of a function (method) determined?



Multi-Dimensional Dispatch for Multi-Polymorphism

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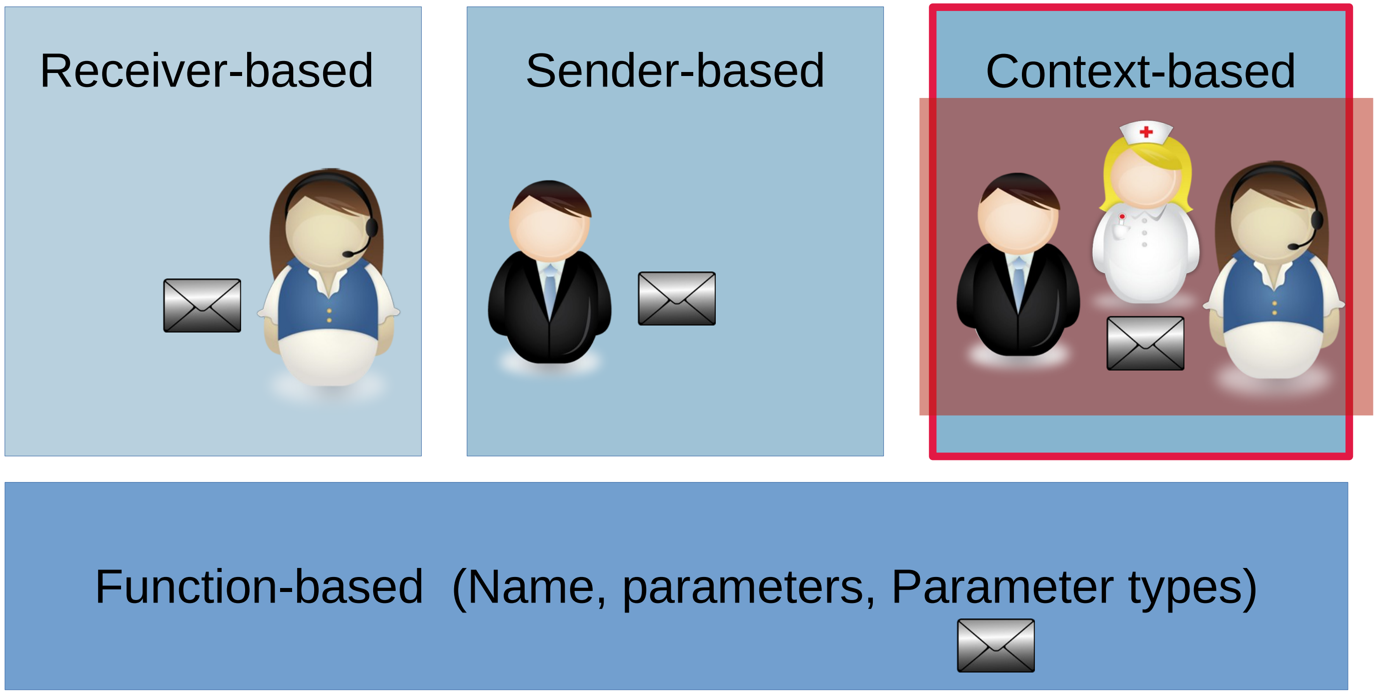

New Application Areas of ROSI

- Roles for context-sensitive cyber-physical systems (CPS)
  - Hypothesis: Role-contracts for safety and security
- Roles for emergence in Systems-of-Systems (SoS)
  - Hypothesis: Role models for unforeseen emergence

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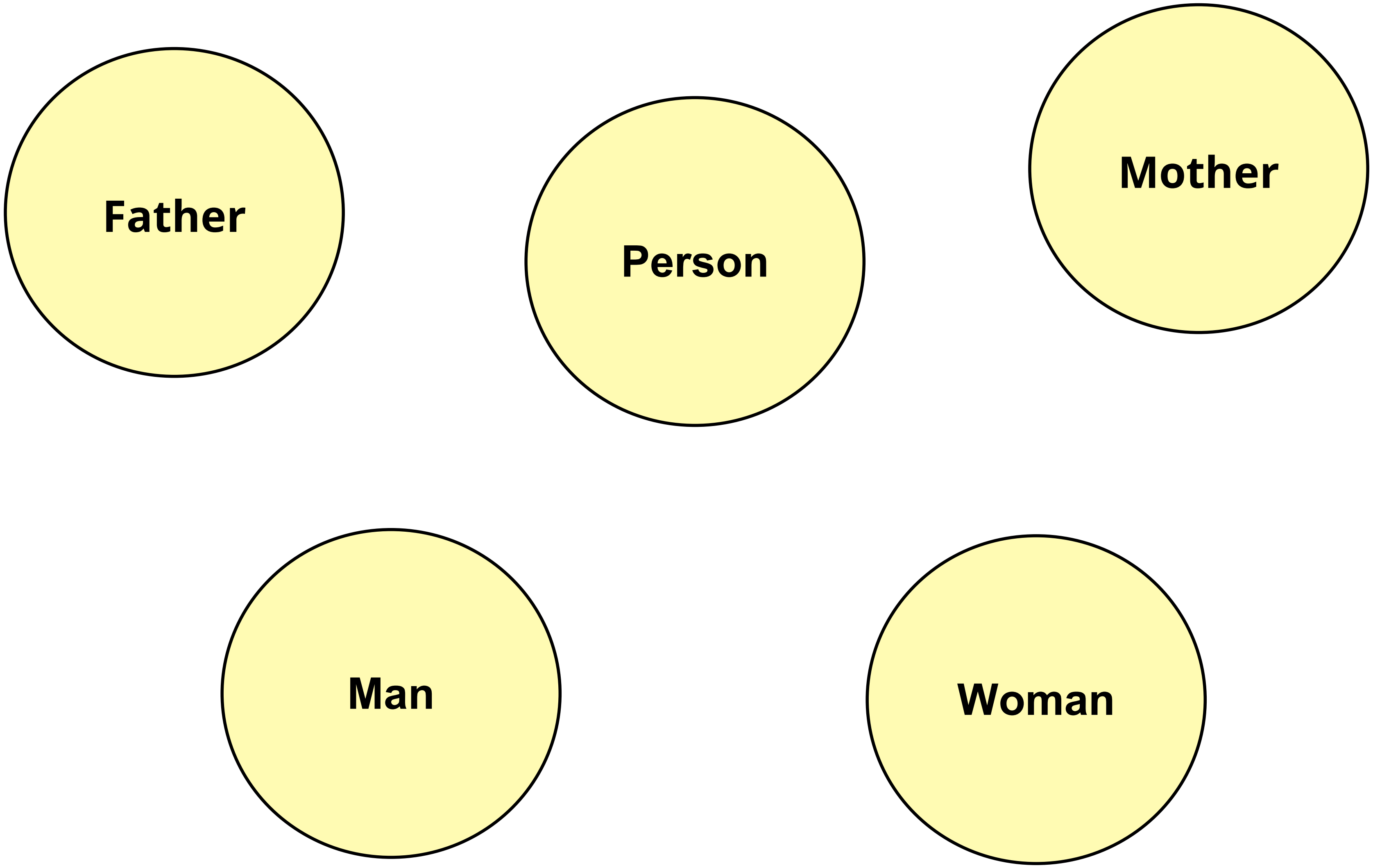
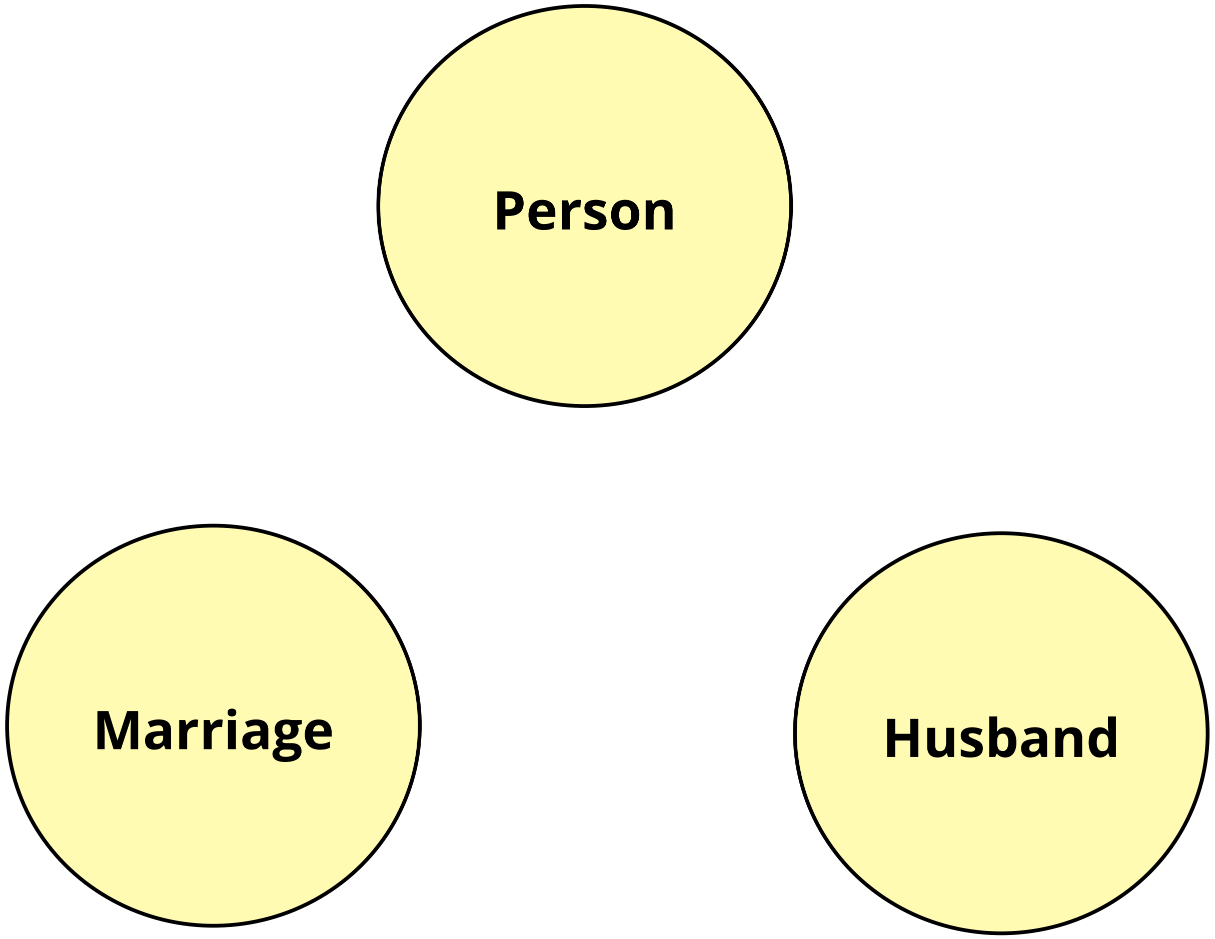
A Riddle..



Another Riddle..



Role-Oriented Context-Aware Software Infrastructures (ROSI)

01. Contexts and Roles

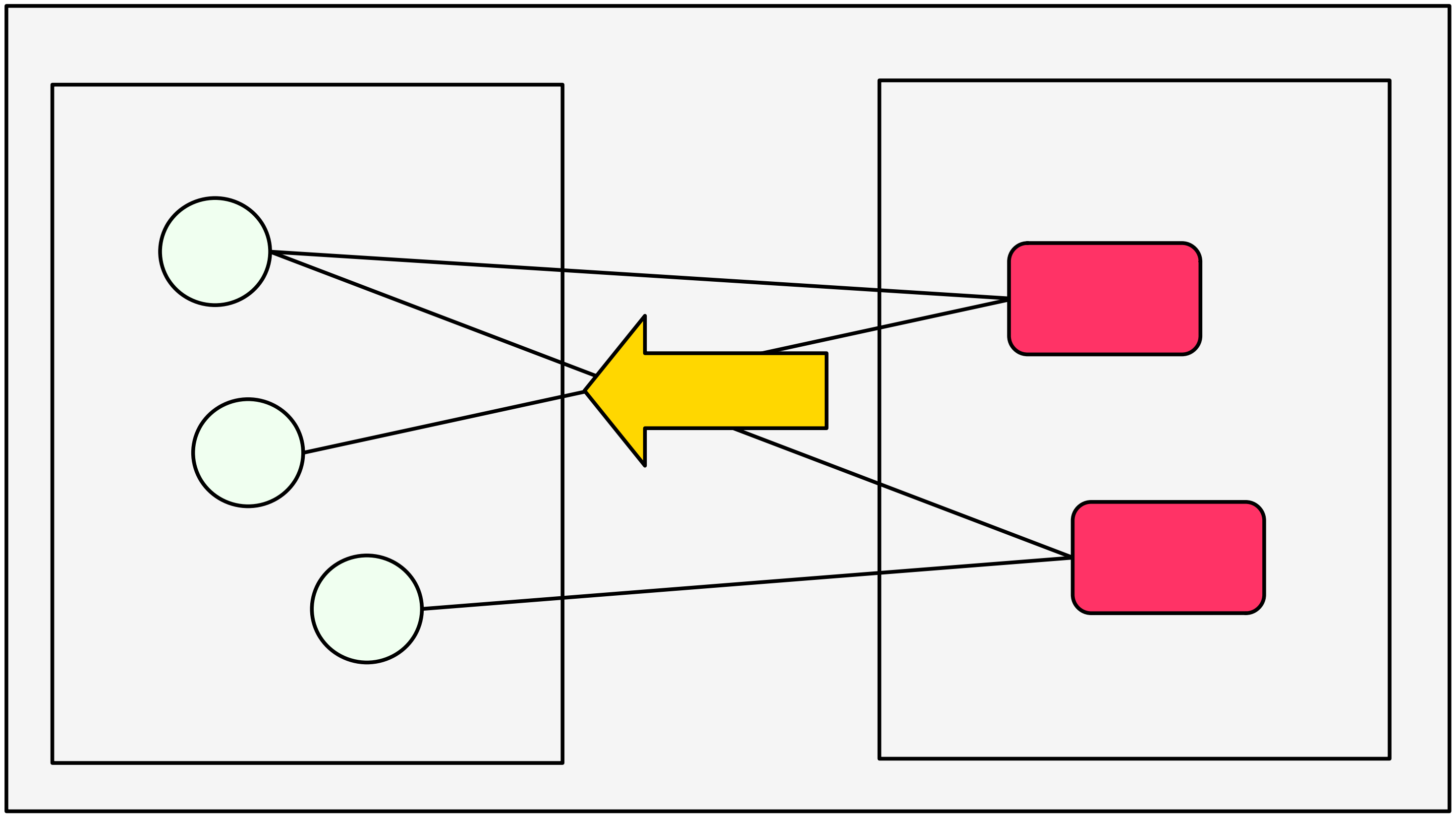
Overview of Talk

Role-Oriented Context-Aware Software Infrastructures (ROSI)

1.1. Adaptation Problems of the Standard Object Model

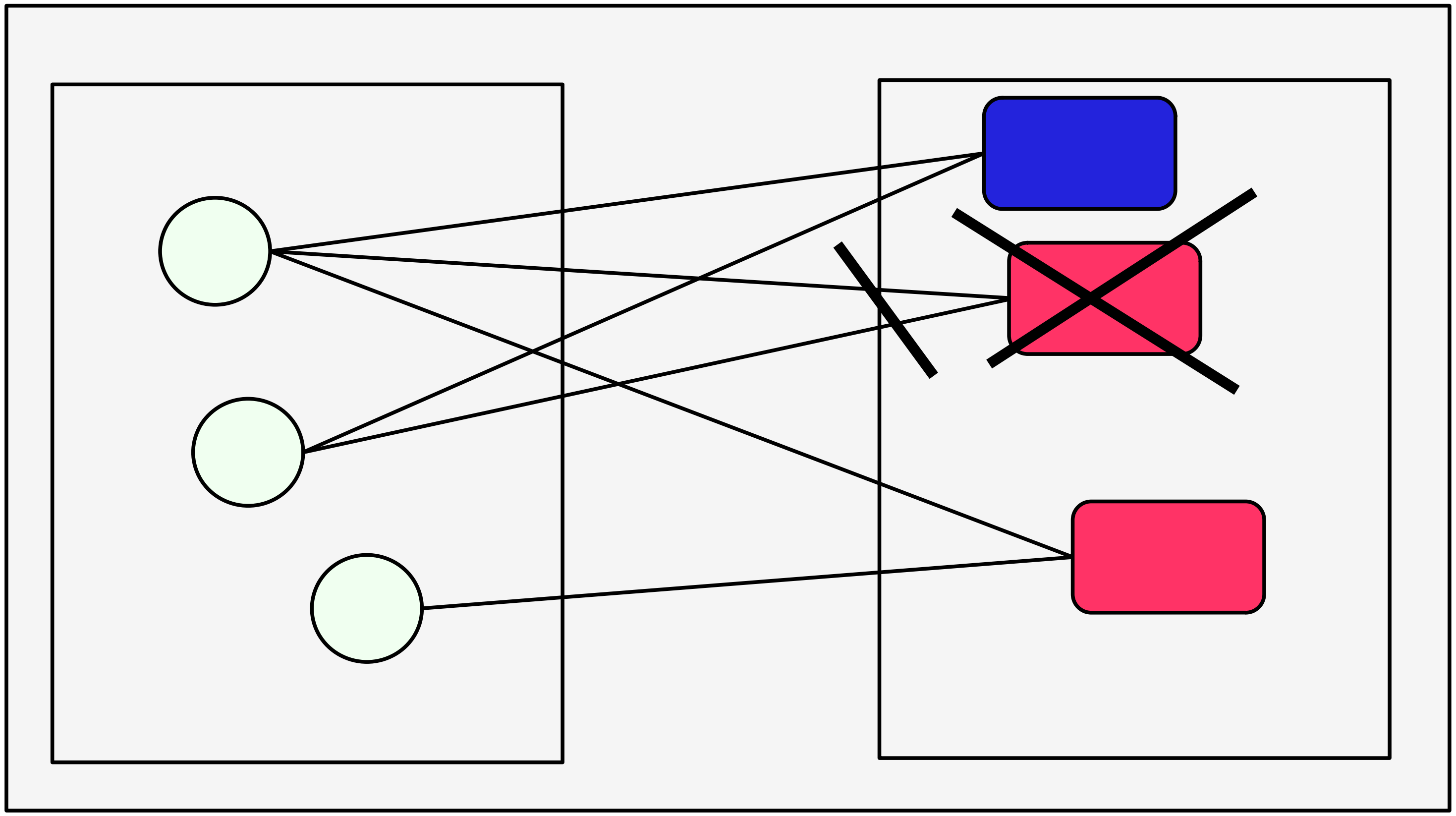
The Extensibility Problem

- How to extend software in a fine-grained way? Obliviousness?



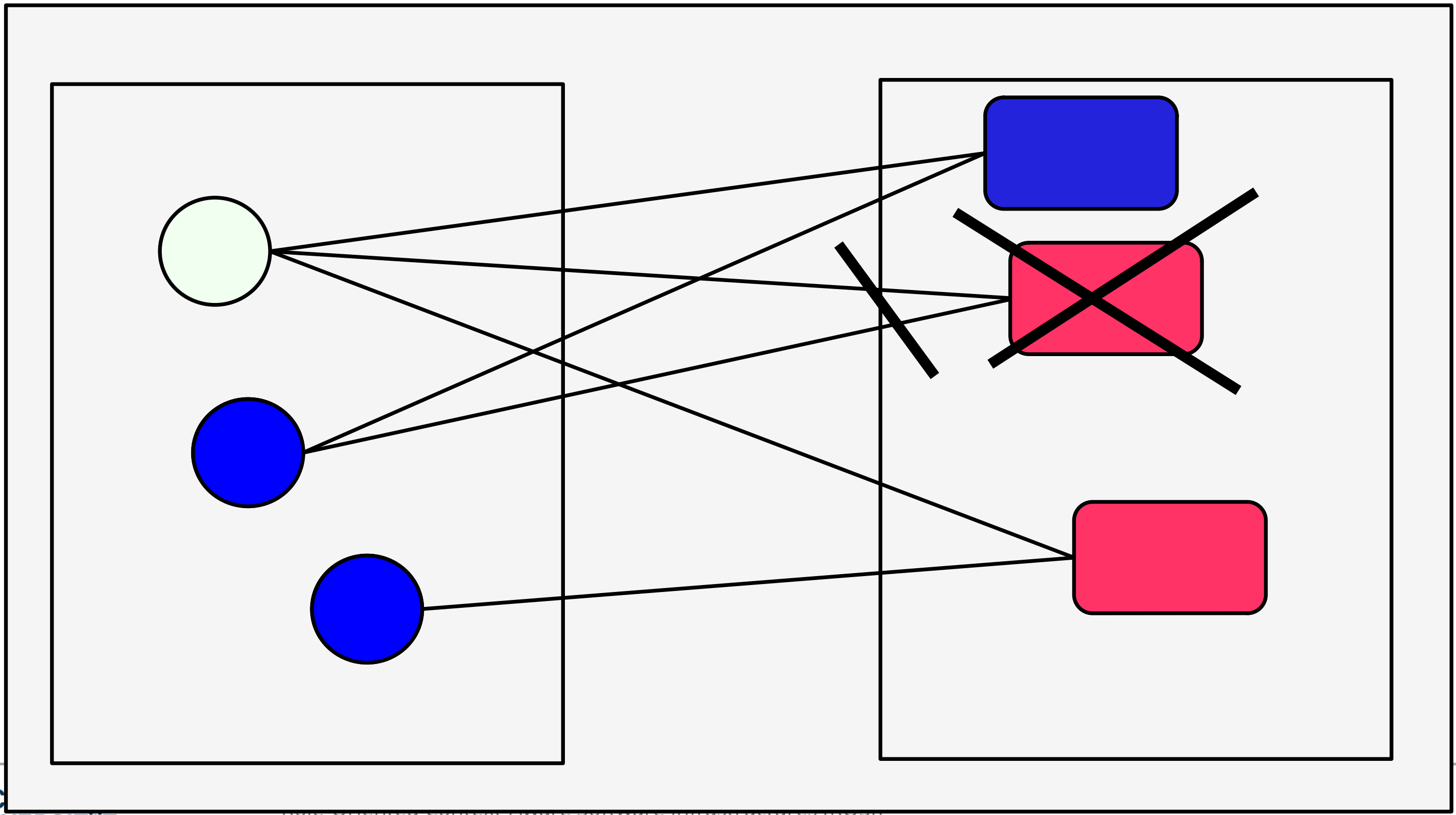
The Substitutability Problem

- How to substitute a component? (contracts necessary)



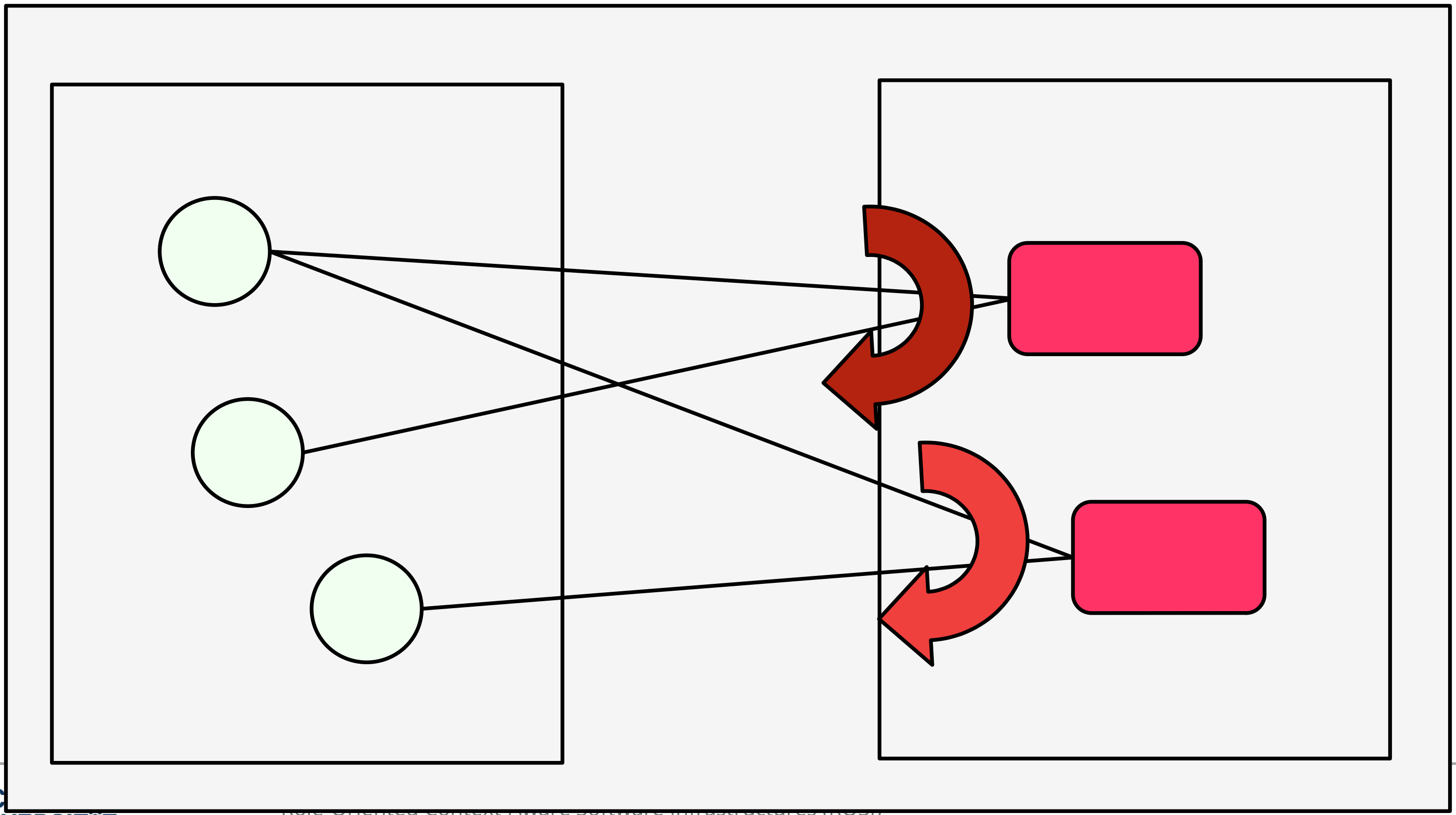
The Variability Problem

- How to vary many components, layers, slices, or a subsystem?



The Wrapping and Synchronization Problem

- How to wrap software with code, e.g., for protection or synchronization, transactions?



Big Problem 1) The Synchronization Problem (Inheritance Anomaly)

1980s: Parallel object-oriented languages (POOL, COOL)

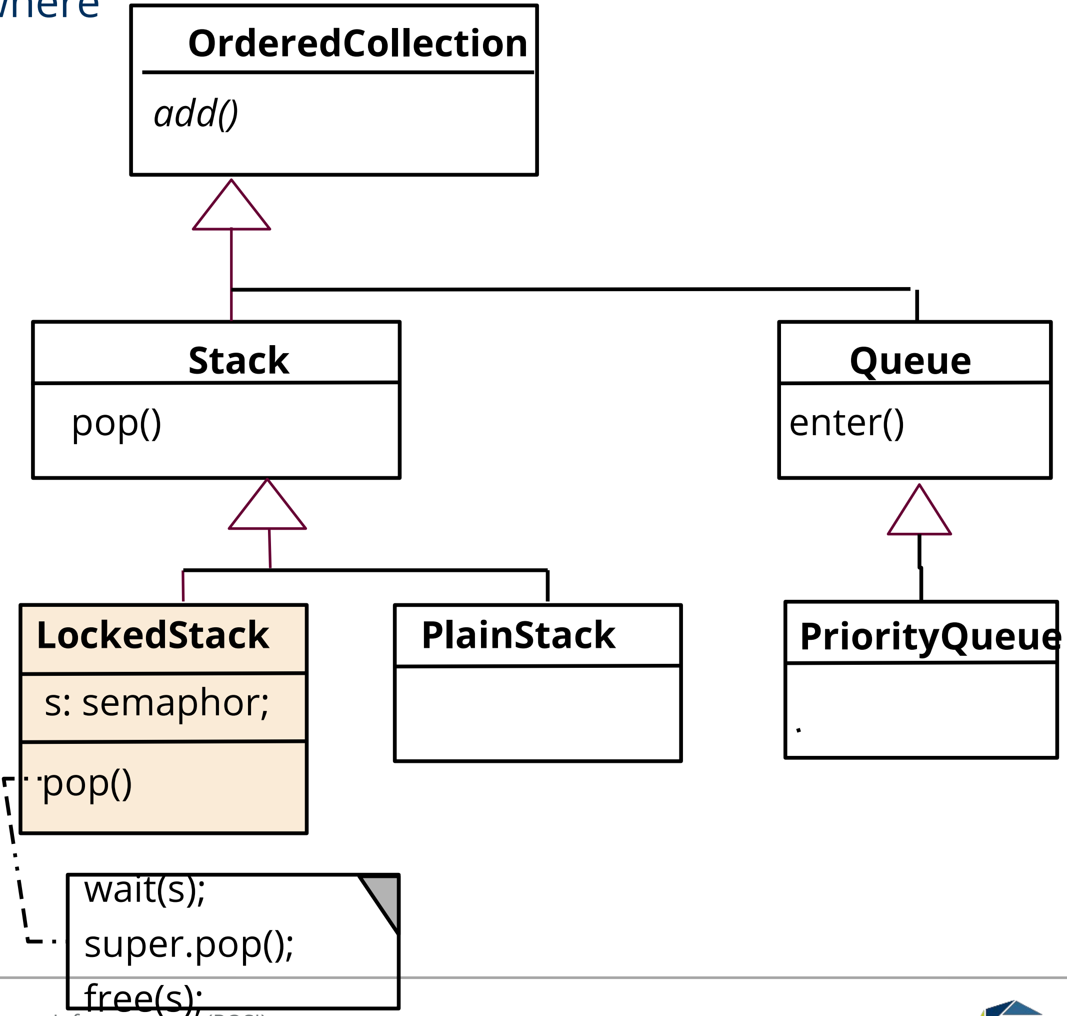
1991: Inheritance Anomaly

1988: Composition Technology (Aksit)
1994: Generic Synchronization Policies (McHale)
1988-94: Composition Filters (Aksit)

1996: Aspect-oriented Programming (AOP)
1996: D+COOL+RIDL (Lopes), 1999: Aspect/J (Kiczales)

Inheritance Anomaly - Why Concerns are Necessary

- In a parallel program or library, where should synchronization code be inserted?
  - Stack?
  - Queue?
  - OrderedCollection?
  - Collection?
  - Object?

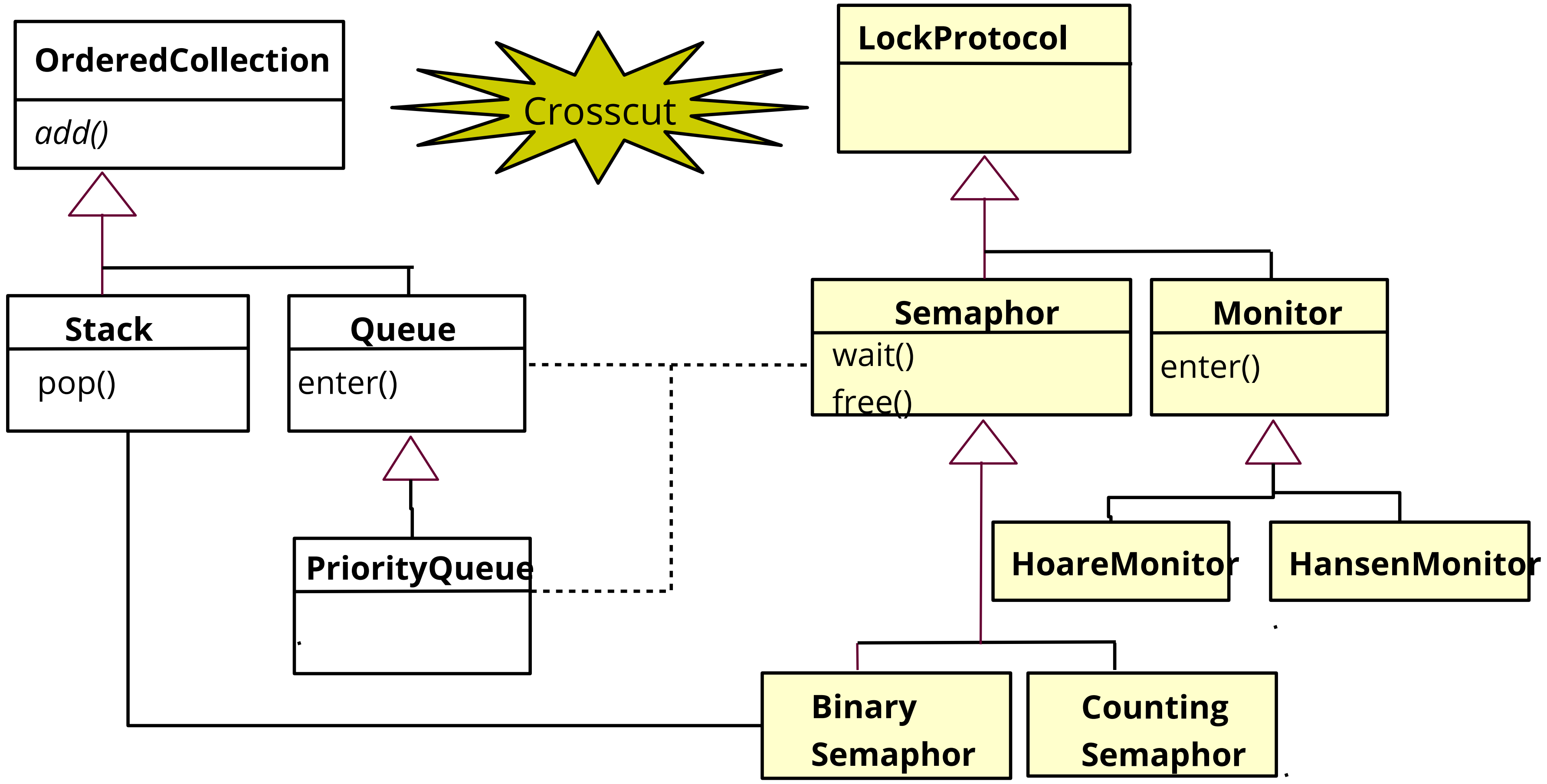


The Synchronization Problem (Inheritance Anomaly)

- At the beginning of the 90s, parallel object-oriented languages failed, due to the inheritance anomaly problem
  - *Inheritance anomaly*: In inheritance hierarchies, synchronization code is intermingled with the algorithm and cannot be easily exchanged
  - *Synchronization tangling*: Because synchronization code *braces* code, it is *tangling*
  - *Synchronization crosscut*: Because synchronization code *is reused* code, it is *crosscutting*

Algorithm and Synchronization are Two Different Concerns (Core and Aspect)

- Composition fixes crosscut between core and aspect

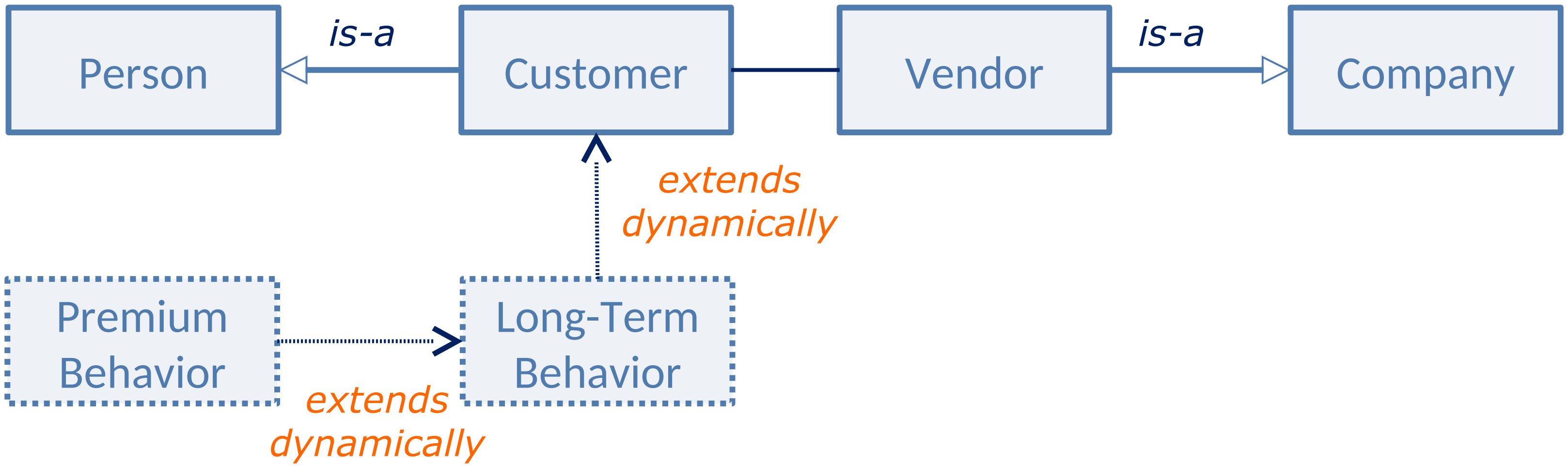


Problems of Aspect-Orientation

- Not well integrated into the standard OO model
- Semantics unclear
- Often only static

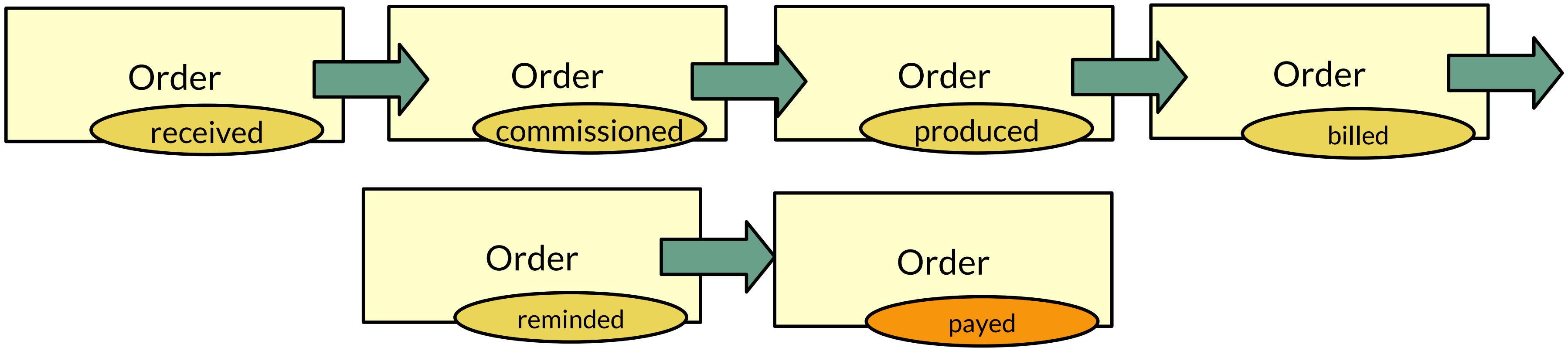
Big Problem 2) Run-time Adaptability
Negative Example: “San Francisco”-Framework of IBM

- Enterprise Resource Planning (ERP) in Java, 1995-99
- Dynamic extensions of classes and life-cycle automata
- Classic object-orientation too inflexible
- FAILED



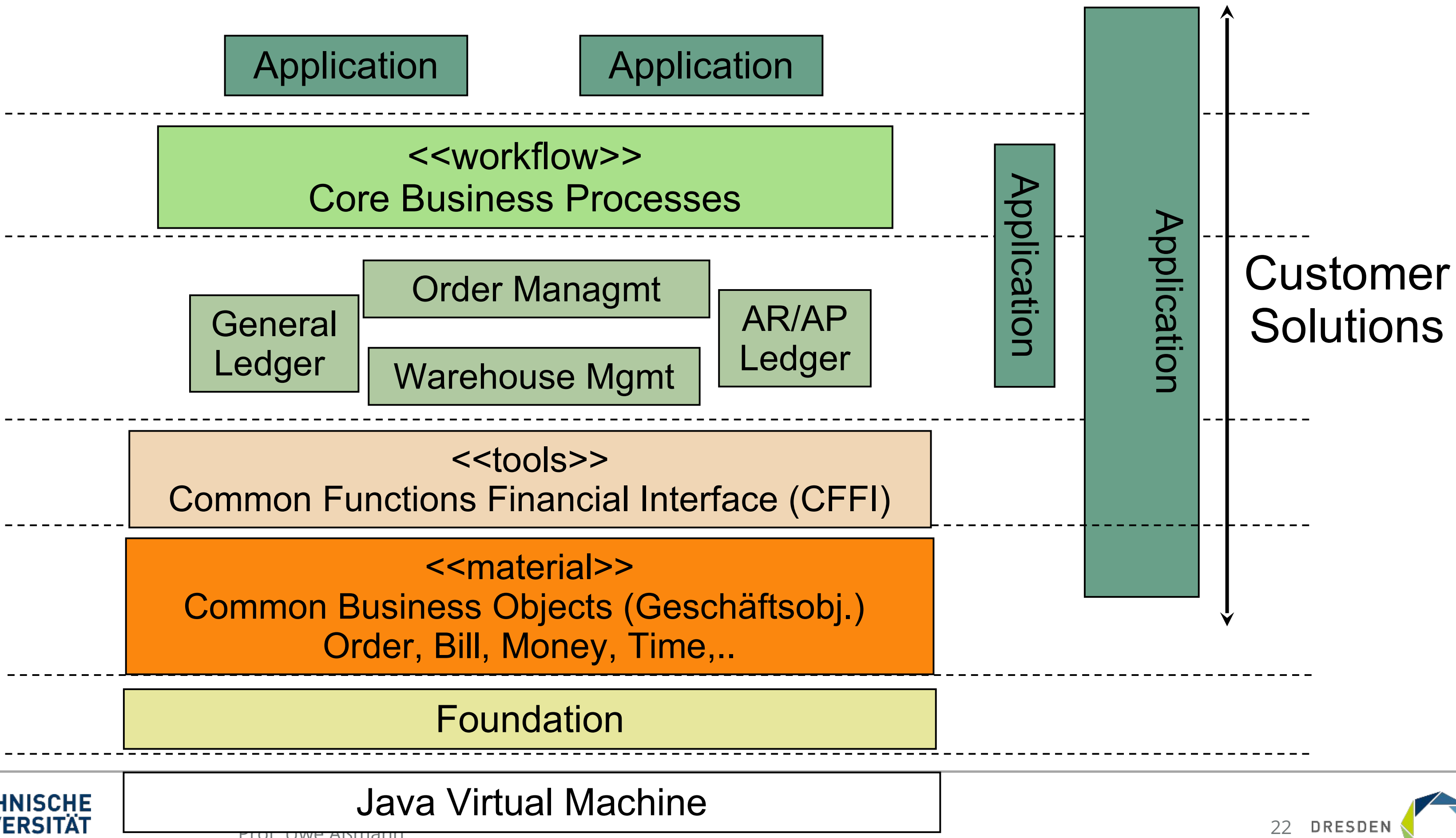
Business Objects

- In large ERP frameworks (see SAP) business objects get very complex
- Ex.: **Order**
  - Many phases and collaborators
  - Many states and roles
- Dynamic Extensibility and Variability (Adaptation) required

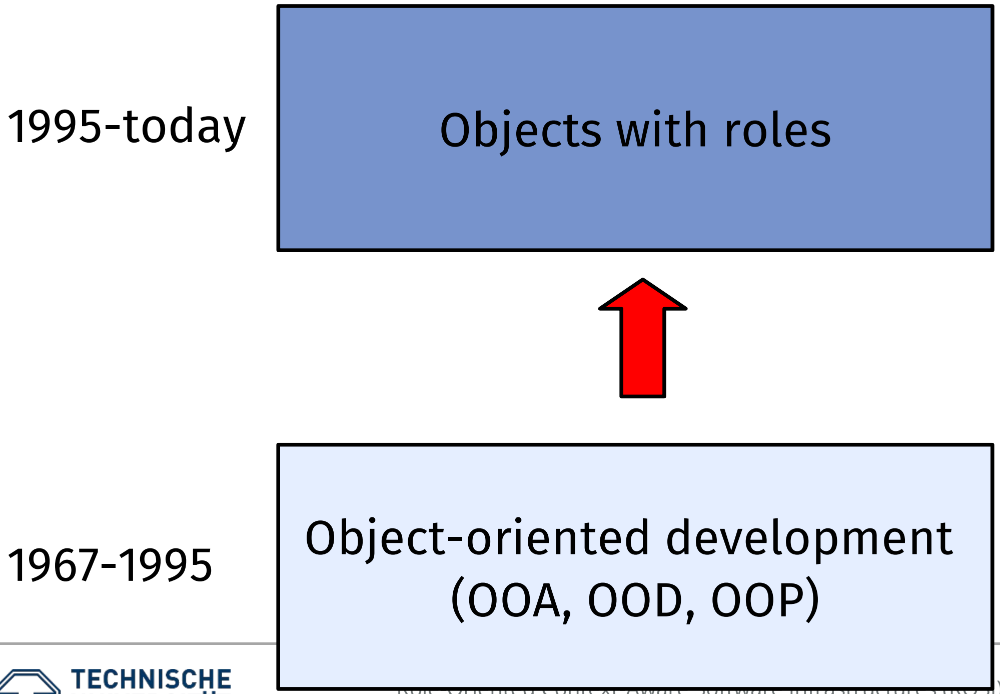


Architecture of IBM San Francisco ERP Java-Framework

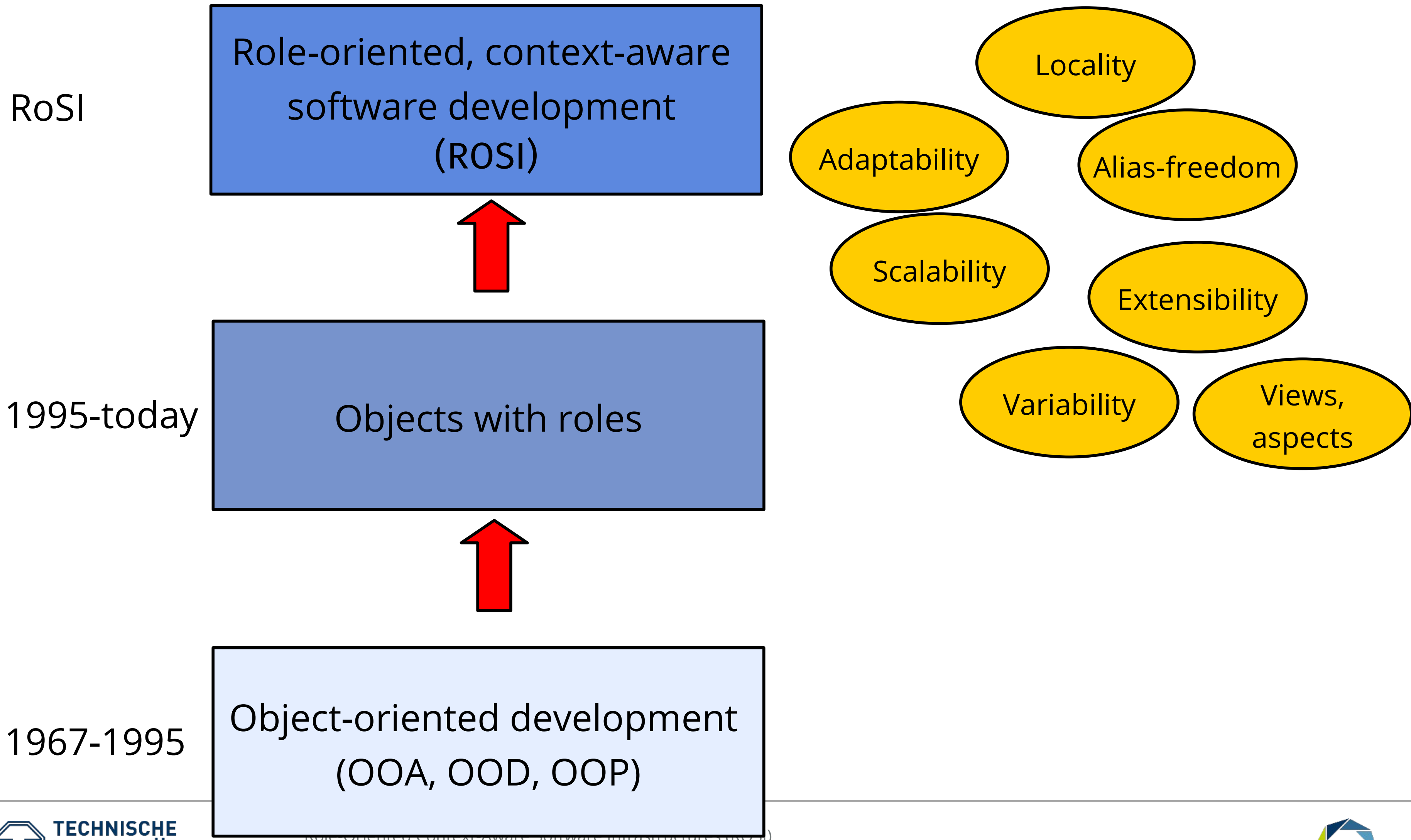
- P. Monday, J. Carey, M. Dangler. SanFrancisco Component Framework: an introduction. Addison-Wesley, 2000.



Ladder of Technologies

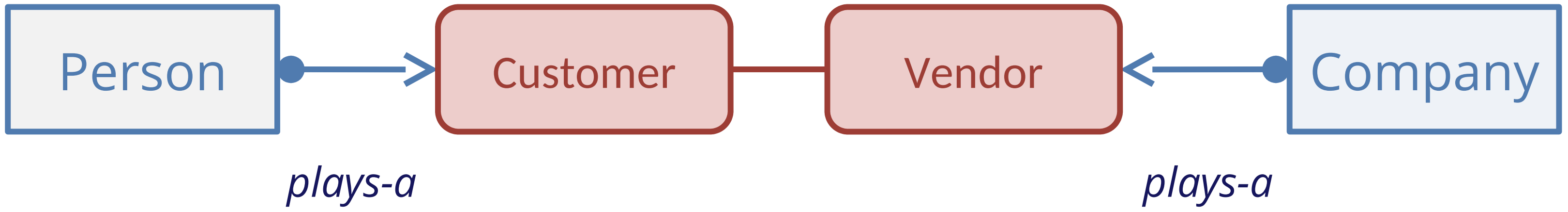


Ladder of Technologies



Role Modelling – a Hope

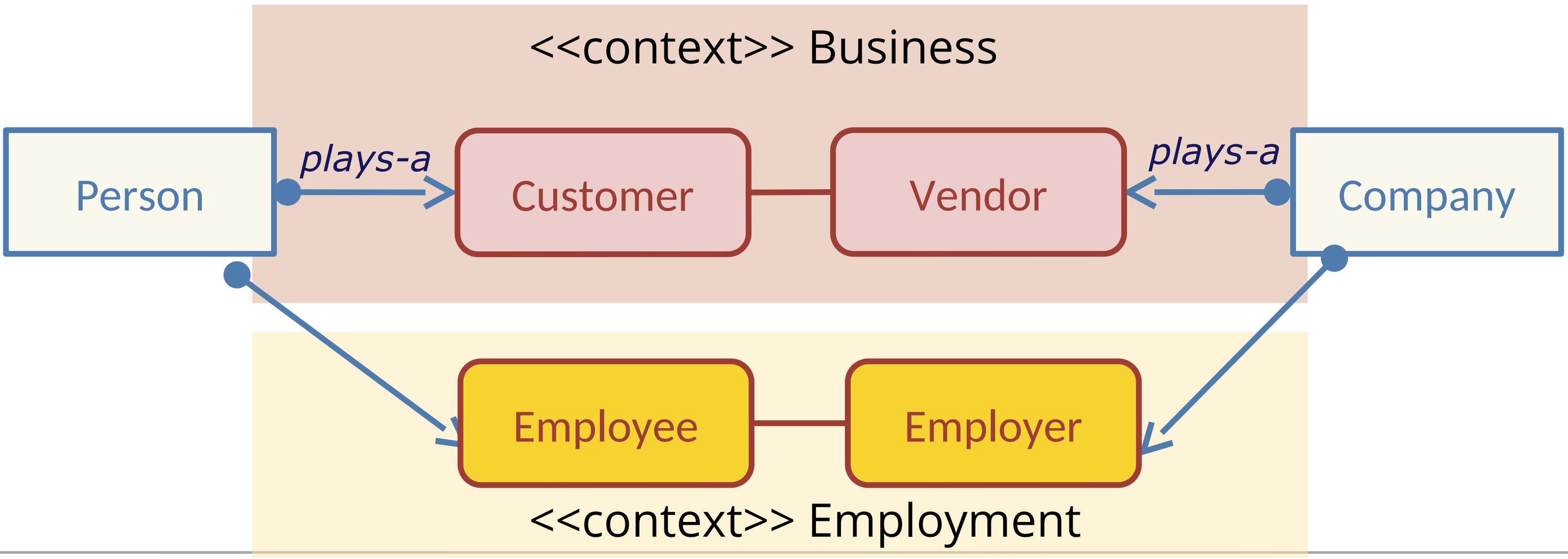
- Separate the **functional core** of an object of its **context-based a**nd **fluid** features



- Restrictions so far:
  - only used in singular fields of Computer Science
  - no cross-layer correspondance
  - no formalization

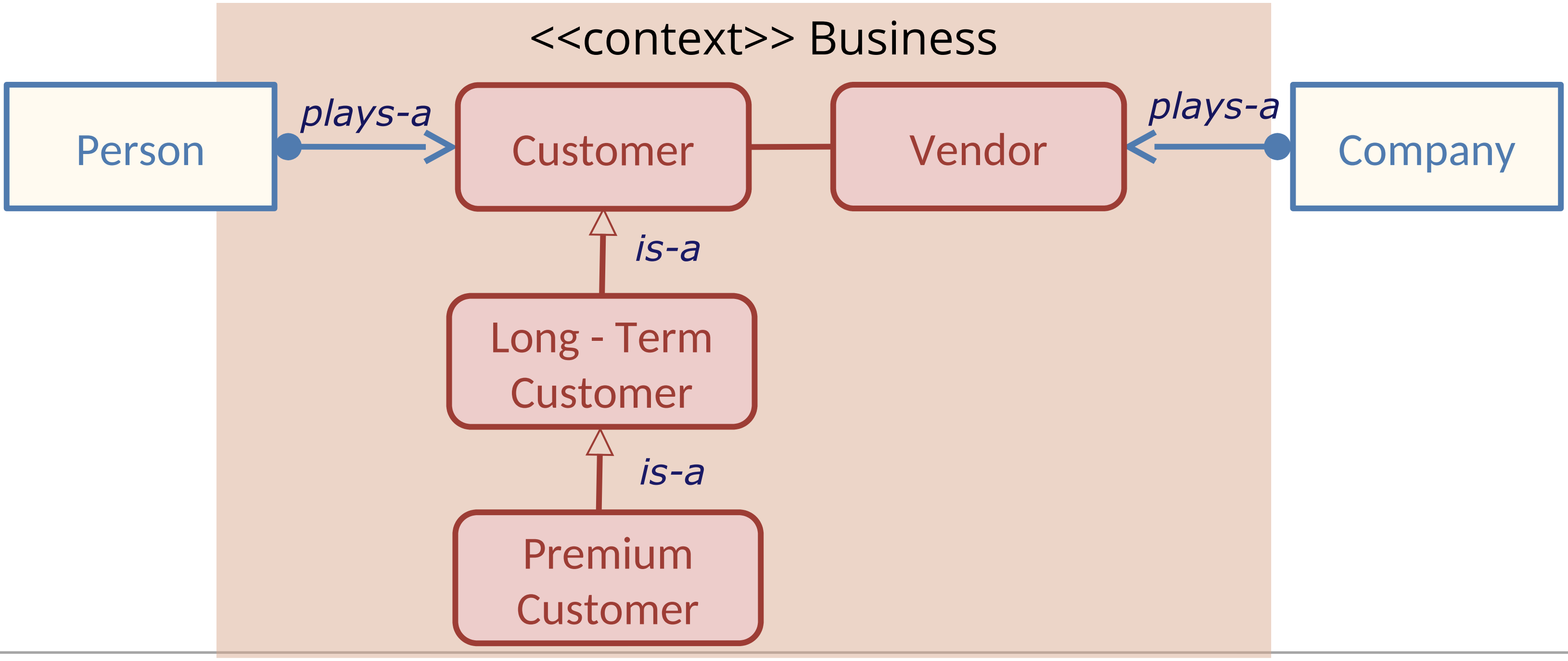
Example: Business Objects

- Extend behavior dynamically by **roles (context-based and fluid types)**
- Convention: Context is expressed by *background boxes* or *color*



Example: Business Objects

- Extend behavior dynamically by **roles (context-based and fluid types)**
- Refinement by role inheritance
-



The Hypothesis of Role-Oriented Context-Aware Development

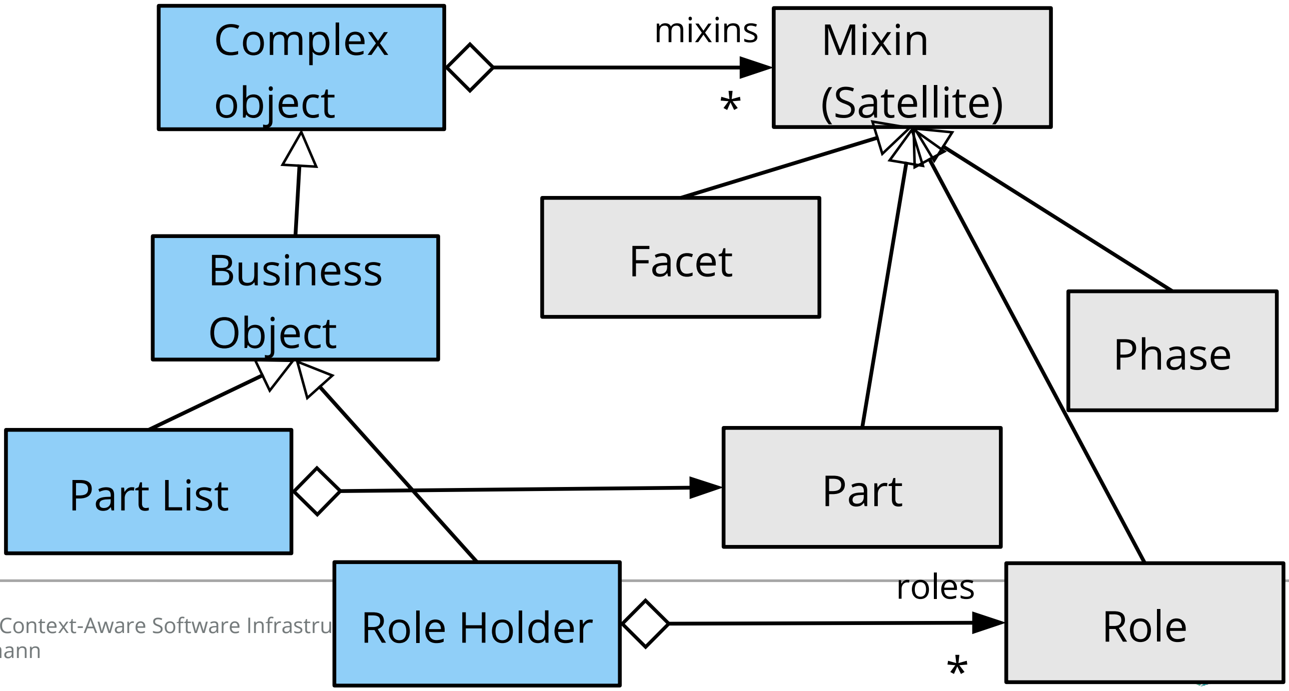
- ...is that **context-based features of objects and systems** can be modeled **with roles, cross-cutting**
  - all phases of the life-cycle
    - requirements, design, implementation, runtime
  - all levels of development
    - Concept modelling in metalanguages,
    - Language modelling,
    - Application modelling and programming,
    - Run-time
- and that this technology is **practically applicable.**

Role-Oriented Context-Aware Software Infrastructures (ROSI)

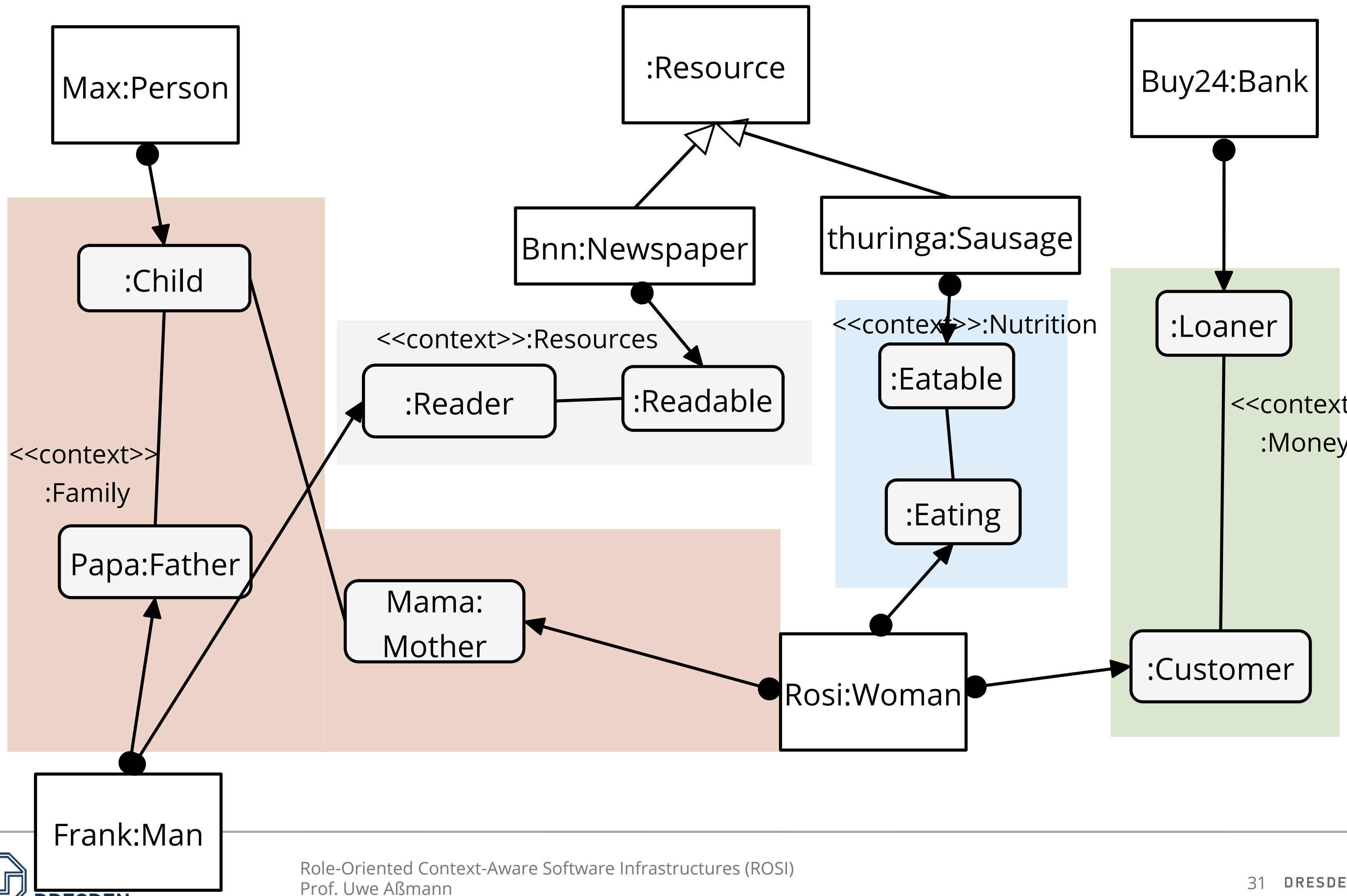
1.1.2. Scenario Families and Banks

Complex Objects

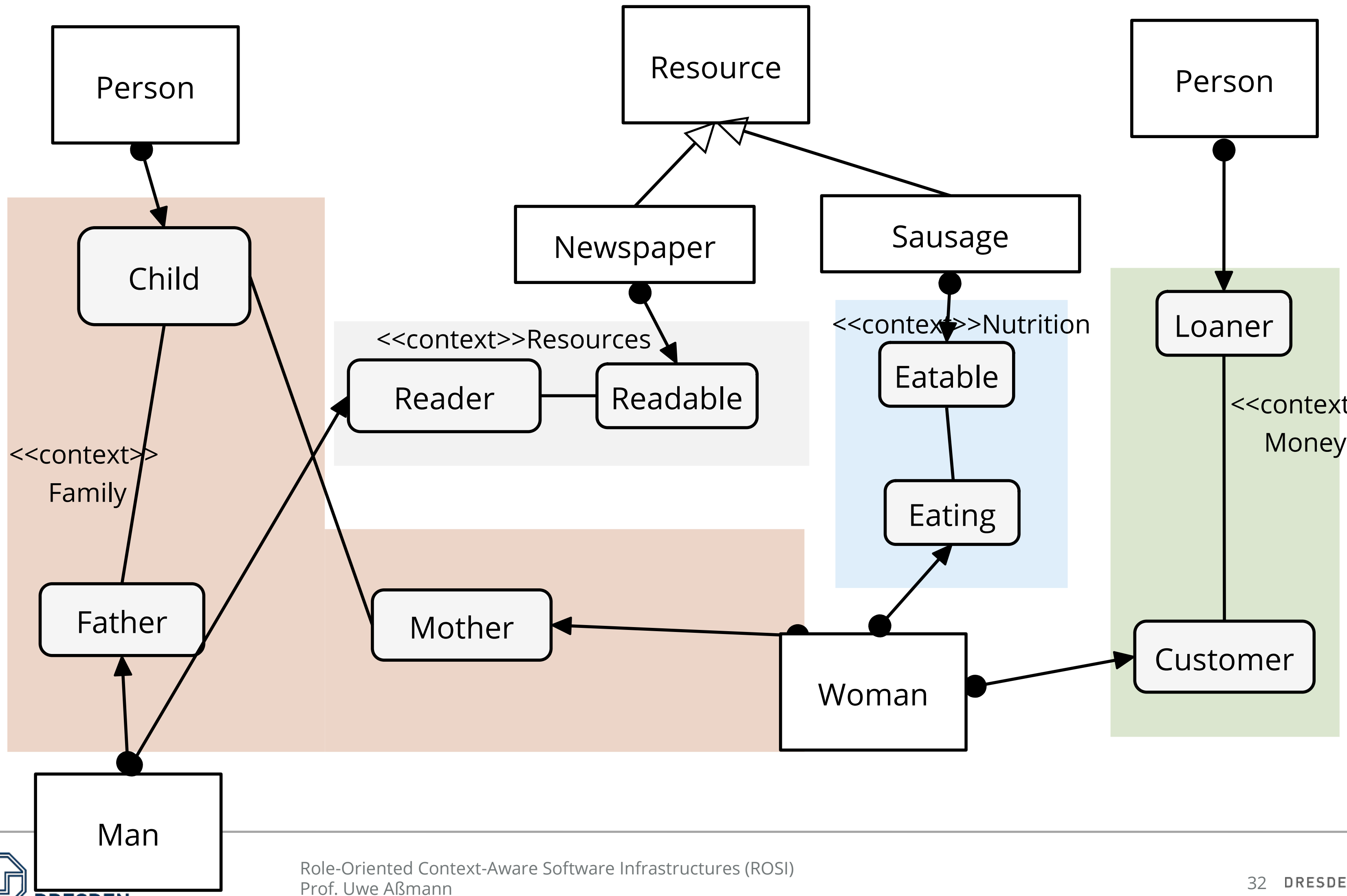
A **complex object (subject, compound object)** is a (logically coherent) object, represented in modeling and programming level by one ***Core*** and several ***Subobjects (mixins)***



Families, Resources and Banks (Snapshot, Object-Role Model)



Families and Banks in Natural and Role Types



Role-Oriented Context-Aware Software Infrastructures (ROSI)

1.2. Beyond Objects - Role Modeling and the Steimann Factorization of Types

Splitting a type into a tuple of natural and founded parts

Roles in the Literature

- Databases (Bachmann 77)
- ER model (Chen 76); though hidden in association ends
- OO Modeling (Reenskaug 95)
  - Design patterns (Riehle 98)
  - Course “Design patterns and frameworks” at TUD
- Product line engineering (Smaragdakis,Batory 02)
- Connectors in architectural languages (Garlan, Shaw 95)
- Security: Role-based Access Control (RBAC)
  - ACL lists in operating systems
- Ontologies (Brachman, description logic)
- ... [Steimann DKE 2000] has many more and tries to unify them
- UML has “collaborations” using role types
- [Kühn 2014] defines compartments as structured context objects

Rigid and Founded Types

If an object that has a ***rigid*** type, it cannot stop being of the type without loosing its identity [Guarino]

- Example:
  - *Book* is a rigid type, *Reader* is a non-rigid type
    - Reader can stop reading, but Book stays Book
- Rigid types are *tied to the identity* of objects
  - A *non-rigid type* is a dynamic type that is indicating a state of the object

A ***founded type*** *(relative type)* is a type that exists always in collaboration (association) with another class.

Role and Natural Types

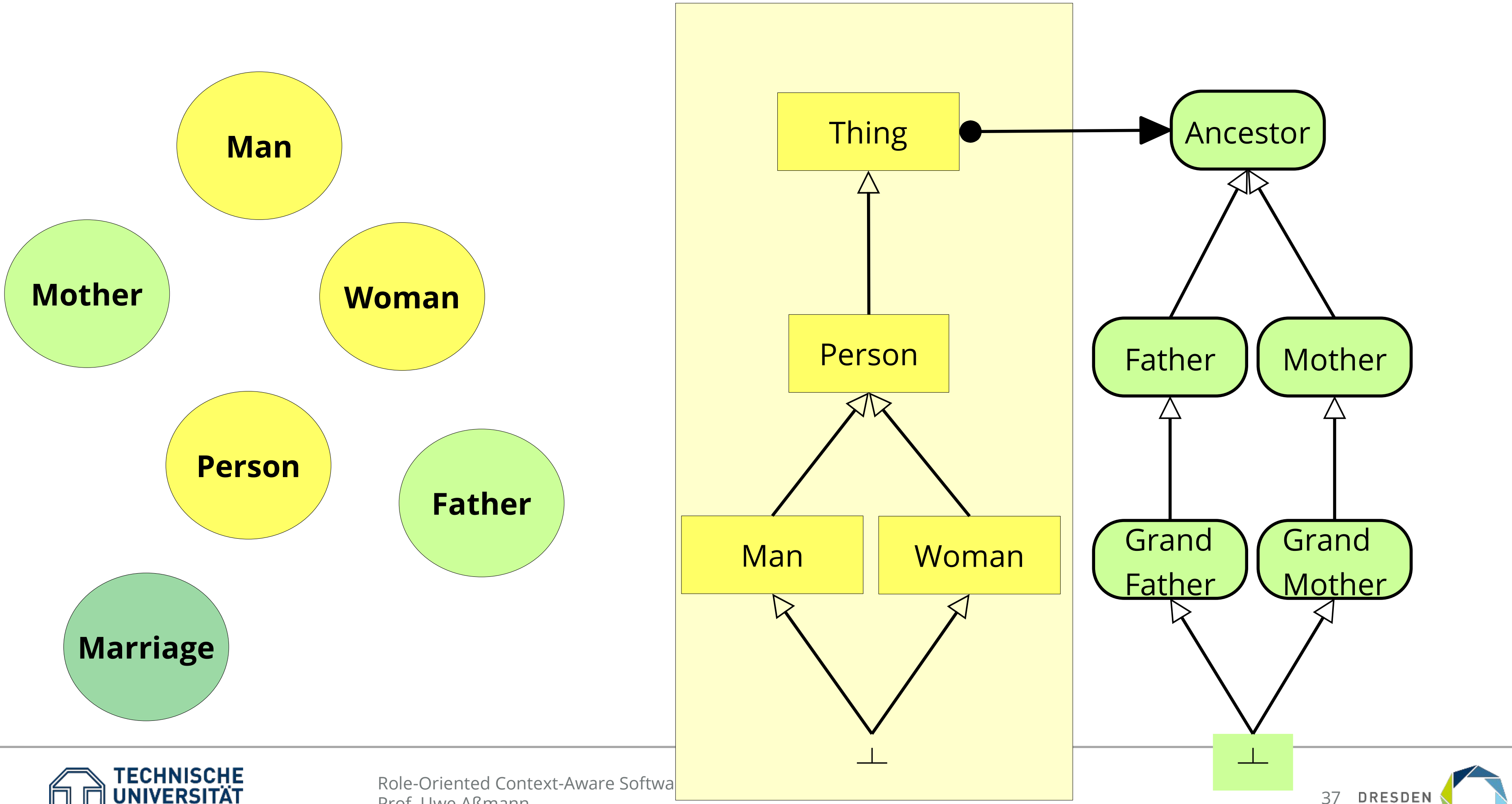
A ***role type*** is a founded and non-rigid type.

Role types are in collaboration and if the object does no longer play the role type, it does not give up identity.

A ***natural type*** *is* non-founded and rigid.

A natural type is *independent* of a relationship.
The objects cannot leave it.

Solution to the Little Riddles..



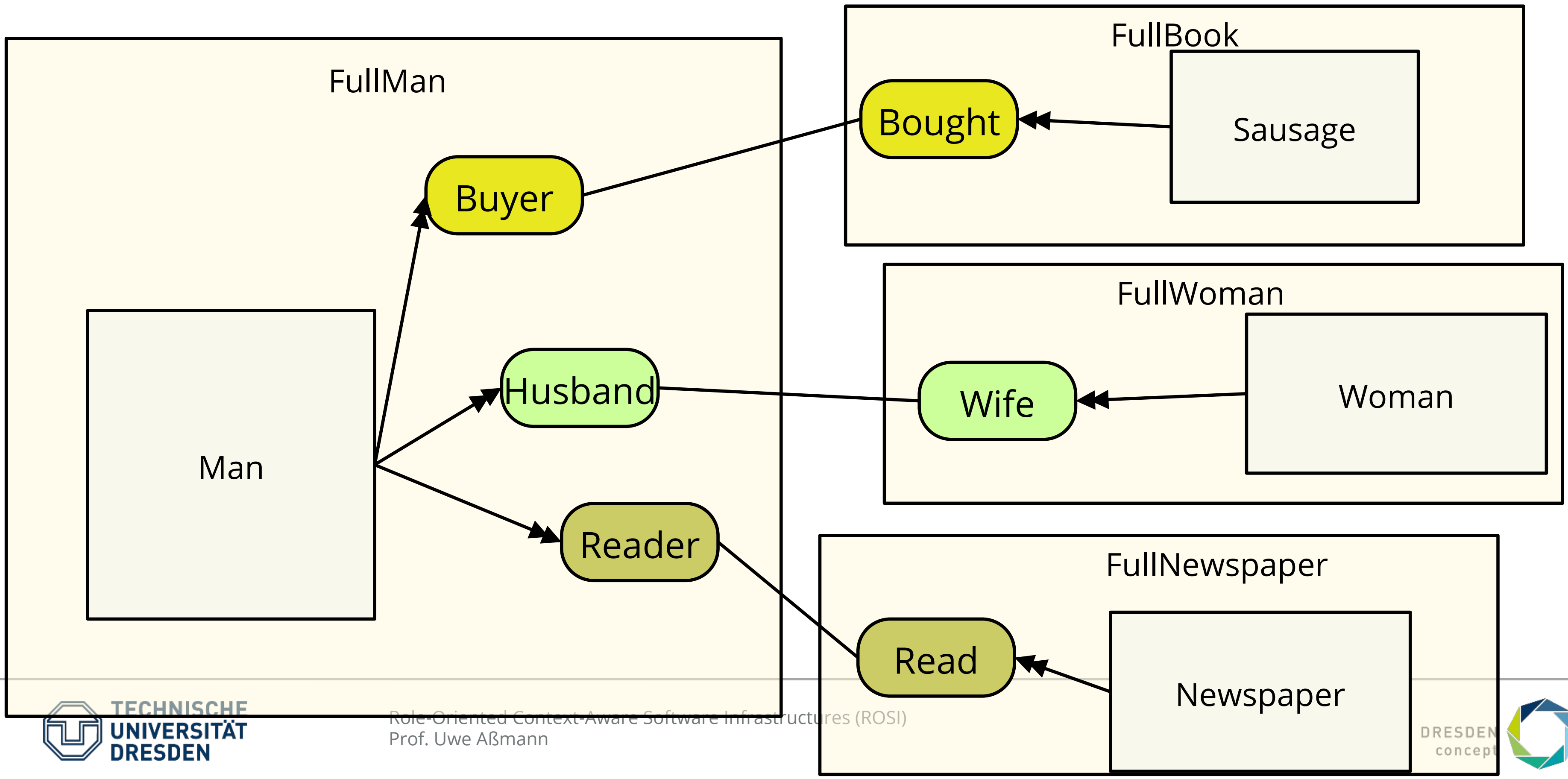
Role Types are Metatypes

- A **metatype** describes a type (is a type of a type)
  - Rigid Type
  - Natural Type
  - Founded Type
  - Role Type

Hypothesis:
The distinction of metatypes promotes
Separations of Concerns.

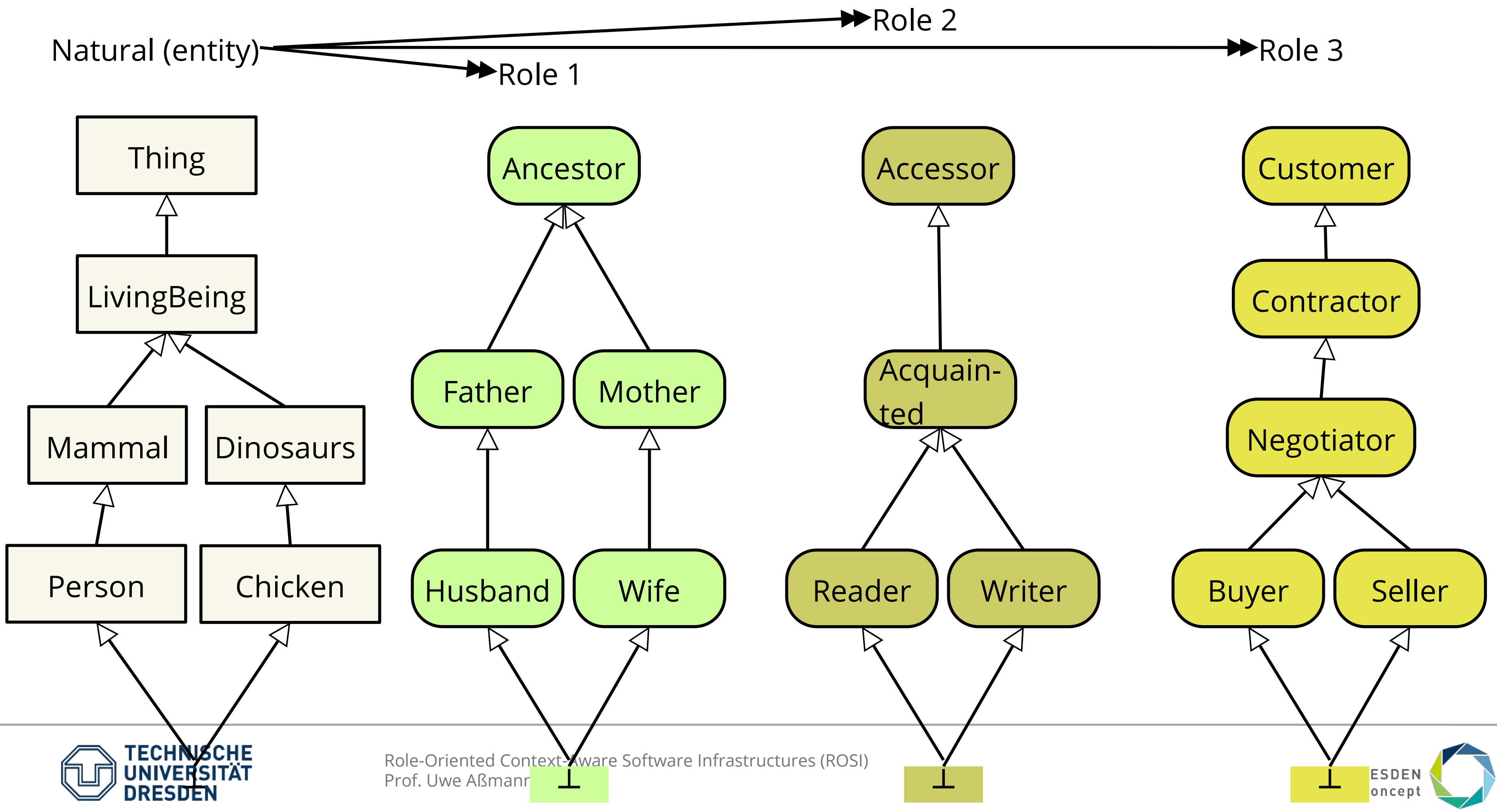
Steimann Factorization [Steimann, DKE 2000]

- Splitting a full type into its *natural* and *role-type* components
  - FullType = Natural x (role-type, role-type, ...)
  - FullMan = Man x (Reader, Husband, Customer, ..)



Full Type is from an Inheritance Product Lattice

- What is a reading buying husband person?



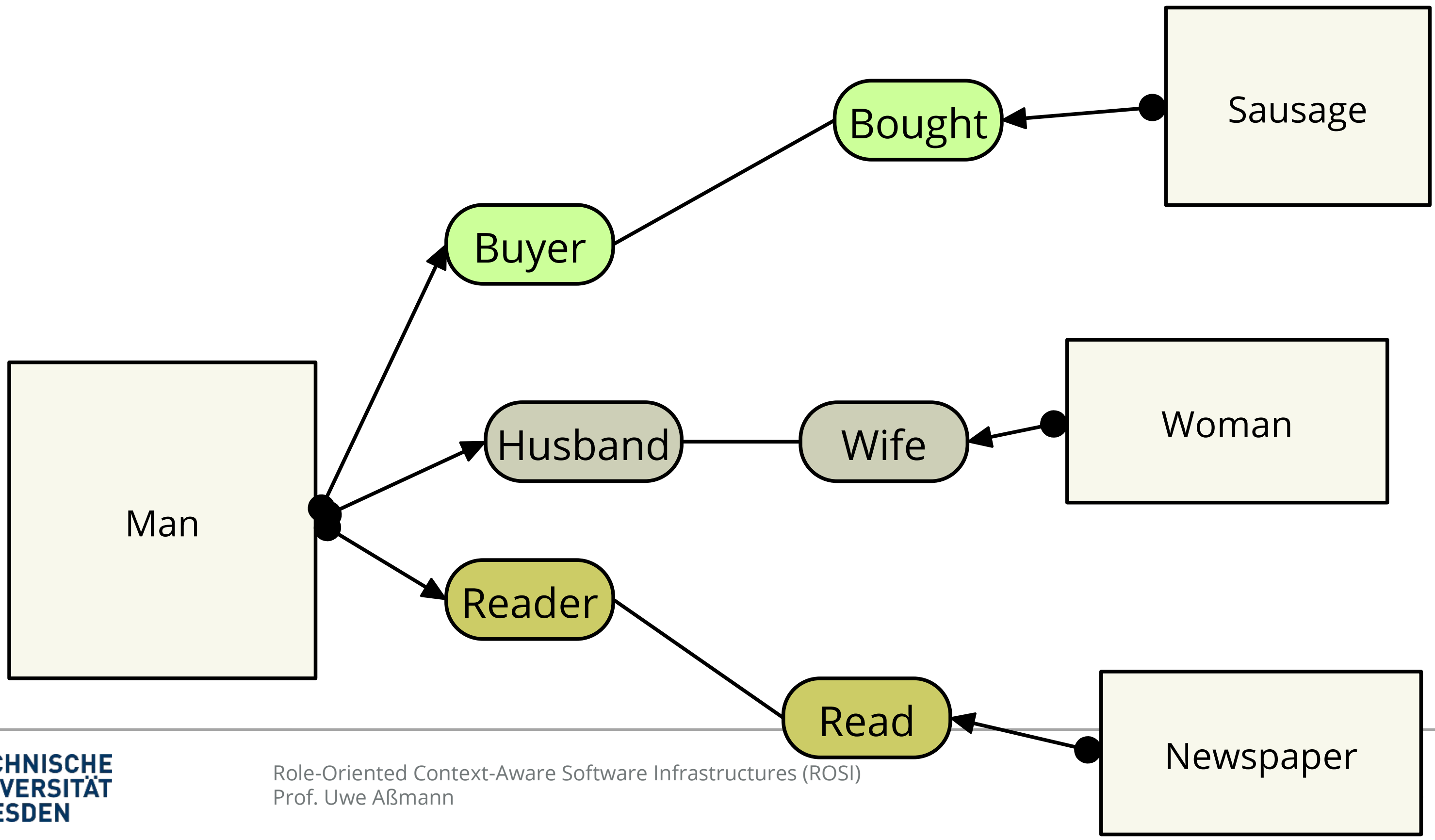
The Steimann Factorization

- Simpler, multi-dimensional inheritance hierarchies (product lattice)

Divide (partition) a *type* into a *tuple type* over a product lattice of a core dimension and n-1 role dimensions(Core, Role_1, ..., Role_n)

Concern-Separated Representation of Object Nets

- Collaborations (Role models) are interprocedural slices and belong to contexts
- Collaboration schemas are schemas for interprocedural slices



ROSI – Role-Oriented Context-Aware Software Infrastructures

1.2.1 Contexts and Compartments

[Kühn 2014]

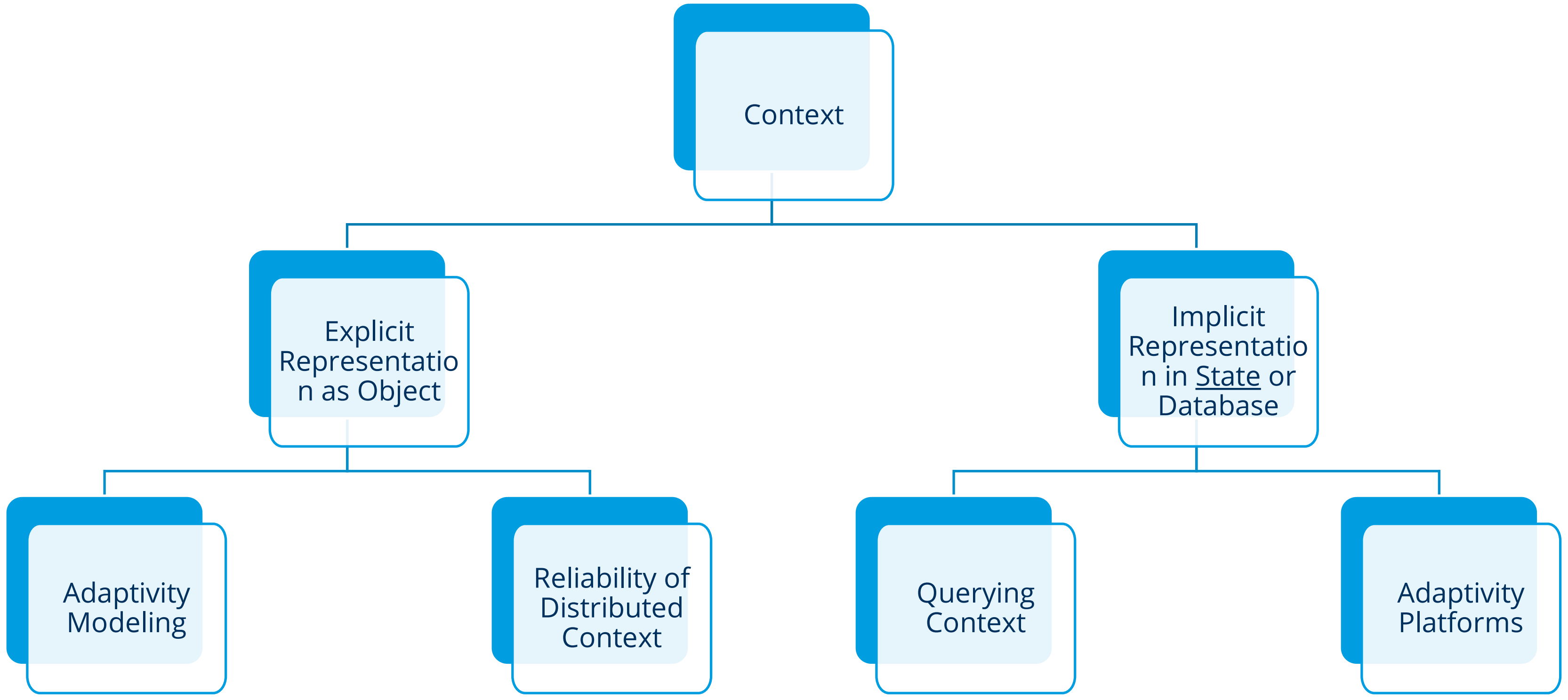
How to Model Contexts

- A ***context*** is an object reifying contextual conditions, *activating* and *deactivating* a set of roles of a set of objects
  - Contexts show that contextual conditions hold
  - *Marriage* (enables Husband and Wife)
  - *Light* (enables reading)
- A ***compartment*** is a structured context *activating* and *deactivating subcontexts*
  - *Marriage*: Mistress (Mätresse) enables lover and lovee during Marriage
  - *Light*: Glasses (enables reading while light is on)
- A ***compartment hierarchy*** is a hierarchy of structured contexts
  - *World model* (town, building, room)
- A ***compartment forest*** is a multi-hierarchy of structured contexts
  - *World model and company model*

Photo by ROOM on Unsplash

Photo by Alex Azabache on Unsplash

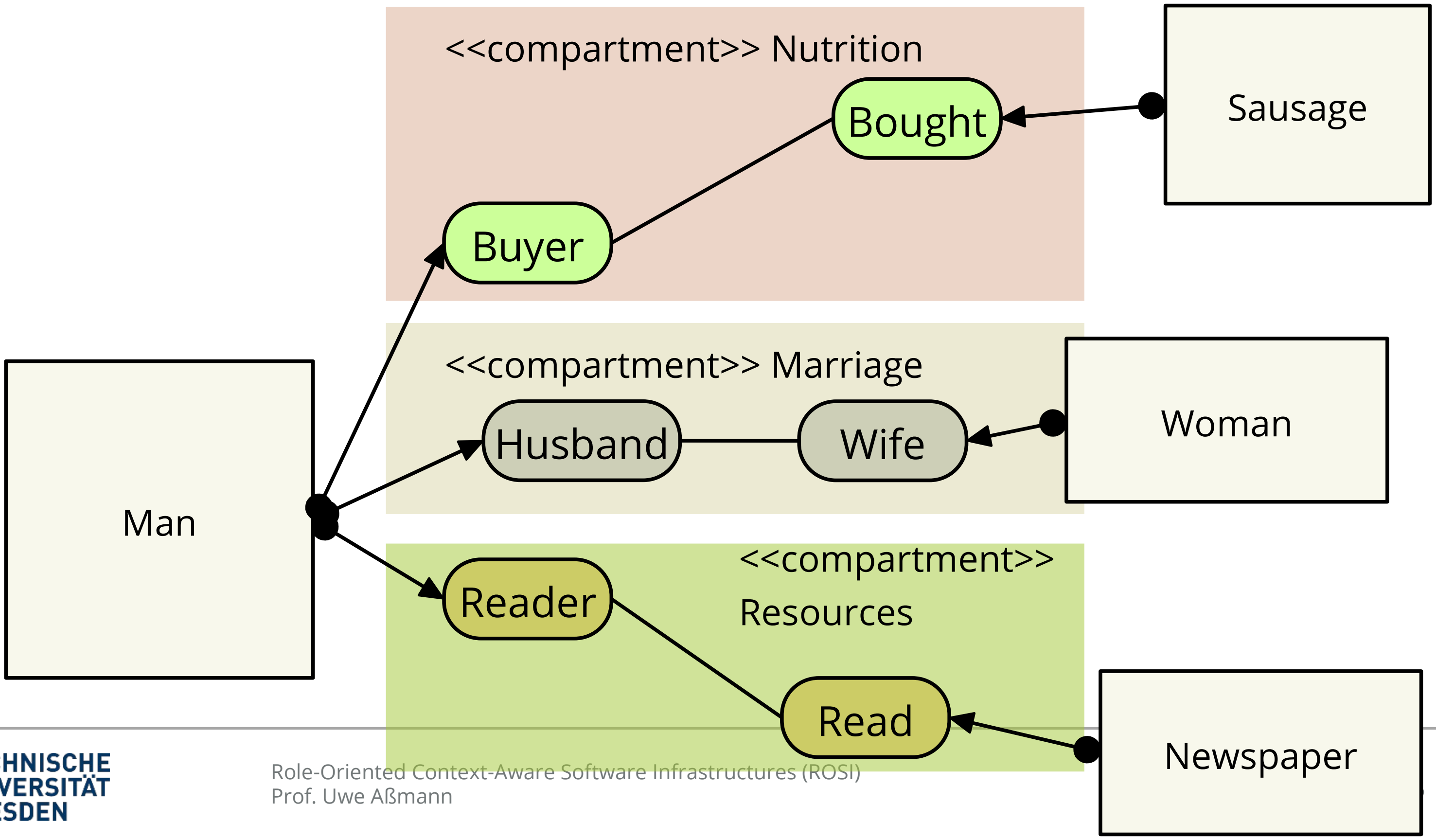
Explicit and Implicit Contexts


Context
Explicit Representation as Object
Implicit Representation in State or Database
Adaptivity Modeling
Reliability of Distributed Context
Querying Context
Adaptivity Platforms

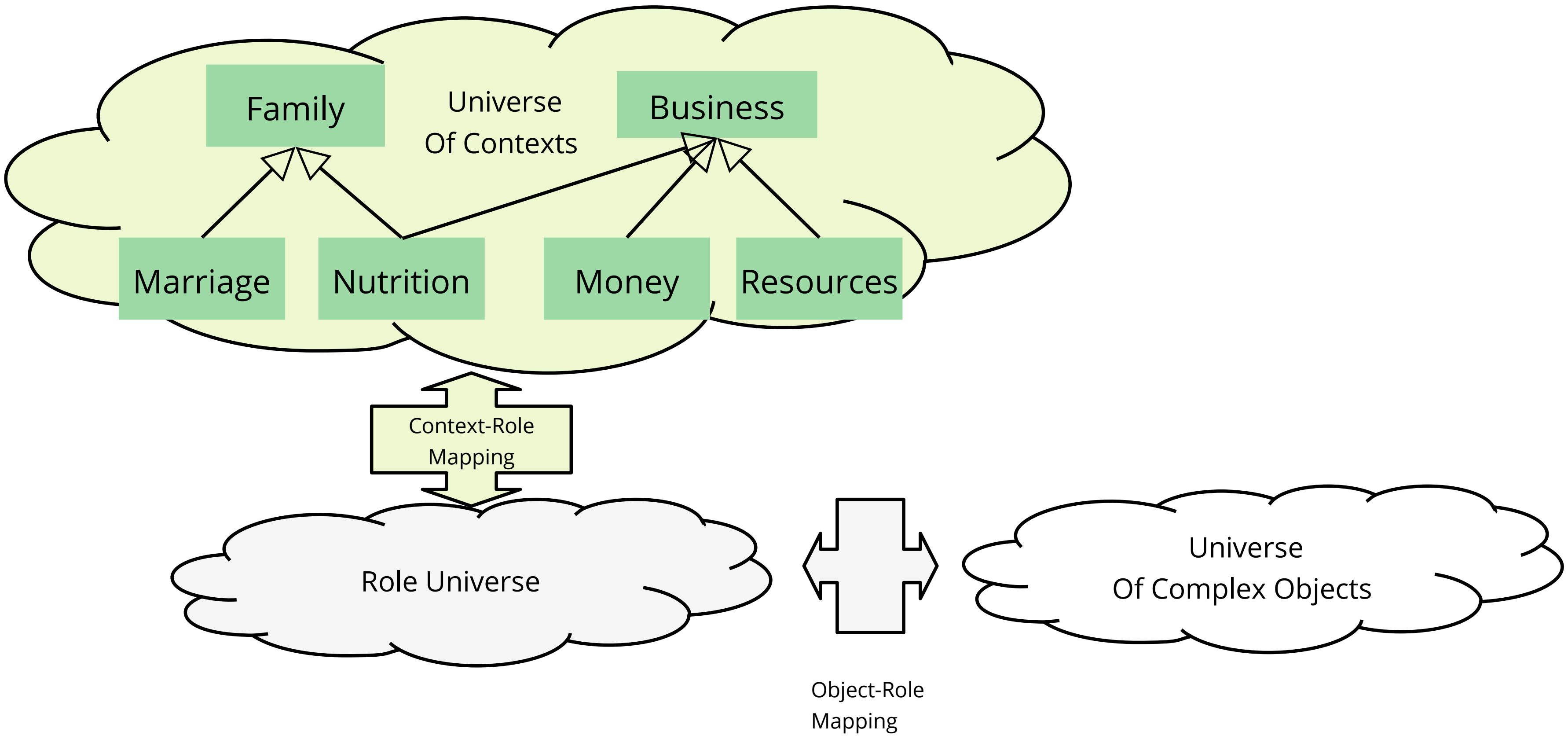
More on Concern-Separated Representation of Object Nets

- Compartments contain collaborations
- Compartments form ***indices*** to interprocedural slices

Photo by Bruno Kelzer on Unsplash



Example of Compartment Multi-Hierarchies



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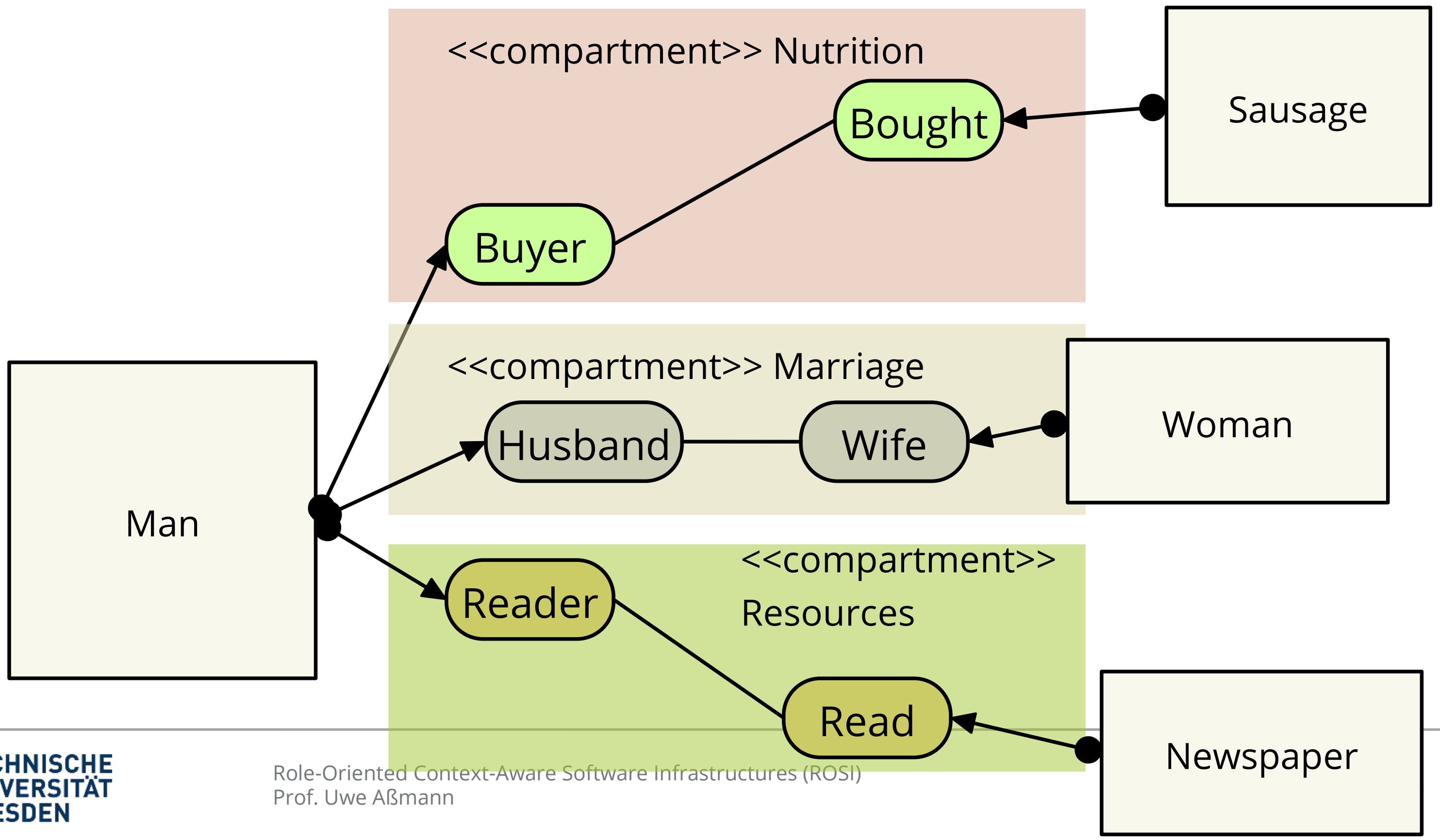
Role-Oriented Context-Aware Software Infrastructures (ROSI)

1.3. Advantages of Roles: Simple Static and Dynamic Data Extensibility

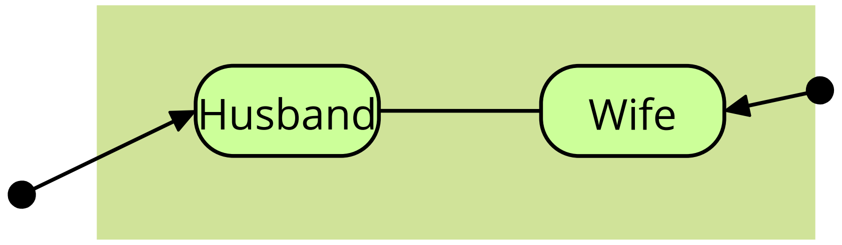
Simplified Extension with Compartments

- Object-role nets can be *extended by* new compartments with new role models collaborations

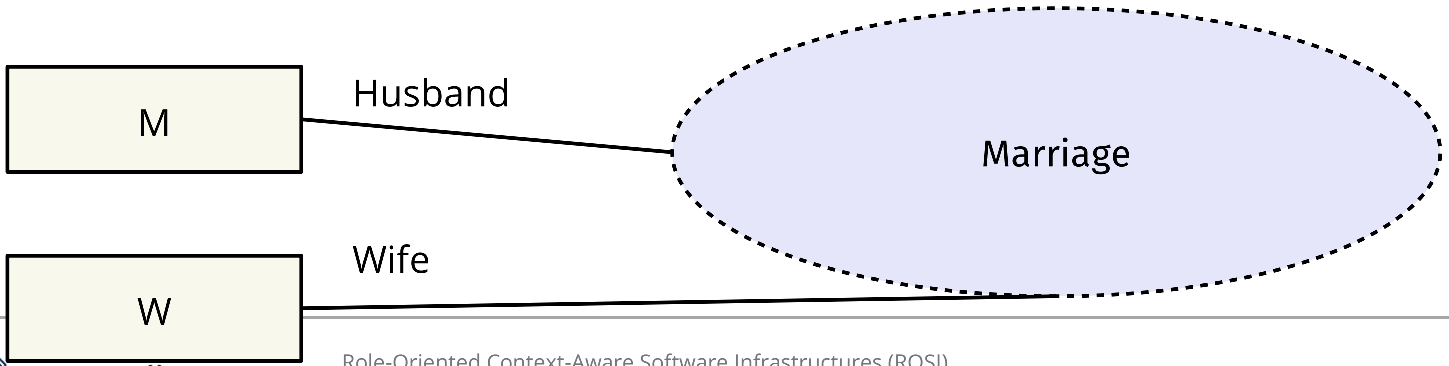


A Compartment is a Relational Module (Collaboration)

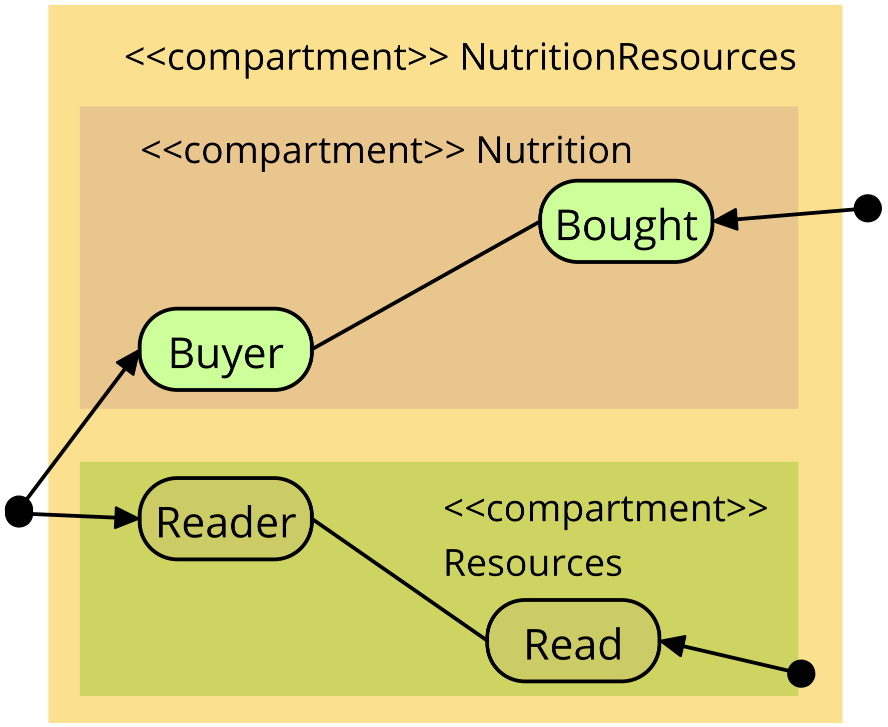
- Nets of roles with open ends, open *plays-a* tentacles,
  - to be attached to object cores



- UML Notation (class level) with *role-type parameter* P:



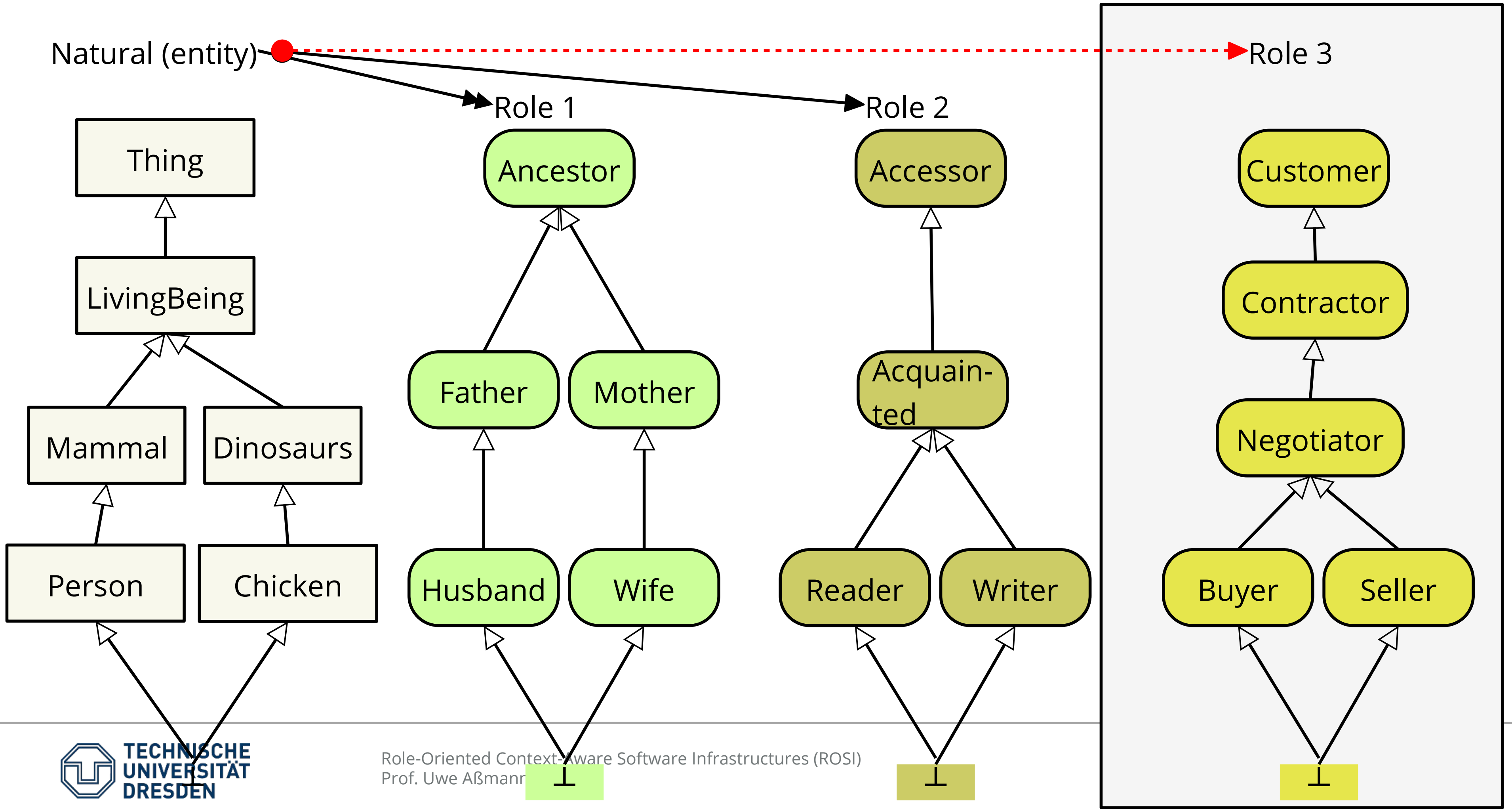
Structured Compartment: Resources and Nutrition



<<compartment>> NutritionResources
<<compartment>> Nutrition
Bought
Buyer
Reader
<<compartment>> Resources
Read

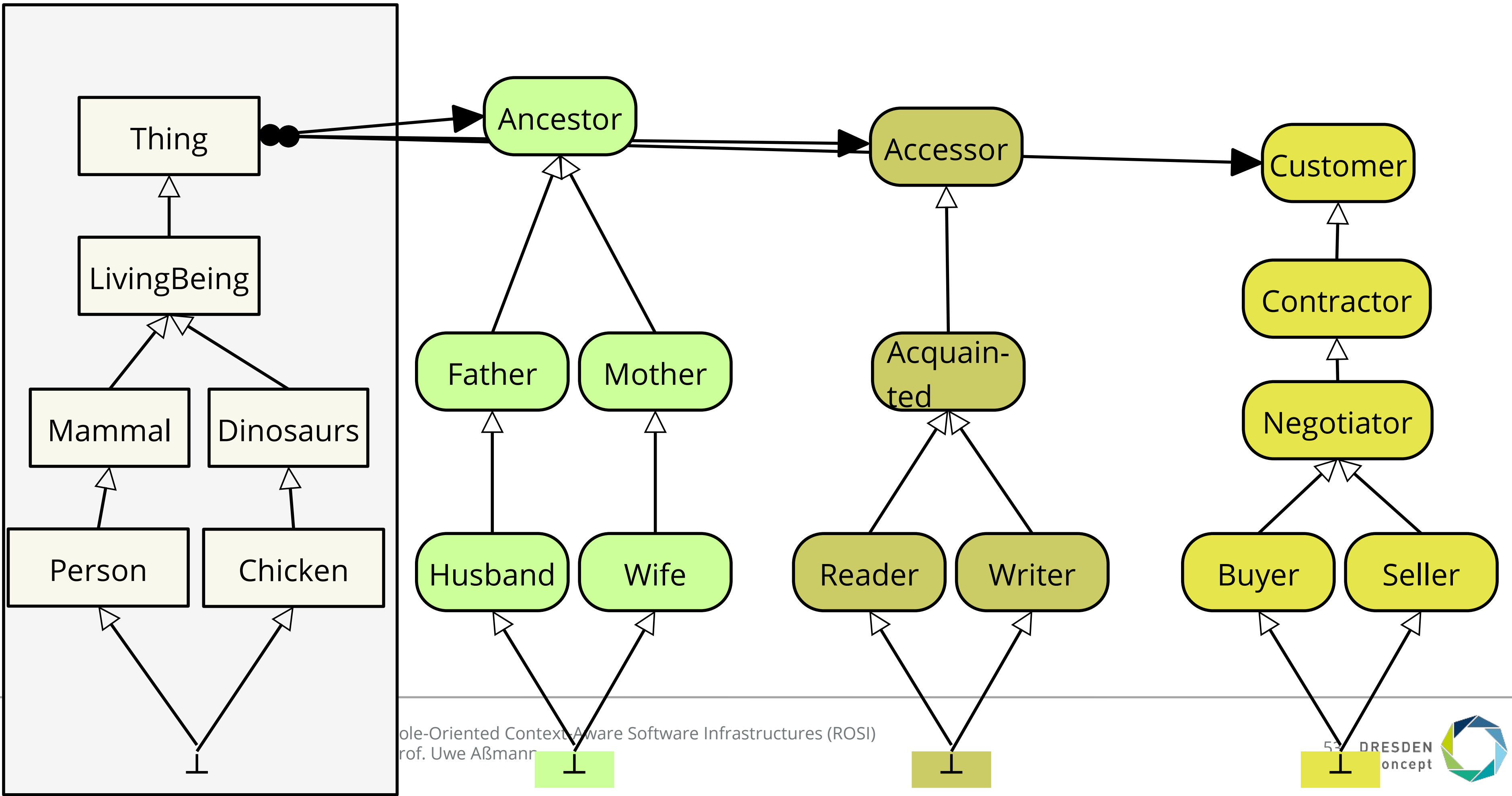
Extension on the Steimann Product Lattice

- A new role relationship extends the product lattice by another dimension.



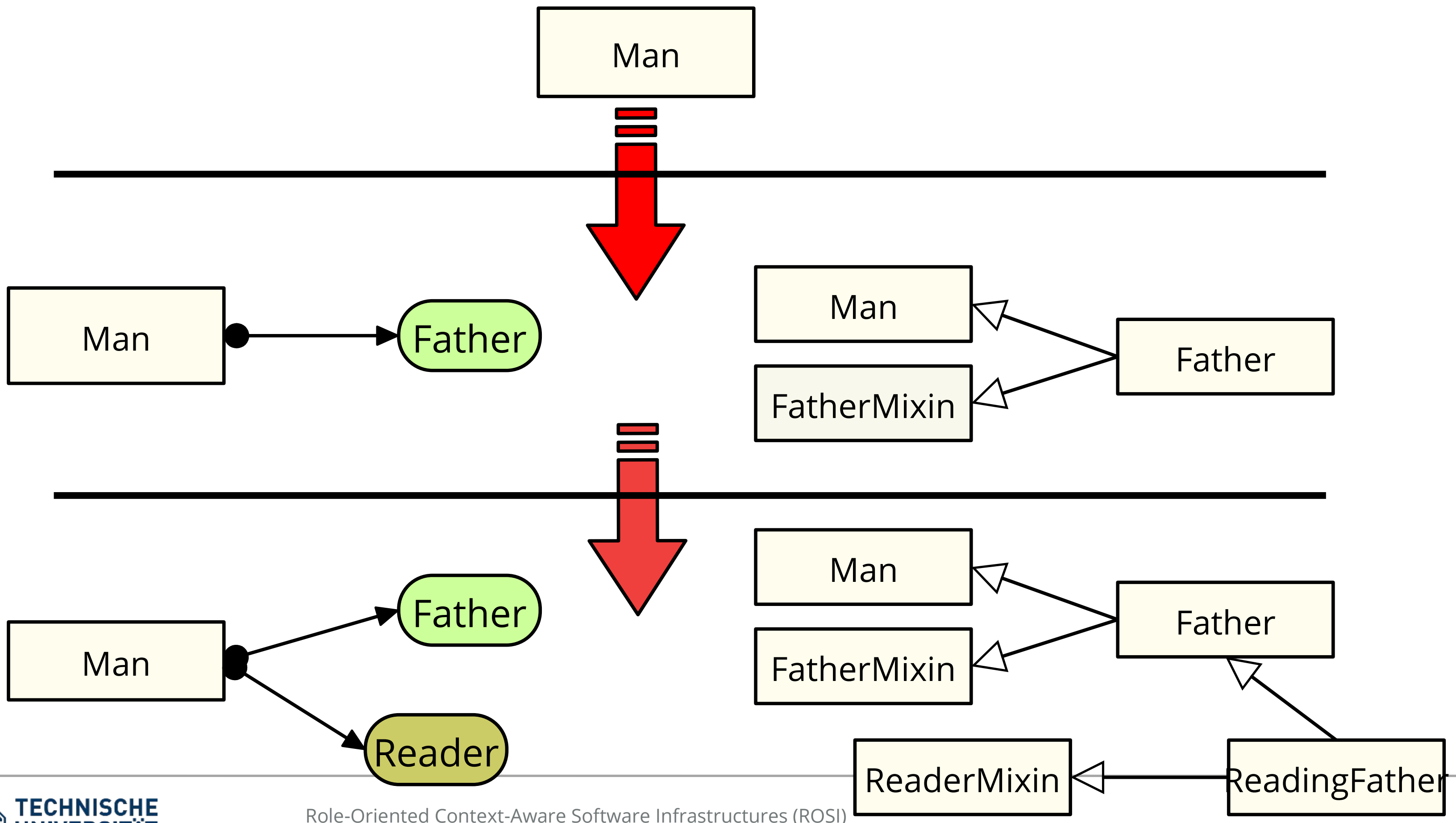
Separation of Concerns with Roles: Identity of Objects is Fixed to Core Facet of Product Lattice

- Role type extensions does not change the name of the core type nor of the full type (polymorphism)

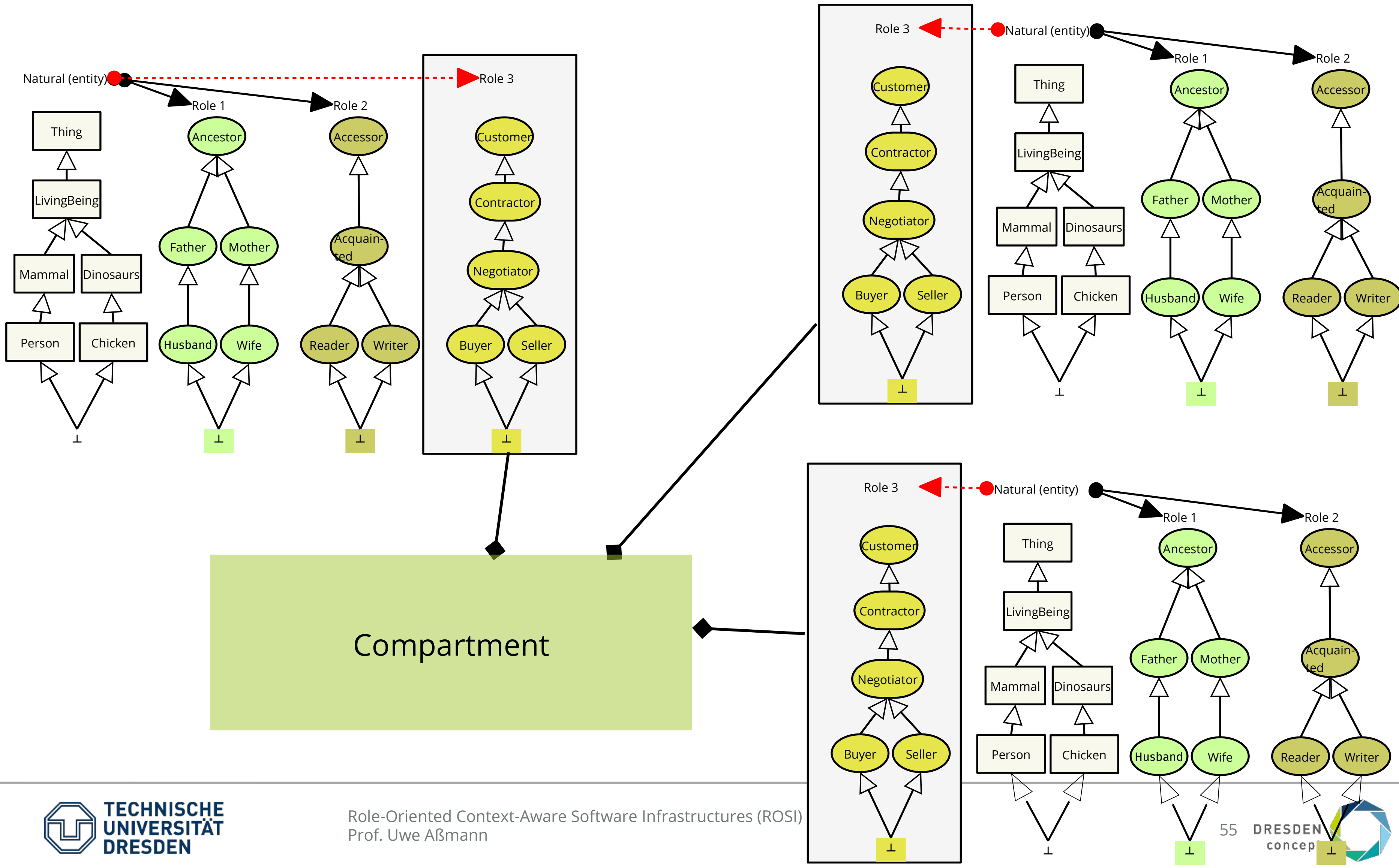


Separation of Concerns with Roles: Simplifies Inheritance Hierarchies

- Role Extension Retains Core Identity



Compartment Superimposition extends the Steimann Lattices of all involved Classes

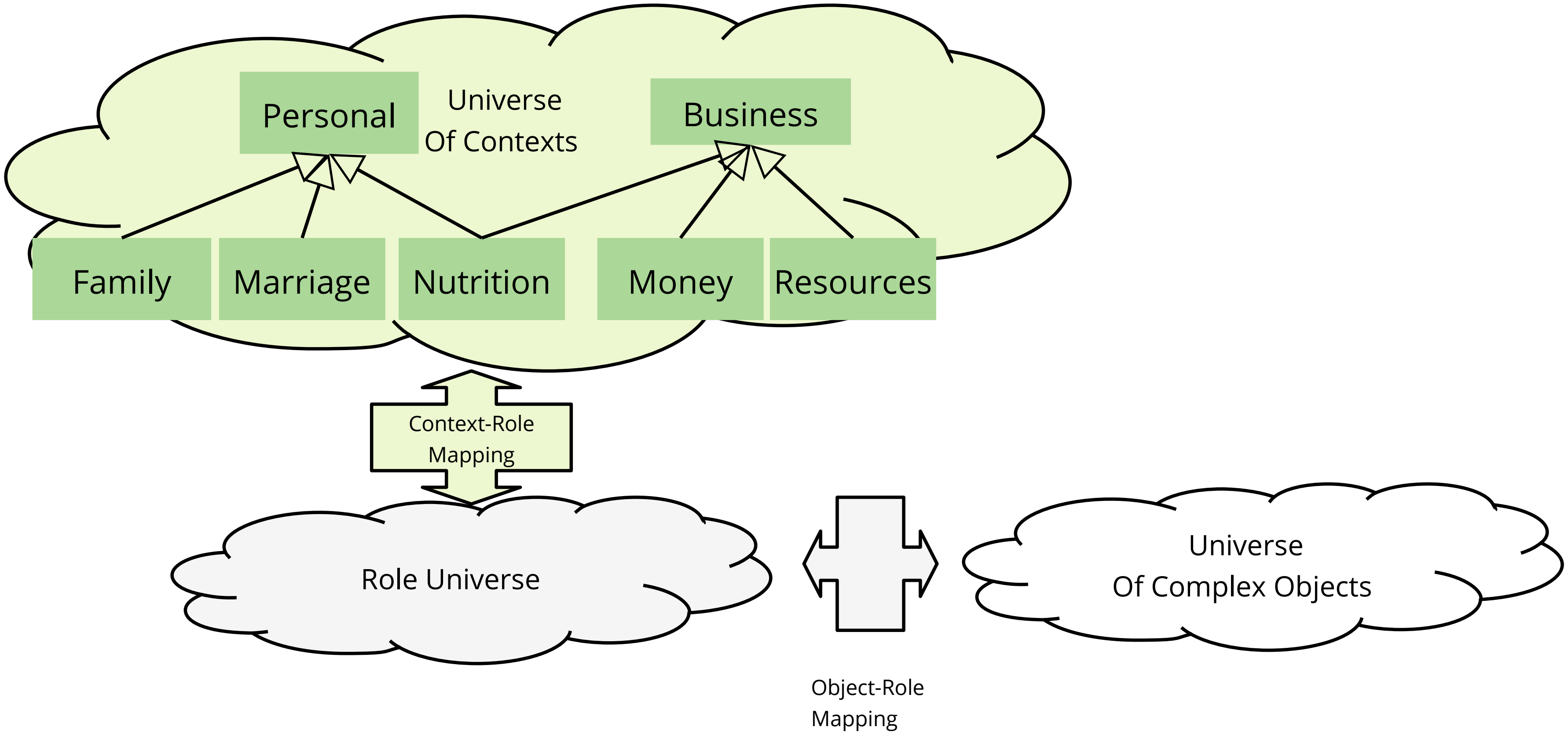


Extension and Adaptatation in the Steimann Lattice Retains Inheritance

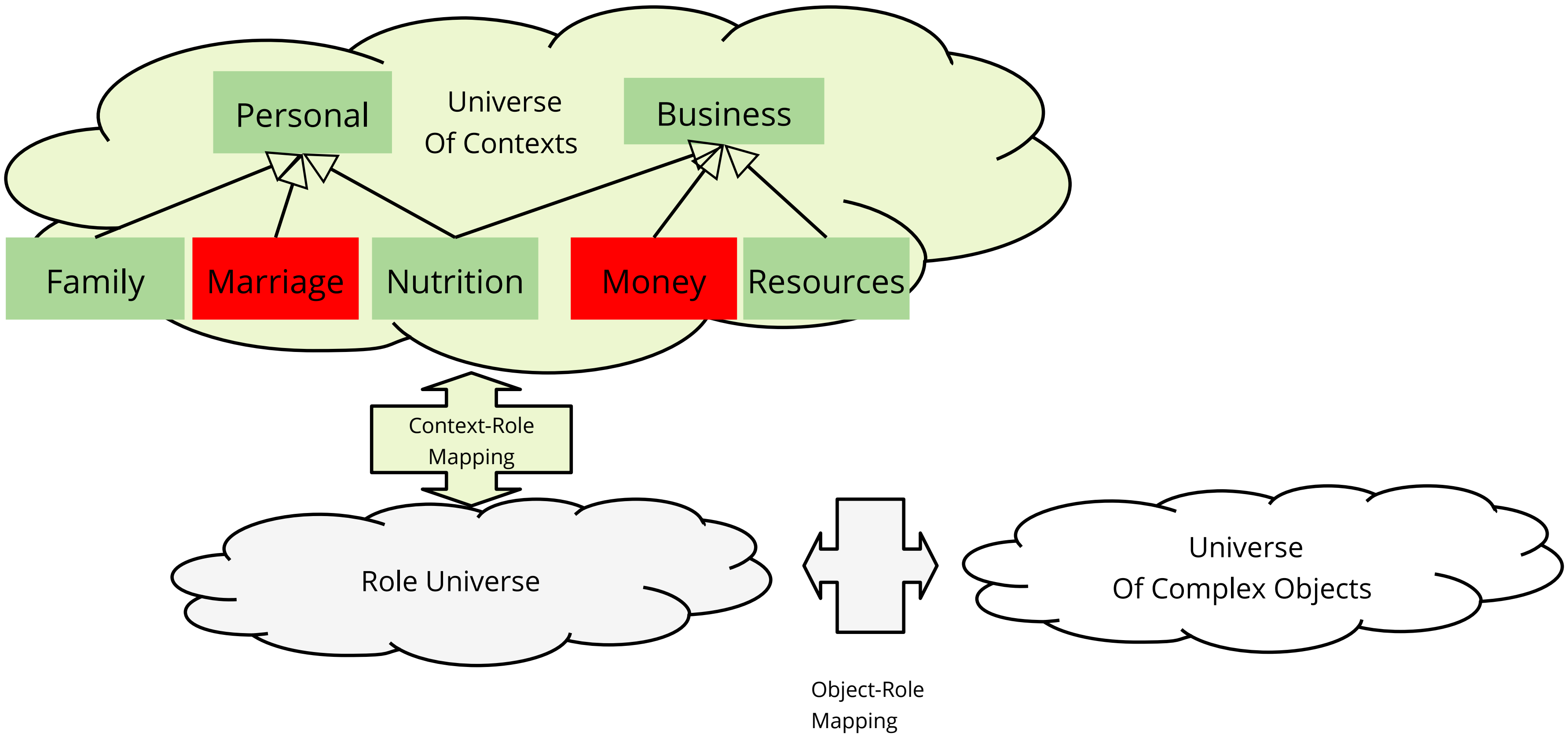
- Stable entity inheritance hierarchies, if concepts are added *relationally* to a model
  - Otherwise: extension of superclasses necessary (role classes become superclasses of entity classes)
  - Adding of new *concerns* is simple (adding a collaboration)

Superimposition of compartments to objects in Steimann-factored form retains all inheritance structures

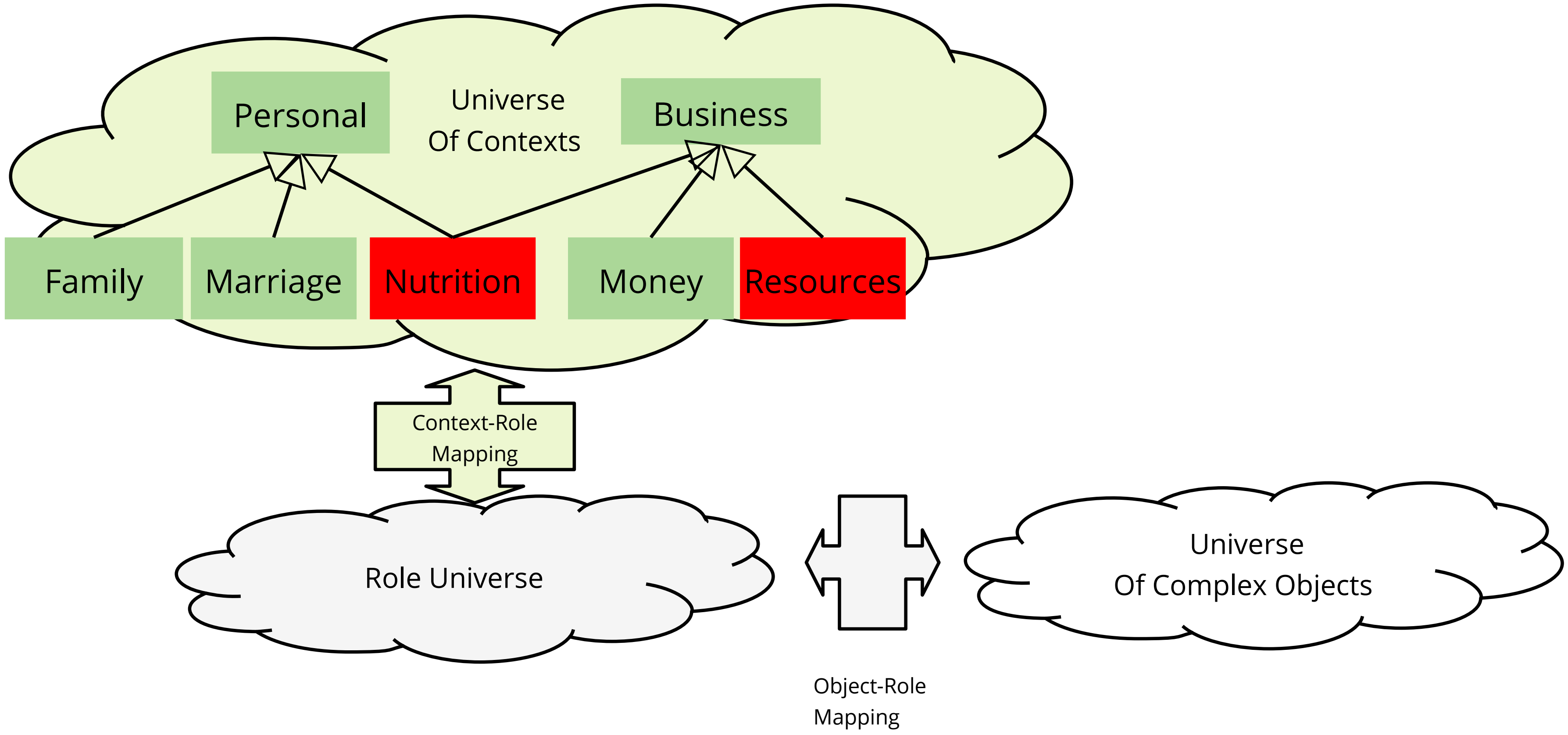
Adaptability with Compartment Multi-Hierarchies



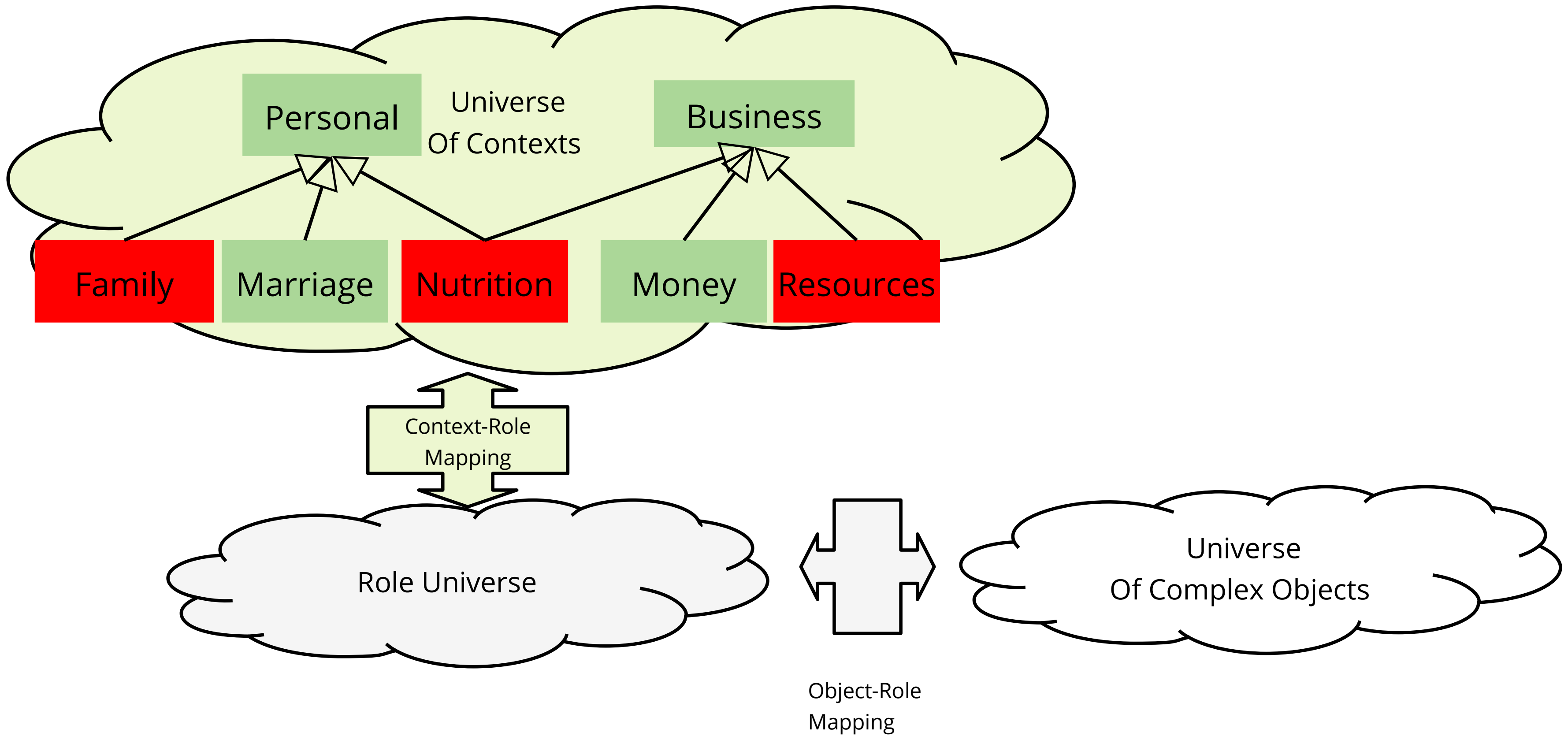
Adaptability with Compartment Multi-Hierarchies



Adaptability with Compartment Multi-Hierarchies



Adaptability with Compartment Multi-Hierarchies



ROSI Programming with SCROLL

- Compartment and Role Classes
- Dynamic Role Playing with *deep roles*
- SCROLL Scala Library https://github.com/max-leuthaeuser
- Change of context means to change to a new variant of the software
- SCROLL is perfect for *dynamic software product lines (DSPL)*

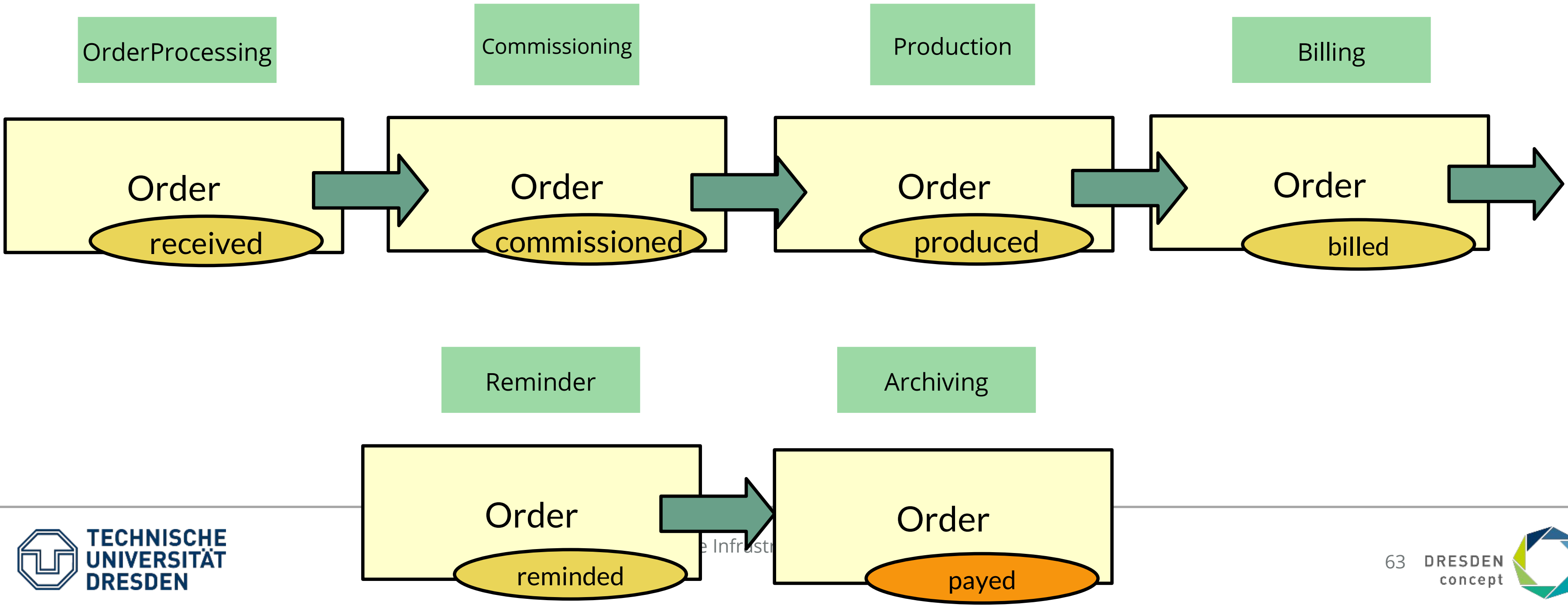
Roles and context are ready for programming in SCROLL

Role-Oriented Context-Aware Software Infrastructures (ROSI)

1.4. Roles and their Benefit for Separation of Concerns

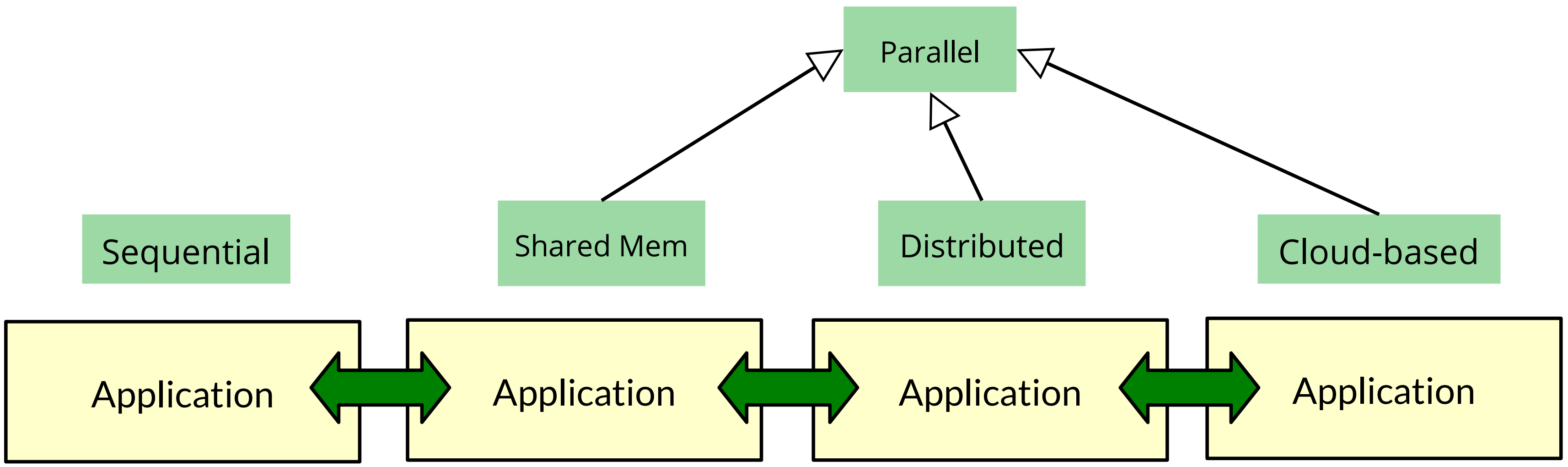
Business Objects with Roles and Contexts

- In large ERP frameworks (see SAP) business objects get very complex
- Ex.: **Order** gets different contexts, with roles
  - Every phase defines a context with different collaborators
- Dynamic Extensibility and Variability (Adaptation) by activation of new contexts



Parallel Objects with Roles and Contexts

- Selection of synchronisationprotocol by activation of new contexts
  -

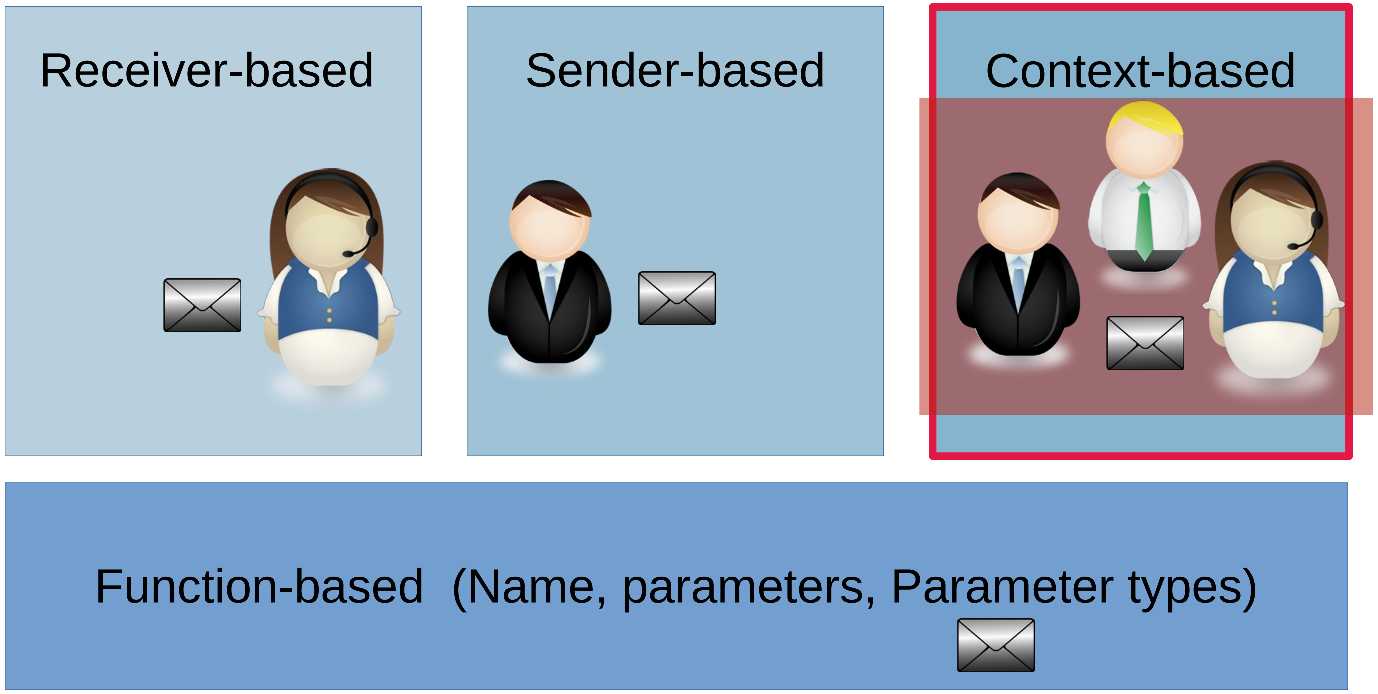


Advantages of ROSI for System Construction

- Separation of Concerns
  - Natural features – Context-dependent features
  - Dynamic features – static features
- Representation of roles as interprocedural graph slices
- Adaptability
  - Extensibility
  - Aspect Orientation (behavioral extensibility)
  - Variability (delayed role embedding decisions)
  - Substitutability (of roles and role models)

ROSI supports Roles and Contexts for Multi-Dimensional Dispatch for Multi-Polymorphism

- How is the semantics of a function (method) determined?



Dijkstra on Separation of Concerns

E. W. Dijkstra “On the Role of Scientific Thought”, EWD 447 Selected Writings on Computing: A Personal Perspective, pages 60–66, 1982.

"Let me try to explain to you, what to my taste is ***characteristic for all intelligent thinking.***

It is, that one is willing to study in depth **an aspect of one's subject matter in isolation** for the sake of its own consistency, all the time knowing that one is occupying oneself only with one of the aspects.

We know that a program must be correct and we can study it from that viewpoint only; we also know that it should be efficient and we can study its efficiency on another day, so to speak. In another mood we may ask ourselves whether, and if so: why, the program is desirable. But nothing is gained --on the contrary!-- by tackling these various aspects simultaneously.

Roles and contexts introduce separations of concerns.

Intelligent thinking and scientific thought

It is what I sometimes have called **"the separation of concerns"**, which, even if not perfectly possible, is yet the only available technique for effective ordering of one's thoughts, that I know of.

This is what I mean by **"focussing one's attention upon some aspect"**: it does not mean ignoring the other aspects, it is just doing justice to the fact that from this aspect's point of view, the other is irrelevant. It is being one- and multiple-track minded simultaneously.

Scientific thought comprises "intelligent thinking" as described above. A scientific discipline emerges with the --usually rather slow!-- discovery of which aspects can be meaningfully **"studied in isolation for the sake of their own consistency"**, in other words: with the discovery of useful and helpful concepts. Scientific thought comprises in addition the conscious search for the useful and helpful concepts.

The End

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