Carving Digital Reality at its joints: The Role of **Ontology**-Driven **Conceptual Modeling** in Next-Generation **Information Systems** Engineering

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ontology & conceptual modeling research group

Acknowledgements

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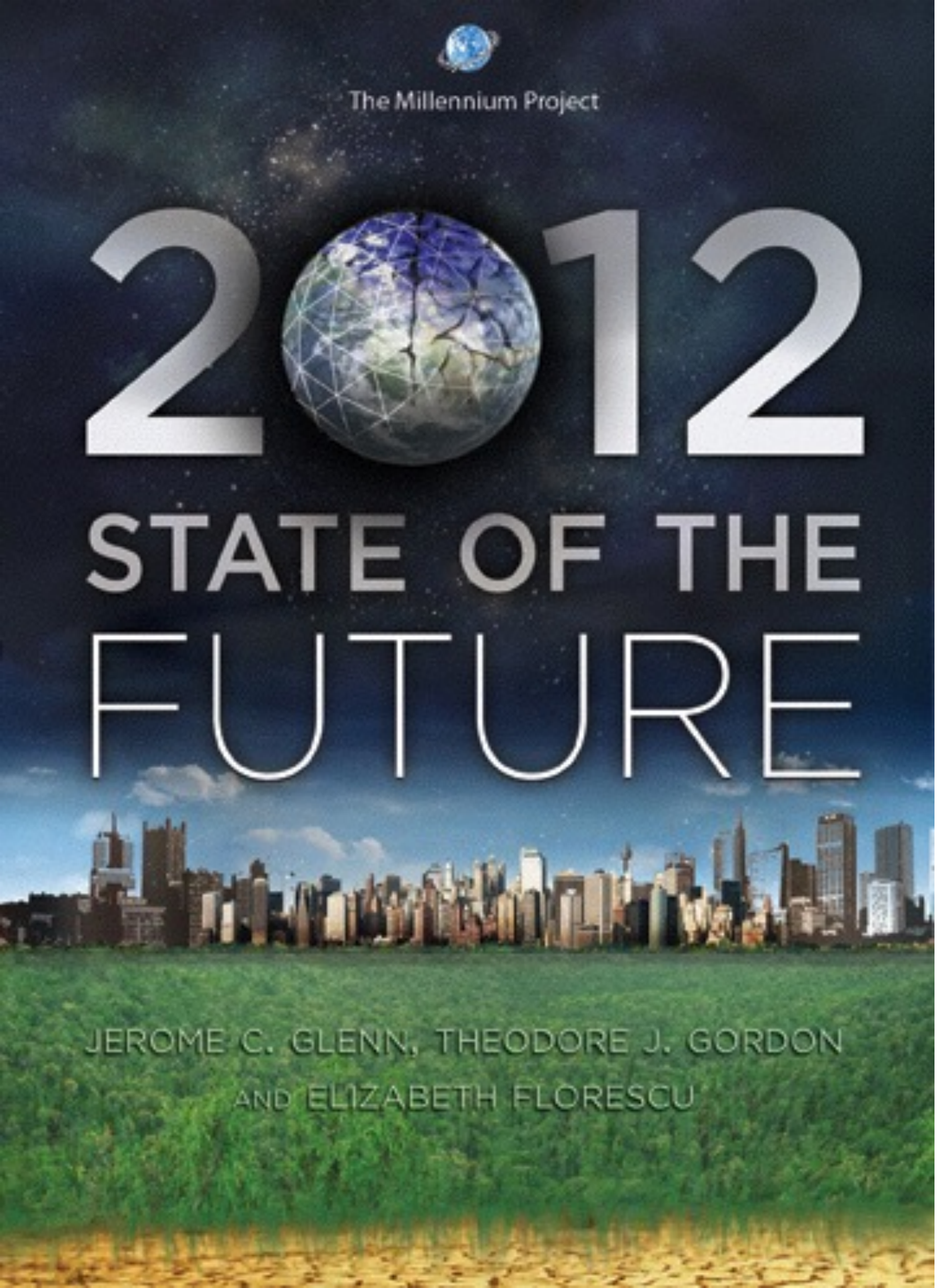

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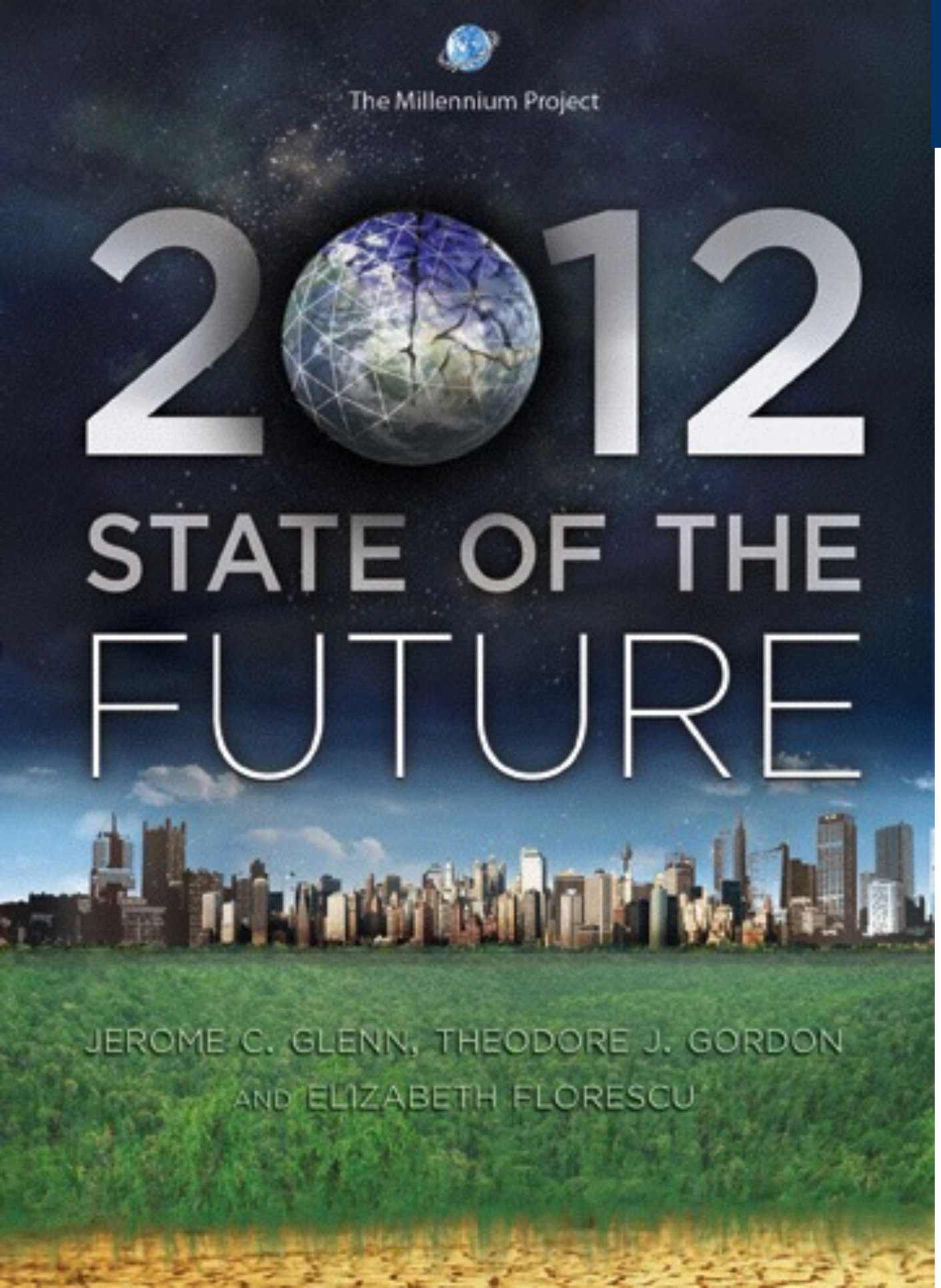
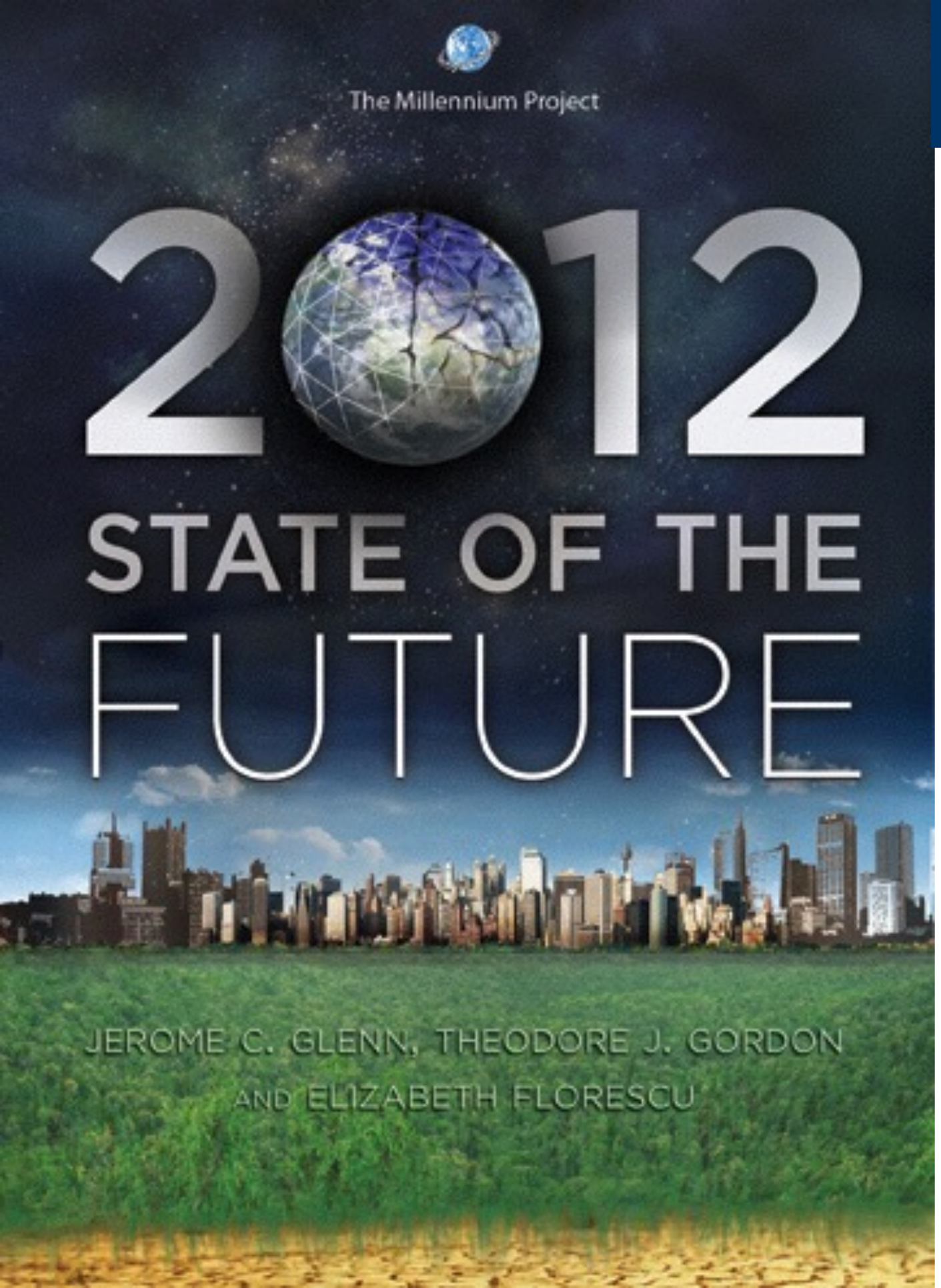


THE FUTURIST
A Magazine of Forecasts, Trends, and Ideas about the Future

"The fast-growing science of ontology could exert a ***greater impact on humanity than the rise of the Internet***…ontologies allow for data to interoperate and for machines to make inferences."



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Semantic Interoperability is considered to be ***the problem of this decade***…[currently] costing productivity, lives and billions of dollars annually…the overall human and financial cost to society from our ***failure*** to share and reuse information is ***many times the cost of the systems' operation*** and maintenance

[OMG, SIMF - Semantic Information Model Federation]

Semantic…

1

An information system is a **representation of** reality according to a particular **worldview**

…Interoperability

2

Modern information systems and artifacts that are constructed in a **collective** and **distributed** way

“Software is **(cr)eating*** the World”

3

Most information systems are representations of **Social Reality** but they also ground (and, hence, create) part of Social Reality

*a variation of Marc Andreessen’s expression
“Software is Eating the World” in the Wall Street Journal, 2011.

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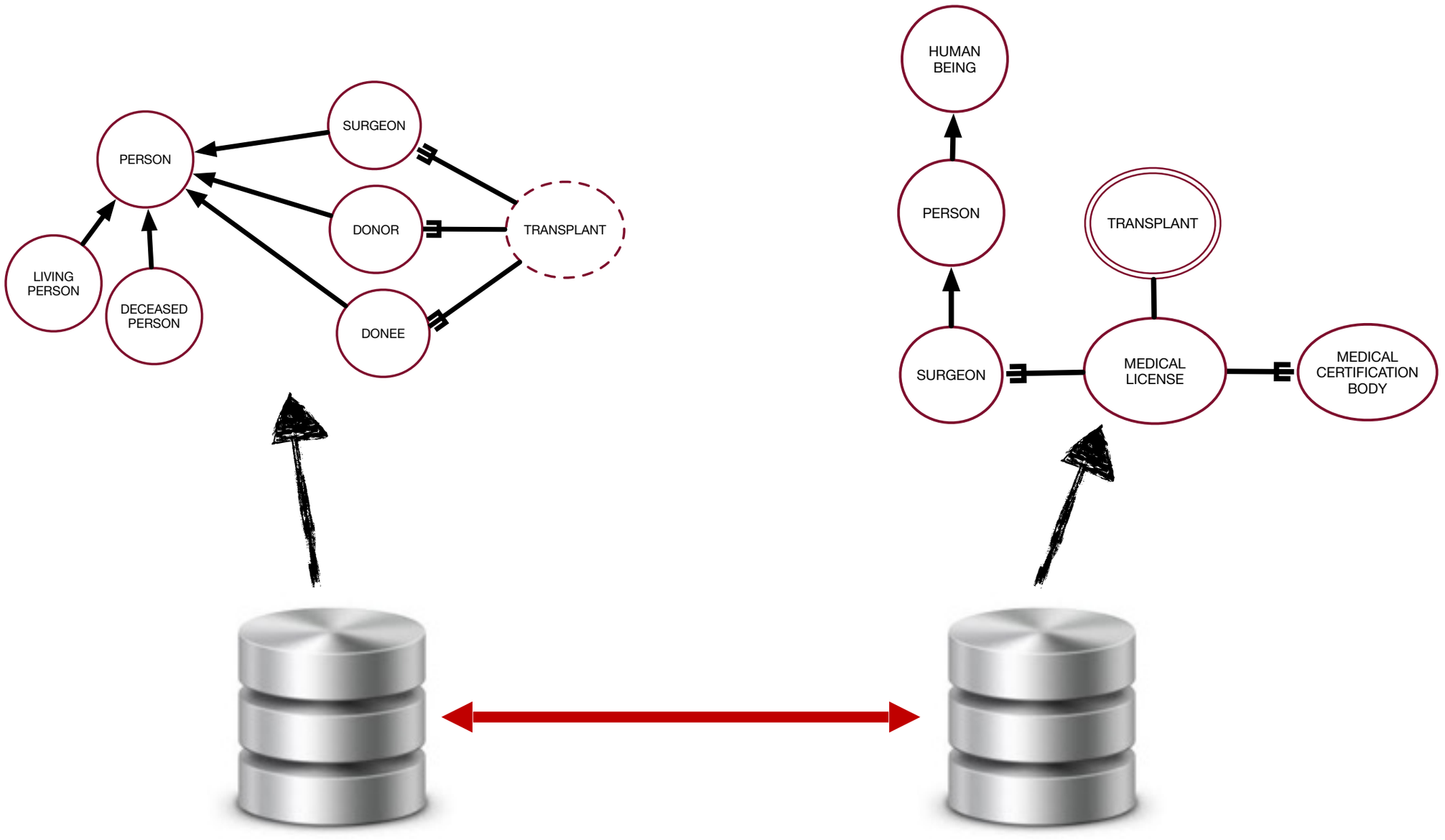
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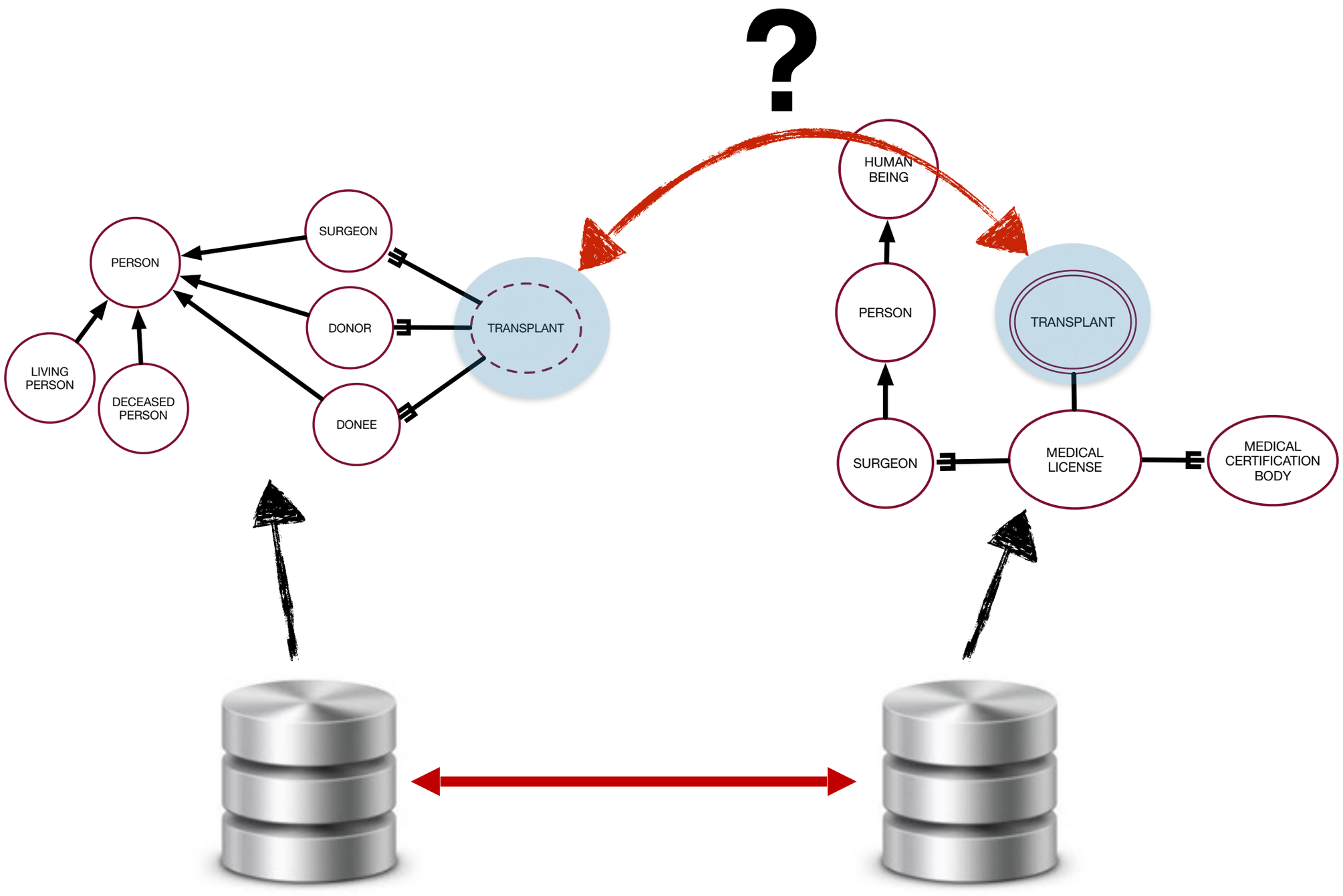
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Semantic Interoperability

=

relating different **worldviews**, i.e., different **conceptualizations** of reality

The **Taxonomy** of Animals in *The Celestial Emporium of Benevolent Knowledge (Borges)*

- Those that belong to the emperor
- Those that resemble flies from a distance
- Those that have just broken a flower vase
- Embalmed ones
- Fabulous ones

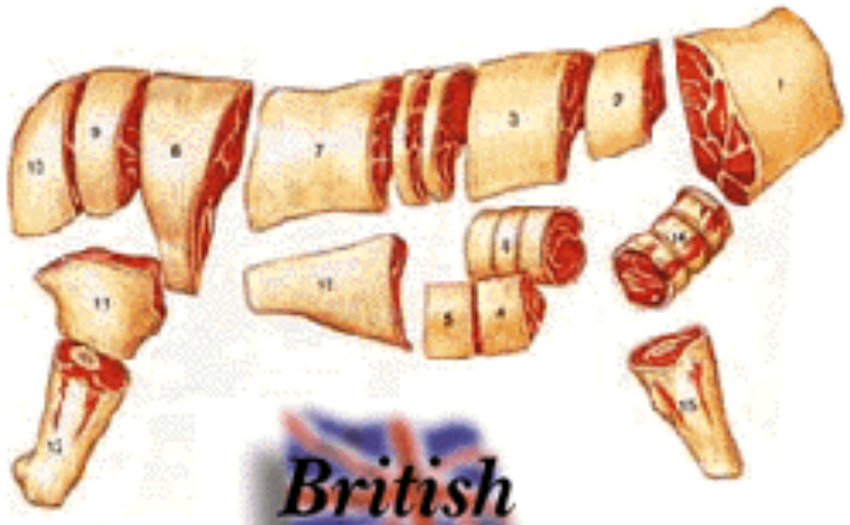
“Those that resemble flies from a distance” is a logically possible way to group objects, but it’s not how we naturally make sense of the world. No real language would have a noun for such a category…Real nouns capture something deep; they refer to **kinds** of things that are thought to share deep properties…”

(Paul Bloom, How Pleasure Works, 2010)

"...As the evolutionary theorist Stephen Jay Gould put it, our classifications don't just exist to avoid chaos, they are ***"theories about the basis of natural order."***

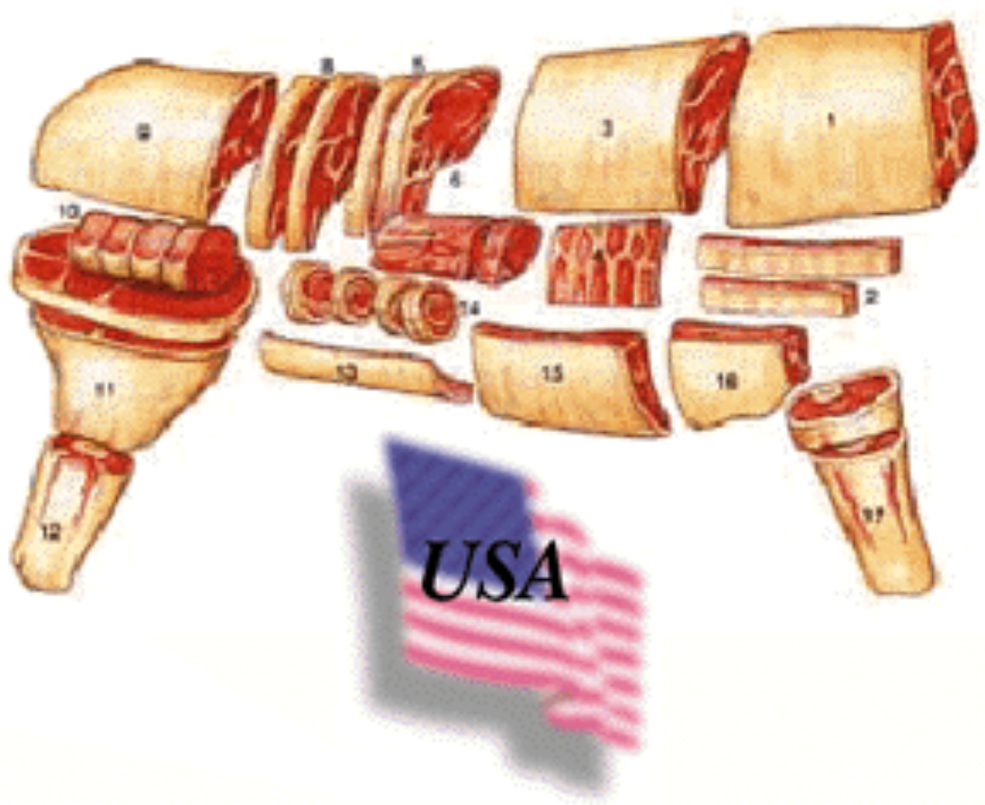
(Paul Bloom, How Pleasure Works, 2010)

Carving reality at its joints: good ontologists like good *butchers* [Plato]



British

French



USA

CTSciNet
Clinical and Translational Science Network

CTSciNet

More Than Words

By Chelsea Wald
February 11, 2011

Most biomedical research laboratories make up their own private language to describe their particular techniques, materials, and measurements. Even medical practitioners have more than a hundred ways to describe a simple fact such as a patient's blood glucose. Talking to other scientists about data

"It's getting to be impossible to do work in bioinformatics without knowledge of biomedical ontology." -- Mark Musen

*"Most biomedical research laboratories make up their own private language to describe their particular techniques, materials, and measurements. Even medical practitioners have more than a hundred ways to describe a simple fact such as a patient's blood glucose…**how can biomedical researchers make the most of the vast amounts of data out there?***

Print Article
Free Newsletter
BOOKMARK

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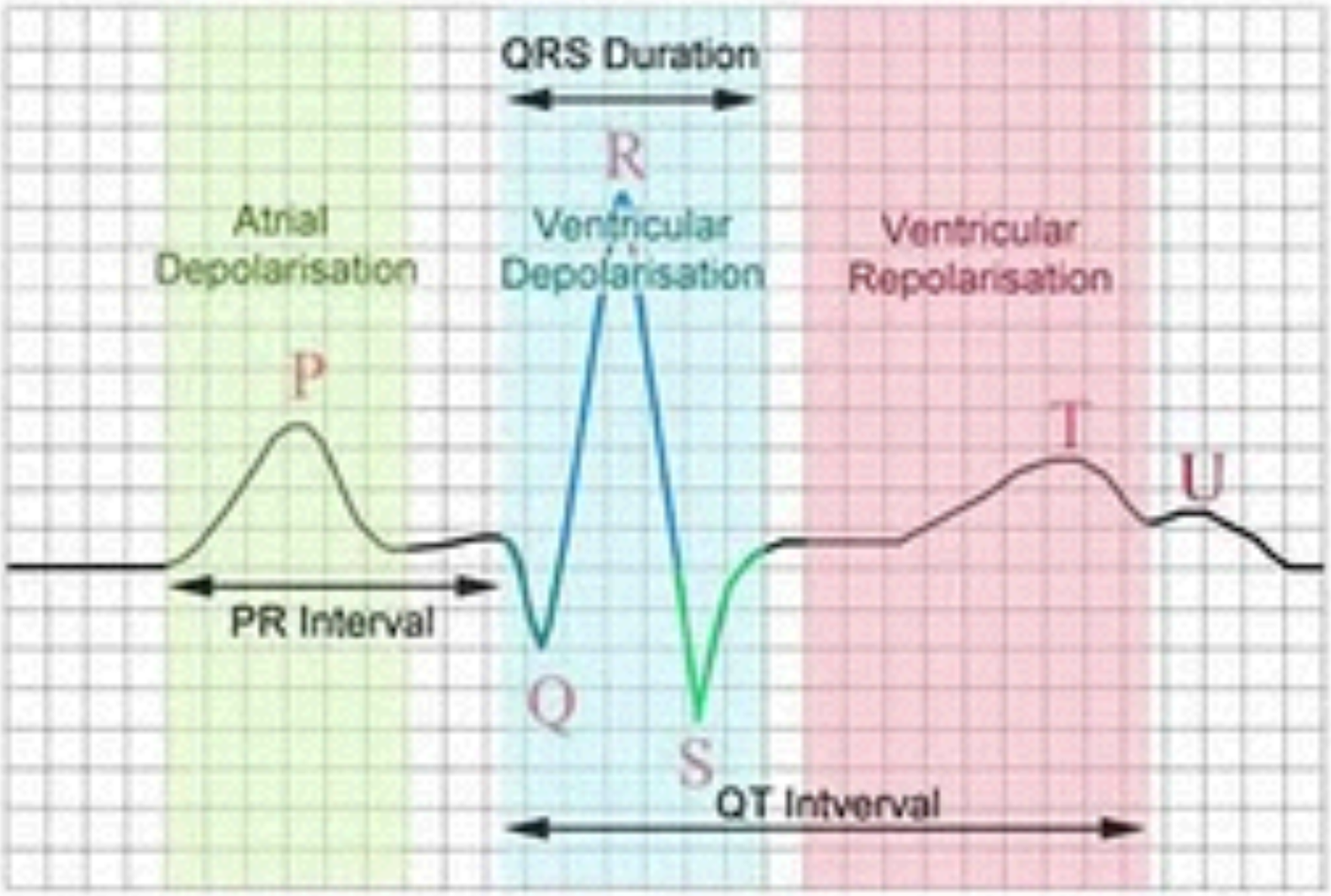
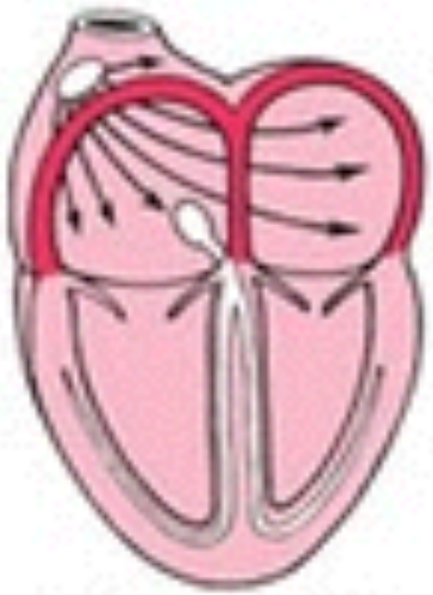
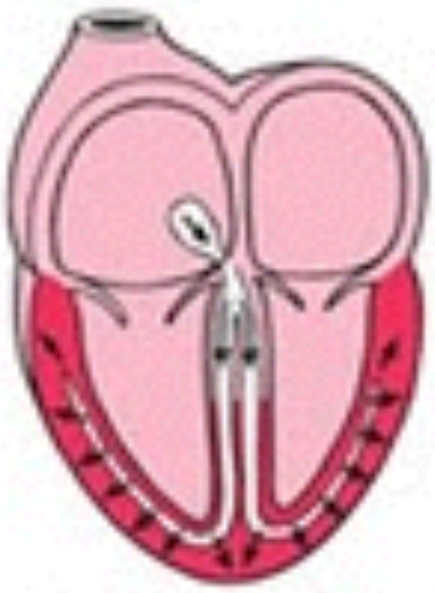
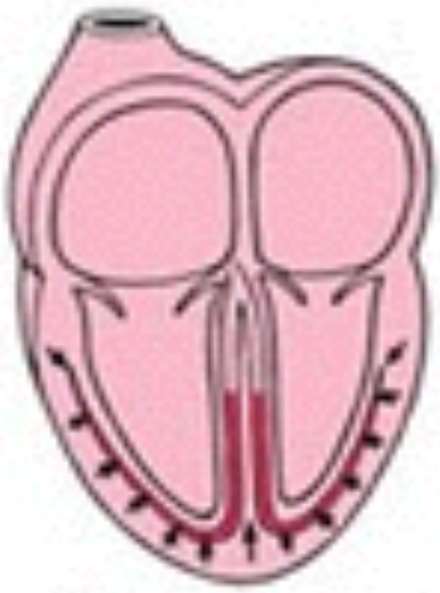




Activation of the atria

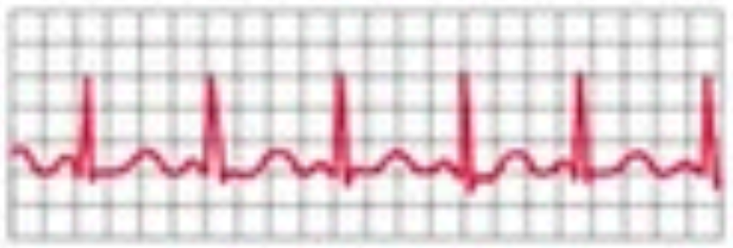


Activation of the ventricles

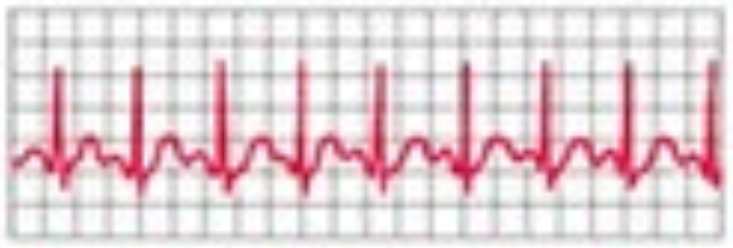


Recovery wave

Normal Heartbeat



Fast Heartbeat



Slow Heartbeat

Irregular Heartbeat

“Carving up Reality”

We need to guarantee

Intra-worldview Consistency

and

Inter-worldview Interoperability

Ontology as a **Calculus** of Content

- For that we need a *a prioristic* system of categories and their ties addressing issues of Identity, Unity (Parts and Wholes), Individuation, Change, Classification and Taxonomic Structures, Dependence (Existential, Historical, Relational, Notional), Causality, Essential and Accidental Characterization

- We need **Formal Ontology** and **Ontological Analysis**

Ontology-Driven Conceptual **Modeling**

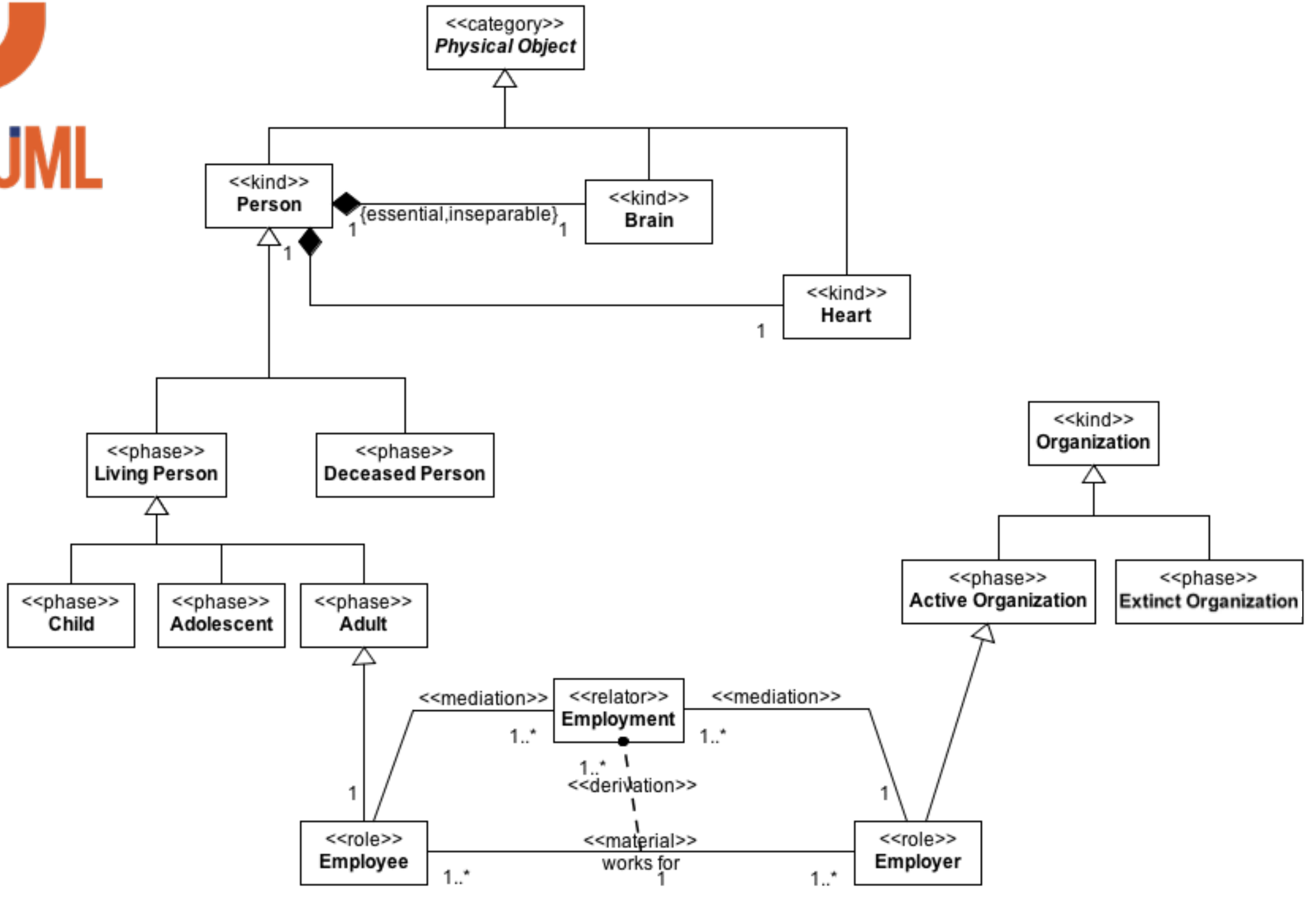
A discipline aiming at developing ontology-based methodologies, computational tools and **modeling languages** for the area of Conceptual Modeling

UFO
(Unified Foundational Ontology)

- Over the years, we have built a Philosophically and Cognitively well-founded Ontology to contribute to the general goal of serving as a Foundation for Conceptual Modeling

- This Ontology has been used to as a theory for addressing may classical conceptual modeling constructs such as Object Types and Taxonomic Structures (CAISE 2004, CAISE 2007, CAISE 2012), Part-Whole Relations (CAISE 2007, CAISE 2009, FOIS2010, CAISE 2011), Intrinsic and Relational Properties (ER 2006, ER 2008, ER 2011, CAISE 2015), Weak Entities, Attributes and Datatypes (ER 2006), Events (ER 2013, AI*IA 2016), Multi-Level Modeling (ER2015), Services (EDOC 2013), Capabilities (EDOC 2013), Values (EDOC 2017), Service Contracts (EDOC 2017), etc…

ONTOUML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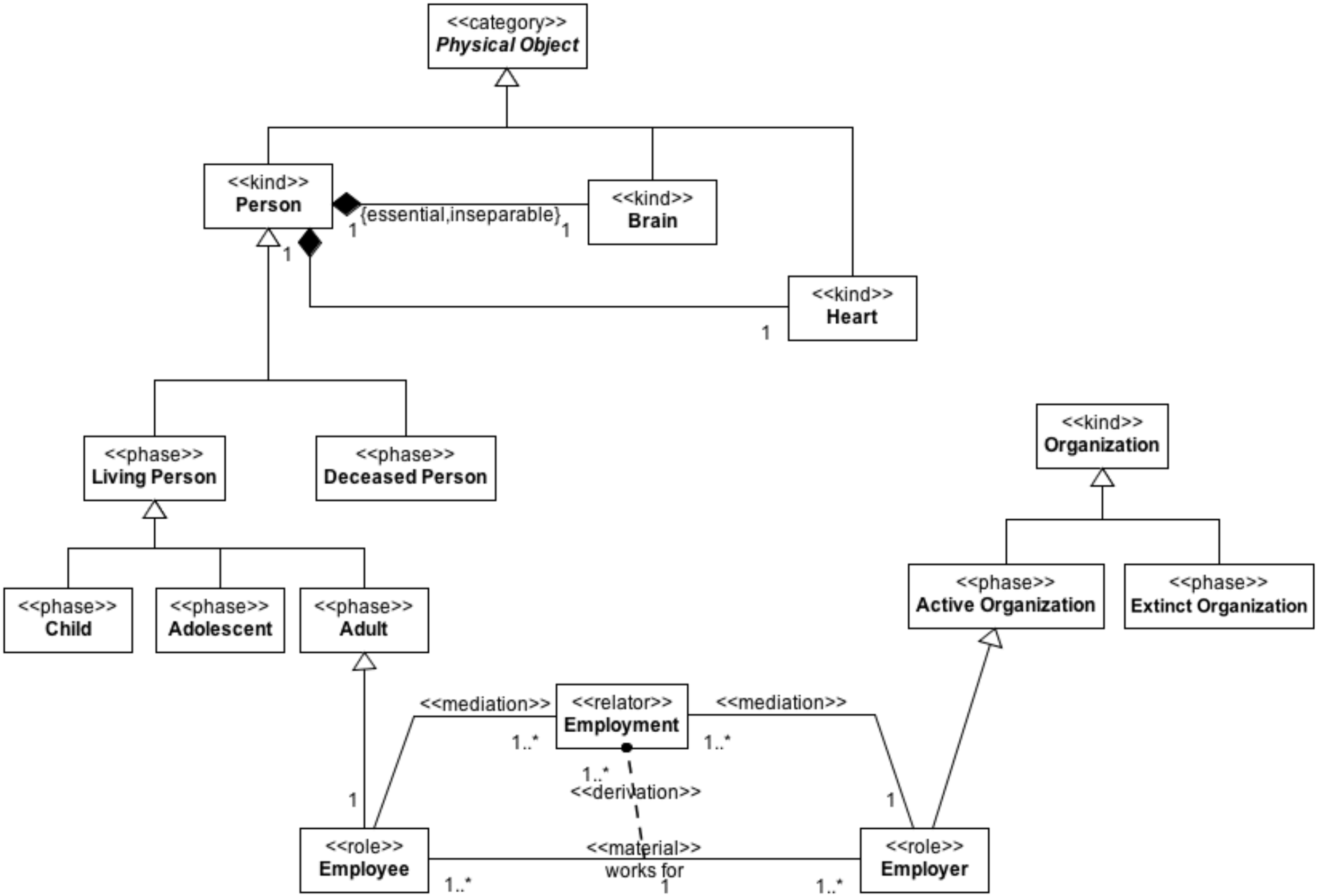
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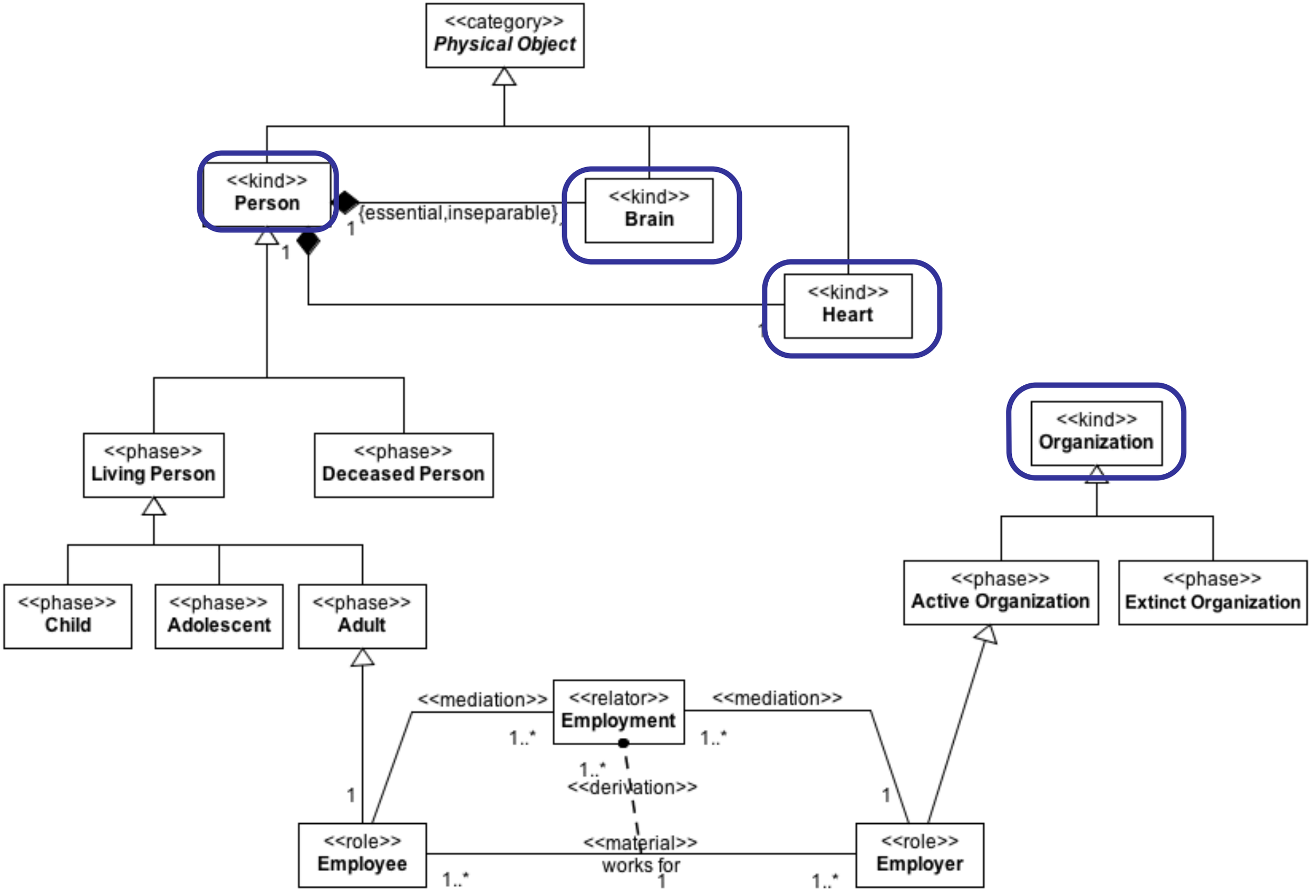
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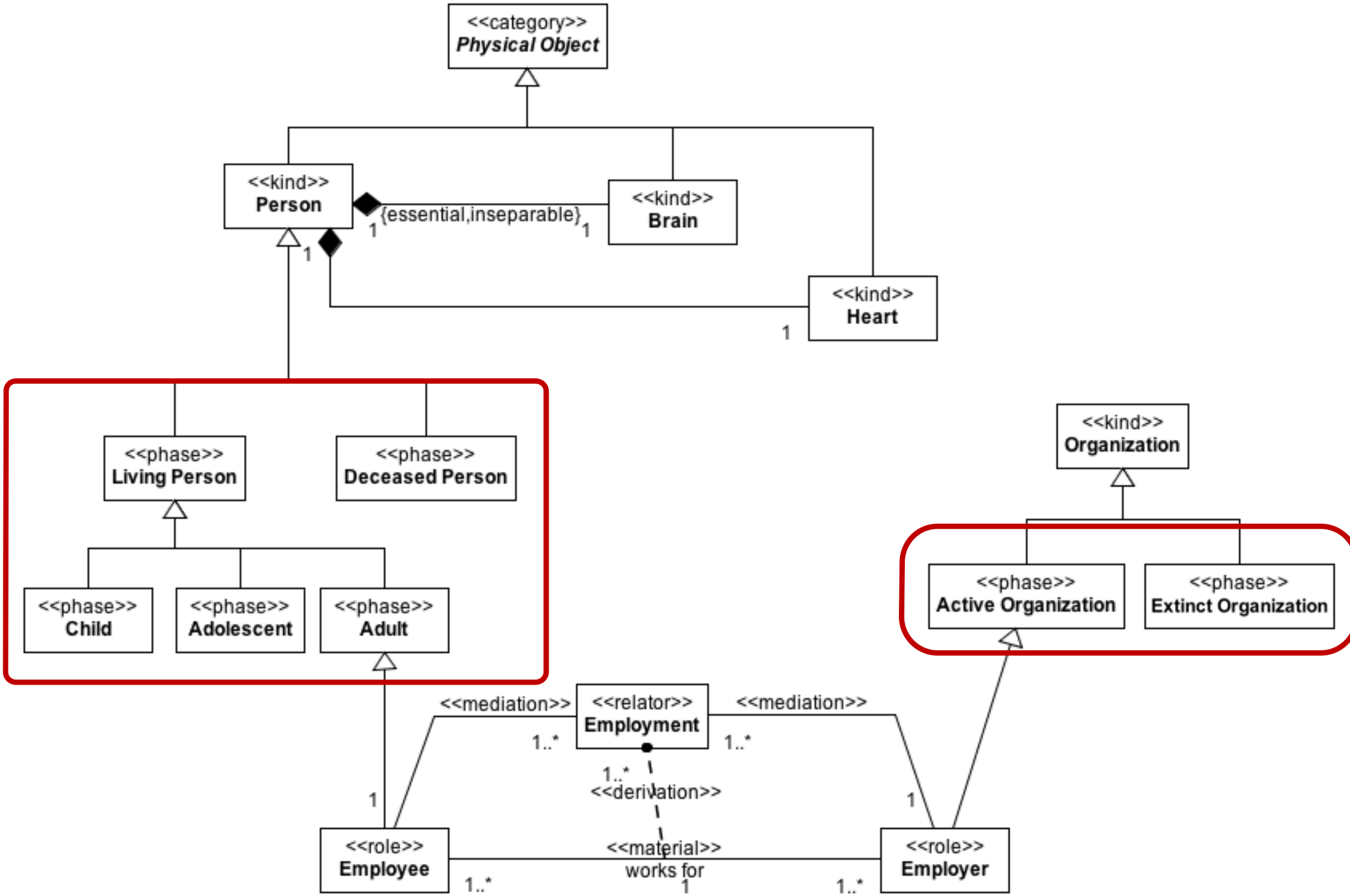
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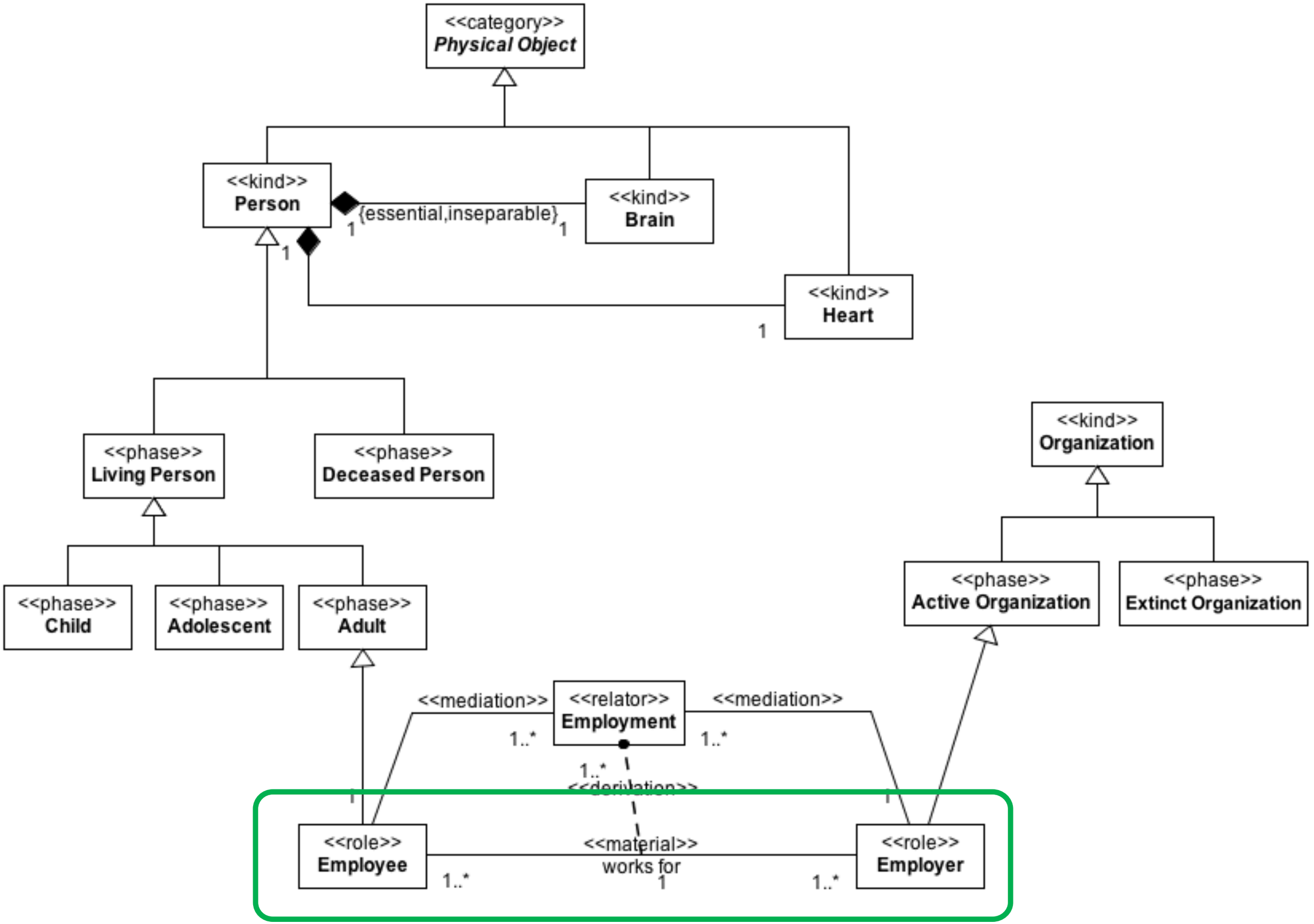
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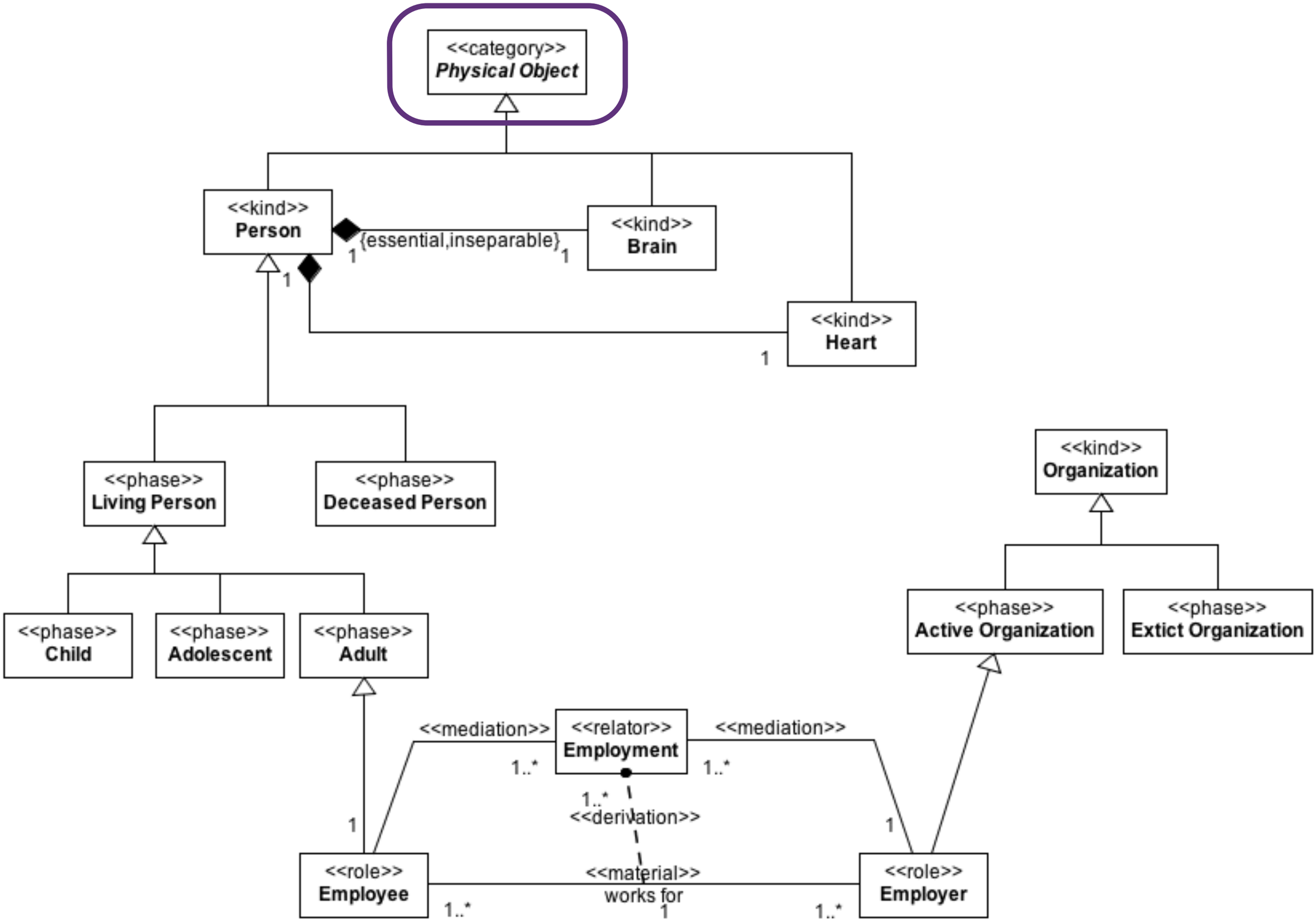
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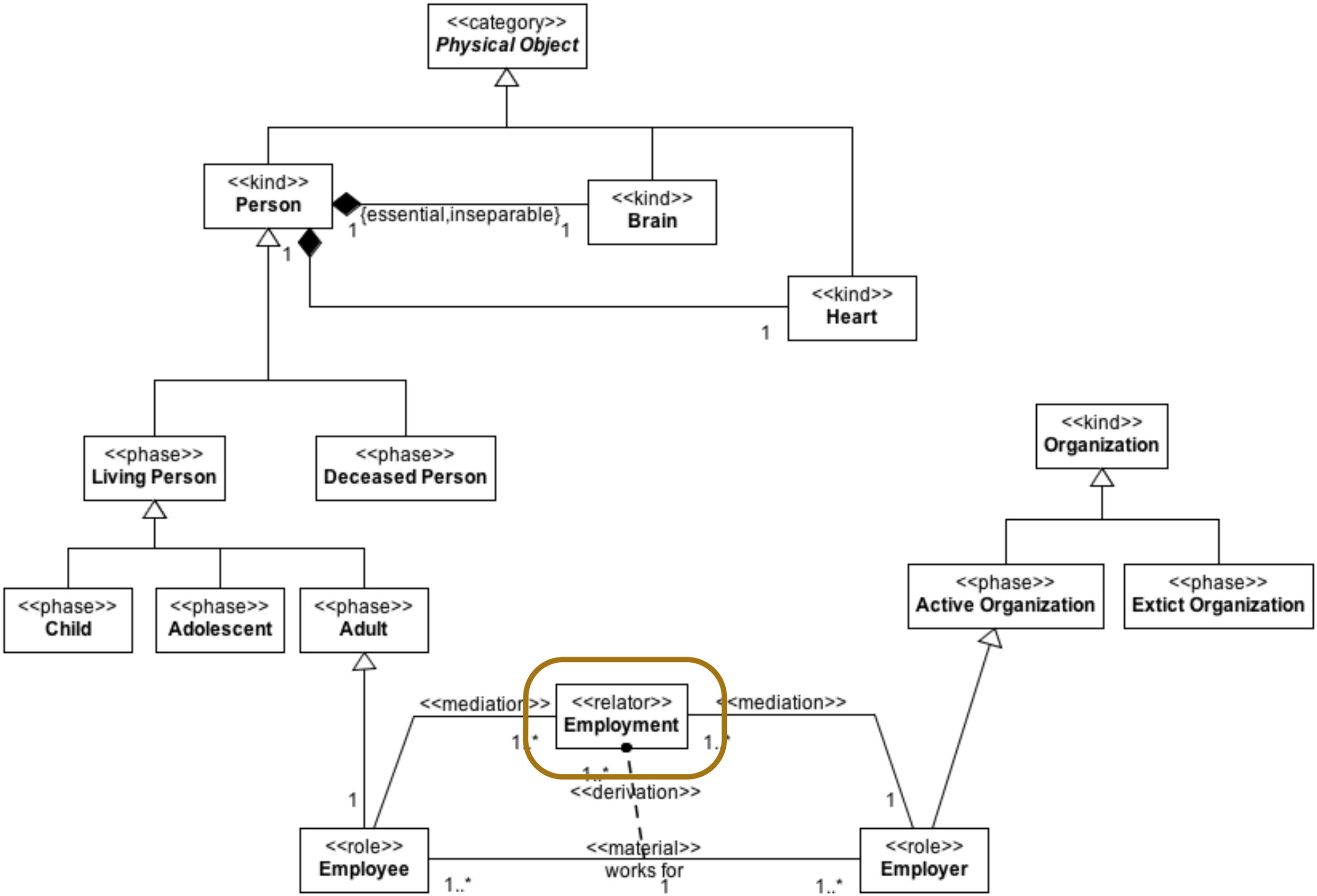
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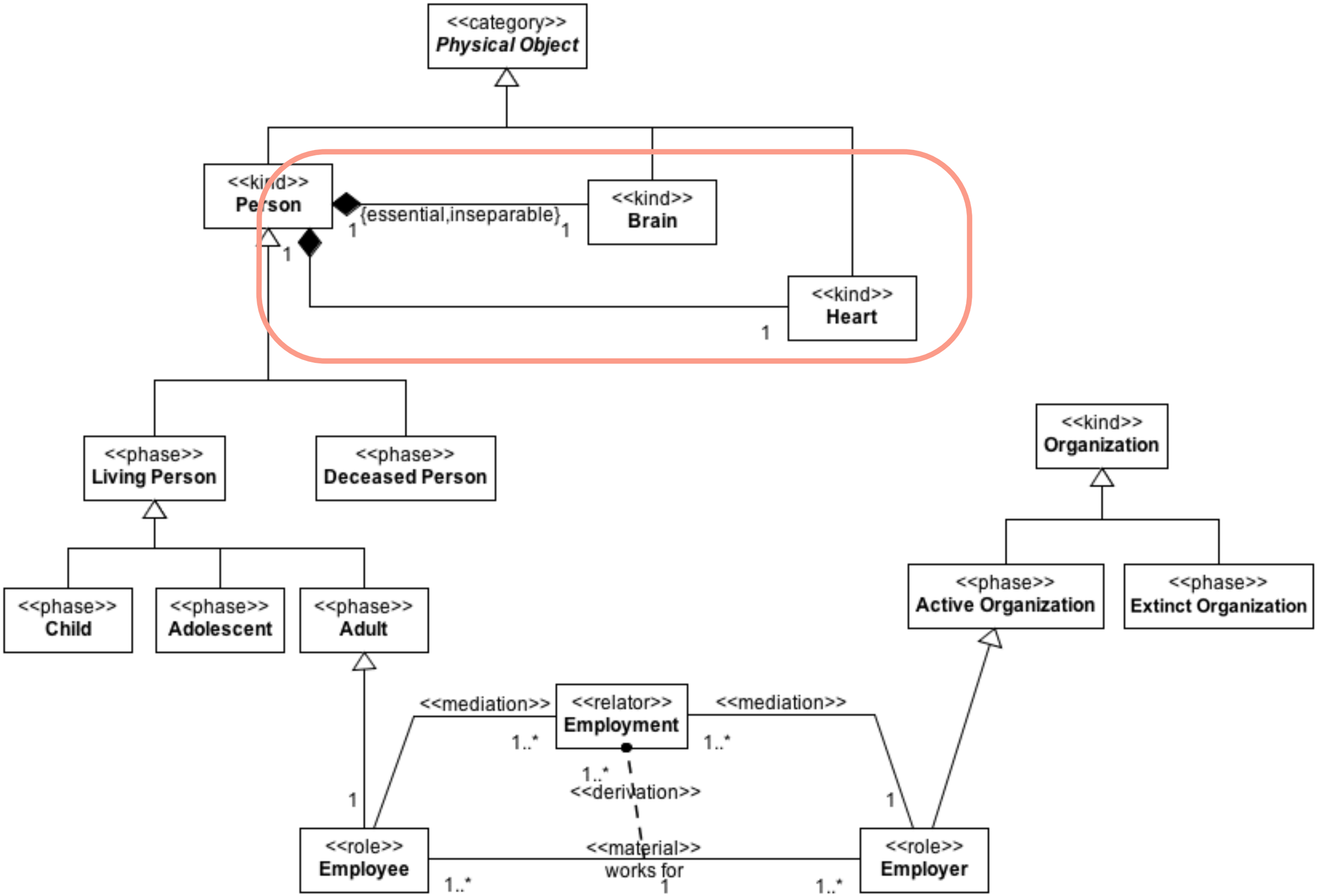
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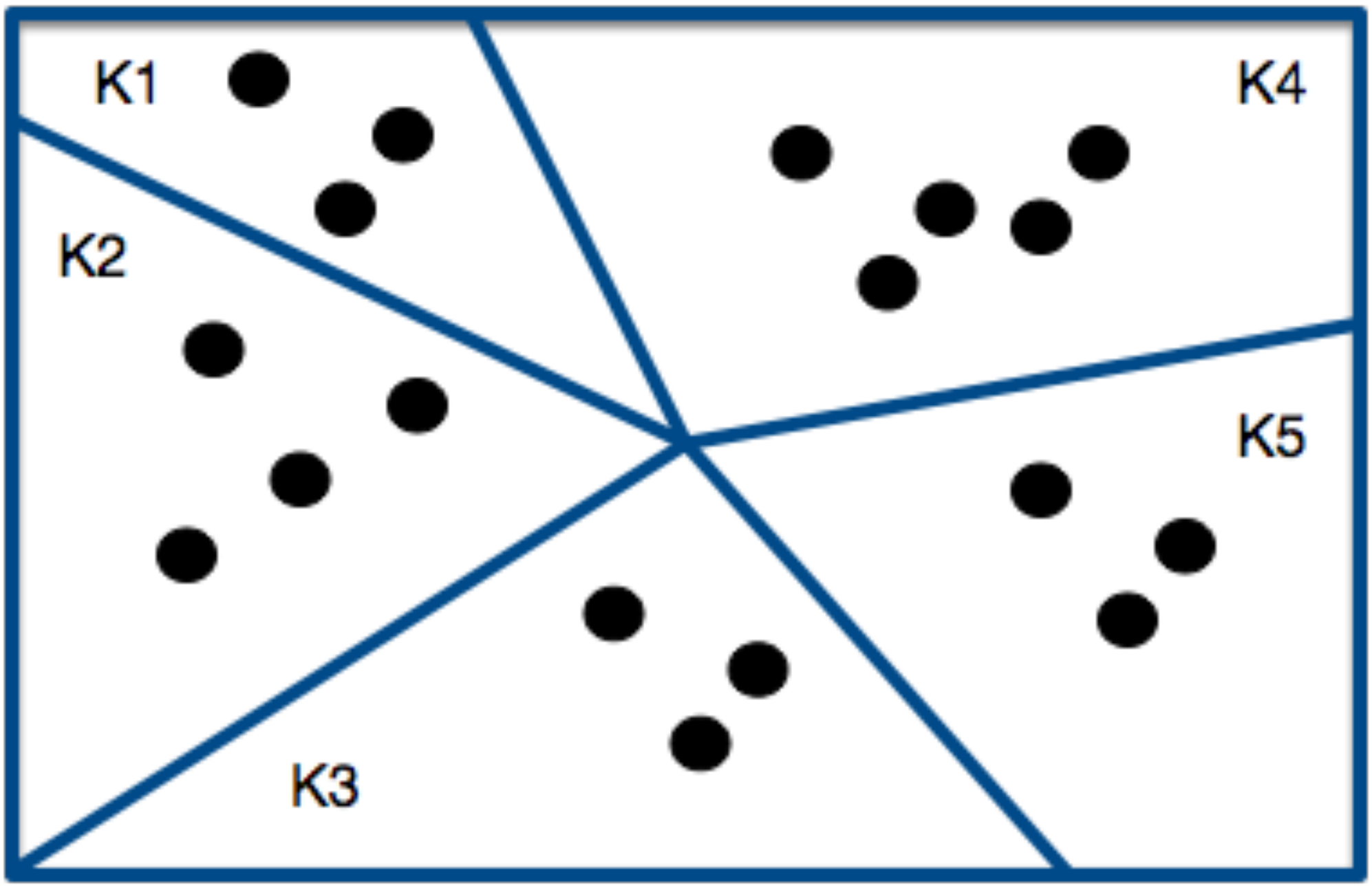
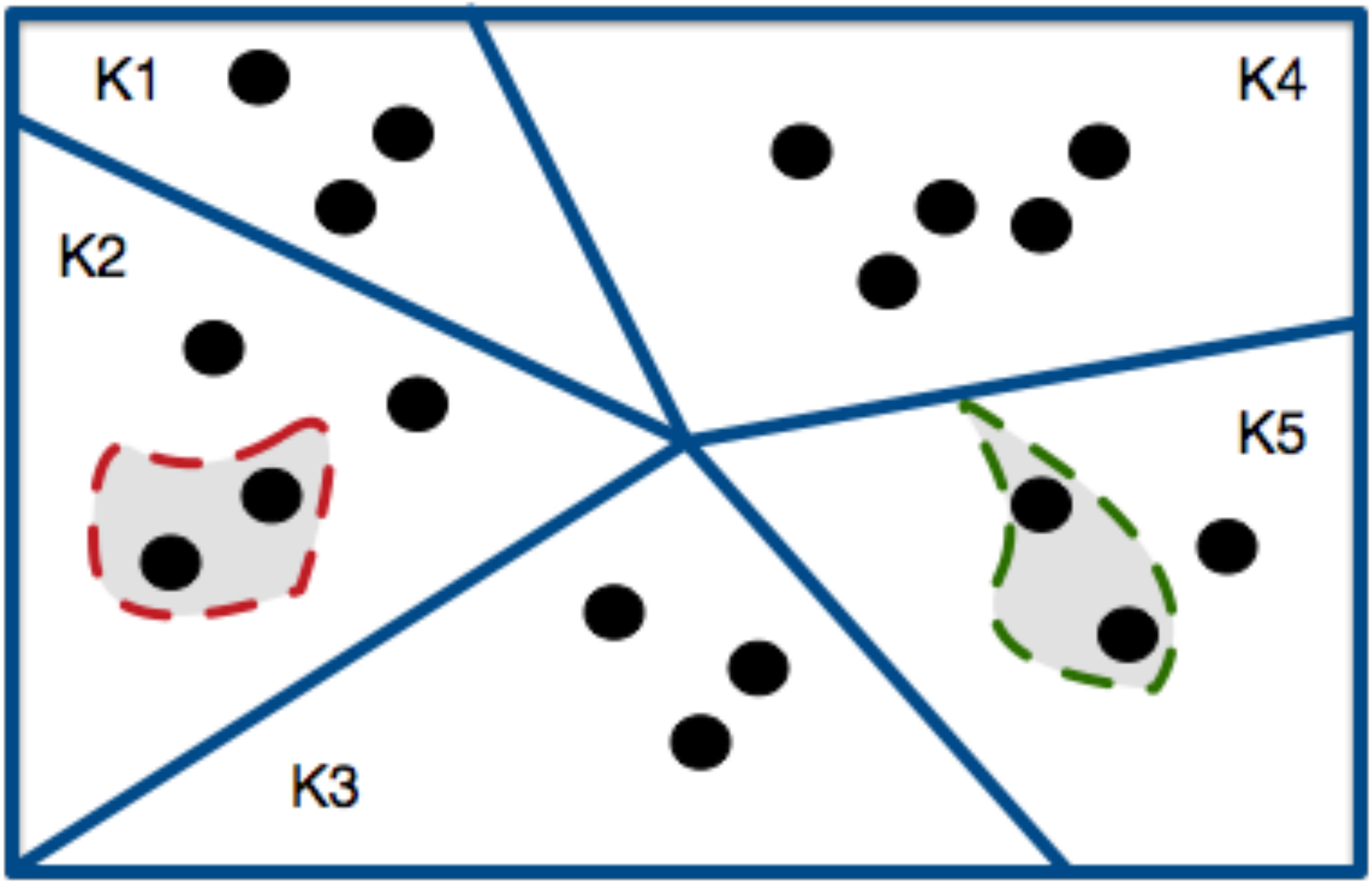


Anti-Rigid Sortals (**Roles** and **Phases**)



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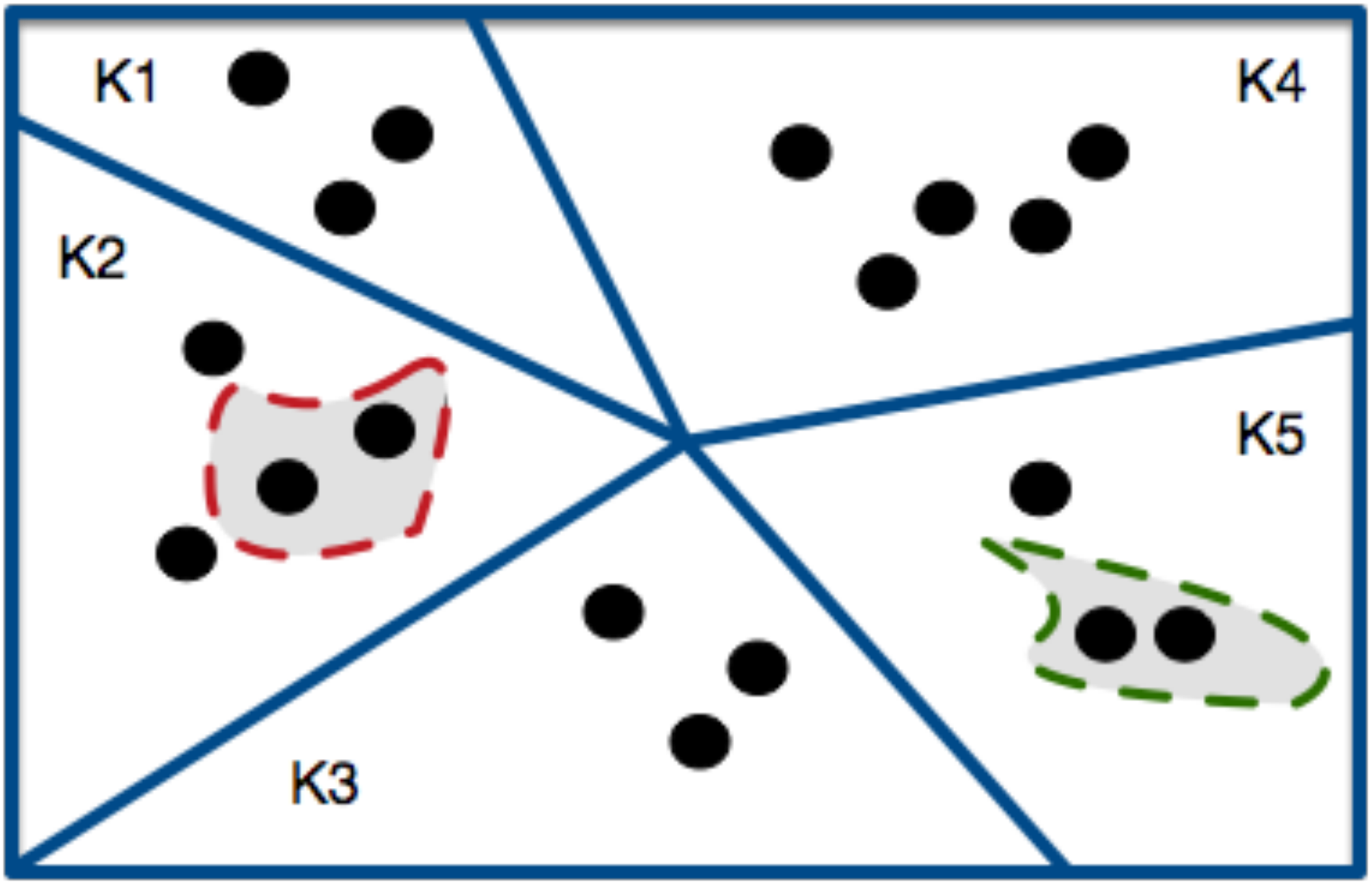
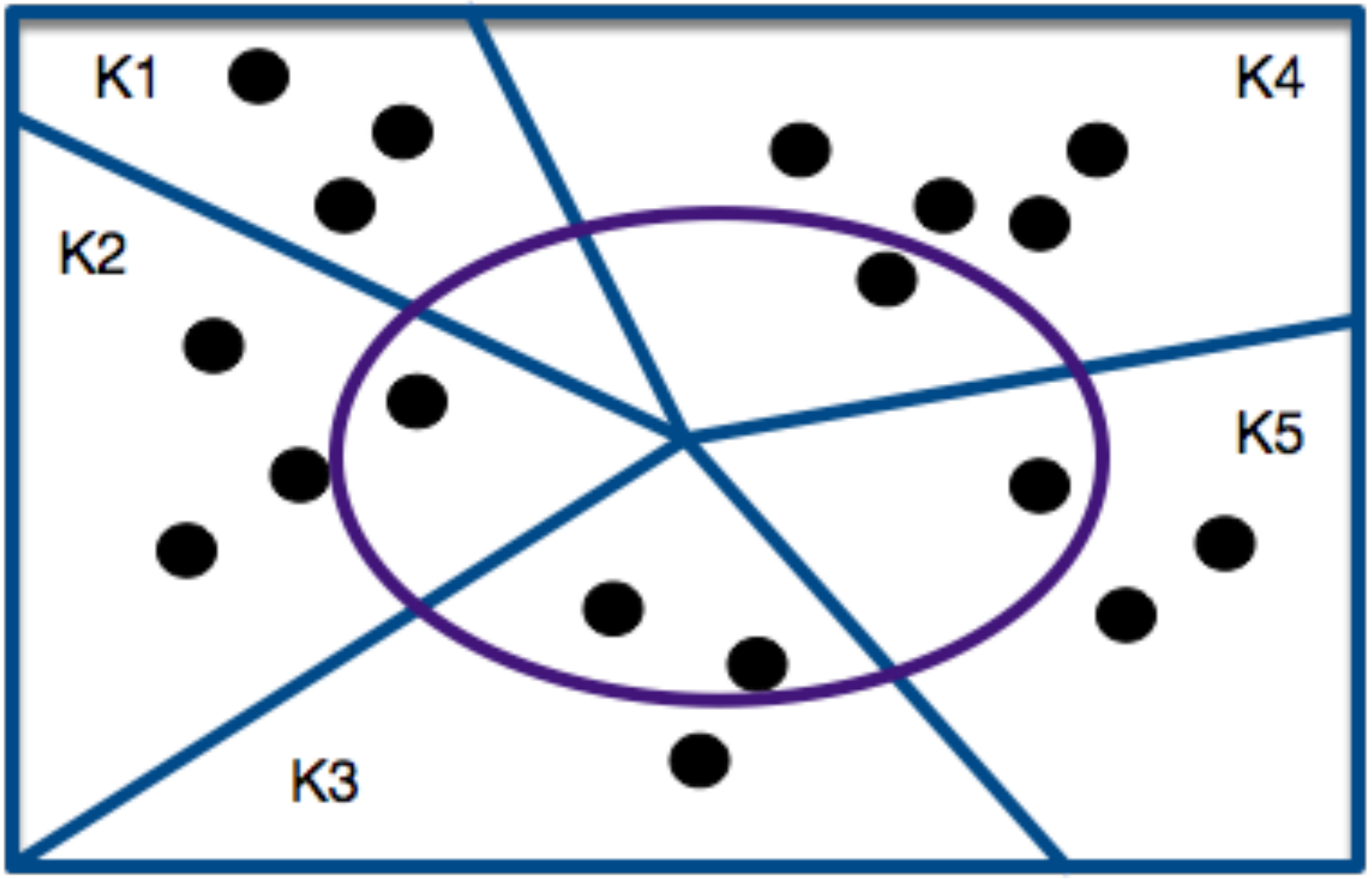
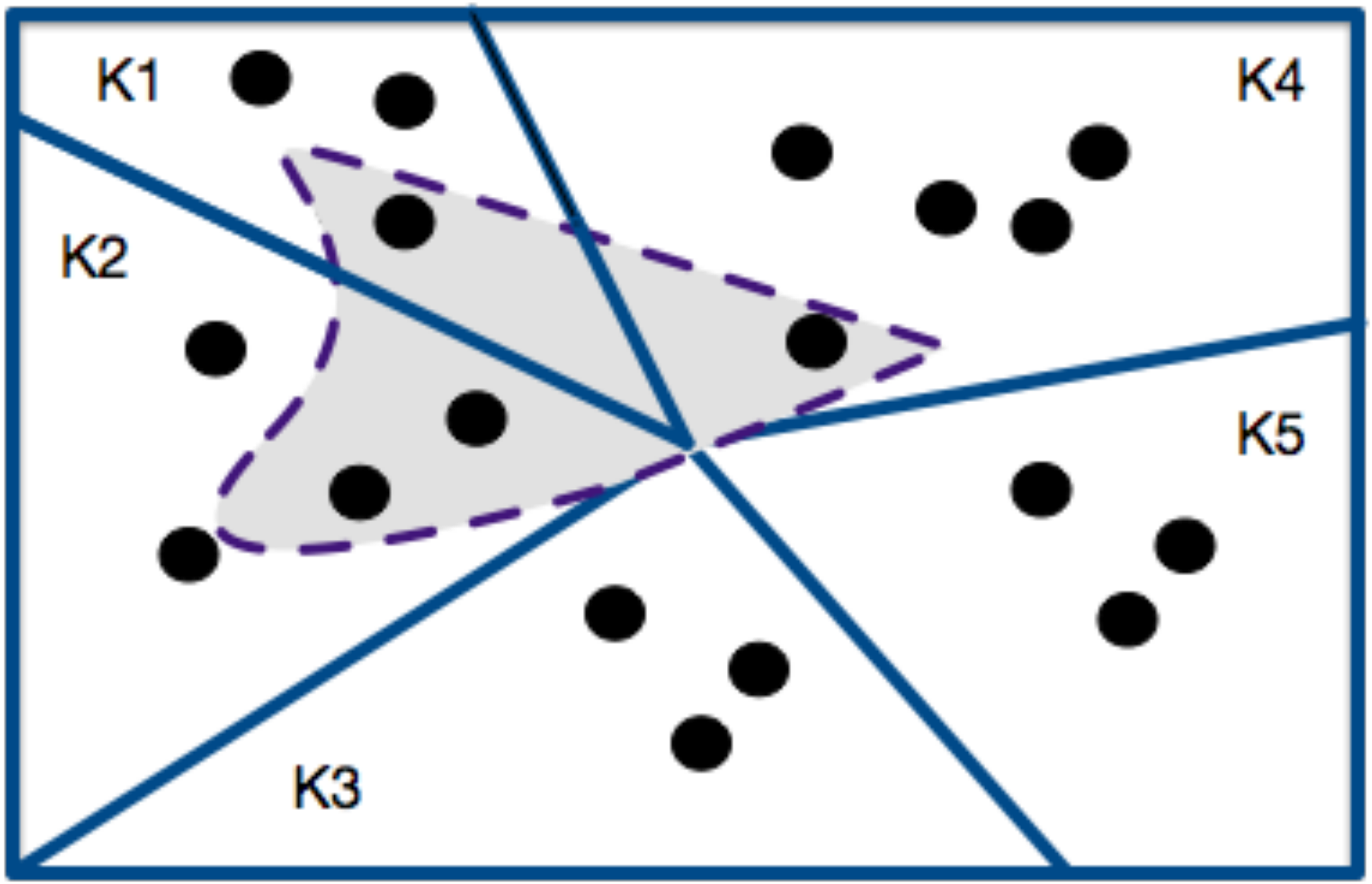


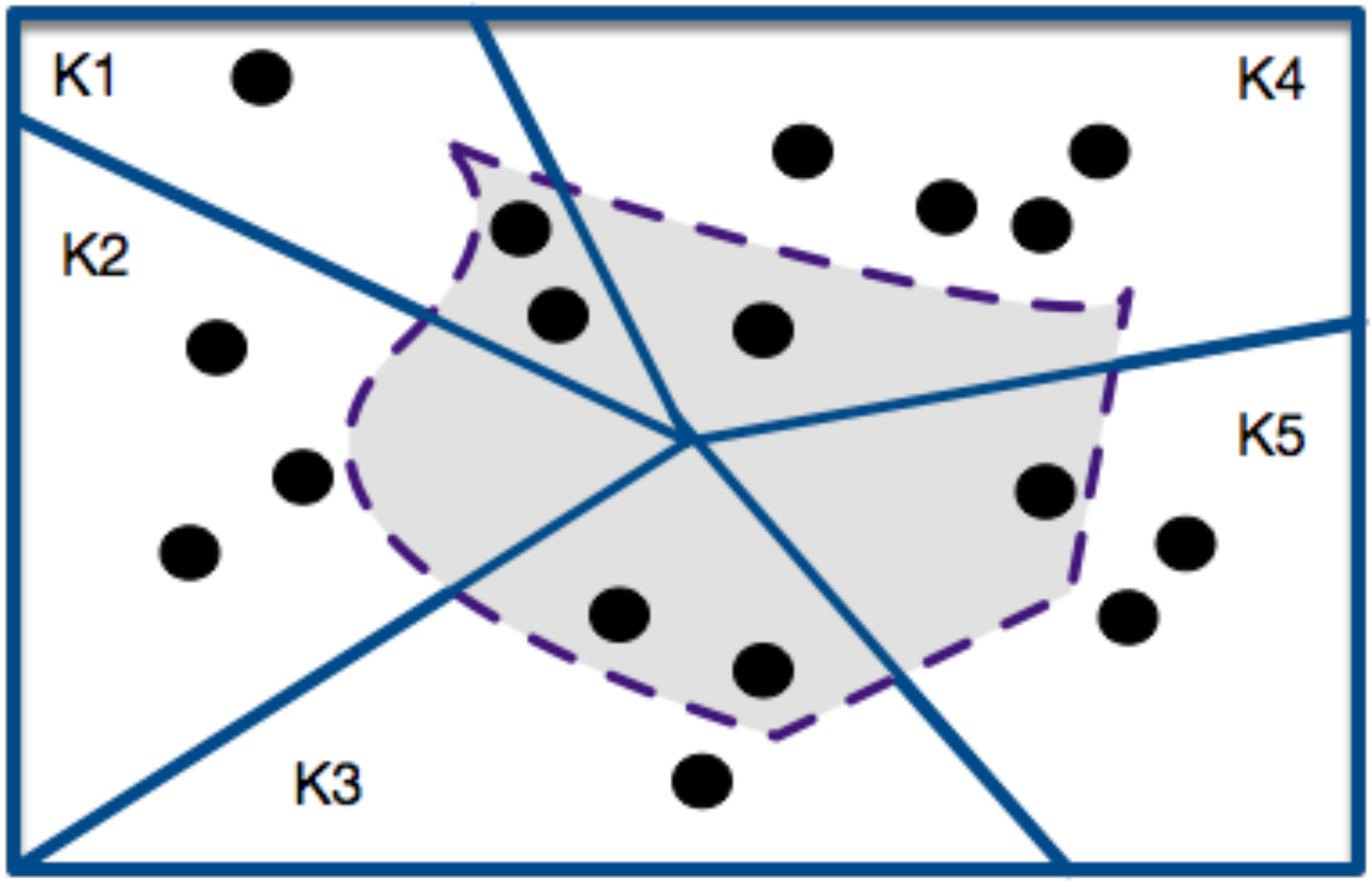
Rigid Mixins



Anti-Rigid Mixins



Anti-Rigid Mixins



Type*

Sortal Type

MIXIN
(e.g., insurable entity, cultural heritage item)

Rigid Sortal Type
or **KIND**
(e.g., person, dog, organization car)

Anti-Rigid Sortal Type
including **ROLES**
(e.g., student, singer)
and **PHASES**
(e.g., living person, metropolis)

*(these ontological distinctions with the meaning they have in OntoUML were first presented at Guizzardi, Wagner, Guarino & van Sinderen in CAISE, 2004 and are strongly based on the ontological distinctions underlying the OntoClean methodology, see Guarino & Welty, 2002, 2004)

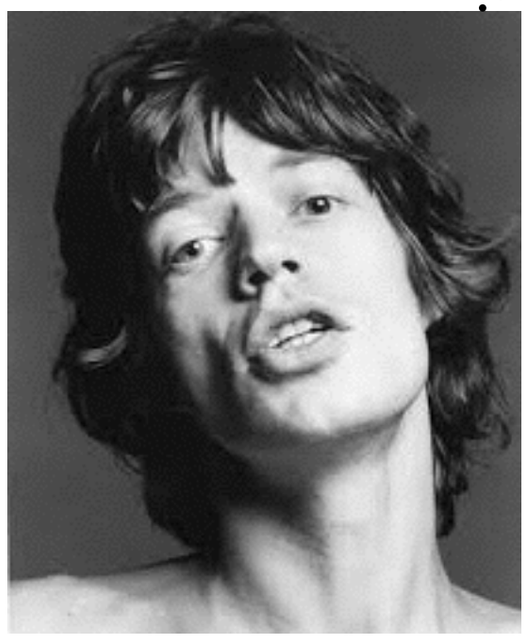
© NBC

Person

Man

Adult Man

Living Person



Young Boy

British Citizen

Singer

Economist

Solution

1. Characterizing the difference between:

   - NATURAL TYPE/KIND (e.g., **PERSON**) = **RIGID SORTAL**

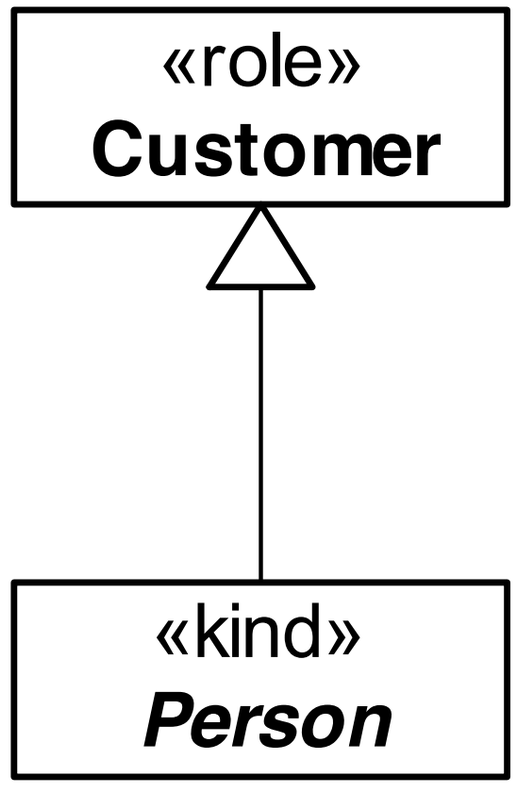
   - ROLE (e.g., **SINGER, ECONOMIST, BRITISH CITIZEN, KNIGHT OF THE BRITISH EMPIRE**) = **ANTI-RIGID + RELATIONALLY DEPENDENT SORTAL**

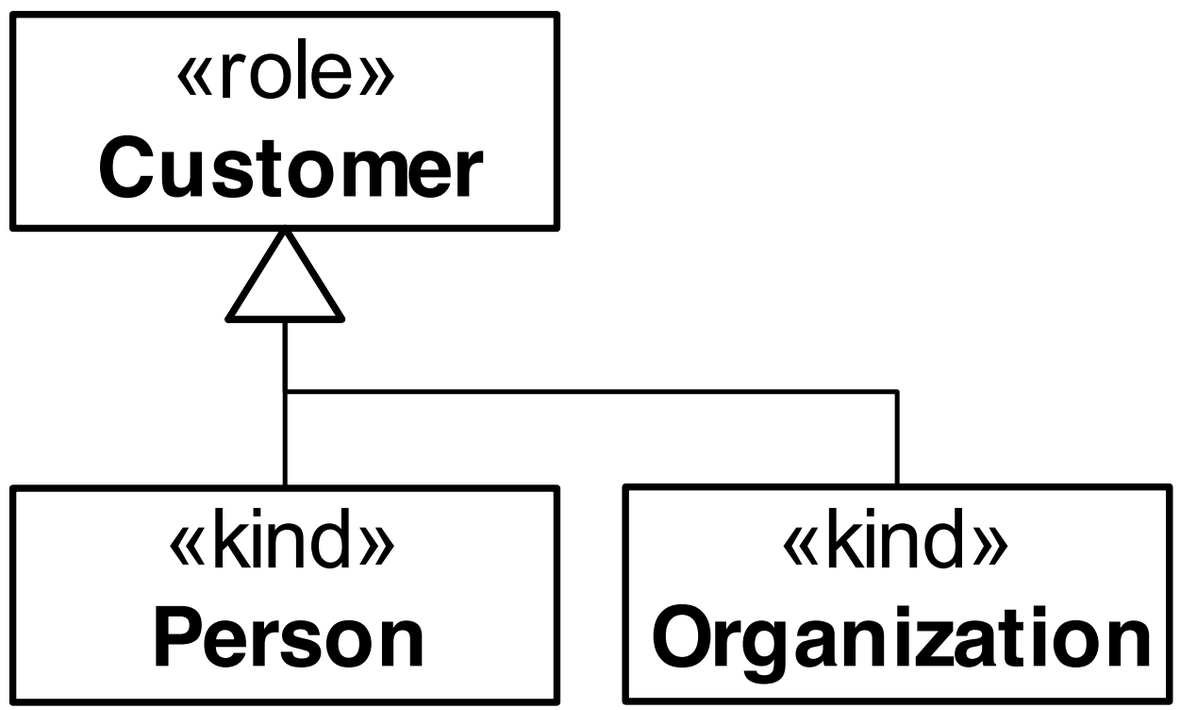
   - PHASE (e.g., **LIVING PERSON, ADULT MAN**) = **ANTI-RIGID + RELATIONALLY INDEPENDENT SORTAL**

   - MIXIN (e.g., **CULTURAL HERITAGE ENTITY, PHYSICAL ENTITY, INSURABLE ITEM**)? = **MIXIN**

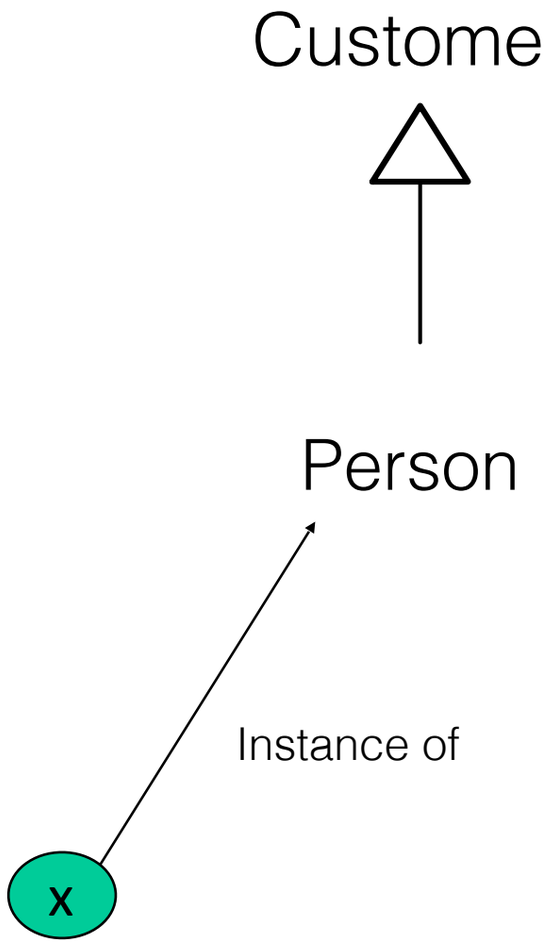
Role

- All instances of a given ROLE are of the same KIND (e.g., all Students are Person)
- All instances of a ROLE instantiate that type only contingently (e.g., no Student is necessarily a Student)
- Instances of a KIND instantiate that ROLE when participating in a certain RELATIONAL CONTEXT (e.g., instances of Person instantiate the Role Student when enrolled in na Educational Institution)
- **A ROLE cannot be a supertype of a Rigid Type**

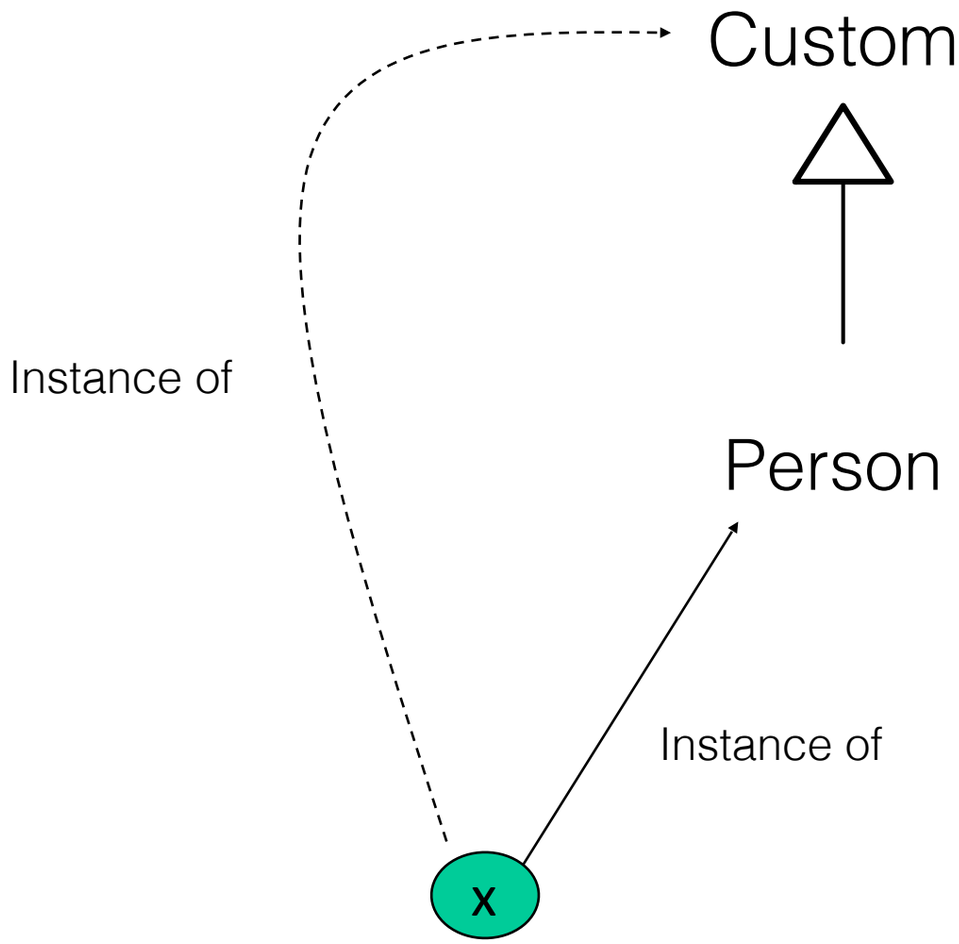

«role»
Customer
«kind»
Person


«role»
Customer
«kind»
Person
«kind»
Organization

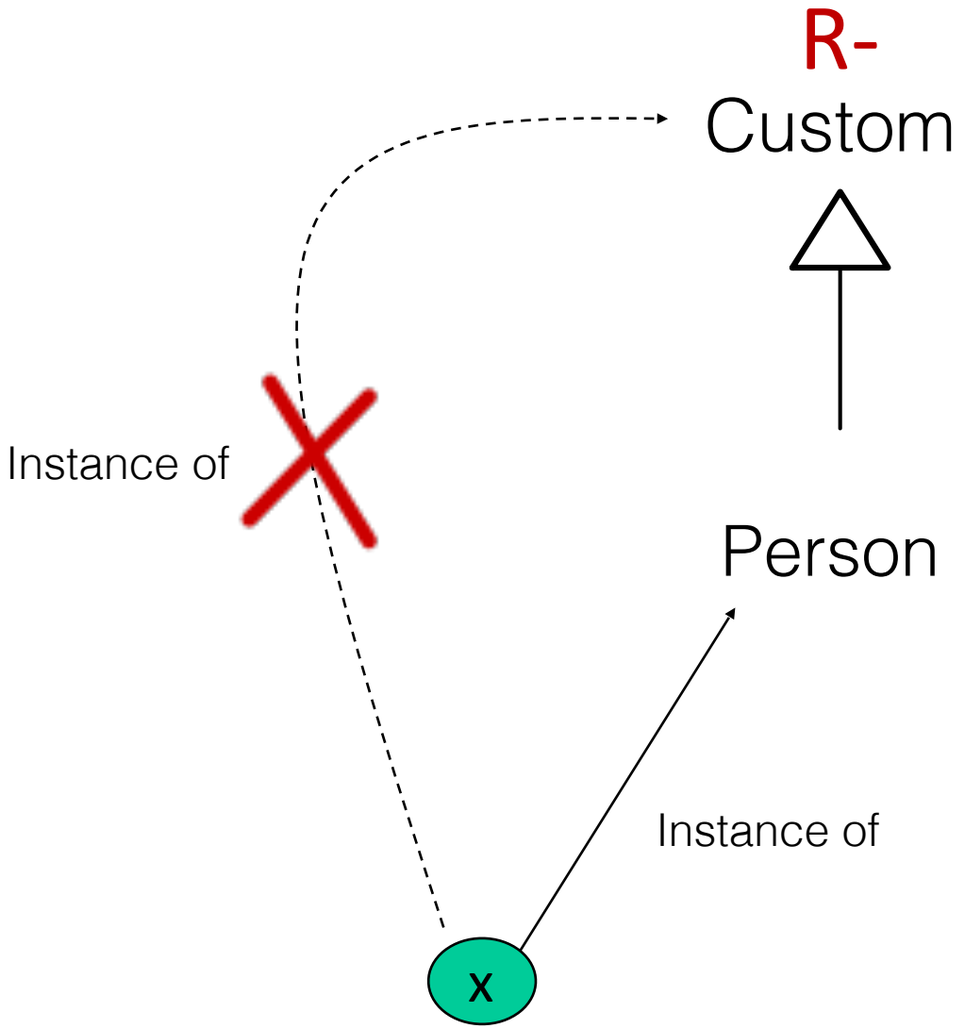
WORLD W



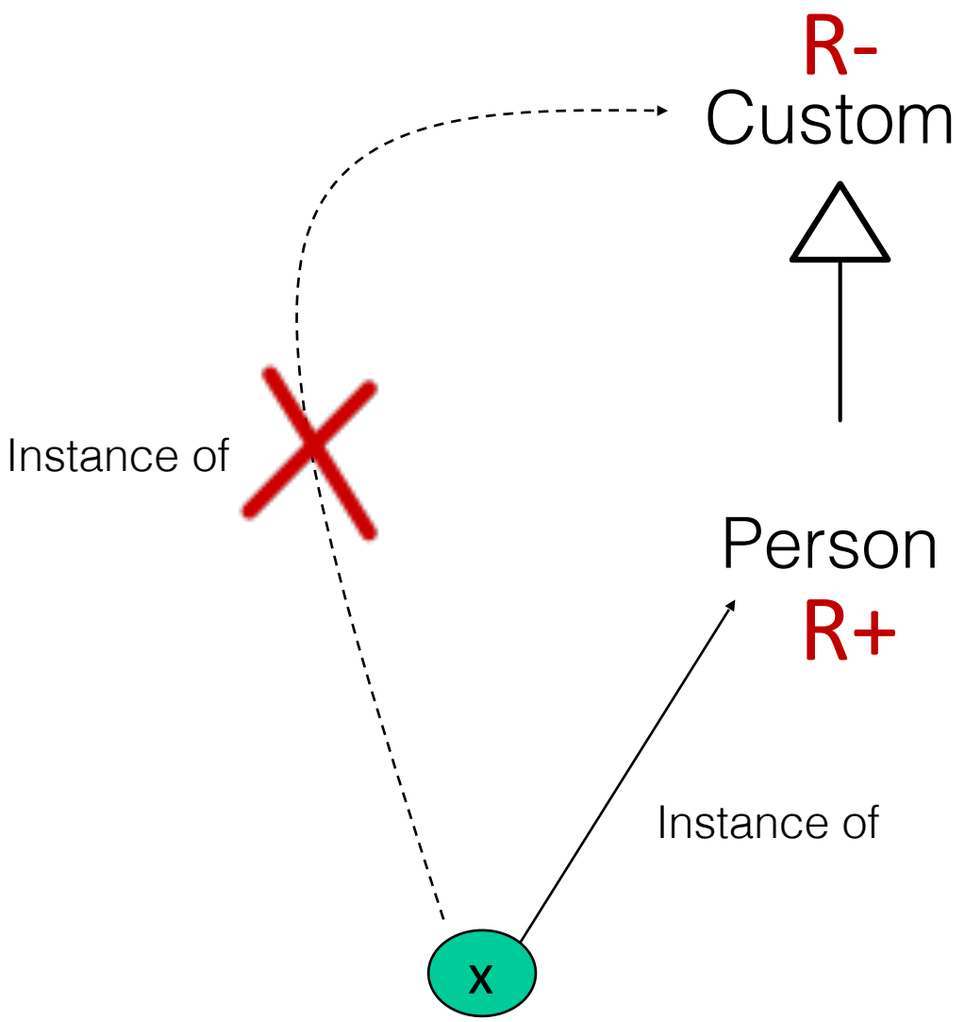
WORLD W



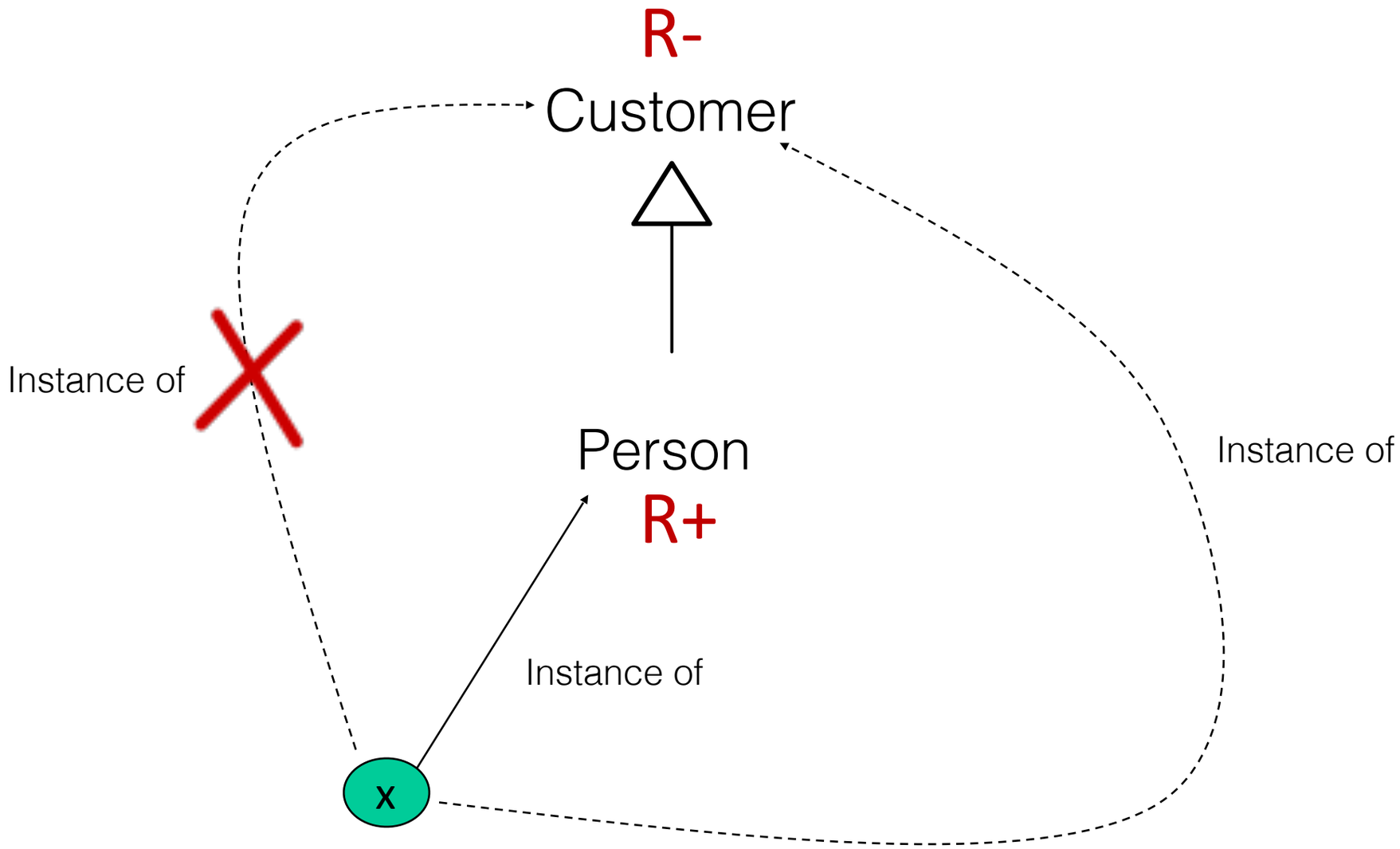
WORLD W’



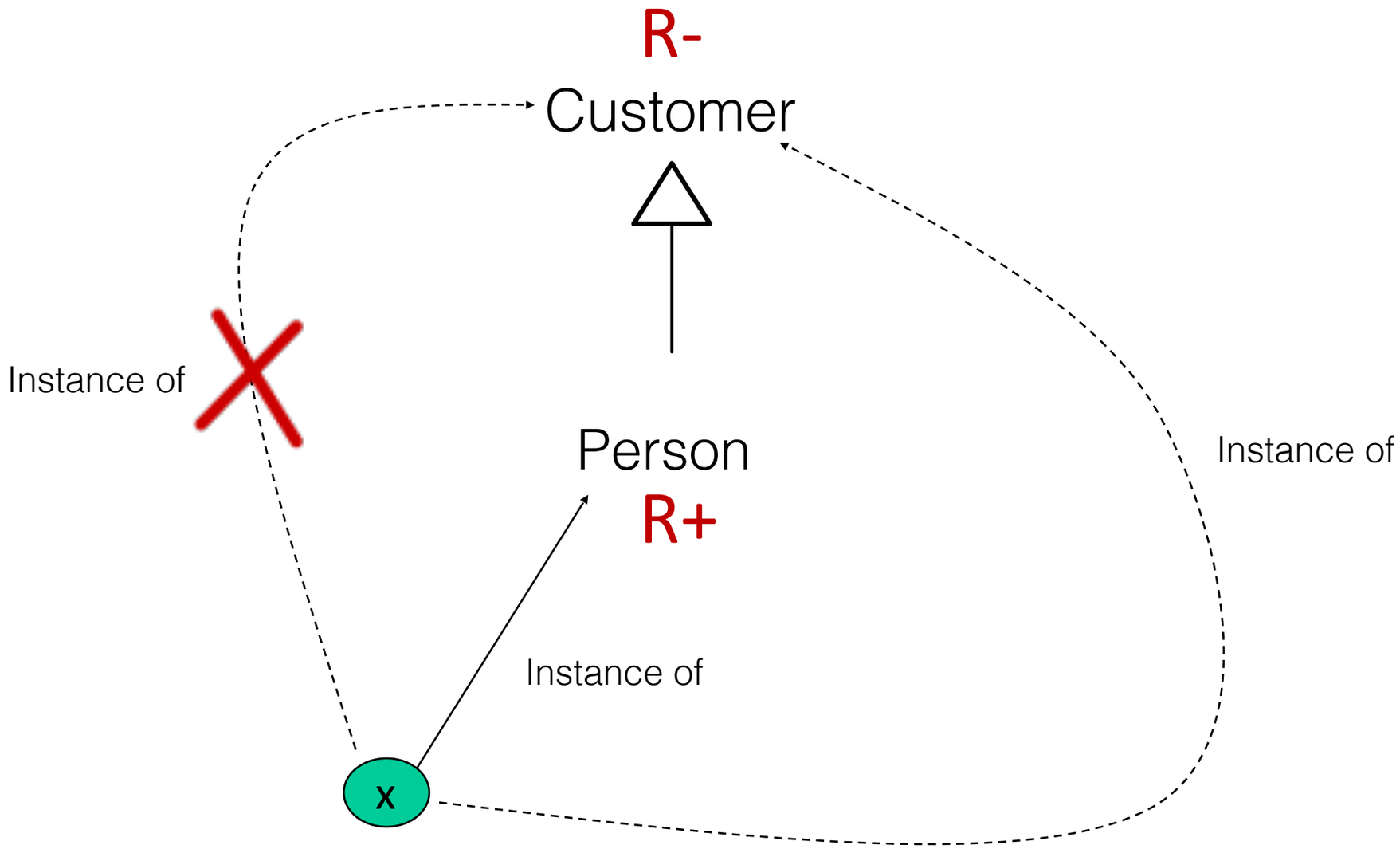
WORLD W’



WORLD W’



WORLD W’



We run into a logical contradiction!

Role

- All instances of a given ROLE are of the same KIND (e.g., all Students are Person)
- All instances of a ROLE instantiate that type only contingently (e.g., no Student is necessarily a Student)
- Instances of a KIND instantiate that ROLE when participating in a certain RELATIONAL CONTEXT (e.g., instances of Person instantiate the Role Student when enrolled in na Educational Institution)
- A ROLE cannot be a supertype of a Rigid Type

«role»
Student

NO!

«role»**Student**

NO!

«kind»
Person

«kind»
Person

NO!

«role»
Student

enrolled at

0..n

«kind»
Educational Institution

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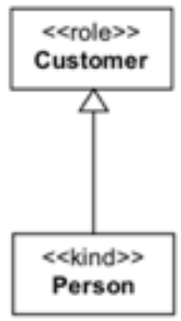
OLED – test.oled

Toolbox

- Elements
  - Nominal Quality
  - Non Perceivable Quality
  - Perceivable Quality
  - Phase
  - Primitive Type
  - Quantity
  - Relator
  - Role
  - Role Mixin
  - SubKind
  - Association
  - Characterization
  - ComponentOf
  - Derivation
  - Formal
  - Generalization
  - Material
  - Mediation
  - MemberOf
  - Structuration
  - SubCollectionOf
  - SubQuantityOf
- Patterns
- Derived Patterns

Editor

100%



Moved: «role» customer, «kind» person, «generalization» [unnamed]

Welcome | Diagram0* ×

Information Footer

Type	Description	Stereotype	Element	Location
Syntactical	01. A RigidSortalClass cannot have an Anti-Rigid parent (role, phase, role...	Kind	Person	Model::Person
Syntactical	02. A Role must be connected (directly or indirectly) to a Mediation	Role	Customer	Model::Customer
Syntactical	03. Every non abstract Sortal must have a Substance Sortal ancestor (or be...	Role	Customer	Model::Customer

Model verified in 1,874 ms, 3 error(s) found

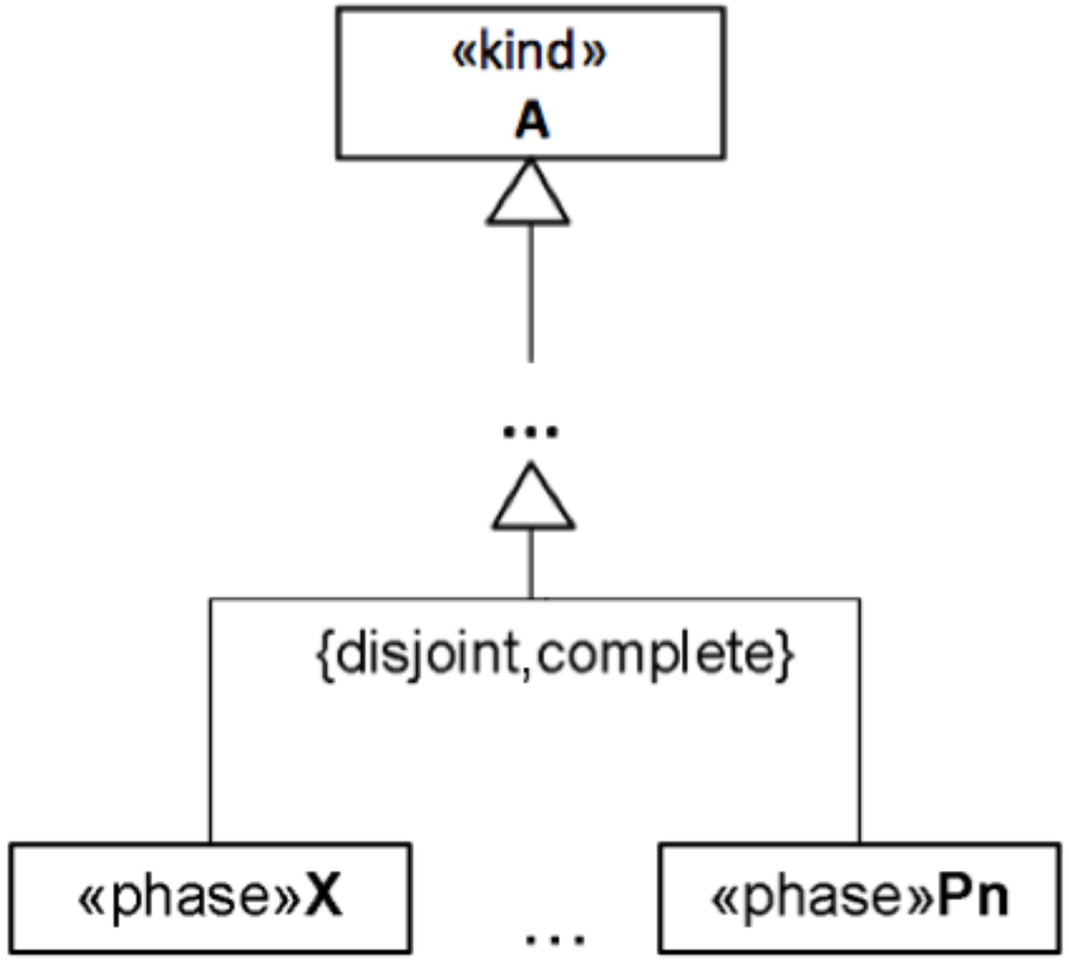
Messages | Console | Problems × | Warnings ×

Project Browser

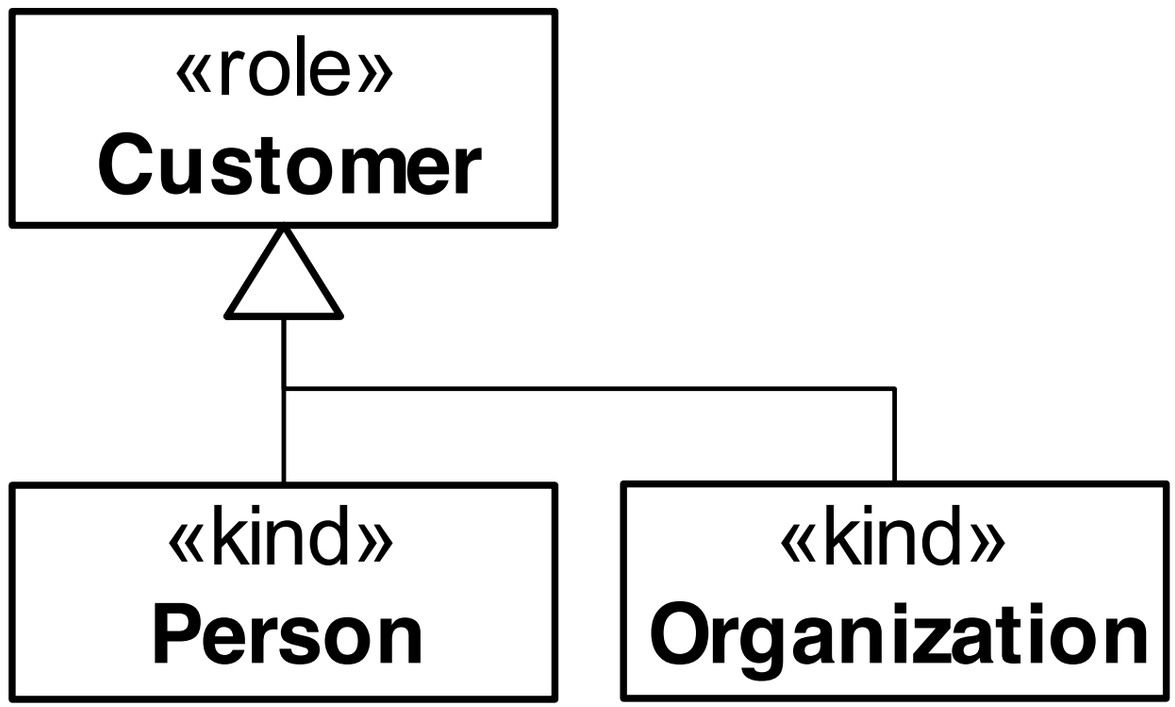
- OLED Project
  - Diagrams
  - Constraints
  - Model
    - «Role» Customer
    - «Kind» Person
      - Generalization Customer

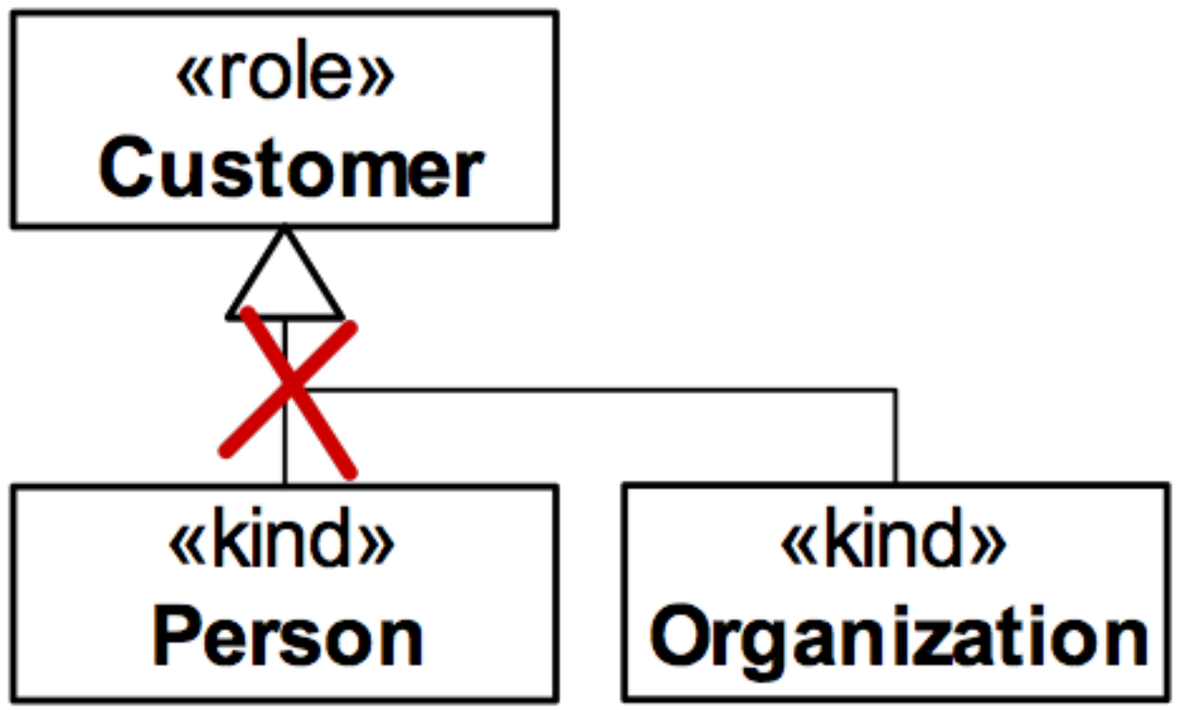
The Emerging **Role** Pattern

The Emerging **Phase** Pattern

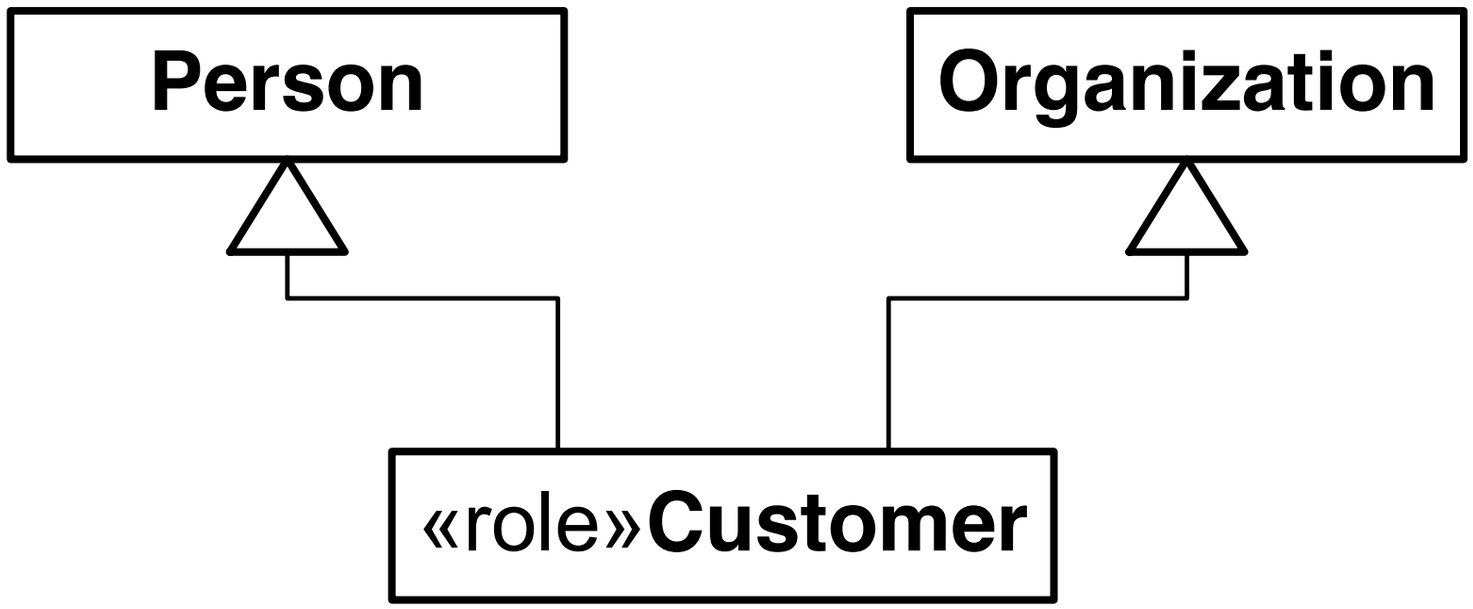


A Classic Problem

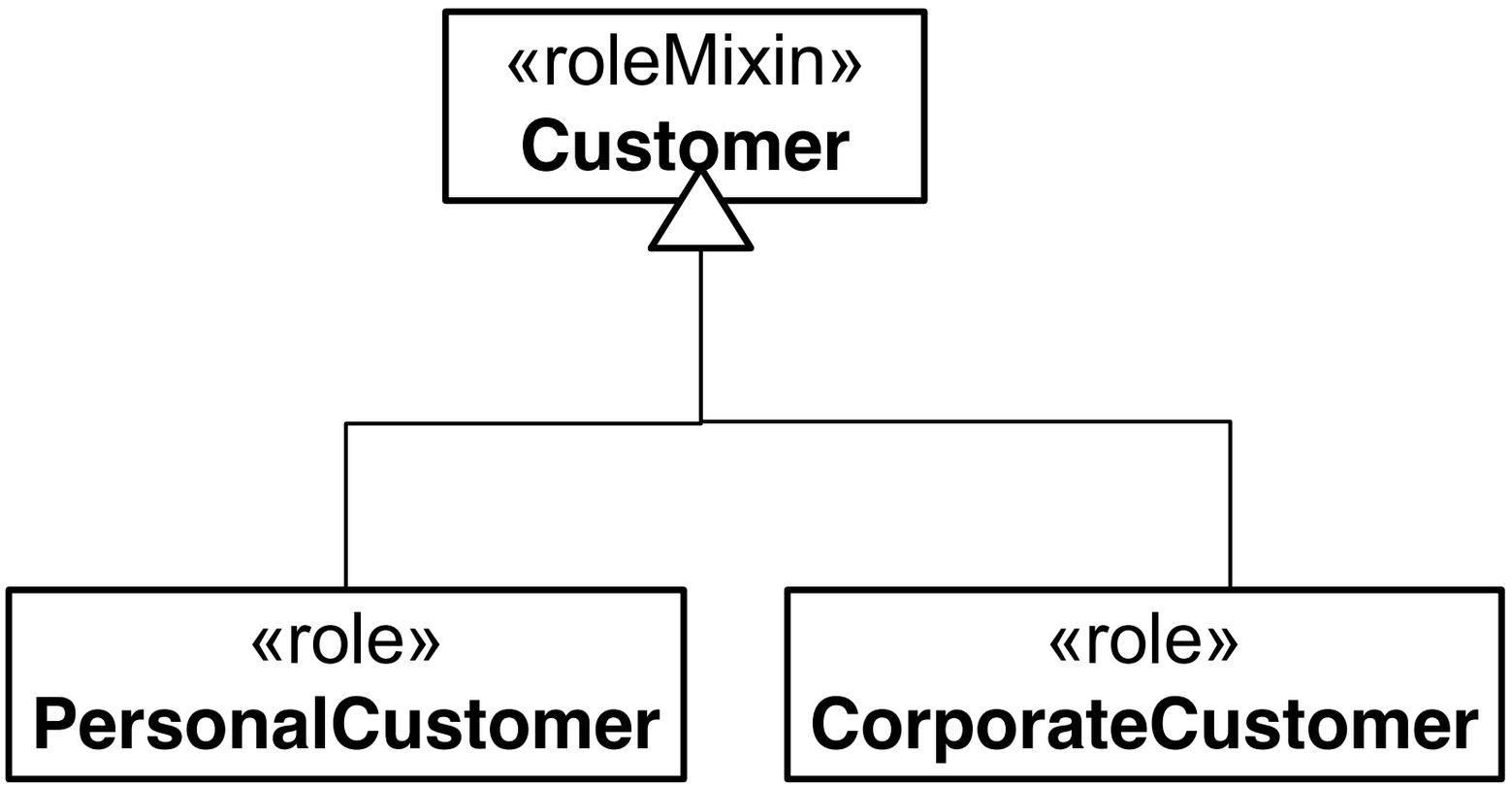


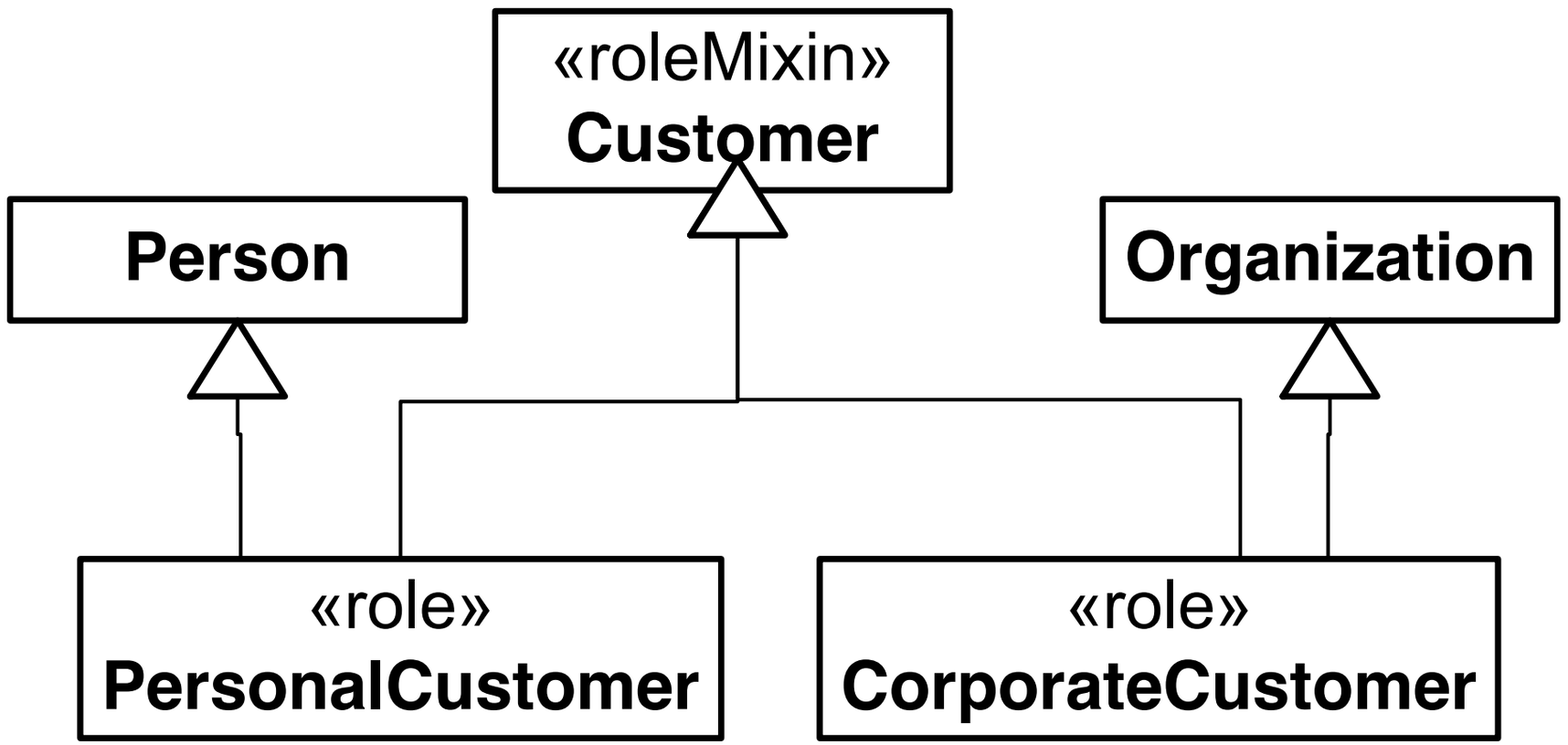

«role»
Customer
«kind»
Person
«kind»
Organization

A Possible Alternative?

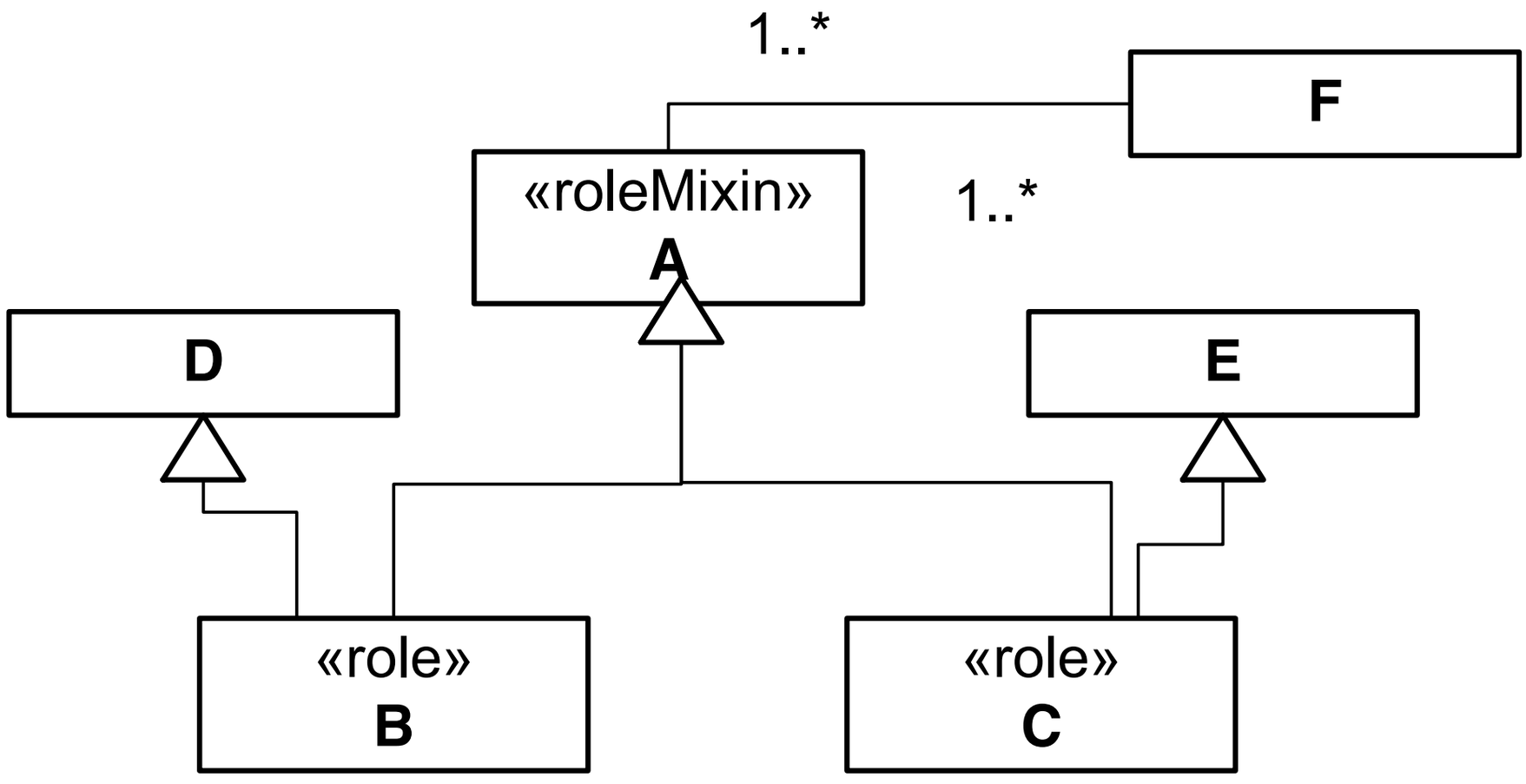


«roleMixin»
Customer


«roleMixin»
Customer
«role»
PersonalCustomer
«role»
CorporateCustomer


«roleMixin»
Customer
Person
Organization
«role»
PersonalCustomer
«role»
CorporateCustomer

The emerging **RoleMixin** Pattern



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Toolbox

Elements

Patterns

Pointer

Principle of Identity

Relator

RoleMixin

Derived Patterns

Editor

100%

Welcome Diagram0

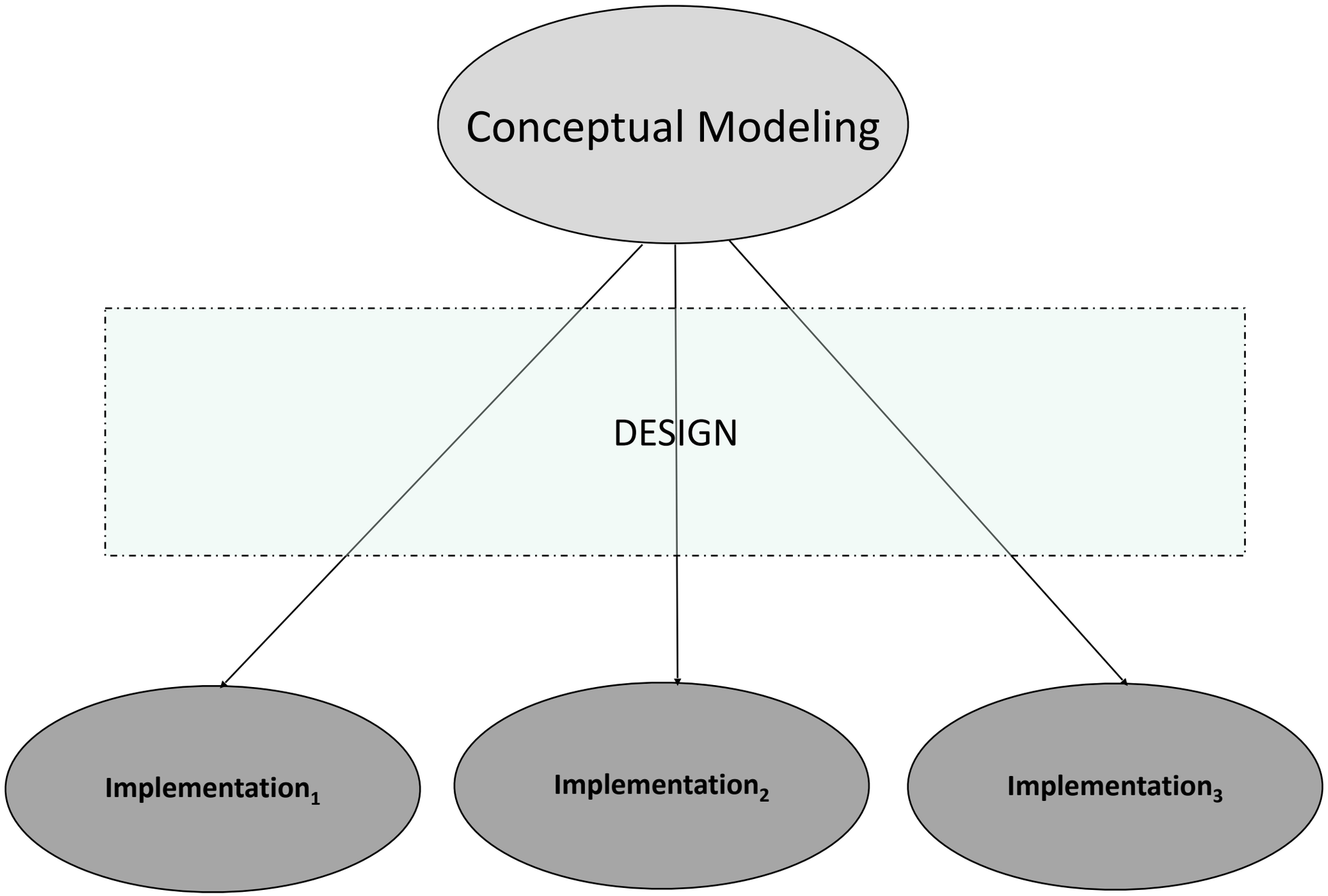
Project Browser

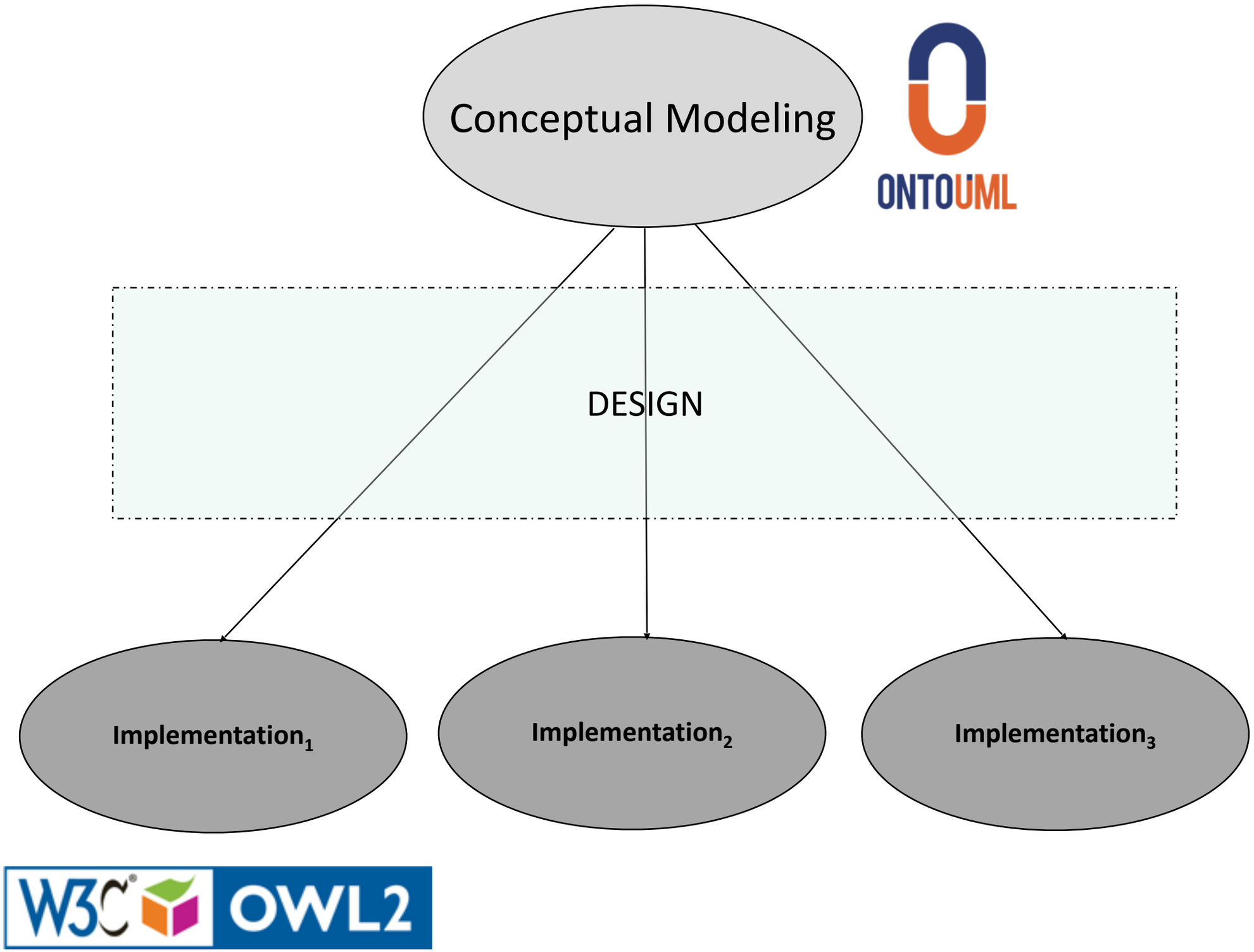
OLED Project

Diagrams

Constraints

Model


Conceptual Modeling
DESIGN
Implementation1
Implementation2
Implementation3


Conceptual Modeling
ONTOUML
DESIGN
Implementation1
Implementation2
Implementation3
W3C OWL2

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Toolbox

Elements

Patterns

Pointer

Principle of Identity

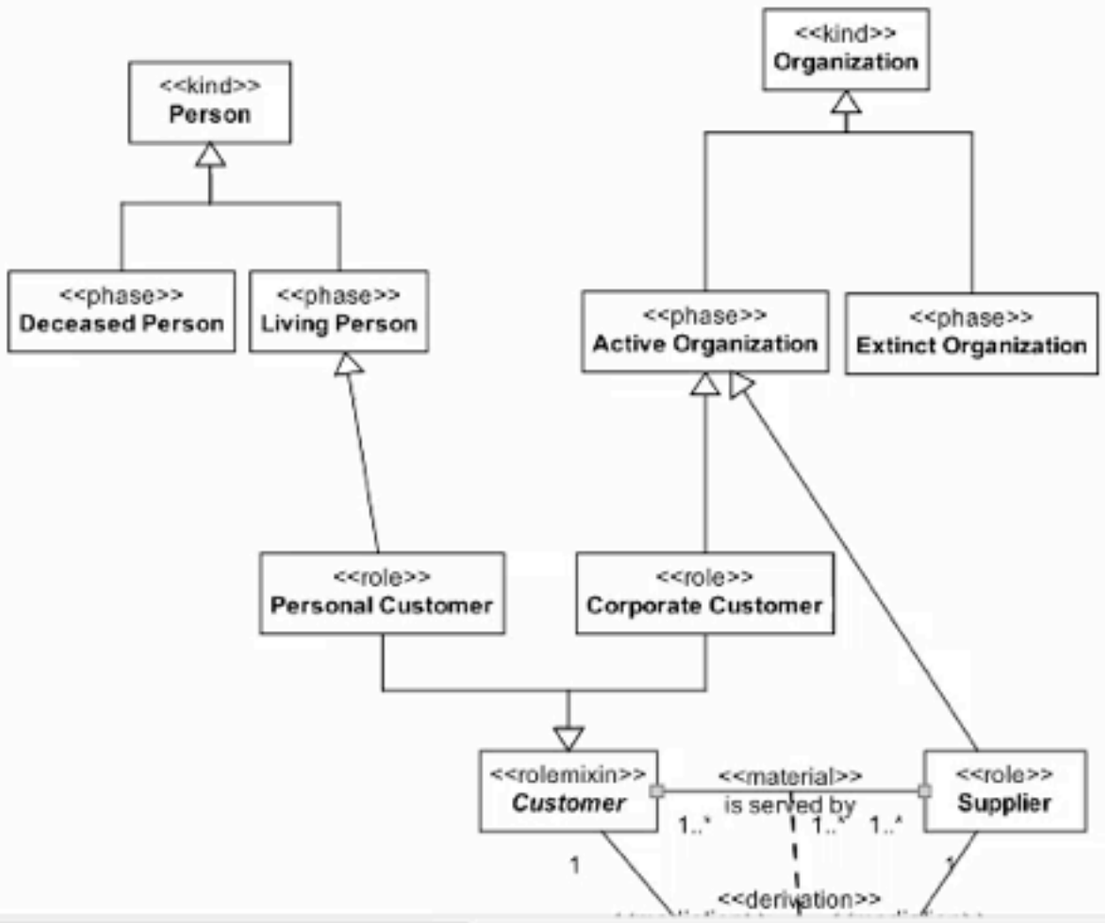
Relator

RoleMixin

Derived Patterns

Editor

100%



Modified: «material» is served by

Welcome

Diagram0*

Project Browser

OLED Project

Diagrams

Constraints

Model

«Phase» Living Person

Generalization Person

«Phase» Deceased Person

Generalization Person

«Kind» Person

GeneralizationSet partition1 { Dece

«Phase» Extinct Organization

Generalization Organization

«Phase» Active Organization

Generalization Organization

«Kind» Organization

GeneralizationSet partition2 { Activ

«RoleMixin» Customer

«Relator» Service Contract

«Role» Supplier

Generalization Active Organizat

«Role» Corporate Customer

Generalization Active Organizat

Generalization Customer

«Role» Personal Customer

Generalization Living Person

Generalization Customer

«Material» is served by

«Mediation»

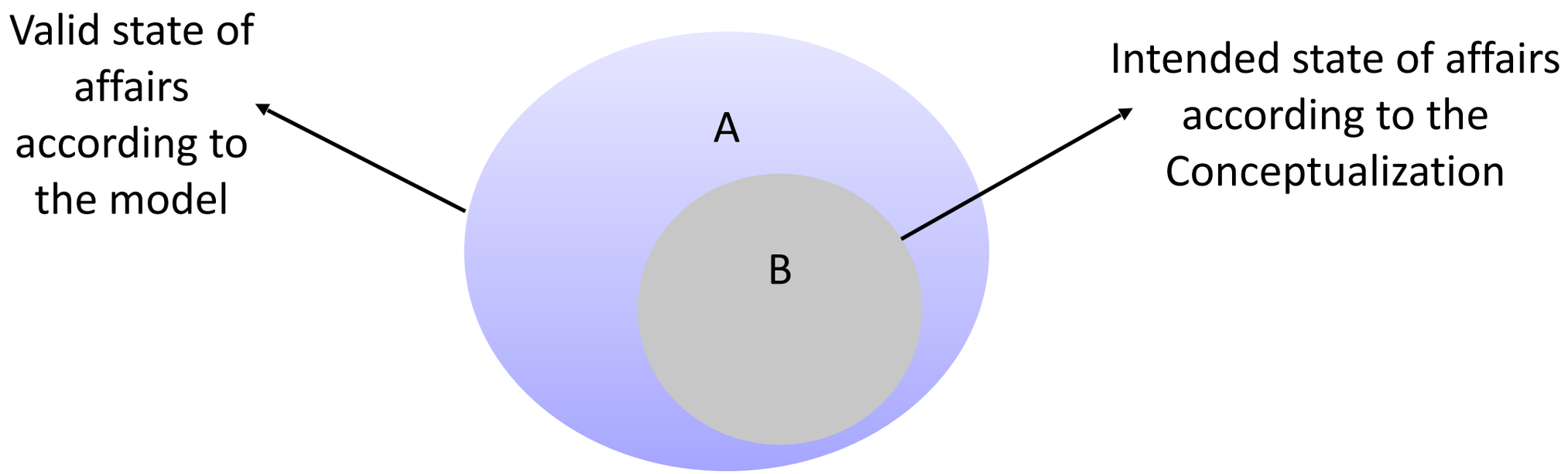
«Mediation»

«Derivation»

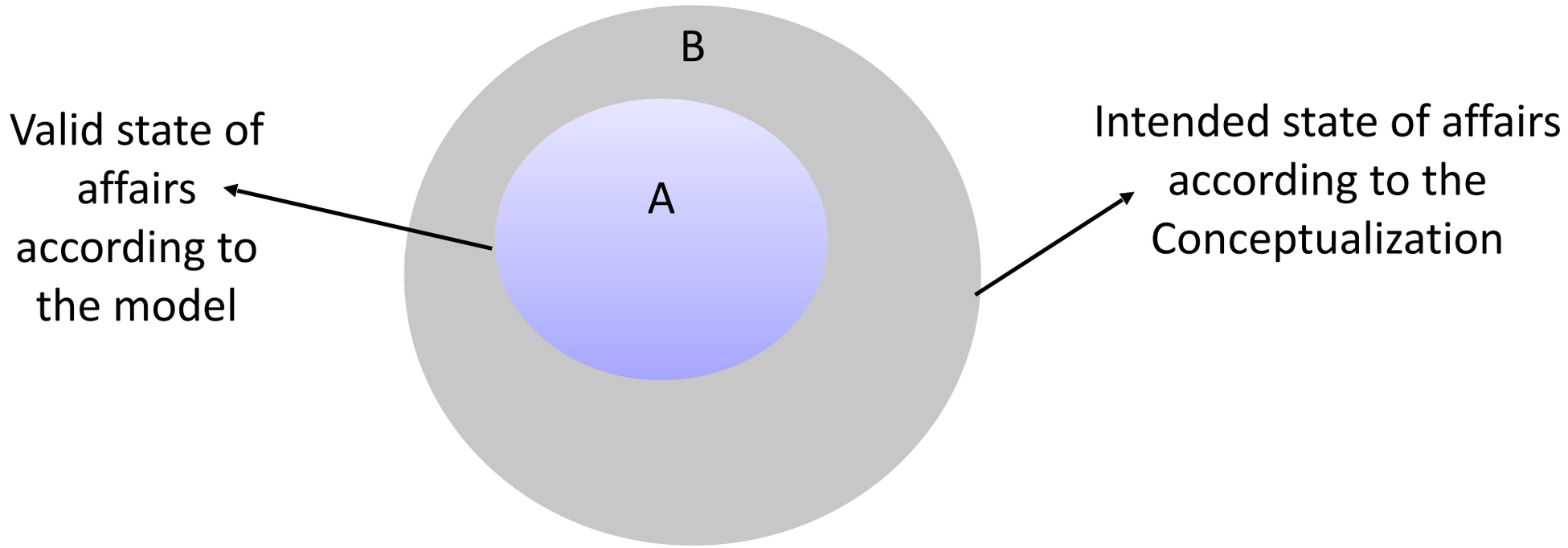
GeneralizationSet roleMixinGS3 { Pe

Valid state of affairs
according to the representation

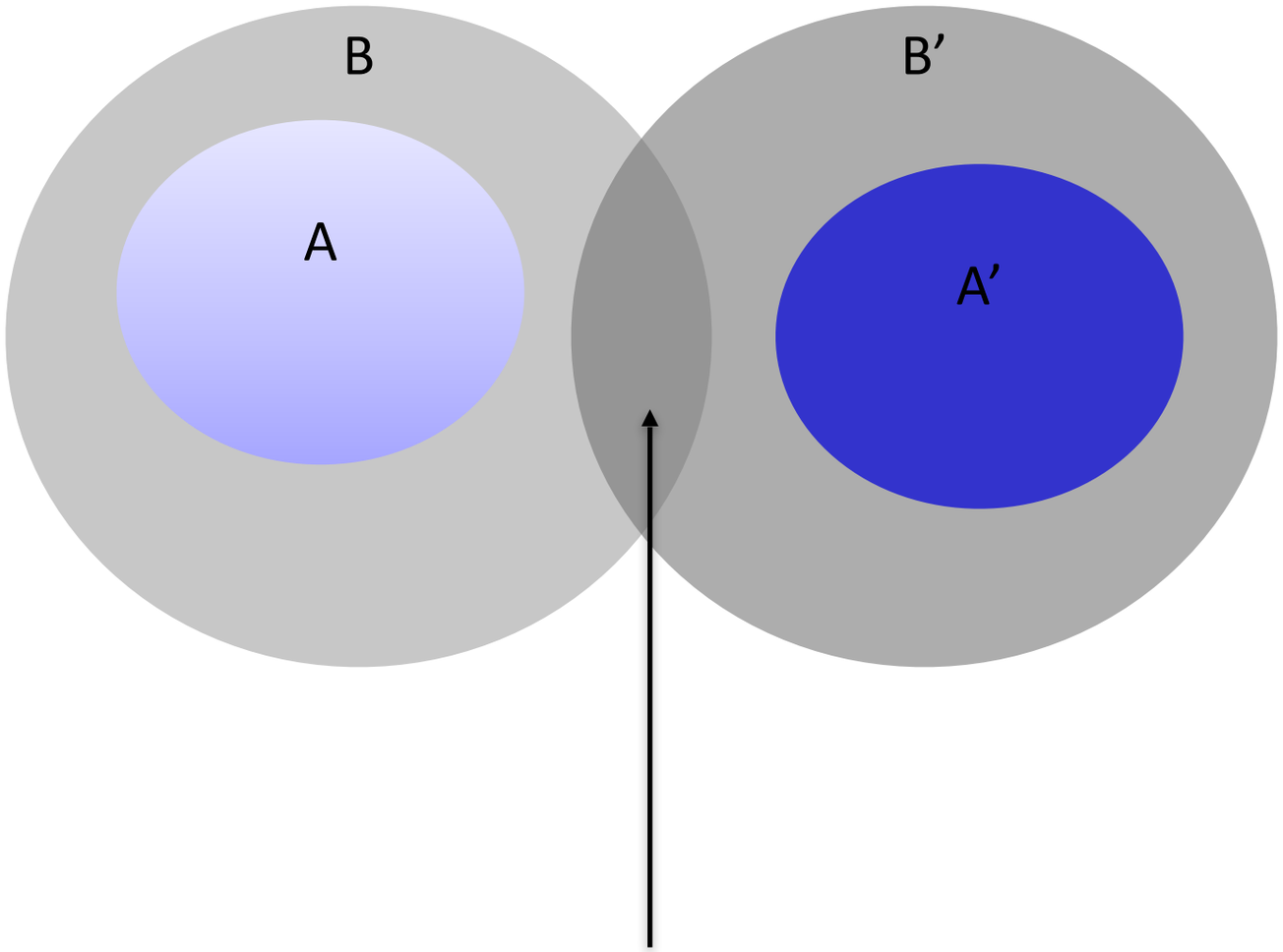
Intended state of affairs
according to the Conceptualization



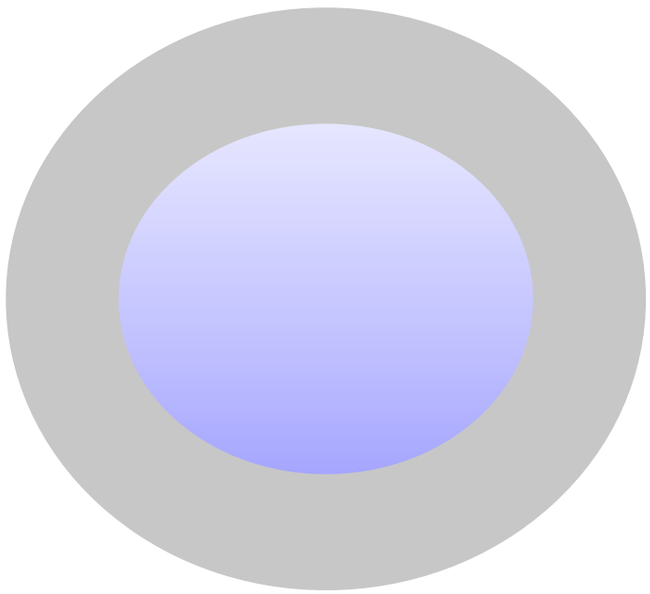
Under-constraining



Over-constraining



False Agreement



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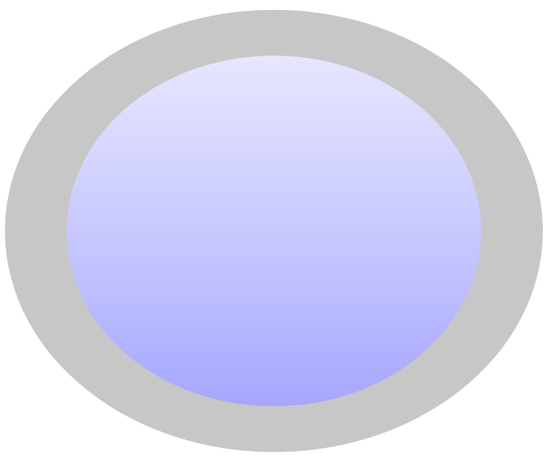

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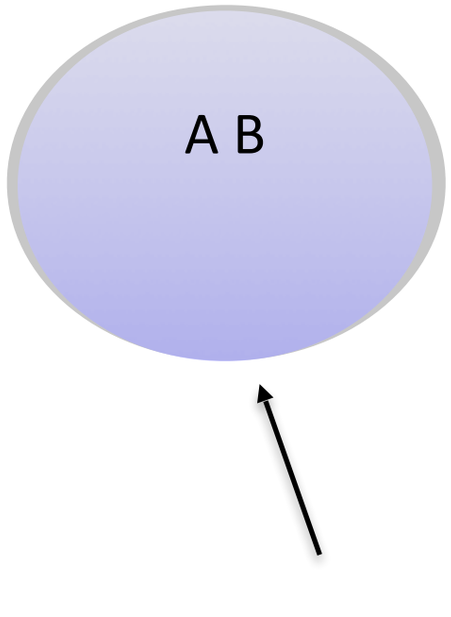

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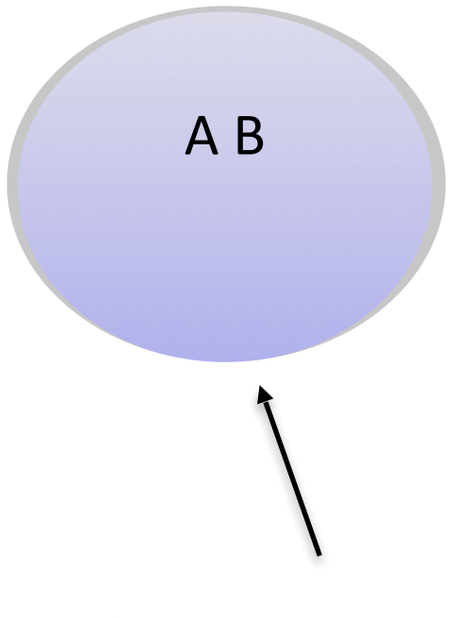
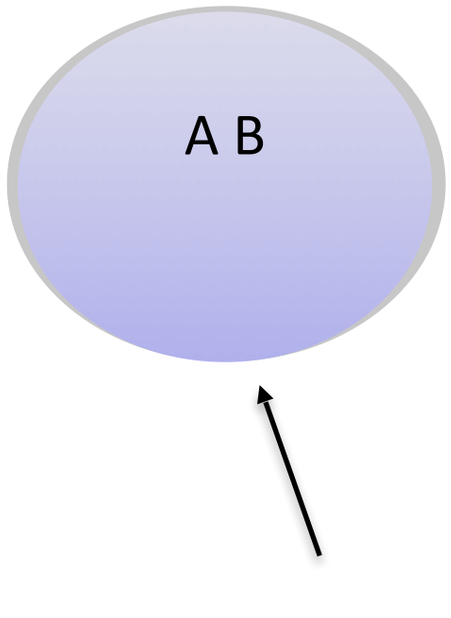
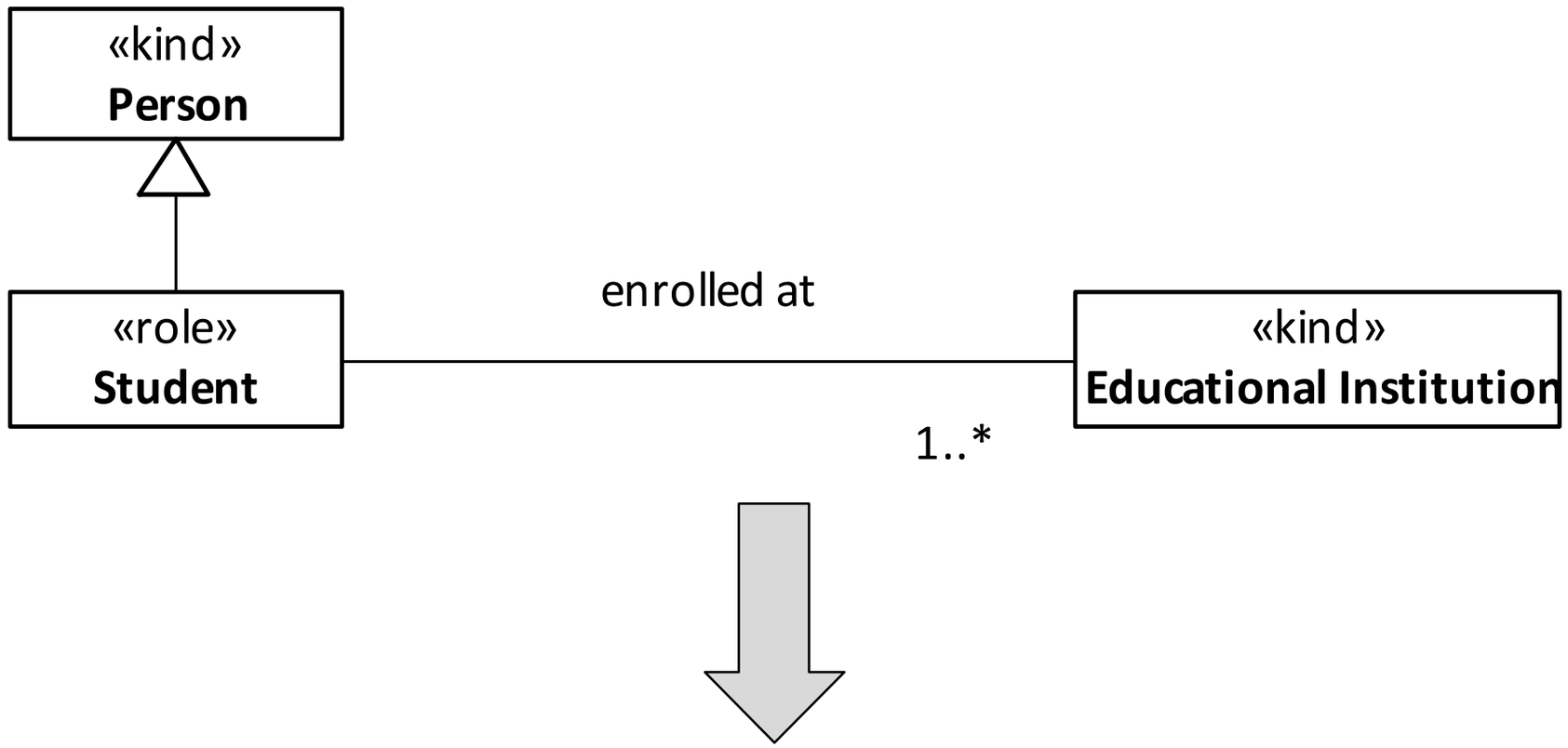


Conceptual Model = Structure + Axiomatization



Conceptual Model = Structure + Axiomatization

(**Ontological Commitment**)



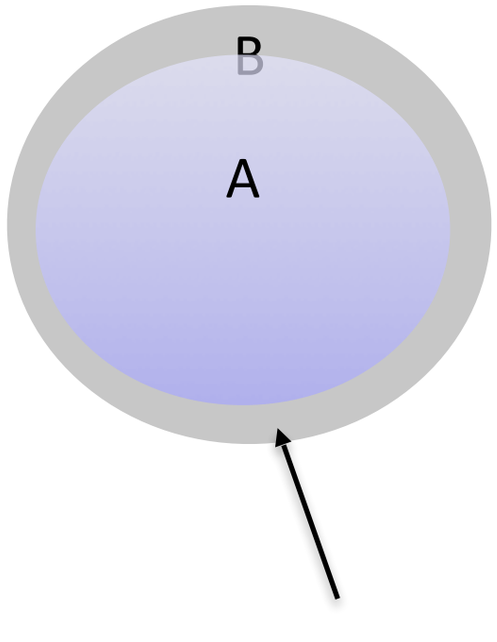
□(∀x **Person(x)** → □(**Person(x)**))

□(∀x **Student(x)** → ◊(¬**Student(x)**))

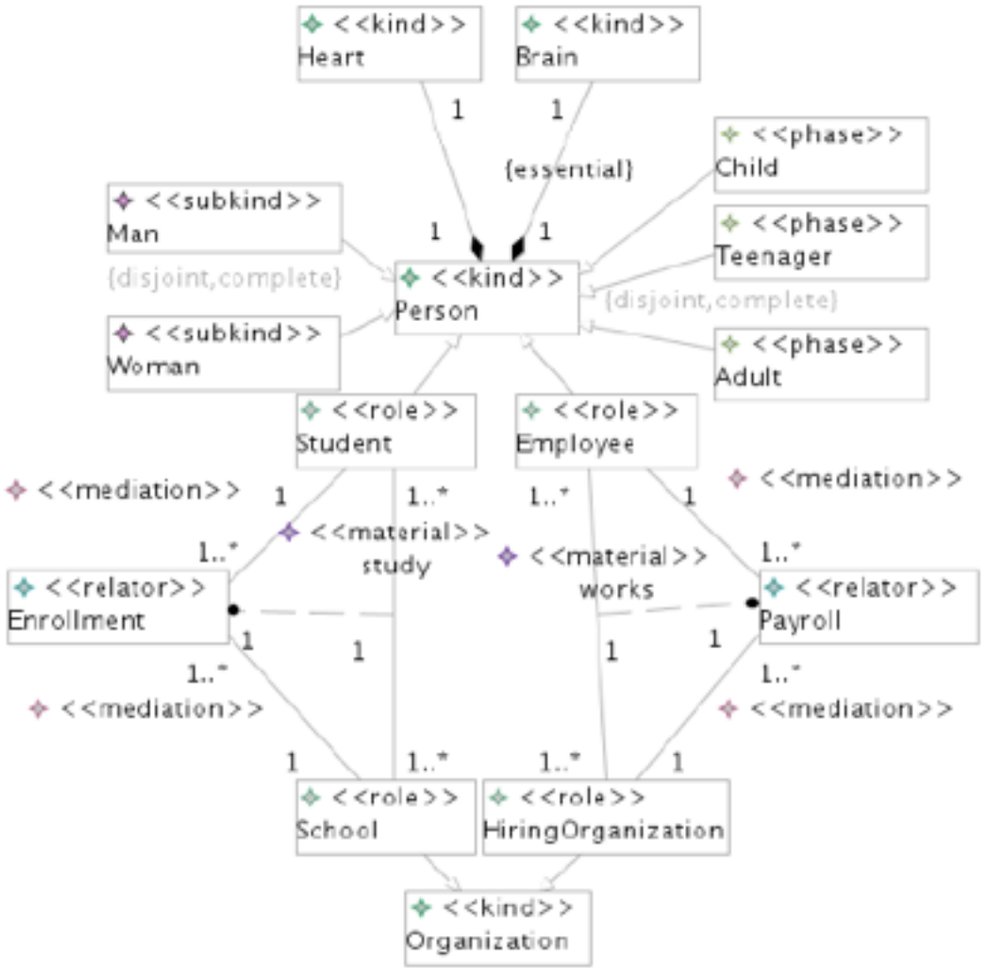
□(∀x **Student(x)** → **Person(x)**)

□(∀x **Student(x)** → ∃y **Educational Institution(y)** ∧ **Enrolled-at(x,y)**)

…



Conceptual Model =
Structure + Domain-Independent Axioms +
Domain-Specific Axioms

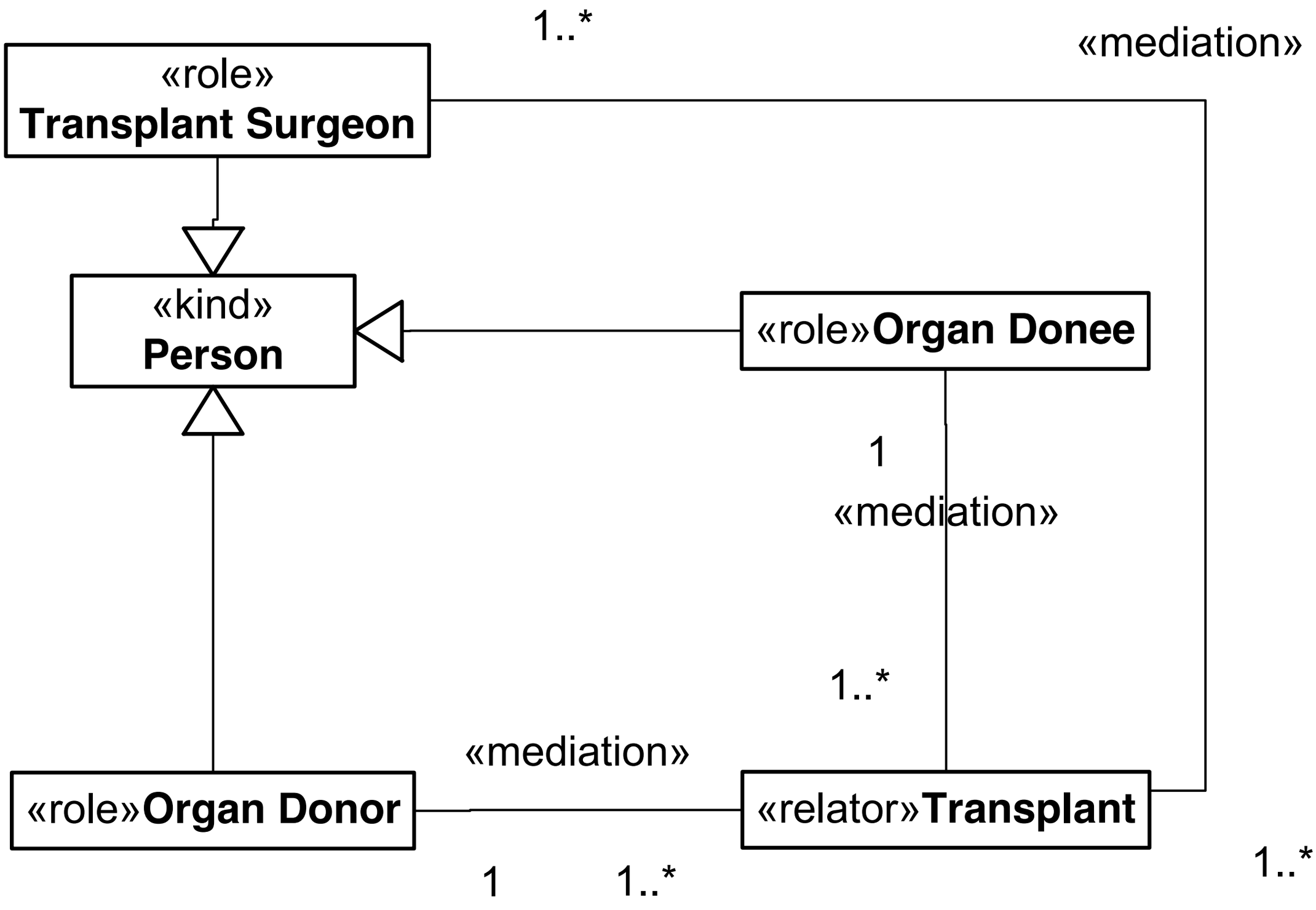


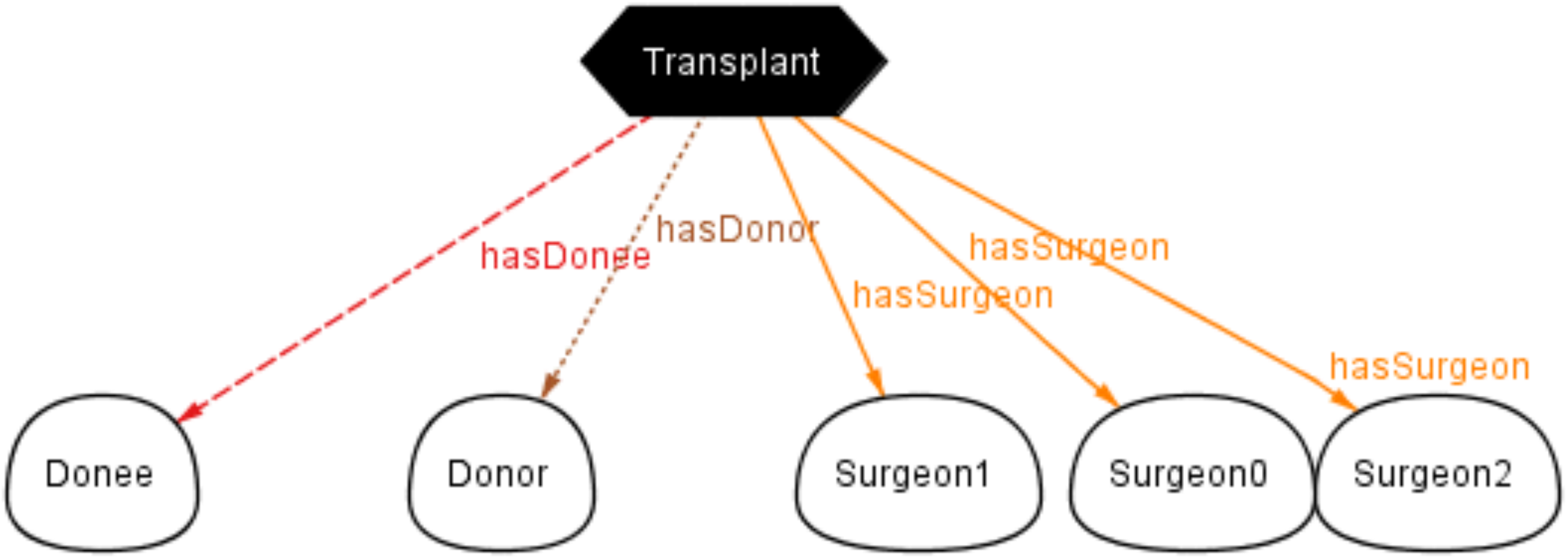
ATL Transformation

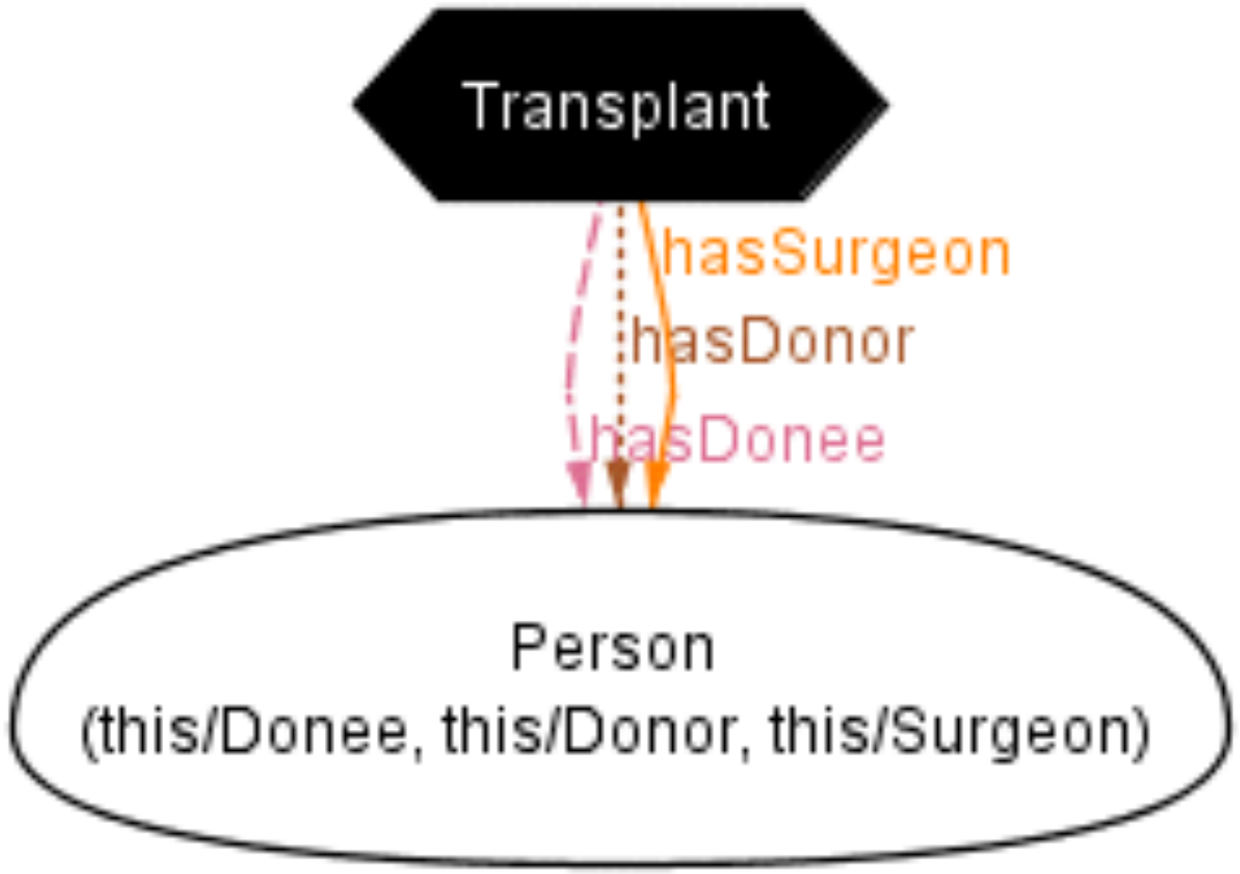
```
1 sig Person_Set in Concept { Person: some World }
2 {
3   Person in existsIn
4   all w1: World | w1 in Person => (all w2:
        w1.access | (w2 in existsIn) => (w2 in
        Person)) -- Rigidity
5   some w: World | w in this.Child -- Phase
6   some w: World | w in this.Teenager -- Phase
7   some w: World | w in this.Adult -- Phase
8   ⋮
9 }
```

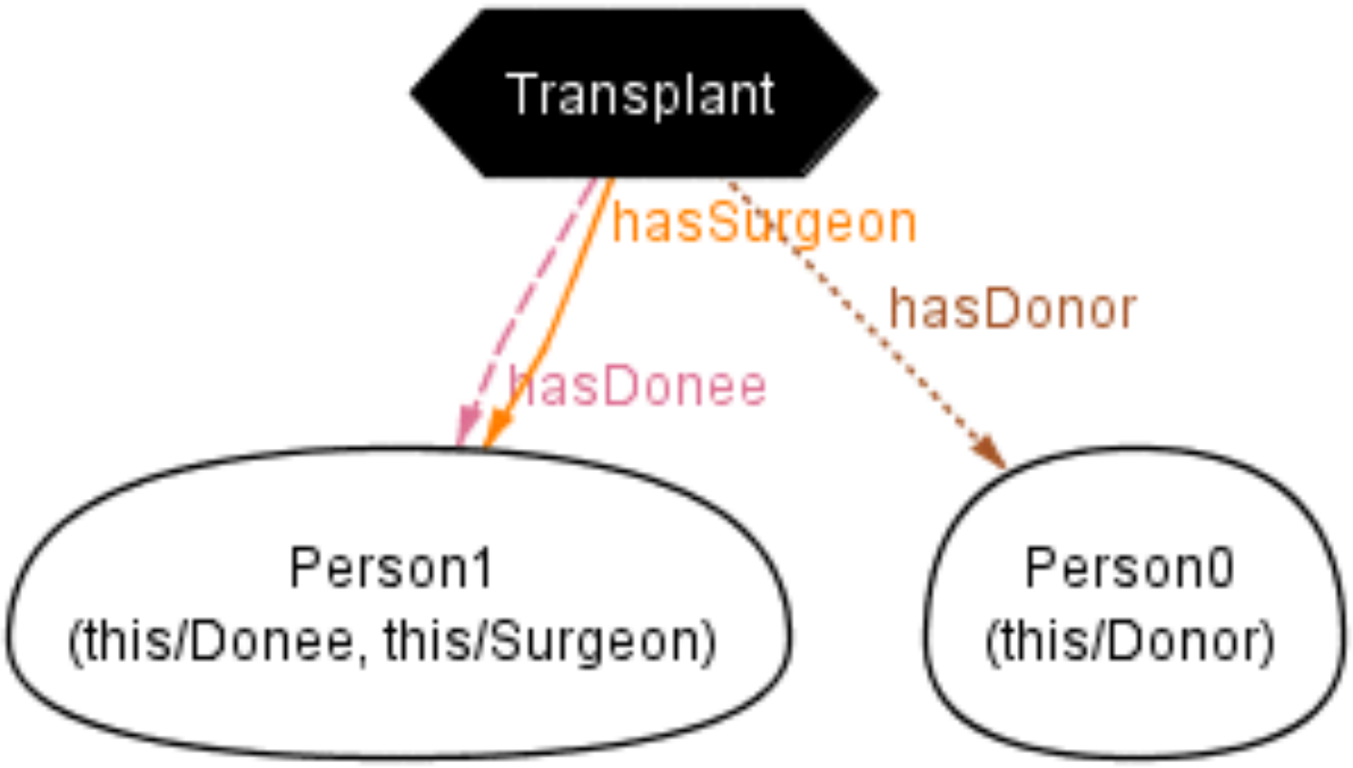
Simulation and Visualization

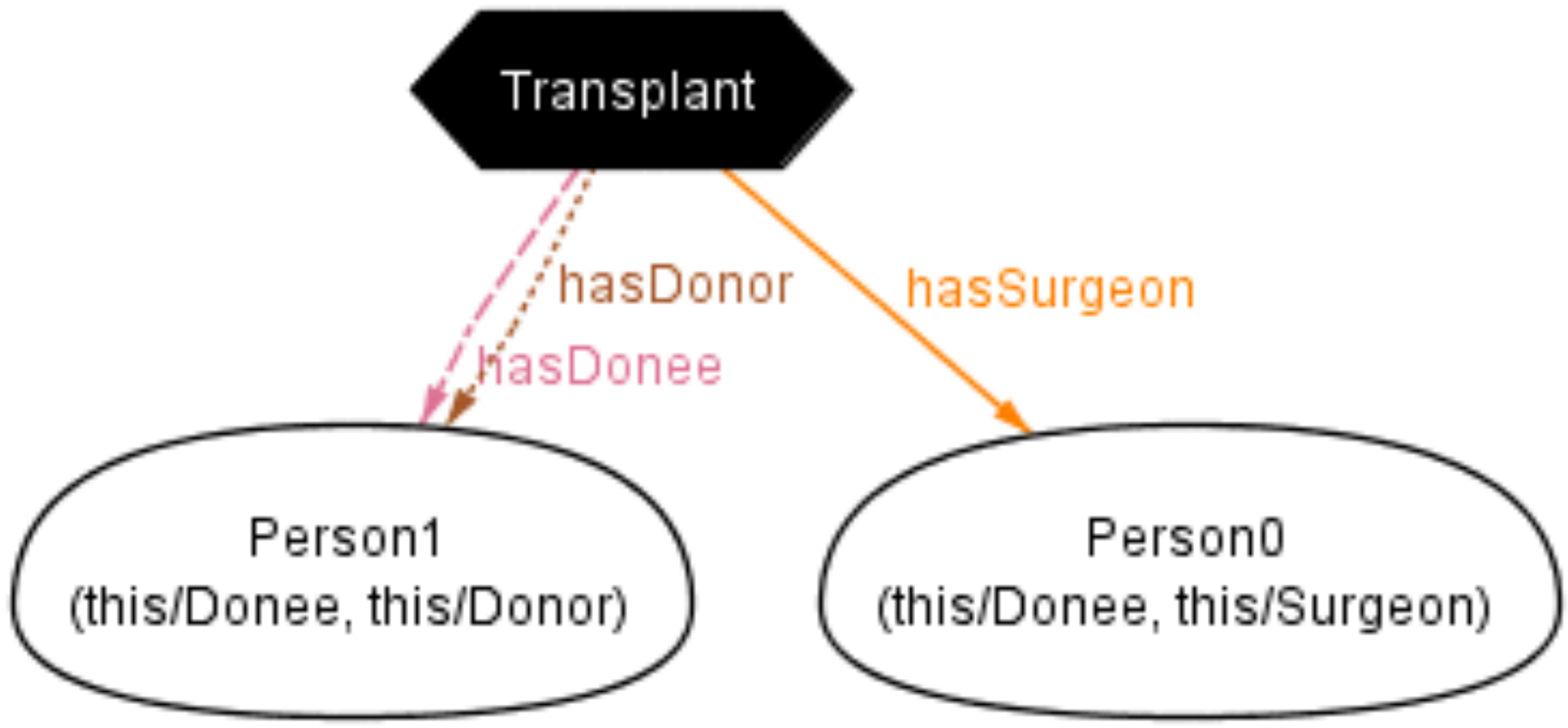
Alloy Analyzer + OntoUML visual Plugin

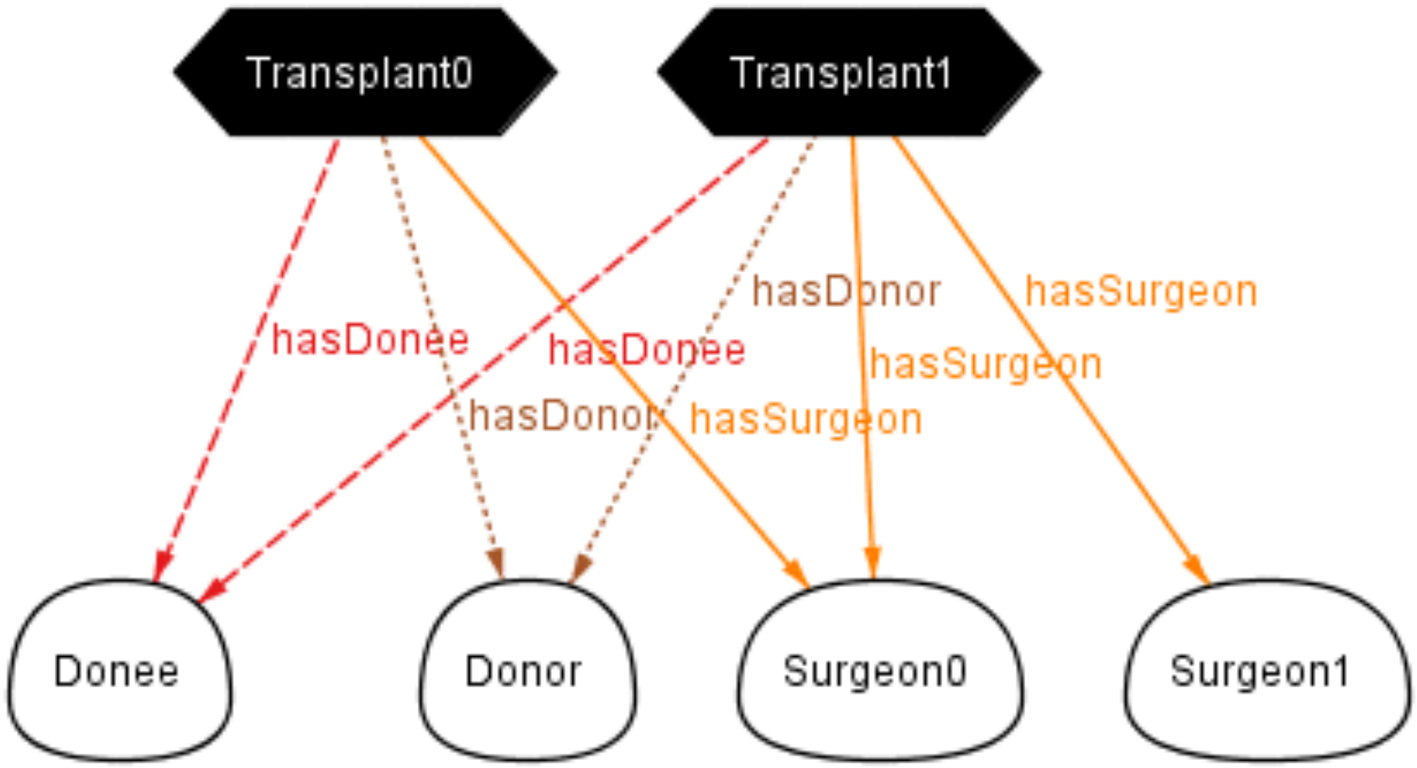

1..*
«mediation»
«role»
Transplant Surgeon
«kind»
Person
«role»Organ Donee
1
«mediation»
1..*
«mediation»
«role»Organ Donor
«relator»Transplant
1
1..*
1..*


Transplant
hasDonee
hasDonor
hasSurgeon
hasSurgeon
hasSurgeon
Donee
Donor
Surgeon1
Surgeon0
Surgeon2

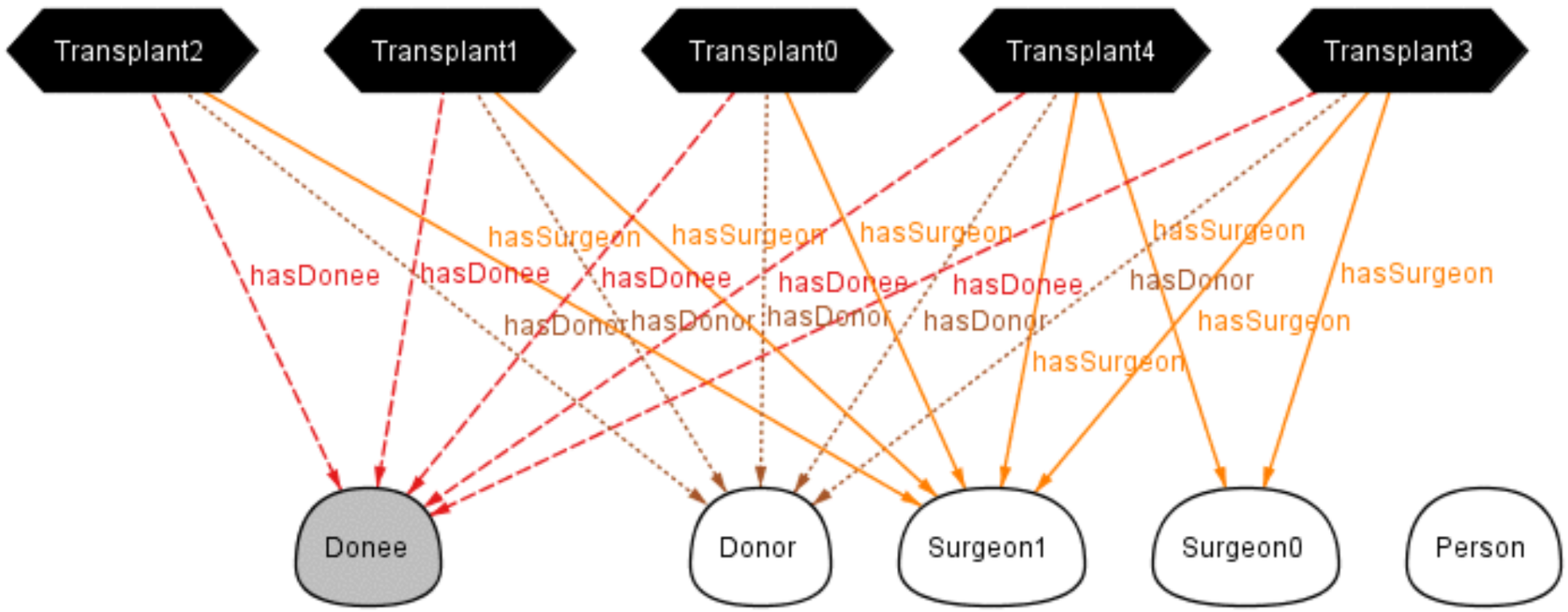

Transplant
hasSurgeon
hasDonor
hasDonee
Person
(this/Donee, this/Donor, this/Surgeon)


Transplant
hasSurgeon
hasDonor
hasDonee
Person1
(this/Donee, this/Surgeon)
Person0
(this/Donor)


Transplant
hasDonor
hasDonee
hasSurgeon
Person1
(this/Donee, this/Donor)
Person0
(this/Donee, this/Surgeon)



Real-Word Semantics



Data Modeling Guide (DMG)

For An Enterprise

Logical Data Model (ELDM)

Version 2.3

March 15, 2011

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Preface

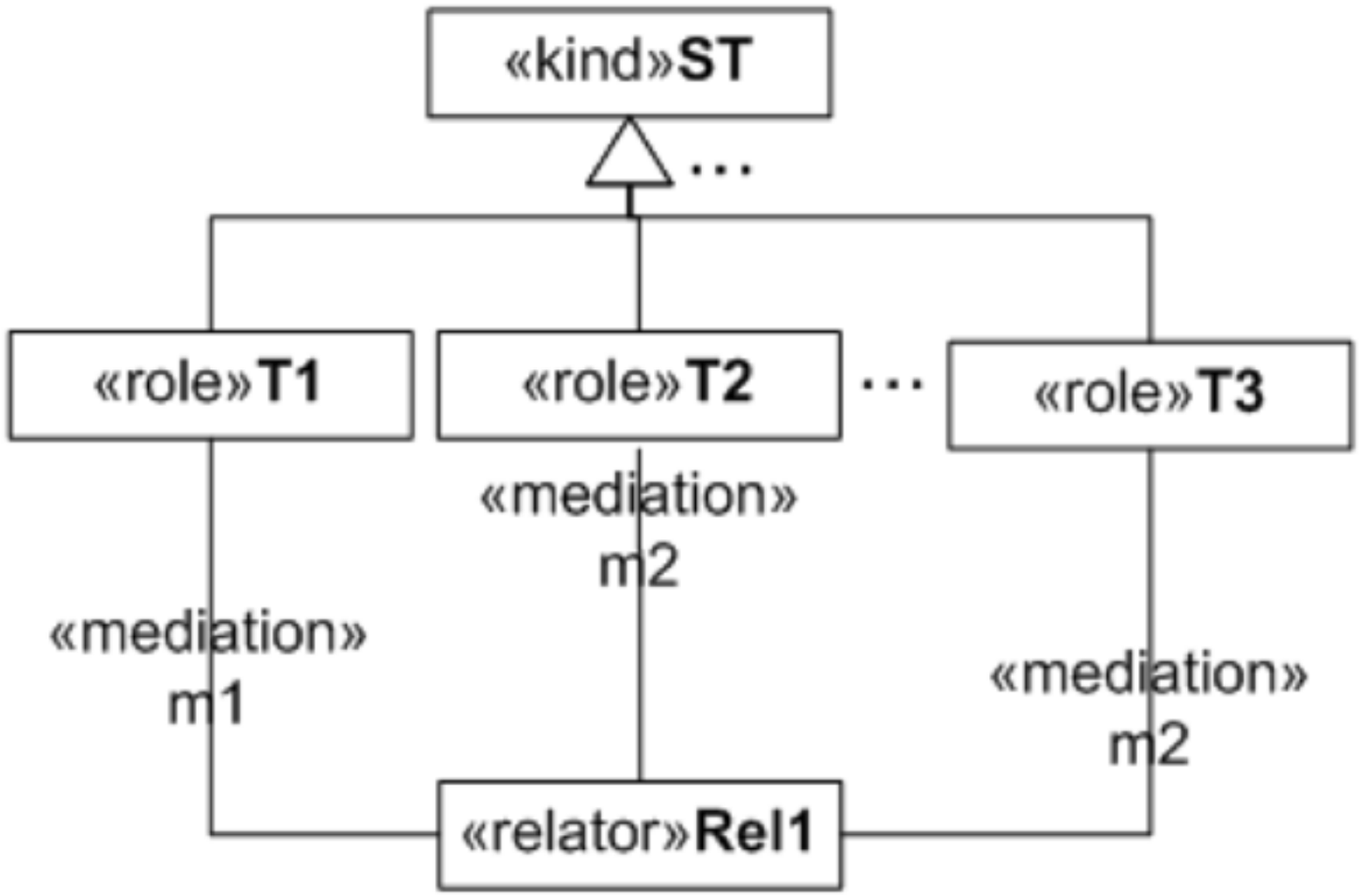
The success of this Data Modeling Guide for an Enterprise Logical Data Model could not have been possible without the inspired and exhaustive research of Giancarlo Guizzardi, notably his "Ontological Foundations for Structural Conceptual Models," published in 2005 in association with the Centre for Telemetrics and Information Technology, which provided the theoretical foundation for the methodologies describe within, and from which real world, practical implementations have already ensued.

At the core of Guizzardi's modeling paradigm are the principles of Rigidity, Uniform Identity and Existential Dependence. From those foundational tenets he extrapolates the concepts of SortalUniversal (Unified Principle of Identity), MixinUniversal (Disparate Set of Concepts), and finally the constructs of SubstanceSortal (Kind, Quantity, and Collective), Subkind, Phase, Role, Category, RoleMixin and Mixin. In short, the total package offered to us by Guizzardi contained a complete and fully integrated set of concepts and constructs that left us wanting for nothing.

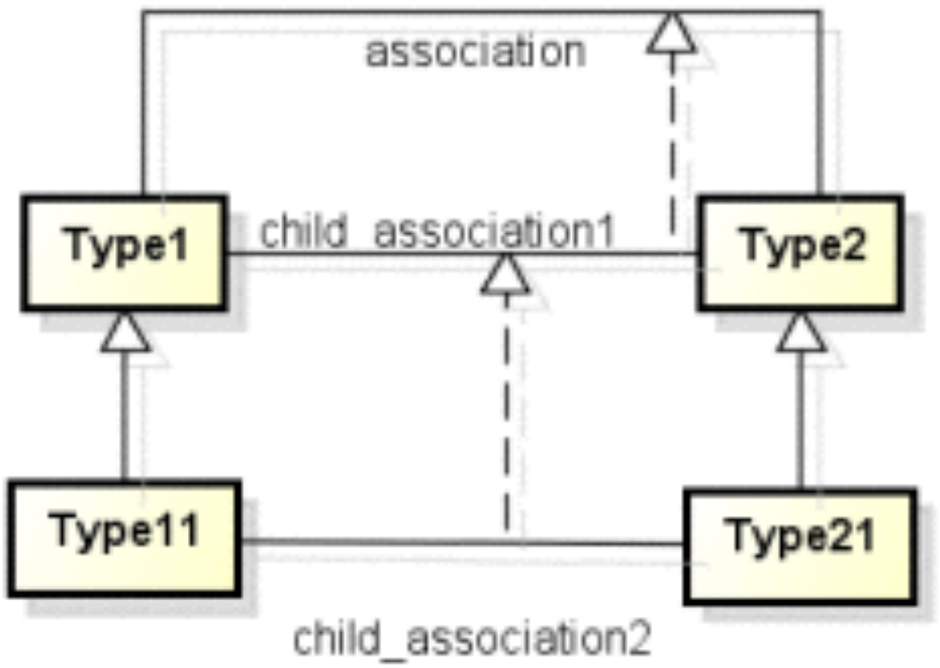
OntoUML Model Benchmark

- Model benchmark with 56 models
- Models in domains such as Provenance in Scientific Workflow, Public Cloud Vulnerability, Software Configuration Management, Emergency Management, Services, IT Governance, Organizational Structures, Software Requirements, Heart Electrophisiology, Amazonian Biodiversity Management, Human Genome, Optical Transport Networks, Federal Government Organizational Structures, Normative Acts, and Ground Transportation Regulation

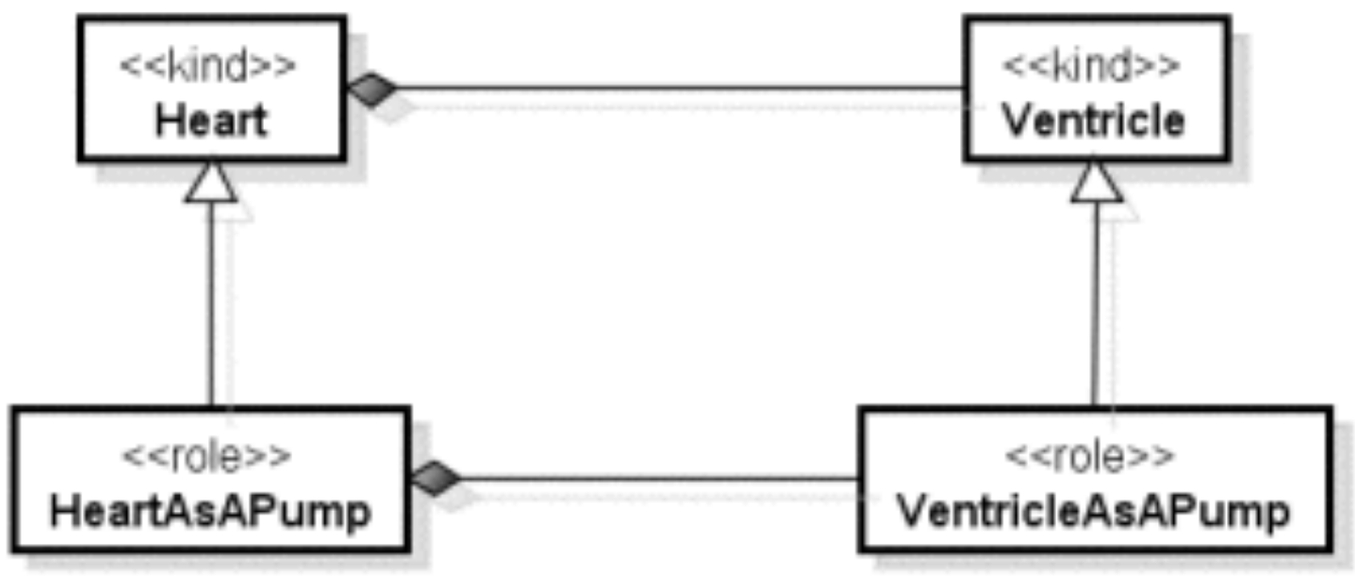
The Emerging Anti-Pattern: Relation Between Overlapping Types (**RelOver**)



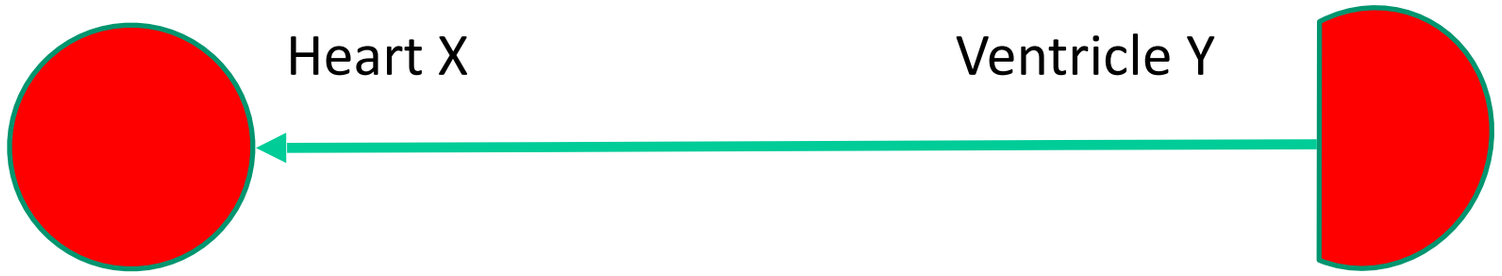
The Emerging Anti-Pattern: Relation Specialization (**RelSpec**)

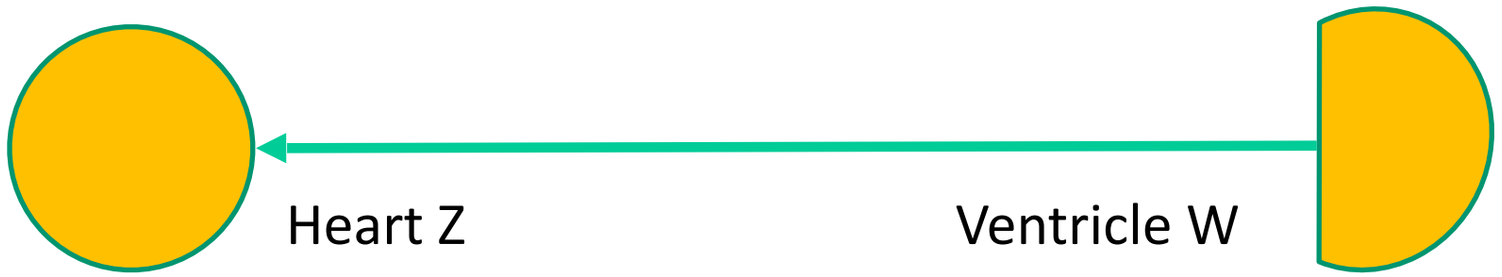


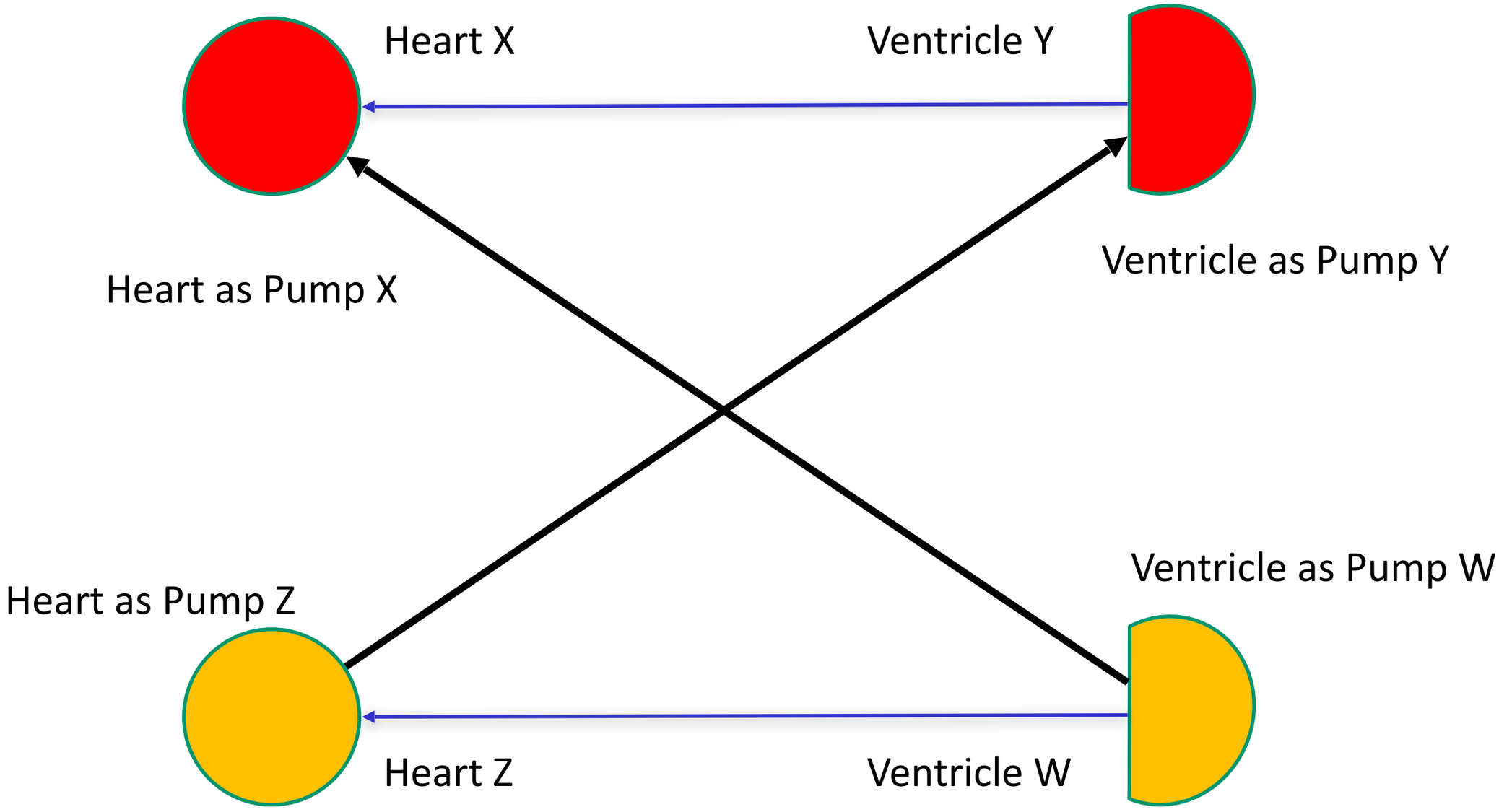
(a)



(b)


Heart X
Ventricle Y


Heart Z
Ventricle W


Heart X
Ventricle Y
Heart as Pump X
Ventricle as Pump Y
Heart as Pump Z
Ventricle as Pump W
Heart Z
Ventricle W

Anti-Pattern Catalogue

- Association Cycle
- Binary Relation Between Over. Types
- Deceiving Intersection
- Free Role Specialization
- Imprecise Abstraction
- Multiple Relational Dependency
- Part Composing Over. Roles
- Whole Composed by Over. Parts
- Relator Mediating Over. Types
- Relation Composition
- Relator Mediating Rigid Types
- Relation Specialization
- Repeatable Relator Instances
- Relationally Dependent Phase
- Generalization Set With Mixed Rigidity
- Heterogeneous Collective
- Homogeneous Functional Complex
- Mixin With Same Identity
- Mixin With Same Rigidity
- Undefined Formal Association
- Undefined Phase Partition
- Family of Multi-Level Anti-Patterns (ML-AP1, ML-AP2, ML-AP3, AL-AP4)

Anti-Patterns (AP)	AP Occurrences	Relevant Model Construct (RMC)	RMC /AP Ratio	% of Qualified Models with AP Occurrence
RelSpec	817	Association	4.92	48.15%
ImpAbs	758	Association	5.30	72.22%
AssCyc	1809	Association	2.22	92.59%
RelOver	149	Relator	8.08	25%
RepRel	319	Relator	3.77	64.58%
BinOver	224	Association	17.93	48.15%

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Anti-Pattern	#Occ.	#Error	#Error / #Occ.	#Refac. /#Error
RelSpec	315	279	88.6%	97.1%
RepRel	221	57	25.8%	84.2%
RelOver	124	70	56.5%	77.1%
BinOver	74	31	41.9%	74.2%
AssCyc	20	14	70.0%	71.4%
ImpAbs	125	11	8.8%	27.3%
Total	879	462	52.56%	88.53%

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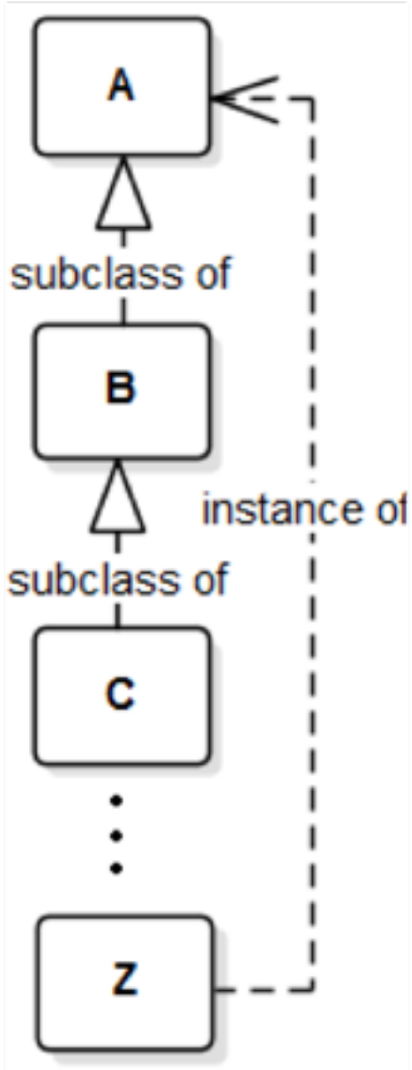
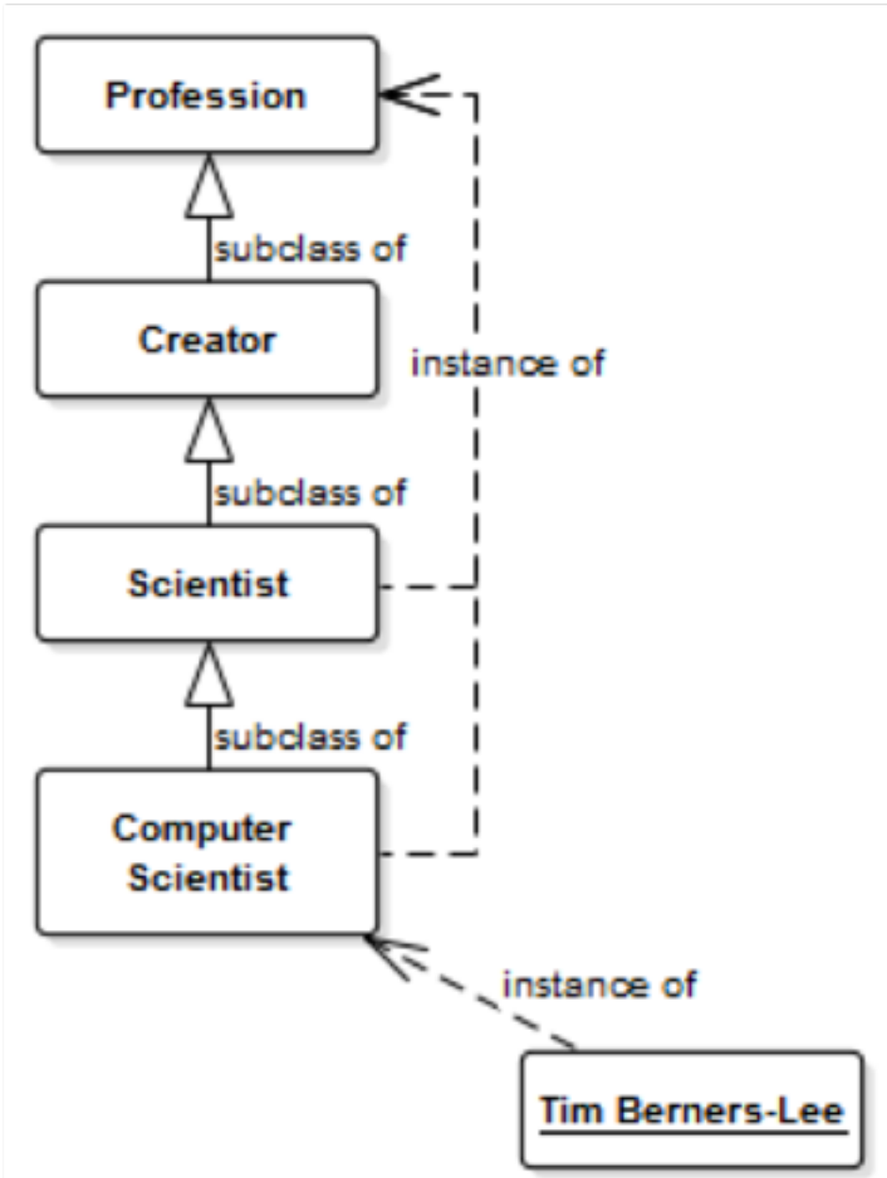
What if we go big…

(searching for Anti-Patterns on WikiData)

Multi-Level Modeling





What if we go big…

Number of classes in any taxonomic hierarchy	337,102
Number of classes in taxonomic hierarchies spanning more than one level	17,819
Number of classes involved in AP1	15,177

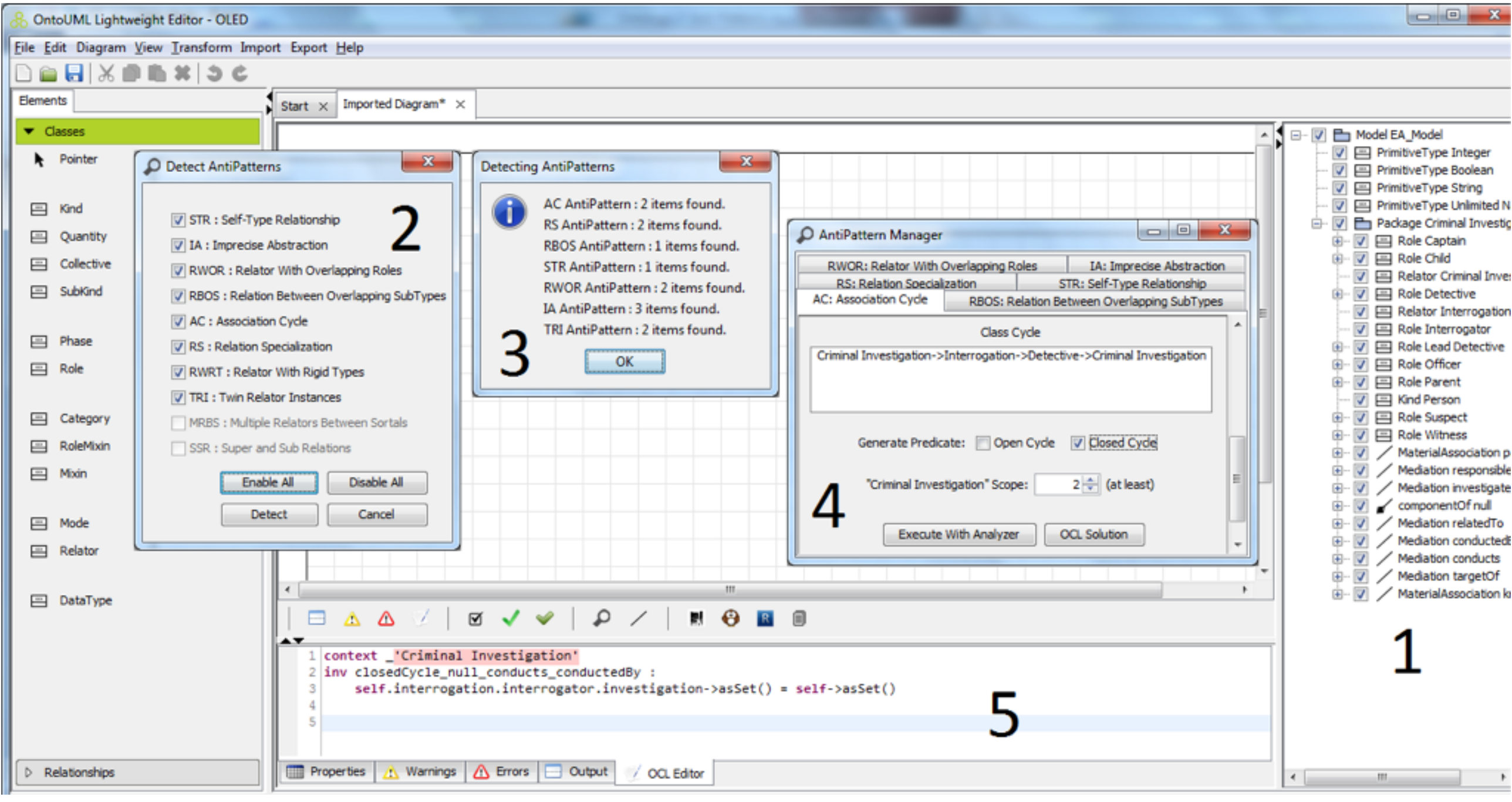
OntoUML Criminal Investigation

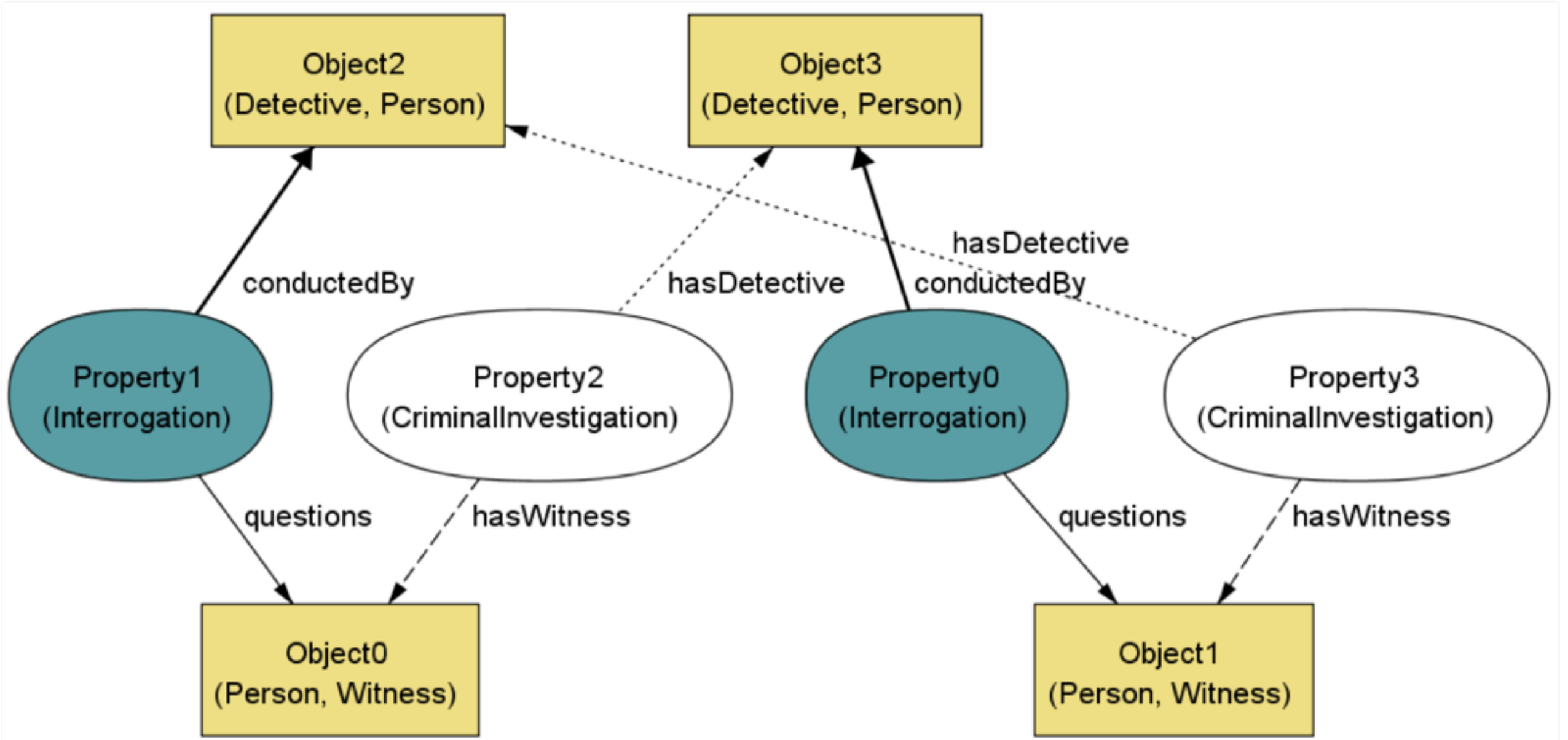
«Role»
Officer

«Role»
Captain

parentOf
+child
«Role»
Child
«Material»
+parent
1..2
«Role»
Parent
«Kind»
Person
«Material»
knows

+detective
conductedBy
investigates
+suspect
1..*
«Role»
Detective
«Mediation»
2..*
«Mediation»
«Role»
Suspect
+investigation
1
1..*
+investigation
1..*
+interrogator
«Relator»
Criminal Investigation
+investigation
1..*
«Mediation»
+investigation
1
relatedTo
1..*
«Role»
Witness
«Role»
Lead Detective
+leader
responsibleFor
1
+investigative context
«ComponentOf»
+witness
+witness
1
«Mediation»
+part of investigatic
1..*
targetOf
«Mediation»
+interrogation
«Relator»
Interrogation
1..*
«Mediation»
+interrogation
conducts
*


OntoUML Lightweight Editor - OLED
File Edit Diagram View Transform Import Export Help
Elements
Classes
Pointer
Kind
Quantity
Collective
SubKind
Phase
Role
Category
RoleMixin
Mixin
Mode
Relator
DataType
Relationships
Start
Imported Diagram*
Detect AntiPatterns
STR : Self-Type Relationship
IA : Imprecise Abstraction
RWOR : Relator With Overlapping Roles
RBOS : Relation Between Overlapping SubTypes
AC : Association Cycle
RS : Relation Specialization
RWRT : Relator With Rigid Types
TRI : Twin Relator Instances
MRBS : Multiple Relators Between Sortals
SSR : Super and Sub Relations
Enable All
Disable All
Detect
Cancel
2
Detecting AntiPatterns
AC AntiPattern : 2 items found.
RS AntiPattern : 2 items found.
RBOS AntiPattern : 1 items found.
STR AntiPattern : 1 items found.
RWOR AntiPattern : 2 items found.
IA AntiPattern : 3 items found.
TRI AntiPattern : 2 items found.
OK
3
AntiPattern Manager
RWOR: Relator With Overlapping Roles
IA: Imprecise Abstraction
RS: Relation Specialization
STR: Self-Type Relationship
AC: Association Cycle
RBOS: Relation Between Overlapping SubTypes
Class Cycle
Criminal Investigation->Interrogation->Detective->Criminal Investigation
Generate Predicate:
Open Cycle
Closed Cycle
"Criminal Investigation" Scope:
2
(at least)
Execute With Analyzer
OCL Solution
4
Model EA_Model
PrimitiveType Integer
PrimitiveType Boolean
PrimitiveType String
PrimitiveType Unlimited N
Package Criminal Investig
Role Captain
Role Child
Relator Criminal Inves
Role Detective
Relator Interrogation
Role Interrogator
Role Lead Detective
Role Officer
Role Parent
Kind Person
Role Suspect
Role Witness
MaterialAssociation p
Mediation responsible
Mediation investigate
componentOf null
Mediation relatedTo
Mediation conducted
Mediation conducts
Mediation targetOf
MaterialAssociation k
1
context _'Criminal Investigation'
inv closedCycle_null_conducts_conductedBy :
self.interrogation.interrogator.investigation->asSet() = self->asSet()
5
Properties
Warnings
Errors
Output
OCL Editor


Object2
(Detective, Person)
Object3
(Detective, Person)
conductedBy
hasDetective
hasDetective
conductedBy
Property1
(Interrogation)
Property2
(CriminalInvestigation)
Property0
(Interrogation)
Property3
(CriminalInvestigation)
questions
hasWitness
questions
hasWitness
Object0
(Person, Witness)
Object1
(Person, Witness)

RWOR: Relator With Overlapping Roles

Relator With Overlapping Roles

Relator: Criminal Investigation

Customizing Disjoints Roles: Add

Lead Detective	Witness	Detective	Suspect
☐	☑	☑	☐
☐	☑	☐	☑
☐	☐	☑	☑

☐ Exclusive ☑ Exclusive from Table ☐ Overlapping

☐ Disjoint ☑ Disjoint from Table

"Criminal Investigation" Scope: 2 (at least)

Execute With Analyzer | OCL Solution

```
1  context _'Criminal Investigation'
2  inv: self.witness.oclAsType(Person)->asSet()->intersection(self.detective.oclAsType(Person)->asSet())->size()=0
3
4  context _'Criminal Investigation'
5  inv: self.witness.oclAsType(Person)->asSet()->intersection(self.suspect.oclAsType(Person)->asSet())->size()=0
6
7  context _'Detective'
8  inv: not self.oclIsTypeOf(Suspect)
9
```

Properties | Warnings | Errors | Output | OCL Editor

"Few modelers, however,
have had the experience of subjecting
their models to continual, automatic review.
Building a model incrementally with an analyzer,
simulating and checking as you go along, is a very
different experience from using pencil and paper alone.
The first reaction tends to be amazement: modeling is
much more fun when you get instant, **visual feedback**.
Then the sense of **humiliation** sets in, as you discover
that **there's almost nothing you can do right**."

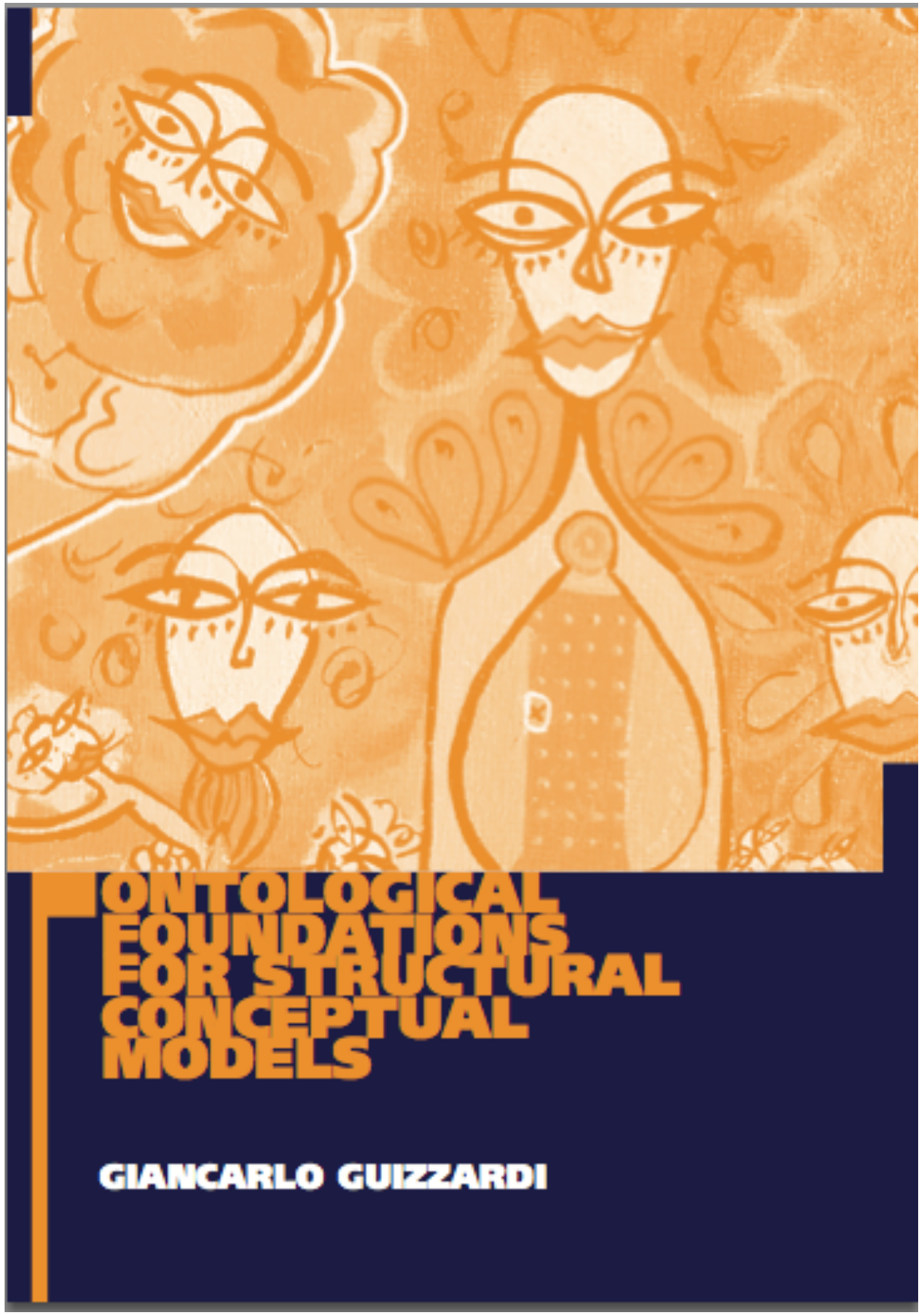
(Daniel Jackson, Software Abstractions : Logic,
Language, and Analysis, 2006)

The Humble **Ontologist**

[What] I have chosen to stress in this talk is the following.
We shall do a much better **ontology** job in the future,
provided that we approach the task with a full
appreciation of its tremendous complexity,…,
provided we respect the intrinsic limitations
of the human mind and approach the task
a Very Humble **Ontologist**

(paraphrasing Dijkstra's Humble Programmer, 1972)

Some **References**


ONTOLOGICAL
FOUNDATIONS
FOR STRUCTURAL
CONCEPTUAL
MODELS
GIANCARLO GUIZZARDI

Reading Material

- GUIZZARDI, G., Ontological Patterns, Anti-Patterns and Pattern Languages for Next-Generation Conceptual Modeling, invited companion paper to the Keynote Speech delivered at the 33rd International Conference on Conceptual Modeling (ER 2014), Atlanta, USA.

- SALLES, T.P., GUIZZARDI, G., Ontological Anti-Patterns: Empirically Uncovered Error-Prone Structures in Ontology-Driven Conceptual Models, Data & Knowledge Engineering (DKE) Journal, Volume 99, September 2015, Pages 72–104.

- RUY, F., GUIZZARDI, G., FALBO, R., REGINATO, C.C., SANTOS, V.A., From Reference Ontologies to Ontology Patterns and Back, Data & Knowledge Engineering, Elsevier, 2017.

Reading Material

- SALES, T.P., GUIZZARDI, G., “Is it a Fleet or a Collection of Ships?”: Ontological Anti-Patterns in the modeling of Part-Whole Relations, 21st European Conference on Advances in Databases and Information Systems (ADBIS 2017), Cyprus, 2017.

- CARVALHO, V.A., ALMEIDA, J.P.A., FONSECA, C, GUIZZARDI, G., Multi-Level Ontology-Based Conceptual Modeling, Data & Knowledge Engineering, Elsevier, 2017.

- BRASILEIRO, F., ALMEIDA, J.P.A., CARVALHO, V.A., GUIZZARDI, G., Expressive Multi-Level Modeling for the Semantic Web, 15th International Semantic Web Conference (ISWC’16), Kobe, Japan, 2016.

Reading Material

- WANG, X., GUARINO, N., GUIZZARDI, G., MYLOPOULOS, J., How Software Changes the World: The Role of Assumptions, IEEE Tenth International Conference on Research Challenges in Information Science (RCIS 2016), Grenoble, France, 2016.

- Sales, T.P., Guizzardi, G., Anti-patterns in Ontology-driven Conceptual Modeling: The Case of Role Modeling in OntoUML, Ontology Engineering with Ontology Design Patterns: Foundations and Applications, A. Gangemi, P. Hizler, K. Janowicz, A. Krisnadhi, V. Presutti, IOS Press, The Netherlands, 2016.

- GUARINO, N., GUIZZARDI, G., We need to Discuss the Relationship: Revisiting Relationships as Modeling Constructs, 27th International Conference on Advance Information Systems Engineering (CAISE 2015), Stockholm, Sweden, 2015.

- GUERSON, J., SALES, T.P., GUIZZARDI, G., ALMEIDA, J.P.,, OntoUML Lightweight Editor: A Model-Based Environment to Build, Evaluate and Implement Reference Ontologies, 19th IEEE Enterprise Computing Conference (EDOC 2015), Demo Track, Adelaide, Australia, 2015.

Reading Material

- BRASILEIRO, F., ALMEIDA, J.P.A., CARVALHO, V.A., GUIZZARDI, G., Applying a Multi-Level Modeling Theory to Assess Taxonomic Hierarchies in Wikidata, Wiki Workshop 2016, at the 25th International World Wide Web Conference (WWW 2016), Montreal, Canada, 2016.

- GUIZZARDI, G., ZAMBORLINI, V., Using a Trope-Based Foundational Ontology for Bridging different areas of concern in Ontology-Driven Conceptual Modeling, Science of Computer Programming, Elsevier, 2014, DOI:10.1016/j.scico.2014.02.022.

- ZAMBORLINI, V.; GUIZZARDI, G., On the representation of temporally changing information in OWL, IEEE 5th Joint International Workshop on Vocabularies, Ontologies and Rules for The Enterprise (VORTE) – Metamodels, Ontologies and Semantic Technologies (MOST), together with 15th International Enterprise Computing Conference (EDOC 2010),Vitória, Brazil, 2010.

Reading Material

- Bauman, B. T., Prying Apart Semantics and Implementation: Generating XML Schemata directly from ontologically sound conceptual models, Balisage Markup Conference, 2009.

- U.S. Department of Defense, Data Modeling Guide (DMG) for an Enterprise Logical Data Model (ELDM), available online: http://www.omgwiki.org/architecture- ecosystem/lib/exe/fetch.php?media=dmg_for_enterprise_ldm_v2_3.pdf.

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