Ontology-Driven Conceptual Modeling

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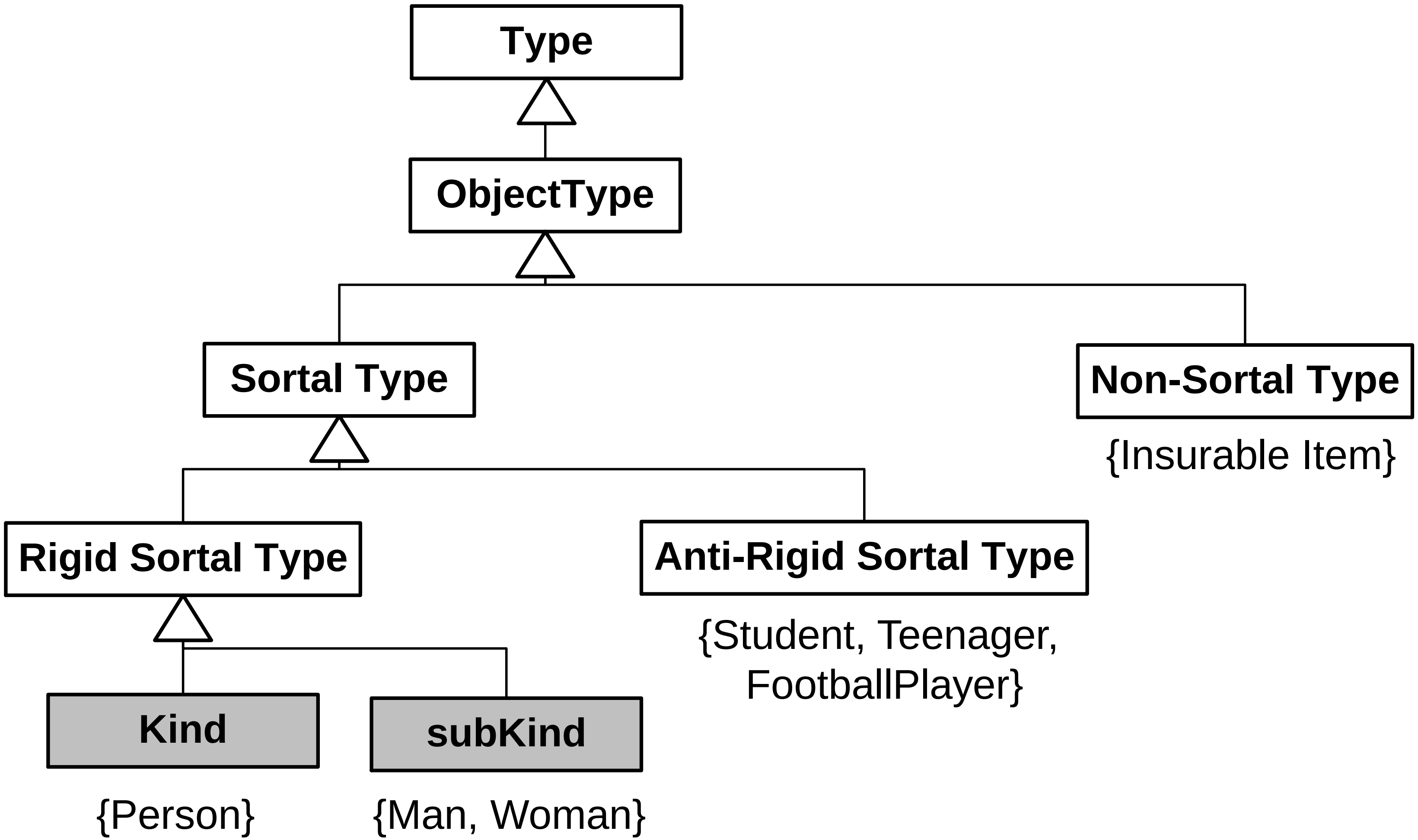
IAOA Summer School
Trento, Italy
Day 3

Distinctions Among Categories of Object Types



Relational Dependence (D+)

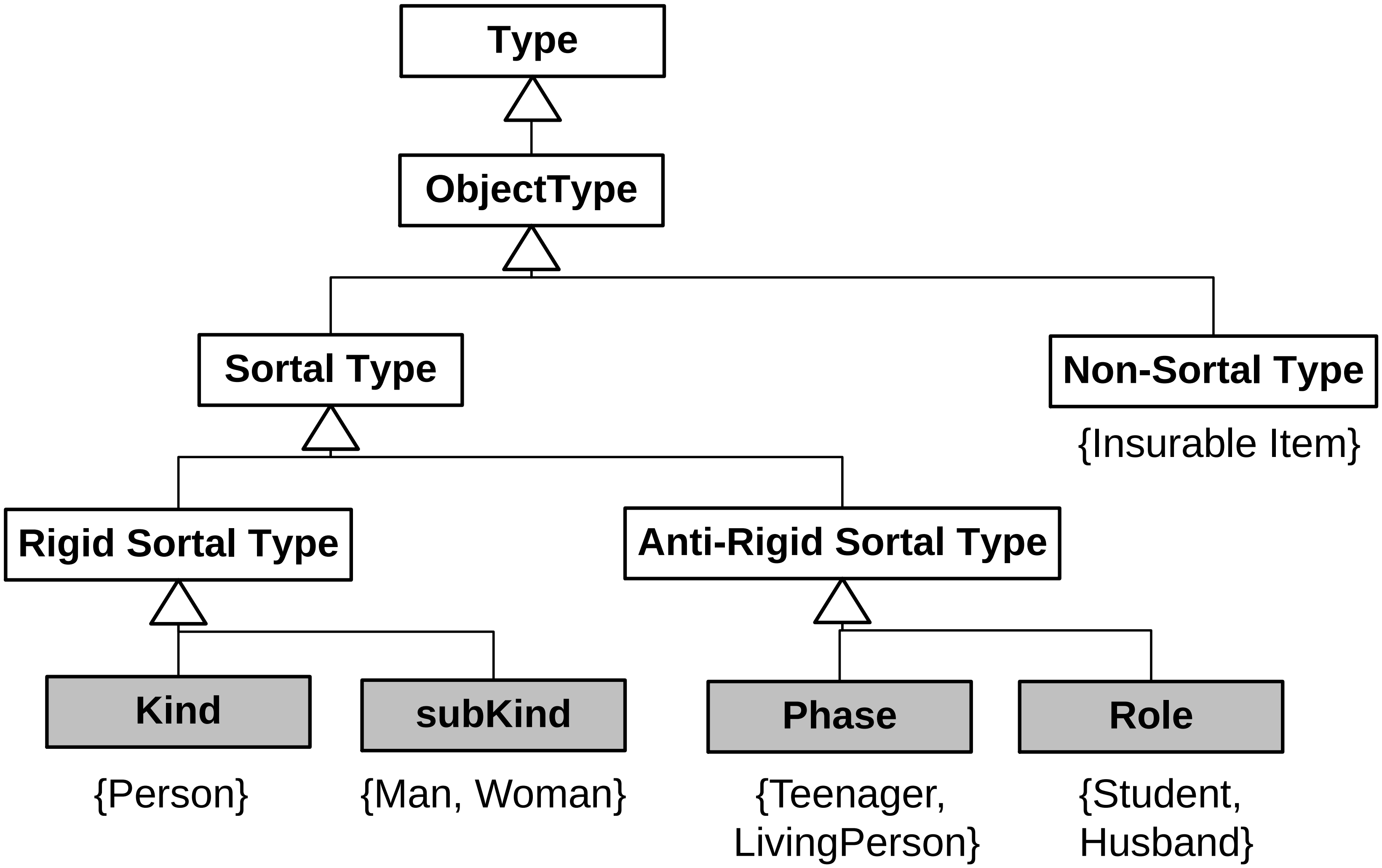
- A type T is relationally dependent on another type P via relation R iff for every instance *x* of T there is an instance *y* of P such that *x* and *y* are related via R:

$$\mathbf{D+(T,P,R)} =_{\mathbf{def}} \Box(\forall x\ \mathbf{T(x)} \rightarrow \exists y\ \mathbf{P(y)} \wedge \mathbf{R(x,y))}$$

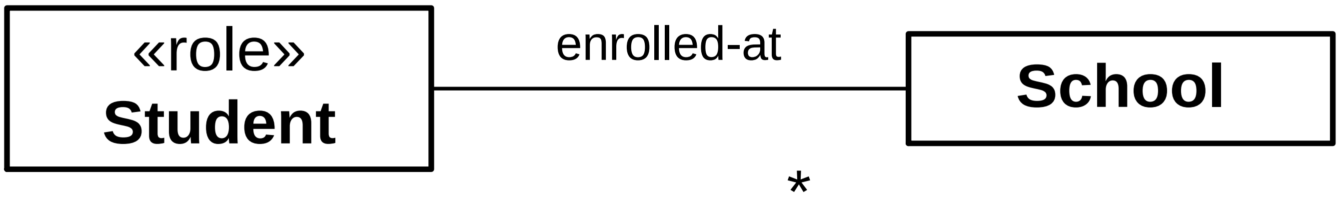
$$\downarrow \text{ e.g.,}$$

$$\mathbf{D+(Student, School, Enrolled\text{-}at)} =_{\mathbf{def}}$$
$$\Box(\forall x\ \mathbf{Student(x)} \rightarrow \exists y\ \mathbf{School\ (y)} \wedge \mathbf{Enrolled\text{-}at(x,y))}$$

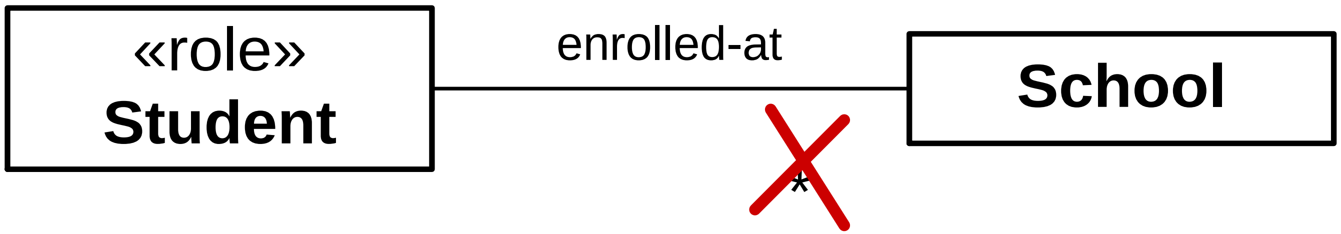
Distinctions Among Categories of Object Types



Roles



Roles

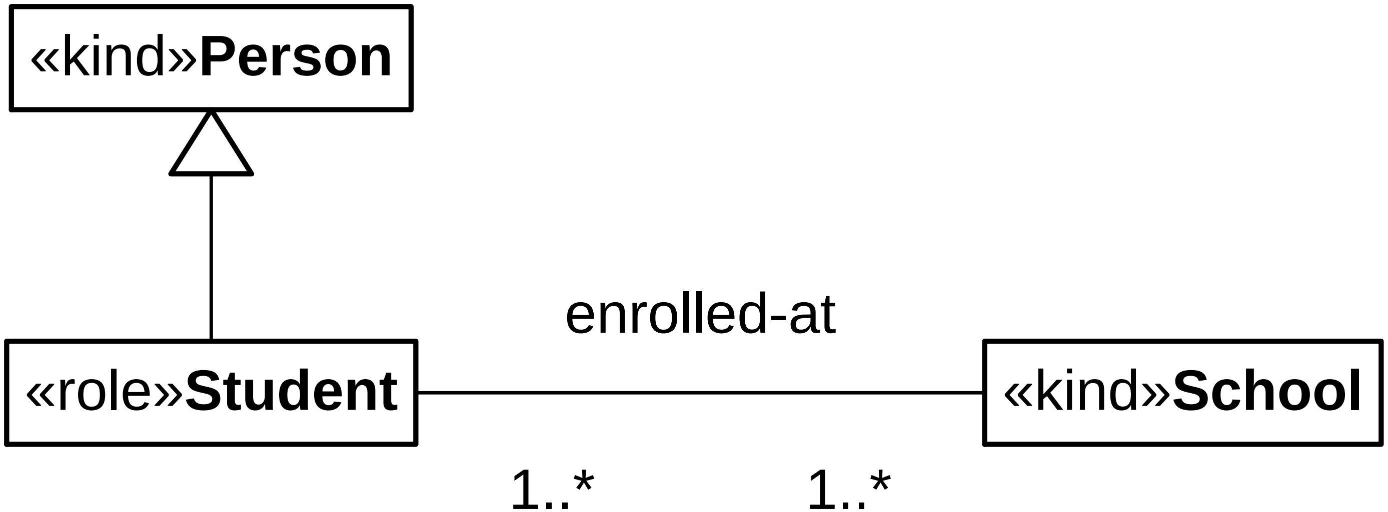


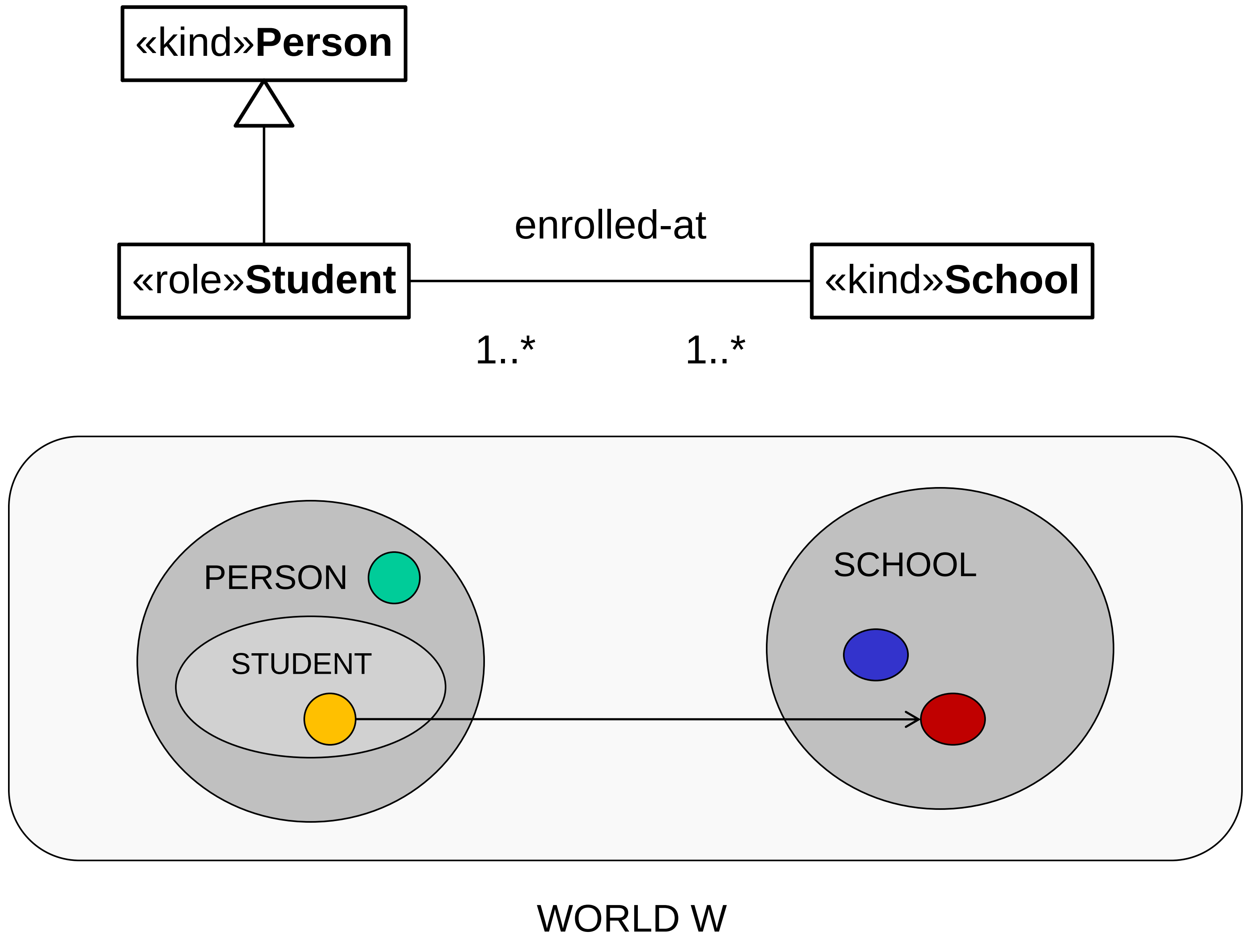
The Relational property in this case is part of the very definition of the Role:

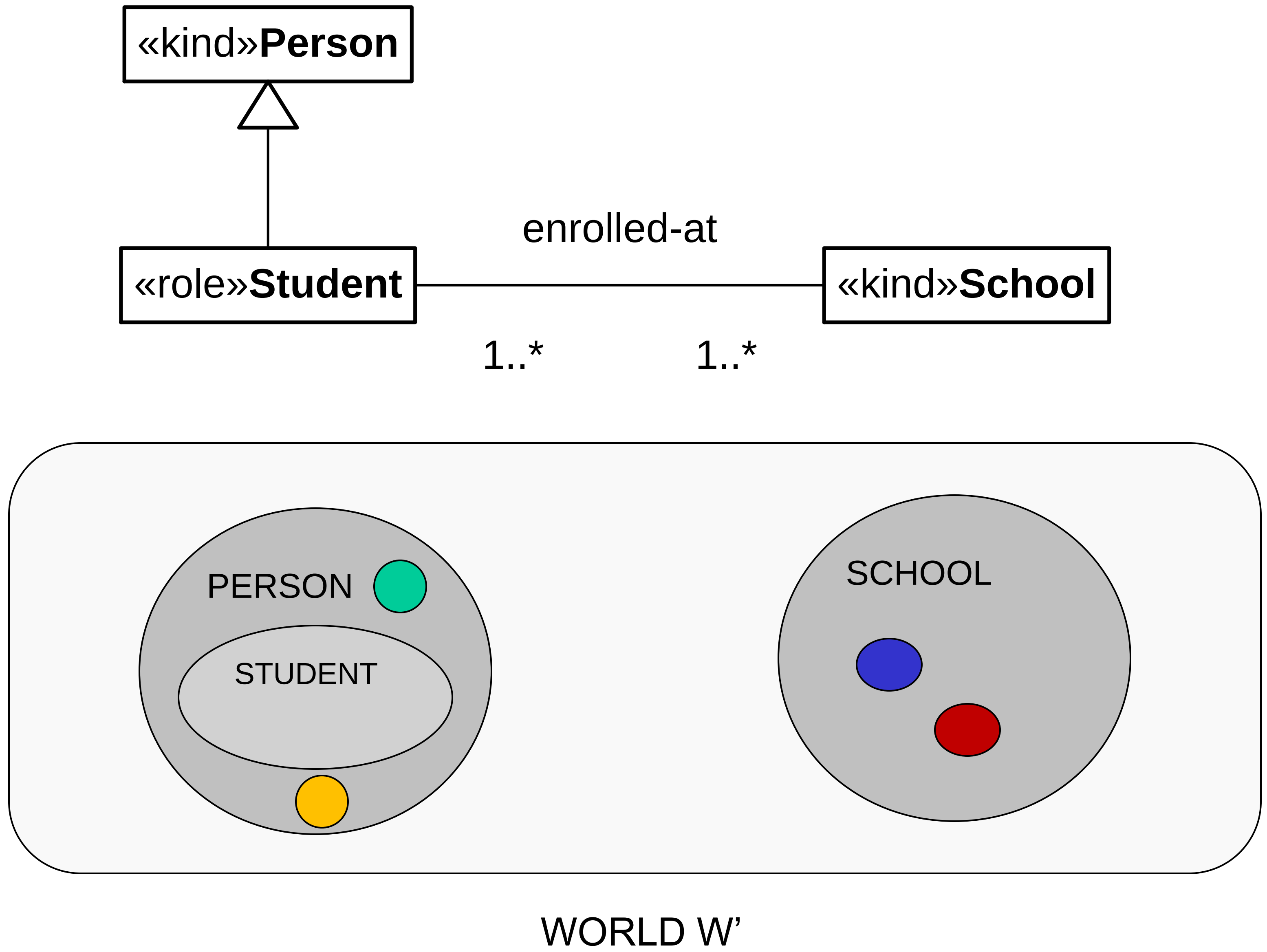
$$\text{Student}(x) =_{def} \text{Person}(x) \wedge \exists y\ \text{School}(y) \wedge \text{enrolled-at}(x,y)$$

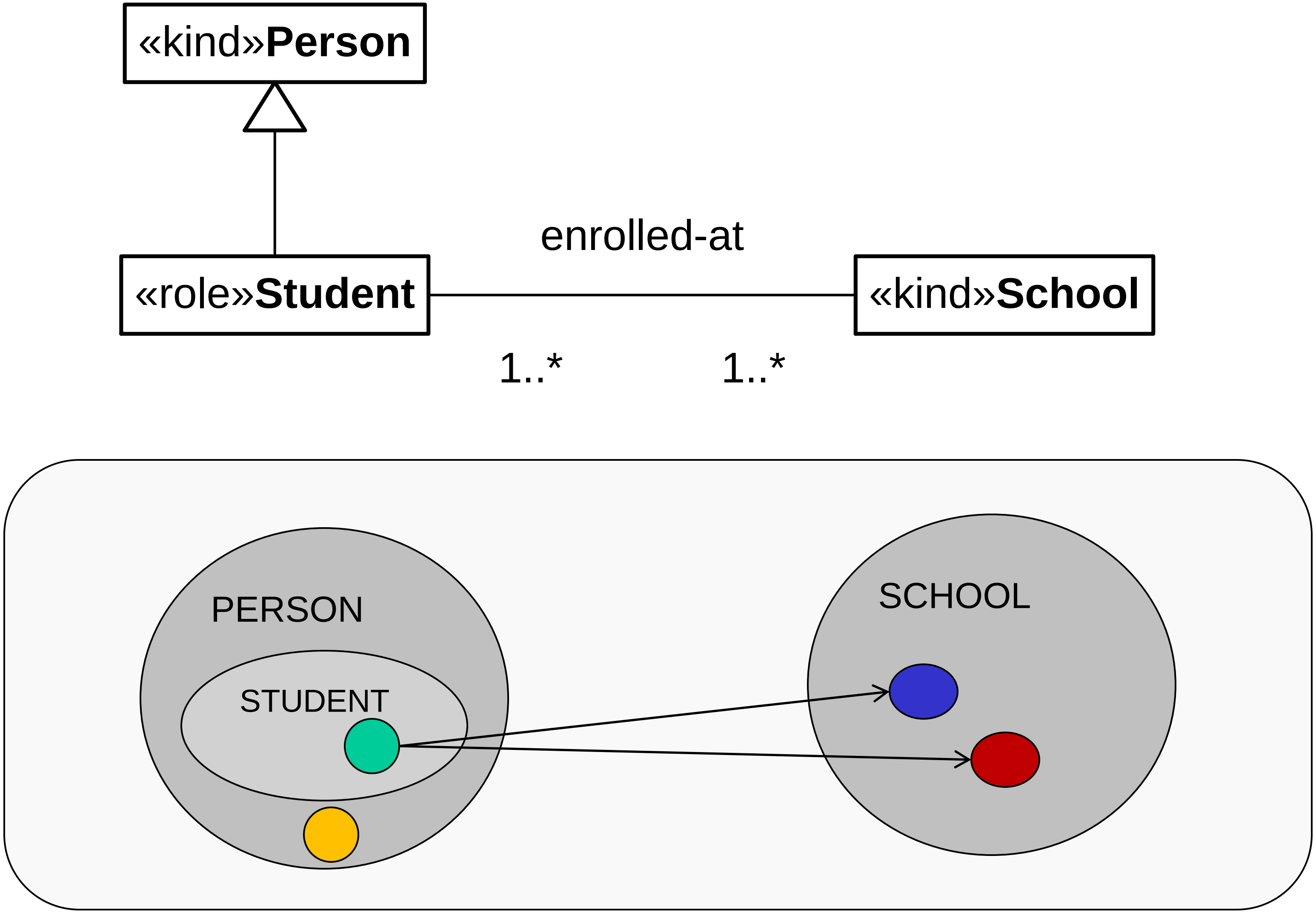
Roles

- Defined as a (anti-rigid) specialization of a kind such that the specialization condition is a relational one (correlated with derivation by participation)




«kind»**Person**
«role»**Student**
enrolled-at
«kind»**School**
1..*
1..*
PERSON
STUDENT
SCHOOL
WORLD W

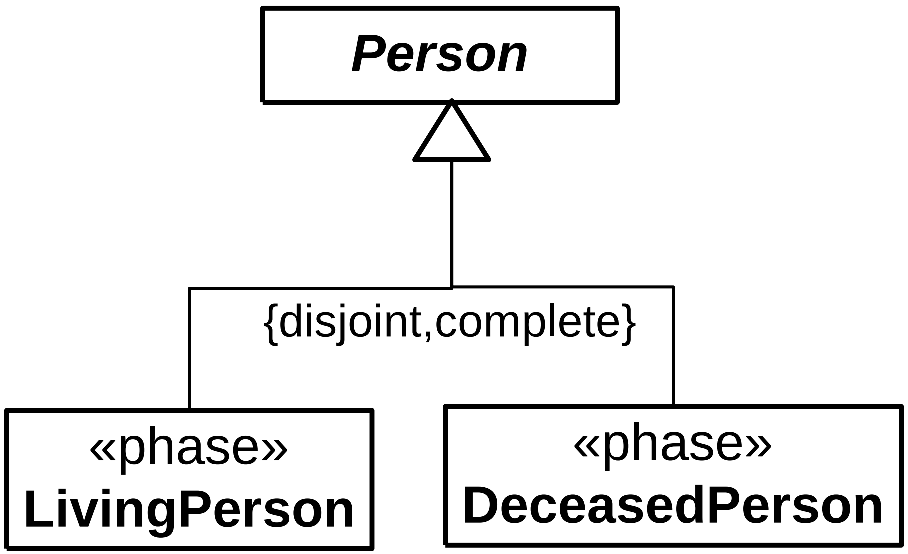

«kind»Person
«role»Student
enrolled-at
«kind»School
1..*
1..*
PERSON
STUDENT
SCHOOL
WORLD W’

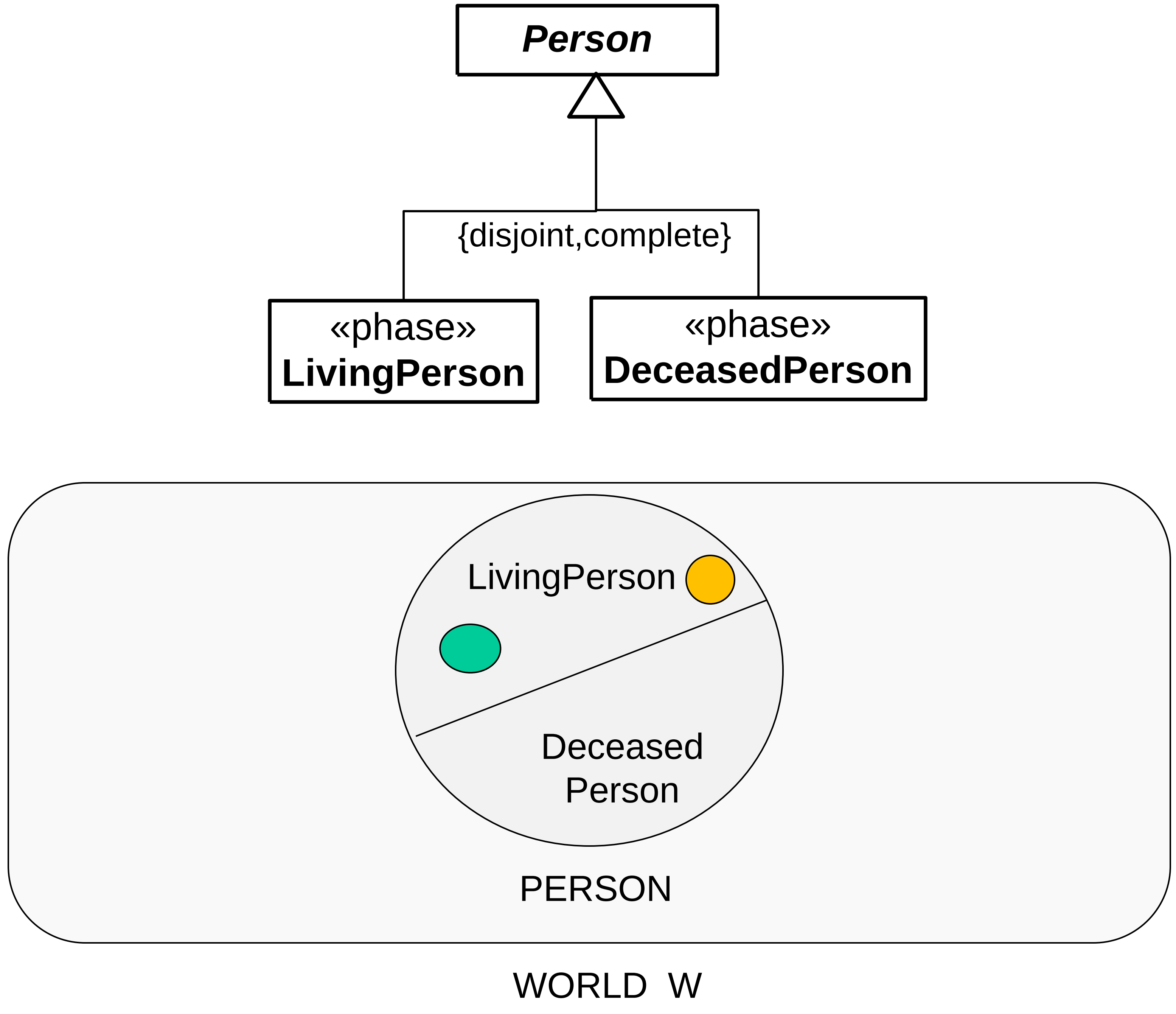

«kind»Person
«role»Student
enrolled-at
«kind»School
1..*
1..*
PERSON
STUDENT
SCHOOL

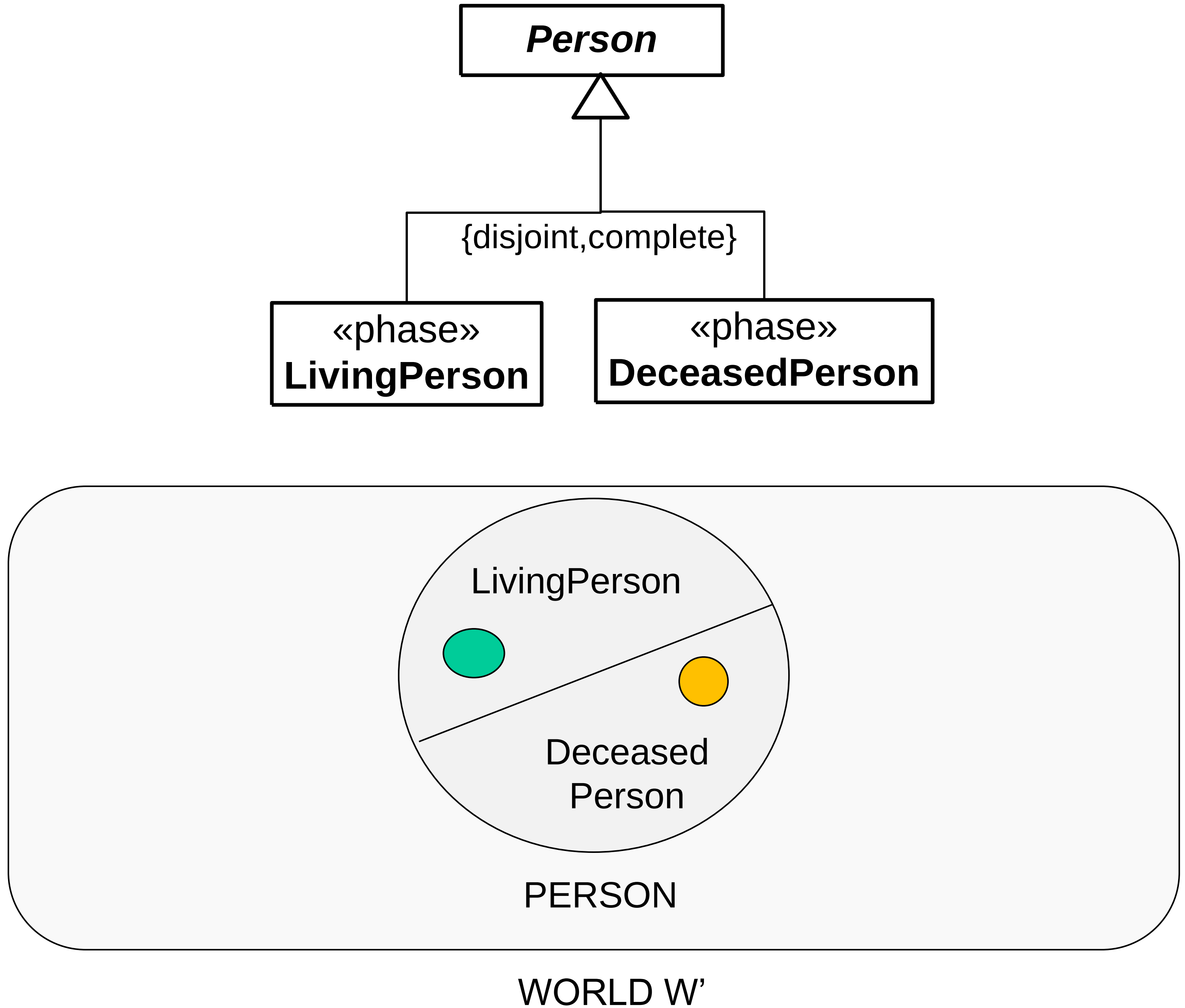
WORLD W’’

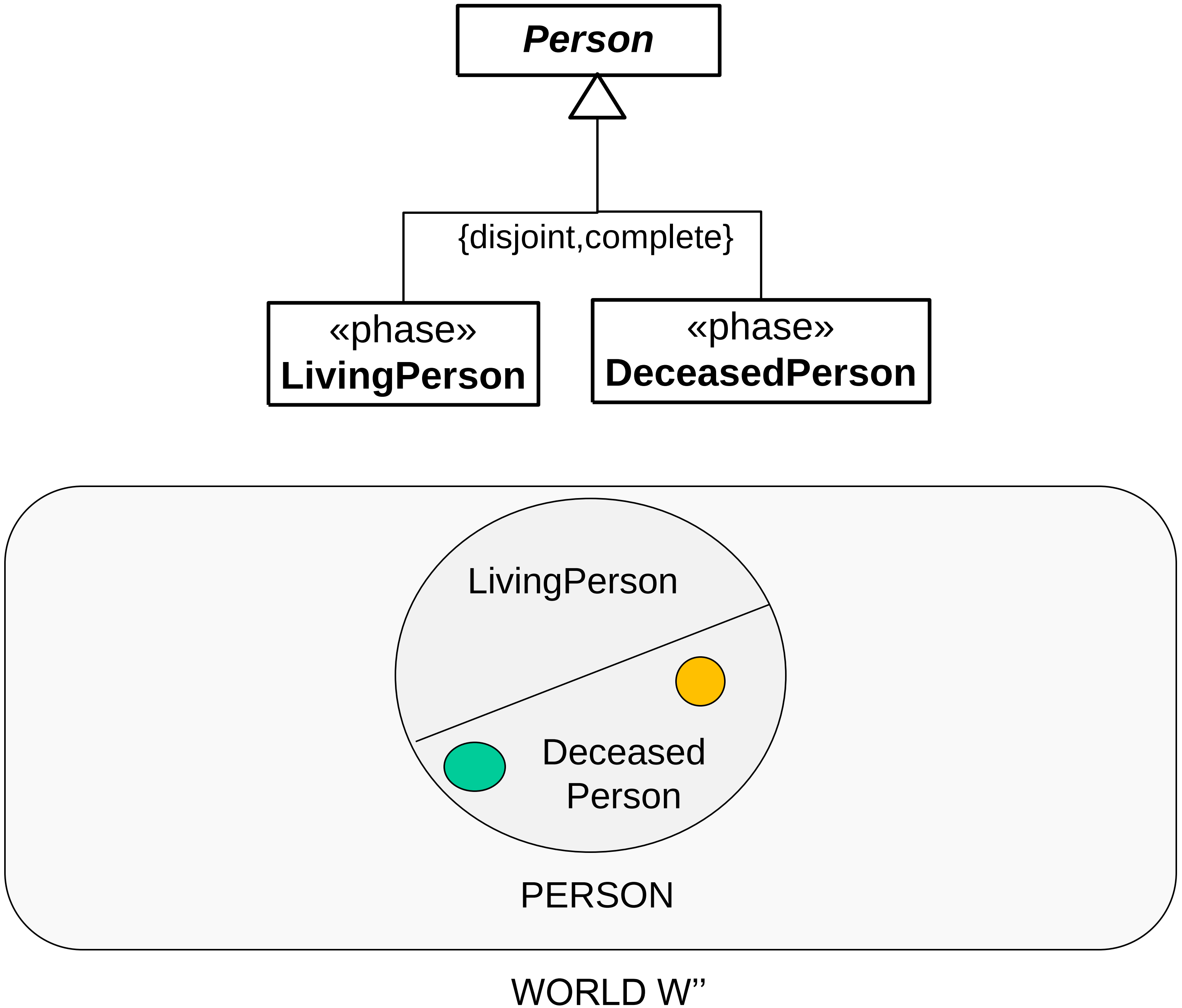
Phases

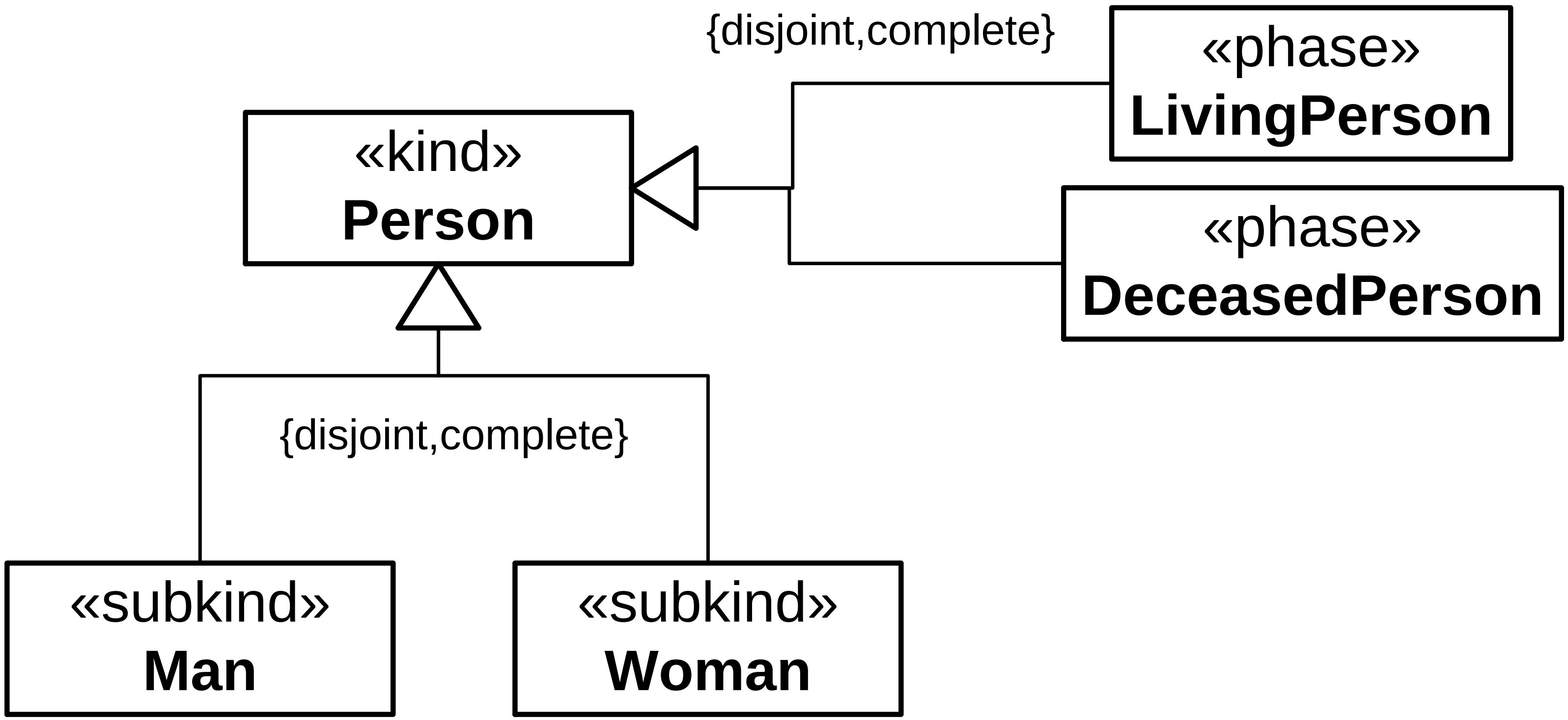
- Defined as a (anti-rigid) specialization of a kind such that the specialization condition is an intrinsic one
- Phases are always defined in a so-called Phase Partition
- Phase Partitions are partitions in strong sense, i.e., they are disjoint and complete generalization sets

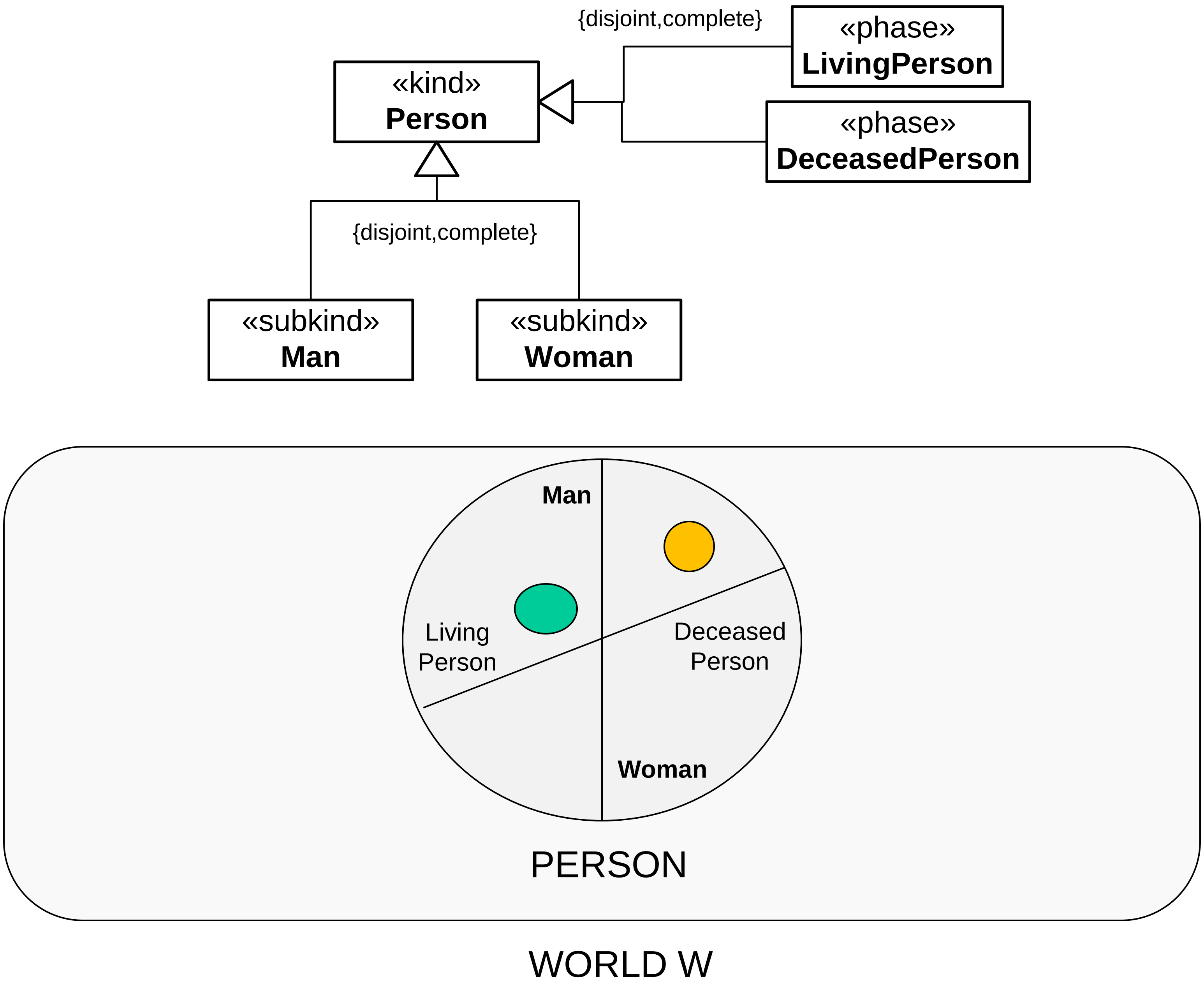



Person
{disjoint,complete}
«phase»
LivingPerson
«phase»
DeceasedPerson
LivingPerson
Deceased
Person
PERSON
WORLD W

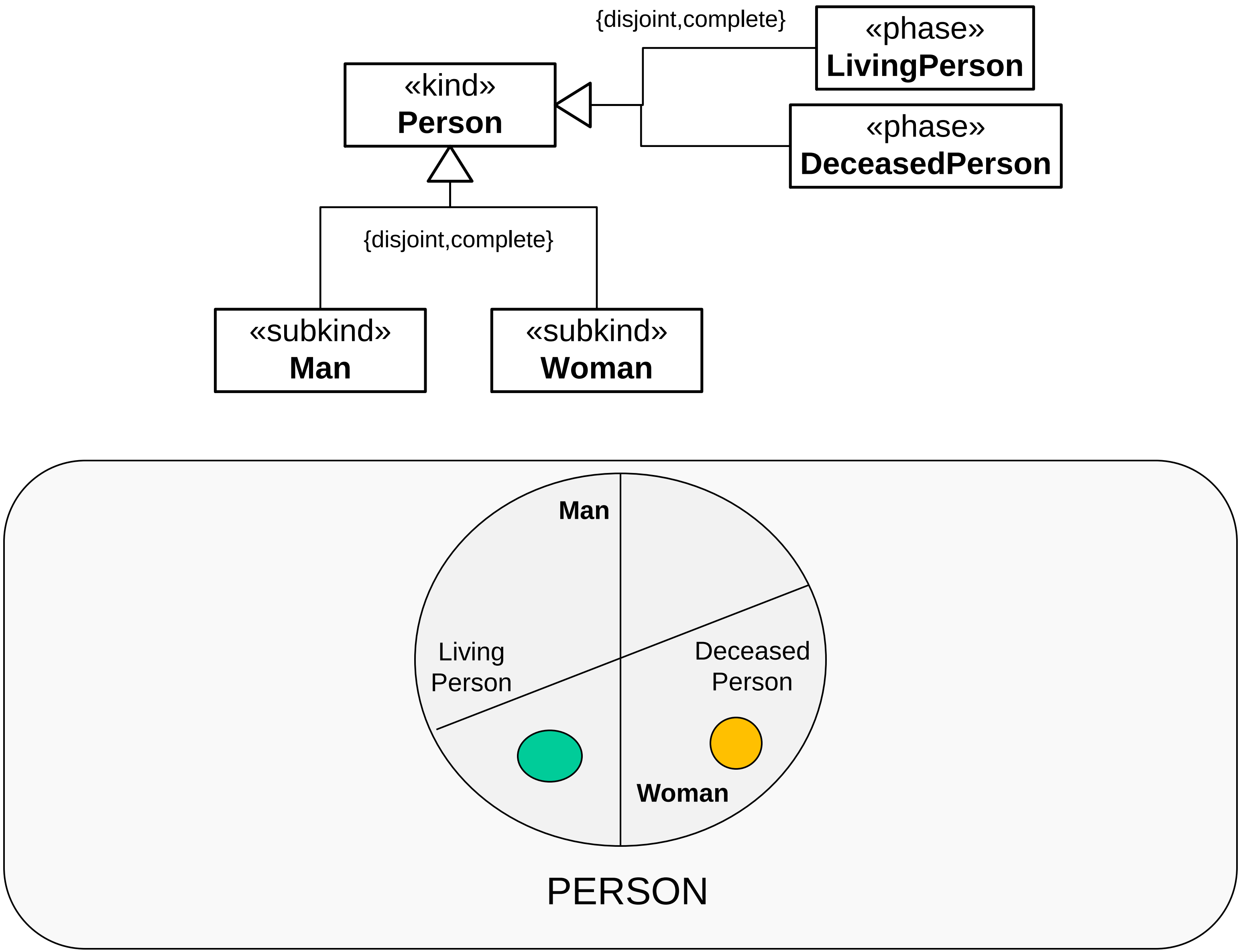

Person
{disjoint,complete}
«phase»
LivingPerson
«phase»
DeceasedPerson
LivingPerson
Deceased
Person
PERSON
WORLD W’


Person
{disjoint,complete}
«phase»
LivingPerson
«phase»
DeceasedPerson
LivingPerson
Deceased
Person
PERSON
WORLD W''

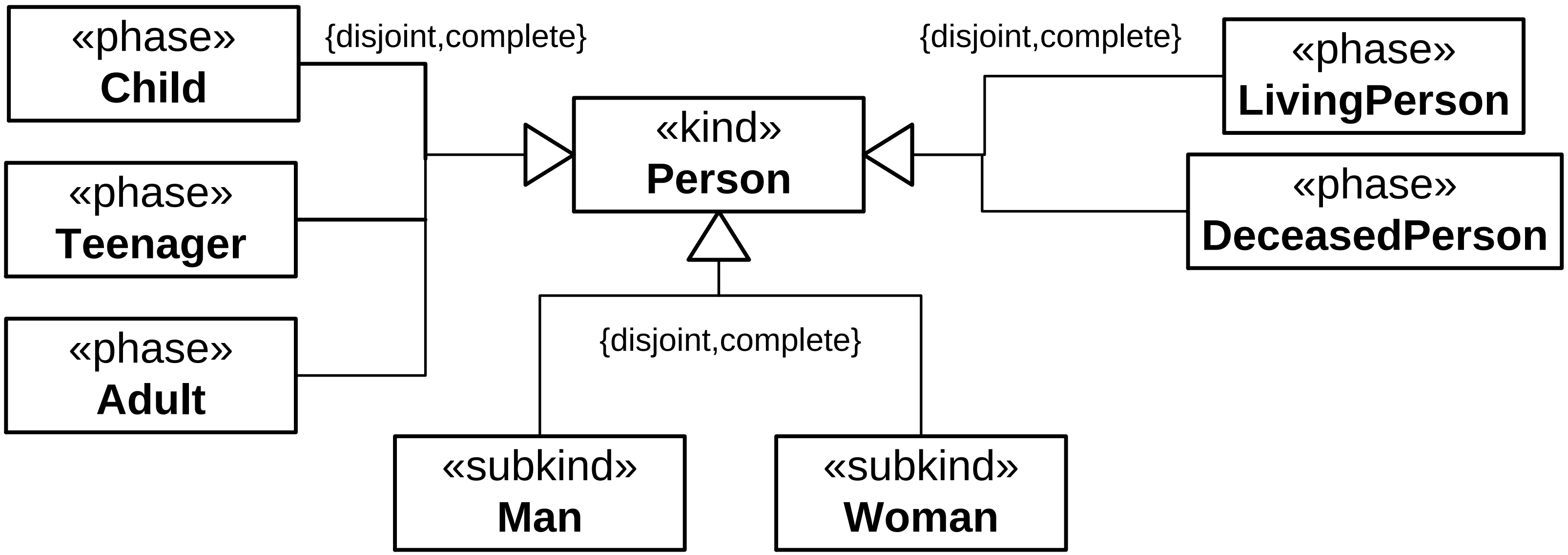

{disjoint,complete}
«phase»
LivingPerson
«kind»
Person
«phase»
DeceasedPerson
{disjoint,complete}
«subkind»
Man
«subkind»
Woman



{disjoint,complete}
«phase»
LivingPerson
«kind»
Person
«phase»
DeceasedPerson
{disjoint,complete}
«subkind»
Man
«subkind»
Woman
Man
Living
Person
Deceased
Person
Woman
PERSON
WORLD W

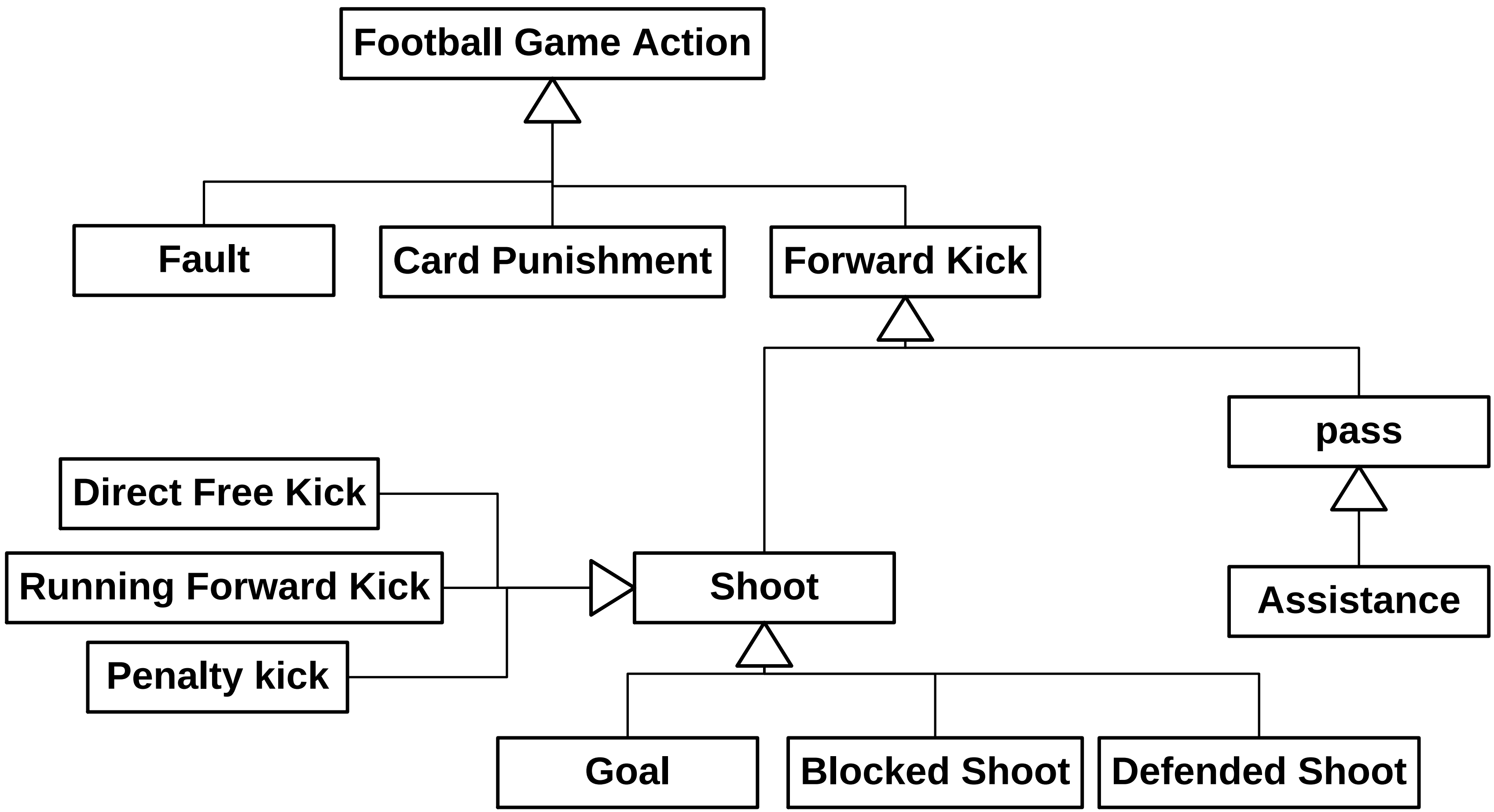

{disjoint,complete}
«phase»
LivingPerson
«kind»
Person
«phase»
DeceasedPerson
{disjoint,complete}
«subkind»
Man
«subkind»
Woman
Man
Living
Person
Deceased
Person
Woman
PERSON

WORLD W’

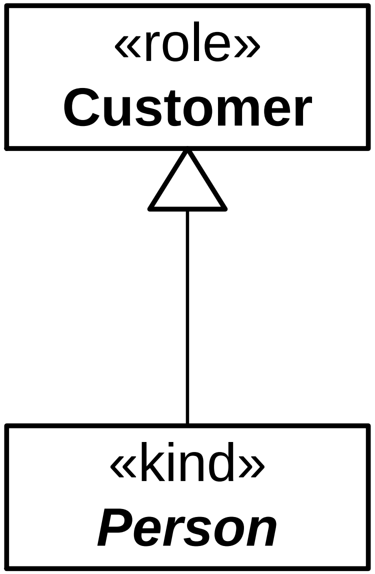

«phase»
Child
{disjoint,complete}
{disjoint,complete}
«phase»
LivingPerson
«kind»
Person
«phase»
Teenager
«phase»
DeceasedPerson
{disjoint,complete}
«phase»
Adult
«subkind»
Man
«subkind»
Woman

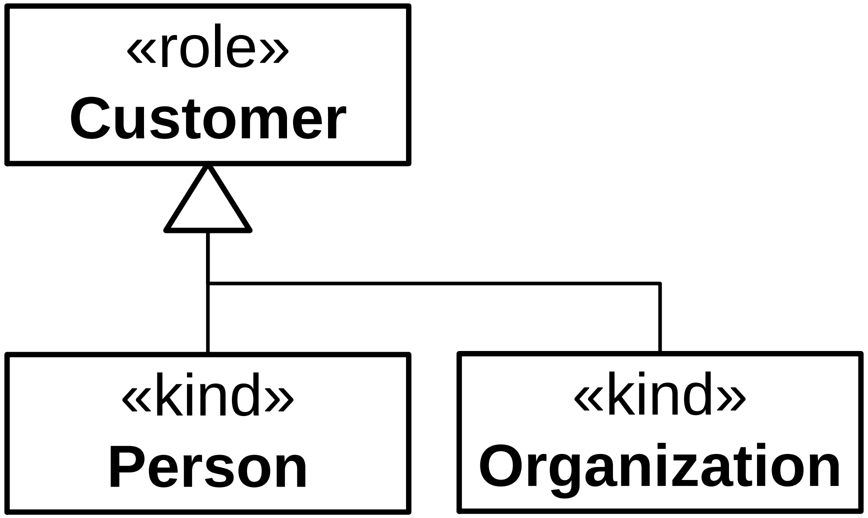
Imagine a game quite like football...

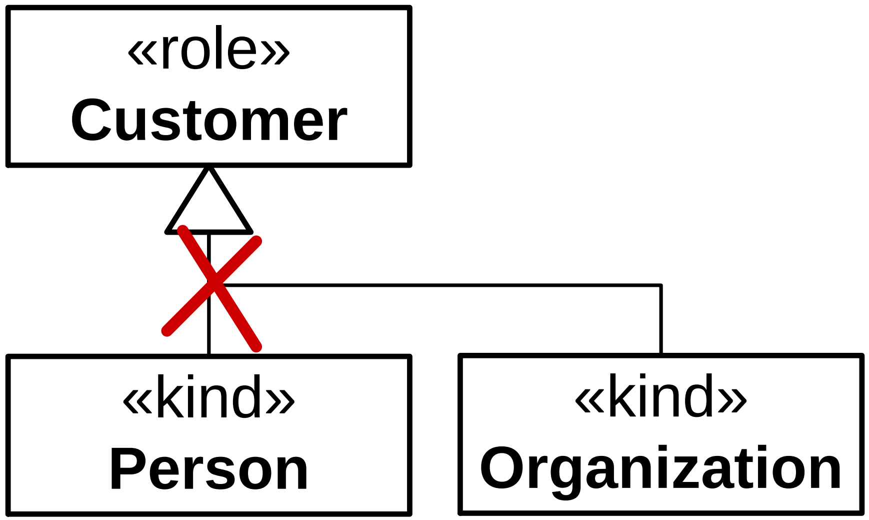
- Fault, Forward Kick, Shoot, Assitance, Blocked Shoot, Defended Shoot, Running Forward Kick, Penalty Kick, Pass, Card Punishment, Goal, Direct Free Kick



Football Game Action
Fault
Card Punishment
Forward Kick
pass
Direct Free Kick
Running Forward Kick
Shoot
Assistance
Penalty kick
Goal
Blocked Shoot
Defended Shoot

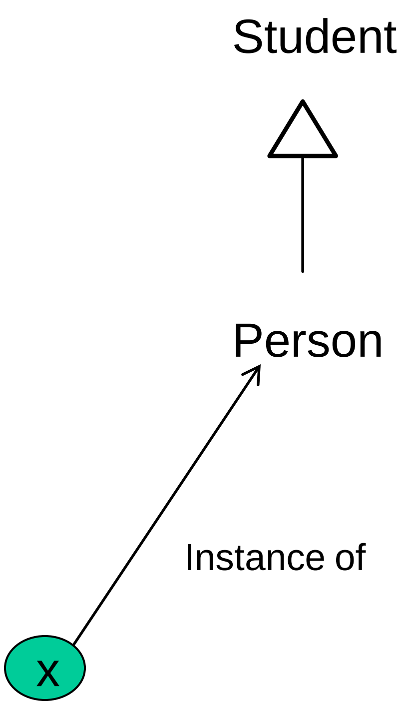

«role»
Customer
«kind»
Person


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

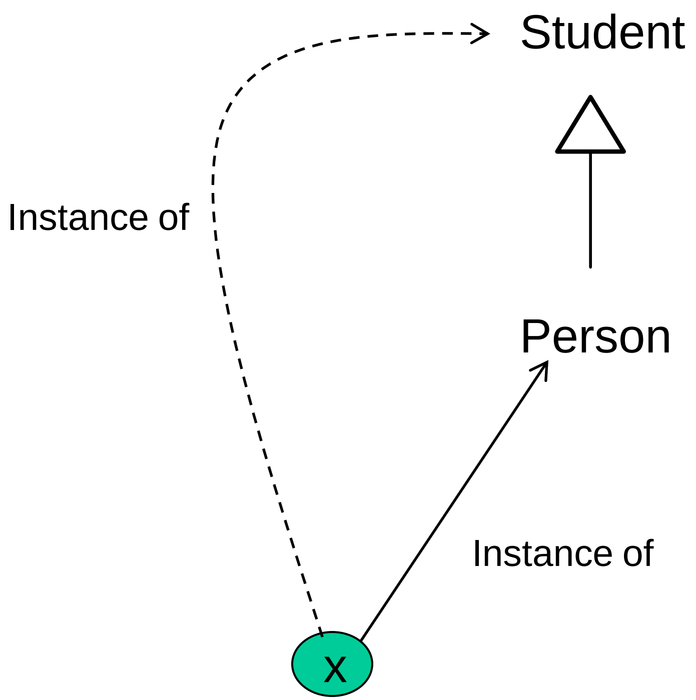


An anti-rigid type cannot be a supertype of a Rigid Type

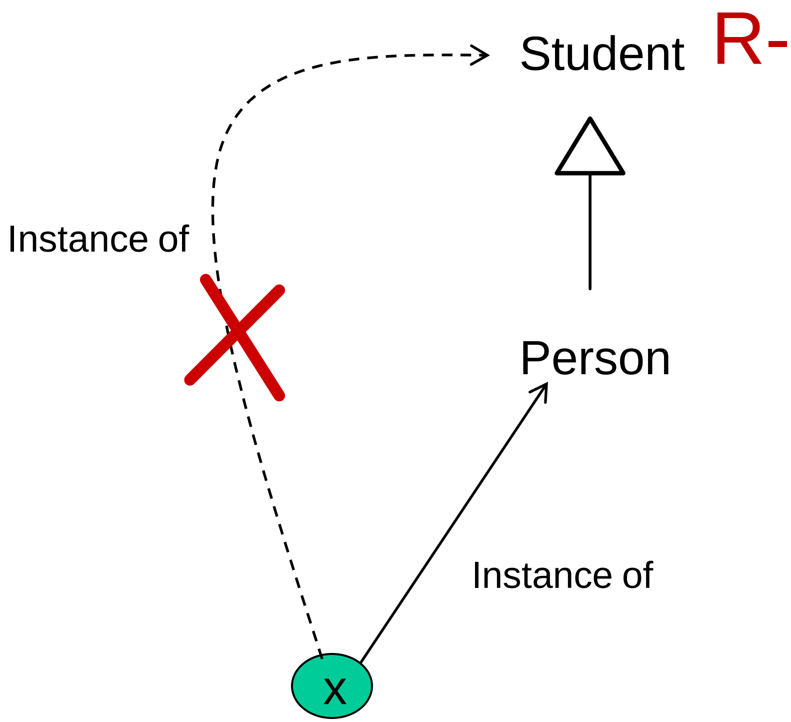
WORLD W



WORLD W

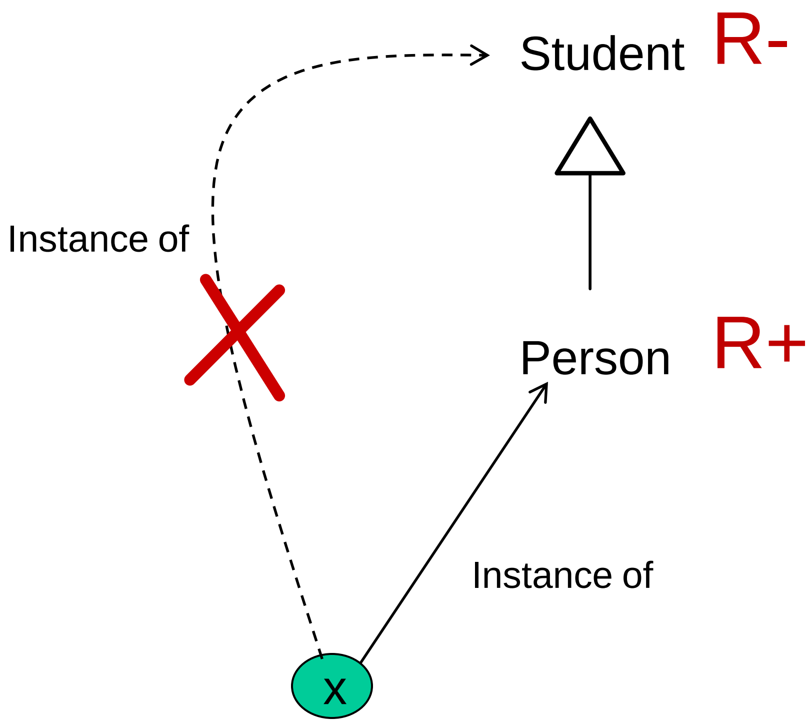


WORLD W’



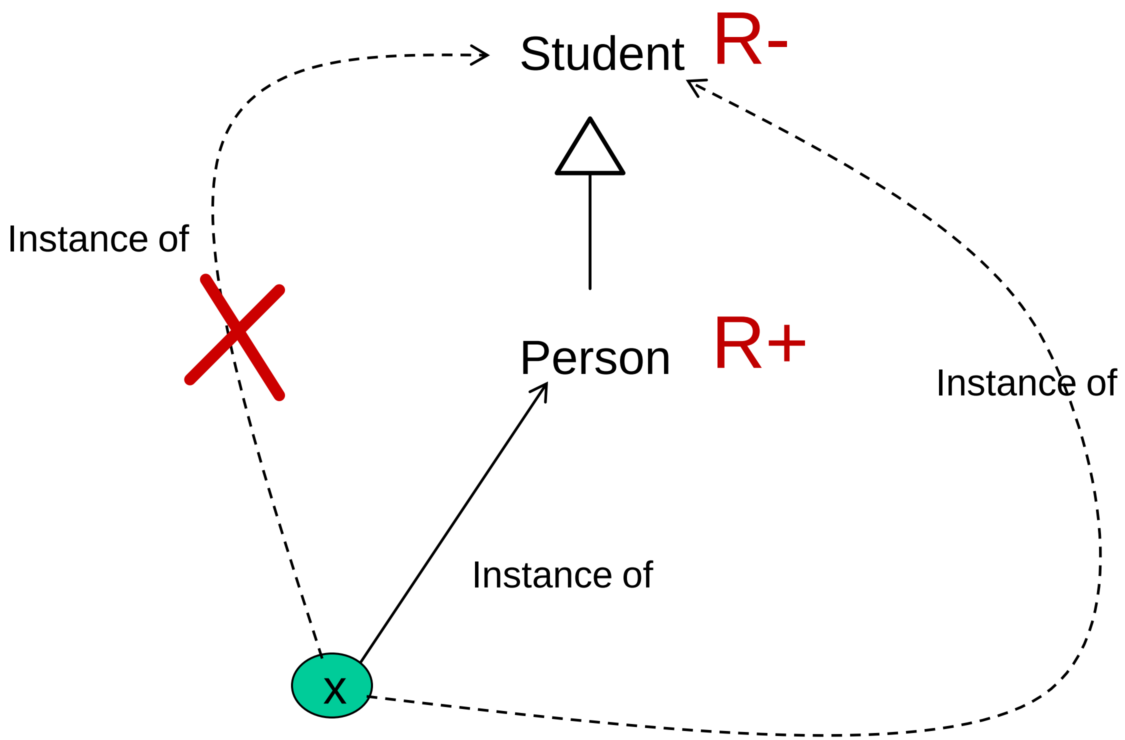
Since Student is anti-rigid, there must be a world W’ such that x is not an instance of Student in W’

WORLD W’



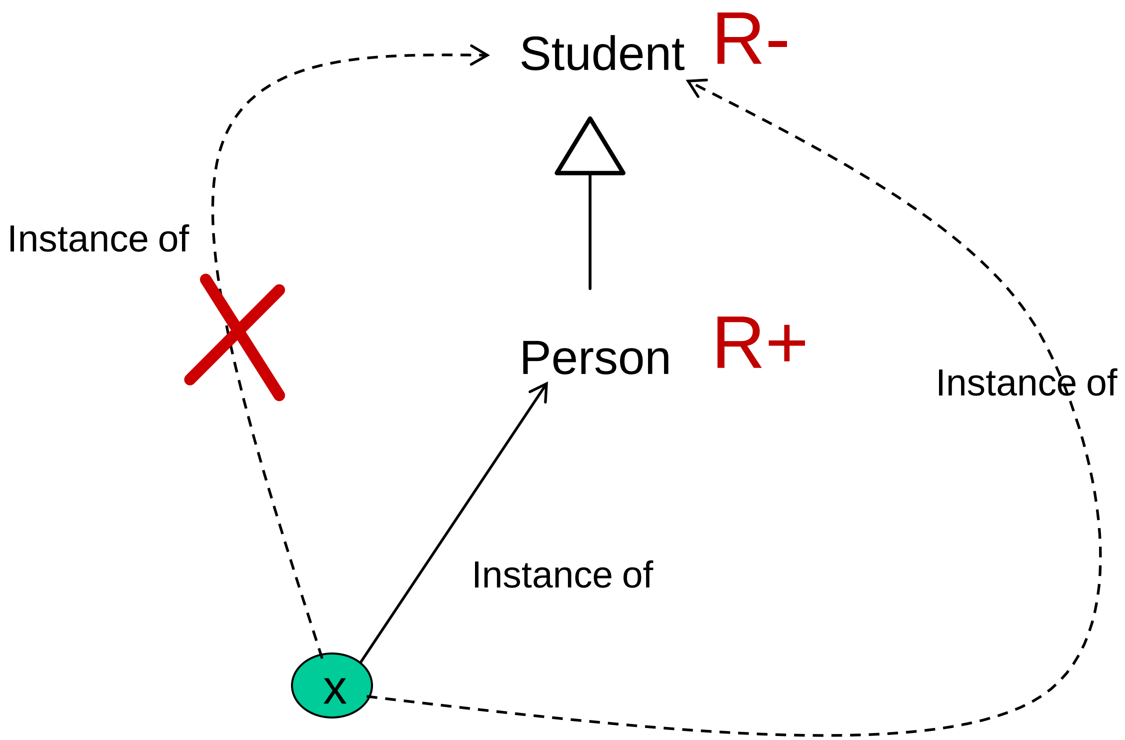
But since Person is rigid then x
must be an instance of Person in all worlds,
including in W’

WORLD W’

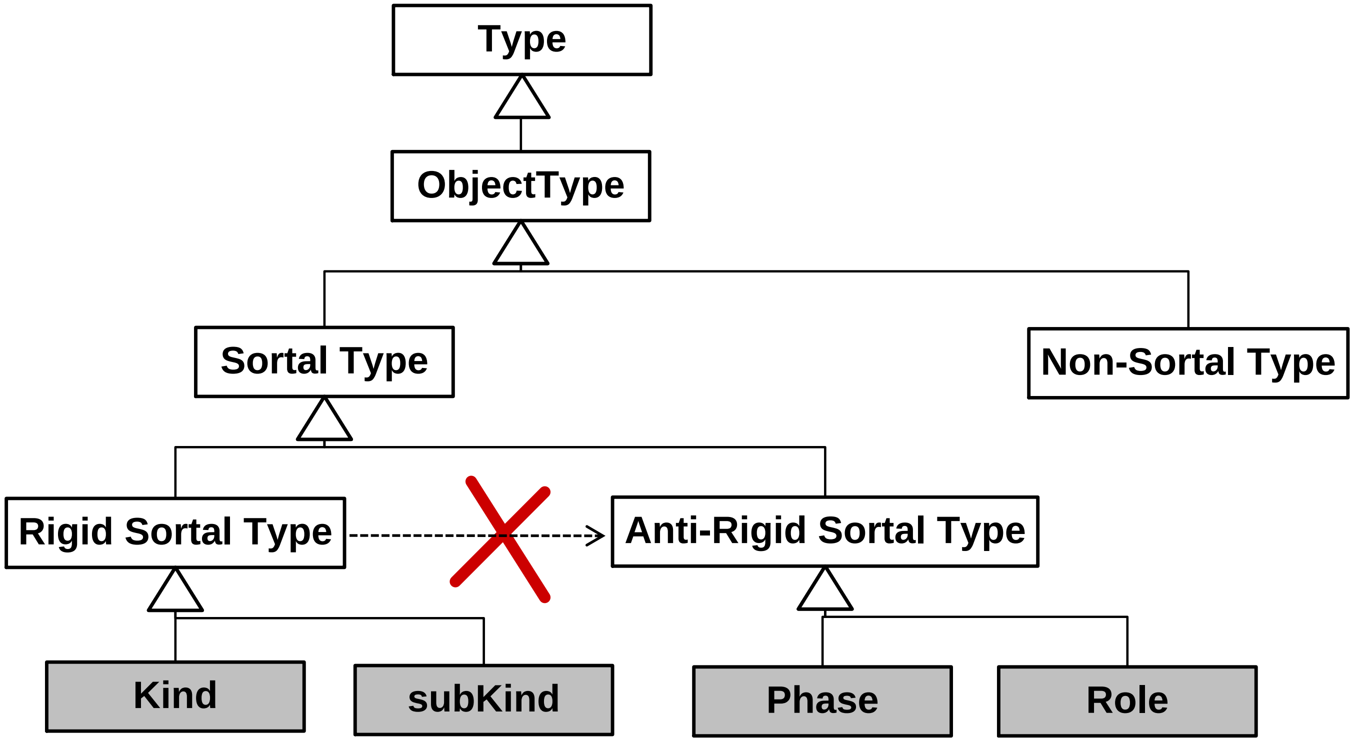


But, given the semantics of supertying, we have that in all worlds (including W’), whoever is a Person is a Student

WORLD W'



We run into a logical contradiction!

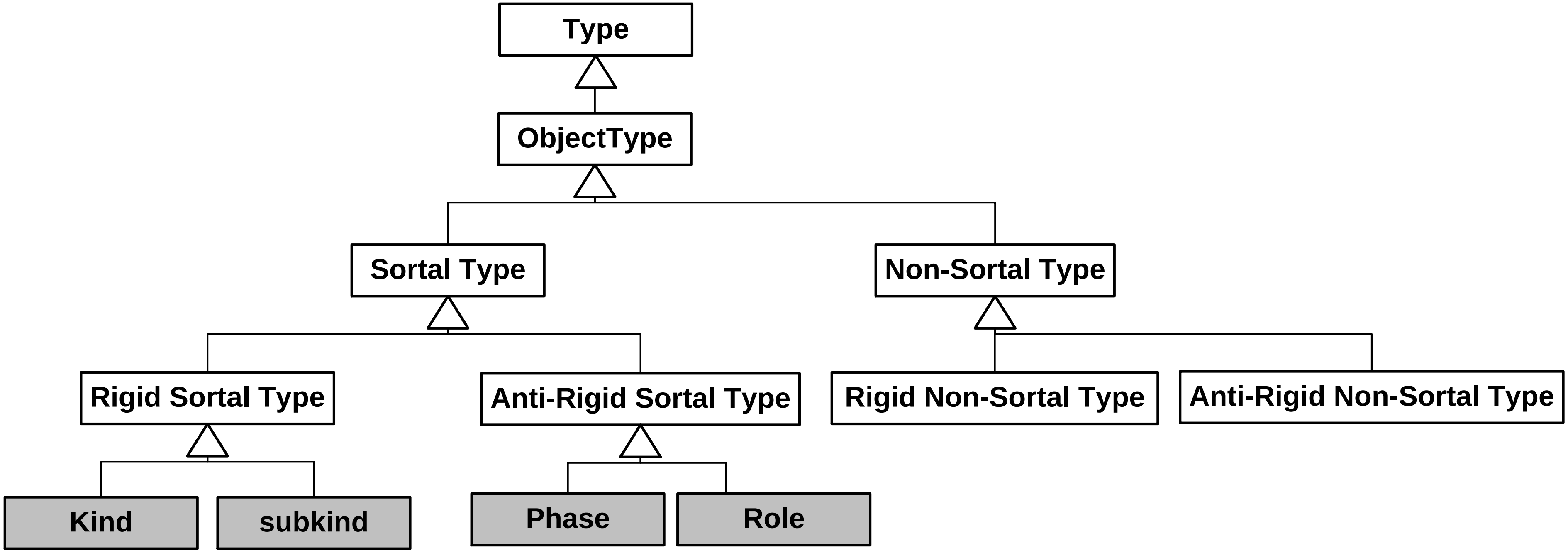


An anti-rigid type cannot be a supertype of a Rigid Type

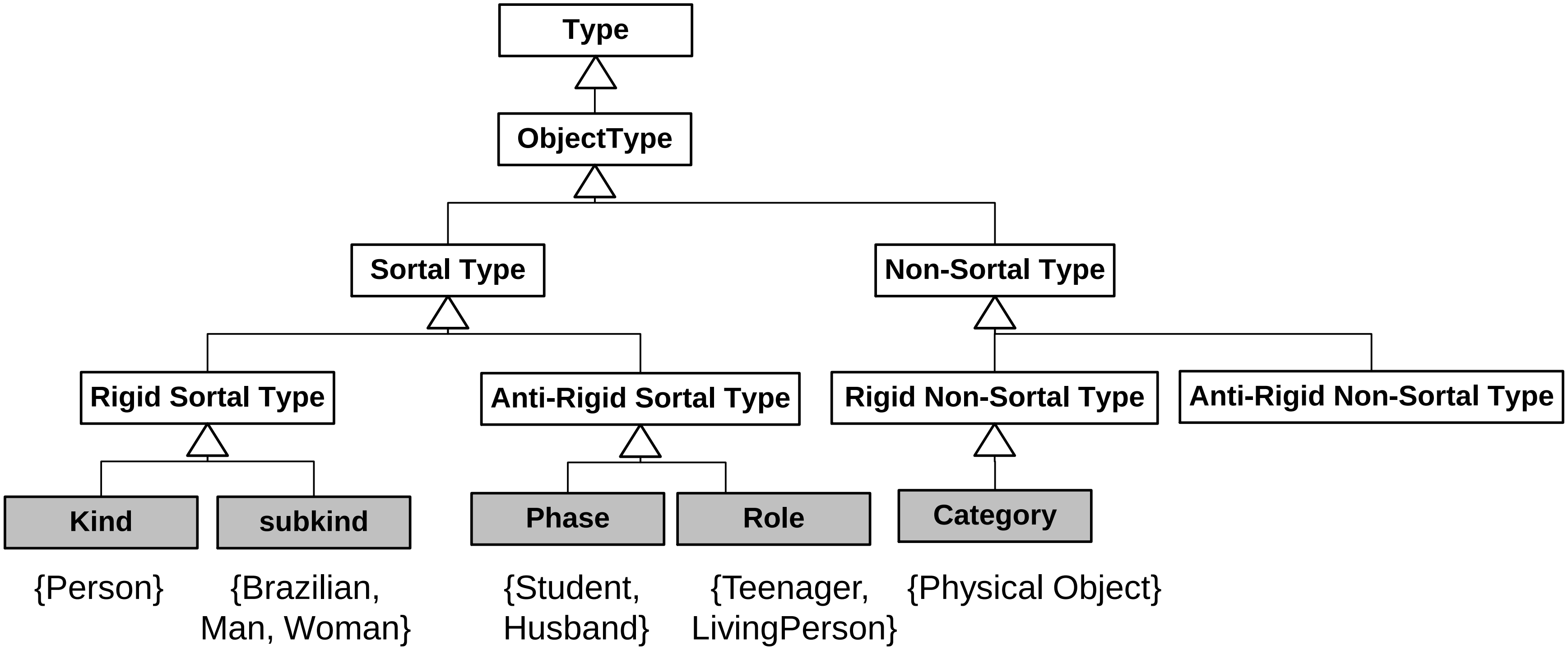
Different Categories of Object Types

Category of Type	Supply Identity	Inherits Identity	Rigidity	Dependence
SORTAL	-	+		
« kind »	+	+	+	-
« subkind »	-	+	+	-
« role »	-	+	-	+
« phase »	-	+	-	-
NON-SORTAL	-	-		

Distinctions Among Object Types

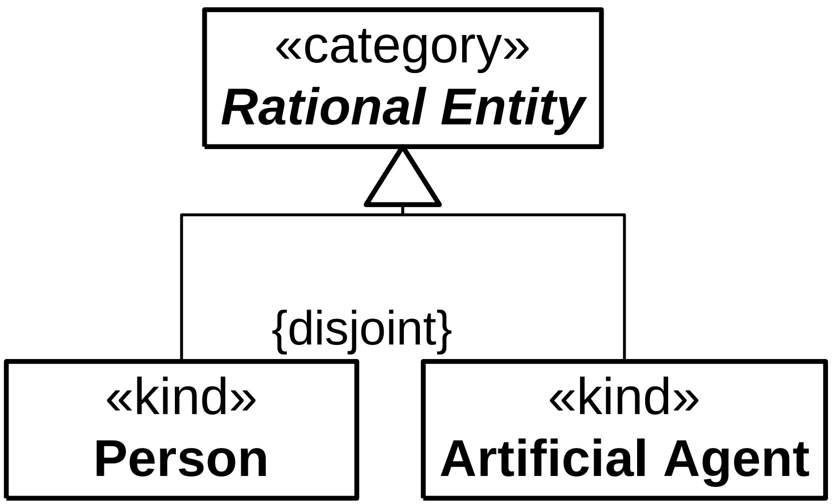


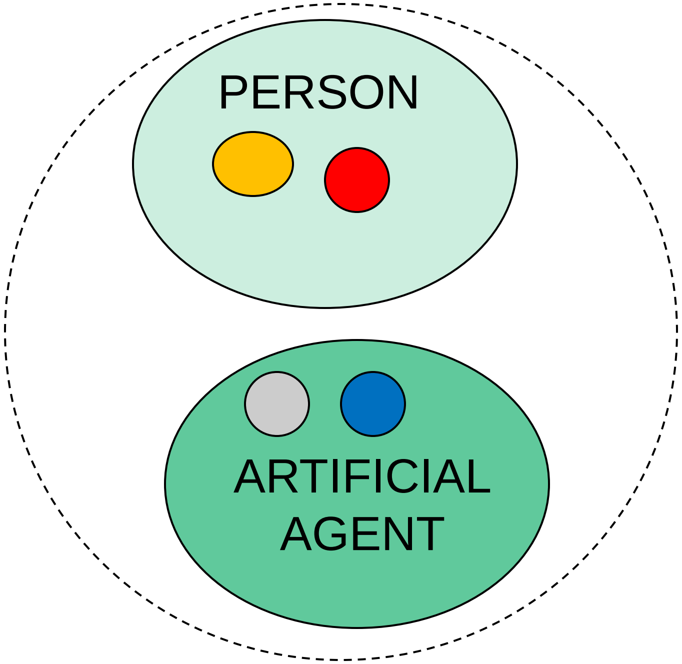
Distinctions Among Object Types



Categories (I-,R+)

- Categories are rigid non-sortals representing necessary (in the modal sense) features of entities of different kinds
- Typically, they form the top-most layer of object types in an ontology

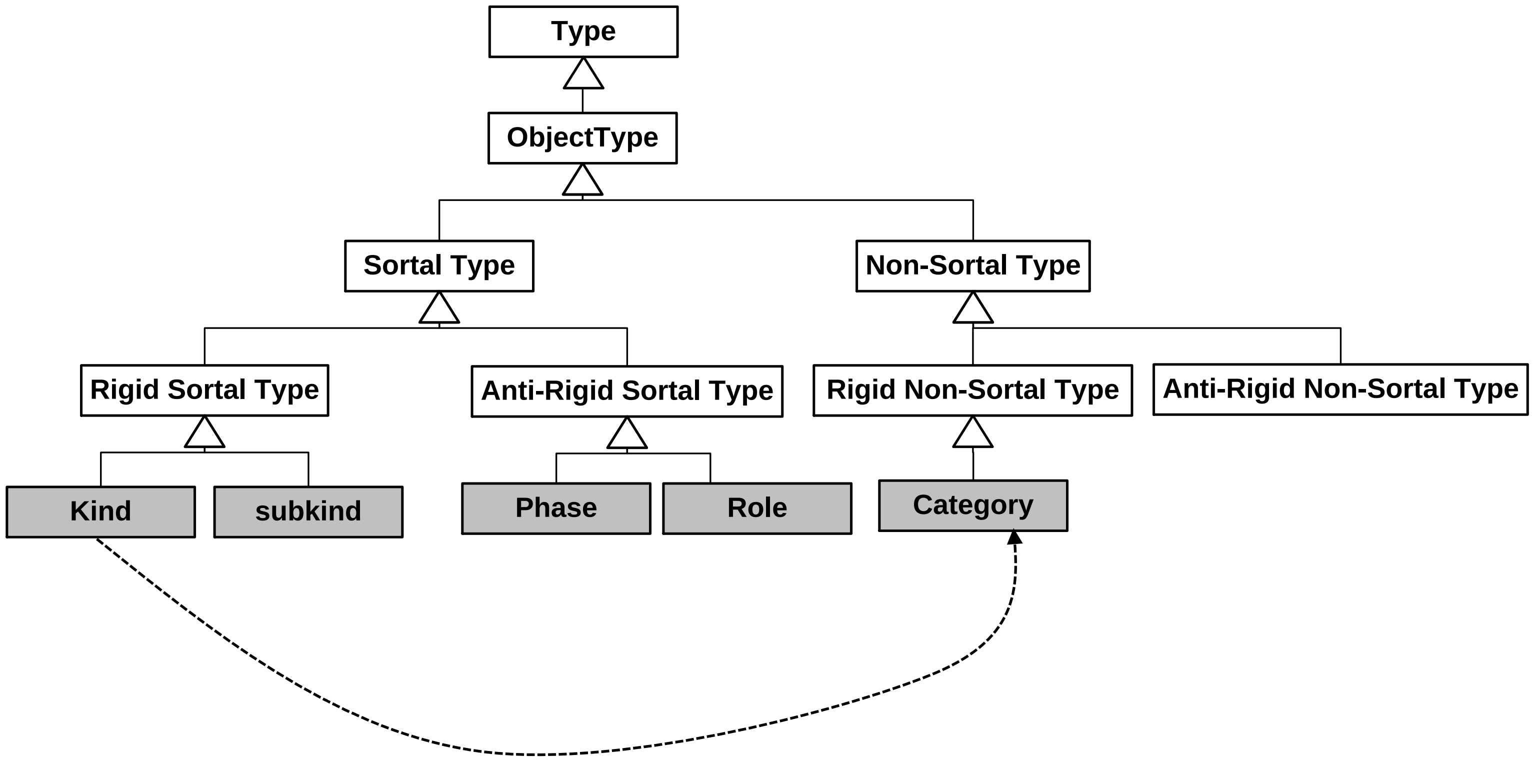




RATIONAL ENTITY

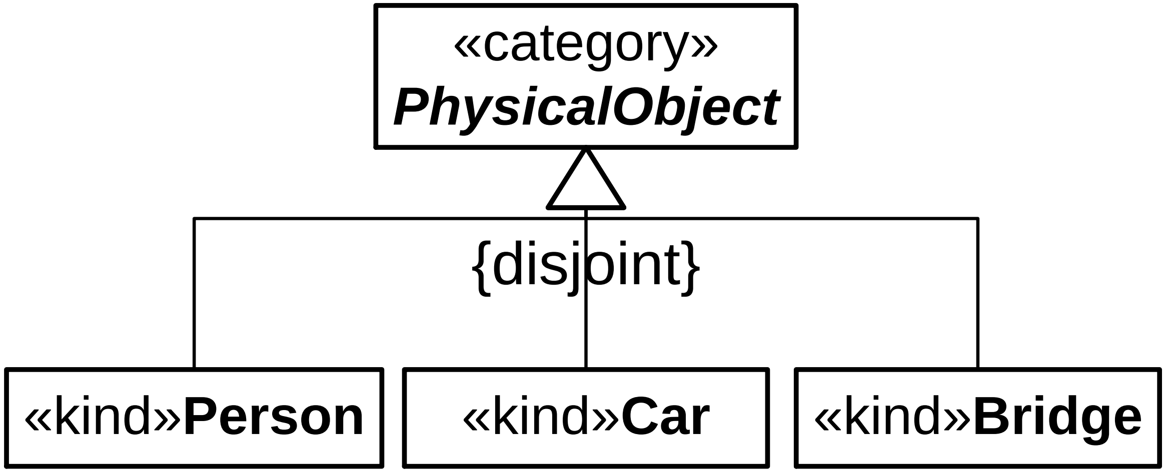
Categories

- Like all non-sortals, categories are always defined as abstract classes, which means that all categories must have at least a kind as a subtype

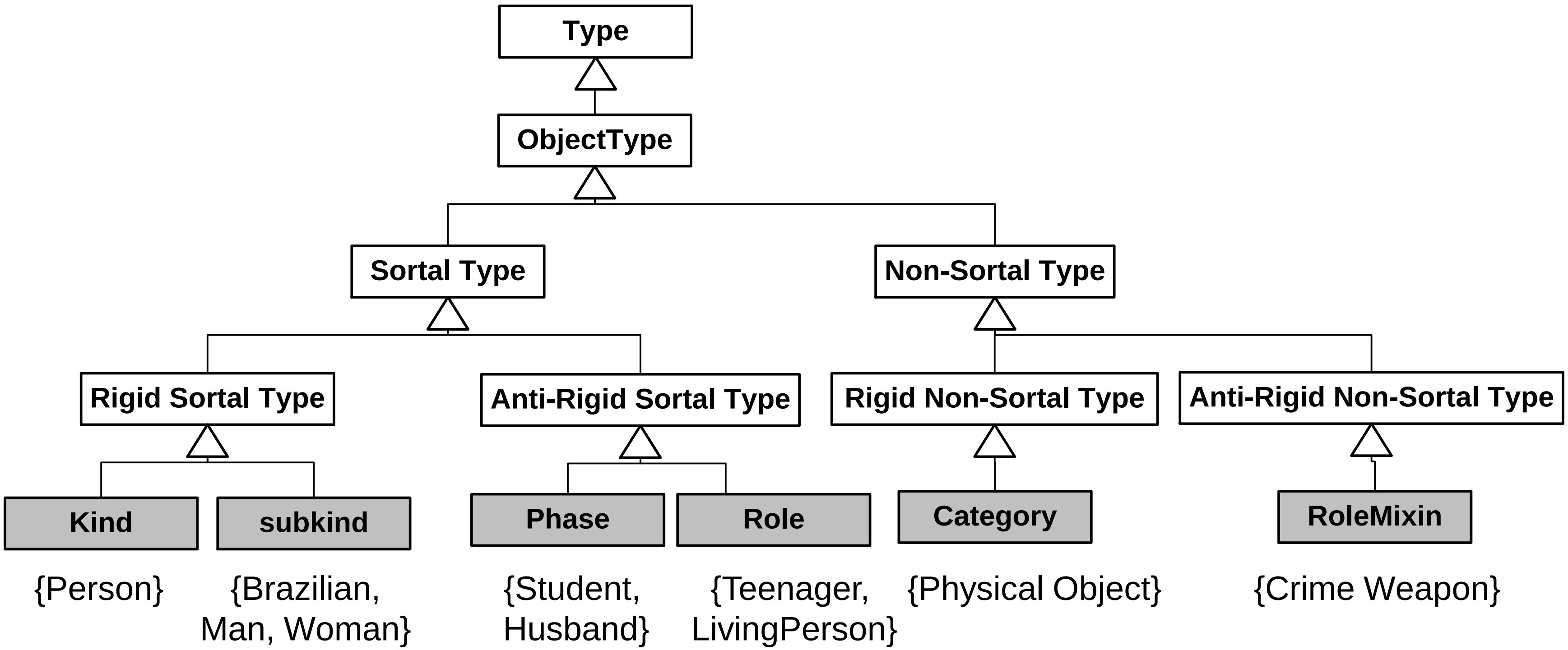


Categories

- A kind can be subtype of multiple categories and a category can be a supertype of multiple kinds
- Since all kinds are disjoint (otherwise the instances in their intersection would inherit multiple principles of identity), all subtypes of a category form a disjoint generalization set
- On the other hand, since categories represent features of multiple kinds, they are very seldom complete



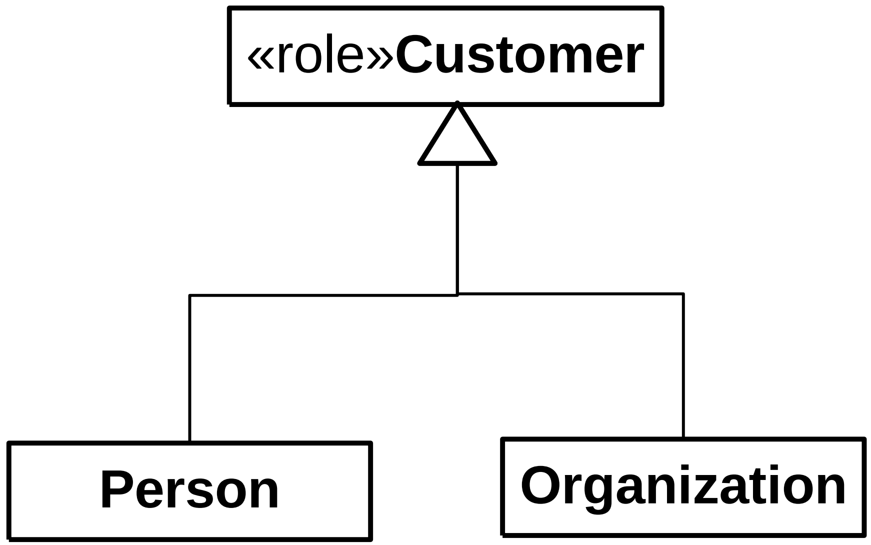
Distinctions Among Object Types



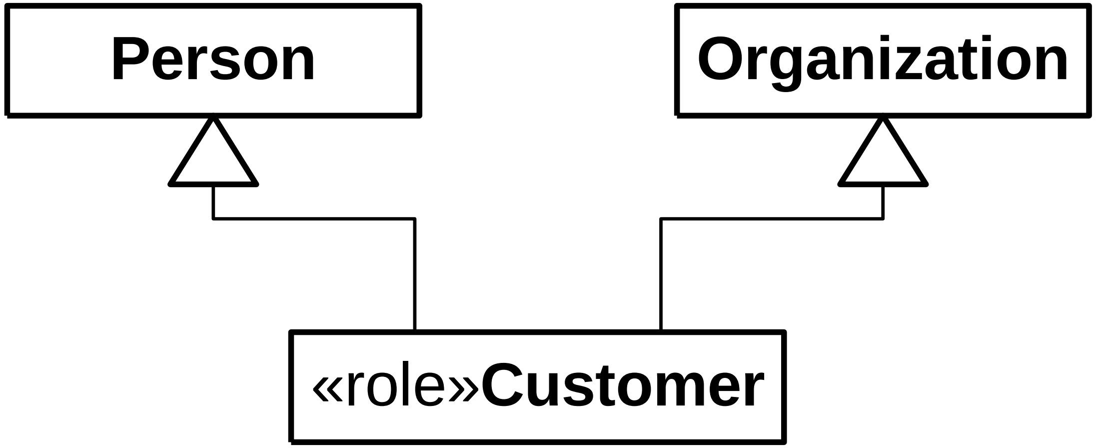
RoleMixin(I-,R-,D+)

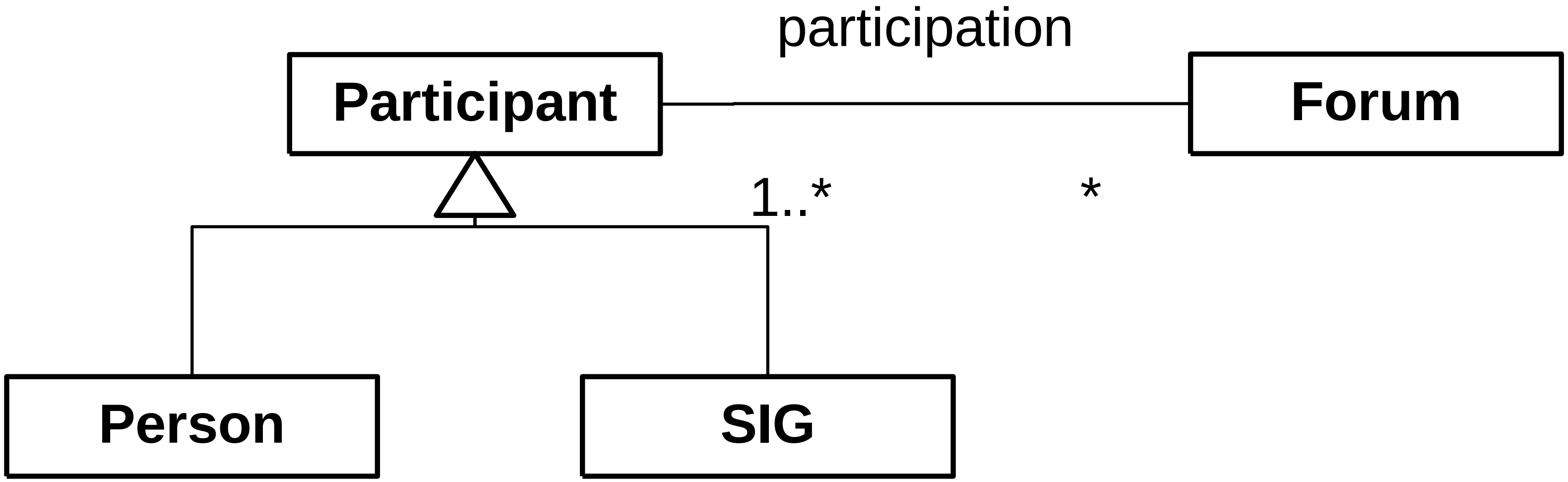
- RoleMixen are anti-rigid and relational dependent non-sortals representing contigent (in the modal sense) features of entities of different kinds
- As all Non-Sortals, RoleMixins classify entities belonging to different kinds
- Like all non-sortals, categories are always defined as abstract classes

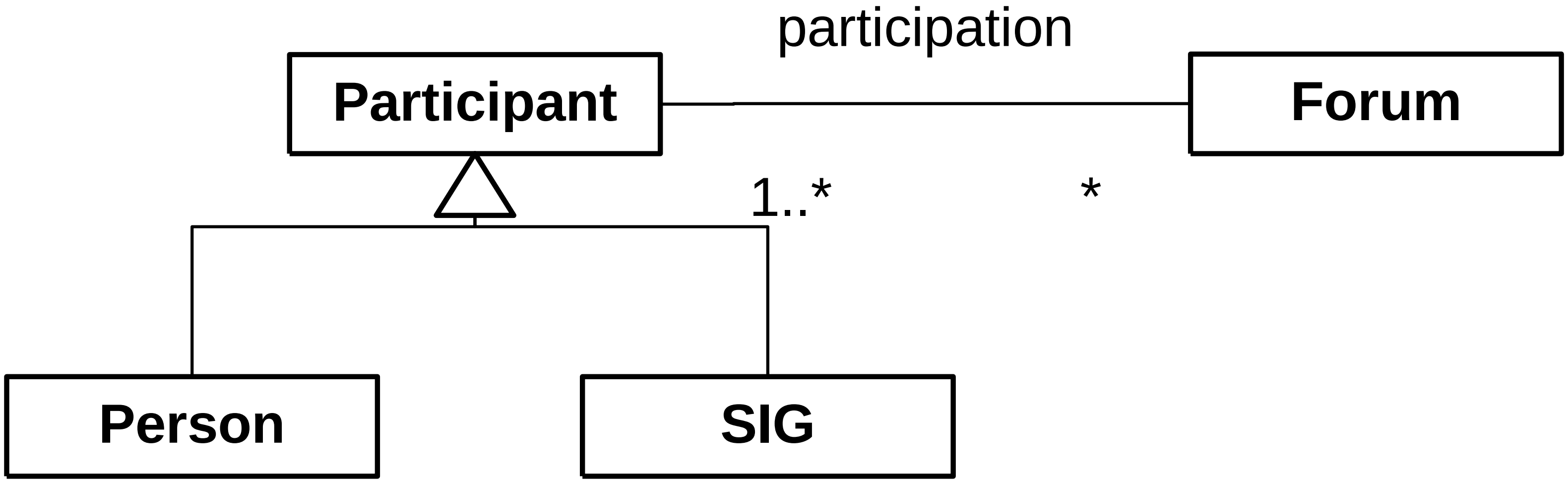
Roles with Disjoint Allowed Types



Roles with Disjoint Allowed Types

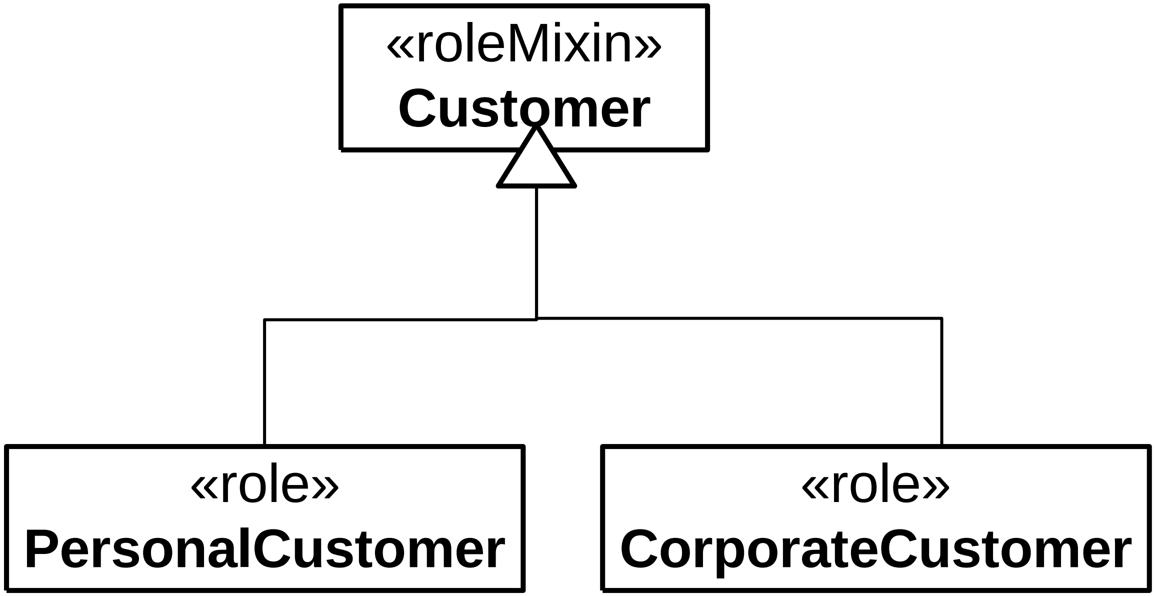



participation
Participant
Forum
1..*
*
Person
SIG

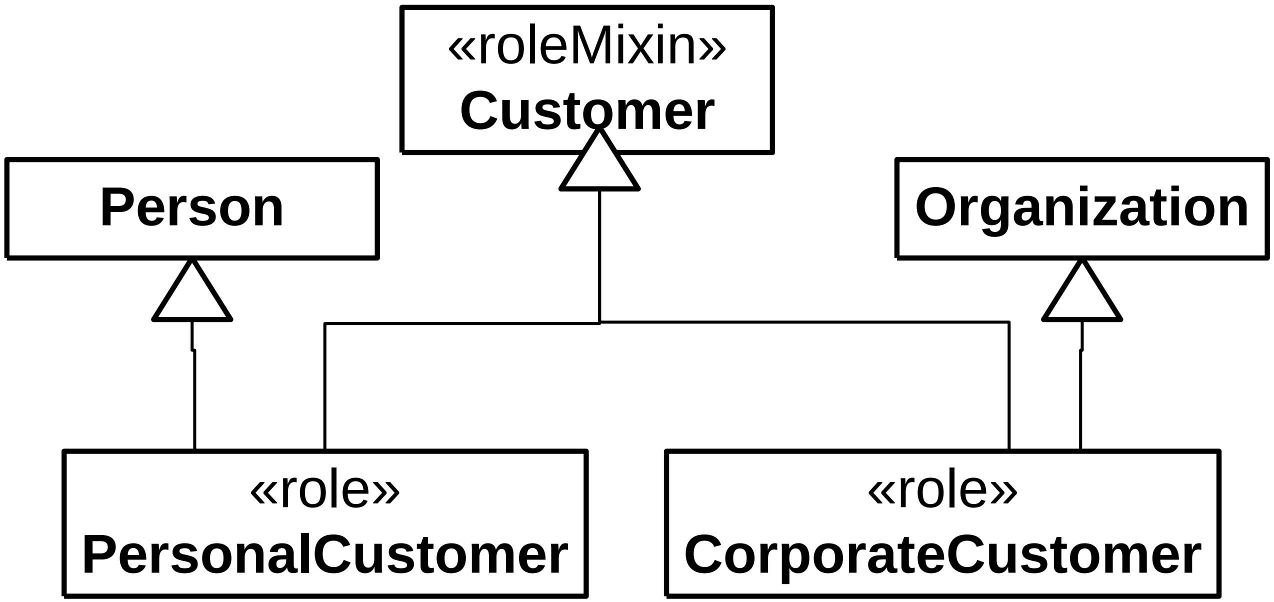

participation
Participant
Forum
1..*
*
Person
SIG

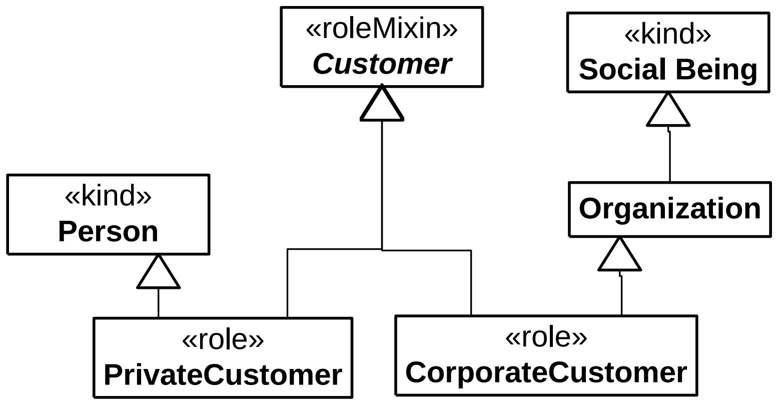
Roles with Disjoint Admissible Types

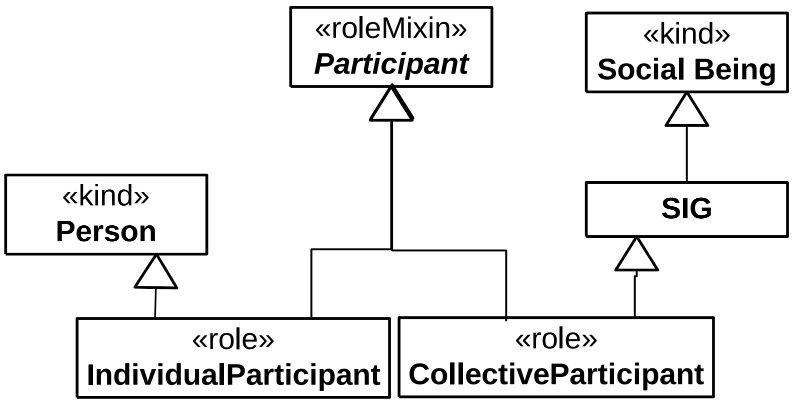
Roles with Disjoint Allowed Types



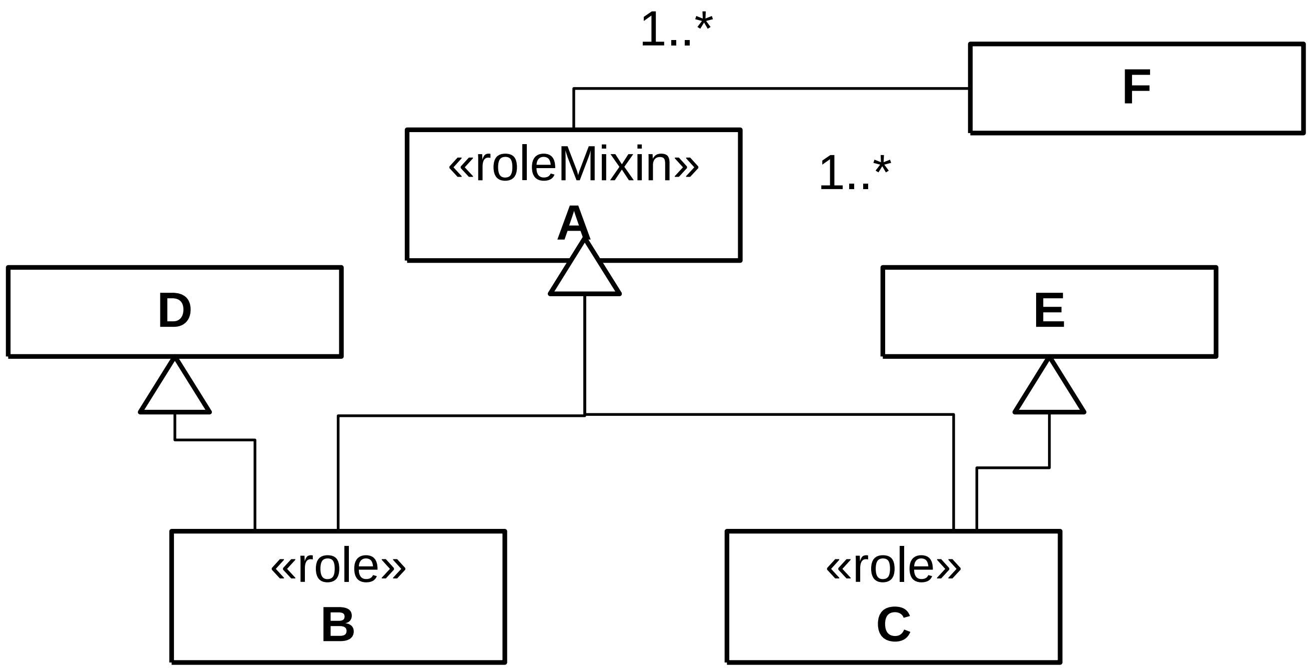
Roles with Disjoint Allowed Types



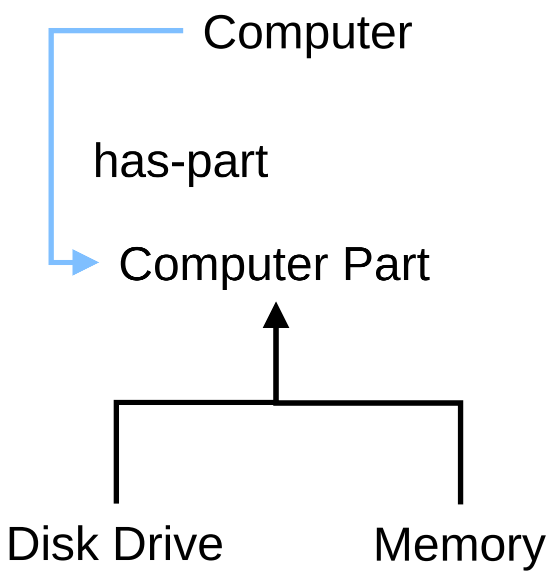

«roleMixin»
Customer
«kind»
Social Being
«kind»
Person
Organization
«role»
PrivateCustomer
«role»
CorporateCustomer

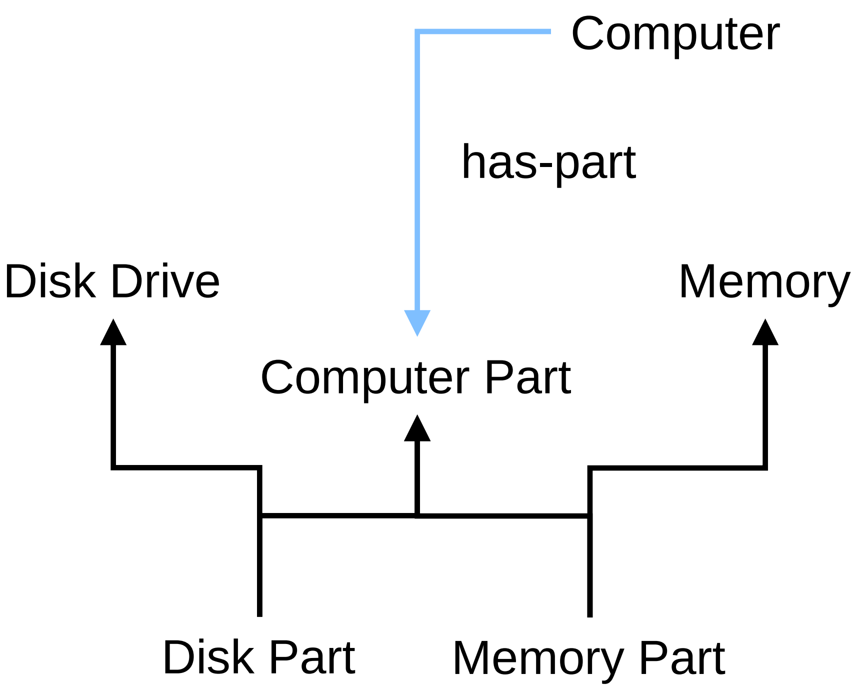

«roleMixin»
Participant
«kind»
Social Being
«kind»
Person
SIG
«role»
IndividualParticipant
«role»
CollectiveParticipant

Roles with Disjoint Admissible Types



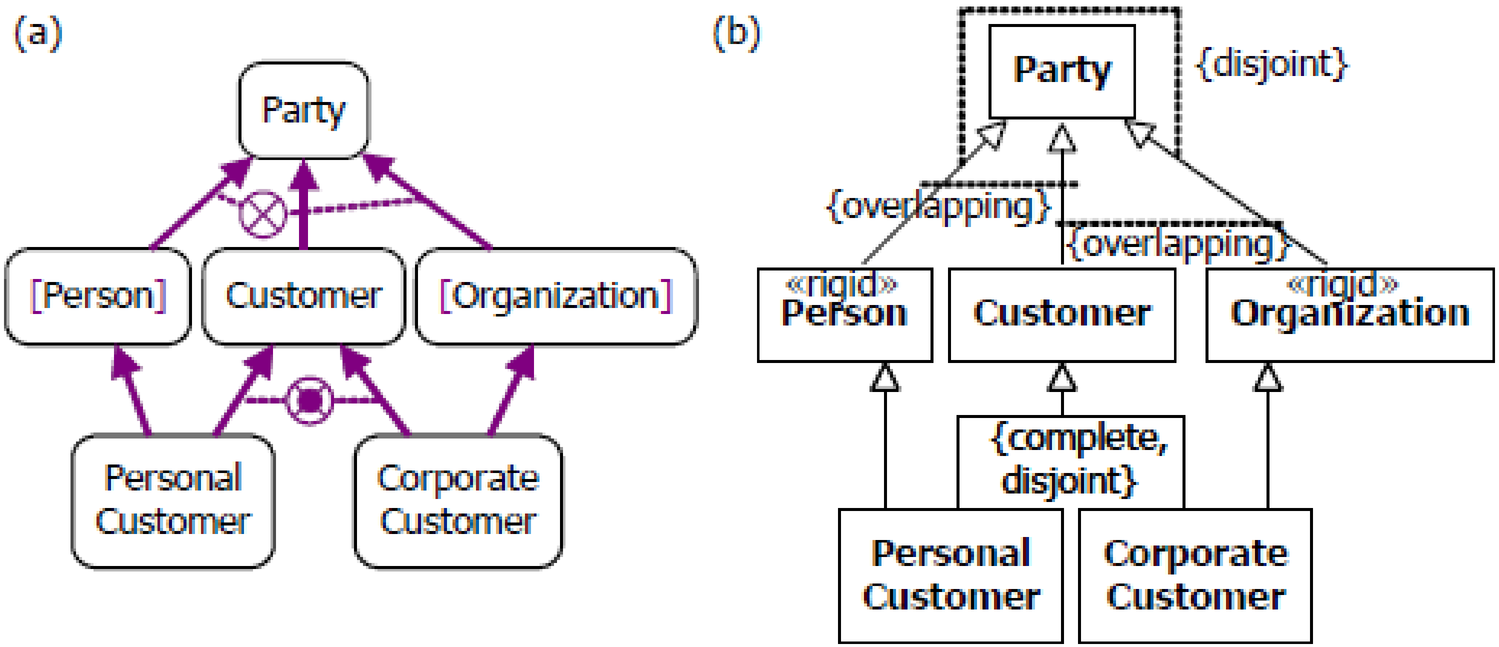
Which one is better?





by Chris Welty

The Pattern in ORM



by Terry Halpin

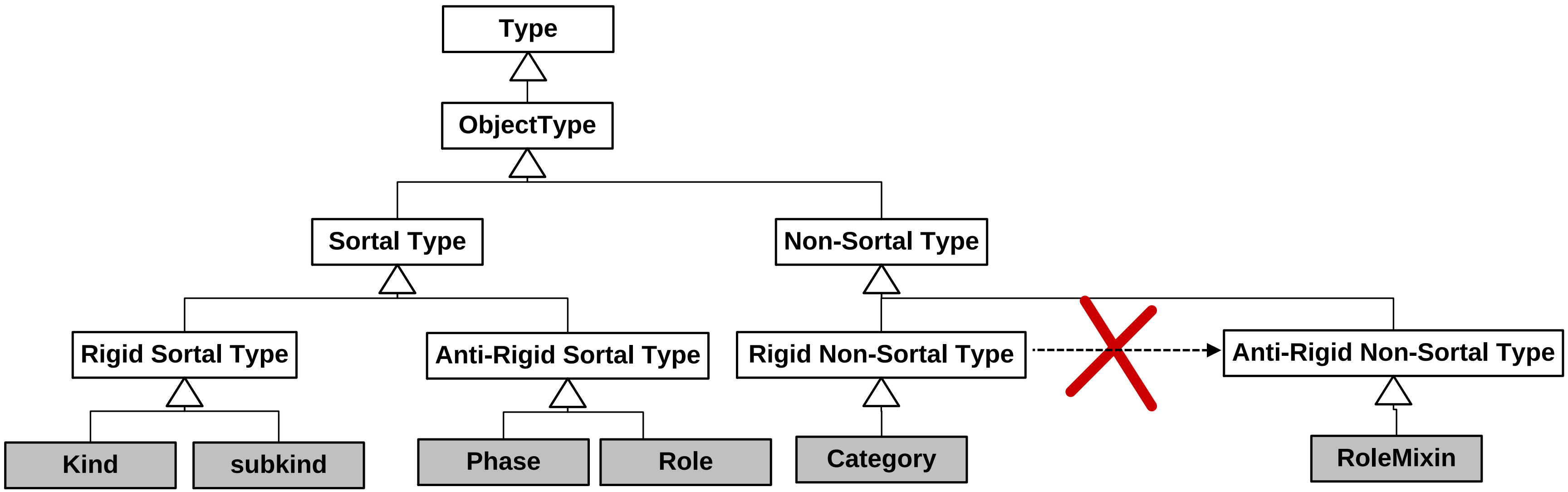
Patterns and Metaphors

nemo

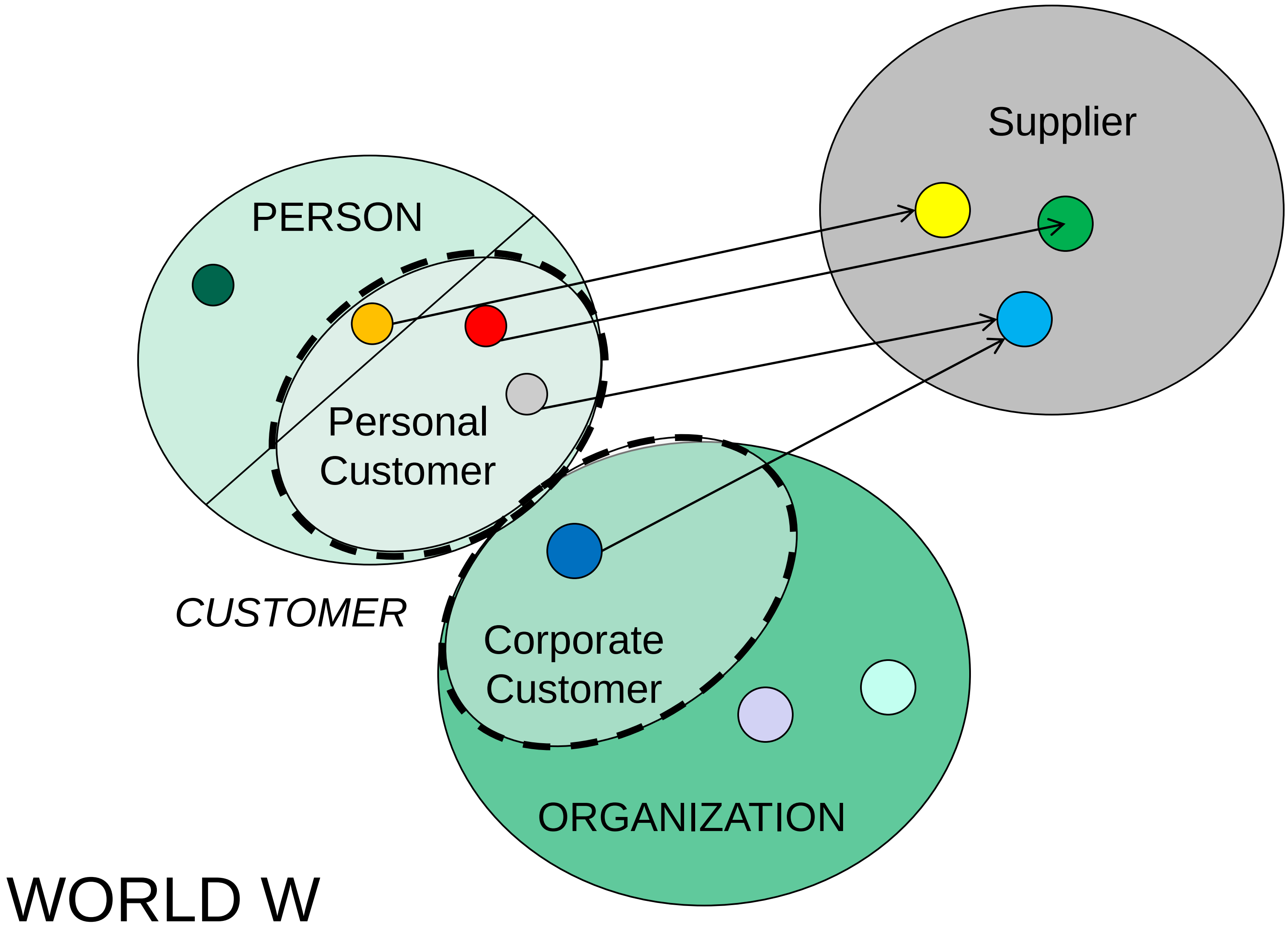
- From a modeling viewpoint, patterns can be seen as higher-granularity modeling primitives
- Design Patterns are the modeling counterpart of a device for Structure Transferability capturing a domain-independent system of types and relations that offer a stardardized solution for a recurrent problem

RoleMixins

- A RoleMixin cannot be a super-type of a category, in fact, an Anti-Rigid Non-Sortal type cannot be a supertype of a rigid one

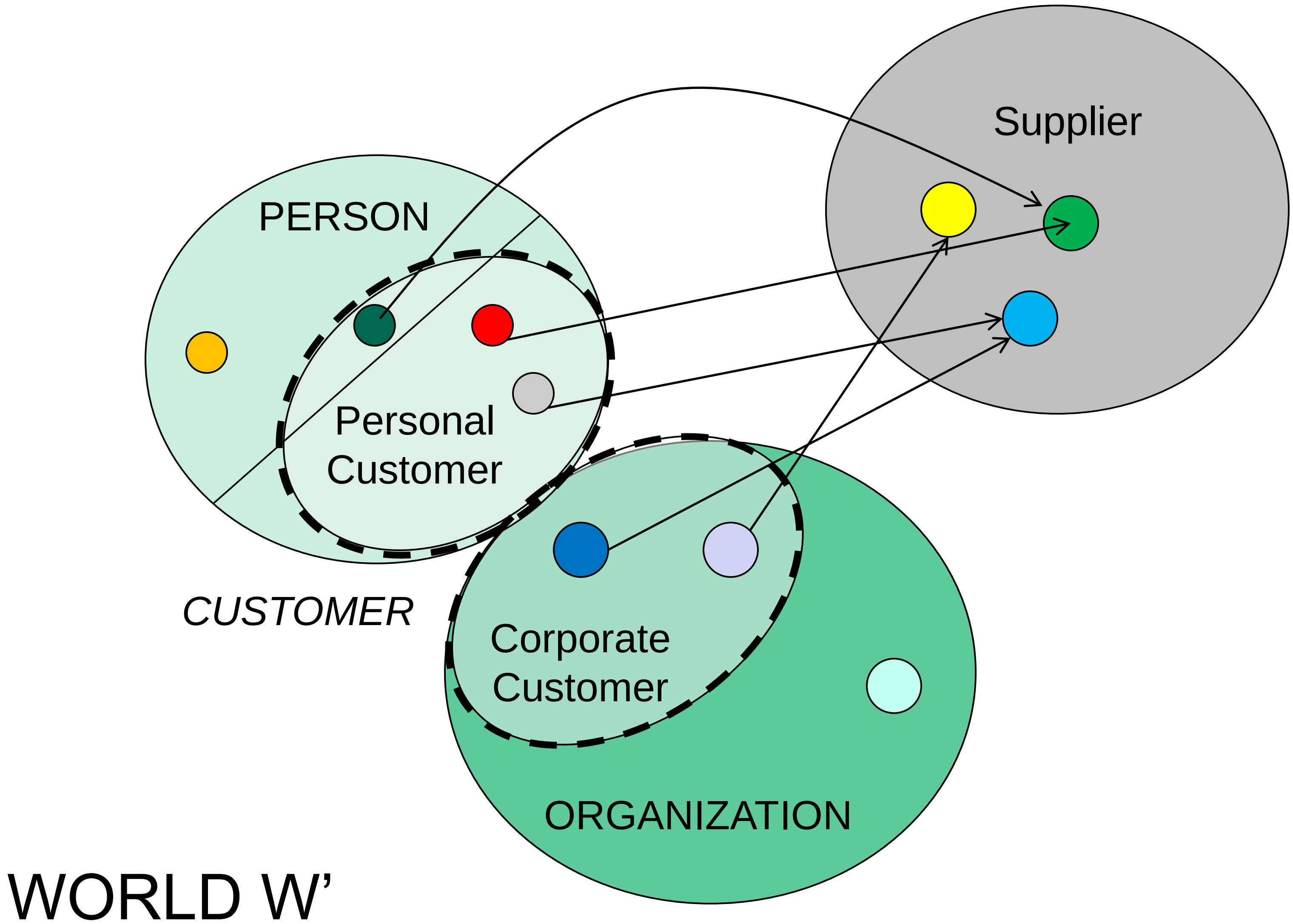


RoleMixin

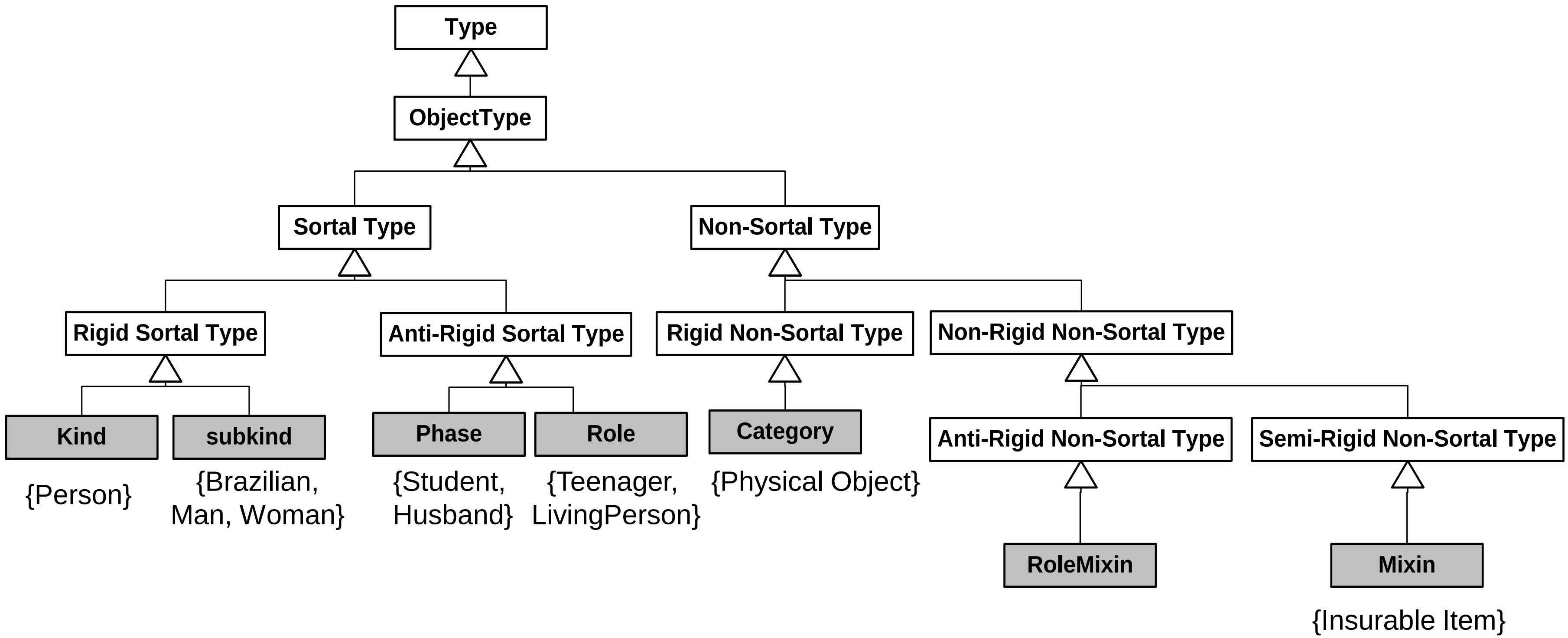


Supplier
PERSON
Personal
Customer
CUSTOMER
Corporate
Customer
ORGANIZATION
WORLD W

RoleMixin

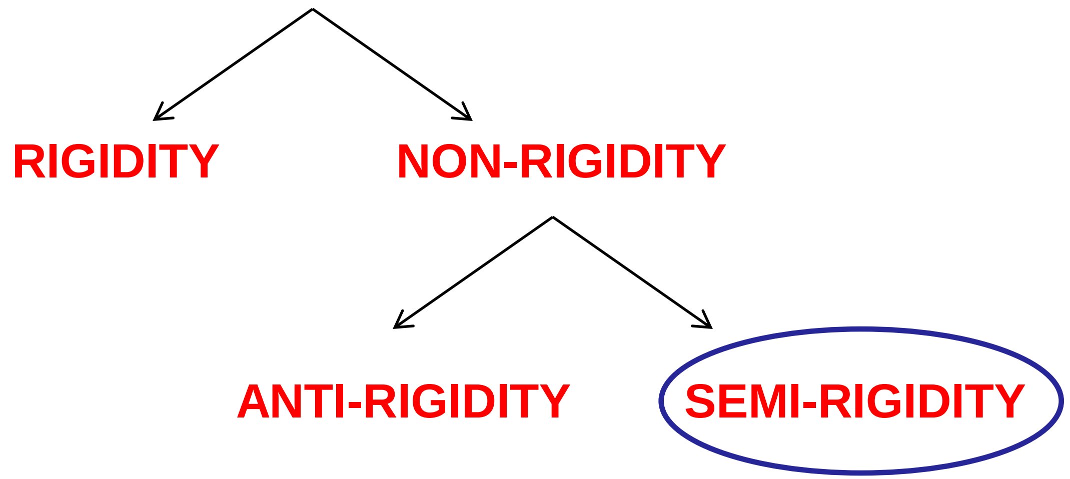

Supplier
PERSON
Personal Customer
CUSTOMER
Corporate Customer
ORGANIZATION
WORLD W'

Distinctions Among Object Types



Modal Meta-Properties

- We will discuss here four types of Ontological Meta-Properties which are of a modal nature



Non-Rigidity

nemo

- Anti-Rigidity is not the logical negation of rigidity, non-rigidity is! Anti-Rigidity is stronger than that as a logical constraint

Rigidity $\mathbf{R+(T) =_{def} \Box(\forall x\ T(x) \rightarrow \Box(T(x)))}$

Logical Negation

Non-Rigidity $\mathbf{R-(T) =_{def} \Diamond(\exists x T(x) \wedge \Diamond \neg T(x))}$

Non-Rigidity

- Anti-Rigidity is not the logical negation of rigidity, non-rigidity is! Anti-Rigidity is stronger than that as a logical constraint

Rigidity $R+(T) =_{def} \Box(\forall x\ T(x) \rightarrow \Box(T(x)))$

$\downarrow$ Logical Negation

Non-Rigidity $R-(T) =_{def} \Diamond(\exists x T(x) \wedge \Diamond\neg T(x))$

Anti-Rigidity $R\sim(T) =def \Box(\forall x\ T(x) \rightarrow \Diamond(\neg T(x)))$

Non-Rigidity

- Anti-Rigidity is not the logical negation of rigidity, non-rigidity is! Anti-Rigidity is stronger than that as a logical constraint

Rigidity $\quad \mathbf{R+(T) =_{def} \Box(\forall x\ T(x) \rightarrow \Box(T(x)))}$

$$\Big\downarrow \text{ Logical Negation}$$

Non-Rigidity $\quad \mathbf{R\neg(T) =_{def} \Diamond(\exists x T(x) \wedge \Diamond\neg T(x))}$

Anti-Rigidity $\quad \mathbf{R-(T) =_{def} \Box(\forall x\ T(x) \rightarrow \Diamond(\neg T(x)))}$

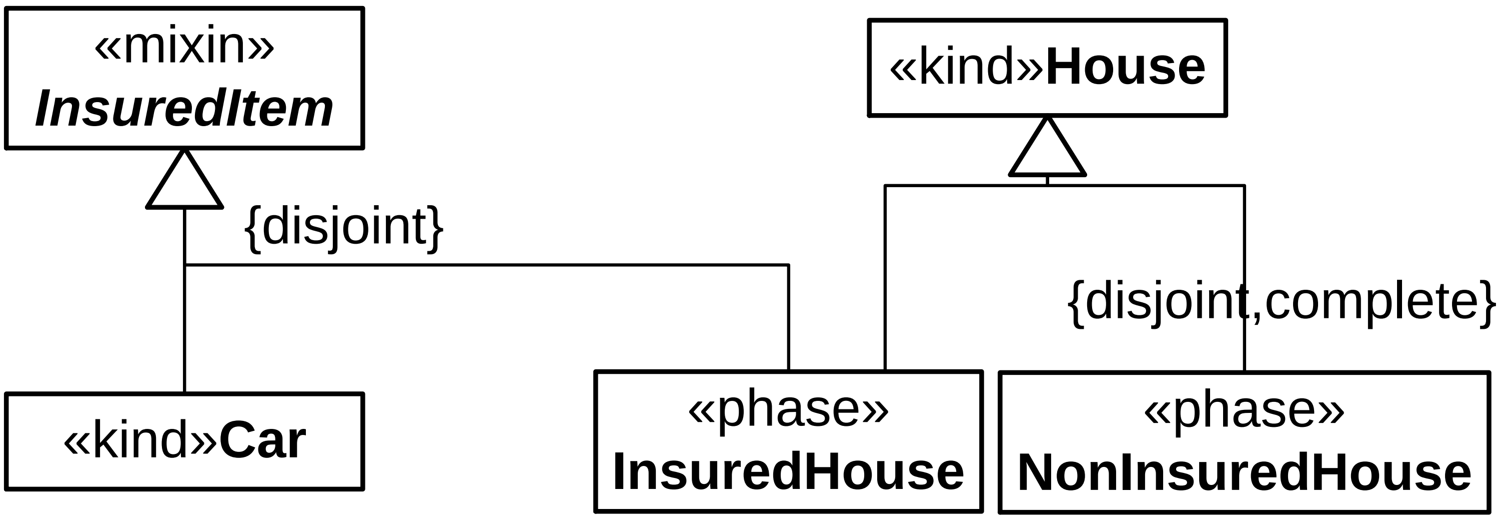
Semi-Rigidity $\quad \mathbf{R\sim(T) =_{def} R-(T) \wedge \neg R\sim(T)}$

Mixin(I-,R~)

- Mixins are semi-rigid non-sortals, i.e., they represent features which are necessary (in the modal sense) for some of its instances but contingent to others

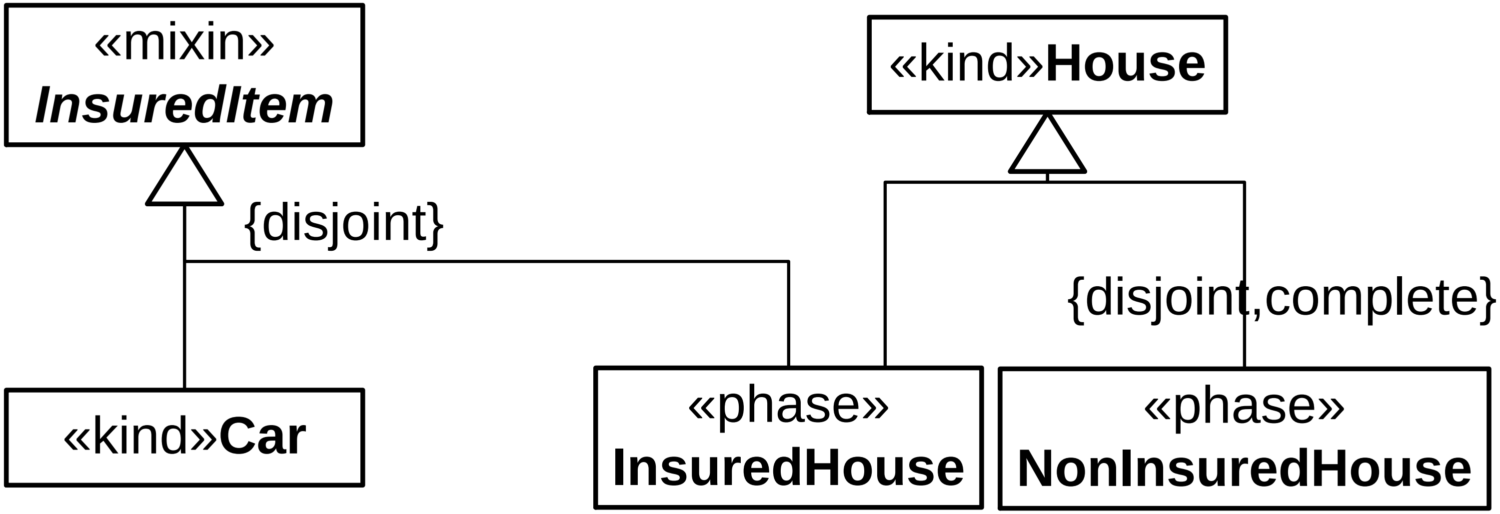
$$\mathbf{SR(T) =def\ NR(T)} \land \neg \mathbf{R\text{-}(T)}$$

- Every Mixin must be a supertype of a rigid type as well as a supertype of a Non-Rigid type (typically a phase)

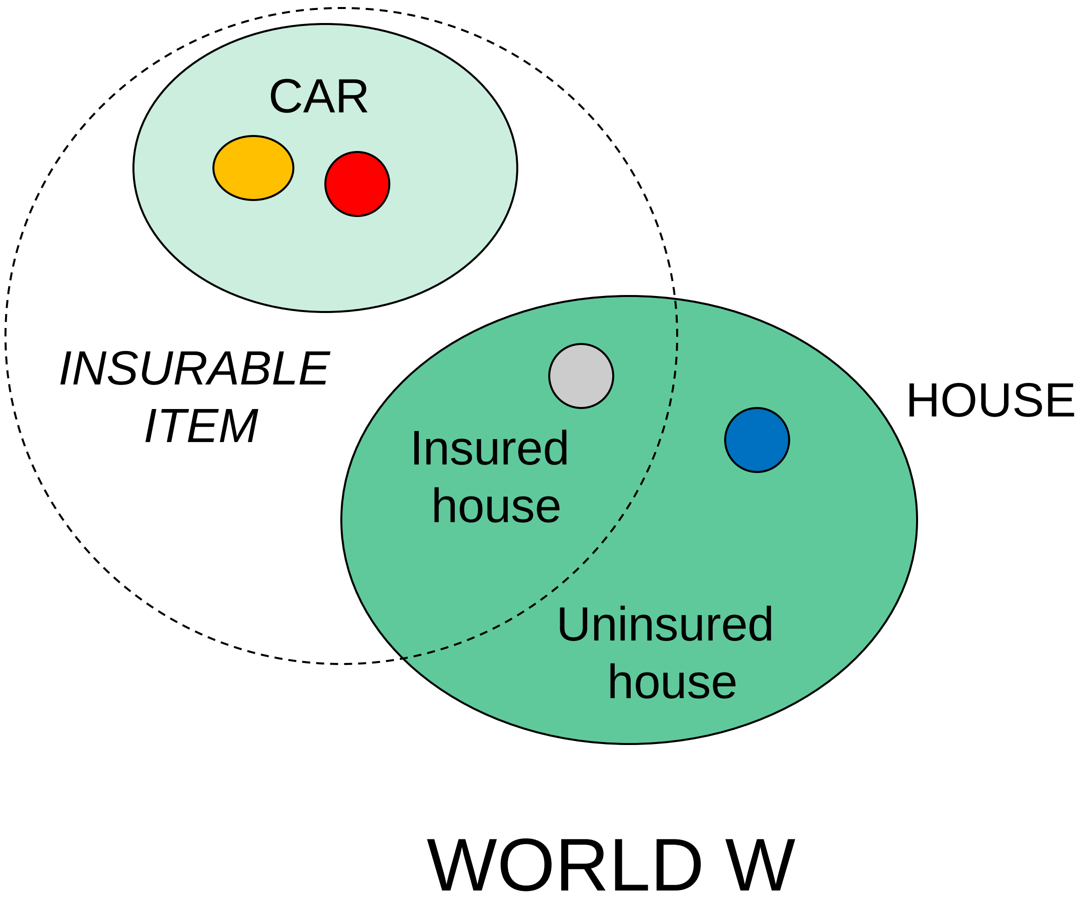


Mixins

- Mixins represent semi-rigid features of multiple kinds
- Since all kinds are disjoint, all subtypes of a mixin form a disjoint generalization set. On the other, like in the case of categories, these generalization sets are very seldom complete

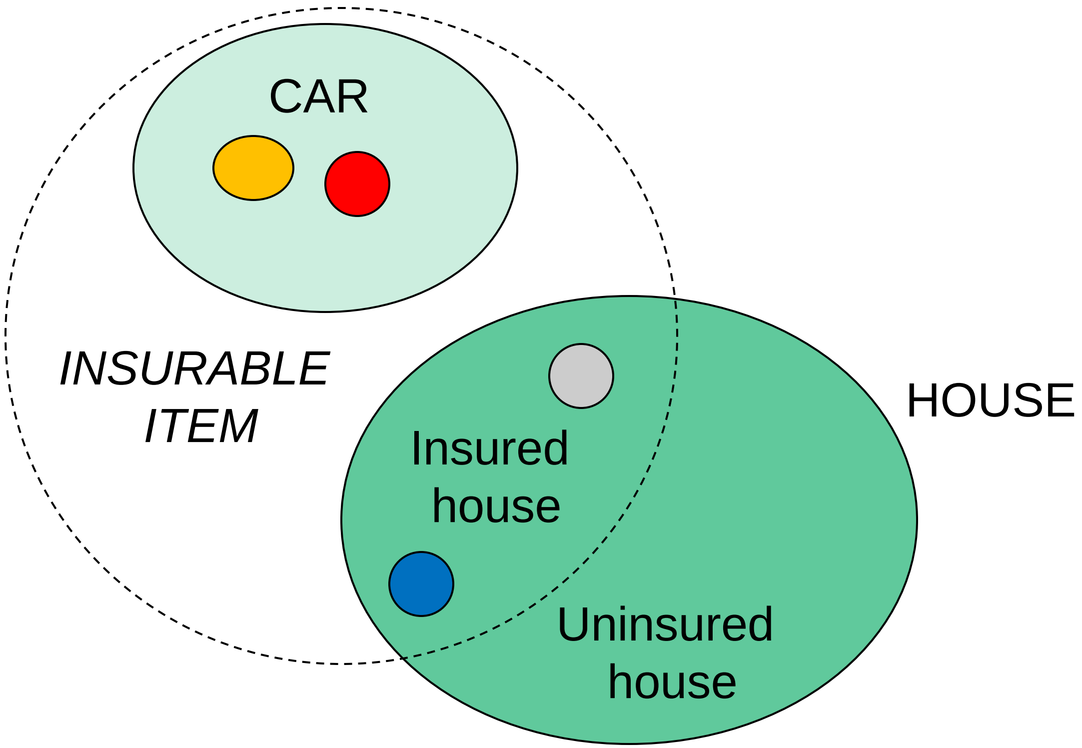


Mixin



CAR
INSURABLE ITEM
HOUSE
Insured house
Uninsured house
WORLD W

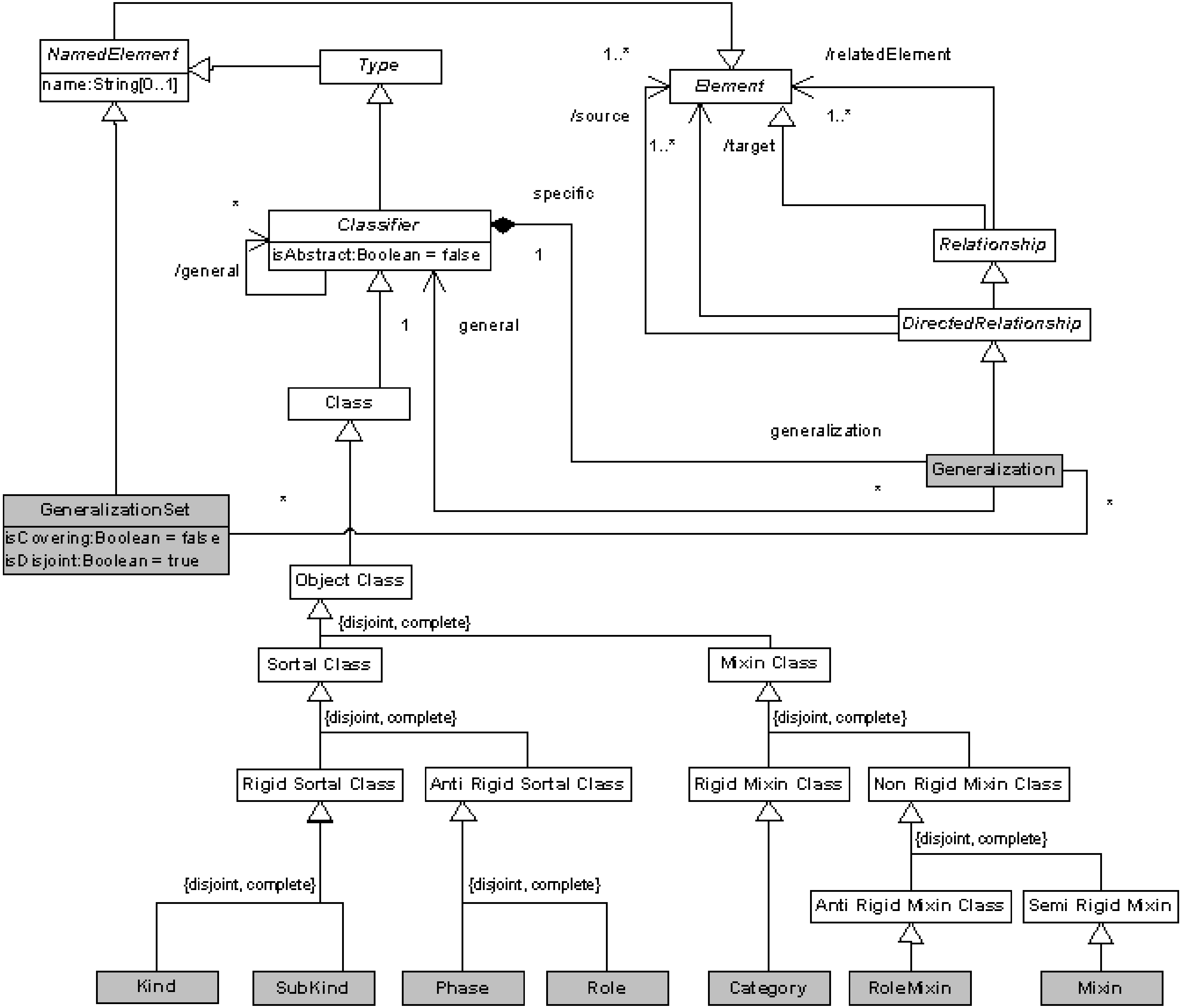
Mixin



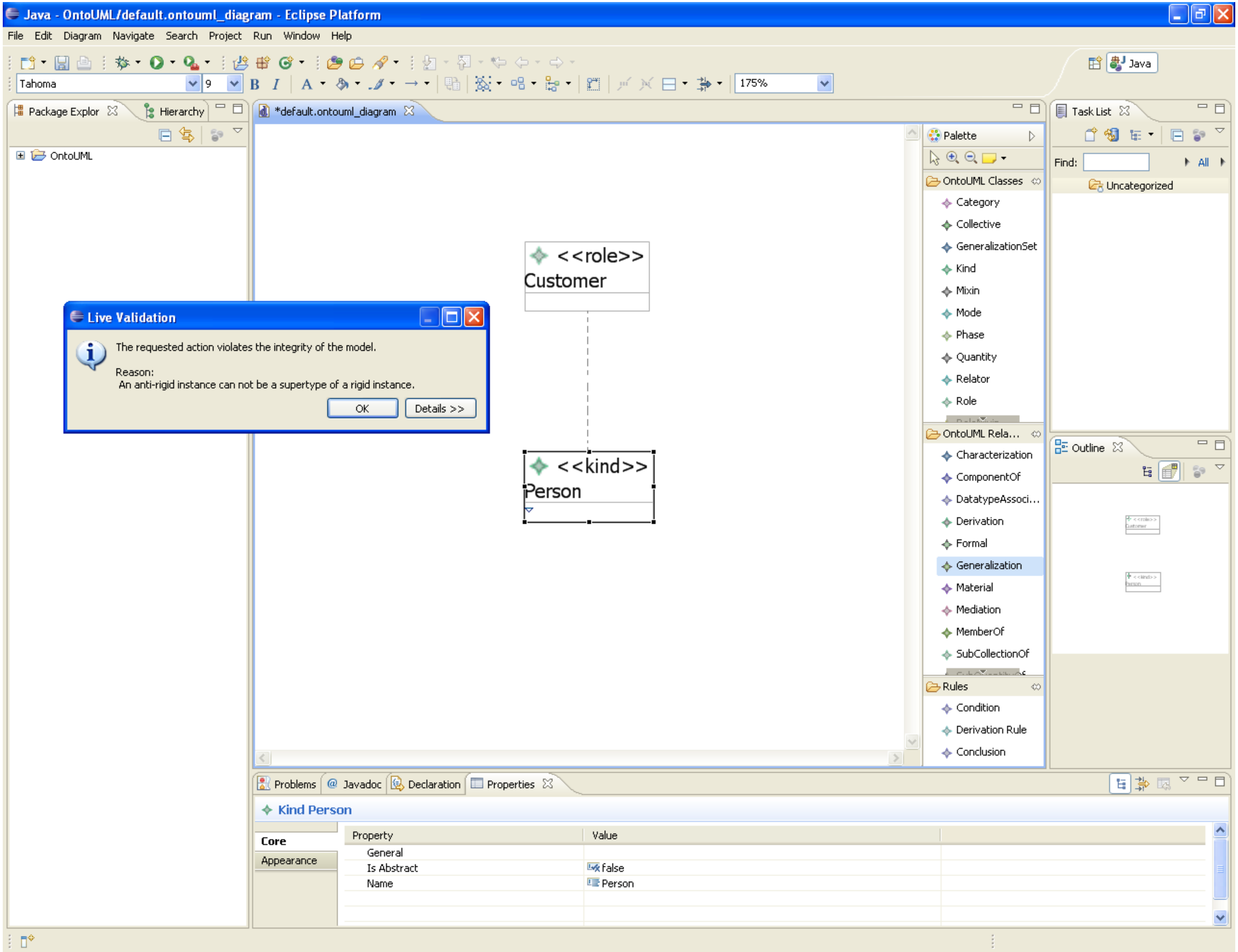
WORLD W’

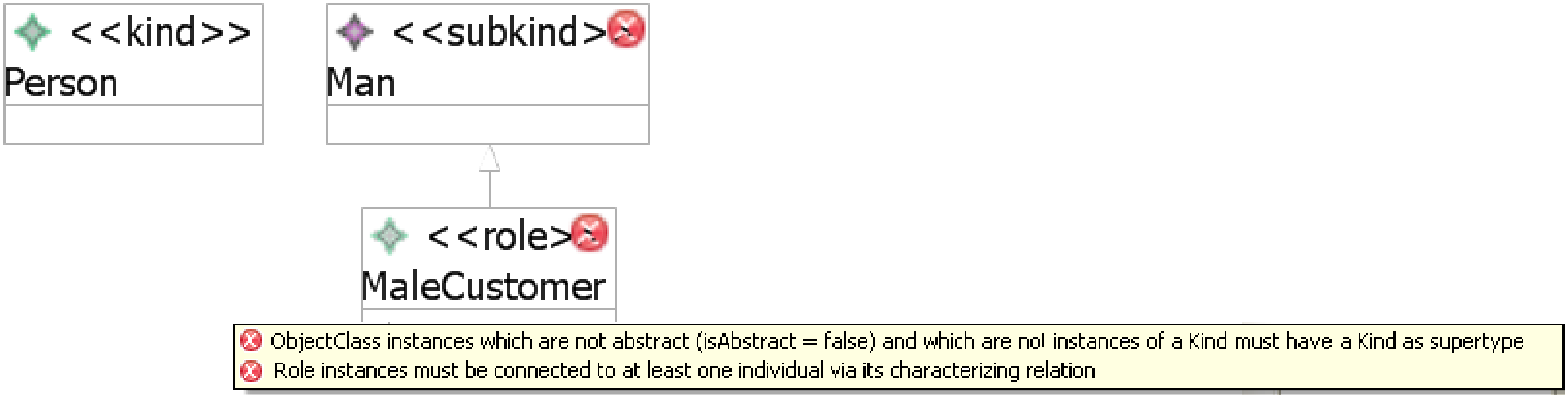
Different Categories of Object Types

Category of Type	Supply Identity	Identity	Rigidity	Dependence
SORTAL	-	+		
« kind »	+	+	+	-
« subkind »	-	+	+	-
« role »	-	+	-	+
« phase »	-	+	-	-
NON-SORTAL	-	-		
« category »	-	-	+	-
« roleMixin »	-	-	-	+
« mixin »	-	-	¬	-


NamedElement
name:String[0..1]
Type
Element
1..*
/relatedElement
/source
1..*
/target
1..*
specific
*
Classifier
isAbstract:Boolean = false
1
/general
Relationship
1
general
DirectedRelationship
Class
generalization
Generalization
GeneralizationSet
isCovering:Boolean = false
isDisjoint:Boolean = true
*
*
*
Object Class
{disjoint, complete}
Sortal Class
Mixin Class
{disjoint, complete}
{disjoint, complete}
Rigid Sortal Class
Anti Rigid Sortal Class
Rigid Mixin Class
Non Rigid Mixin Class
{disjoint, complete}
{disjoint, complete}
{disjoint, complete}
Anti Rigid Mixin Class
Semi Rigid Mixin
Kind
SubKind
Phase
Role
Category
RoleMixin
Mixin

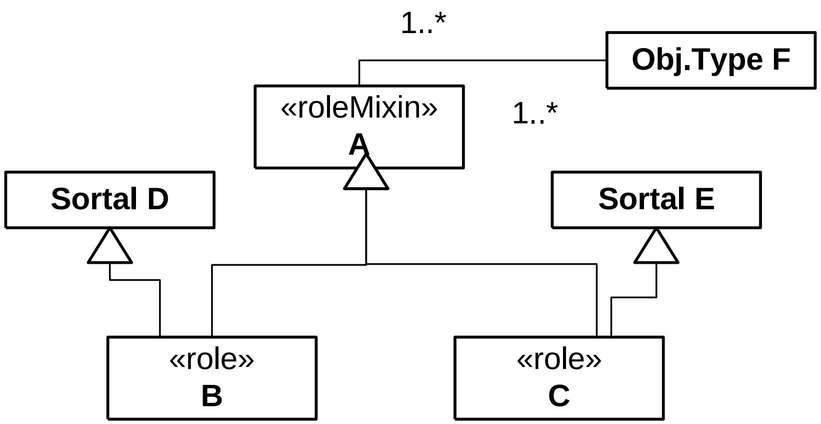
Stereotype	Constraints
	RIGID SORTALS
« kind »	supertype is **not** a member of {« subkind », « phase », « role », « roleMixin »}
« subkind »	supertype is **not** a member of {« phase », « role », « roleMixin »} For every subkind SK there is a unique kind K such that K is a supertype of SK
	ANTI-RIGID SORTALS
« phase »	Always defined as part of disjoint and complete partition. For every Phase P there is a unique Kind K such that K is a supertype of P
« role »	Let X be a class stereotyped as « role » and R be an association representing X's restriction condition. Then, $\#X.R \geq 1$ For every Role X there is a unique Kind K such that K is a supertype of X
	NON-SORTALS
« category »	supertype is **not** a member of {« kind », « subkind », « phase », « role », « roleMixin »} Always defined as an abstract class Always specialized by a unique kind Always defined in a disjoint partition
« roleMixin »	supertype is **not** a member of {« kind », « subkind », « phase », « role »}. Let X be a class stereotyped as « roleMixin » and R be an association representing X's restriction condition. Then, $\#X.R \geq 1$ Always defined as an abstract class Always defined in a disjoint partition Always specialized by Sortals
« mixin »	supertype is **not** a member of {« kind », « subkind », « phase », « role », « roleMixin »} Always defined as an abstract class

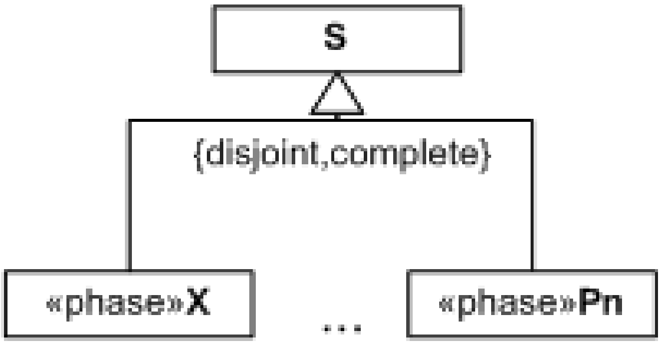

Java - OntoUML/default.ontouml_diagram - Eclipse Platform
File Edit Diagram Navigate Search Project Run Window Help
Tahoma
9
175%
Java
Package Explor
Hierarchy
OntoUML
*default.ontouml_diagram
<<role>>
Customer
<<kind>>
Person
Live Validation
The requested action violates the integrity of the model.
Reason:
An anti-rigid instance can not be a supertype of a rigid instance.
OK
Details >>
Palette
OntoUML Classes
Category
Collective
GeneralizationSet
Kind
Mixin
Mode
Phase
Quantity
Relator
Role
OntoUML Rela...
Characterization
ComponentOf
DatatypeAssoci...
Derivation
Formal
Generalization
Material
Mediation
MemberOf
SubCollectionOf
Rules
Condition
Derivation Rule
Conclusion
Task List
Find:
All
Uncategorized
Outline
Problems
Javadoc
Declaration
Properties
Kind Person
Core
Appearance
Property
Value
General
Is Abstract
false
Name
Person

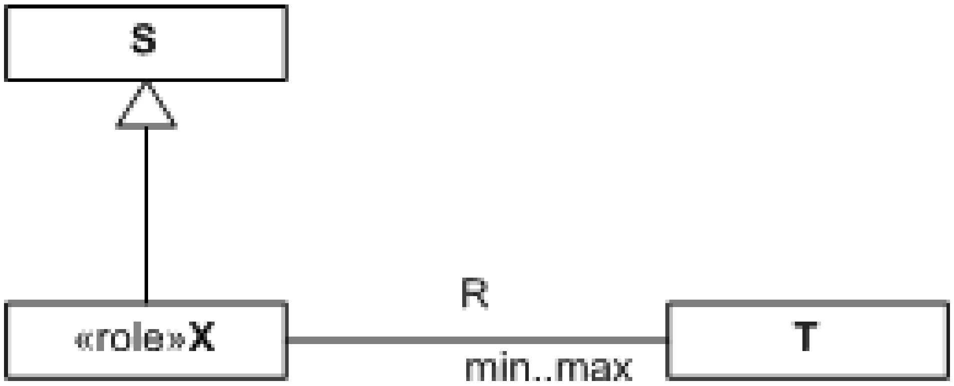


<<kind>>
Person
<<subkind>
Man
<<role>
MaleCustomer
ObjectClass instances which are not abstract (isAbstract = false) and which are not instances of a Kind must have a Kind as supertype
Role instances must be connected to at least one individual via its characterizing relation

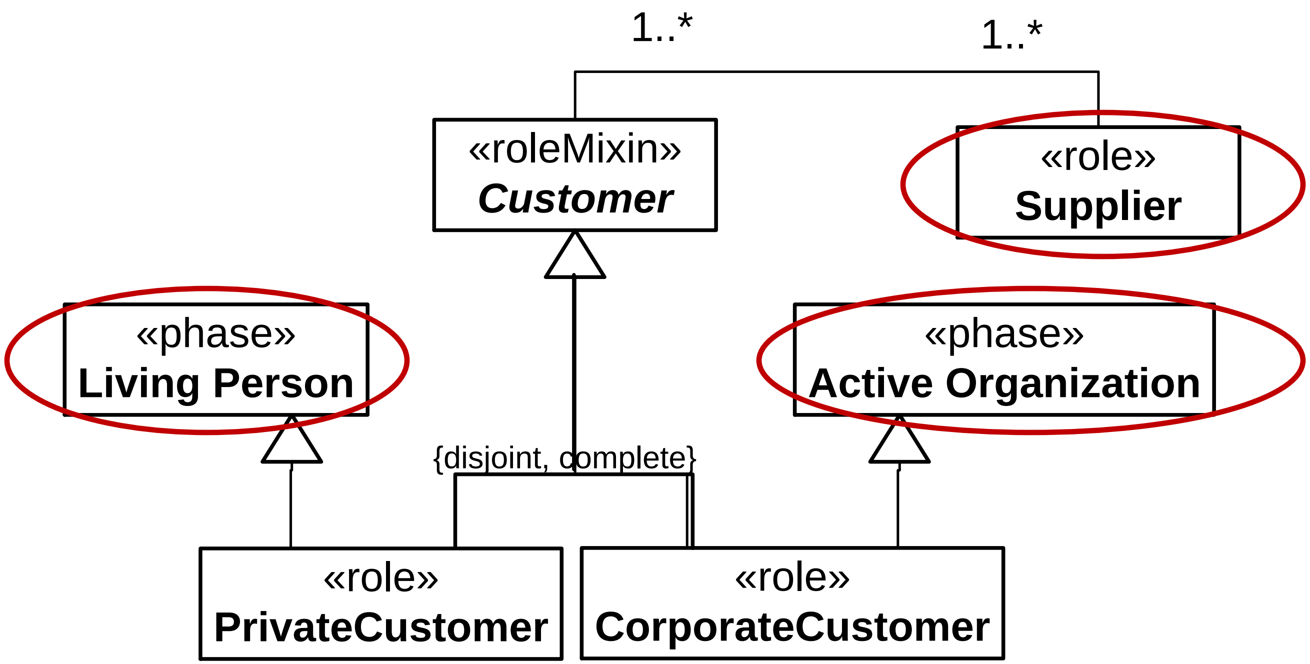
Ontology-Derived Patterns

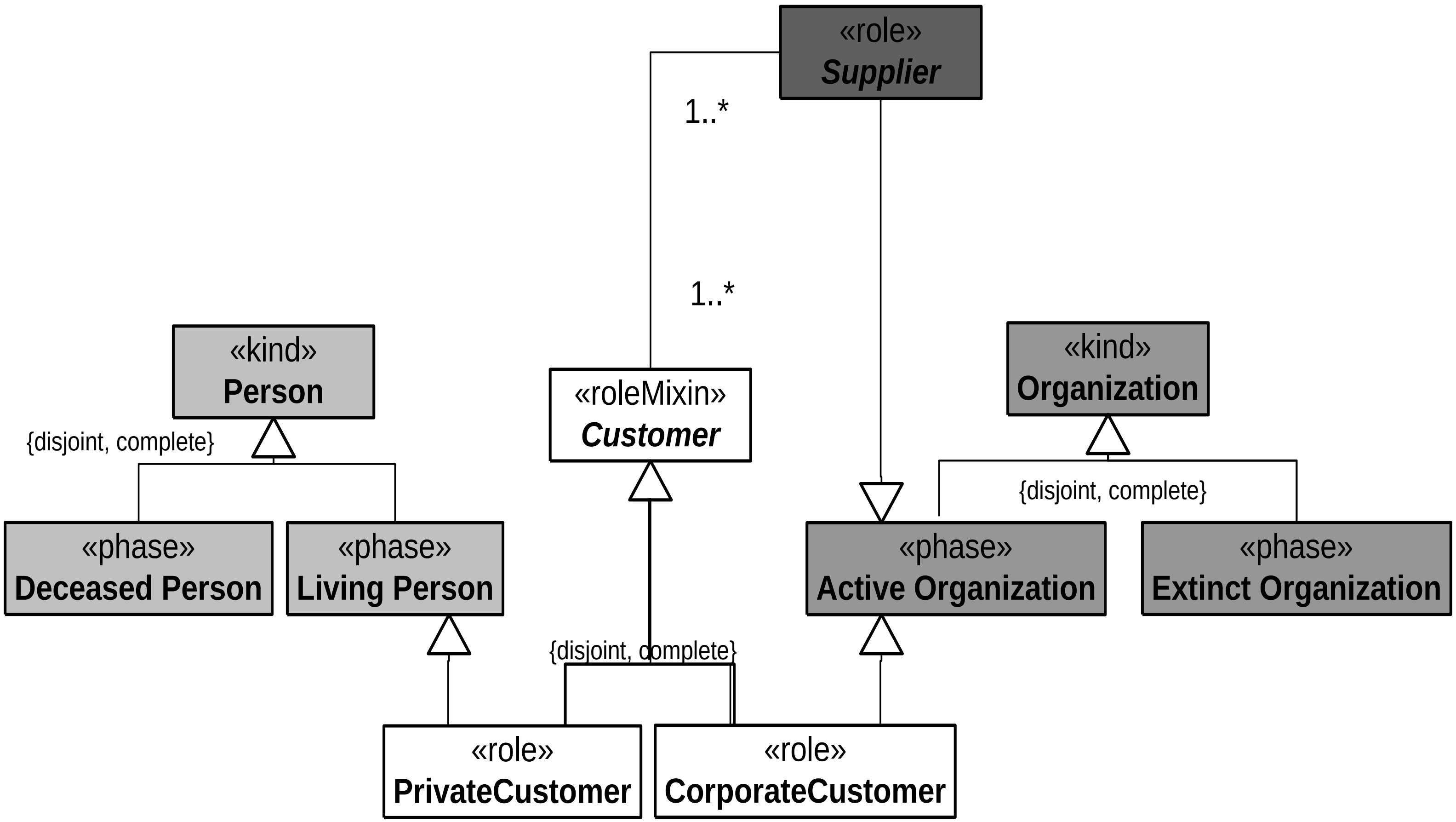






min≥1


1..*
1..*
«roleMixin»
Customer
«role»
Supplier
«phase»
Living Person
«phase»
Active Organization
{disjoint, complete}
«role»
PrivateCustomer
«role»
CorporateCustomer

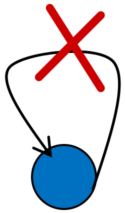

«role»
Supplier
1..*
1..*
«kind»
Person
{disjoint, complete}
«roleMixin»
Customer
«kind»
Organization
{disjoint, complete}
«phase»
Deceased Person
«phase»
Living Person
«phase»
Active Organization
«phase»
Extinct Organization
{disjoint, complete}
«role»
PrivateCustomer
«role»
CorporateCustomer

PARTHOOD

Parthood

- Part-whole relations are fundamental from a cognitive perspective, i.e., for the realization of many important cognitive tasks.
- Moreover, and also for this reason, parthood is a relation of significant importance in conceptual modeling, being present in practically all conceptual/object-oriented modeling languages (e.g., OML, UML, EER)
- Although it has not yet been adopted as a modeling primitive in the semantic web languages, there is a significant body of work discussing its relevance for reasoning in description logics
- From now on, we use the symbol (<) to represent the part-whole relation

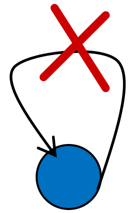
Ground Mereology



Parthood is irreflexive, i.e., nothing is part of itself

$\forall x\ \neg(x<x)$

Ground Mereology



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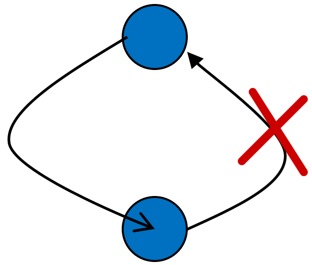
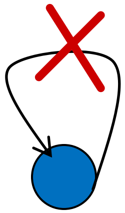


Parthood is anti-symmetric, i.e., if X is part of Y then Y cannot be part of X

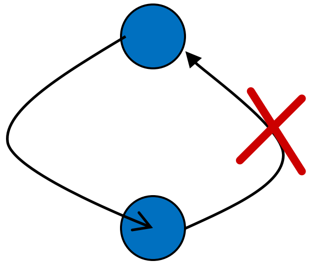
$\forall x,y\ (x < y) \rightarrow \neg(y < x)$

Ground Mereology



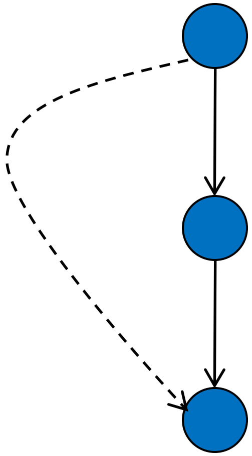
Parthood is irreflexive, i.e., nothing is part of itself

$\forall x \neg(x<x)$



Parthood is anti-symmetric, i.e., if X is part of Y then Y cannot be part of X

$\forall x,y\ (x < y) \rightarrow \neg(y < x)$



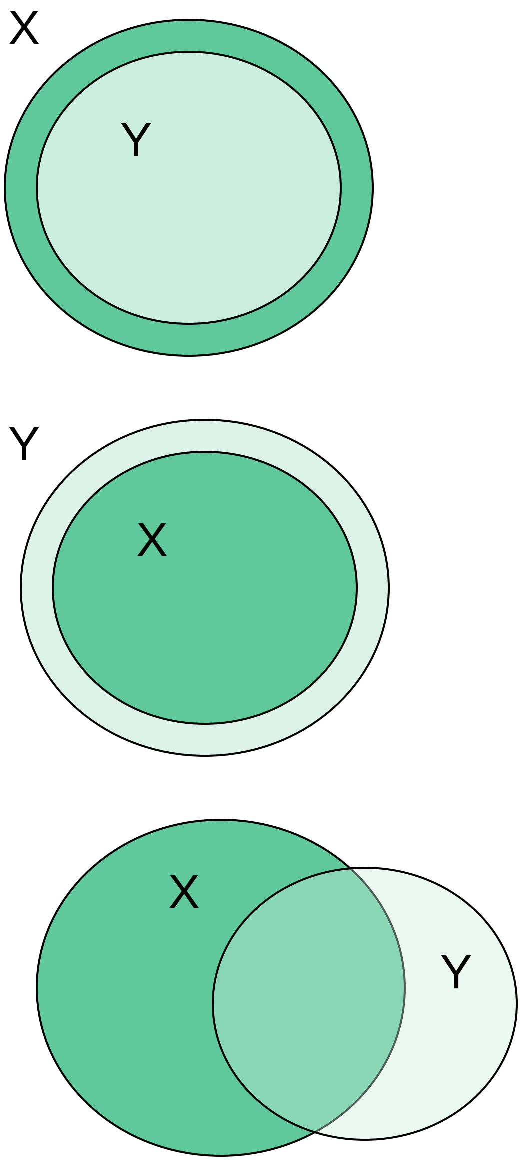
Parthood is transitive, i.e., if X is part of Y and Y is part of Z then X is part of Z

$\forall x,y,z\ (x < y) \wedge (y < z) \rightarrow (x < z)$

Minimum Mereology

- The formal semantics just present defines a so-called *strict partial order* relation
- These axioms are not sufficient to differentiate parthood from other partial order relations (e.g., less-than, bigger-than, causality, strict temporal precedence)
- A stronger theory named Minimum Mereology, thus, defines some additional notions

Overlap

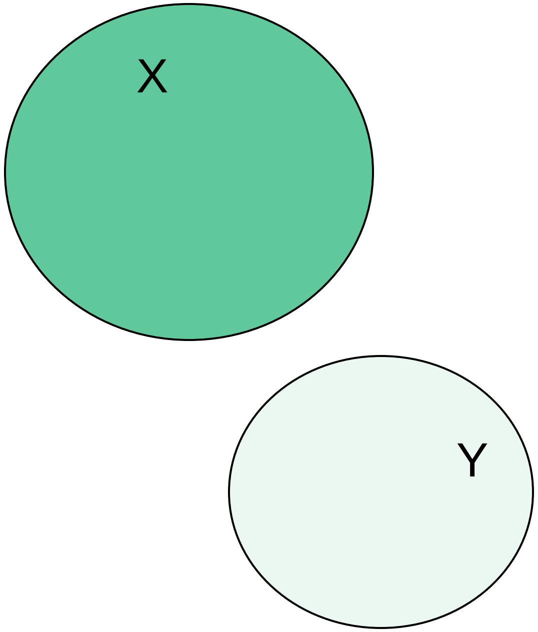


Two entities overlap if they share a part

$$(x \bullet y) =_{def} \exists z\, (z \leq x) \wedge (z \leq y)$$

Notice that this includes the case in which one is part of the other

Disjointness

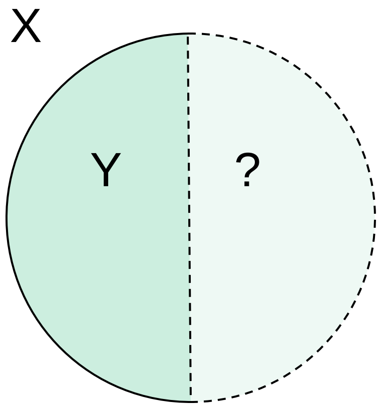


Two entities are disjoint if they do no overlap

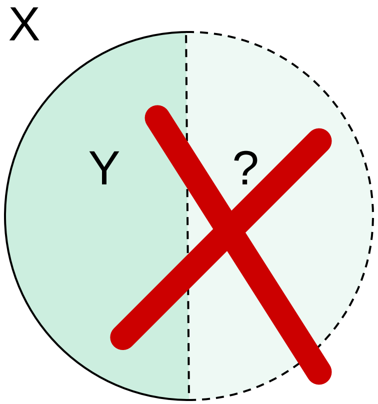
$$(\mathbf{x} \int \mathbf{y}) =_{\mathrm{def}} \neg(\mathbf{x} \bullet \mathbf{y})$$

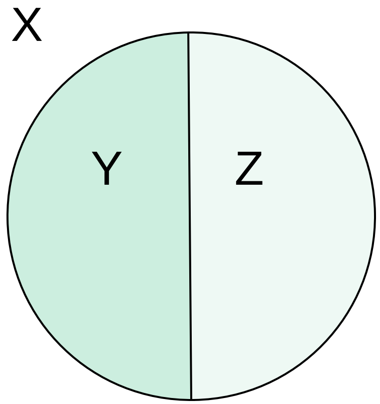
Weak Supplementation

- Mininum Mereology takes the partial order axioms of Ground Mereology and includes the so-called WSP (Weal Supplementation Property)



Weak Supplementation



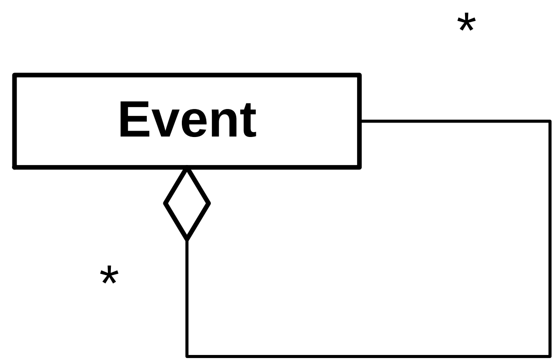


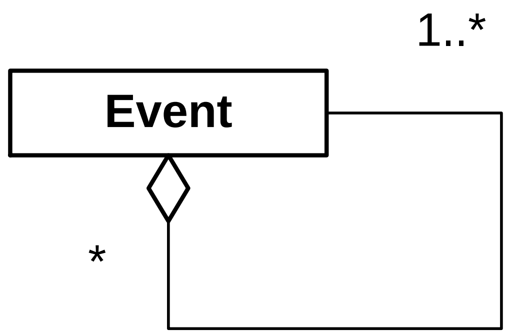
Weak Supplementation Principle

If Y is part of X and if parthood is irreflexive
Then there must be another part of X which is complementary to Y

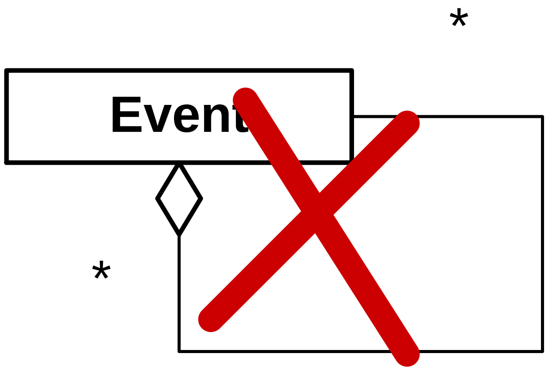
$$\forall \mathbf{x,y}\ (\mathbf{y} < \mathbf{x}) \rightarrow \exists \mathbf{z}\ (\mathbf{z} < \mathbf{x}) \wedge (\mathbf{z} \int \mathbf{y})$$

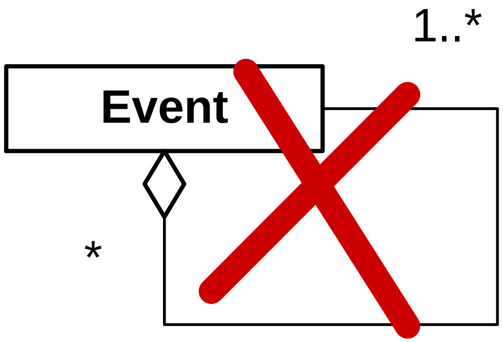
Weak Supplementation Principle



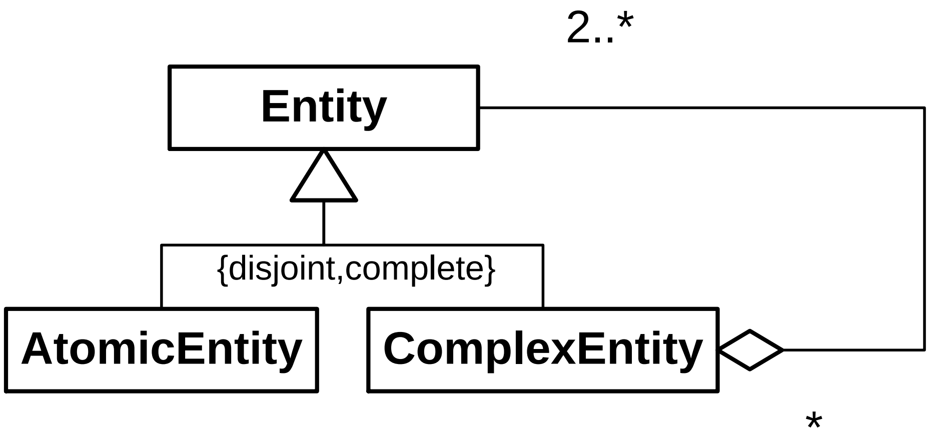


Weak Supplementation Principle

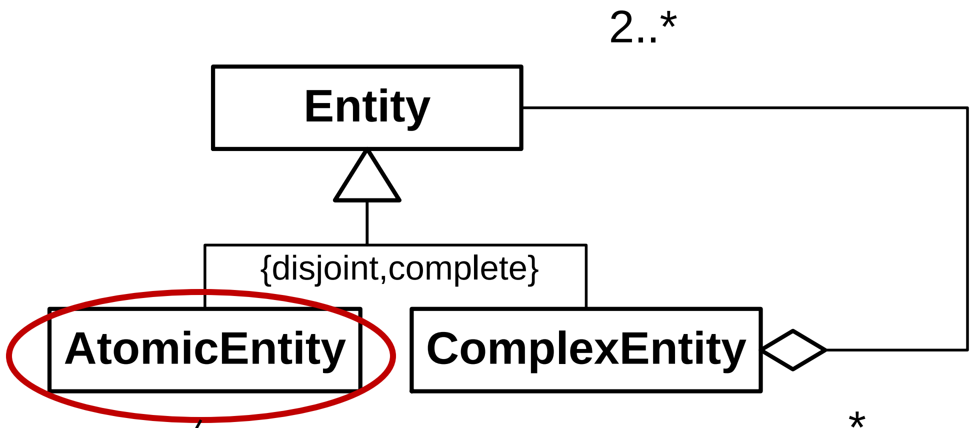




Weak Supplementation Pattern

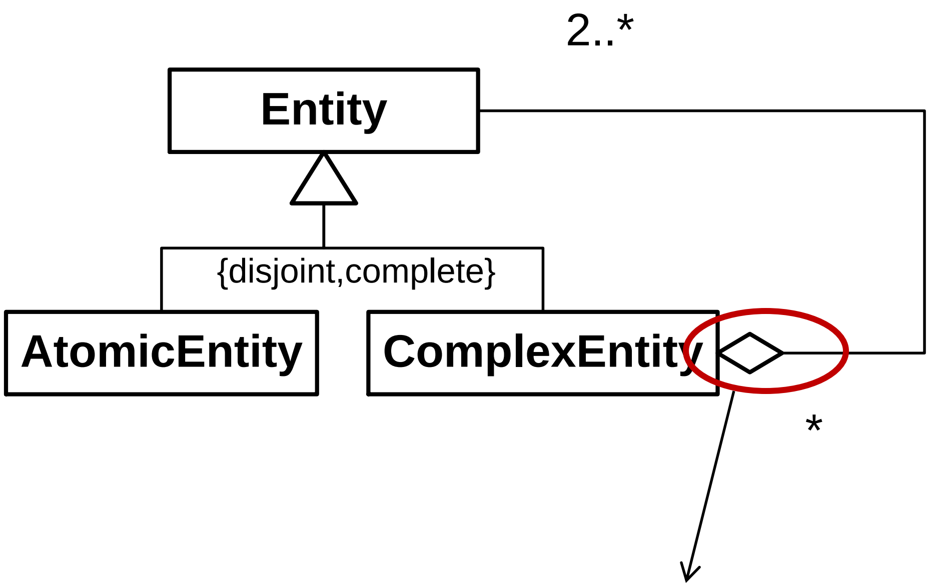


Weak Supplementation Pattern



$$\textbf{AtomicEntity}(x) =_{def} \neg\exists y\ (y < x)$$

Parthood in UML: Aggregation



- One of the representations of parthood in UML termed Aggregation
- The hollow diamond is connected to the whole
- Aggregation is supposed to be a irreflexive and anti-symmetric relation

Extensional Mereology

- From a formal perspective, the most used theory of parthood is the Extensional Mereology, which can be obtained from the Minimum Mereology by including a Strong Supplementation Principle

Extenstional Mereology (+Strong Supplementation Principle)

↑

Minimum Mereology (+WSP)

↑

Ground Mereology (Irreflexivity, Anti-Symmetry, Transitivity)

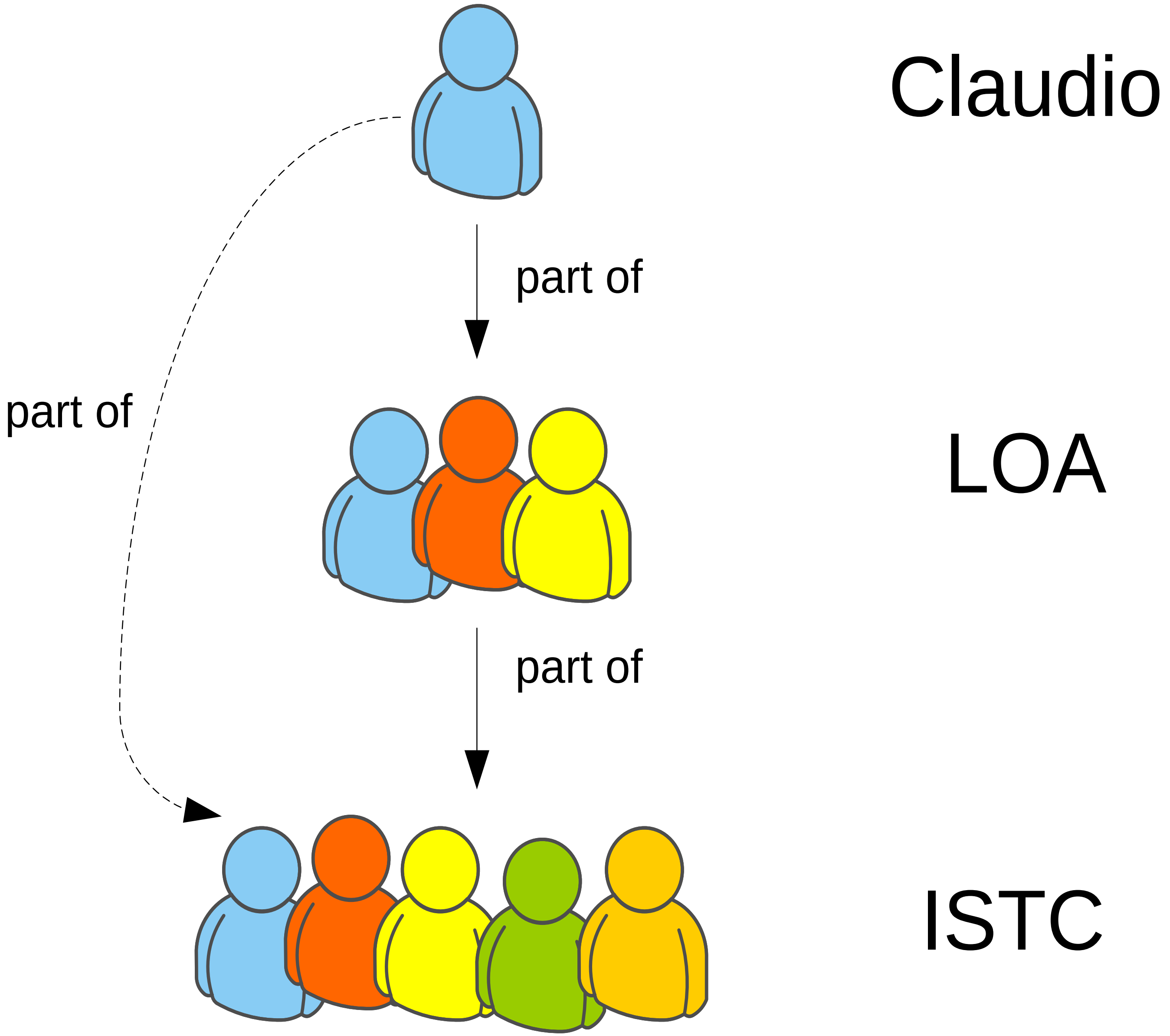
Extensional Mereology

- The Strong Supplementation Principle implies something called the Extensional Principle which implies that: two e entities are identical if they have the same parts

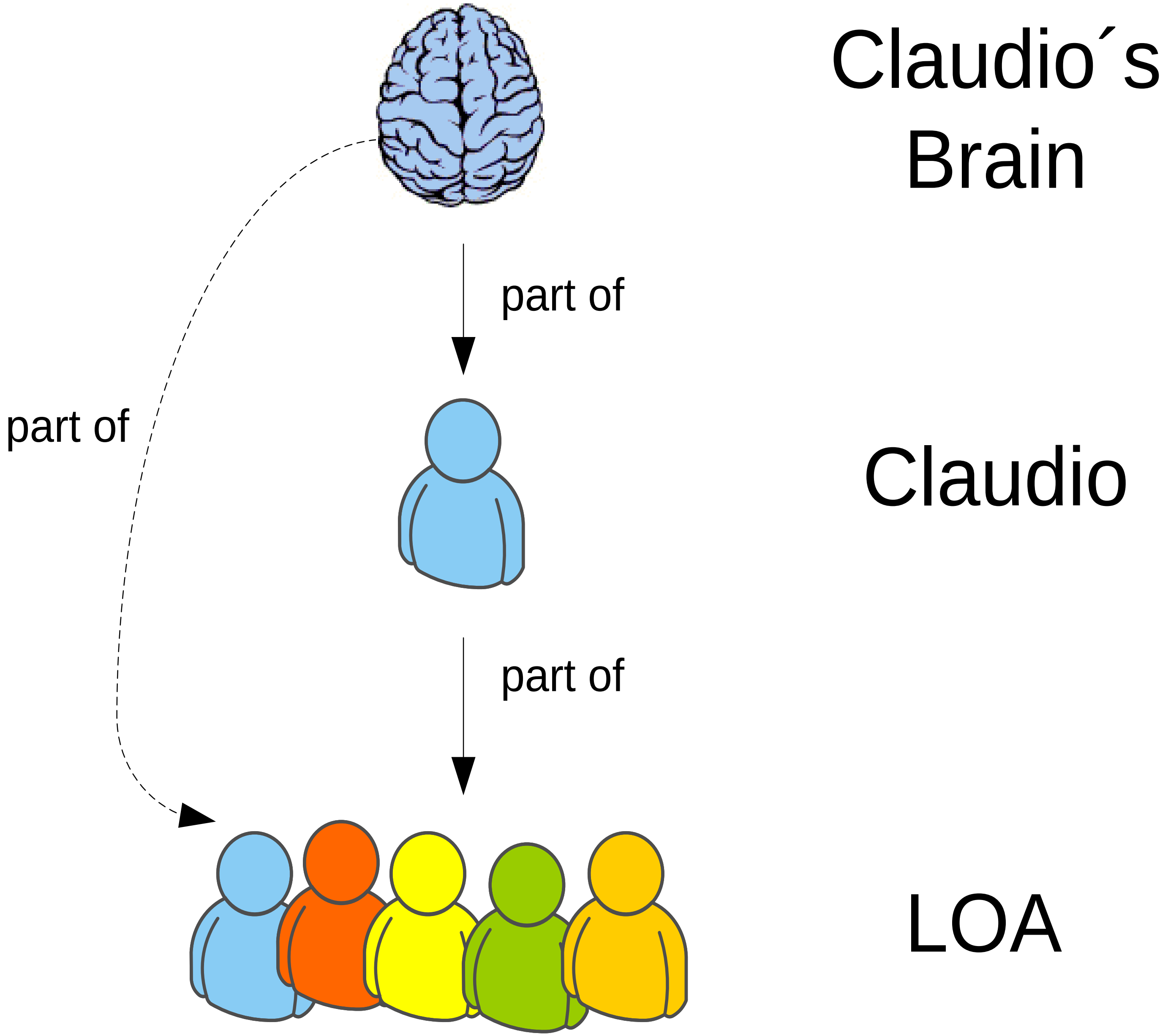
$$((x=y) \leftrightarrow \forall z\ ((z < x) \leftrightarrow (z < y)))$$

Problems from a Conceptual Modeling point of view

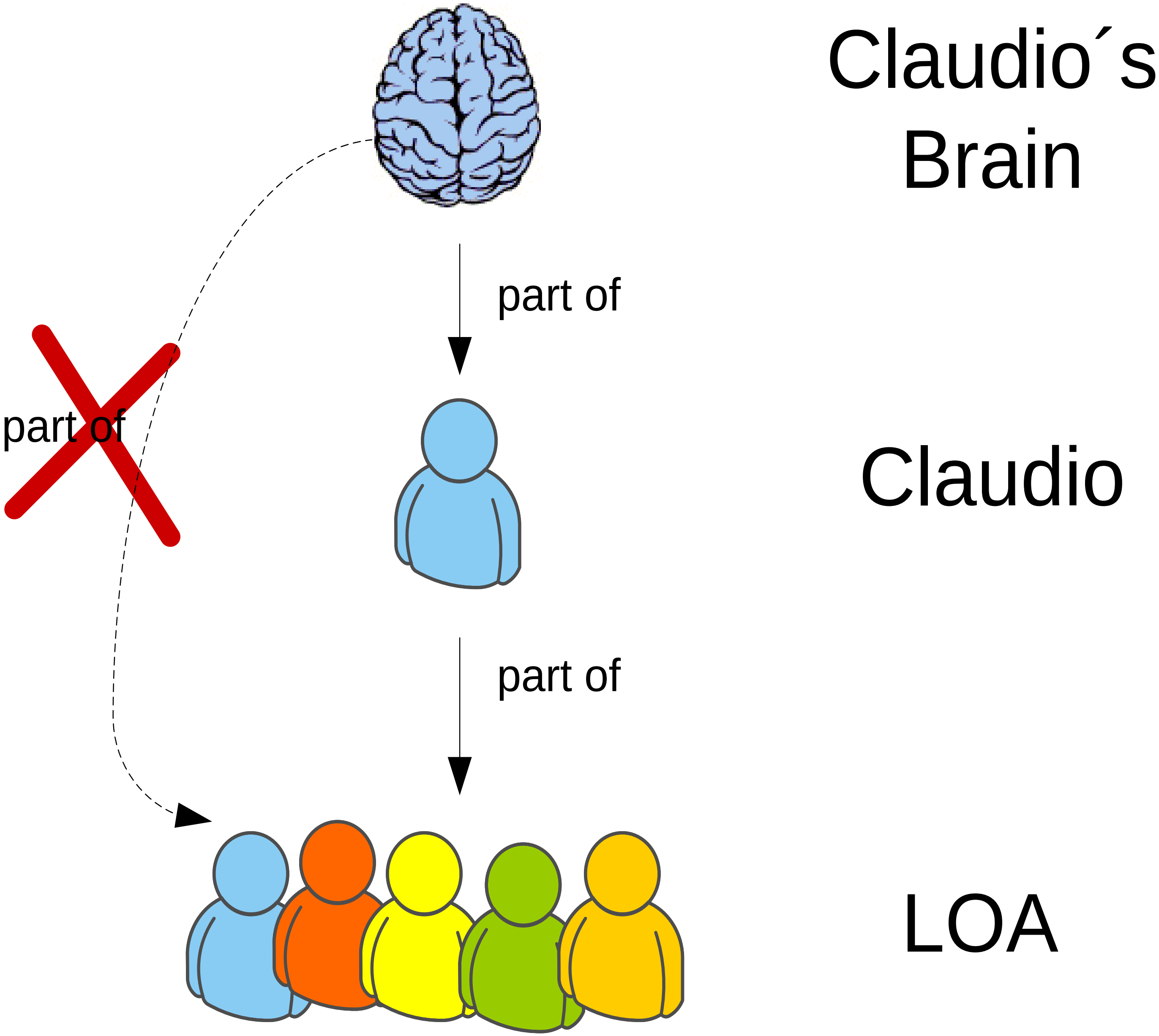
- Ground Mereology
  - Unrestricted transitivity of parthood



Claudio
part of
part of
LOA
part of
ISTC

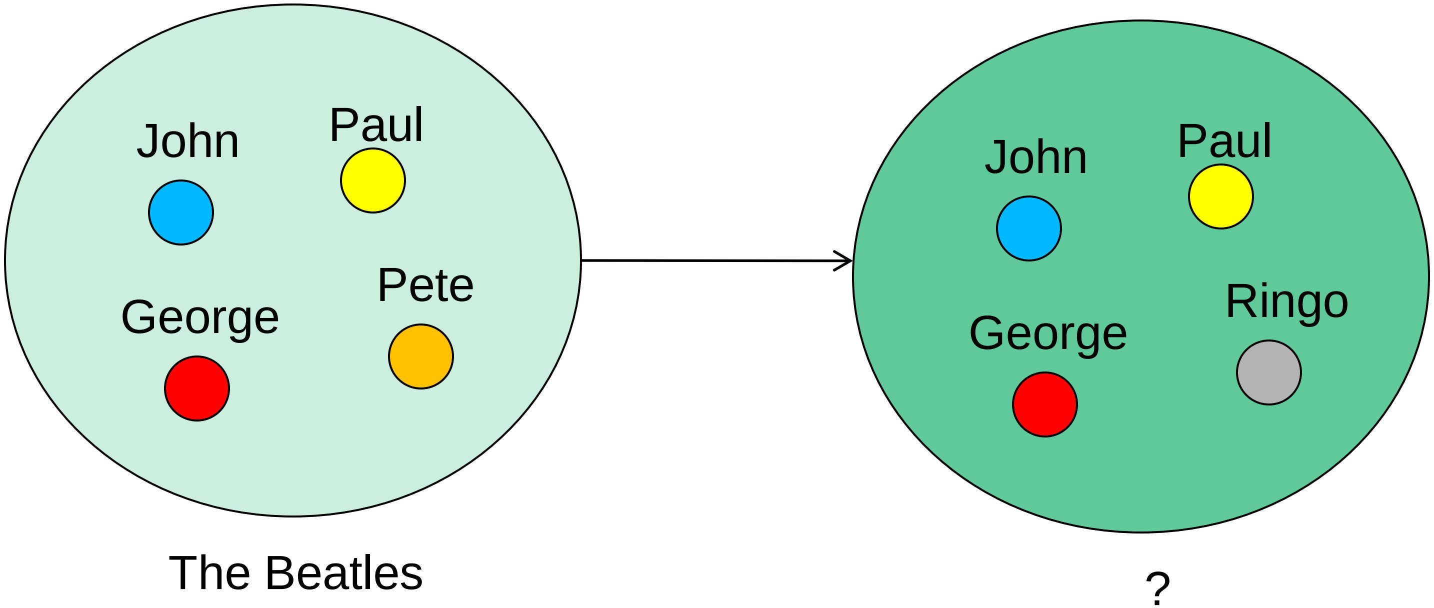


Claudio´s
Brain
part of
part of
Claudio
part of
LOA


Claudio´s
Brain
part of
part of
Claudio
part of
LOA

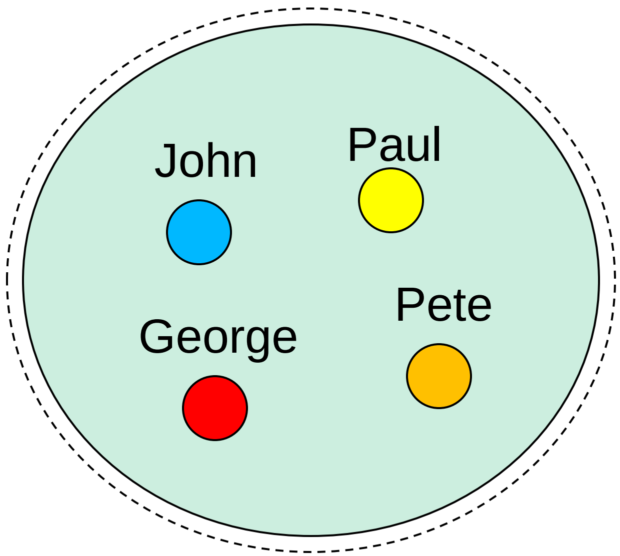
Problems from a CM point of view

- Extensional Mereology
  - Extensional Principle of Identity which makes all parts of an entity as *essential parts*
  - In other words, every object is defined by the sum of its. Thus, we have that:
    - (i) The change of any of the parts changes the identity of the object



Problems from a CM point of view

- Extensional Mereology
  - Extensional Principle of Identity which makes all parts of an entity as *essential parts*
  - In other words, every object is defined by the sum of its. Thus, we have that:
    - (ii) Two objects are the same if and only if they have the same parts



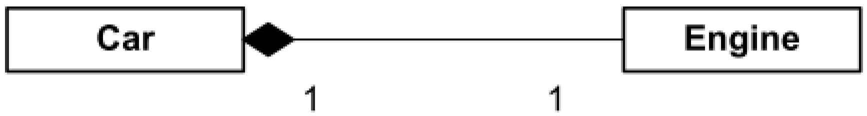
The Beatles = The Liverpool Indoors Football Team

Problems from a CM point of view

- Extensional Mereology
  - Failure to take into account the different roles that parts play within the whole. In other words, not all parts have the same importance with respect to the whole: some parts are optional, some parts can be replaced by others of the same kind, some parts cannot be replaced without causing the entity to change its class. Finally, some parts cannot be replaced at all, i.e., without altering the identity of the whole

Problems from a CM point of view

- Extensional Mereology
  - There are other meta-properties that can be used to qualify the relation between parts and wholes. An common one is the distinction between shared or non-shared parts.



Problems from a CM point of view

- Extensional Mereology
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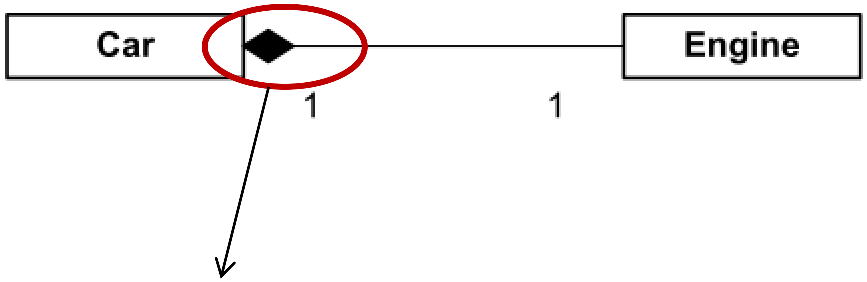


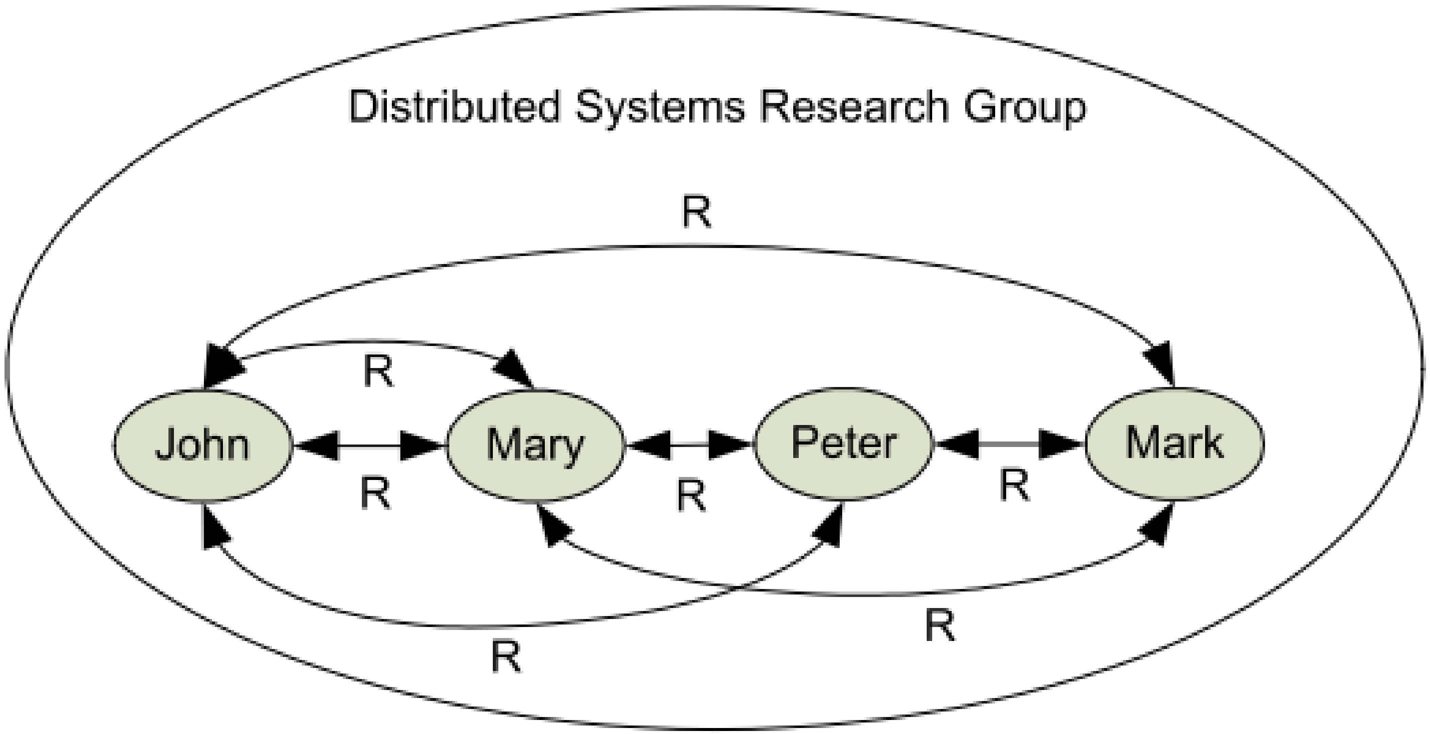
•The other representations of parthood in UML is termed Composition
•The black diamond is connected to the whole
•Composition is supposed to be a irreflexive, anti-symmetric and transitive relation
•It is also suppose to imply non-shareability of parts and lifetime dependence from the part to the whole
•As we will see, the notions of non-shareability, lifetime dependence and transitivity are orthogonal!

Problems from a Conceptual Modeling point of view

- In general, mereological theories treat aggregates (wholes) roughly as *sets of entities*
- As a consequence, the conditions that bind all the parts of a whole together are minimal. Thus, a whole formed by any arbitrary sum of entities is considered as good as any other (e.g., the aggregate of number 3, van Gogh's ear and the third act of Turandot)
- However, humans only accept the aggregation of entities if the resulting aggregate plays some role in their conceptual schemes, i.e., if the wholes they form represent genuine categories
- We need then genuine unifying (characterizing) relations for ***Integral Wholes***

Integral Wholes

- We must complement mereology (the theory of parts) with a *theory of wholes*, in which the relations that tie the parts of a whole together are also considered.



Not one but several parthood relations

- Studies in Cognitive Science and Linguistics have shown that we do not have a single notion of part, but multiple parthood relations forming different types of aggregates
  - (a) Quantities
    - *Subquantity of* (alcohol-wine)
  - (b) Collectives
    - *Member of* (a specific tree – the black forest)
    - Subcollective of (the north part of the black forest – the black forest)
  - (c) Functional Entities
    - *Component of* (heart-circulatory system)

Not one but several parthood relations

- These different notions of part are neither orthogonal to the previously mentioned mereological axioms nor to the different meta-properties that can be applied to part-whole relations. Moreover, different notions of parts are related to different sorts of unifying relations

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