

Formal Semantics and Ontological Analysis for Understanding Subsetting, Specialization and Redefinition in UML

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Goals

- To explain the specific characteristics of the three constructs.
- To provide a non-ambiguous real-world semantics to them.
- To provide some methodological guidelines for helping conceptual modelers to choose the best construct for a specific domain problem.

Presentation Outline

- Motivation
- Related Work
- Formal Semantics for Association Specialization, Subsetting and Redefinition in UML
- Ontological Analysis for Association Specialization, Subsetting and Redefinition in UML
- Final Considerations

Motivation

It seems also to be generally accepted that redefinition, specialization and subsetting of associations still need to be studied in more detail.

- *"The distinction between subsetting and specializing on association is not clearly described in the UML 2.0 specification"* [RJB05].
- *"Further research is needed to cover some important aspects related to association semantics such as association redefinition, association generalization/specialization and subsets/unions of association ends"* [Mil07].

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Related Work

	Reference	Subset	Spec	Red	Semantic domain	Ontological analysis
Informal definition	Stevens (2002)	X	✓	X	-	X
	Milicev (2009)	✓	X	✓	-	X
	Costal et al (2006)	X	X	✓	-	X
	Olivé (2007)	✓	✓	✓	-	X
Semantics formalization	Alanen et al (2006)	✓	X	X	Set theory	X
	Kleppe et al (2008)	✓	X	✓	Graphs	X
	Amelunxen et al (2008)	✓	✓	✓	Set theory	X
	Bildhauer (2010)	✓	✓	✓	Set theory	X
	Our work (2011)	✓	✓	✓	Basic UML Layer	✓

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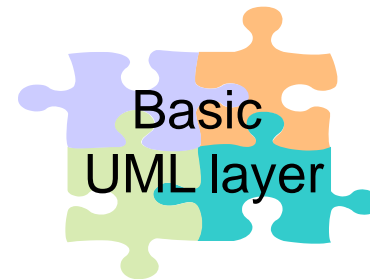
Formal Semantics for Association

Specialization, Subsetting and Redefinition in UML: Semantics

- A semantic domain must be defined
- Our semantic domain: basic UML layer
 - Classes, Binary associations, Multiplicities, Class generalization/specialization, OCL constraints
- Mapping between a generic schema with the construct and another generic schema using only concepts of the semantic domain



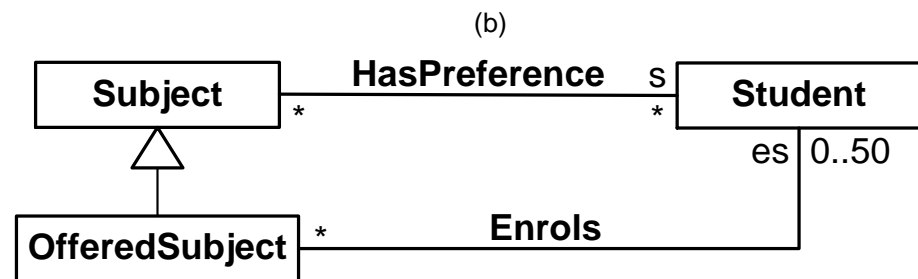
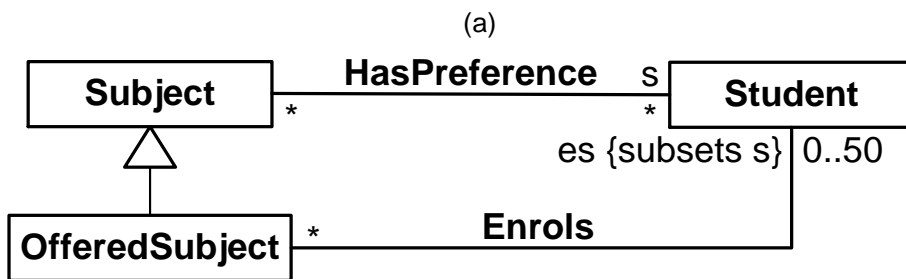
Semantics of the construct



Formal Semantics for Association Subsetting

Subsetting translation definition:

- 1) To eliminate from the schema the adornment which denotes that the subsetting end b1 subsets the subsetted end b
- 2) To attach to the schema the OCL expression:
context A1 inv: self.b ->includesAll(self.b1)

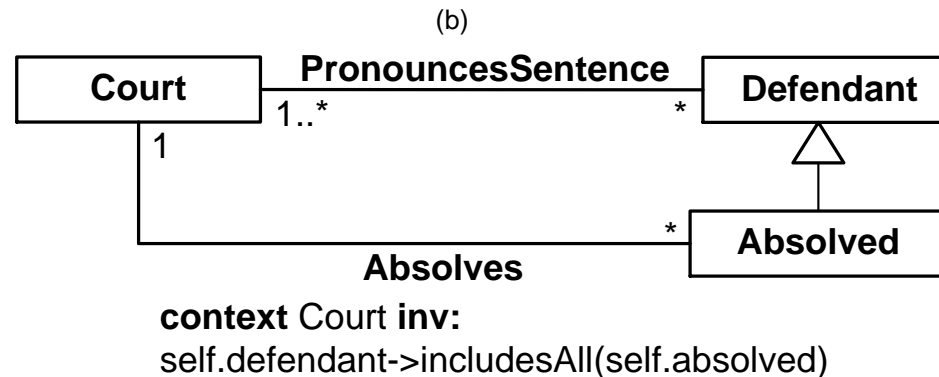
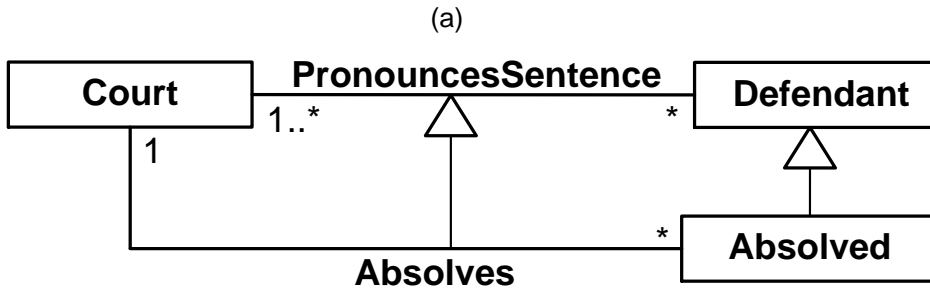


context OfferedSubject inv:
self.s->includesAll(self.es)

Formal Semantics for Association Specialization

Specialization translation definition:

- 1) To eliminate from the schema the specialization symbol that relates the two associations
- 2) To attach to the schema the OCL expression:
context A1 inv: self.b ->includesAll(self.b1)



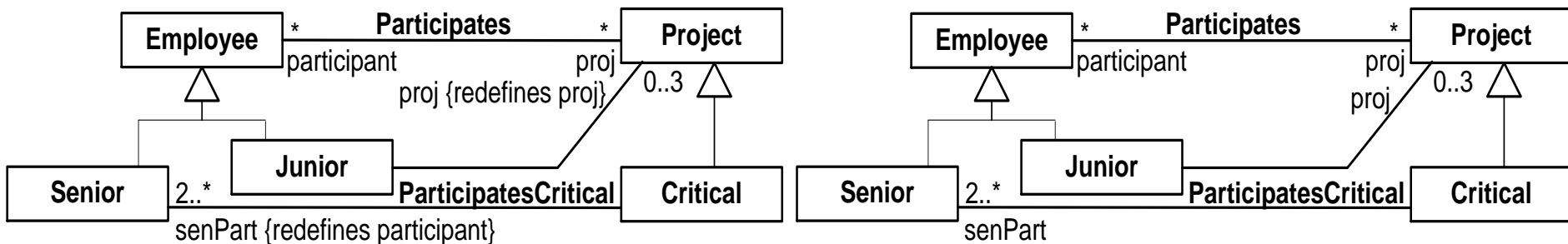
Formal Semantics for Association Redefinition

Redefinition translation definition:

- 1) To eliminate from the schema the adornment which denotes that the redefining end b1 redefines the redefined end b
- 2) To attach to the schema the OCL expression:

context A1 inv: self.b = self.b1 in case b name \neq b1 name

context A1 inv: self.oclAsType(A).b = self.b1 in case b name = b1 name



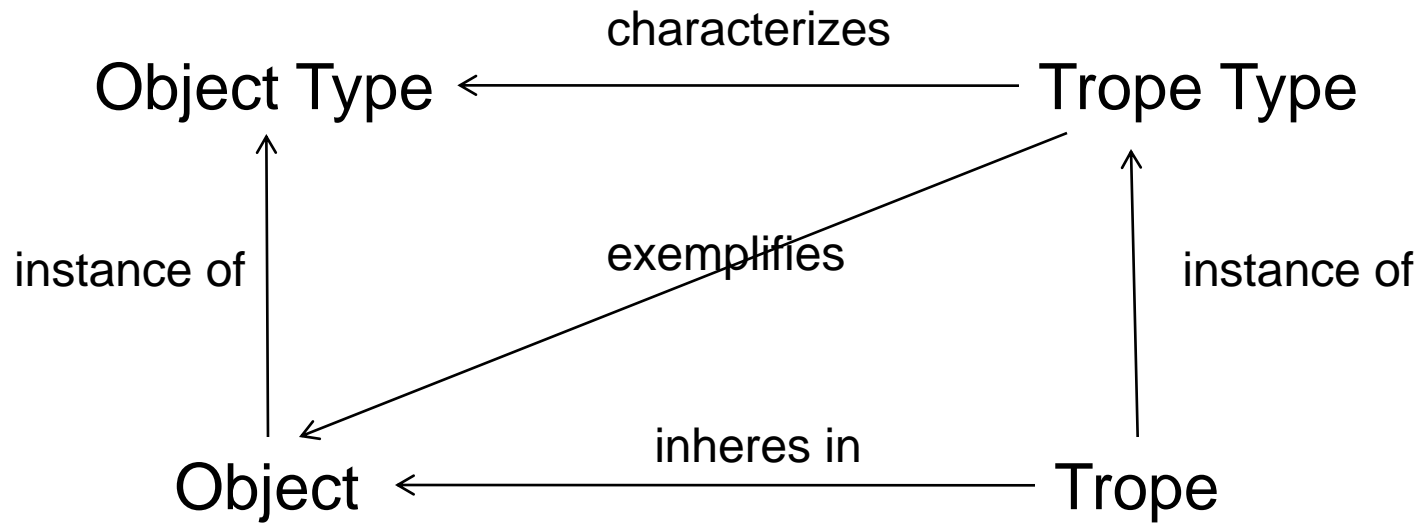
context Junior inv: self.oclAsType(Employee).proj = self.proj

context Critical inv: self.participant = self.senPart

Comparing the three constructs

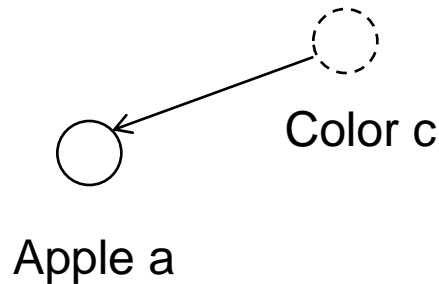
		Subsetting	Specialization	Redefinition
Syntactic	Specified for	Association end	Association	Association end
	Rules for association end classes	Descendant or same classes	Descendant or same classes	End opp. redefining end: desc. class Redefining end: desc. or same class
Sem.	Inclusion constr.	Yes	Yes	Yes
	Induced constr.	Min. card.	Min. card.	Participation Min. & max. card.

A Four Category Ontology



Objects x Tropes

- A trope is an entity that can only exist in another individual, i.e., every trope is *existentially dependent* on some other individual (e.g. a charge in a conductor, the color of a fruit, a flight connection, a kiss)



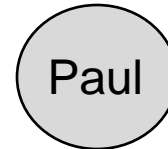
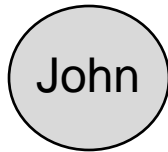
- In this case, the color c of an apple a is not a specific color value (e.g., red), it is the objectification of that property (characteristic, feature) of that specific apple a

Intrinsic and Relational Tropes

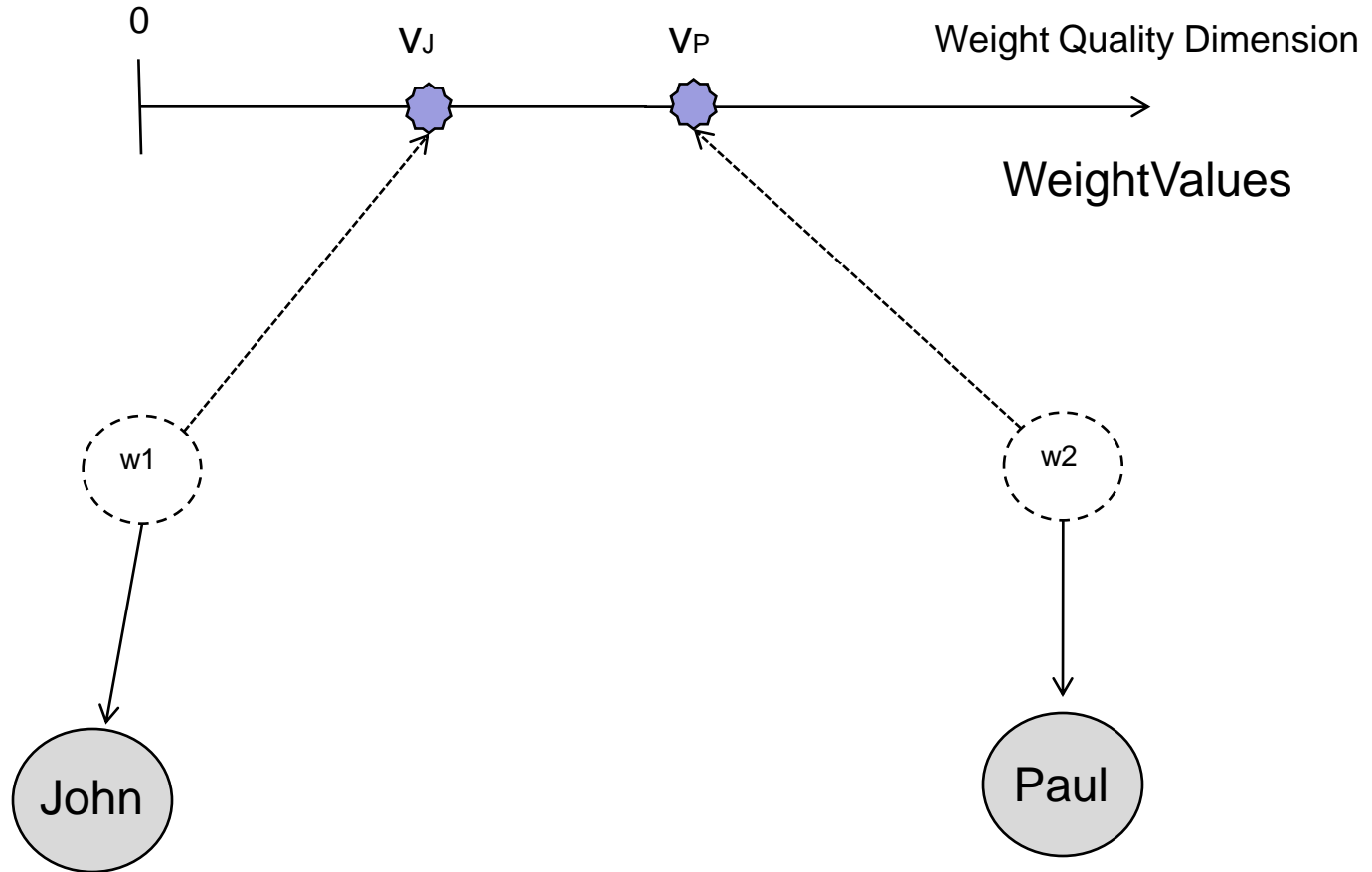
- Existential Dependence also provides a criterion for distinguishing between two sorts of tropes:
 - (a) Intrinsic Tropes or Qualities: an individualized (objectified) color, temperature, or weight, a symptom, a skill, a belief, an intention, an electric charge;
 - (b) Relational Moments or Relators: a covalent bond, a medical treatment, but also social objects such as an enrollment, an employment, a purchase order and a commitment or claim.

Formal Relations

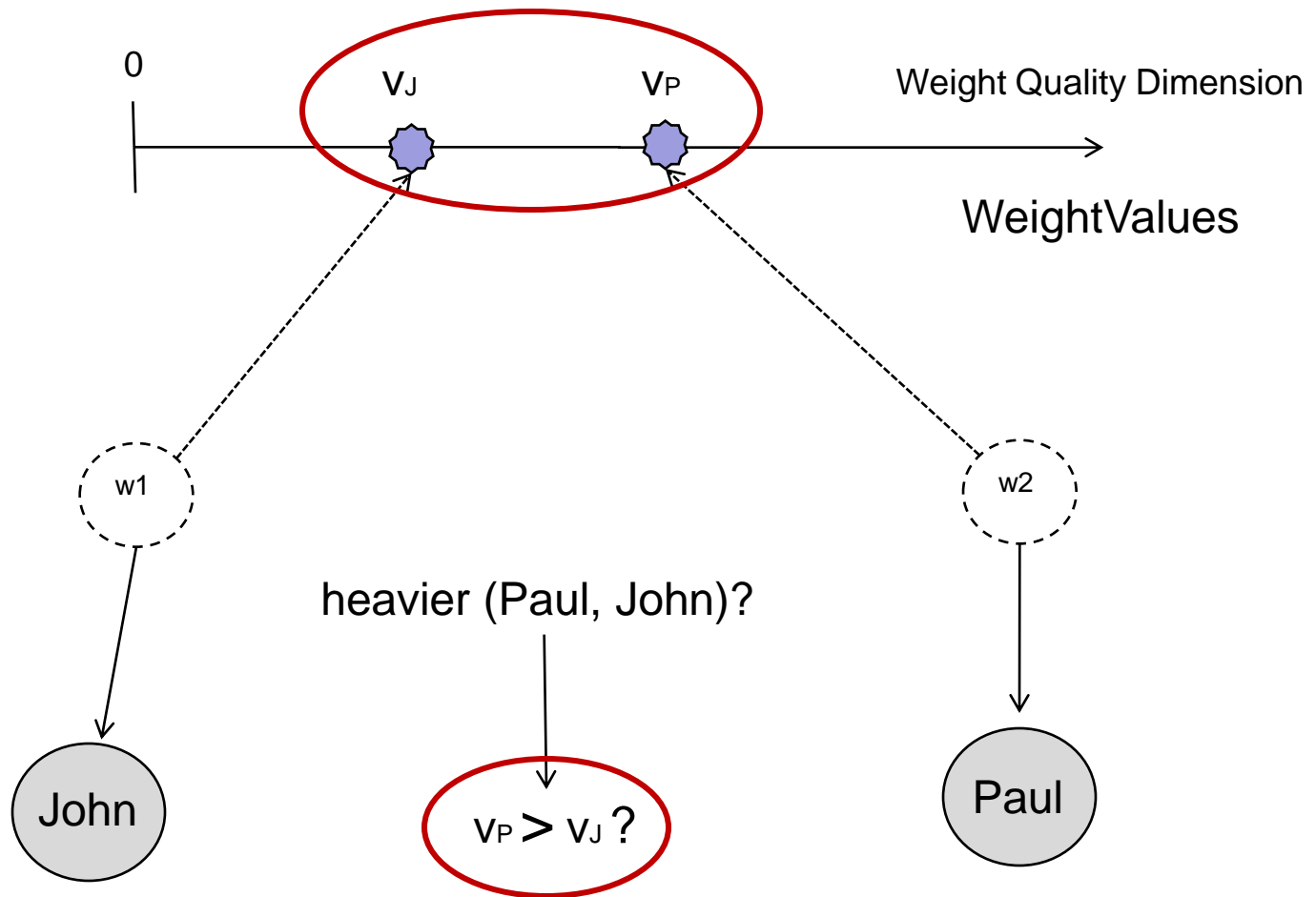
heavier (Paul, John)?



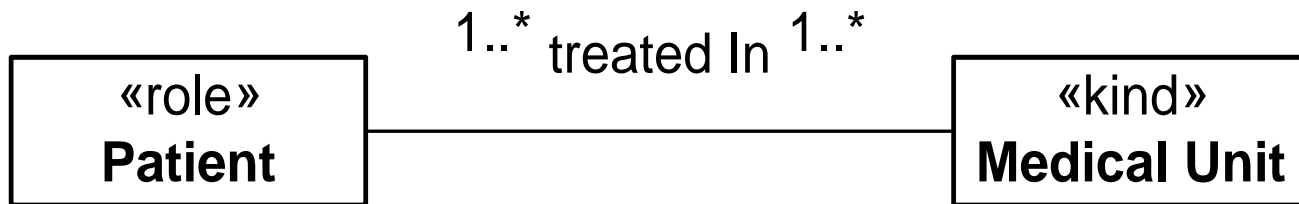
Formal Relations



Formal Relations



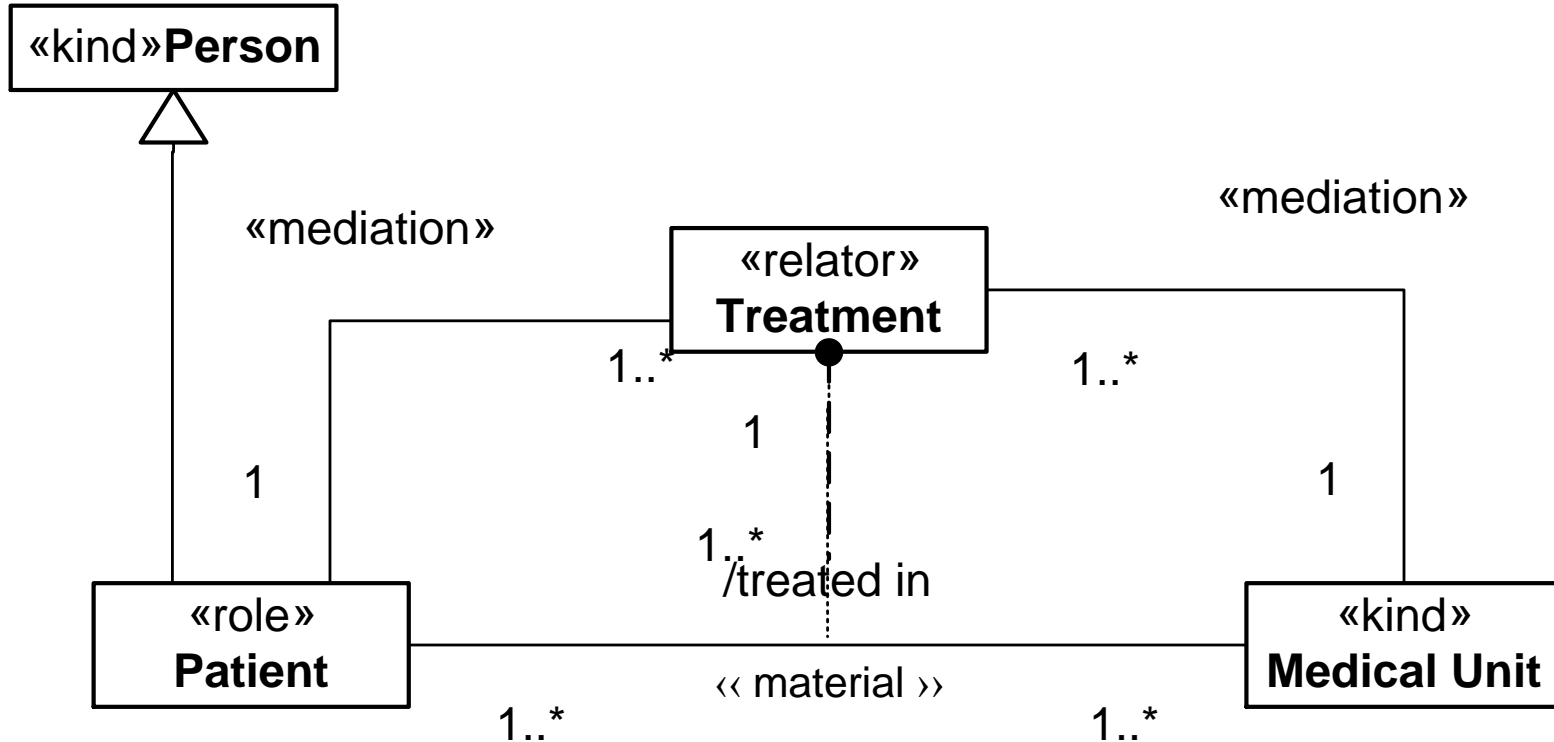
Material Relations



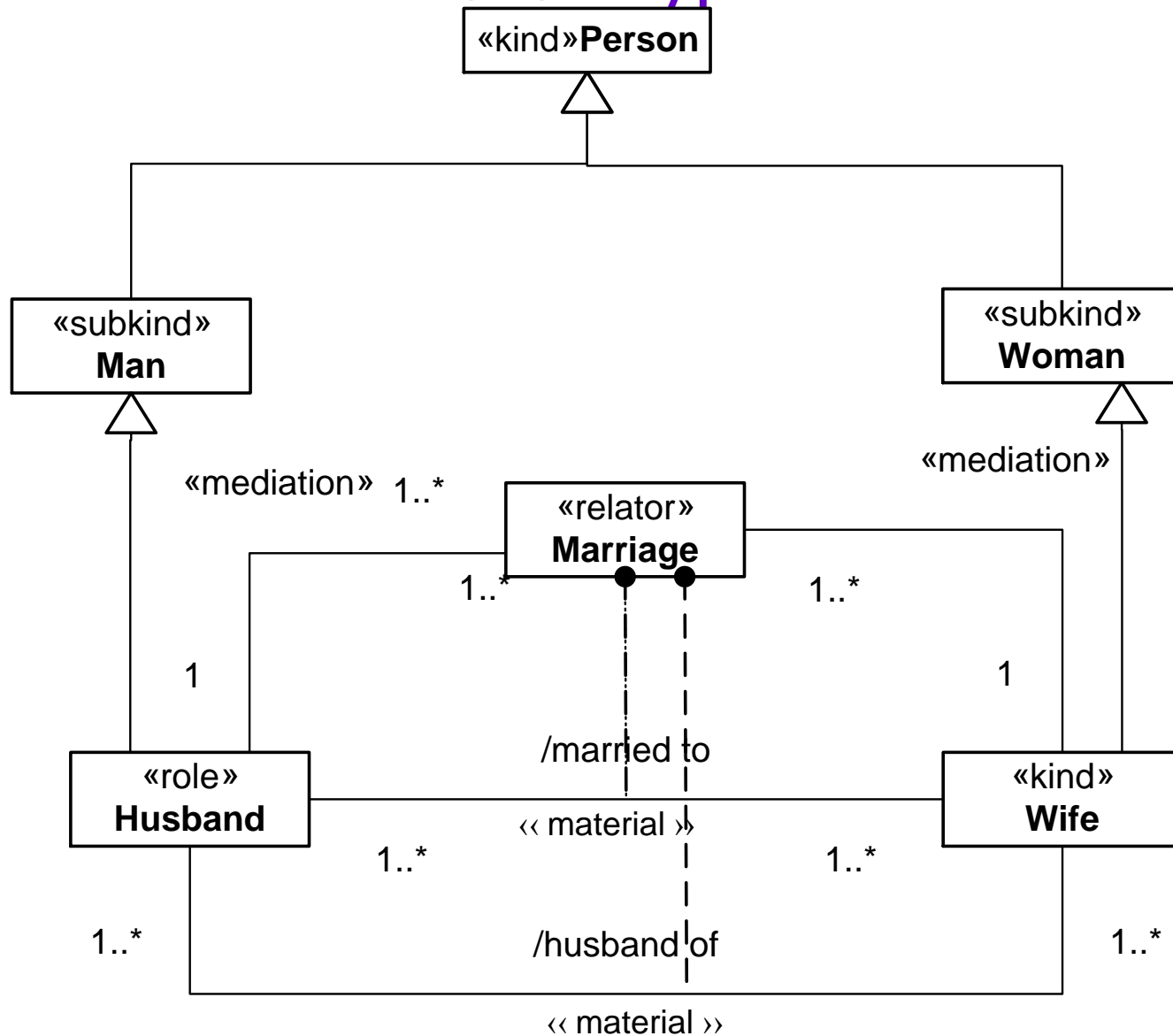
Material Relations

- How are these cardinality constraints to be interpreted ?
 - In a treatment, a patient is treated by several medical units, and a patient can participate in many treatments
 - In a treatment, a patient is treated by several medical units, but a patient can only participate in one treatment
 - In a treatment, several patients can be treated by one medical unit, and a medical unit can participate in many treatments
 - In a treatment, a patient is treated by one medical unit, and a patient can participate in many treatments
 - ...

Relators and Derived Material Relations



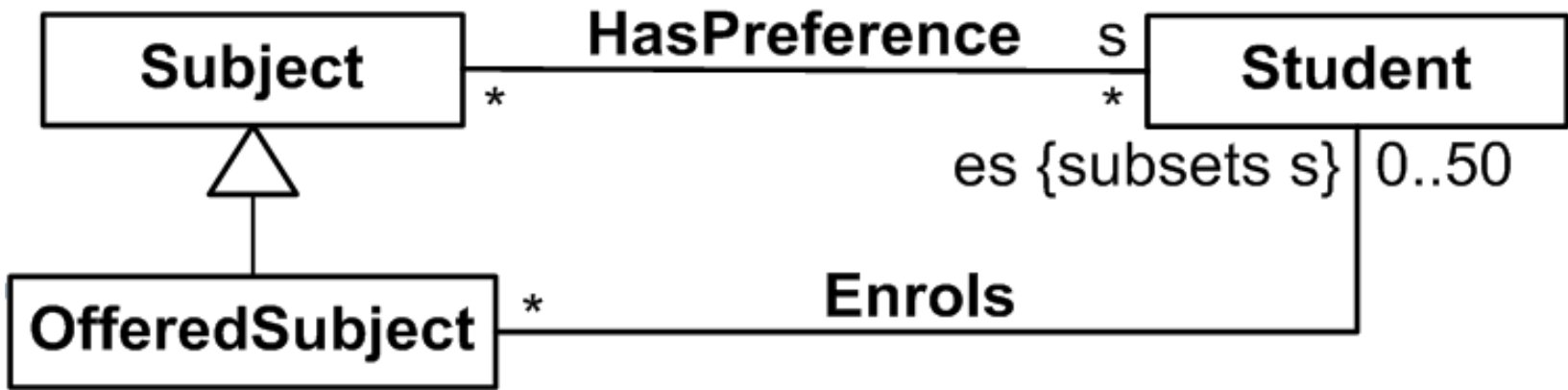
Material Relations derived from the same Relator Type



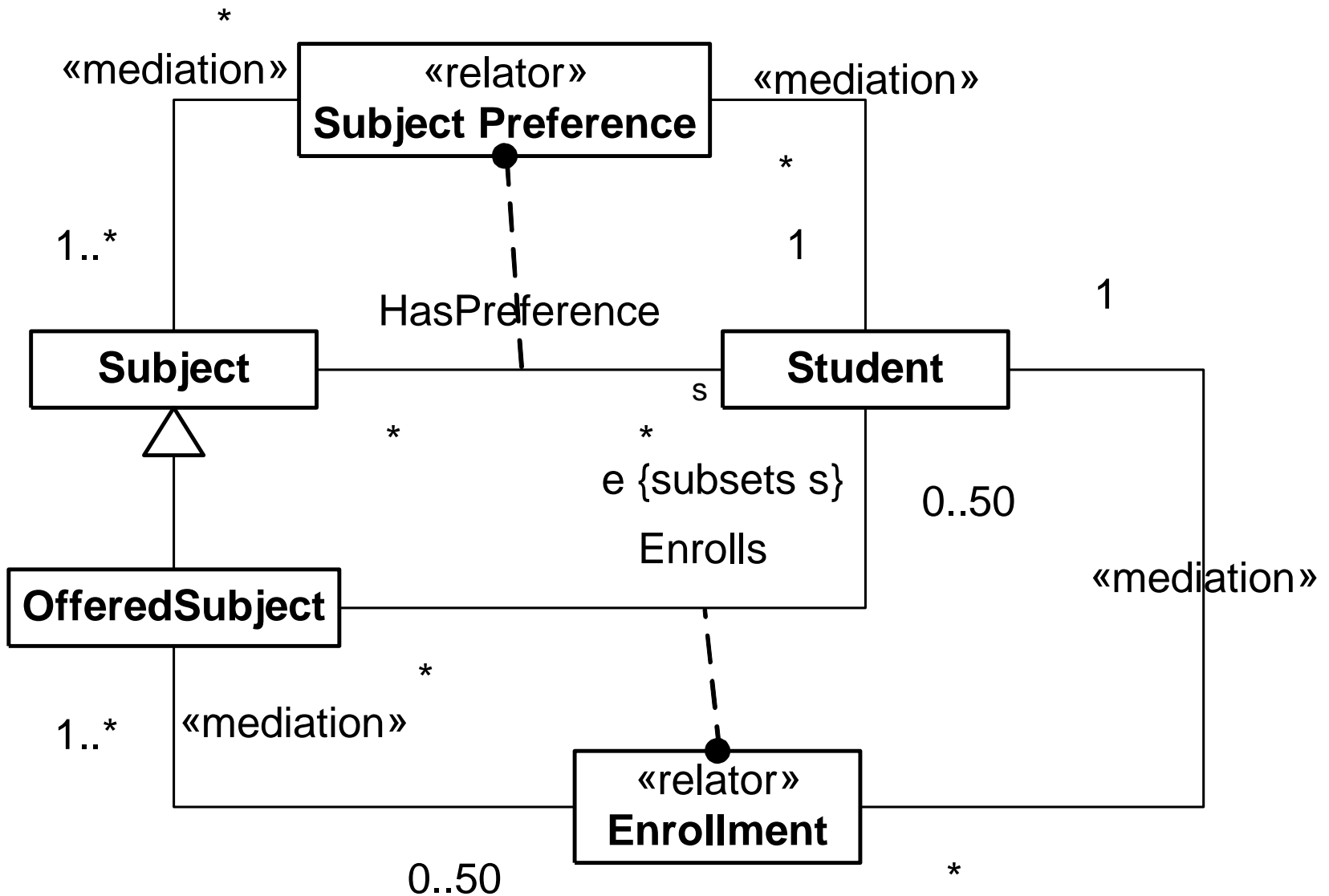
Material Relations

- As seen before from a relator and mediation relation we can derive several material relations
- Besides from all the benefits previously mentioned, perhaps the most important contribution of explicitly considering relations is to force the modeler to answer the fundamental question of what is *truthmaker* of that relation

Subsetting



An Ontological Analysis of Subsetting



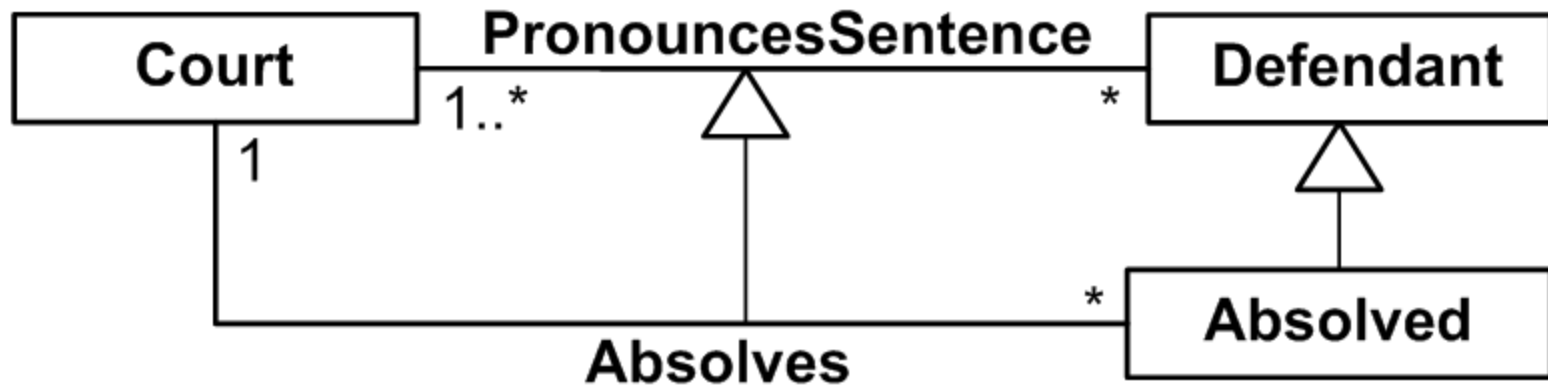
Subsetting: Ontological Semantics

- The two relations in this model are derived from relator types of different kinds and are based on different foundational events
- There is no necessary connection between the truthmakers of these two relations.
 - It is just a matter of accident that the extension of *Enrolls* is included in the extension of *HasPreference*
 - One can easily imagine an alternative conceptualization of this domain in which this constraint is abandoned, i.e., in which students are allowed to enroll in Subjects regardless of their manifested preferences.

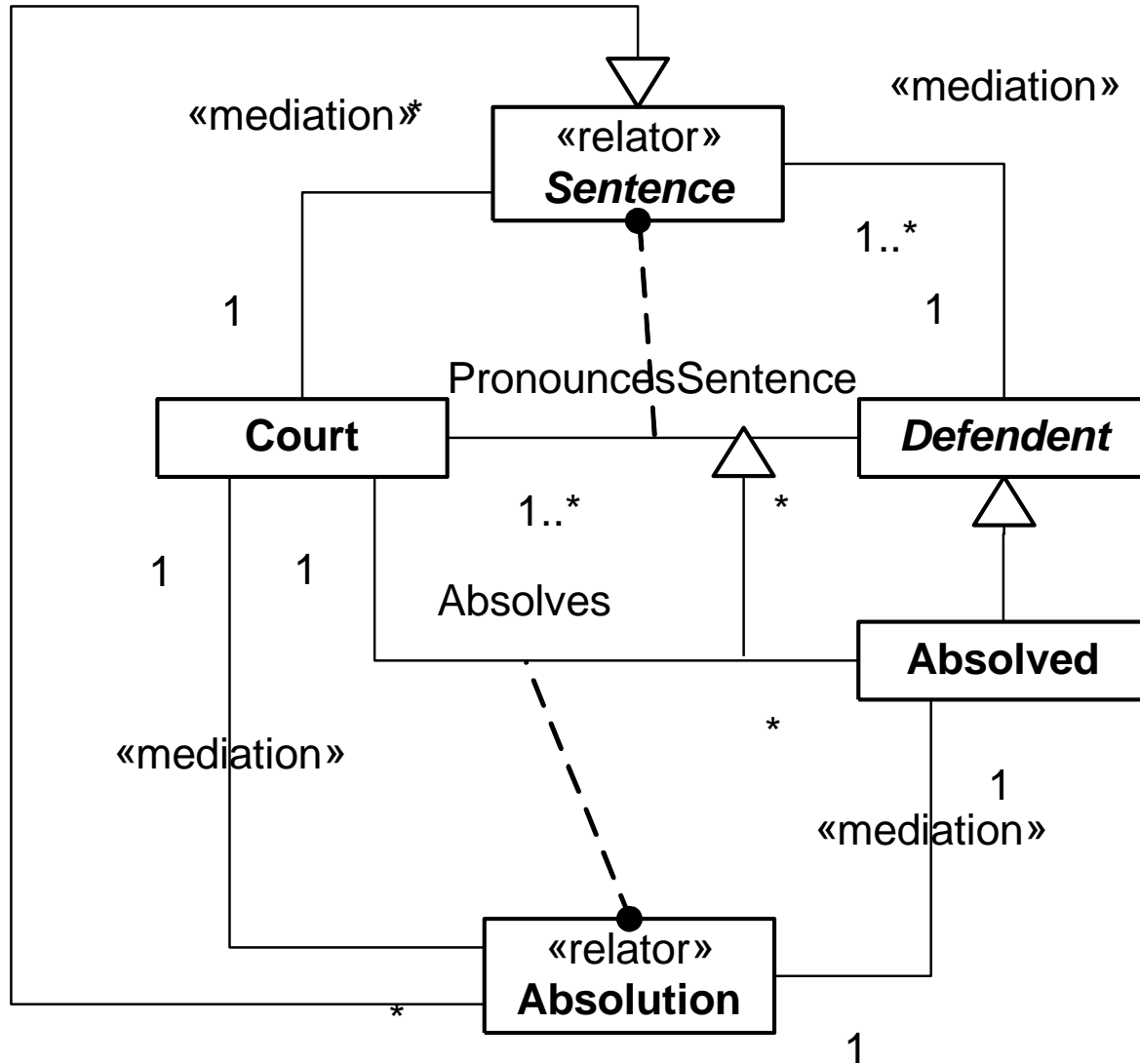
Subsetting: Ontological Semantics

Postulate 1: *a subsetting relation should be defined between two material relations $R2$ and $R1$ ($R2$ _{subsets} $R1$) iff these relations are derived from relators of disjoint kinds and there is an inclusion constraint that includes the extension of $R2$ in the one of $R1$.*

Association Specialization



An Ontological Analysis of Specialization



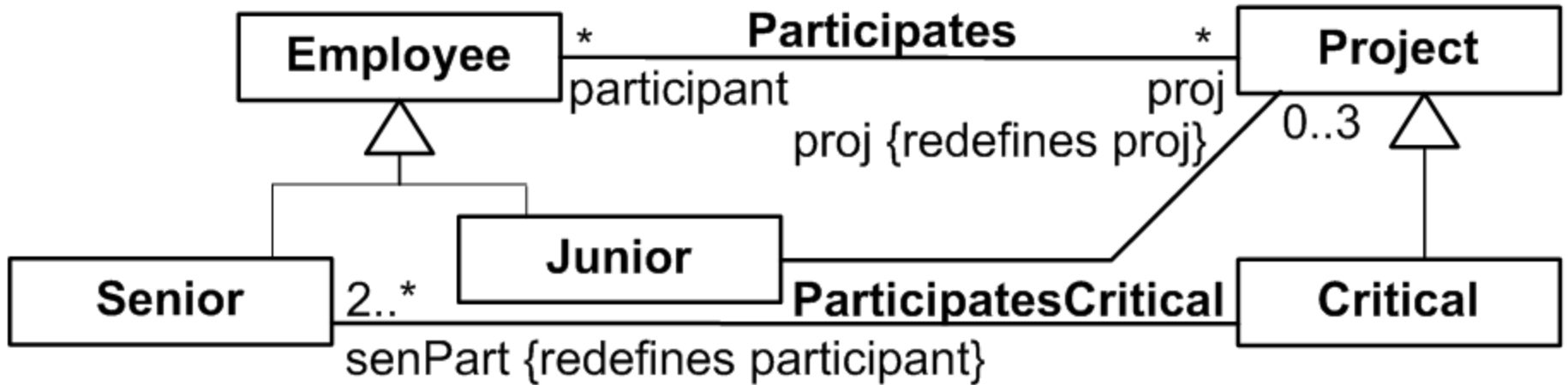
Specialization: Ontological Semantics

- The Relator of PronouncesSentence (i.e., a sentence) is an abstract one. In other words, there is no general instance of *Sentence* which is not one of its specific kinds (e.g., Conviction, Absolution).
- We have that the relator type associated with the Absolves relation, i.e., Absolution, is a specialization of the Sentence relator type. In other words, to be absolved is a specific kind of being sentenced.
- In contrast with subsetting, in the case of specialization, we clearly have an intentional relation between types: an absolution has all the properties of a general sentence (e.g., date of pronounciation) and it is founded on the very same individual event (the sentence pronounciation).

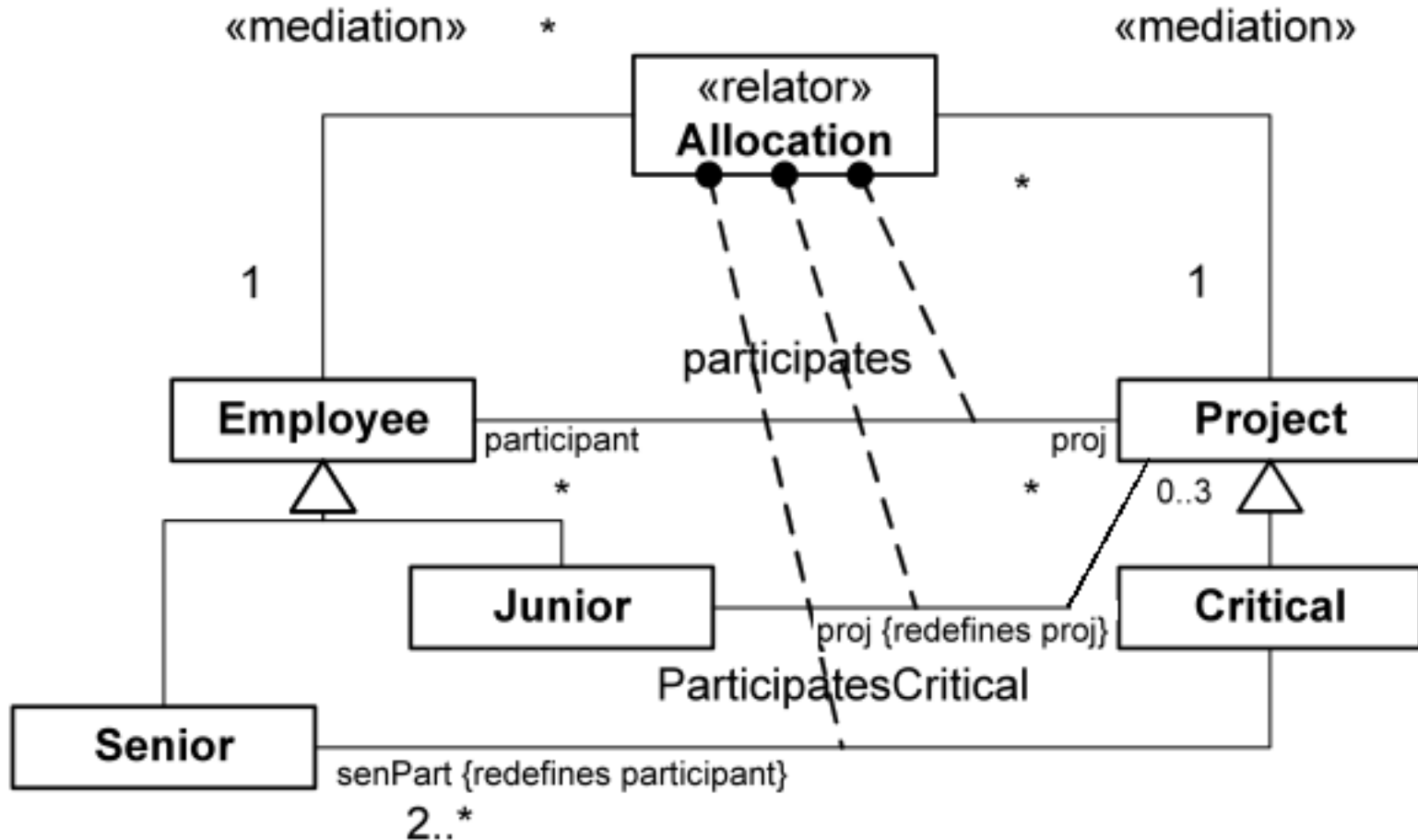
Specialization: Ontological Semantics

Postulate 2: *a specialization relation should be defined between two material relations R_2 and R_1 (R_2 subsets R_1) if these two relations are derived from relator types RR_1 and RR_2 such that RR_2 specializes RR_1 (RR_2 specializes RR_1).*

Association Redefinition



An Ontological Analysis of Redefinition



Redefinition: Ontological Semantics

- We have that all these relations are derived from the same relator type and the same foundation, namely, an allocation event and the resulting *Allocation* contract.
- In the situation represented by this model, the different ways of participating in a project (which entail the different relations of participation) are defined by the different types associated with the association end opposite to the redefining end of these relations
- In other words, the differences in the ways a Junior or Senior Employee participate in a Project are motivated by *difference in properties of these different types of Employees not by difference in different types of Allocation*

Redefinition: Ontological Semantics

- Notice that one instantiates Junior Employee (the specializing class) prior to establishing any relation to a Project, i.e., the nature of this relation is constrained by the specific type one instantiates
- In contrast, if one examines the specializing type Absolved, one shall realize that an individual instantiates Absolved *because* of the specific type of Sentence that mediates him. Thus, in that case, it is the specific type this individual instantiates which is determined by the specific nature of the relator that mediates him

Redefinition: Ontological Semantics

- In the case of redefinition, the type the relata (instances connected to the association end) instantiate is defined *a priori* and the participation constraints in the relation follows from that;
- In the case of specialization, the type the relata instantiates in that relation is defined *a posteriori* entailed by the type of relator binding them.
- Notice that this also explains the cardinality restriction which is typical of redefinition

Redefinition: Ontological Semantics

Postulate 3: *a redefinition relation should be defined between two material relations R_2 and R_1 (R_2 redefines R_1) if: (i) these two relations are derived from the same relator type RR ; (ii) there is a type A_1 connected to one of the association ends of R_2 such that A_1 is a specialization of A and A is connected to the association end of R_1 equivalent to that of A_1 .*

Final Considerations

- Two fundamental quality attributes for a conceptual modeling language are:
 - (i) semantic discrimination, i.e., users of the language must understand the semantic distinctions between language's constructs and the semantic consequences of applying these constructs;
 - (ii) ontological clarity: the users of the language must understand what these constructs represent in terms of phenomena in reality.
- In this paper, we make a contribution in both these directions by specifying the formal semantics and the (ontology-based) real-world semantics of three important, yet poorly understood, UML association constructs

Final Considerations

- The solution proposed here is founded on a theory which is part of much larger ontological theory.
- The theory together with the modeling postulates derived from it constitute a *descriptive theory for explaining and predicting*, as well as a *prescriptive theory for design and action*