On the Meanings of Subsetting, Specialization and Redefinition in UML

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Introduction

Associations (also termed relationship types or simply relations) are central structural elements in conceptual modelling, in general, and in UML, in particular. UML 2 has improved the expressiveness of the language with respect to associations in several manners. A significant one has been the introduction of the association redefinition concept. This concept allows enhancing the definition of an association by means of another association that defines it more specifically in a particular context. Association subsetting and association specialization have been included in UML since its earliest versions and share some relevant features with association redefinition. These similarities among the three constructs make it frequently difficult, especially to novice users, to: decide which one of these concepts is the best suited to model a particular situation; systematically justify their modelling choices.

In this report, we present a preliminary empirical investigation on these constructs using as a benchmark a catalogue of model examples produced by different authors which can be considered experts in the conceptual modelling field.

For each example: 1) an ontological analysis has been performed; 2) the analysis has been used to predict which one of the three constructs should be the modelling choice of the author; and 3) our prediction has been compared to the actual choice of the author.

The ontological analysis of the examples focuses on the relator types of the involved associations and discriminates three cases: 1) the relator types are different (in that case we postulate that a subsetting should be defined if there is an inclusion constraint between their extensions); 2) one relator type specializes the other (we postulate a specialization for this case); and 3) their relator type is the same (redefinition).

The sources used to obtain the examples have been:
Our investigation focuses on subsetting, specialization and redefinition of associations over base (non-derived) associations. Therefore, we have taken all the examples from the previous references where one or more of the three constructs has been used for non-derived associations. Those cases where the constructs are combined with derived associations or those where subsetting is combined with a derived union have been discarded. Then, we have selected 10 examples out from the 4 source references used. In the following, we describe the study of each example and, finally, we give some conclusions.

Example 1


Figure:

Description from the source:

This diagram shows two classes: Vertex and Edge, and four properties: from, to, outgoing and incoming. Each property has another property as its opposite. Together they define an association that is represented as a single line. In the example, we have the from-outgoing and the to-incoming associations.

…The classes Blue Vertex and Red Vertex will now be specializations of Vertex. Also, the fromRed and toBlue properties will become subsets of the from and to properties, and similarly for the other properties. …The intuition behind the metamodel is as follows: an element of type Red Vertex has four slots that correspond to properties outgoing, incoming, outgoingRB and incomingBR. Elements of type Edge can be inserted into the outgoing or incoming slot and elements of type RedBlue
Edge can also be inserted into outgoingRB. At any moment, the contents of the slot outgoingRB should be a subset of the contents of the slot outgoing.

Constructs according to source:
- Association toRed-incomingBR and association to-incoming: association subsetting
- Association fromRed-outgoingRB and association from-outgoing: association subsetting
- Association fromBlue-outgoingBR and association from-outgoing: association subsetting
- Association toBlue-incomingRB and association to-incoming: association subsetting

Ontological analysis:

Independently of the colour of vertexes, the relations that connect a vertex with an outgoing edge are derived from the same relator OutConnection. Similarly, the relations that connect a vertex with an incoming edge are also derived from the same relator InConnection. In other words, the different ways of connecting vertexes and edges represented by the associations of the example are motivated by the vertex colour not by difference in different types of OutConnection or InConnection. Therefore:
- Association toRed-incomingBR and association to-incoming: their relator type is the same.
- Association fromRed-outgoingRB and association from-outgoing: their relator type is the same
- Association fromBlue-outgoingBR and association from-outgoing: their relator type is the same
- Association toBlue-incomingRB and association to-incoming: their relator type is the same

Constructs according to the ontological analysis:

According to the ontological analysis above the construct that relates the associations are not subsettings as specified in the original example but redefinitions.

- Association toRed-incomingBR and association to-incoming: association redefinition
- Association fromRed-outgoingRB and association from-outgoing: association redefinition
- Association fromBlue-outgoingBR and association from-outgoing: association redefinition
- Association toBlue-incomingRB and association to-incoming: association redefinition

Example 2


Figure:
Description from the source:

RIM comprises …backbone classes: Act, Participation, Entity, Role… Figure … shows a few refinements related to the ActAppointment class. The instances of this class are appointments (a particular kind of Act). There may be several kinds of participations in an appointment. Figure … shows only two of them: PerformerOfActAppointment and SubjectOfActAppointment. …The overall semantics of these redefinitions is that the performer of an appointment is a Person that plays the role AssignedPerson and that the subject of an appointment is a Person that plays the role Patient. …Figure … also shows the redefinitions of associations player-playedRole and scoper-scopedRole between Entity and Role. The player and the scoper of an AssignedPerson and of Patient must be a Person and an Organization, respectively.

Constructs according to source:

- Association player-playedRole and association assigned-assignedPerson: association redefinition
- Association player-playedRole and association patient-patient: association redefinition
- Association scoper-scopedRole and association represented-assignedPerson: association redefinition
- Association scoper-scopedRole and association provider-patient: association redefinition
- Association role-participation and association assignedPerson-performerOfActAppointment: association redefinition
- Association role-participation and association patient-subjectOfActAppointment: association redefinition
- Association act-participation and association actAppointment-performerOfActAppointment: association redefinition
- Association act-participation and association actAppointment-subjectOfActAppointment: association redefinition

Ontological analysis:
- Association player-playedRole and association assigned-assignedPerson: their relator type is the same
- Association player-playedRole and association patient-patient: their relator type is the same
- Association scoper-scopedRole and association represented-assignedPerson: their relator type is the same
- Association scoper-scopedRole and association provider-patient: their relator type is the same
- Association role-participation and association assignedPerson-performerOfActAppointment: their relator type is the same
- Association role-participation and association patient-subjectOfActAppointment: their relator type is the same
- Association act-participation and association actAppointment-performerOfActAppointment: their relator type is the same
- Association act-participation and association actAppointment-subjectOfActAppointment: their relator type is the same

**Constructs according to the ontological analysis:**

The same constructs as the source states.
Example 3


Figure:

Description from source:
The association grouping specifies that a User Group, in general, can have an arbitrary number of Users as its members. However, an Administration Group, which is a special kind of User Group, can have only Administrators as its members, and at most five of them. Of course, an Administrator is also a kind of User. Note that an Administrator (being also a Person and a User) can still be a member of a general User Group because it has not be redefined the property owner.

Construct according to the source:
- Association grouping and association administratorGroup-administrator: association redefinition

Ontological analysis:
Construct according to our analysis:

The same construct as the source states since, as the previous figure shows, the redefined and redefining relations are derived from the same relator type (Membership) and the same foundation. 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.

Example 4


Figure:

Description from source:
An Actor, in general, can have an arbitrary number of pending Tasks. However, a Worker, as a kind of Actor, can have only Manual Operations as its pending Tasks, while a Machine can have at most one Automated Operation as its pending Task. It is interesting to note that, as long as the class ManualOperation does not redefine the property performer, it can be assigned as pending Task of an Actor of a different kind than Worker (or Machine, since Machine constrains its pending Tasks to Automated Operations only)

Construct according to the source:
- Association performer-pendingTasks and association worker-pendingTasks: association redefinition
- Association performer-pendingTasks and association machine-pendingTasks: association redefinition

Ontological analysis:
Construct according to our analysis:

Our analysis is able to explain the choice adopted by the author. In this case all the material relations are derived from the same relator type (Assignment).

Example 5


Figure:

Description from source:

The population of Participates is the union of Works and of Advises.

Construct according to the source:

- Association Participates and association Works: association specialization
- Association Participates and association Advises: association specialization

Ontological analysis:
Construct according to our analysis:

The same constructs as the source states since, as the previous figure shows, the relator types (Work Participation and Advise Participation) of the specific relations are subtypes of the relator type (Participation) of the general relation.

Example 6


Figure:

Description from source:

The population of HasWorked is the union of Works and the set of relationships explicitly classified as HasWorked.

Construct according to the source:

- Association HasWorked and association Works: association specialization
Ontological analysis:

Construct according to our analysis:
The same construct as the source states since, as the previous figure shows, the relator type of the specific relation is a subtype of the relator type of the general relation.

Example 7


Figure:

Description from source:
The model represents agents and resources. An agent may use a resource only if it is authorized to use it.
Construct according to the source:

- Association *IsAuthorizedToUse* and association *Uses*: association subsetting

Ontological analysis:

Construct according to our analysis:

Here, our analysis is able to explain the modelling choice adopted by the author. Both material relations are founded on relators of disjoint kinds (*Authorization* and *Use*) and the set of resources used by an agent is a subset of the set of the authorized resources to use by the agent. Note that, in this case, it is merely accidental that (in this conceptualization) resources must be authorized before used.

Example 8


Figure:

Description from source:
The model represents athletes that win gold medals in events. If the winner is an instance of MaleAthlete, then the event must be an instance of ManEvent. If the winner is an instance of FemaleAthlete, then the event must be an instance of WomanEvent.

Construct according to the source:
- Association WinsGoldMedal and association winner-manEvent: association redefinition
- Association WinsGoldMedal and association winner-womanEvent: association redefinition

Ontological analysis:

Construct according to our analysis:
The same constructs as the source states. Our analysis concludes that all the material relations are founded on the same relator type (GoldWinner).

Example 9


Figure:
Description from source:
The model represents people that may be married or unmarried. Two redefinitions have been defined: one to indicate that the husband must be a Man and that the wife must be a Woman and another to indicate that the husband and the wife must be MarriedPeople.

Construct according to the source:
- Association wife-husband and association man-woman: association redefinition
- Association wife-husband and association marriedPerson-marriedPerson: association redefinition

Ontological analysis:

Construct according to our analysis:
Our analysis recommends the same constructs as the author used. In this scenario, all the material relations are derived from the same relator type (Marriage) and the same foundation. Moreover, 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.
Example 10


Figure:

Description from source:
An Agent has ownership in a thing if it owns part of it or the whole thing. An agent owns a thing if it has full ownership of the thing (taken from the Cyc ontology). Obviously, multiplicity of owner role could be more restrictive (0..1).

Construct according to the source:
- Association HasOwnershipIn and association Owns: association specialization
- Association DoesBusinessWith and association SellsTo: association specialization

Ontological analysis:

Construct according to our analysis:
The same constructs as the source states since, as the previous figure shows. The relator type (FullOwnership) of the specific relation (Owns) is a subtype of the relator...
type \textit{(Ownership)} of the general relation \textit{(HasOwnershipIn)}. Similarly, the relator type \textit{(SellRelation)} of the specific relation \textit{(SellTo)} is a subtype of the relator type \textit{(BusinessRelation)} of the general relation \textit{(DoesBusinessWith)}.

**Conclusions**

In this report, we have described a preliminary empirical investigation on association subsetting, association specialization and association redefinition using as a benchmark a catalogue of model examples produced by different authors who can be considered experts in the conceptual modelling field. We have studied 10 examples out from 4 different sources. There are 3 examples which use association specializations, 2 using subsettings and 5 using redefinitions. There are 9 examples in which the constructs predicted by the ontological analysis are the same constructs chosen by the author and 1 case in which the prediction is different from the actual choice of the author (see example 1). Therefore, our postulates have been able to predict the modeling choices made by the authors in 90% of the cases.