

Domain Modeling: Essence and A Sample of Highlights

(Based partly on [Fowler 1997, Analysis Patterns])

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What Is Domain Modeling?

- 🌐 **Domain modeling** is an activity of requirements/systems analysis for constructing a **conceptual model**, usually called the **domain model**, of the **application/problem domain**.
- 🌐 A domain model represents real-world **entities/concepts** and their **relations**, to help understand the problem and provide guidelines for software development.
- 🌐 The focus is often on the **data** part, though the behavioral aspect is inevitably considered in the modeling process.
- 🌐 Virtues to pursue: **simplicity**, **flexibility**, and **reusability**.

Domain Models in UML

- 🌐 A conceptual/domain model may be described using various modeling notations such as UML **class diagrams**.
- 🌐 In a UML class diagram, concepts are represented by **classes** and relations by relationships, mostly **associations** and **generalizations**.

Note: you may want to review the lecture “UML: An Overview” to recall the basics of modeling and UML classes and relationships.

Identifying Classes, Objects, and Relationships

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- 🌐 Multiplicity/cardinality is the most fundamental constraint to consider for a relationship.
- 🌐 Constraints that cannot be easily captured by multiplicities may be stated in a note. (Can you think of one such constraint?)

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- 🌐 So, many-to-one and one-to-many relationships/relations should be treated differently.
- 🌐 One should also be careful about from which side of a one-to-one relationship the relation is a total function.

Sets and Types

- 🌐 A *set* is a collection of things/objects, each called an *element* of the set.
- 🌐 A set may be built from existing sets:
 - ☀️ Union, intersection, and complement
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- 🌐 A *multiset* allows repetitions of a same element; use this notion when the ordinary set is not suitable.
- 🌐 One can think of an element a from a set A as being of *type* A .
- 🌐 So, types or data types basically are just sets; and subtypes are subsets. (More about this later.)

Tuples and Records

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- A tuple with k ($k \geq 0$) components is called a *k-tuple*.
- A 2-tuple is usually called a *pair*.
- The *Cartesian product*, or simply product, of A and B , written as $A \times B$, is the set of all pairs (x, y) such that $x \in A$ and $y \in B$.
- For example,
 $\{a, b\} \times \{0, 1, 2\} = \{(a, 0), (a, 1), (a, 2), (b, 0), (b, 1), (b, 2)\}$.

Tuples and Records (cont.)

- 🌐 Cartesian products generalize to k sets, A_1, A_2, \dots, A_k , written as $A_1 \times A_2 \times \dots \times A_k$.
- 🌐 So, every element of $A_1 \times A_2 \times \dots \times A_k$ is a k -tuple.
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- 🌐 A *record* is essentially a generalization of a tuple, where every component is given a name, called a *field name* or *attribute*.
- 🌐 Below is an example record:
(ID: "IM5027", Title: "Software Development Methods", Credit: 3).

Relations

- 🌐 A subset R of $A_1 \times A_2 \times \dots \times A_k$ is called a k -ary *relation* on A_1, A_2, \dots, A_k .
- 🌐 We usually write $R(a_1, a_2, \dots, a_k)$ to denote that $(a_1, a_2, \dots, a_k) \in R$.
- 🌐 So, one can view a relation $R \subseteq A_1 \times A_2 \times \dots \times A_k$ as a *predicate*.
- 🌐 When the A_i 's are the same set A , it is simply called a k -ary relation on A .

Relations (cont.)

- 🌐 A 1-ary relation is usually called a *unary relation*, which is also a way of defining subsets from an existing set.
- 🌐 A 2-ary relation is called a *binary relation*; for a binary relation R , $R(x, y)$ is also written as xRy .
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- 🌐 $R \subseteq (A_1 \times A_2 \times \dots \times A_m) \times (B_1 \times B_2 \times \dots \times B_n)$ is a binary relation on $A_1 \times A_2 \times \dots \times A_m$ and $B_1 \times B_2 \times \dots \times B_n$.

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- 🌐 Alternatively, $R \subseteq A_1 \times A_2 \times \dots \times A_m \times B_1 \times B_2 \times \dots \times B_n$ is a $(m + n)$ -ary relation.

Functions

- 🌐 A (total) *function* (or mapping) f from D to R , denoted $f : D \rightarrow R$, maps every element in D , called the *domain* of f , to some element in R , called the *range* of f .
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- 🌐 A *partial* function may not produce an output for some inputs.

Functions (cont.)

- 🌐 A function is said to be *k*-ary if its domain is a product of *k* sets.
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- 🌐 Recall that f may be seen as a special kind of binary relation, i.e., $f \subseteq (D_1 \times D_2 \times \dots \times D_k) \times R$.
- 🌐 Function f may also be seen as a special kind of $(k + 1)$ -ary relation, i.e., $f \subseteq D_1 \times D_2 \times \dots \times D_k \times R$.

Subsets, Subtypes, and Subclasses

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- Mathematical relations can be conveniently used to represent types/classes and are themselves sets.
- A k -ary relation, when seen as a predicate, constrains its k components and **nothing beyond**.
- A k -tuple (d_1, d_2, \dots, d_k) in a k -ary relation may be extended as a $(k + 1)$ -tuple $(d_1, d_2, \dots, d_k, _)$, where the $(k + 1)$ -th component may contain any value ("don't care"), denoted by $_$.
- The extension may be generalized to include more than one additional components.

Why Mathematics?

- 🌐 It is precise.
 - ☀️ Being abstract/conceptual does not imply being vague/imprecise.
 - ☀️ Abstraction is about singling out commonalities and removing/hiding unnecessary details.

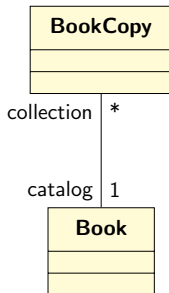
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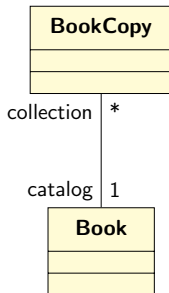
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- 🌐 It is common ultimately, for all.
- 🌐 It is expressive.

Books vs. Book Copies

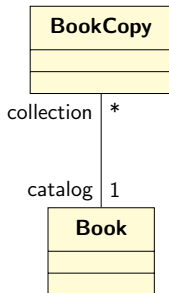


Books vs. Book Copies



It is a BookCopy, not a Book, that you reserve or check out from the library!

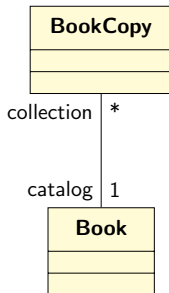
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An Association Class

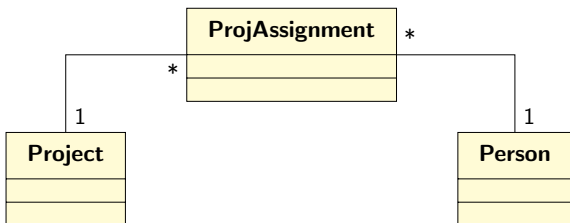


A many-to-many relation (at the operational level) should be avoided. Why?

An Association Class

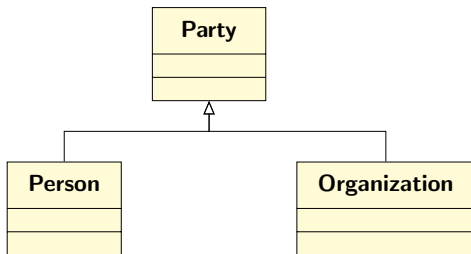


A many-to-many relation (at the operational level) should be avoided. Why? It may instead be represented as follows.



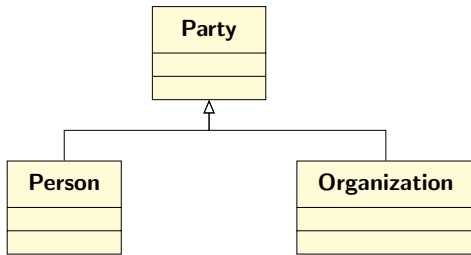
The class **ProjAssignment** is called an **association class**, created to represent the original many-to-many association relation between **Project** and **Person**.

The Abstract Concept/Class of “Party”



The Party generalization may apply to other entities, e.g., Post.

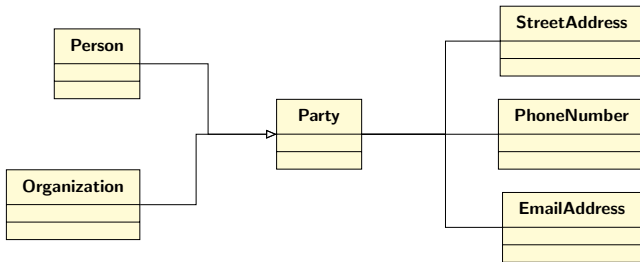
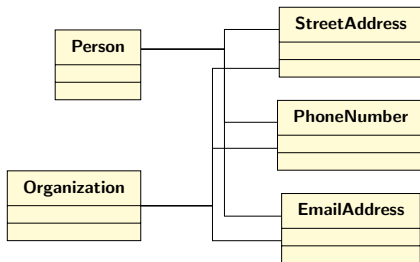
The Abstract Concept/Class of “Party”



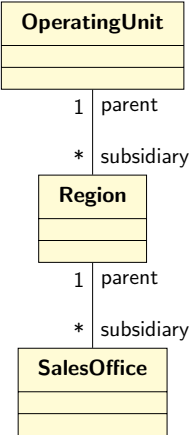
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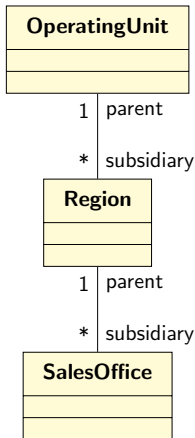
Can you see Person and Organization as subsets of Party **mathematically**?

The Party Abstraction Simplifies Relations

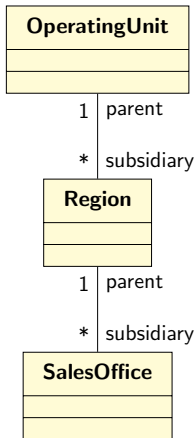


Hierarchies





What if additional levels are needed?

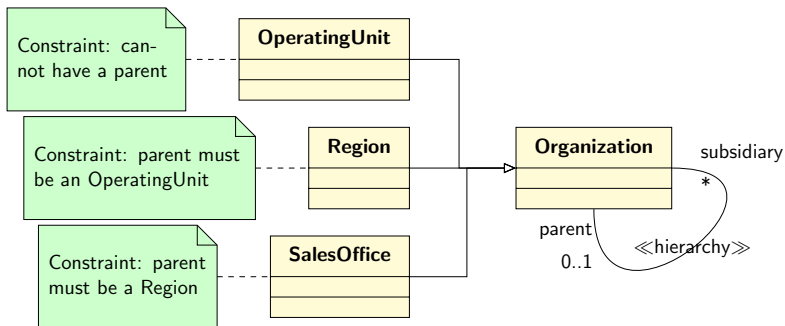


What if additional levels are needed?

Modeling a hierarchy with explicit levels is inflexible.

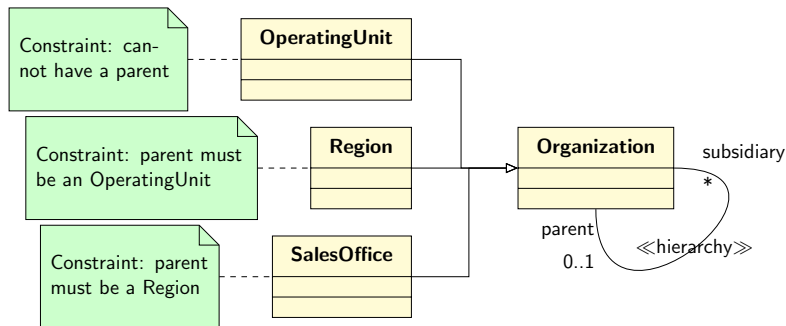
Hierarchies (cont.)

A hierarchical association provides better flexibility:



Hierarchies (cont.)

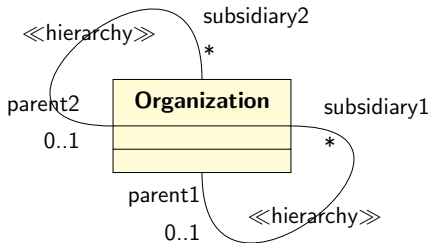
A hierarchical association provides better flexibility:



Can you see the hierarchical association as a binary relation on **Organization** mathematically?

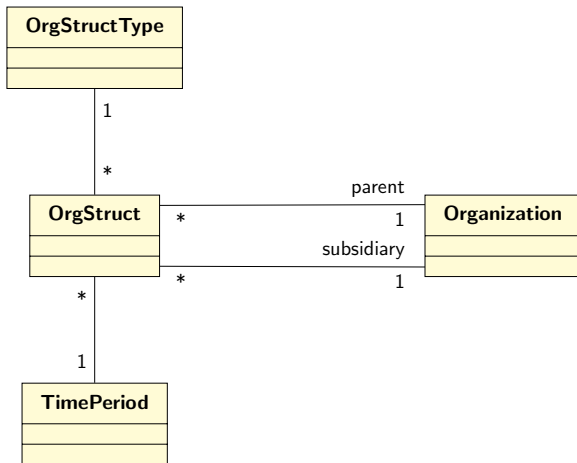
More about Hierarchies

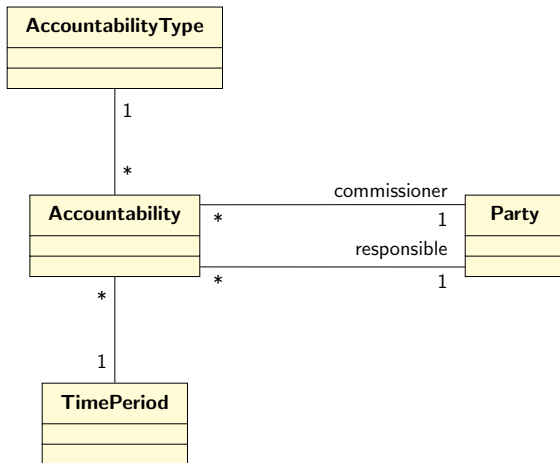
What if several different hierarchies are needed?



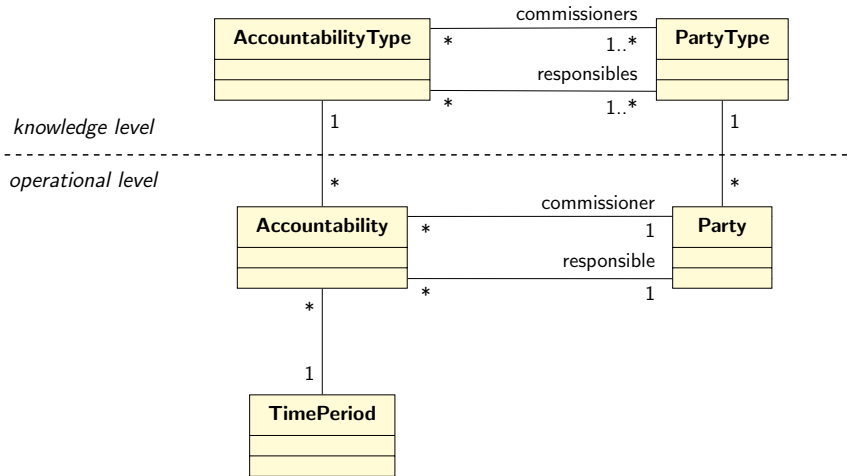
This will become messy, when there are many hierarchies.

Typed Relationship





Knowledge vs. Operational Levels



Concluding Remarks

- 🌐 Domain modeling requires domain knowledge and experience.
- 🌐 Experience can be passed on and learned by good examples, namely **patterns**.
- 🌐 Patterns are not fixed and should be adapted to fit your needs.
- 🌐 Always strive for simplicity, flexibility, and reusability.