UML Class Diagrams 1

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Class Diagram

- describes objects from the structural point of view
  - What kinds of objects and relationships among them are important?
  - What kinds of features the kinds of objects and relationships have?

- at conceptual (domain) level
  - specifies a vocabulary to talk about a problem domain
  - objects = real-world entities

- at implementation (logical) level
  - specifies (a) how a domain is mapped to software elements (i.e. software/data structures) or (b) completely new software elements without any counterparts in the real world (e.g. GUI, controller, etc.)
  - elements correspond directly to elements in the developed software system
  - objects = machine-interpretable logical structures
    - (Java/C#/...) class instances, relational tables, XML elements, etc.
Class Diagram – Conceptual Example

```
class P...
Contract
- referenceNumber
- title
- description
- mainObject
- additionalObject [0..*]
- startDate
- endDate
- estimatedPrice
- agreedPrice
- actualPrice
- numberOfTenders

Organization
- legalName
- officialNumber
+contractingAuthority 1
+awardedSupplier 0..1
+issuedContract 0..*
+tenderingSupplier 0..*
+tenderedContract 0..*

ItemType
- code
- title

Address
- streetName
- streetNumber
- city
- country
+mainAddress 0..1
+tenderAddress 0..1

Tender
- estimatedEndDate
- offeredPrice
+contractingSupplier 0..*
+awardedSupplier 1
+mainAddress 0..1
+tenderAddress 0..1

+parentContract 1
+lot 0..*
```

Exercise 1

- Create a conceptual UML class diagram for the movie domain
  - movies
  - directors, writers
  - cast (actors and their characters)
  - scenes and filming locations
Class Diagram – Implementation Example (GUI)

```
PortalConfiguration
- name: String
- isDefault: boolean
- cloneable: boolean
# initialize() : void
+ clone() : void

Portlet
- name: String
- description: String
+ show() : void
+ hide() : void
+ refresh() : void
+ relocate(int, int) : void

GUIContainer

EntityList

Advertisement

List
```

«interface» List

GUI Mo...
Class Diagram – Implementation Example (DB)
Exercise 2

- Create an implementation UML class diagram describing implementation of the previous one in a relational DB
  - In addition, consider links to relevant information sources (e.g., DBPedia, Wikidata, LinkedMDB, ...)
Class Diagram – Basic Constructs

- Class
- Class Property
  - Class attribute
  - Association end
- Association
Class

- describes a set of objects that share the same specification of features, constraints and semantics

Discussion

- What does the term ‘object’ mean
- What do the terms ‘feature’, ‘constraint’ and ‘semantics’ mean
Class

- **term ‘object’**
  - from the conceptual (domain) point of view
    - real-world entities (objects)
  - from the implementation (logical) point of view
    - machine-interpretable representation of real-world entities (objects)
    - purely programmatic data structures (no counterparts in the real world)

- **term ‘feature’**
  - feature declares behavioral or structural characteristics of objects

- **term ‘constraint’**
  - constraint is a condition or restriction which must be held by objects described by class

- **term ‘semantics’**
  - meaning of the objects for stakeholders
Class

- syntactically, class has a **name** and a set of **features**

- **feature**
  - **property** = structural characteristics
    - two kinds of properties which are the same thing but have different notations
    - **attribute**
      - more suitable for properties with simple data values (strings, integers, ...) or with complex but less important data values (e.g. address in some cases)
    - **association end**
      - more suitable for properties with complex data values (other classes)
  - **operation** = behavioral characteristics
    - actions performed on objects
    - note: actions to manipulate properties usually considered implicitly
Exercise 3

- **name**: ?
- **features**
  - **properties**
    - attributes: ?
    - association ends: ?
  - **operations**
    - ?
Exercise 3

- name: Person

  - features
    - properties
      - attributes: name, email, phone, registrationDate, homepage, dblp
      - association ends: colleague, person (default name), team (default name)
    - operations
      - no operations
Exercise 4

- name: ?
- features
  - properties
    - attributes: ?
    - association ends: ?
  - operations
    - ?
Exercise 4

- **name**: Team

- **features**
  - **properties**
    - attributes: name, homepage
    - association ends: member
  - **operations**
    - notify

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Class Attribute

- notation for a class property displayed inline in the class
- each attribute displayed as a single line
- use it to model properties with simple, non-structured, values
- you can also use it to model properties with more complex, structured, values but they should be the less important ones in your schema
Class Attribute

<property> ::=  
  [<visibility>] [ '/' ]  
  <name> [ ':' <prop-type> ] [ '['<multiplicity> ']' ] 
  [ '=' <default> ]  
  [ '{' <prop-modifier> [ ',', <prop-modifier> ]* '}' ]

- <visibility>: public (+) / private (-) ( / protected (#) / package (~)
- <name>: label we use to refer the attribute in the context of the class
- <prop-type>: restricts possible values of the attribute only to values of a given data type or instances of a given class
- <multiplicity>: restricts the number of possible values the attribute may have (default is 1)
- <default>: initial value of the attribute
- <prop-modifier>: additional meta-properties of the attribute
  - readOnly, non-unique, id, ordered, ...
Exercise 5

- Explain each attribute below

<table>
<thead>
<tr>
<th>Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>- name: String [0..1] = &quot;no-name&quot; {readOnly}</td>
</tr>
<tr>
<td>+ degree: DegreeType = assistant_prof</td>
</tr>
<tr>
<td>+ phone: String [0..*] {non-unique}</td>
</tr>
<tr>
<td>- contactPhone: String</td>
</tr>
<tr>
<td>+ address: Address [1..3] {ordered}</td>
</tr>
<tr>
<td>- personalNumber {id}</td>
</tr>
</tbody>
</table>
Binary Association

- notation for a class property displayed as a solid line between the class (source class) and class which is the type of the property (target class)
- declares that there can be semantic links between instances of associated classes
- use it to model properties with structured values
Exercise 6

- Explain the binary association below

```
Person

+ address
1..3

{ordered}

Address

- street: String
- city: String
- country: String
```
Exercise 7

- Express the previous binary association as an attribute

```
+ address
1..3
{ordered}
```

```
- street: String
- city: String
- country: String
```
Binary Association vs. Attribute

Person

+ address: Address [1..3] {ordered}

Address

- street: String
- city: String
- country: String
Bidirectional Associations

- binary association can be used to model pair of properties that are linked together as inverses
Navigability

- navigable association end means that its instances can be accessed efficiently from instances of the other end (symbol > at the association end)
- non-navigable end means that navigation is possible but is not optimized (symbol X at the association end)
- no symbol at association end means that navigability is not specified
Exercise 8

- Read multiplicities in the following diagram.

- Explain in words multiplicities in the following table.

<table>
<thead>
<tr>
<th>Multiplicity</th>
<th>Annotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0..1</td>
<td>...?...</td>
</tr>
<tr>
<td>1 or 1..1</td>
<td>...?...</td>
</tr>
<tr>
<td>* or 0..*</td>
<td>...?...</td>
</tr>
<tr>
<td>1..*</td>
<td>...?...</td>
</tr>
<tr>
<td>1..6</td>
<td>...?...</td>
</tr>
</tbody>
</table>
Exercise 8

A Team has none or one manager.

A researcher manages zero or more teams.

<table>
<thead>
<tr>
<th>Expression</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0..1</td>
<td>zero or one (optional)</td>
</tr>
<tr>
<td>1 or 1..1</td>
<td>exactly one</td>
</tr>
<tr>
<td>* or 0..*</td>
<td>zero or more (arbitrary number)</td>
</tr>
<tr>
<td>1..*</td>
<td>1 or more (at least one)</td>
</tr>
<tr>
<td>1..6</td>
<td>1 up to 6</td>
</tr>
</tbody>
</table>
Association Classes

- combination of class and association
- use it to model association with properties
Exercise 9

- Model a membership of a person in a team using an association class
Exercise 9

- Model a membership of a person in a team using an association class
N-ary Associations

- association with three or more association ends
  - declares a link between three or more class instances
- how to read it: take N-1 association ends, instantiate them (you get instances I{1}, ..., I{N-1}) and ask “What instances of N the tuple (I{1}, ..., I{N-1}) is linked to?
Exercise 10

- Read the following diagram
- What would cardinalities 1..1 or 1..* mean?
Exercise 11

- compare properties name (attribute) and worker (association end)
- attribute assigns its type instance to a class instance
- association end assigns its class instance to a combination of instances of each class at the other ends

*Can you explain it on the example above?*
Exercise 12

- reminder: links between class instances modeled by associations
- How many links modeled by a single association may exist between connected instances?

```
class Nary
Person Team
Project
+worker 0..* 0..1
0..1

class Multiplic...
Team Researcher+managedTeam 0..*
+manager 0..1
```
Exercise 12

- Only 1 (by default)
More on Links

- we can use non-unique property modifier to specify that there can be more links connecting the same instances
  - one or more association ends with non-unique
  - some tools use bag property modifier (from OCL)
Exercise 13

- What does it mean on the following example?

What does it mean on the following example?
Exercise 13

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class AssociationClass
Person Team
Membership
- fromDate: Date
- toDate: Date
- position: String
+ member
1..*
{ordered}
0..*

Person

Person 1

Person 2

Team A

Team

{non-unique}