Introduction to Software Technique
3. Just Enough UML

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The UML is the Unified Modeling Language
- Successor to a wave of OO analysis & design methods that appeared in the 1980s and 1990s

It is a modeling language to express high-level design
- Defines several diagram types

Implicitly associated with the UML is also a method or process
- Method: advice on what steps to take in doing a design

There are different ways to use UML. We will mainly use it as a notation to communicate high-level OO design ideas.

But keep in mind: No user is going to thank you for pretty pictures; what a user wants is software that executes
Class Diagrams

- A class diagram describes the types of objects in a system and the various kinds of static relationships between them
  - Associations
  - Subtypes
- Class diagrams also show the attributes, names/types of operations, and constraints that restrict how objects are connected
Class Diagrams

Example
Three ways to use class diagrams

- **Conceptual**: Draw a diagram that represents the concepts in the domain under study
  - Little or no regard for the software that might implement it

- **Specification**: Describing the interfaces of the software, not the implementation
  - Often confused in OO since classes combine both interfaces and implementation

- **Implementation**: Diagram describes actual implementation classes
  - Understanding the intended perspective is crucial to drawing and reading class diagrams
  - Even though the lines between them are not sharp
Associations

- Associations represent relationships between instances of classes
- Conceptual perspective: Associations represent conceptual relationships
- Specification perspective: Associations represent responsibilities
- Implementation perspective: Associations represent pointers/fields between related classes
Associations

- Each association has two ends
  - Each end can be named with a label called role name
  - An end also has a multiplicity: How many objects participate in the given relationship
    - General case: give upper and lower bound in lower..upper notation
    - Abbreviations: * = 0..infinity, 1 = 1..1
    - Most common multiplicities: 1, *, 0..1

- In the specification perspective, one can infer existence and names (if naming conventions exist) of methods to navigate the associations, for example:

```java
Class Order {
    public Customer getCustomer();
    public Set<OrderLine> getOrderLines();
    ...
}
```
Associations

- In the implementation perspective we can conclude existence of pointers in both directions between related classes

```java
class Order {
    private Customer _ customer;
    private Set<OrderLine> _orderLines;
    ...
}
class Customer {
    private Set<Order> orders;
    ...
}
```
Associations
Unidirectional vs bidirectional

- Arrows in association lines indicate navigability
  - Only one arrow: unidirectional association
  - No or two arrows: bidirectional association

- Specification perspective: Indicates navigation operations in interfaces

- Implementation perspective: Indicates which objects contain the pointers to the other objects

- Arrows serve no useful purpose in conceptual perspective

- For bidirectional associations, the two navigations must be inverses of each other
Unidirectional Associations

Order
- dateReceived
- isPrepaid
- number : String
- price : Money
- dispatch()
- close()

Customer
- name
- address
- creditRating():String

Navigability

Corporate Customer
- contactName
- creditRating
- creditLimit
- remind()
- billForMonth(Integer)

Personal Customer
- creditCard#

Line items

Order Line
- quantity : Integer
- price : Money
- isSatisfied : Boolean

Employee
- sales rep : 0..1

Product

(if Order.customer.creditRating is “poor,” then Order.isPrepaid must be true)
Class Diagrams: Attributes

- Attributes are very similar to associations
  - Conceptual level: A customer’s name attribute indicates that customers have names
  - Specification level: Attribute indicates that a customer object can tell you its name
  - Implementation level: customer has a field (aka instance variable) for its name
- UML syntax for attributes:
  
  \[ \text{visibility name} : \text{type} = \text{defaultValue} \]
  
  - Details may be omitted
Class Diagrams: Attributes vs Associations

- Attributes can describe non-object-oriented data
  - Integers, strings, booleans, ...
- From conceptual perspective this is the only difference
- Specification and implementation perspective:
  - Attributes imply navigability from type to attribute only
  - Implied that type contains solely its own copy of the attribute objects
Class Diagrams: Operations

- Operations are the processes that a class knows to carry out
- Most obviously correspond to methods on a class
- Full syntax:
  \[ \text{visibility } \text{name}(\text{parameter-list}) : \text{return-type} \]
  - \text{visibility} is + (public), # (protected), or - (private)
  - \text{name} is a string
  - \text{parameter-list} contains comma-separated parameters whose syntax is similar to that for attributes
    - Can also specify direction: input (in), output(out), or both (inout)
    - Default: in
  - \text{return-type} is comma-separated list of return types (usually only one)
Class Diagrams: Constraint Rules

- Arbitrary constraints can be added by putting them inside braces({})
- Mostly formulated in informal natural language
- UML also provides a formal Object Constraint Language (OCL)
- Constraints should be implemented as assertions in your programming language
Object Diagrams

(Class diagram that belongs to the object diagram)
Aggregation expresses “part-of” relationships, but rather vague semantics.

Composition is stronger: Part object live and die with the whole.
Abstract classes and methods

- UML convention for abstract classes/methods: Italicize name of abstract item or use \{abstract\} constraint
Interfaces and Lollipop notation
CRC cards

- CRC = Class-Responsibility-Collaboration
- Invented by Ward Cunningham and Kent Beck in the 1980s to ease the development of a class model from the requirements
- Not part of UML, but have proven to be quite useful
## Sample CRC card

<table>
<thead>
<tr>
<th>Responsibility</th>
<th>Collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check if items in stock</td>
<td>Order Line</td>
</tr>
<tr>
<td>Determine price</td>
<td>Order Line</td>
</tr>
<tr>
<td>Check for valid payment</td>
<td>Customer</td>
</tr>
<tr>
<td>Dispatch to delivery address</td>
<td></td>
</tr>
</tbody>
</table>
CRC Cards

- Idea: Describe responsibilities and collaboration of each class on an index card ("Karteikarte")
- Motivation: Capture purpose of class in a few sentences without thinking about data, processes, and other implementation details
- Chief benefit of CRC cards: They encourage discussion among developers
- Common mistake: Long lists of low-level responsibilities
  - Responsibilities should fit conveniently on an index card
  - Otherwise consider to split the class or summarize low-level responsibilities in higher-level responsibilities
Interaction Diagrams

- Interaction diagrams describe how groups of objects collaborate in some behavior.
- Two kinds of interaction diagrams: sequence diagrams and collaboration diagrams.
Sequence Diagram Example
Sequence Diagrams

- Vertical line is called lifeline
- Each message represented by an arrow between lifelines
  - Labeled at minimum with message name
  - Can also include arguments and control information
  - Can show self-call by sending the message arrow back to the same lifeline
- Can add condition which indicates when message is sent, such as [needsReorder]
- Can add iteration marker which shows that a message is sent many times to multiple receiver objects
Collaboration Diagram Example

1. prepare()

2. for all order lines: prepare()
   3. hasStock := check()
   4. [hasStock]: remove()

5. needsReorder := needToReorder()

6. [needsReorder]: new

7. [hasStock]: new
Collaboration Diagram Example

Decimal Numbering System
Sequence vs Collaboration Diagrams

- Sequence diagrams are better to visualize the order in which things occur.
- Collaboration diagrams also illustrate how objects are statically connected.
- You should generally use interaction diagrams when you want to look at the behavior of several objects within a single use case.
The UML universe

- There is a lot more to the UML than what we have shown here
  - More diagram types
    - State diagrams, activity diagrams, use cases, deployment diagrams, ...
  - More notational features in all diagram types
    - Stereotypes, parameterized classes, ...
- We will touch some UML features not shown here during the course and will explain them as needed
UML Misconceptions and Limitations

- UML is not language-independent. It *is* a language, as the L in UML suggests.
- This language is something like a high-level “best-of” of common OO programming language features
  - It contains notation for features that are only available in some (or even no) programming language (such as: dynamic classification)
  - Every OO language has features that have no corresponding notation in the UML (e.g. wildcards in Java)
  - The same UML notation may have a different meaning in different OO languages (e.g. visibility)
- The UML has no clearly defined semantics. This is both a limitation and a feature
  - Good for informal diagrams, bad for formal specifications
- No consensus in the community about the scenarios where UML is useful
Literature

- Beck, Cunningham: *A Laboratory For Teaching Object-Oriented Thinking*. OOPSLA’ 89 available online at c2.com/doc/oopsla89/paper.html