Software Design, Modelling and Analysis in UML

Lecture 1: Introduction

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Content

- An Analogy: Construction Engineering
  - Floorplans as Formal Specification Language
  - The Notion of Model
  - “Floorplans” for Software

- Goals, Content and Non-Content of the Course
  - The UML Standard Documents
  - The Map

- A Brief History of UML

- UML Modes

- Course
  - Organisation
    - Lectures
    - Tutorials
    - Exam
An Analogy: Construction Engineering

Requirements:
- ...
- The bathroom must not have a window.
- ...

Specification:
- ...
- The outer walls will be built using AAC, the inner walls of sand-lime bricks.
- Steel door frames.
- ...

A (semi-)formal design description and specification language – every construction engineer has pretty much the same understanding of it. (The customer need not understand it; a construction engineer can “translate”.)

Check whether design satisfies specification – before building the house.

Build house according to the plan.

Housing!

Customer Developer

http://wikimedia.org (CC nc-sa 3.0, Ottoklages)
http://wikimedia.org (CC nc-sa 3.0, Bobthebuilder82)
Definition. [Folk] A model is an abstract, formal, mathematical representation or description of structure or behaviour of a (software) system.

Definition. (?, 425) A model is a concrete or mental image (Abbild) of something or a concrete or mental archetype (Vorbild) for something. Three properties are constituent:

(i) the image attribute (Abbildungsmerkmal), i.e. there is an entity (called original) whose image or archetype the model is,

(ii) the reduction attribute (Verkürzungsmerkmal), i.e. only those attributes of the original that are relevant in the modelling context are represented,

(iii) the pragmatic attribute, i.e. the model is built in a specific context for a specific purpose.
Floorplan **abstracts** from properties, e.g.,

- kind, number, and placement of bricks,
- subsystem details (e.g., window style),
- water pipes/wiring,
- wall decoration

→ construction engineers can **efficiently** work on an **appropriate** level of abstraction, and find design errors **before building** the system (e.g. regarding bathroom windows).

Floorplan **preserves** properties, e.g.,

- house and room extensions (to scale),
- presence/absence of windows and doors,
- placement of subsystems (like windows),
- etc.
Floorplans as Models

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- ...

Document existing house: image.

Build house according to the plan: pre-image
Can We Have the Same for Software?

**Construction Engineering:**

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**Software Engineering:**

Software

Customer Developer

?

??

? + ??

Customer Developer

?:-)

?:-)
Construction Engineering:

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- ... The bathroom must not have a window.
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Software Engineering:

Sequence Diagrams (behaviour, reflective)

Class Diagrams (structure)

State Machine Diagrams (behaviour, constructive)
Goals, Content and Non-Content of the Course
(i) We need to know how the words of the language **look like**: Syntax.  
(UML example: is this a proper UML state machine diagram?)

(ii) We need to know what a word of the language **means**: Semantics.

→ Then we can **formally analyse** the model, e.g., **prove** that the design satisfies the requirements, **simulate** the model, automatically **generate test cases**, automatically **generate** equivalent code, etc.

(UML example: can sending event $E$ and then $G$ kill the object?)

- UML is sometimes (neutrally, or as offence) called **“semi-formal”**:  
  the UML standard ?? is strong on (i), but weak(er) on (ii).  
  (“the diagram is self-explanatory”, “everybody understands the diagram” – No.)

- **In the lecture**: **study** the (!) syntax, **define** one (!) semantics.
OMG Unified Modeling Language™ (OMG UML),
Infrastructure

Version 2.4.1

OMG Document Number: formal/2011-08-05
Standard document URL: http://www.omg.org/spec/UML/2.4.1/Infrastructure
Associated Normative Machine-Readable Files:
- http://www.omg.org/spec/UML/20110701/L0.xmi
- http://www.omg.org/spec/UML/20110701/PrimitiveTypes.xmi

Version 2.4.1 supersedes formal/2010-05-04.

(230 pages)

OMG Unified Modeling Language™ (OMG UML),
Superstructure

Version 2.4.1

OMG Document Number: formal/2011-08-06
Standard document URL: http://www.omg.org/spec/UML/2.4.1/Superstructure
Associated Normative Machine-Readable Files:
- http://www.omg.org/spec/UML/20110701/L0.xmi
- http://www.omg.org/spec/UML/20110701/PrimitiveTypes.xmi

Version 2.4.1 supersedes formal/2010-05-06.

(748 pages)
\( \mathcal{S}_0 = (\{ \text{Int}, \text{Bool} \}, \{ C, D \}, \{ x : \text{Int}, p : C_{0,1}, n : C_* \}, \{ C \mapsto \{ p, n \}, D \mapsto \{ p, x \} \}, \{ f : \text{Int} \to \text{Bool}, \text{get}_x() : \text{Int} \}, \{ C \mapsto \emptyset, D \mapsto \{ f, \text{get}_x \} \}) \)
The class diagram syntax can be used to **visualise code**: provide rules which map (parts of) the code to class diagram elements.

```java
package pac;
import pac.D;

public class C {
    public D n;
    public void print_nx() {
        System.out.printf("%i\n", n.get_x());
    }

    public C() {}
}
```

```java
package pac;
import pac.C;

public class D {
    private int x;

    public int get_x() {
        return x;
    }

    public D() {};
}
```

![Class diagram example](image)
- open favourite IDE,
- open favourite project,
- press “generate class diagram”
- wait... wait... wait...

- ca. 35 classes,
- ca. 5,000 LOC C#
Table of Contents

- Introduction (VL 1)
- Semantical Domain (VL 2)

**Modelling Structure:**
- OCL Syntax & Semantics (VL 3–4)
- Object Diagrams (VL 5)
- Class Diagrams (VL 6–9)
- Behavioural Models + UML Style (VL 10)

**Modelling Behaviour:**
- **Constructive:**
  - Core State Machines (VL 11–14)
  - Hierarchical State Machines (VL 15,17)
  - Model-based Testing (VL 16)
- **Reflective:**
  - Live Sequence Charts (VL 18–19)

**The Rest:**
- Inheritance (VL 20)
- Meta-Modeling (VL 21)
- Putting it all together: MDA, MDSE (VL 22)
Everything else, including

- **Development Process**
  UML is only the language for artefacts. **But:** we’ll discuss exemplarily, where in an abstract development process which means could be used.

- **How to come up with a good design**
  UML is only the language to write down designs. **But:** we’ll have a couple of examples.

- **Artefact Management**
  Versioning, Traceability, Propagation of Changes.

- **Every little bit and piece of UML**
  Boring. Instead we learn how to read the standard.

- **Object Oriented Programming**
  Interestingly, inheritance is one of the last lectures.
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A Brief History of UML
Boxes/lines and finite automata are used to visualise software for ages.

1970’s, Software Crisis™

Idea: learn from engineering disciplines to handle growing complexity.
Modelling languages: Flowcharts, Nassi-Shneiderman, Entity-Relation Diagrams

Mid 1980’s: Statecharts (?), StateMate™ (?)

Early 1990’s, advent of Object-Oriented-Analysis/Design/Programming
– Inflation of notations and methods, most prominent:
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    - **Object-Oriented Software Engineering (OOSE)** (?)

Each “persuasion” selling books, tools, seminars…
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- Late 1990’s: joint effort of “the three amigos” yielded UML 0.x and 1.x
  The standards are published by Object Management Group (OMG), “international, open membership, not-for-profit computer industry consortium”. Much criticised for lack of formality.

- Since 2005: UML 2.x, split into infra- and superstructure documents.
Recall: UML Diagrams (?, 694)

Diagram

Structure Diagram
- Class Diagram
  - Composite Structure Diagram
  - Profile Diagram
- Component Diagram
- Deployment Diagram
- Package Diagram

Behavior Diagram
- Activity Diagram
- Use Case Diagram
- State Machine Diagram

Interaction Diagram
- Sequence Diagram
- Interaction Overview Diagram
- Communication Diagram
- Timing Diagram

OCL
UML Modes
With UML it’s the same [http://martinfowler.com/bliki]:

“[… ] people differ about what should be in the UML because there are differing fundamental views about what the UML should be.

So when someone else’s view of the UML seems rather different to yours, it may be because they use a different UmlMode to you.”
With UML it's the same:

**Sketch:**
In this UmlMode developers use the UML to help communicate some aspects of a system. [...] Sketches are also useful in documents, in which case the focus is communication rather than completeness. [...] The tools used for sketching are lightweight drawing tools and often people aren't too particular about keeping to every strict rule of the UML. Most UML diagrams shown in books, such as mine, are sketches. Their emphasis is on selective communication rather than complete specification. Hence my sound-bite “comprehensiveness is the enemy of comprehensibility.”

**Blueprint:**
 [...] In forward engineering the idea is that blueprints are developed by a designer whose job is to build a detailed design for a programmer to code up. That design should be sufficiently complete that all design decisions are laid out and the programming should follow as a pretty straightforward activity that requires little thought. [...] Blueprints require much more sophisticated tools than sketches in order to handle the details required for the task. [...] Forward engineering tools support diagram drawing and back it up with a repository to hold the information. [...]  

**Program:**
If you can detail the UML enough, and provide semantics for everything you need in software, you can make the UML be your programming language. Tools can take the UML diagrams you draw and compile them into executable code. The promise of this is that UML is a higher level language and thus more productive than current programming languages. The question, of course, is whether this promise is true. I don't believe that graphical programming will succeed just because it's graphical. [...]
UML-Mode of the Course

So, the “mode” fitting the lecture best is AsBlueprint.

Aim of the Course:
• show that UML can be precise – to avoid misunderstandings.
• allow formal analysis of models on the design level – to find errors early.
• be consistent with (informal semantics in) ? as far as possible.

Side Effects:
After the course, you should…
• have a good working knowledge of UML,
• have a good working knowledge of software modelling,
• be able to also efficiently and effectively work in AsSketch mode,
• be able to define your own UML semantics for your context/purpose, or define your own Domain Specific Languages as needed.
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Formalia
Formalia: Lectures

- **Lecturer:** Dr. Bernd Westphal
- **Support:** Claus Schätzle
- **Homepage:** [http://swt.informatik.uni-freiburg.de/teaching/WS2016-17/sdmauml](http://swt.informatik.uni-freiburg.de/teaching/WS2016-17/sdmauml)
- **Time/Location:** Tuesday, Thursday, 8:00 – 10:00 / here (building 51, room 03-026)
- **Course language:** English (slides/writing, presentation, questions/discussions)
- **Presentation:** half slides/half on-screen **hand-writing** – for reasons
- **Script/Media:**
  - slides with annotations on homepage, typically soon after the lecture
  - recording on ILIAS with max. 1 week delay (links on homepage)
- **Break:**
  - We'll have a **10 min. break** in the middle of each event from now on, unless a majority objects now.
You should work in groups of approx. 3, clearly give names on submission.

Please submit via ILIAS (cf. homepage): paper submissions are tolerated.

Schedule:

- Week $N$, Thursday, 8–10 Lecture A1 (exercise sheet $A$ online)
- Week $N+1$, Tuesday 8–10 Lecture A2
- Thursday 8–10 Lecture A3
- Week $N+2$, Monday, 12:00 (exercises $A$ early submission)
- Tuesday, 8:00 (exercises $A$ late submission)
- 8–10 Tutorial A
- Thursday 8–10 Lecture B1 (exercise sheet $B$ online)

Rating system: “most complicated rating system ever”

- Admission points (good-will rating, upper bound)
  (“reasonable proposal given student’s knowledge before tutorial”)
- Exam-like points (evil rating, lower bound)
  (“reasonable proposal given student’s knowledge after tutorial”)

10% bonus for early submission.

Tutorial: Plenary, not recorded.

Together develop one good solution based on selection of early submissions (anonymous) – there is no “Musterlösung” for modelling tasks.
Formalia: Exam

- **Exam Admission:**

  Achieving 50% of the regular admission points in total is **sufficient** for admission to exam.

  Typically, 20 regular admission points per exercise sheet; some exercise sheets have **bonus tasks**.

- **Exam Form:**

  - oral for BSc and on special demand (Erasmus),
  - **written** for everybody else (if sufficiently many candidates remain).

  Scores from the exercises **do not** contribute to the final grade.

- **Exam Date:**

  Please remind me in early December that we need to agree on an exam date.
• **Approach:**

  The lectures is supposed to work as a **lecture**: spoken word + slides + discussion

  It is **not our goal** to make any of the three work in isolation.

• **Interaction:**

  Absence often moaned but **it takes two**: please ask/comment immediately.

• **Exercise submissions:**

  Each task is a **tiny little scientific work:**

  (i) Briefly rephrase the task in your own words.

  (ii) State your claimed solution.

  (iii) Convince your reader that your proposal is a solution (proofs are very convincing).
Example:

Task: Given a square with side length $a = 19.1$. What is the length of the longest straight line fully inside the square?

Submission A:

Submission B:

Exercise submissions:

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• Approach:

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Example:

Task: Given a square with side length \( a = 19.1 \). What is the length of the longest straight line fully inside the square?

Submission A:

Submission B:

The length of the longest straight line fully inside the square with side length \( a = 19.1 \) is 27.01 (rounded).

The longest straight line inside the square is the diagonal. By Pythagoras, its length is \( \sqrt{a^2 + a^2} \). Inserting \( a = 19.1 \) yields 27.01 (rounded).
Literature
Literature: Modelling


http://www.springerlink.com/content/0170-6012

Literature: UML

- OMG: Unified Modeling Language Specification, Infrastructure, 2.4.1
- OMG: Unified Modeling Language Specification, Superstructure, 2.4.1
- OMG: Object Constraint Language Specification, 2.0
  All three: http://www.omg.org (cf. hyperlinks on course homepage)

- A. Kleppe, J. Warmer: The Object Constraint Language,

- D. Harel, E. Gery: Executable Object Modeling with Statecharts,
  Whitepaper, 1999.

- B. Oesterreich: Analyse und Design mit UML 2.1,