Software Design, Modelling and Analysis in UML

Lecture 1: Introduction

2nd Ed.

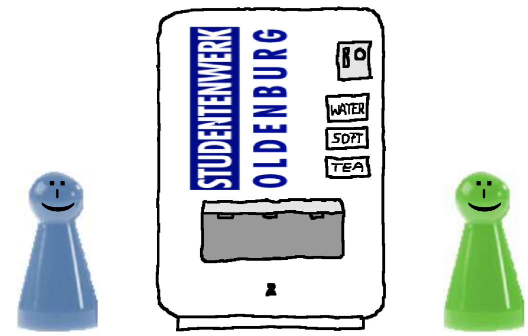
2015-10-20

Prof. Dr. Andreas Podelski, **Dr. Bernd Westphal**

Albert-Ludwigs-Universität Freiburg, Germany

Motivation and Context

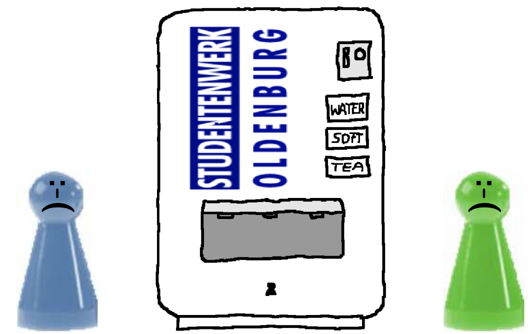
"if there is water in stock, it must be possible to buy water at the price of 50 cent"



Among other interactions:

- insert 50 cent coin,
- press 'WATER', wait,
- check: yes, water in stock,
- press 'WATER' again,
- wait. . .

> “if there is water in stock, it must be possible to buy water at the price of 50 cent”



Among other interactions:

- insert 50 cent coin,
- press ‘WATER’, wait,
- check: yes, water in stock,
- press ‘WATER’ again,
- wait. . .

What went wrong?

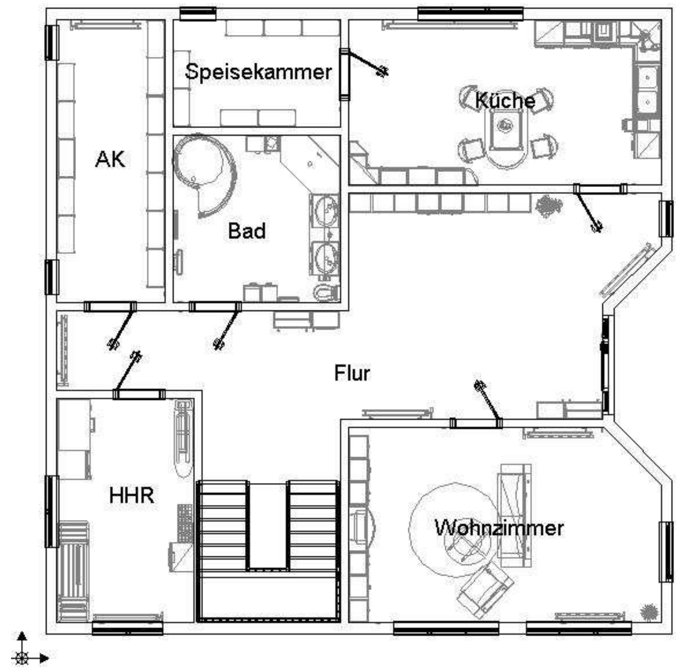
- Was there a misunderstanding of the **requirements**? (→ redo all the work)
- Is there an error in our **design**? (→ redo design and implementation)
- Is there a “bug” in our **implementation**? (→ fix the implementation)

And can we do something to avoid it in the next project. . . ?

An Analogy: Construction Engineering

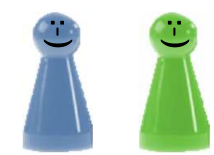
Customer Developer

"the bathroom must not have a window"



http://wikimedia.org (CC nc-sa 3.0, Ottoklages)

http://wikimedia.org (CC nc-sa 3.0, Bobthebuilder82)



Recall: Model

Definition. [Folk] A model is an abstract, formal, mathematical representation or description of structure or behaviour of a (software) system.

Definition. (Glinz, 2008, 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,

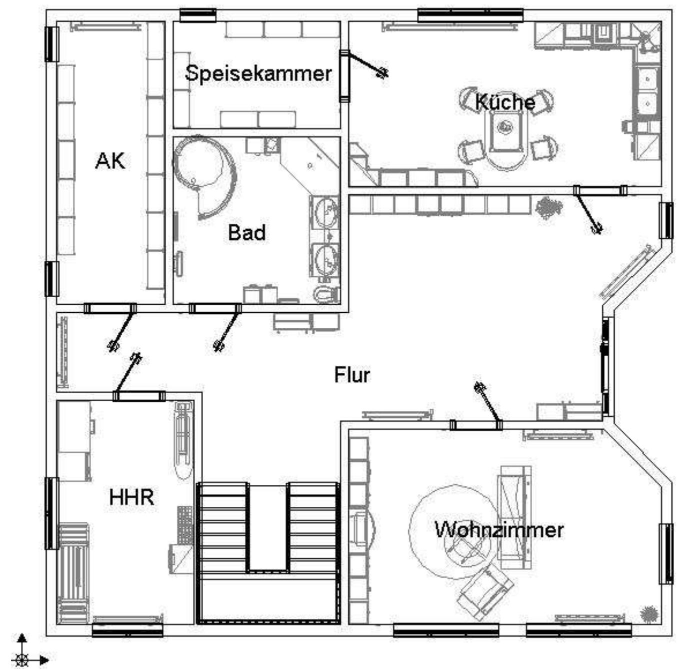
(ii) the reduction attribute (Verkürzungsmerkmal), i.e. only those attributes of the original that are relevant in the modelling context are represented,

(iii) the pragmatic attribute, i.e. the model is built in a specific context for a specific purpose.

Floorplans as Models

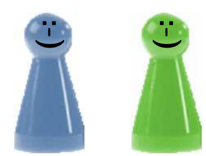
Customer Developer

“the bathroom must not have a window”



http://wikimedia.org (CC nc-sa 3.0, Ottoklages)

http://wikimedia.org (CC nc-sa 3.0, Bobthebuilder82)



Floorplan **abstracts** from properties, e.g.,

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

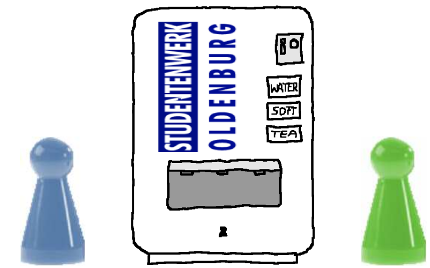
Floorplan **preserves** properties, e.g.,

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

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

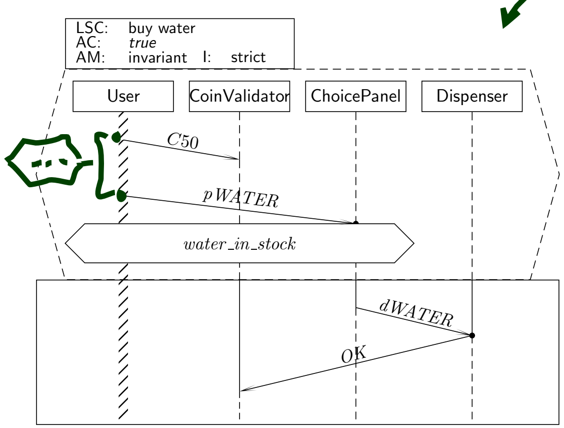
Models in Software Engineering

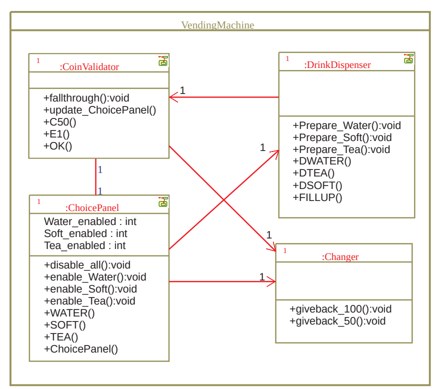
Customer Developer

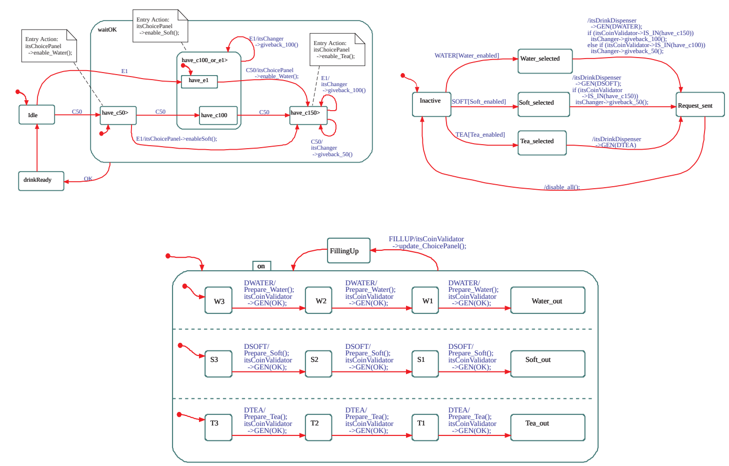


"if there is water in stock, it must be possible to buy water at the price of 50 cent"

?

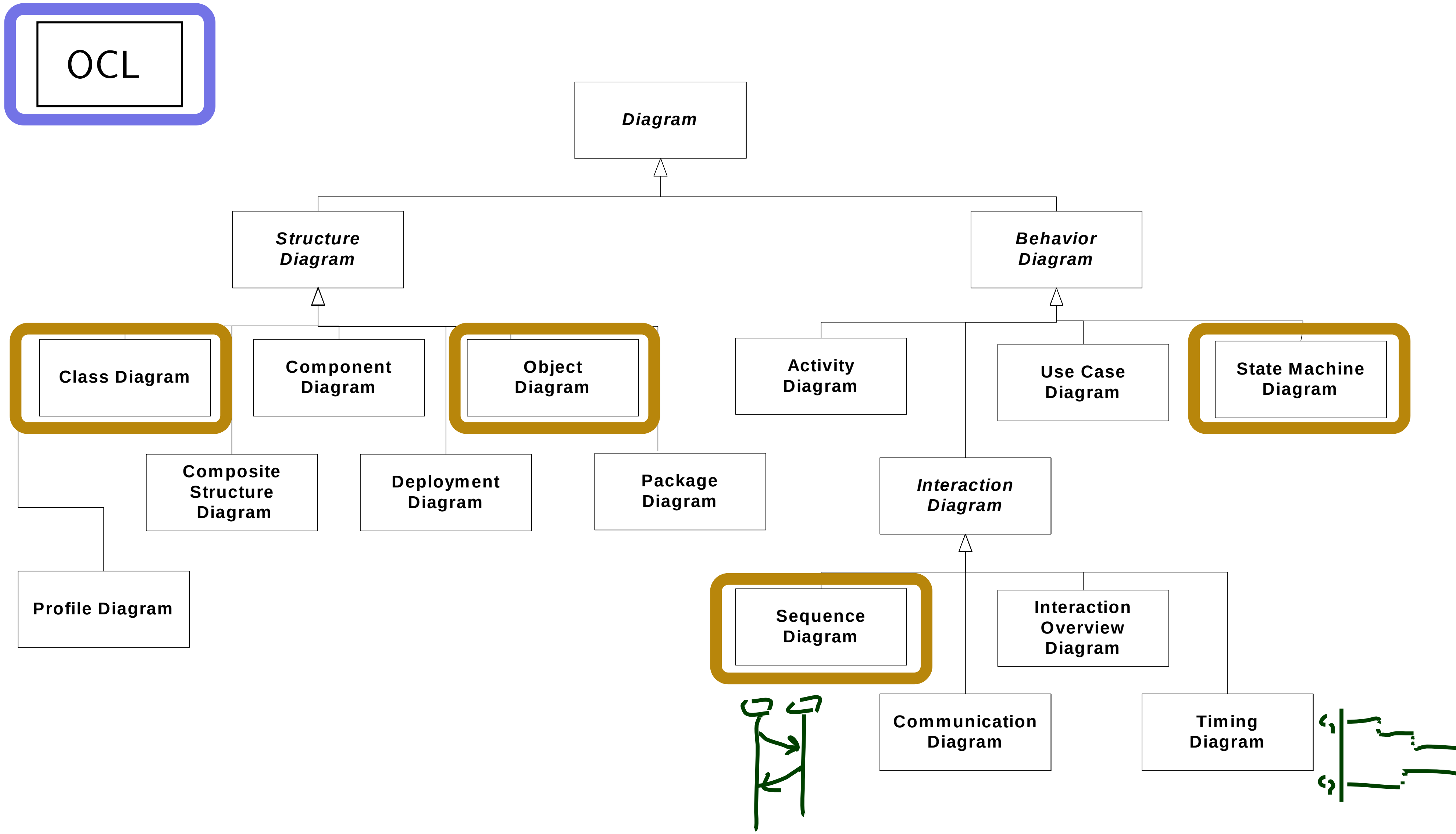






requirements model **design model/structure** **design model/behaviour**

One Software Modelling Language: UML (OMG, 2011b, 694)

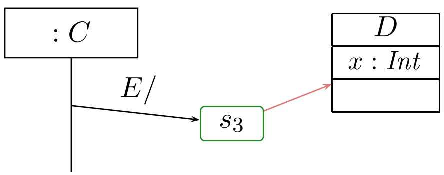


Dobing and Parsons (2006)

(Our) Premises for Using a Software Modelling Language

(i) We want to know
how the words of the language **look like**: **Syntax**.

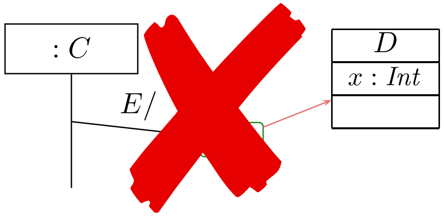
(In UML: when is a diagram a proper state machine?)



(Our) Premises for Using a Software Modelling Language

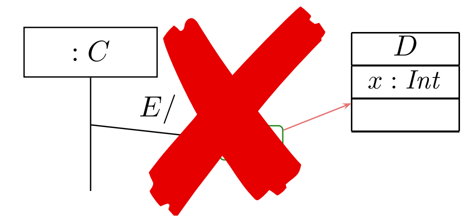
(i) We want to know
how the words of the language **look like**: **Syntax**.

(In UML: when is a diagram a proper state machine?)

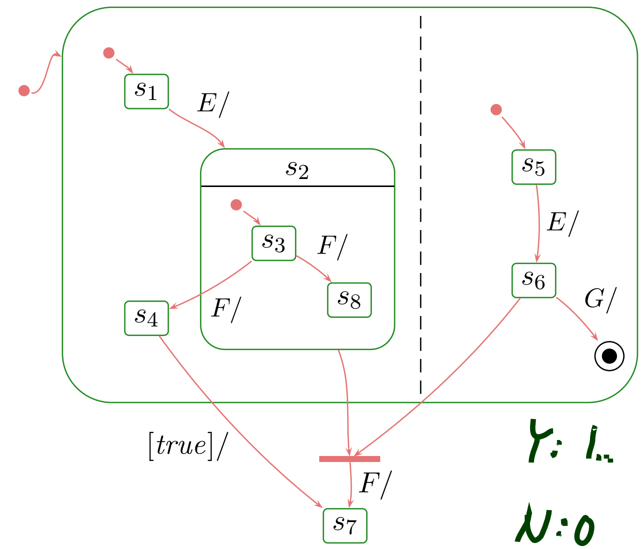


(Our) Premises for Using a Software Modelling Language

(i) We want to know
how the words of the language **look like**: **Syntax**.
(In UML: when is a diagram a proper state machine?)



(ii) We want to know
what a word of the language **means**: **Semantics**.
(In UML: can sending event E and then G kill the object?)



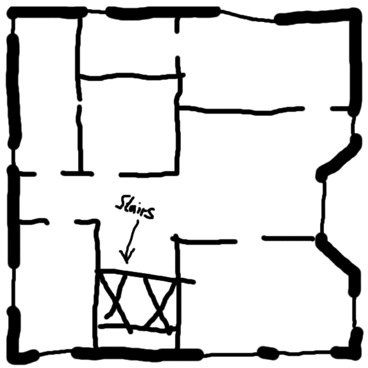
→ then we can formally analyse the model, e.g.,
prove that the design satisfies the requirements,
simulate the model, automatically generate test cases,
generate code, etc.

- UML is sometimes (neutrally, or as offence) called **"semi-formal"**:
  the UML standard OMG (2011a,b) is strong on (i), but weak(er) on (ii).
  ("the diagram is self-explanatory", "everybody understands the diagram" — No.)

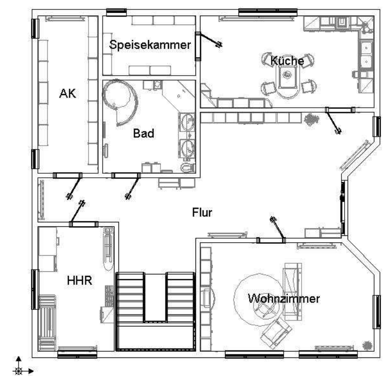
- **In the lecture**: **study** the (!) **syntax**, **define** one (!) **semantics**.

Our? Floorplan Modes!

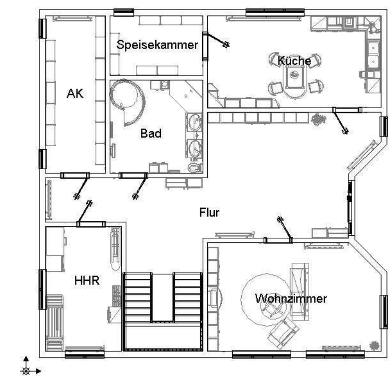
Sketch:

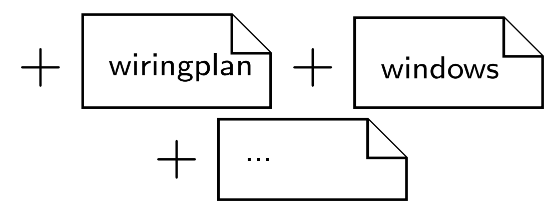


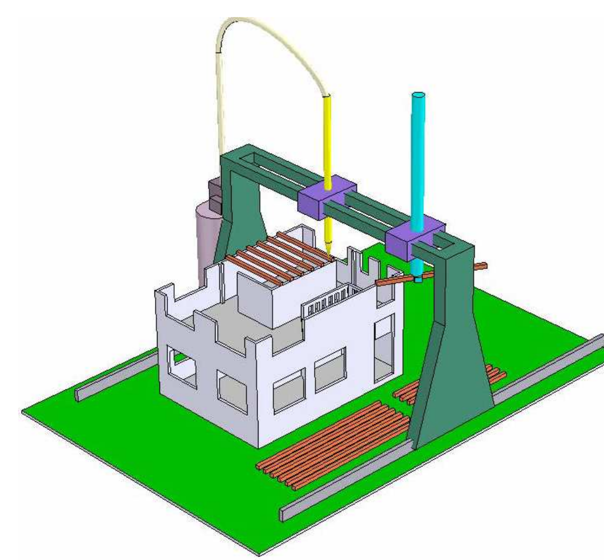
Blueprint:



Program:







Khoshnevis (2004)

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."*

Our? Floorplan Modes!

Sketch: **Blueprint**: **Program**:

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 ra- ther 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. [...]

Programming Language

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.

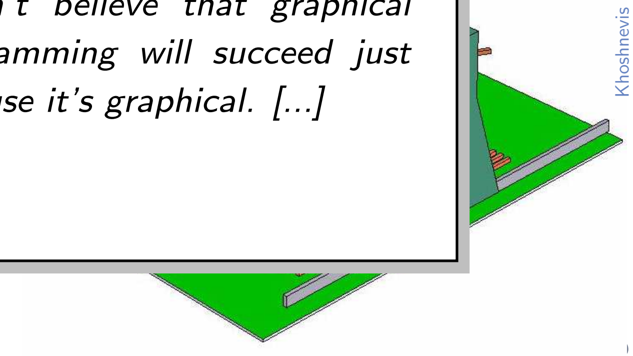
Tools can take the UML diagrams you draw and compile them into executable code.

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. [...]

With



Khoshnevis (2004)

UML-Mode of the Course

The "mode" fitting the lecture best is **AsBlueprint**.

Aim of the Course:

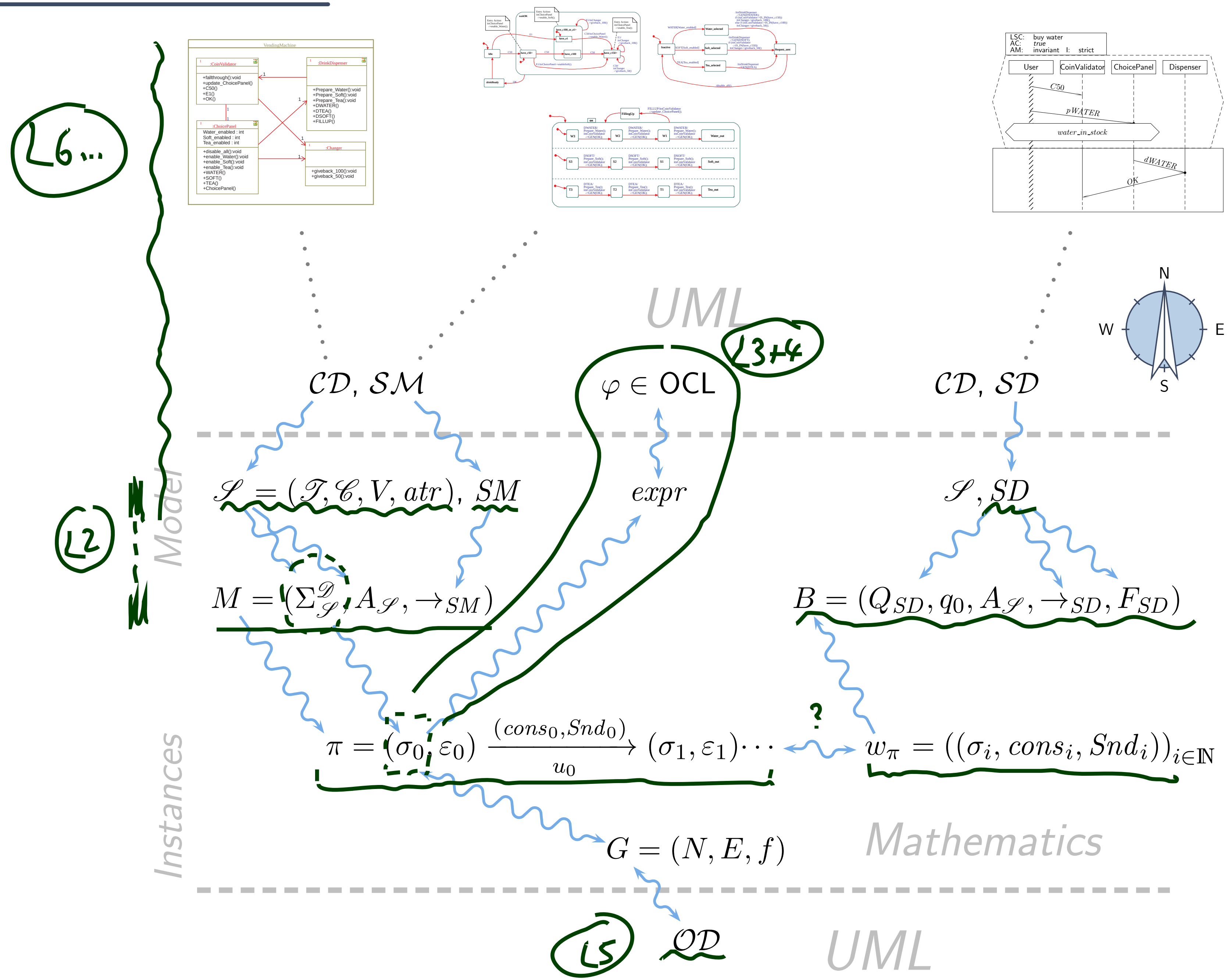
- show that UML can be **precise** — to **avoid misunderstandings**.
- allow **formal analysis** of models on the **design level** — to **find errors early**.
- be consistent with (informal semantics in) OMG (2011b) as far as possible.

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 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.

The Lecture: Content and Non-Content

Course Map



L6...
UML
L3+4
CD, SM
φ ∈ OCL
CD, SD
N
W
E
S
Model
L2
𝒮 = (𝒯, 𝒞, V, atr), SM
expr
𝒮, SD
M = (Σ_𝒮^𝒟, A_𝒮, →_SM)
B = (Q_SD, q_0, A_𝒮, →_SD, F_SD)
Instances
π = (σ_0, ε_0) —(cons_0, Snd_0) / u_0→ (σ_1, ε_1) · · ·
?
w_π = ((σ_i, cons_i, Snd_i))_{i∈ℕ}
G = (N, E, f)
Mathematics
L5
OD
UML

Table of Contents

Table of Non-Contents

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**
  Interesting: inheritance is one of the last lectures.

Formalia

Formalia: Lectures

- **Lecturer:** Dr. Bernd Westphal
- **Support:** Milan Vujinovic
- **Homepage:** `http://swt.informatik.uni-freiburg.de/teaching/WS2015-16/sdmauml`
- **Time/Location:** Tuesday, Thursday, 10:00 – 12:00 / 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.

Formalia: Exercises and Tutorials

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

- **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:**

  Remind me in early December that we need to agree on an exam date.

User's Guide

- **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**.

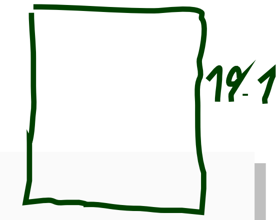
- **Exercise submissions:**

  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).



- **Ap|**

  The

  It is

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:

27

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).

cussion

- **Int**

  Abs

ly.

- **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).

User's Guide

- **App**

  The … **cussion**

  It is

- **Inte**

  Abs … **ly**.

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 squa… with side length $a = 19.1$ is 27… (rounded).

The longe… … line inside the square is t… …onal. By Pythagoras, its lengt… $\sqrt{a^2 + a^2}$. Inserting $a = 19.1$ yields 27.01 (rounded).

- **Exercise submissions:**

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

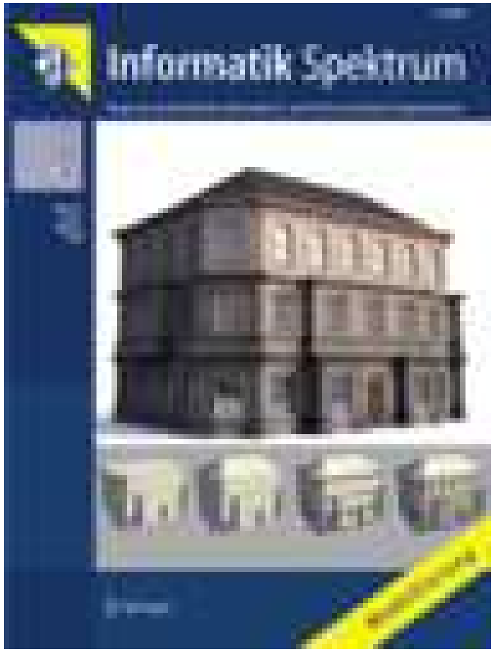
  (i) Briefly rephrase the task in your own words.

  (ii) State your claimed solution.

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

Literature

Literature: Modelling

- 

  - W. Hesse, H. C. Mayr: Modellierung in der Softwaretechnik: eine Bestandsaufnahme, Informatik Spektrum, 31(5):377-393, 2008.
  - O. Pastor, S. Espana, J. I. Panach, N. Aquino: Model-Driven Development, Informatik Spektrum, 31(5):394-407, 2008.
  - M. Glinz: Modellierung in der Lehre an Hochschulen: Thesen und Erfahrungen, Informatik Spektrum, 31(5):408-424, 2008.

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

- U. Kastens, H. Kleine Büning: Modellierung – Grundlagen und Formale Methoden, 2. Auflage, Hanser-Verlag, 2008.

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, Second Edition, Addison-Wesley, 2003.

- D. Harel, E. Gery: Executable Object Modeling with Statecharts, IEEE Computer, 30(7):31-42, 1997.
- B. P. Douglass: Doing Hard Time, Addison-Wesley, 1999.
- B. P. Douglass: ROPES: Rapid Object-Oriented Process for Embedded Systems, i-Logix Inc., Whitepaper, 1999.

- B. Oesterreich: Analyse und Design mit UML 2.1, 8. Auflage, Oldenbourg, 2006.
- H. Stoerrle: UML 2 für Studenten, Pearson Studium Verlag, 2005.

WARNING: as Sketch

References

References

Dobing, B. and Parsons, J. (2006). How UML is used. *Communications of the ACM*, 49(5):109–114.

Glinz, M. (2008). Modellierung in der Lehre an Hochschulen: Thesen und Erfahrungen. *Informatik Spektrum*, 31(5):425–434.

Khoshnevis, B. (2004). Automated construction by contour crafting — related robotics and information technologies. *Journal of Automation in Construction*, 13:5–19.

OMG (2006). Object Constraint Language, version 2.0. Technical Report formal/06-05-01.

OMG (2011a). Unified modeling language: Infrastructure, version 2.4.1. Technical Report formal/2011-08-05.

OMG (2011b). Unified modeling language: Superstructure, version 2.4.1. Technical Report formal/2011-08-06.