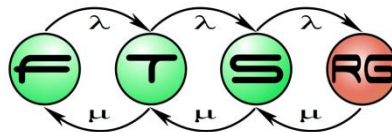


System Modelling

Course leader: Dr. PATARICZA András

Lecturer: HUSZERL Gábor

**Budapest University of Technology and Economics
Fault Tolerant Systems Research Group**



The Course

- Course (VIMIAA00)
 - 3 in 1 (in Hungarian/English/German)
 - students of B.Sc. in computer engineering (2nd semester)
- Dr. PATARICZA András
 - professor in charge
- GÖNCZY László
 - operative lead, organising
- HUSZERL Gábor (huszerl@mit.bme.hu)
 - English speaking lectures, ...

The English Speaking Course

- Lectures and lead
 - HUSZERL Gábor
- Hand-on Trainings
 - HUSZERL Gábor
- No video or audio recording!
 - But take your own notes

- Web site

<https://inf.mit.bme.hu/en/edu/courses/remo-en>

- Infos, news, slides, ...

The Course

- 13 lectures
 - Thursdays 10-12 AM, Q.BF10 (no lecture on 15th March!!!)
- 6 hand-on trainings
 - on odd weeks (beware of the spring holidays!)
 - Thursdays 2-4 PM in I.L405 (GA2: 20 students)
 - Fridays 2-4 PM in I.E224 (GA1: 30 students)
 - First time on the 22nd/23rd February
 - Tests (not an entry test!), presence mandatory
- 1 home assignment (with oral defence)
- 2 mid-term exams (with entry tests)

Grading

- Mid-term exams (with entry tests): 30% + 40%
- Home assignment (with defence): 30% of the mark
 - all three of them with at least 40% of the points
 - the mid-term exams and the home assignment can be repeated
- Optional additional points:
 - Hand-on training tests (min. 5 tests out of 6): +5%
 - optional assignments for additional points

Home Assignment

- Mandatory submission, mandatory oral defence
- Personal Assignment
- Deadlines
 - Release of assignments: 3. semester week
 - First submission (opt.): 5. semester week
 - Final submission: 12. semester week
- Electronic submission
- Oral defence

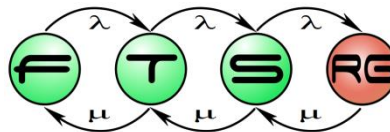
Course Topics

- Structure modelling
- Behaviour modelling
 - State based, process based
- Development of models
- Checking of models
- Performance modelling
- Simulation
- Benchmarking, Code generation
- Visual data analysis

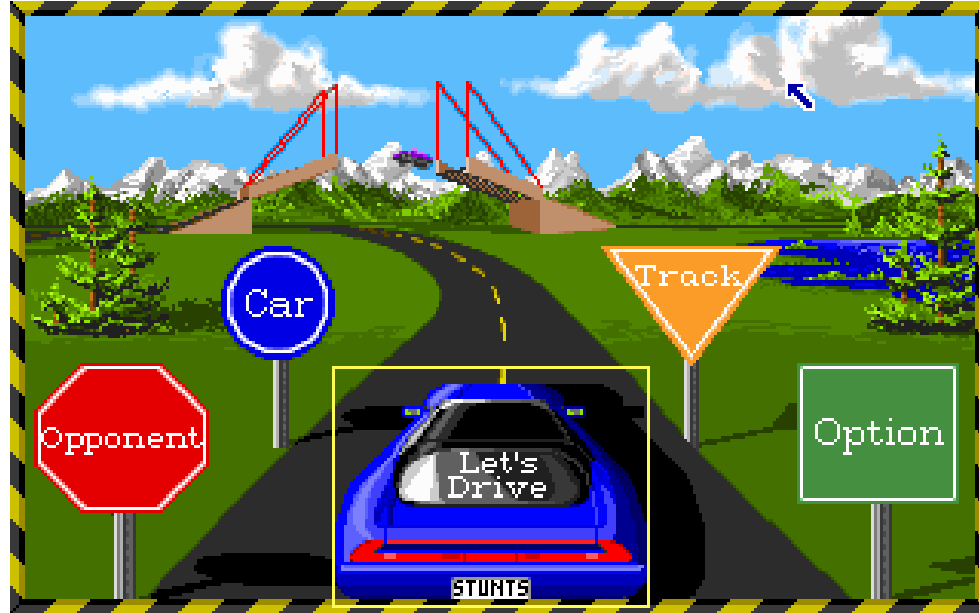
Foundations of Modelling

Dr. PATARICZA András, BERGMANN Gábor
HUSZERL Gábor

Budapest University of Technology and Economics
Fault Tolerant Systems Research Group

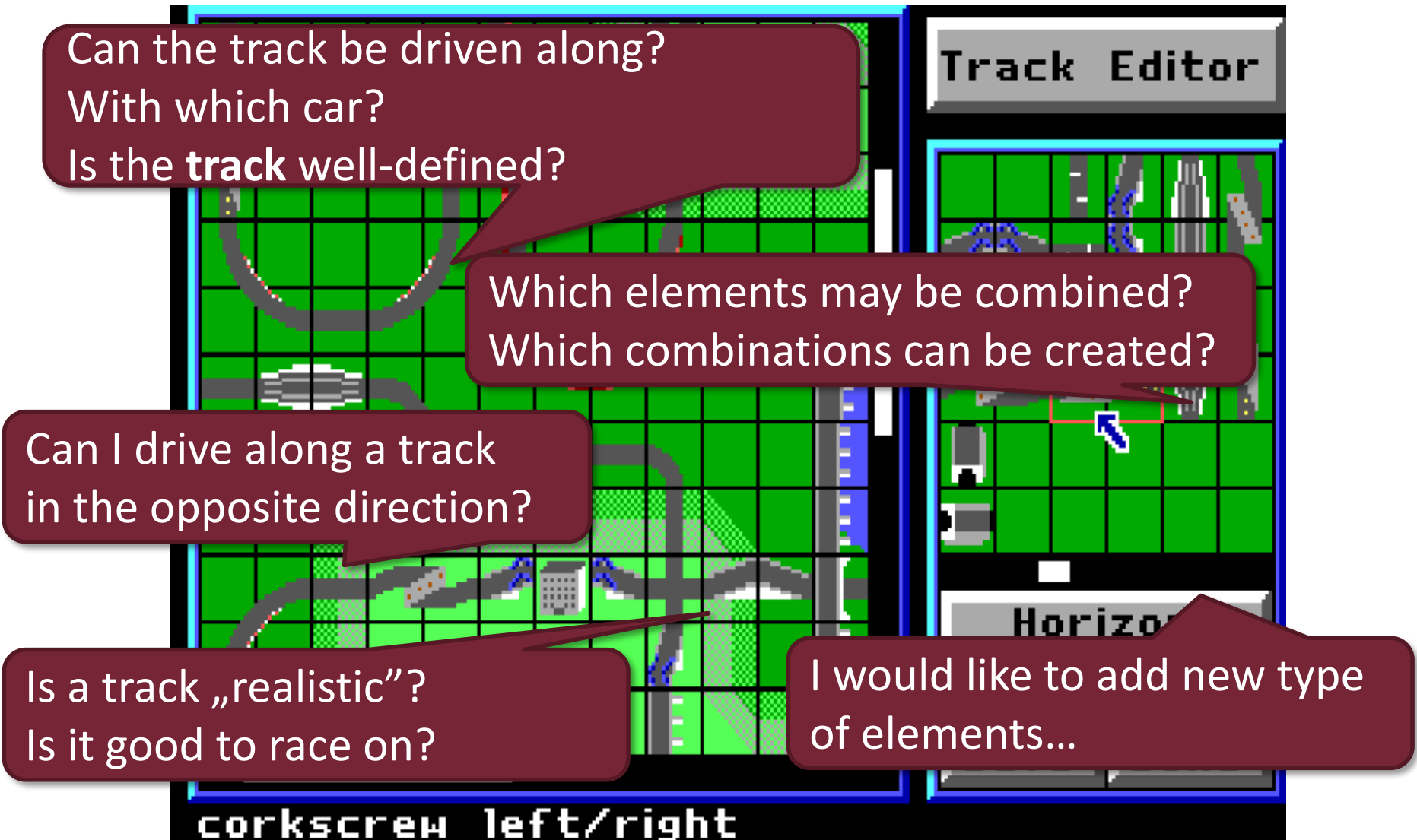


“Motivation”



- Stunts racing game, 1990.
 - Distinctive Games/Brøderbund Software
 - [https://en.wikipedia.org/wiki/Stunts_\(video_game\)](https://en.wikipedia.org/wiki/Stunts_(video_game))
- Racing + track creation (!)
 - „domain specific model”

“Motivation”: why to model?



Pic: <http://www.abandonia.com/games/73/Stunts.htm>

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Models and
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Purpose of the
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Basic Concepts

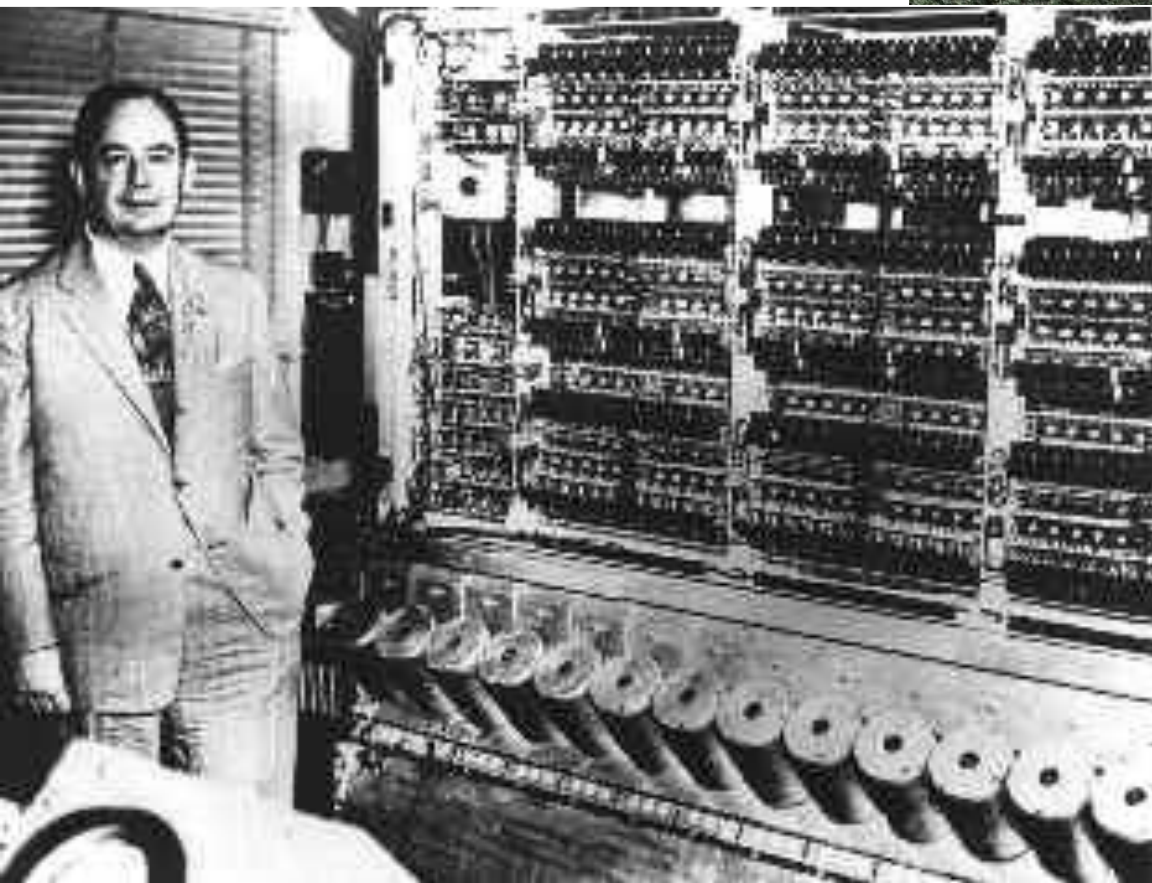
Examples

MODELS AND MODELLING

What is a model?

- "The sciences do not try to explain, they hardly even try to interpret, they mainly make models.
- By a model is meant a mathematical construct which, with the addition of certain verbal interpretations, describes observed phenomena.
- The justification of such a mathematical construct is solely and precisely that it is expected to work – that is correctly to describe phenomena from a reasonably wide area.
- Furthermore, it must satisfy certain esthetic criteria – that is, in relation to how much it describes, it must be rather simple.,,

John von Neumann



E HÁZBAN SZÜLETETT
ÉS ÉLT 18 ÉVES KORÁIG
NEUMANN JÁNOS
1903 — 1957

A XX. SZÁZAD EGYIK LEGKIVÁLÓBB
MATEMATIKUSA.

AKI 1951 — 1952 — BEN
AZ AMERIKAI MATEMATIKAI
TÁRSULAT ELNÖKE VOLT.

AZ EMLÉKTÁBLÁT SZÜLETÉSÉNEK
100. ÉVFORDULÓJÁRA

A BOLYAI JÁNOS MATEMATIKAI
TÁRSULAT ÉS

AZ AMERIKAI MATEMATIKAI
TÁRSULAT KÖZÖSEN ÁLLÍTOTTA.



IN THIS HOUSE WAS BORN
AND LIVED UNTIL HE WAS 18

JOHN VON NEUMANN
1903 — 1957

ONE OF THE MOST OUTSTANDING
MATEMATICIANS OF THE 20TH
CENTURY. PRESIDENT OF THE
AMERICAN MATHEMATICAL
SOCIETY IN 1951 — 1952.

THIS MEMORIAL PLAQUE WAS
ERECTED JOINTLY BY THE
JÁNOS BOLYAI MATHEMATICAL
SOCIETY AND THE AMERICAN
MATHEMATICAL SOCIETY ON THE
100TH ANNIVERSARY OF HIS BIRTH.

What is a model?

- Model is a **partial and simplified depiction of the real or a hypothetical world (the „system“)**, of which can be **substituted** for specific viewpoints
- Decisions:
 - Which part of the world?
 - What is simplified?
 - How it can be mapped to the world?
- Benefits
 - smaller (finite)
 - has manageable size

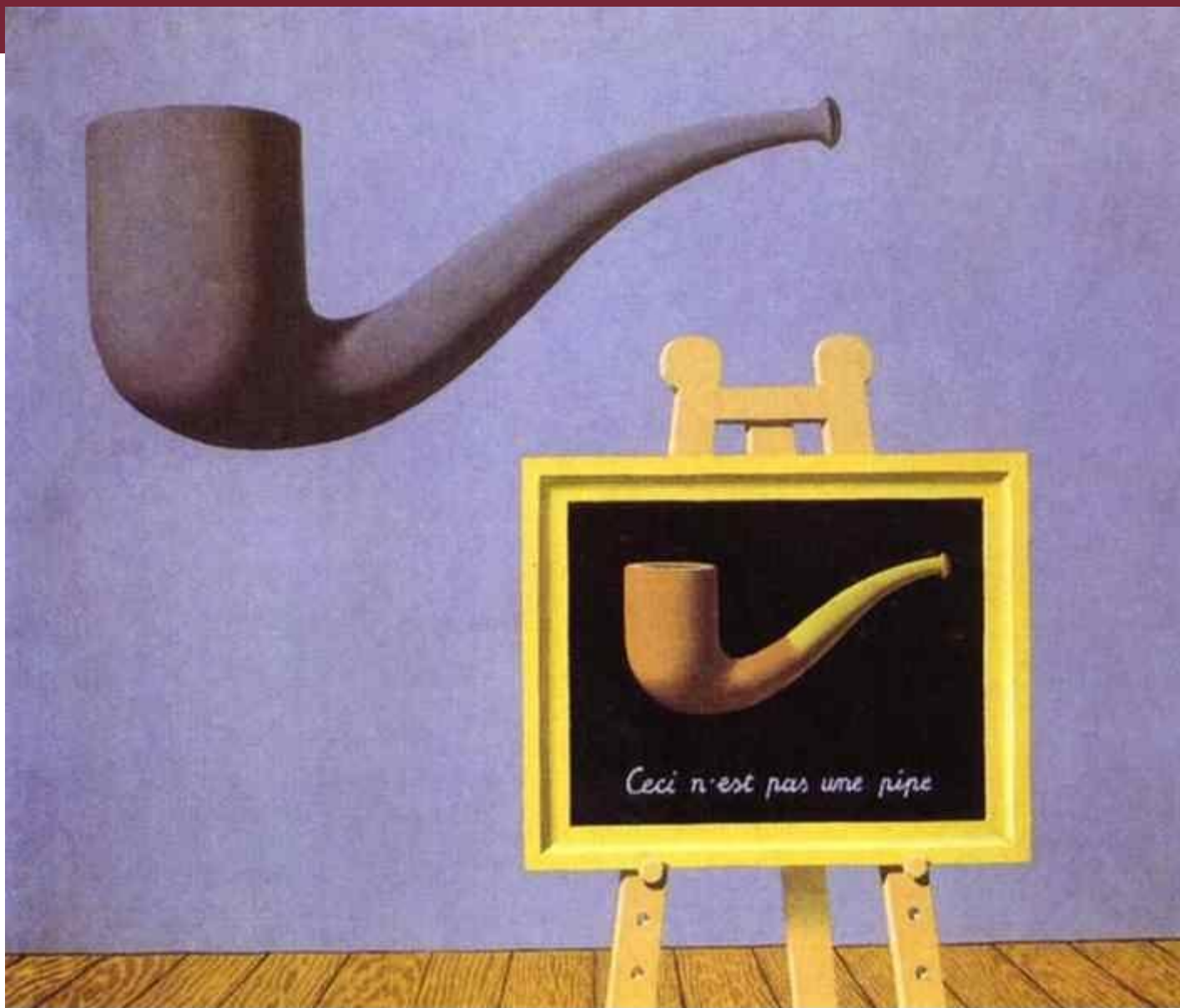
When is it possible or recommended to use?

What is NOT a model?

- The model is NOT the reality!



- The model is not a diagram.
 - It is only a view...



abcgallery.com - Internet's biggest art collection

Model vs. Real World



Mathematical Models vs. Real World

- All of the models are: closed world
 - Effects, factors
 - Parameters
 - Validity
- The models have no defined behavior outside its scope
- Not all aspects can be expressed in advance
 - *Human decisions*
 - *Generate models*
- *Validation of the solutions*
- *Constructed to answer questions...*

- Normal operations
 - Scope:
 - Enough materials are available
 - **All** of the orders can be completed in time
 - Target function:
 - Minimal cost
- Corner case
 - Scope:
 - Not enough materials are available
 - Target function :
 1. **As many as possible** orders completed in time
 2. Minimal cost

Example: safety critical SW

- Braking of an airplane: wheel brake + thrust



1993 Warsaw: Lufthansa 2904

- (SW) protection:

(*load on both weels*)

OR

(*one wheel is rotating fast*)

→ (*plane on the ground*)

→ (PILOT CAN BRAKE)

Wheel sliding

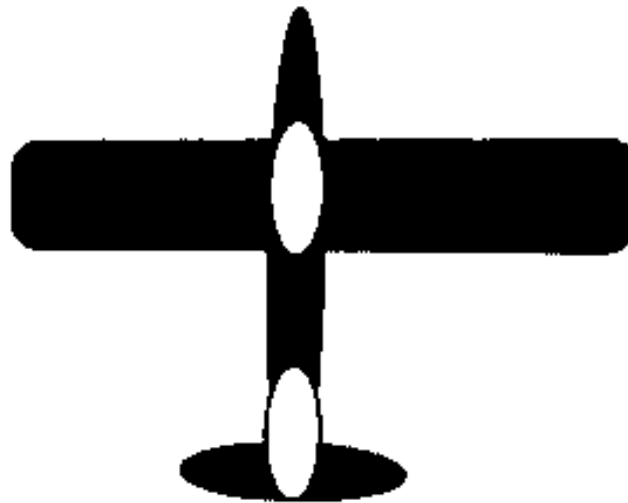
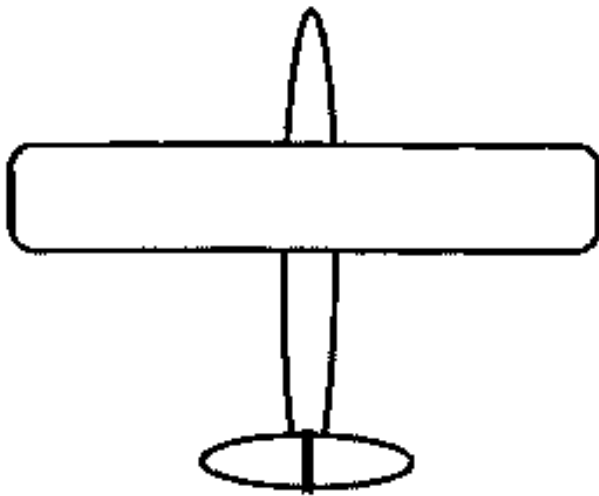
Wheel in the air



Model quality

- Reality: **open world** $\leftrightarrow$
Model: closed world
- “Faithfulness” of models:
 - Probable + critical cases
- Implementation of a bad model can be deadly...

Armor? → Abraham Wald



Armor? → Abraham Wald



**Model is valid only with
environment...**

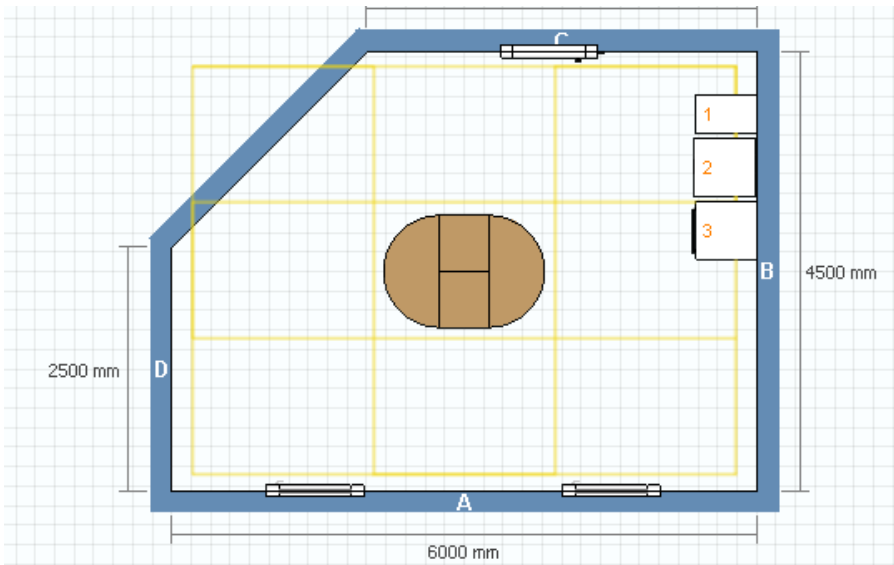


What is the point of modelling?

- I am developing software. Should I do modelling?
 - Yes! In fact, you already do!
 - (The source code is a kind of model...)
 - Most importantly: **mental models**
 - When should be these models documented?
 - Role of the model: **communication**
 - Human → Human
 - Human → Machine
 - Machine → Machine
 - Human → Human (themselves in the future)
 - E.g. Why we implemented this algorithm this way some years ago...

Modelling in real life?

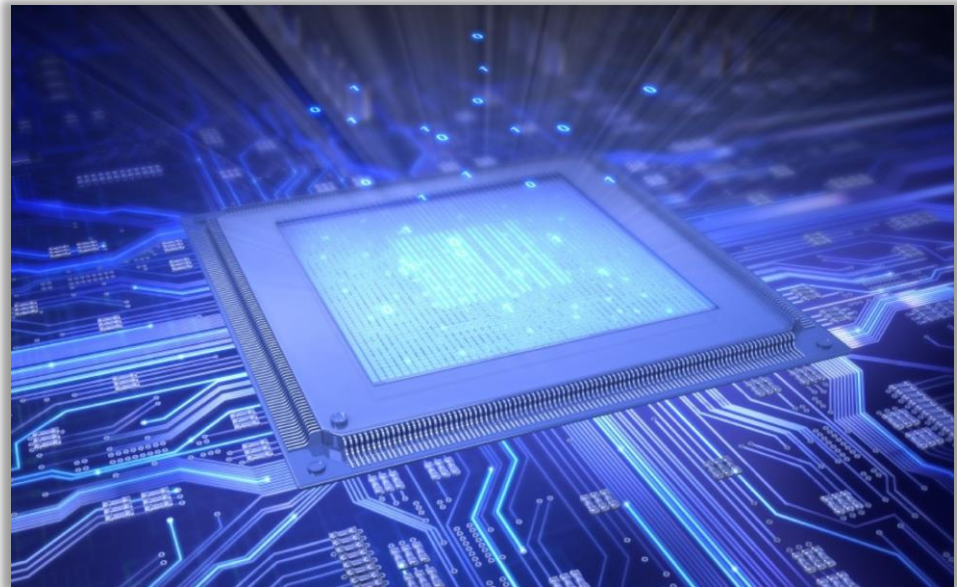
E.g.: web-based kitchen designer
[of a Scandinavian company]



This is also a modelling language!

- VHDL, Verilog – domain specific hardware description

```
1
2 ...
3 ARCHITECTURE Struct OF MyLogic IS
4
5     COMPONENT And2 IS
6         PORT (x, y: IN std_logic;
7             f: OUT std_logic);
8     END COMPONENT;
9
10    COMPONENT CustomHW IS
11        PORT (x: IN std_logic;
12            f: OUT std_logic);
13    END COMPONENT;
14
15    SIGNAL n1, n2: std_logic;
16
17 BEGIN
18     And2_1: And2 PORT MAP ( , , );
19     And2_2: And2 PORT MAP ( , , );
20     CustHW: CustomHW PORT MAP ( , );
21 END Struct;
22
```



Modelling language

- The purpose of the model is to help the communication
 - Understanding of the model is necessary
 - **Modeling languages** (when do we need them?)
- Syntax
 - „Mathematical structure”: abstract syntax
 - Notation: concrete syntax
 - graphical symbols / textual format
- Semantics
- Boundary conditions, constraints
 - Syntactical correctness, well-formedness
 - Design conventions (can vary by teams)

Models and
modelling

Purpose of the
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PURPOSE OF THE MODELS

Models in Engineering Jobs

■ Engineering Jobs

(Architects, Mechanical Eng., Civil Eng., Electro Eng., ..., Landscape Architects, ...)

It is the widely used engineering approach: **Planning**

System Design Process

Management

- purchasing, supplies
- Planning, operations, assessment

ANSI/EIA 632
standard

System
Design

- Requirement definitions
- Solution definitions

Engineering tasks

Product
Development

- Implementation
- Usability

These steps
are usually
supported by
models

Quality
Check

- System Analysis
- Requirements validation
- System Verification
- End-product Verification

System Design Process - Analogy

Management

System
Design

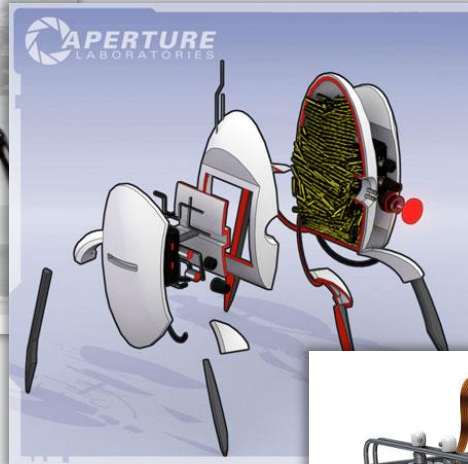
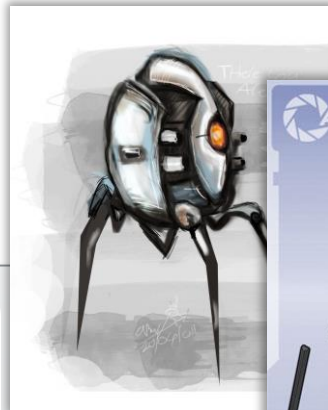
Product
Development

Quality
Check

Validation: Are we building the
right product?
Verification: Are we building the
product right?

PORTAL 2

Engineering Tasks



Application – Documentation

- The model is simpler to handle
 - Easier to communicate than the whole reality
 - Can be refined step-wise (explained later)
- Communication, Visualization
 - Demonstrations (explained later)
 - Easy to understand textual language
 - Expressive diagram
- Supporting conceptualization, design
 - Similar viewpoints
 - „thinking tool“

Application - Analysis

- Human contribution or (semi-)automated
- Method
 - Review, static analysis
 - Dynamic state space exploration – model checking
 - Proving theorems about the model
- Goal
 - Detecting errors (best effort)
 - Proving safety properties (stronger requirement!)
 - Calculating properties of the model (e.g. timing)

Application – Deriving Artifacts

- Human contribution or (semi-)automated
- Output
 - Generating program code, analyzable language, etc.
 - Another model
 - Refinement, next design (abstraction) phase
 - Partial view
 - Model integration
 - May preserve model properties

Usage of models - Simulation

- Demonstration

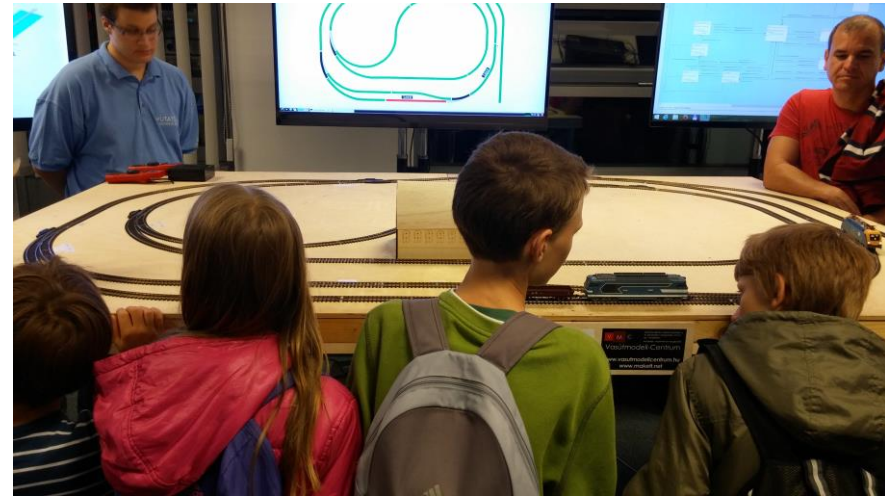
- A tool for communication

- Validation

- „I built it correctly... but did I build the right thing?”

- Experiment

- Proof for desired system characteristics
 - Measurement of quantitative properties
 - Substitute expensive real-life experiments
 - Properties that cannot be predicted using formulae



Model and
modelling

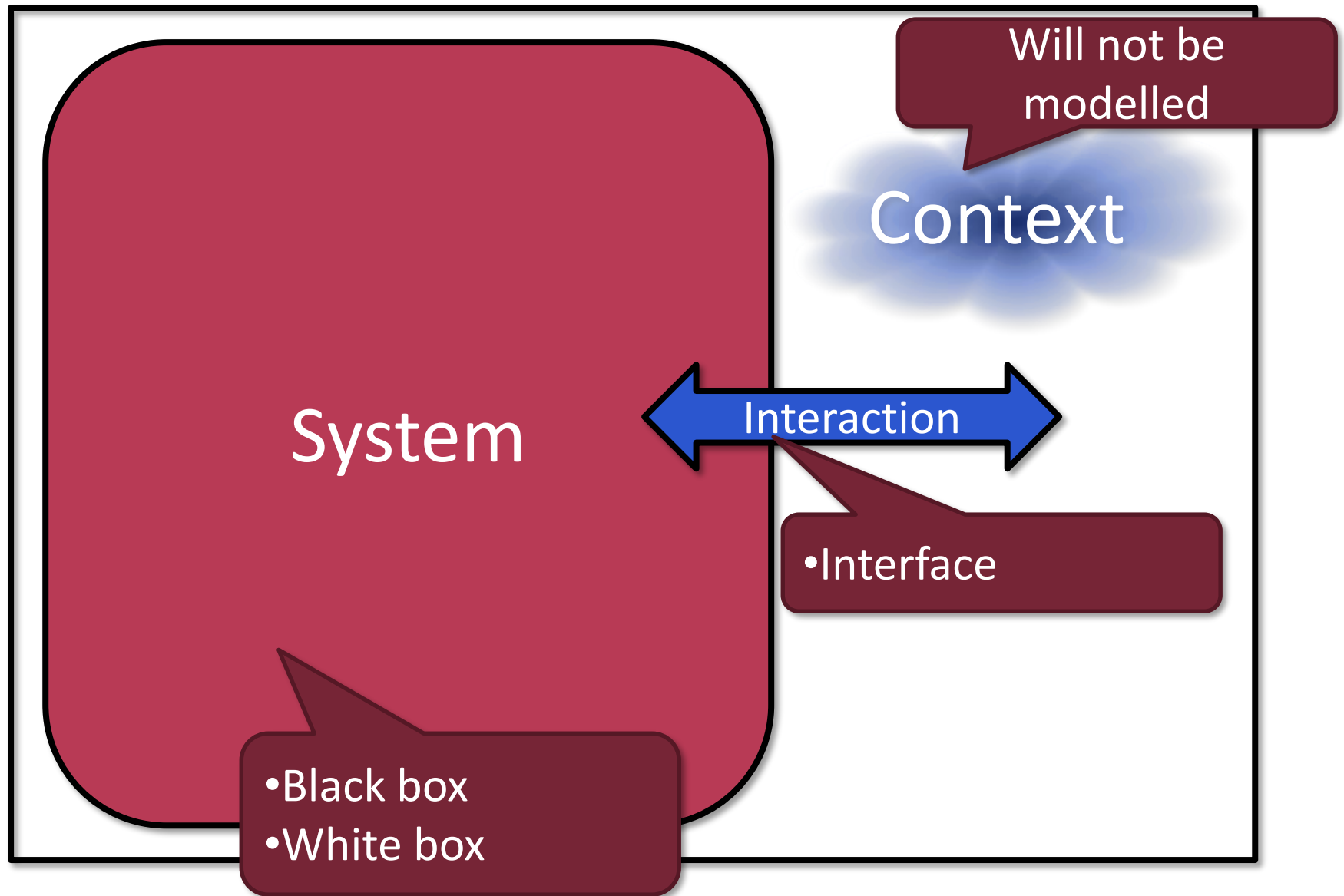
Purpose of the
models?

Basic Concepts

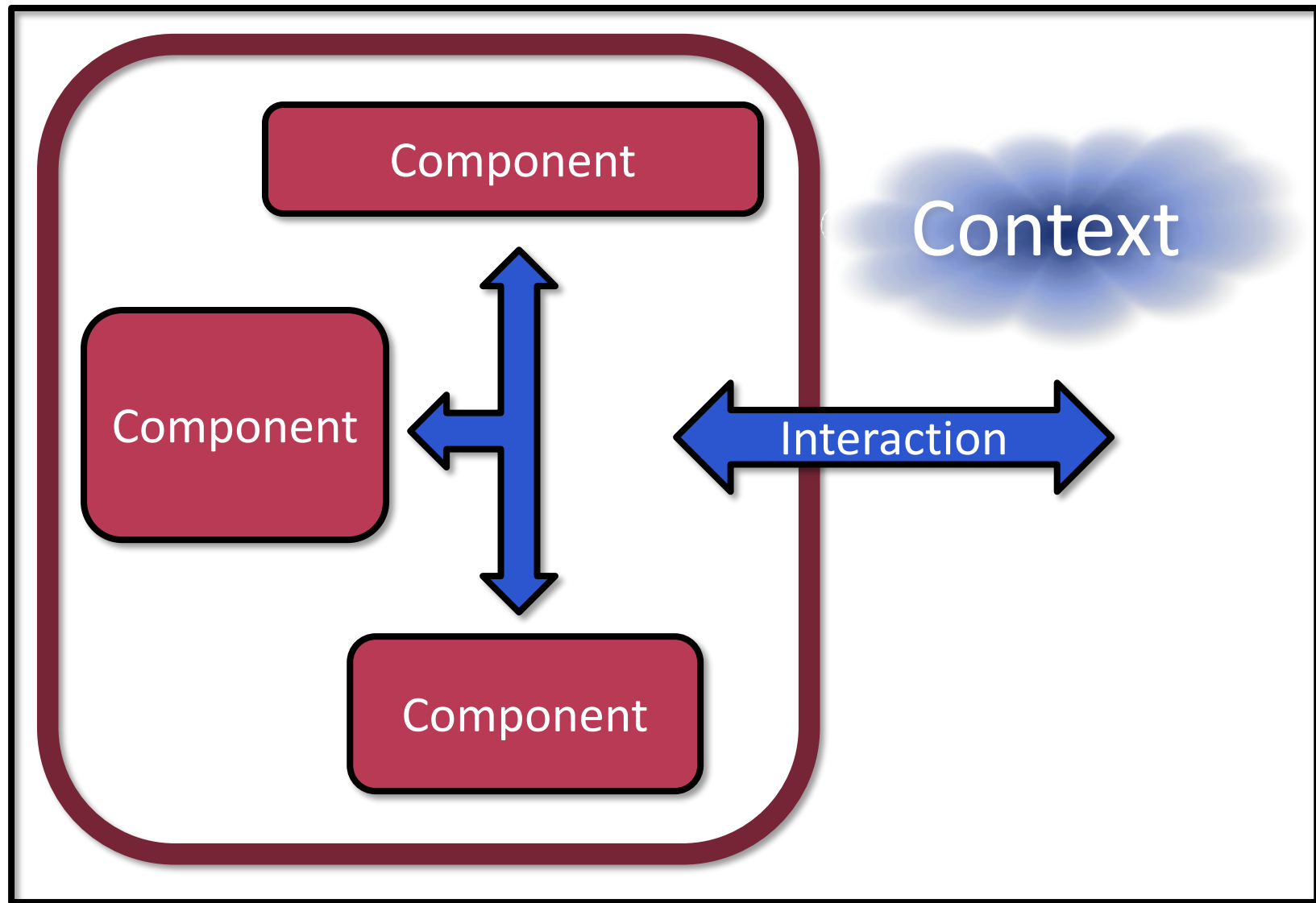
Examples

BASIC CONCEPTS

Basic concepts – System and Context



Basic concepts – System and Context



Basic Concepts – Refinement/Abstraction

- *Refinement*: adding further details to the model...
- ...keep the abstraction of the input model
- Inverse: *(vertical) abstraction*
- There was a *hierarchial refinement* on the previous slide
 - „refinement of the boxes”
- Other aspects can be refined as well...
 - E.g. partitioning of a set (variable domain refinement)
 - **Good** / **bad** can be refined with:
 - **Fast** / **average** / **slow** / **incomplete** / **dangerous**

Basic Concepts - Refinement

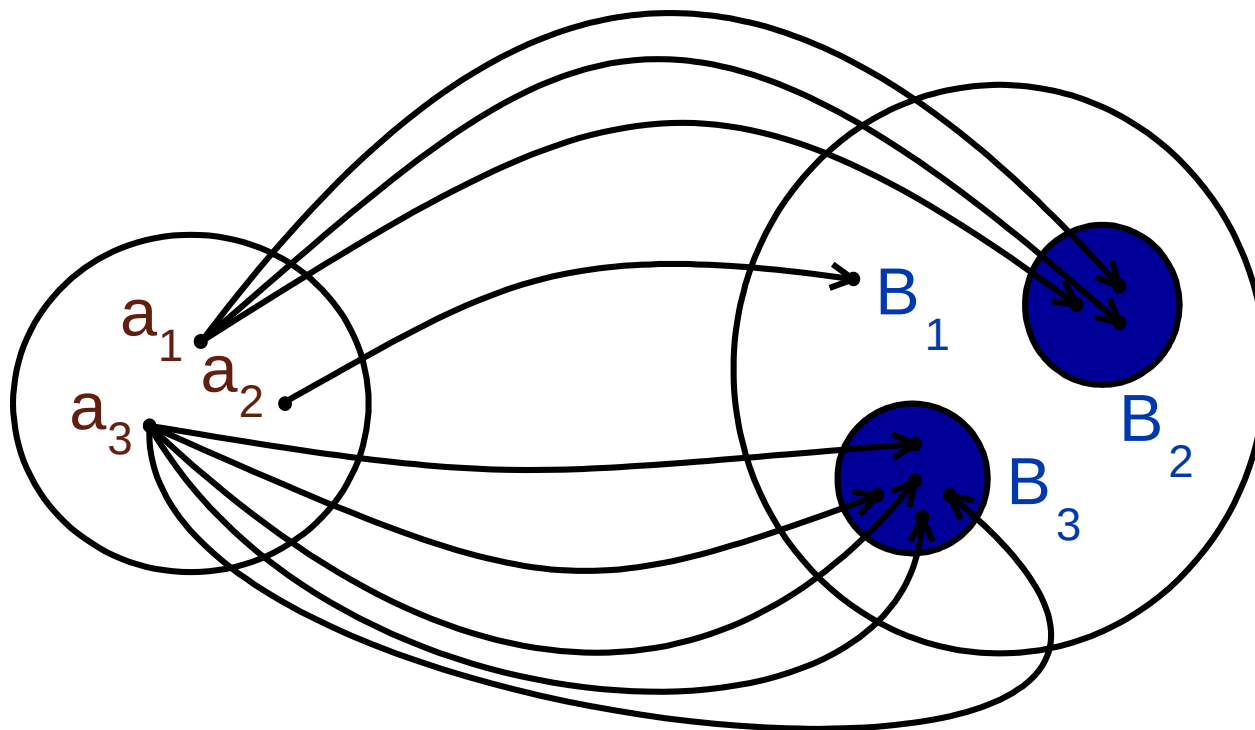


Basic Concepts - Refinement



Partitions of Set Elements

Mapping of disjunct subsets to elements of a set



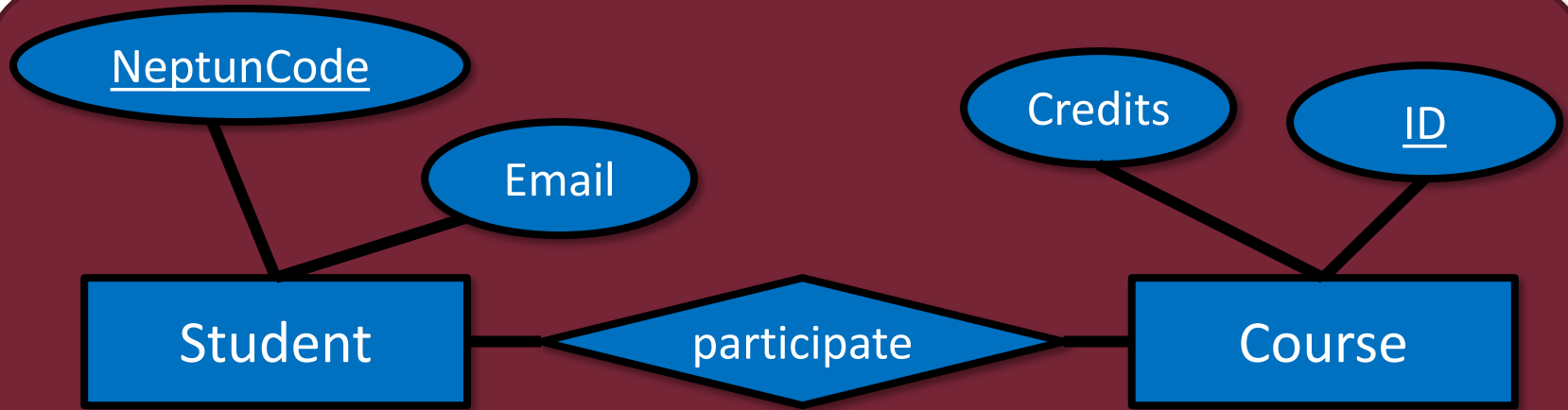
$$\forall a_i, a_j \in A, R(a_i) \subset B \mid \forall a_i, a_j R(a_i) \cap R(a_j) = \emptyset$$

Basic Concepts - Metamodelling

- Modeling language: what are the types of the objects?
 - + what can be the connection between the objects?
 - + how the types can be related to each other?
- **Metamodell** = model of a modeling language
- Well known examples
 - Entity-Relationship (ER) model
 - UML object diagram → class diagram
 - Database table → Relational database schema
 - XML document → XML schema (or DTD)

Basic Concepts - Metamodeling

- Metamodeling
- Metamodels
- Well known examples



- Entity-Relationship (ER) model
- UML object diagram → class diagram
- Database table → Relational database schema
- XML document → XML schema (or DTD)

Model and
modelling

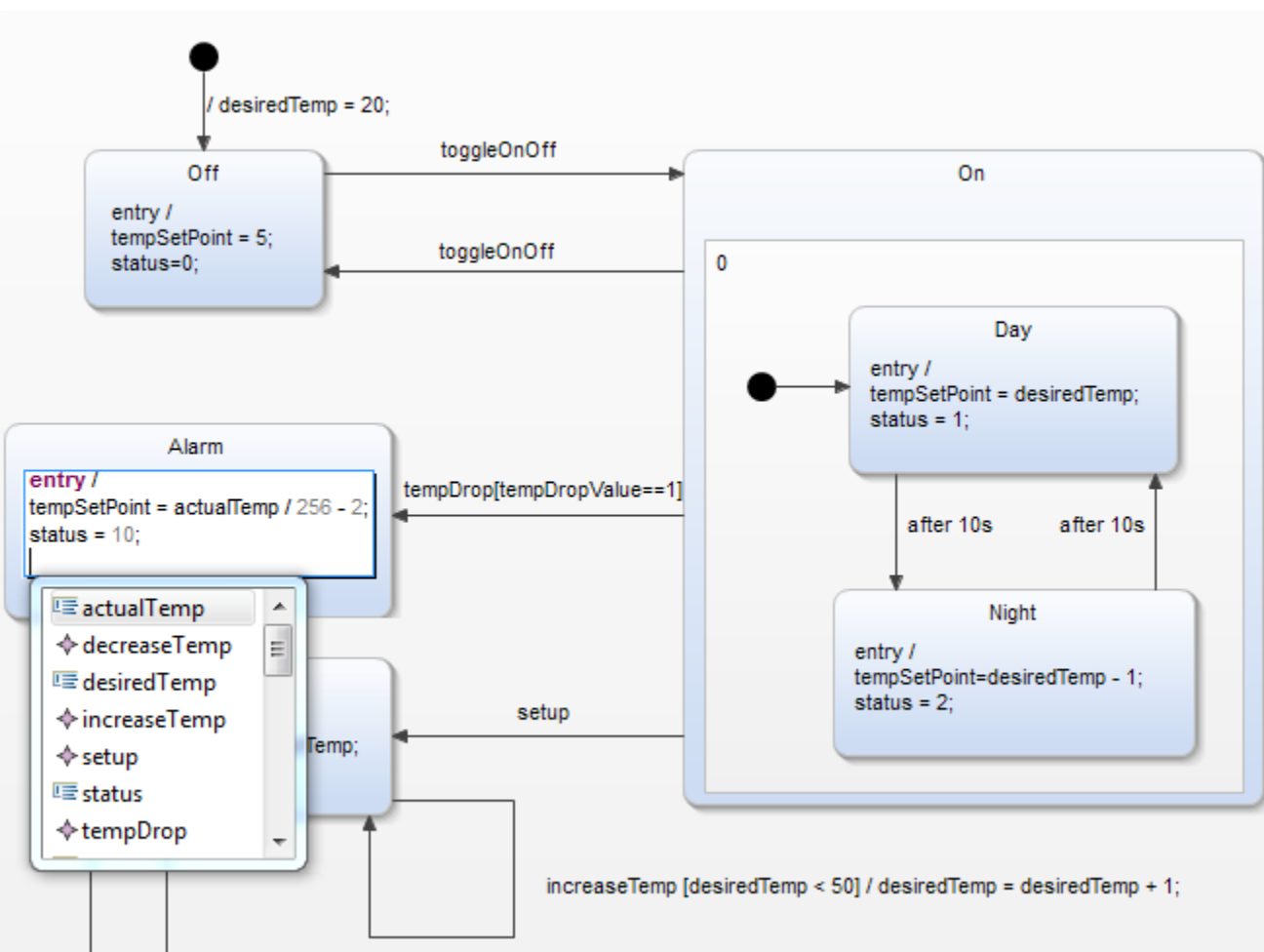
Purpose of the
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EXAMPLES

Yakindu – State Charts



```

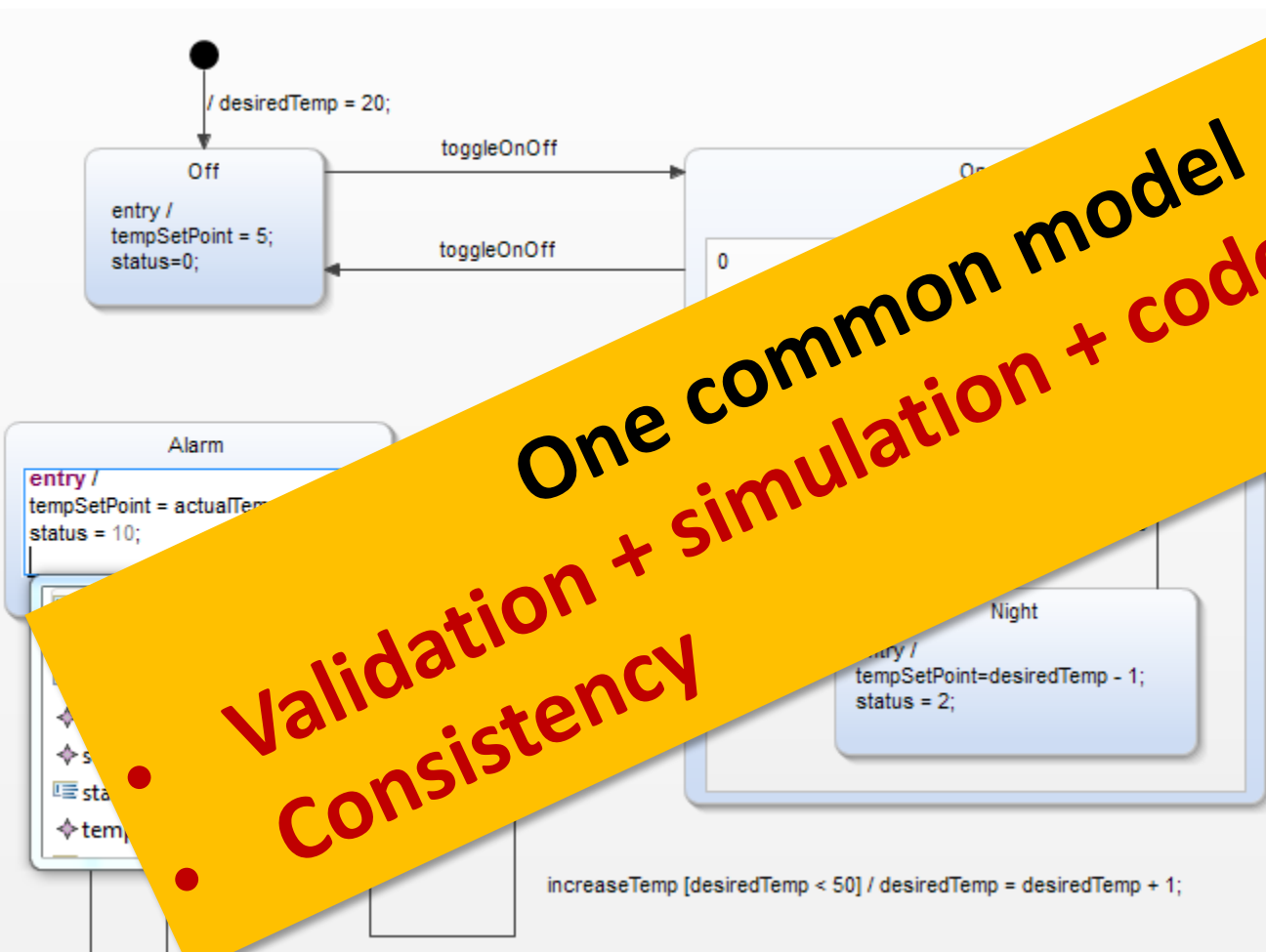
import java.io.*;
import java.net.*;
import java.security.*;
import protection;

public class Client {
    public void sendAuthentication(String username,
    OutputStream outStream) throws IOException {
        DataOutputStream out = new DataOutputStream(
        DataOutputStream out = (new Date()).getTime();
        long t1 = Math.random();
        double q1 = Math.random();
        byte[] protected1 = Protection.main(
        byte[] t2 = (new Date()).getTime();
        long t2 = Math.random();
        double q2 = Math.random();
        byte[] protected2 = Protection.
        out.writeUTF(user);
        out.writeInt(protected1.length);
        out.write(protected2);
        out.flush();
    }
}

public static void main(String[] args) {
    String host = args[0];
    int port = 7999;
    String user = "John";
    String password = "shh";
    Socket s = new Socket(host, port);

    Client client = new Client();
    client.sendAuthentication(user, s.getOutputStream());
}
    
```

Yakindu – State Charts

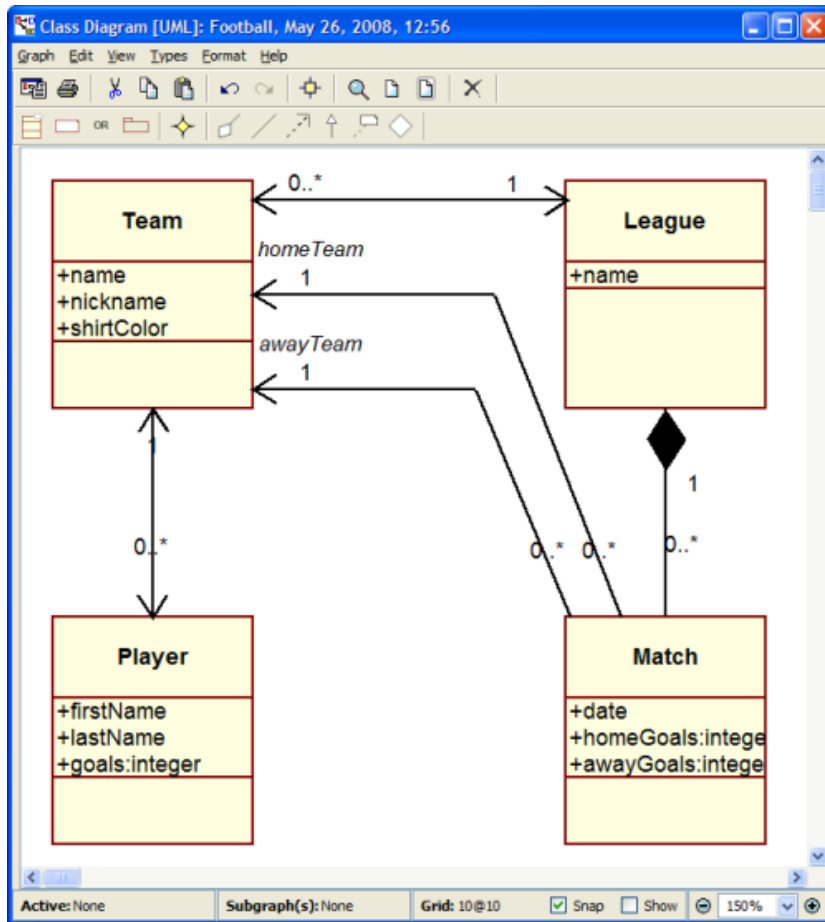


One common model
Validation + simulation + code generation
Consistency

```
public static void main(String[] args) {
    String host = "localhost";
    int port = 7999;
    String user = "John";
    String password = "secret";
    Socket s = new Socket(host, port);

    Client client = new Client(s);
    client.sendAuthenticat...
```

Web Application Development



League [Gears] - Mozilla Firefox

File Edit View History Bookmarks Tools Help

League [Gears]

Enter a League to store in the database:

name

OK

Teams name

Matches date

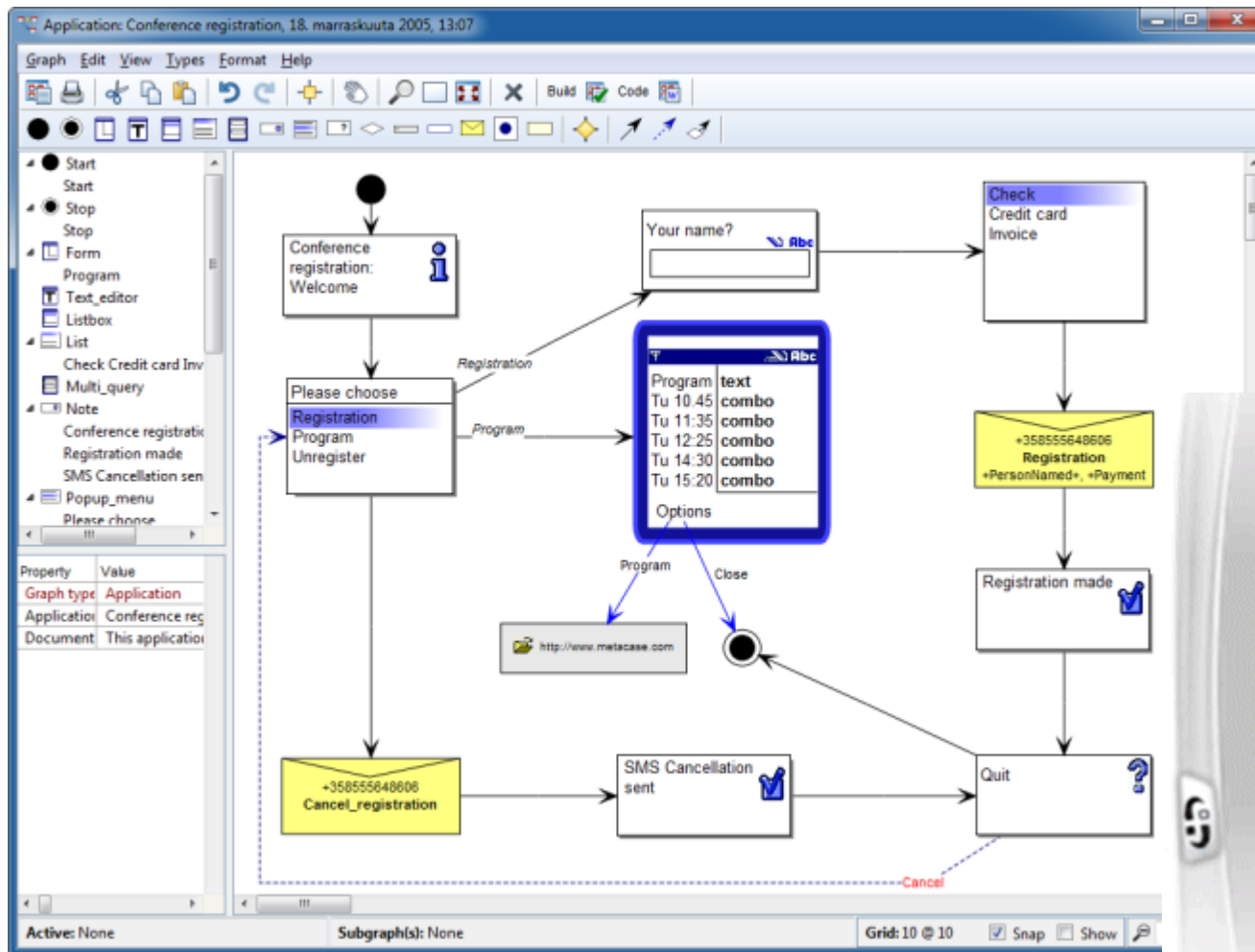
4 most recently edited League entries:

name	
Edit	Premiership Delete

[Back to top page of Football application.](#)

This page uses Gears to record your entries on the local disk. If you navigate away and revisit this page, all your data will still be here. Try it!

Smartphone App Development



Some representative projects...



R3COP (EU ARTEMIS)

- Automated testing of robots
- Robustness and security analysis
- ARTEMIS Innovation Award 2012
- Altogether: 15 EU projects

TRANS-IMA (Embraer)

- Eclipse based development tooling
- HW-SW allocation: avionics architecture
- Integration to the distributed Embraer simulator
- (1st time in Europe)

Data Storage Systems (IBM)

- Supply-chain simulation and optimization
- Prediction of order data
- IBM Vác: Data Storage Systems
- Supply Chain Technology Award 2012

VCL: Virtual Computing Lab

- Open source cloud infrastructure
- Apache project
- Education: lab courses" (BYOD)
- First time in Hungary
- Tempus Award