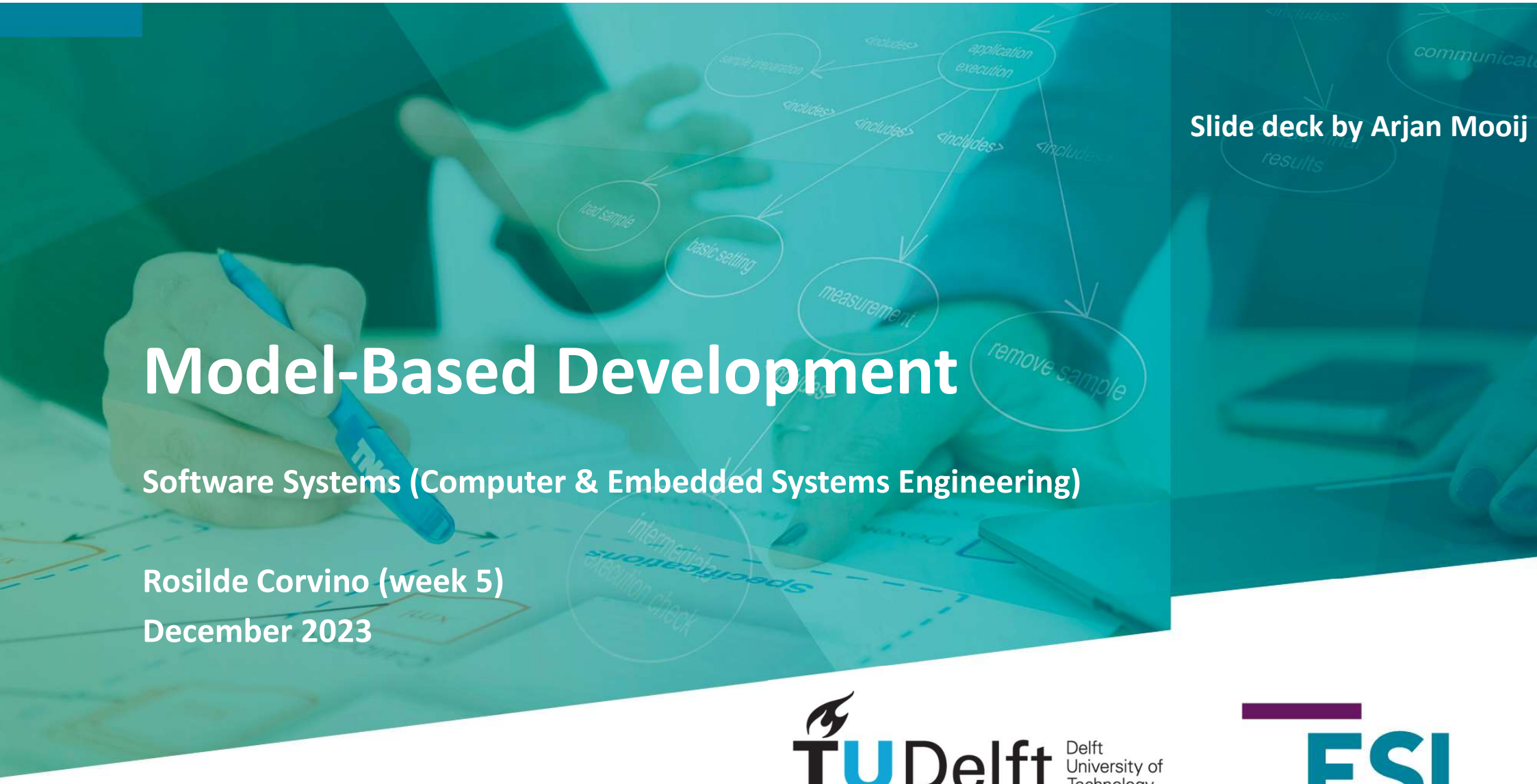


Model-Based Development

Software Systems (Computer & Embedded Systems Engineering)

Slide deck by Arjan Mooij

Rosilde Corvino (week 5)

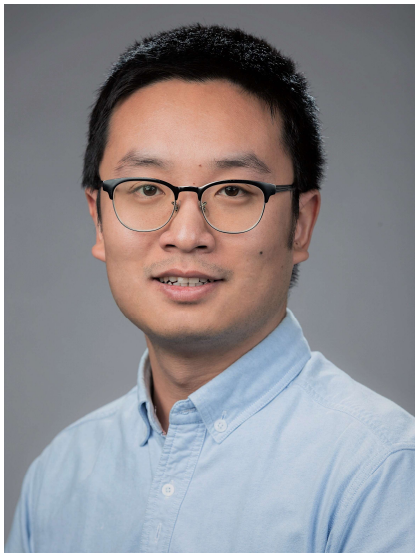
December 2023

An initiative of industry, academia and TNO

TU Delft Delft University of Technology

ESI

Learning facilitators



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TNO-ESI at a glance

Mission: ***Embedding leading edge methodologies into the Dutch high-tech systems industry to cope with the ever increasing complexity of their products.***

Synopsis

- ❑ **Foundation ESI started in 2002**
- ❑ **ESI acquired by TNO per January 2013**
- ❑ **~60 staff members, many with extensive industrial experience**
- ❑ **7 Part-time Professors**
- ❑ **Working at industry locations**
- ❑ **From embedded systems innovation to embedding innovation**

Focus

Managing complexity of high-tech systems

through

- **system architecting,**
- **system reasoning and**
- **model-driven engineering**

delivering

- **methodologies validated in cutting-edge industrial practice**

Partner Board

ASML, ThermoFisher Scientific, Philips, itec, Thales, Canon, Vanderlande, TNO, University of Amsterdam, TU Delft, Radboud University Nijmegen, University of Twente., TU/e Eindhoven University of Technology, Capgemini engineering

Objectives

At the end of the course, you should be able to:

- Explain some complexity challenges of software-intensive high-tech systems
- Explain 4 approaches for dealing with complexity
- Explain the purpose of Model-Based Development
- For 3 specific modeling techniques: explain their purpose and concepts + create basic models
- Compare Model-Based Development with other methodologies

Assessment:

- Modeling assignments for 3 modeling techniques (in groups of 2 students)
  - Maximum of 2 points per assignment
- Reflection document on Model-Based Development (individual)
  - Maximum of 4 points

Agenda for Model-Based Development
(Each week the Software Systems course has 2 lecture hours + 4 lab hours)

- **Week 5 Lecture**
  - 10 minutes Opening
  - 15 minutes Complexity challenges in large-scale software systems
  - 20 minutes Model-based development to manage the complexity

- **Week 5-8 Lectures/labs on 3 types of models (2 lecture hours for each type)**

- **Week 8 Lecture**
  - 35 minutes Reflection on 3 types of models
  - 10 minutes Wrap-up

Challenge

What are we talking about?

- **You are enrolled in a program on “Computer & Embedded Systems Engineering”**
- **You are following a course on “Software Systems”**
- **You may have an idea what you want to be working on after your studies**

What kind of systems do you know that are related to all of the following terms:

- Embedded systems
- Cyber-physical systems
- Software-intensive systems
- Dutch high-tech systems industry

Think/Write → Pair → Share

Dutch high-tech systems industry → Software-intensive systems

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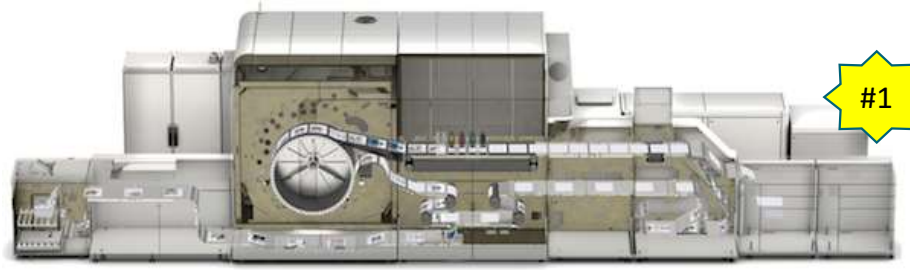
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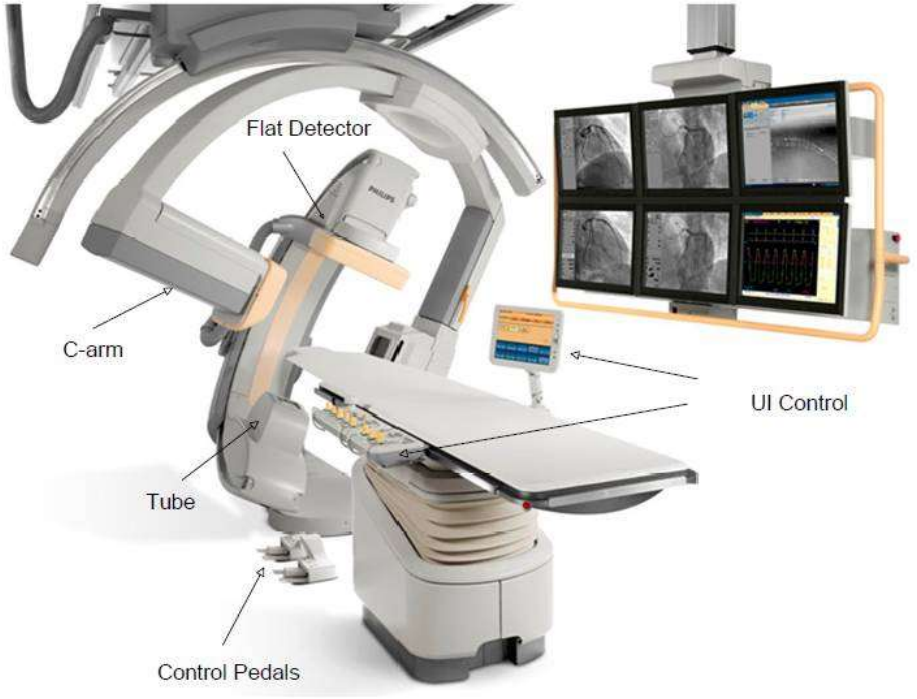
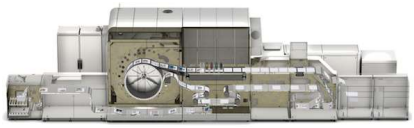
Modeling assignment is inspired by interventional X-ray systems

- **Systems used during medical interventions:**
  - Minimally-invasive surgery
  - Cardiac, vascular and neurological
  - X-ray is used as “eyes of the surgeon”

- **1 or 2 X-ray planes (connected by a C-arm), consisting of:**
  - Tube: generates X-ray
  - Detector: receives X-ray
- **Table at which the patient lays**
  - Patient is positioned between the tube and detector
- **User interface for the surgeon:**
  - Tablet to select the medical procedure
  - Joysticks to move the table and C-arms
  - 3-6 pedals to control the system during a medical procedure
  - Screen to display visual images and video





Managing complexity in cyber-physical systems

Complexity = being difficult to understand, or lacking simplicity

Some related questions:

- **What makes such systems complex?**
- **What makes the software of such systems complex?**
- **What makes the design of such systems complex?**
- **What makes the design of the software inside such systems complex?**

Think/Write → Pair → Share

Complex software projects

- **Large code bases:** tens of thousands, or even millions, of lines of code (LOC)
- **Code reuse:** embedded software evolves over decades

- **Team effort:** multiple development teams that evolve over time
- **Multi-disciplinary:** closely related to physical systems and application domains

- **Integration:** interaction with other systems and humans (outside of your control)
- **Customization:** not many identical systems in the field

- **Performance:** quantitative performance criteria (hard real-time, competition)
- **Dependability:** non-functional requirements like availability, reliability, maintainability

Design Approaches

Approaches for dealing with complexity

- You have seen software-intensive systems from the Dutch high-tech systems industry
- You have seen that these systems and their development are complex
- You are following university education on challenging, complex topics

What kind of approaches do you know to handle complex challenges?

Think/Write → Pair → Share

Approaches for dealing with complexity

A. Abstraction: Identify high-level concepts that hide low-level details

- Architects design a building in terms of walls (instead of bricks)
- Aerospace engineers reason about processor instructions instead of individual transistors

B. Boundedness: Impose acceptable restrictions on the considered problem space

- Architects design a building for a specific set of usage scenarios (residential, industrial, retail)
- Aerospace engineers assume that airplanes do not need to be usable in outer space

C. Composition: Divide one problem into multiple independent smaller problems

- Architects design a new district in terms of buildings with separate foundations
- Aerospace engineers separate flight control from cabin control and in-flight entertainment

D. Duplication: Use multiple overlapping approaches for the same problem

- Architects use blueprints with multiple perspectives on the same building
- Aerospace engineers introduce fallback systems for safety-critical functionality

Model-Based Development

What do you think of when you hear the term “model-based development”?

What kind of engineering models do you know?

- **Level:** system, software, requirements, etc.
- **Representation:** graphical, textual, etc.
- **Etc.**

Think/Write → Pair → Share

Model-Based Development

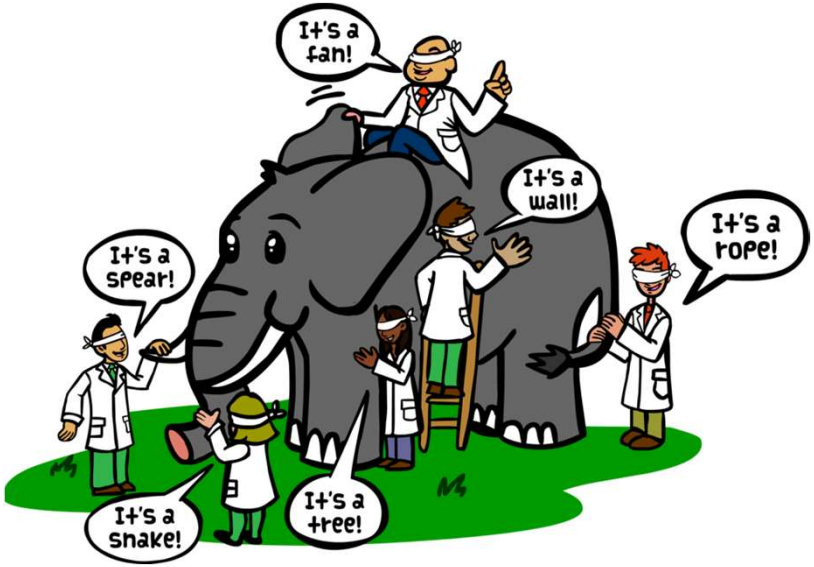
- **General modeling goals:**
  - Speeding up software development of large complex systems
    - Human understanding
    - Early validation
    - Code generation
    - Automated testing
  - Bridging the gap between application domain expertise and technical system realization
- **Model-based development uses all four approaches for dealing with complexity:**
  - Abstraction: Identify high-level concepts that hide low-level details
  - Boundedness: Impose acceptable restrictions on the considered problem space
  - Composition: Divide one problem into multiple independent smaller problems
  - Duplication: Use multiple overlapping approaches for the same problem
- **Notes:**
  - Modeling is for a specific purpose; there exist many different types of models
  - Modeling often helps you to detect important unclarities

Software development principles → also for modeling!

- **“Keep it simple, stupid” (KISS)**
  - https://en.wikipedia.org/wiki/KISS_principle
  - Most models work best if they are kept simple rather than made complicated
  - Simplicity should be a key goal in design, and unnecessary complexity should be avoided

- **“Don't repeat yourself" (DRY)**
  - https://en.wikipedia.org/wiki/Don%27t_repeat_yourself
  - Replace repetition of software patterns with abstractions and use data normalization (no variations)

Modeling for a specific purpose



- **In this course we will focus on the following 3 modeling techniques:**
  - Unified Modeling Language (UML)
  - Finite-State Machines (FSM)
  - Domain-Specific Languages (DSL)