UMLEmb:
UML for Embedded Systems
I. Introduction

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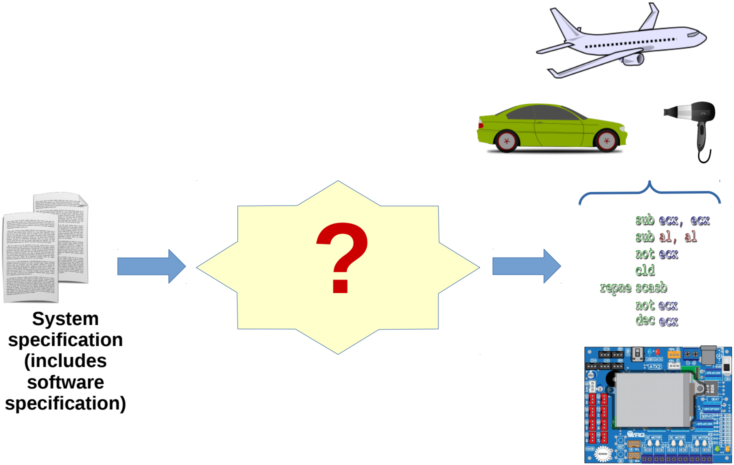
Goals



System specification (includes software specification)

```
      sub ecx, ecx
      sub al, al
      not ecx
      cld
repne scasb
      not ecx
      dec ecx
```

Goals (Cont.)

- To propose a method, a language, and a tool, that can be applied to the design of a broad variety of systems
  - Real-time and embedded systems
  - Transportation systems, smart objects, . . .
- To practice modeling using a UML/SysML framework
- To answer your questions
- To interact together e.g. be able to evaluate the model of someone else
  - And be able to evaluate your own work!

Origin of this Course

- This course was designed with *Prof. Pierre de Saqui-Sannes, ISAE Sup'Aero*
- It has been used worldwide for years in different formats for:
  - Master students
  - Tutorials in international conferences
  - Trainings in companies

Outline of the Lectures and Labs

From a system specification, you will learn how to:

- Capture system requirements
- Analyze the system
- Design the system
- Validate the system

All stages will be explained with UML/SysML models

BTW: Do you know what is a *system specification*?

Lecture Organization

Applies only to Eurecom students

Lectures: ∼4 sessions

- Presentation of SysML diagrams
- Exercises

Labs: ∼3 sessions

- Modeling a system with TTool
  - Requirements, analysis, design, validation

Grading policy

- 30% on labs. Attendance is therefore obligatory.
- 70% on exam. (Exam is like a lab).

Recommended Books

(Also available on the course's website)

- F. Kordon et al, "Embedded systems : Analysis and modeling with SysML, UML and AADL"
- D. Alan et al, "Systems analysis and design with UML version 2.0: an object-oriented approach"
- L. Doldi, "UML 2 illustrated - Developing real-time and communications systems"
- See the "link" section of UMLEmb website for videos of examples on how to model with similar aproaches

Outline

Introduction to modeling

OMG, UML and SysML

UML/SysML for Embedded Systems

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Designing Embedded Systems

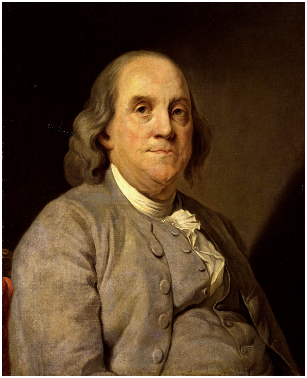
How to Handle Complexity?

Modeling and verification!
(But there are other options)

Modeling is not Really a New Technique. . .

. . . and it is not limited to Software!

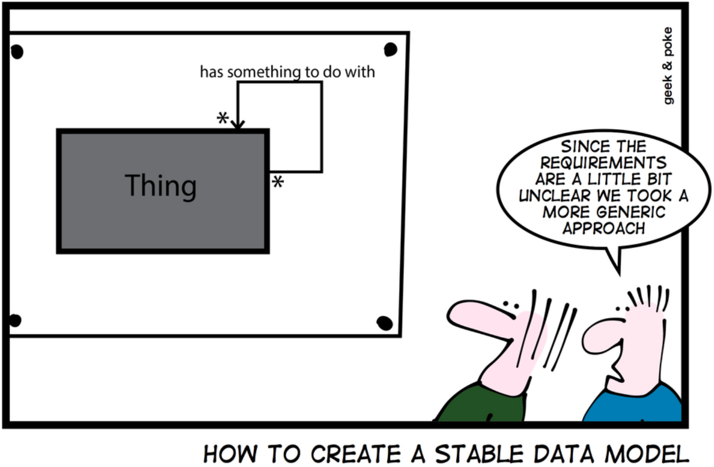
Modeling is not Really a New Technique. . .



Painting by Duplessis.
Source: Wikipedia

”If you fail to plan,
you are planning to fail!”

Abstraction Level


has something to do with
*
*
Thing
geek & poke
SINCE THE REQUIREMENTS ARE A LITTLE BIT UNCLEAR WE TOOK A MORE GENERIC APPROACH
HOW TO CREATE A STABLE DATA MODEL

(*source: Geek and Poke, 2013*)

So, What is Modeling?

A modeling = An abstraction of the system to design

- Representation of the main functionalities of a complex system
- Non relevant details are ignored

Abstractions make it possible to deal with complexity

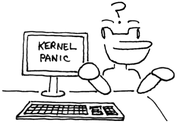
An engineer, or a development team, cannot have a global understanding of complex systems

A modeling is a view of a system according to some **assumptions**

Software Development Techniques for E. S.

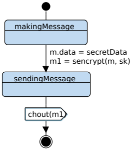
Code-based approaches

- Extreme Programming
  - Strongly tested step-by-step code increments
- Agile Software Development
  - Focus on change in specification

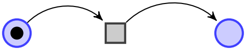


Model-based approaches

- V-Cycle
  - KAOS, AADL, MDE, ...



- Formal models
  - B, LOTOS, Petri nets, ...



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Introduction to modeling

OMG, UML and SysML

UML/SysML for Embedded Systems

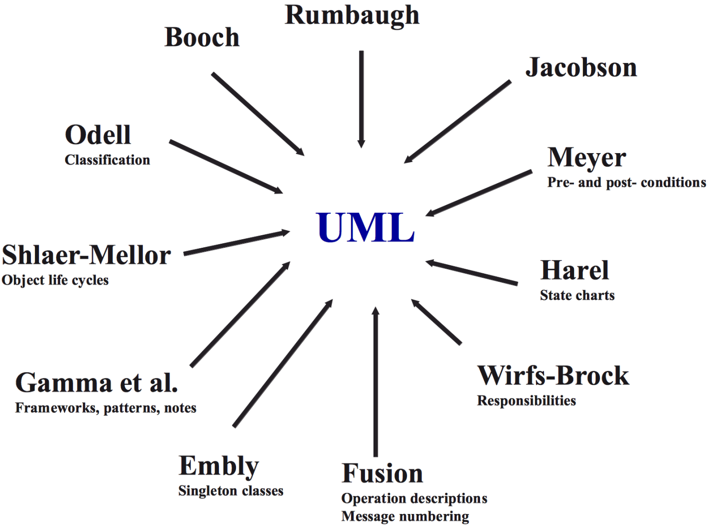
What is UML?

UML = Unified Modeling Language

Main characteristics of UML

- Standard graphical modeling language for complex systems
  - Defined by OMG
- Specification, design, automatic code generation, documentation
- Independent of any programming language
- Object-oriented design
- Supported by many CASE Tools
  - CASE = Computer-Aided Software Engineering
- **But**: No standard UML methodology

Origin of UML



Rumbaugh

Booch

Jacobson

Odell
Classification

Meyer
Pre- and post- conditions

UML

Shlaer-Mellor
Object life cycles

Harel
State charts

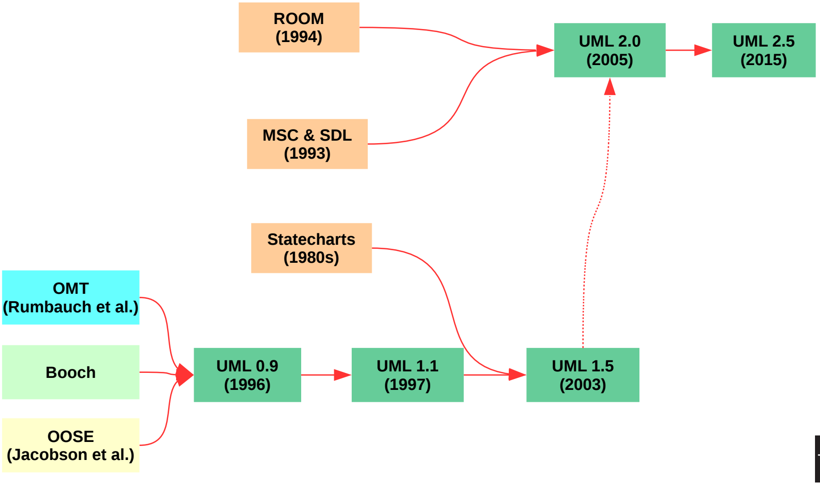
Gamma et al.
Frameworks, patterns, notes

Wirfs-Brock
Responsibilities

Embly
Singleton classes

Fusion
Operation descriptions
Message numbering

Genesis of UML



ROOM (1994)

MSC & SDL (1993)

Statecharts (1980s)

OMT (Rumbauch et al.)

Booch

OOSE (Jacobson et al.)

UML 0.9 (1996)

UML 1.1 (1997)

UML 1.5 (2003)

UML 2.0 (2005)

UML 2.5 (2015)

OMG: Object Management Group

- Non-profit organization
- Goal: definition of standards related to object-oriented services
  - MOF, UML, XMI, CWM, CORBA (includes IDL, IIOP)
- 11 creating members
  - Hewlett-Packard, IBM, Sun Microsystems, Apple Computer, American Airlines, Data General,. . .
- Nowadays: ∼300 members
  - https://www.omg.org/cgi-bin/apps/membersearch.pl

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UML for Embedded Systems

Specificity of embedded systems

- Strict constraints
  - Performance constraints, real-time constraints, limited resources, etc.

→ Specific UML operators, diagrams, methodologies, toolkits

- Make use of some UML diagrams rather than others
- Make use of simulation techniques as soon as possible in the development cycle
- Specific UML toolkits
- Profiles

UML Profiles

Definition

- UML defines extension mechanisms to e.g.,
  - Define new operators
  - Provide a semantics
  - Give a methodology

Example of profiles

- Profiles defined by OMG (e.g., SPT, MARTE, SysML)
- Profiles defined by tool vendors (e.g. in Rhapsody, Artisan)
- User-defined and company-defined profiles

From UML to SysML

What's wrong with UML? (as far as system modeling is concerned)

- Objects are for computer-literates, not for systems engineers
- Requirements are described outside the model using, e.g., IBM DOORS
- Allocation relations are not explicitly supported

Nevertheless SysML is a UML 2 profile

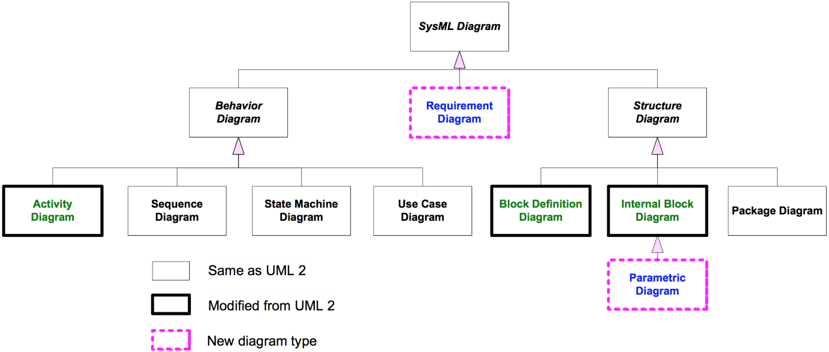
- Developed by the Object Management Group (OMG) and the International Council on Systems Engineering (INCOSE)

SysML standard:
www.omgsysml.org

SysML

- **An international standard** at OMG
  - UML profile
- **A graphical modelling language** that supports the specification, analysis, design, verification, and validation of systems that include hardware, software, data, staff, procedures, and facilities
- **A notation**, not a method
- **Proprietary tools**
  - Enterprise Architect, Rhapsody, Modelio, . . .
- **Free software tools**
  - Polarsys, Papyrus, **TTool**, . . .
- **User communities**
  - http://sysmlfrance.blogspot.com/
  - http://sysmlbrasil.blogspot.fr/p/sysml-brasil.html

SysML Diagrams vs. UML Diagrams



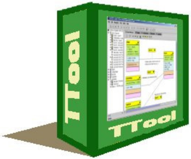
From SysML to AVATAR

- **AVATAR reuses most SysML diagrams**
  - Requirement capture: requirement diagrams
  - Analysis: use case, sequence and activity diagrams
  - Design: block and state machines diagrams
- **AVATAR does not entirely comply with the OMG-based SysML**
  - In AVATAR, block diagrams merge block and internal block diagrams
  - AVATAR does not support continuous flows
- **AVATAR gives a formal semantics to several diagrams, including**:
  - Block instance and state machine diagrams
    - Starting point for simulation, verification and code generation

TTool: A Multi Profile Platform

TTool

- Open-source and free toolkit mainly developed by Telecom Paris
- Multi-profile toolkit
  - DIPLODOCUS, AVATAR, . . .
- Support from academic (e.g. LIP6, ISAE) and industrial partners (e.g., Nokia)



Main ideas

- Lightweight, easy-to-use toolkit
- Simulation with model animation
- Formal proof at the push of a button

End of Introduction. . .

So, what's next?

1. **Modeling in SysML/AVATAR**
   - Methodology
   - Diagrams
2. **Validation**
   - Simulation
   - Formal verification
   - Code generation, and execution of that code