UMLEmb:
UML for Embedded Systems

I. Introduction

Ludovic Apvrille
ludovic.apvrille@telecom-paristech.fr
Eurecom, office 470

http://soc.eurecom.fr/UMLEmb/
@UMLEmb_Eurecom
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 Pierre de Saqui-Sannes, ISAE
- 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

Lectures: ~4 sessions
- Presentation of SysML diagrams
- Exercises

Labs: ~3 sessions
- Modeling a system with TTool
  - Requirements, analysis, design, validation

Grading policy (Applies only to Eurecom students)
- 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
Outline

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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!

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

Painting by Duplessis.
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**Abstraction Level**

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

**So, What is Modeling?**

(source: peek and Poke, July, 2013)
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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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
### Genesis of UML

- **ROOM** (1994)
- **MSC & SDL** (1993)
- **Statecharts** (1980s)
- **OMT** (Rumbaugh et al.)
- **Booch**
- **OOSE** (Jacobson et al.)

- **UML 1.5**

#### Requirement capture
Outside the UML model

#### Use case driven analysis

- Use case = main function
- System / environment (actors)
- Use cases need documentation

#### Object-oriented design

- Object = Name + Attributes (state) + Methods
- Objects communicate using method calls
- Class diagrams for software architectures
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UML 2

Requirement capture
Outside the UML model

Analysis
- Enhanced sequence and activity diagrams

Object-oriented design
- Object can communicate
  - by method calls
  - via ports
    - Input and output signals are defined by interfaces

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
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- OMG, UML and SysML
- UML/SysML 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.omg.sysml.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://sysmlfrance.blogspot.com/)
  - [http://sysmlbrasil.blogspot.fr/p/sysml-brasil.html](http://sysmlbrasil.blogspot.fr/p/sysml-brasil.html)

**SysML Diagrams vs. UML Diagrams**

![Diagram showing differences between SysML and UML diagrams](image-url)
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 ParisTech
- 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