

# Semantics and Verification of Software

## Lecture 26: Wrap-Up

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(Software Modeling and Verification)

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- 1 Further Topics in Formal Semantics
- 2 Topics for Diploma and Master's Theses
- 3 Upcoming Courses and Seminars
- 4 Evaluation of the Course

- Program = list of **function definitions**
- Simplest setting: **first-order** function definitions of the form

$$f(x_1, \dots, x_n) = t$$

- function name  $f$
- formal parameters  $x_1, \dots, x_n$
- term  $t$  over (base and defined) function calls and  $x_1, \dots, x_n$

- **Operational semantics** (only function calls)
  - **call-by-value** case:

$$\frac{t_1 \rightarrow z_1 \ \dots \ t_n \rightarrow z_n \ \ t[x_1 \mapsto z_1, \dots, x_n \mapsto z_n] \rightarrow z}{f(t_1, \dots, t_n) \rightarrow z}$$

- **call-by-name** case:

$$\frac{t[x_1 \mapsto t_1, \dots, x_n \mapsto t_n] \rightarrow z}{f(t_1, \dots, t_n) \rightarrow z}$$

- Denotational semantics
  - program = **equation system** (for functions)
  - induces call-by-value and call-by-name **functional**
  - **monotonic and continuous** w.r.t. graph inclusion
  - semantics := **least fixpoint** (Tarski/Knaster Theorem)
  - **coincides** with operational semantics
- **Extensions:** higher-order types, data types, ...
- see [Winskel 1996, Sct. 9] and *Functional Programming* course [Giesl]

- **Problem:** “classical” view of sequential systems

Program : Input → Output

- not adequate for concurrent settings
- Missing: aspect of **interaction**
- Typical approach:
  - concurrency modelled by **interleaving**
  - interaction modelled by (explicit) **communication**
- Example: Milner’s *Calculus of Communicating Systems (CCS)*
- Syntax:  $P ::= 0 \mid \alpha.P \mid P_1 + P_2 \mid P_1 \parallel P_2 \mid \dots$
- (Operational) Semantics: **labelled transition systems** defined by transition rules of the form

$$\frac{}{\alpha.P \xrightarrow{\alpha} P} \quad \frac{P \xrightarrow{\alpha} P'}{P + Q \xrightarrow{\alpha} P'} \quad \frac{P \xrightarrow{\alpha} P'}{P \parallel Q \xrightarrow{\alpha} P' \parallel Q} \quad \frac{P \xrightarrow{\alpha} P' \quad Q \xrightarrow{\bar{\alpha}} Q'}{P \parallel Q \xrightarrow{\tau} P' \parallel Q'} \quad \dots$$

- see course on **Modelling Concurrent and Probabilistic Systems** in Summer 2009 [Katoen, Noll] and [Winskel 1996, Sct. 14]

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## COMPASS

Correctness, Modelling and Performability of Aerospace Systems

### Current Situation

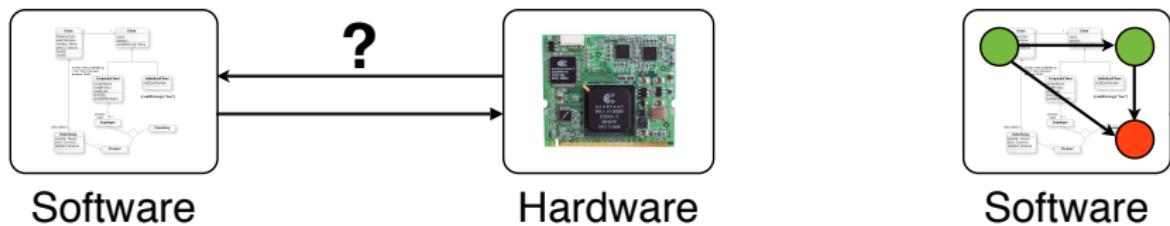
Yes, formal methods are applied for aerospace systems, but not in a **coherent** manner at the **systems engineering level**

### Systems Engineering

*“Identification and quantification of system goals, creation of alternative system design concepts, performance of design trades, selection and implementation of the best design, verification that the design is properly built and integrated, and post-implementation assessment of how well the system meets (or met) the goals.”*

- NASA’s Systems Engineering Handbook, 1995

# Evaluating Critical Embedded Systems is **Hard**



## Coherency issues

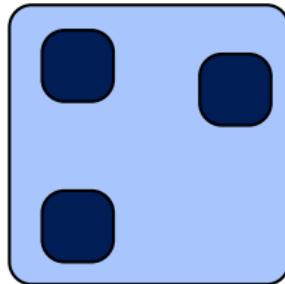
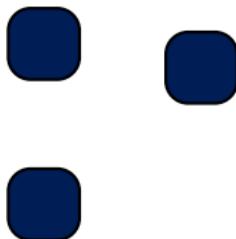
- Co-engineering
- Analysis of degraded modes of operation
- Assessment of **Fault Detection, Isolation and Recovery** analysis



*“Provide a unified modelling language that is amenable for validation and verification”*

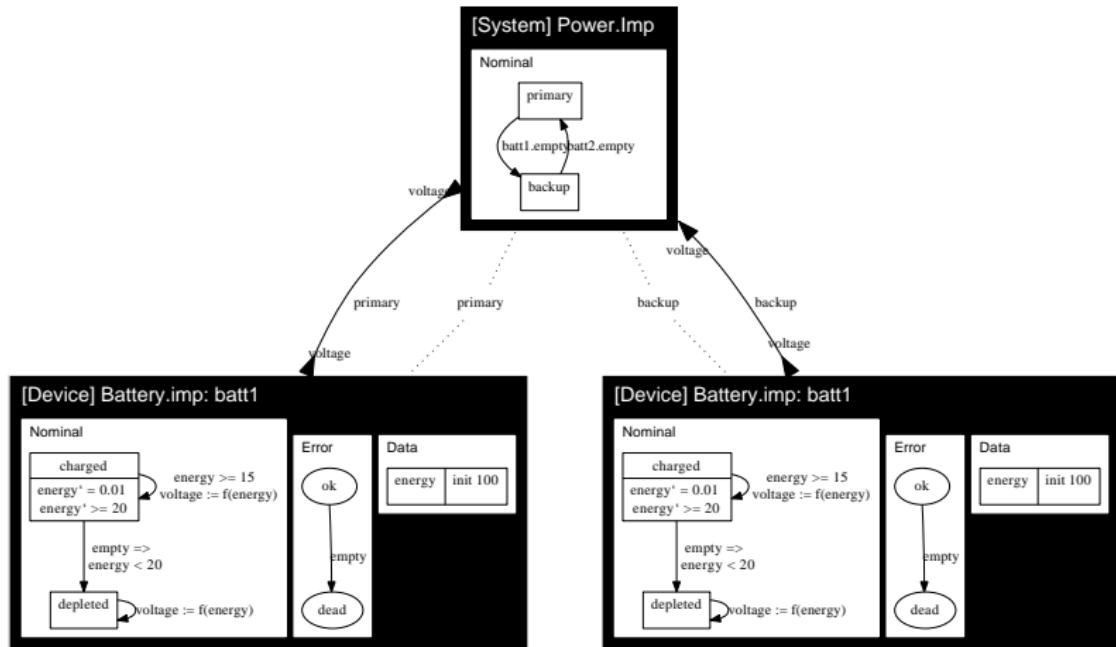
## Three Components

- Modelling language
- Verification and validation activities
- Toolset



- Component-oriented
- Sub/supercomponents
- Event/data ports
- (Functional) nominal behaviour
- (Probabilistic) error behaviour
- Hybrid behaviour

# SLIM Example: Battery



# SLIM Example: Battery

```
device type Battery
  features
    empty: out event port;
    voltage: out data port real;
  end Battery;

device implementation Battery.Imp
  subcomponents
    energy: data continuous initially 100;
  modes
    charged: initial mode
      while energy'=-0.01 and energy>=20;
    depleted: mode
      while energy'=-0.015;
  transitions
    charged -[when energy>=15
      then voltage:=f(energy)]->
      charged;
    charged -[empty when energy<20]->
      depleted;
    depleted -[then voltage:=f(energy)]->
      depleted;
  end Battery.Imp;
```

# SLIM Example: Redundant Battery System

```
system Power
  features
    voltage: out data port real;
end Power;

system implementation Power.Imp
  subcomponents
    batt1: device Battery.Imp in modes (primary);
    batt2: device Battery.Imp in modes (backup);
  connections
    data port batt1.voltage -> voltage
      in modes (primary);
    data port batt2.voltage -> voltage
      in modes (backup);
  modes
    primary: initial mode;
    backup: mode;
  transitions
    primary -[batt1.empty]-> backup;
    backup -[batt2.empty]-> primary;
end Power.Imp;
```

```
error model BatteryFailure
  features
    normal: initial state;
    dead: error state;
  end BatteryFailure;

error model implementation BatteryFailure.Imp
  events
    fault: error event occurrence poisson 5;
  transitions
    normal -[fault]-> dead;
  end BatteryFailure.Imp;
```

Fault injection: in error state dead, voltage:=0

## ① Visualization of SLIM Specifications

- tool: SLIM specification → graphical representation
- visualization of hierarchical system structure and component interconnections
- challenge: support dynamic reconfiguration

## ② Translation of SLIM into PRO[B]MELA

- PROMELA: input language of SPIN model checker
- re-use for validating SLIM specifications
- probabilistic extension called PROBMELA

## ③ Translation of SLIM into UPPAAL

- UPPAAL: tool for modeling, validation and verification of real-time systems
- modeled: networks of timed automata, extended with data types
- re-use for validating SLIM specifications

## ④ TERMA Case Study

- case study from Quasimodo project
- goal: model (abstraction of) HW and SW of Attitude and Orbit Control System (AOCS) of Herschel and Planck satellites

## ⑤ Formal Semantics of SLIM Language

- hierarchical semantics has been developed

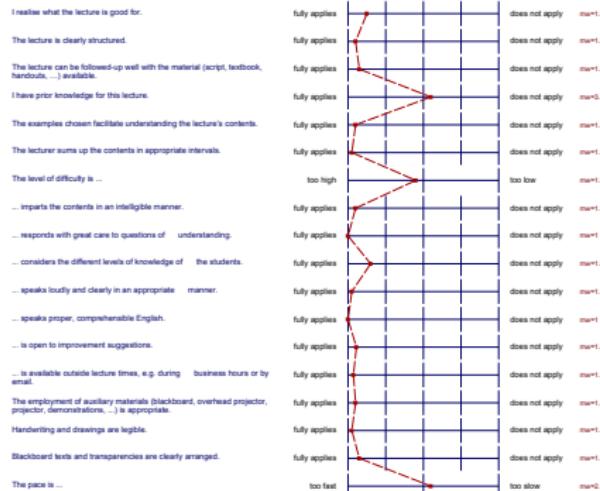
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- Course Advanced Model Checking [Katoen]
- Course Modeling Concurrent and Probabilistic Systems [Katoen/Noll] (“Hiwi” jobs available!)
- Course Testing of Reactive Systems [Bohnenkamp]
- Seminar Applying Formal Verification Methods to Embedded Systems [Noll/Schlich]

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## Profillinie

Teilbereich: Name des Lehrenden: Titel der Lehrveranstaltung: (Name der Umfrage)	Informatik Priv.doz. Dr.rer.nat. Thomas Noll Semantik und Verifikation von Software (1033682)
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Auswertungsteil der offenen Fragen

In your opinion, what makes the lecture especially bad or good? How can the lecture be improved. (presentation, media, equipment, ...)? Please note that your handwritten comments may possibly lead back to you. We therefore suggest that you make your handwritten comments in block letters. Comments made outside the text box will not ...

Slides should have more details about the topic. Current slides are very dense. There should be projectors fixed on lecture rooms. Every teacher has to bring his own projector that is not good.



Mr. Noll was always well prepared for the lectures and presented the contents in a very structured way, which I enjoyed much. The slides and the handouts could be more detailed (sometimes)

## Profillinie

Teilbereich: Informatik  
Name des/dieses Lehrenden: Priv.-doz. Dr.rer.nat. Thomas Noll  
Titel der Lehrveranstaltung: Semantik und Verifikation von Software (1033382)  
(Name der Umfrage)

Lecture and exercise harmonize with regard to contents.	fully applies		does not apply
Lecture and exercise harmonize with regard to time planning.	fully applies		does not apply
I realize what the exercise course is good for.	fully applies		does not apply
The process of the exercise course is well-structured.	fully applies		does not apply
The exercises chosen facilitate understanding the course content.	fully applies		does not apply
The exercise tasks are comprehensible.	fully applies		does not apply
The exercise tasks have a reasonable scope.	fully applies		does not apply
The solutions presented are comprehensible.	fully applies		does not apply
In case you could deliver your solution: was it controlled in an appropriate manner?	fully applies		does not apply
The level of difficulty is ...	too high		too low
... imparts the contents in an intelligible manner.	fully applies		does not apply
... responds with great care the questions of understanding.	fully applies		does not apply
... considers the different levels of knowledge of the students.	fully applies		does not apply
... speaks proper, comprehensible English.	fully applies		does not apply
... speaks loudly and clearly in an appropriate manner.	fully applies		does not apply
... is open to improvement suggestions.	fully applies		does not apply
... prepared for this exercise course adequately.	fully applies		does not apply
... is available outside exercise course times, e.g. during business hours or by email.	fully applies		does not apply
The employment of auxiliary materials (blackboard, overhead projector, projector, ... ) is appropriate.	fully applies		does not apply
Hancherings and drawings are legible.	fully applies		does not apply
Blackboard texts and transparencies are clearly arranged.	fully applies		does not apply
The pace is ...	too fast		too slow

#### Auswertungsteil der offenen Fragen

In your opinion, what makes this exercise course especially bad or good? How can this exercise course be improved (presentation, media, equipment, ...)? Please note that your handwritten comments may possibly lead back to you. We therefore suggest that you make your handwritten comments in block letters. Comments made outside the lettering box will not be taken into account.

More detailed exercises (description, and some applications for each theory...)

Ting Ting was well prepared for the exercise courses and presented the solutions very detailed.  
Critics on Alexandrou: You have to speak up  
and try <sup>little</sup> on your handwriting. Thanks for <sup>putting</sup> solving  
the solutions on the website!