TDDD07 Real-time Systems

Lecture 9: Dependability & Design

Simin Nadjm-Tehrani

Real-time Systems Laboratory

Department of Computer and Information Science
Linköping University

Two lectures

This lecture and lecture 9:

- Basic notions of dependability and redundancy in fault-tolerant systems
- Relating faults/redundancy to distributed systems from lectures 4-6
- Relating timing and fault tolerance

Lecture 9:

- Fault prevention and design aspects

Treatment of faults

- Last lecture: We mentioned four approaches for treating faults in dependable systems
- This lecture:
  1. Fault prevention
  2. Fault removal
  3. Fault tolerance
  4. Fault forecasting

Reading: Section 5.1 & 5.3 of article by Avezienis et al.

Also article on platform-independent design
Huang et al.

System requirements

- Functional requirements
  - Describe the main objectives of the system, also referred to as correct service
- Extra-functional requirements
  - Also called non-functional properties
  - Cover other requirements than those relating to main function, in particular dependability attributes: the frequency and severity of service failures
- Example non-functional requirements
  - Timeliness, availability, energy efficiency

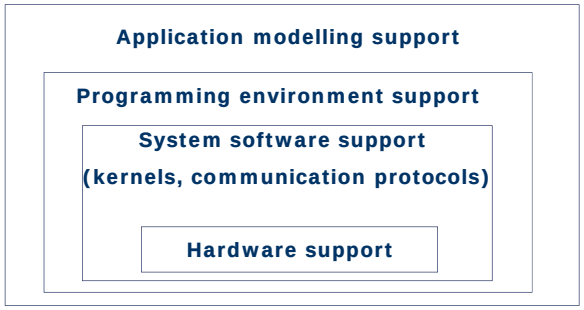
Basic approach

Design for timeliness:

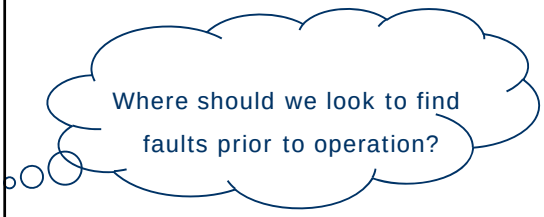
- define end-to-end deadlines
- define deadlines for individual tasks
- ascertain (worst case) execution/communication time for each task/message
- document assumptions/restrictions
- Prove/show that implementation satisfies requirements

So, what is so hard about this?

Layers of design



Fault prevention/removal



Historical snapshots

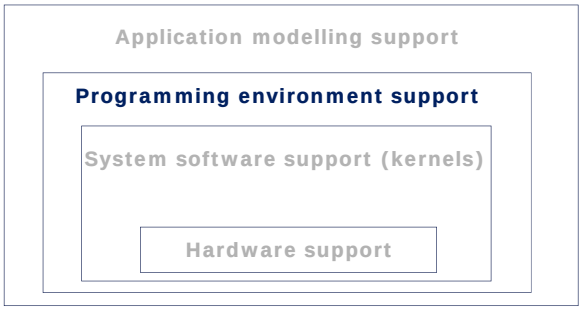
- Hardware design
  - 1970´s Dedicated hardware
  - 1980´s Micro computers & ASICS
  - 1990´s High performance Micro computers, FPGAs, MEMs
  - 2000 ’s SoCware
- Earlier predictable hardware is replaced with components that are complex to analyse (including cache, pipeline)

Layers of design

Historical snapshots

- Scheduling principles
  - 1970´s Fixed priority scheduling
  - 1980´s Multiprocessor, Dynamic
  - 1990´s Incorporating shared resources
  - 2000´s Load variations, adaptation Multicore scheduling for real
- OS interfaces to optimise memory management, prefetching instructions to boost performance

Layers of design



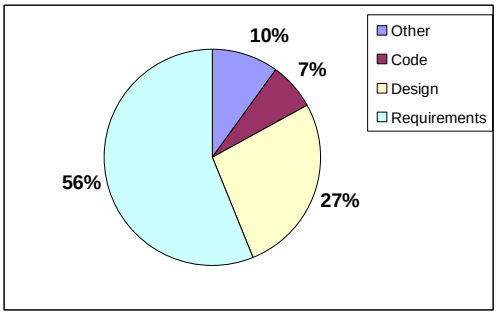
Historical snapshots

- Programming environments
  - 1970´s ”High” level programming
  - 1980´s Real-time specific: Ada
  - 1990´s OO languages, languages with formal semantics
  - 2000´s Software libraries, reuse
- Industry lecture: Reactive/actor-based!

Engineers: Fool me once, shame on you – fool me twice, shame on me

Software developers: Fool me N times, who cares, this is complex and anyway no one expects software to work…

Frequency of faults



[Jim Cooling 2003, cited from DeMarco78]

Testing does not do …

If a test fails, what was the cause?

- Undocumented assumptions on operational conditions, external impact?
- Wrong program code?
- Unexpected impact of OS functionality?
- Hardware timing dependencies?
- Embedded test code affecting timing?

Platform-independent design

Eliminating “butterfly effect” means trying to isolate the impacts of different layers

Back to basics

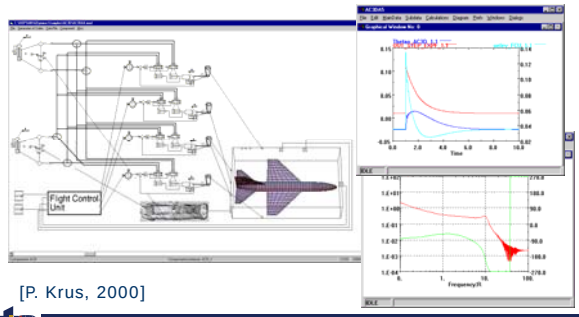
- define end-to-end deadlines
  - Model the environment!
- define deadlines for individual tasks
  - Specify system decomposition!
- ascertain (worst case) execution/communication time for each task/message
  - Assume hardware/bus characteristics!
- document assumptions/restrictions
  - Model, model, model!
- Prove/show that implementation satisfies requirements
  - Analyse models, then test implementation!

An engineering discipline

Using mathematics can never be wrong!

Non-digital hardware

Extensive simulations of coupled aircraft flight dynamics and actuator dynamics



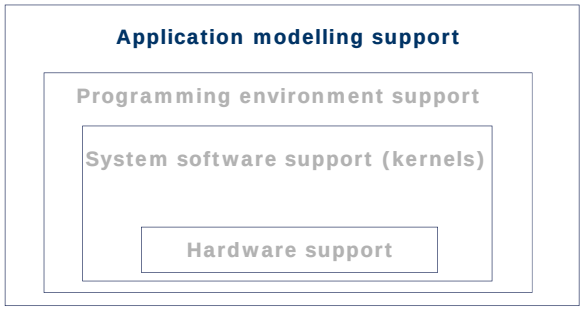
[P. Krus, 2000]

Model-based development

In software-intensive systems:

- Models as “higher level” programs
- Idea: use models to analyse the design, automatically generate code from the model!
- Adequate support for modularisation: Well-tested libraries with well-defined interfaces

Layers of design



Historical snapshots

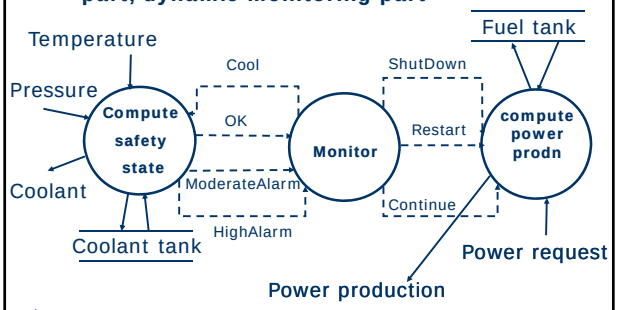
- Application modelling & analysis tools
  - 1970´s Sequential systems
  - 1980´s Concurrent/Distributed systems
  - 1990´s Timed models, Combining discrete & continuous, UML
  - 2000’s Incorporation in CASE tools
- 2012 crossroad: Domain-specific or Unified?

UML standard

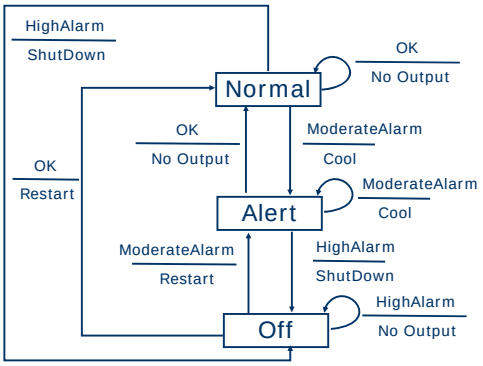
- UML 2.0 models components with required and provided interfaces
- Itself a follow up of modelling techniques suggested in early 80's, for example: Ward & Mellor Diagrams
- Next two slides from an example presented in [Heitmeyer and Mandrioli, Wiley, 1996].

Power plant

- **Transformation schemata for functional part, dynamic monitoring part**



Monitor state machine



Advances in 2000's

- CASE tool design models for digital hardware and software components, and *functional analysis* by
  - Simulations

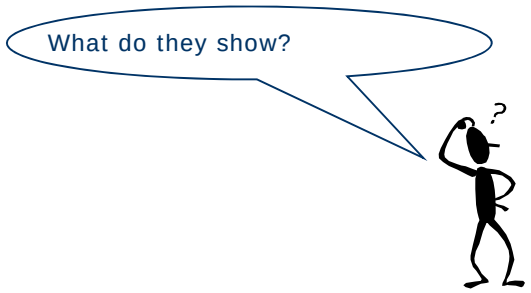
  and sometimes…
  - Formal verification of functional properties
  - Semi-automatic code generation

Simulations of a model

Need a unique interpretation:

- The language should be platform-independent
- The language should have an operational semantics to enable "execution" of the model

Simulations



Formal techniques (proofs)

- **Remove** (design) faults that lead to demonstrated bad things
  - debugging the design
- **Prove** that *specific* bad things *never* happen
- Can be automated, but suffer from combinatorial explosion

Advanced techniques

- Smart data structures for efficient representation of state space
- Smart deduction engines (satisfiability checkers) that find proofs fast
- Smart abstractions of the design to capture the essential properties
  - Synchronous languages (e.g. Esterel, Lustre), used for Airbus 320 software

Historical snapshots

- Application modelling & analysis tools
  - 1970´s Sequential systems
  - 1980´s Concurrent/Distributed systems
  - 1990´s Timed models, Combining discrete & continuous, UML
  - 2000's Incorporation in CASE tools
- 2012 crossroad: Domain-specific or Unified?

Adding time to UML

- Has not been easy
- No industry-wide tool support
- Recent development: UML profile for Real-time and Embedded Systems (MARTE)
- Meta-models for a class of systems with timing and performance parameters

Reading: handout on MARTE!