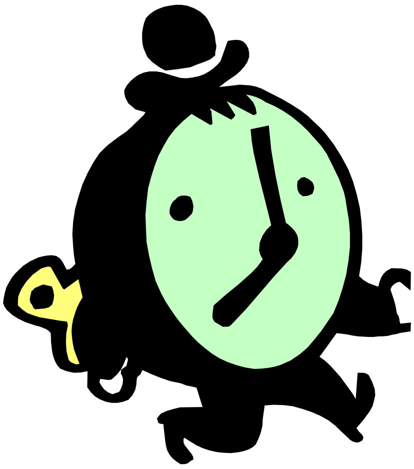
Real-Time Systems Programming

Summer-Semester 2002
Lecture 5
25 April 2002



Design Stages

The 5-Minute Review Session

1) What is *system engineering*?

2) What is *software engineering*?

3) What is the *V-Model*?

4) How does the *3-V Model* differ from it?

5) What are possible uses of a *system model*?

Designing RT Systems

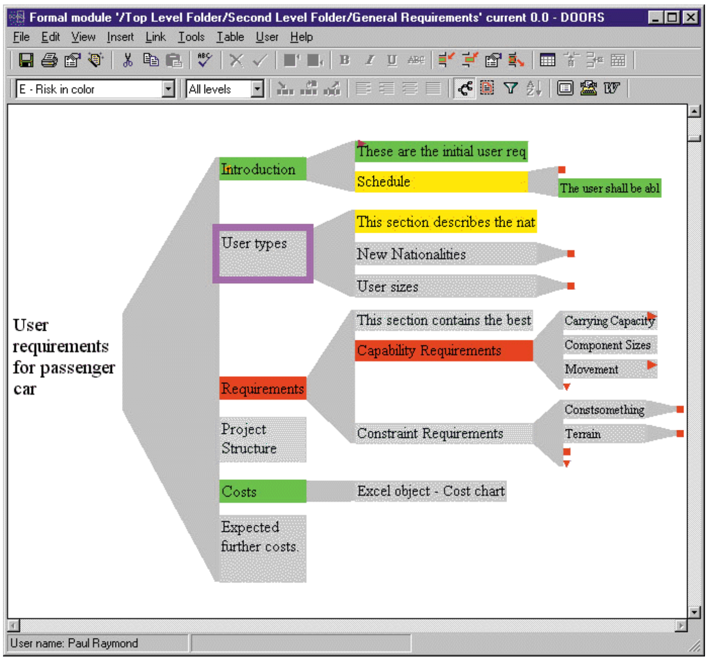
- In the following, will discuss these design stages:
  - Requirement specification
  - Architectural Design
  - Implementation
  - Validation/Testing
  - Prototyping

Requirement Specification

- Projects typically start with informal specification of ***objectives***
- Next, should perform extensive analysis of ***requirements***
  - Defines functionality of system
- For RT systems, requirements should include
  - *Temporal* behavior
  - *Dependability* requirements
  - Behavior in case of component *failure*
- Requirements also define later *acceptance tests*!

Requirement Specification

- Some structured/formal approaches used in requirements analysis:
  - *ALBERT* (Agent-oriented Language for Building and Eliciting Requirements for Real-Time Systems)
  - *VDM*, *Z*, *B*
  - *DOORS*


Formal module '/Top Level Folder/Second Level Folder/General Requirements' current 0.0 - DOORS
File Edit View Insert Link Tools Table User Help
E - Risk in color
All levels
User requirements for passenger car
Introduction
These are the initial user req
Schedule
The user shall be abl
User types
This section describes the nat
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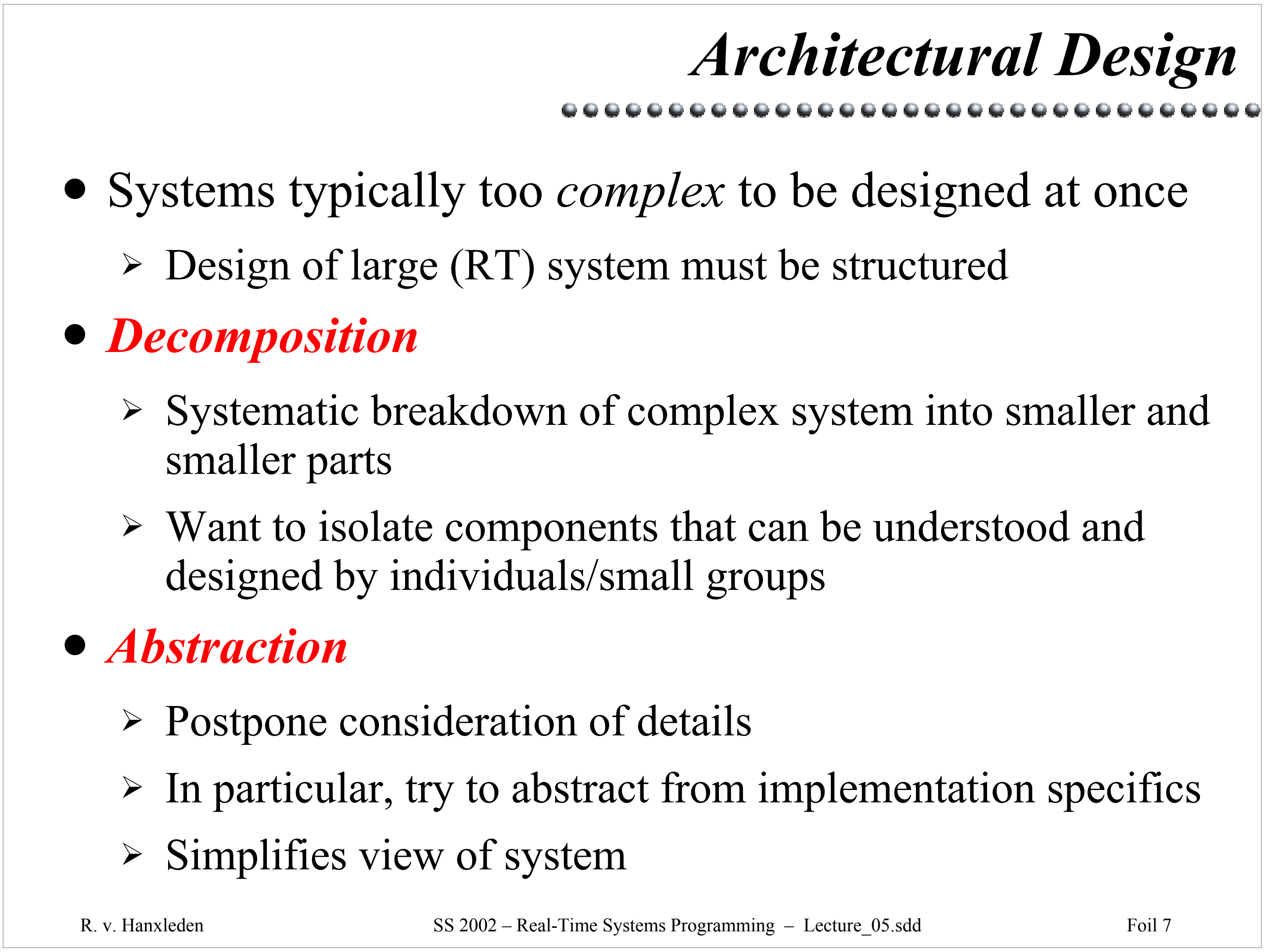
User sizes
This section contains the best
Capability Requirements
Carrying Capacity
Component Sizes
Movement
Requirements
Constsomething
Terrain
Constraint Requirements
Project Structure
Costs
Excel object - Cost chart
Expected further costs.
User name: Paul Raymond

Telelogic AB, 2002

- ***ALBERT:***
  - E. Dubois, P.D. Bois, J. Zeippen, A formal requirements engineering method for real-time, concurrent, and distributed systems, *Proceesings of the Real-Time Systems Conference RTS '95, Paris, France,* 1995
- ***VDM:***
  - C. Jones, *Systematic Software Development using VDM*, Prentice Hall, 1986
- ***Z:***
  - M. Spivey, *The Z Notation – A Reference Manual*, Prentice Hall, 1989, http://spivey.oriel.ox.ac.uk/~mike/zrm/
- ***B:***
  - The B-Book: Assigning Programs to Meanings, J.-R. Abrial, Cambridge University Press, 1996
  - http://www.afm.sbu.ac.uk/b/
- ***DOORS:***
  - http://www.telelogic.com

Requirement Specification

- Requirement analysis must characterise
  - ***System under development*** (***SUD***)
  - ***Environment*** where SUD will be deployed
    - Physical characteristics
    - Max. interrupt rates
    - *etc.*
- Requirement specification is typically ***most critical*** design phase!
  - ... and, at the same time, often the phase done rather carelessly – so better pay attention here ...



Architectural Design

- Systems typically too *complex* to be designed at once
  - Design of large (RT) system must be structured
- ***Decomposition***
  - Systematic breakdown of complex system into smaller and smaller parts
  - Want to isolate components that can be understood and designed by individuals/small groups
- ***Abstraction***
  - Postpone consideration of details
  - In particular, try to abstract from implementation specifics
  - Simplifies view of system

- Taken together, the two complementary approaches of *decomposition* and *abstraction* form the basis of most common SW engineering methodologies

Encapsulation

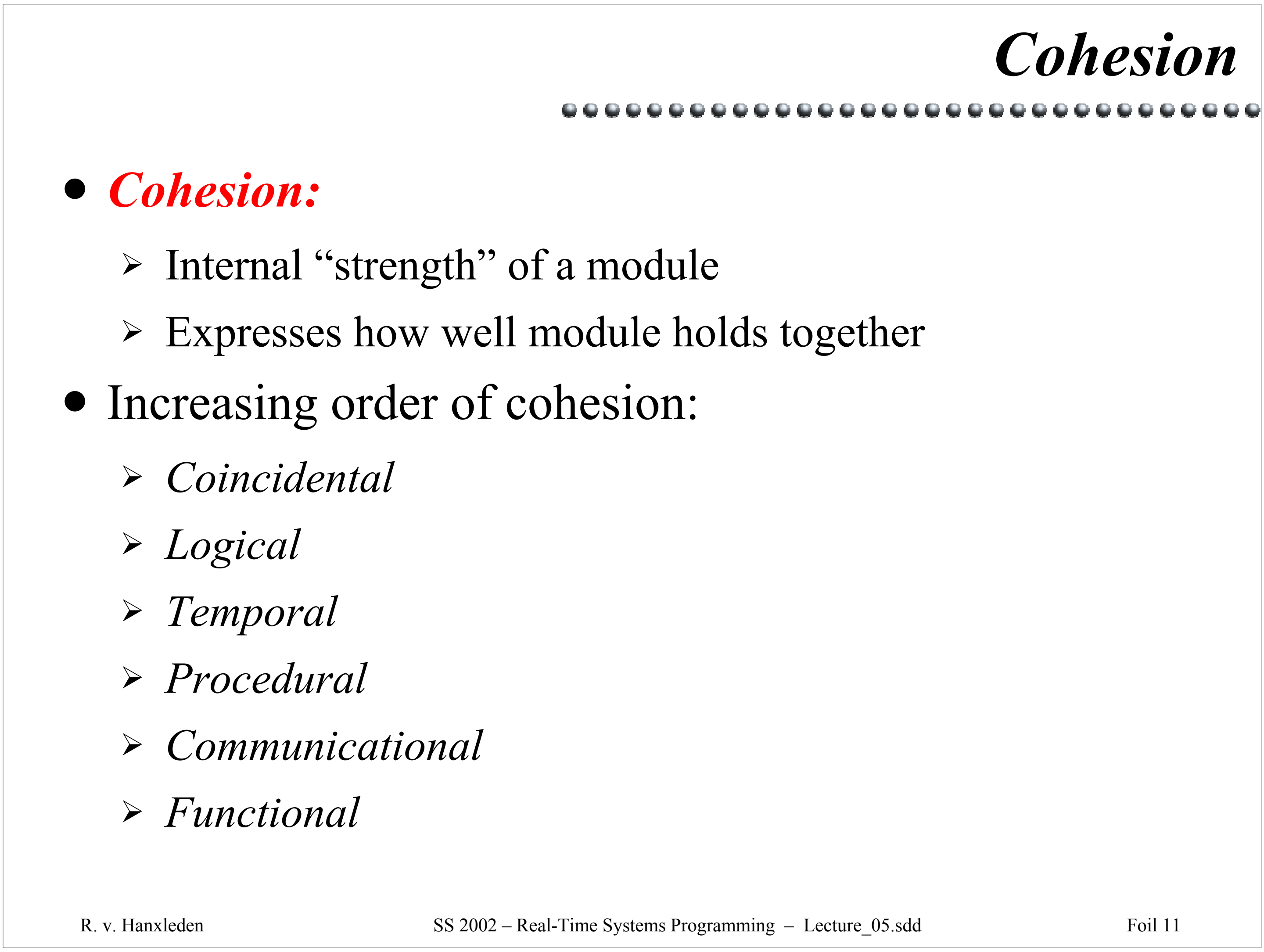
- *Decomposition* of system:
  - Specification/design of *subsystems*
- *Abstraction*:
  - Subsystem must have well-defined roles
  - Interfaces must be unambiguous
- ***Compositional*** decomposition:
  - Entire system can be verified just in terms of subsystem specifications

Encapsulation

- *Sequential* programs particularly amenable to compositional methods
  - ***Simula*** – introduced **class** construct
  - ***Modula 2*** – uses **module** structures
  - OO-languages (***C++***, ***Java***, ***Eiffel***) – build upon class construct
  - ***Ada*** – combination of modules and type extensions
- ***Objects***
  - Provide abstract interface
  - In *concurrent* environments, require extra facilites – namely, the **process** abstraction

How to Decompose a System?

- *Objects* and *processes:*
  - Provide good encapsulation facilities for system decomposition
- The remaining, critical question:
  - Into which parts should a system be decomposed?
- ***Approach:***
  - Evaluate prospective decompostions wrt certain *metrics*
- Here, strive for decompositions that have
  - Strong *coherence*
  - Loose *coupling*



Cohesion

- ***Cohesion:***
  - Internal “strength” of a module
  - Expresses how well module holds together
- Increasing order of cohesion:
  - *Coincidental*
  - *Logical*
  - *Temporal*
  - *Procedural*
  - *Communicational*
  - *Functional*

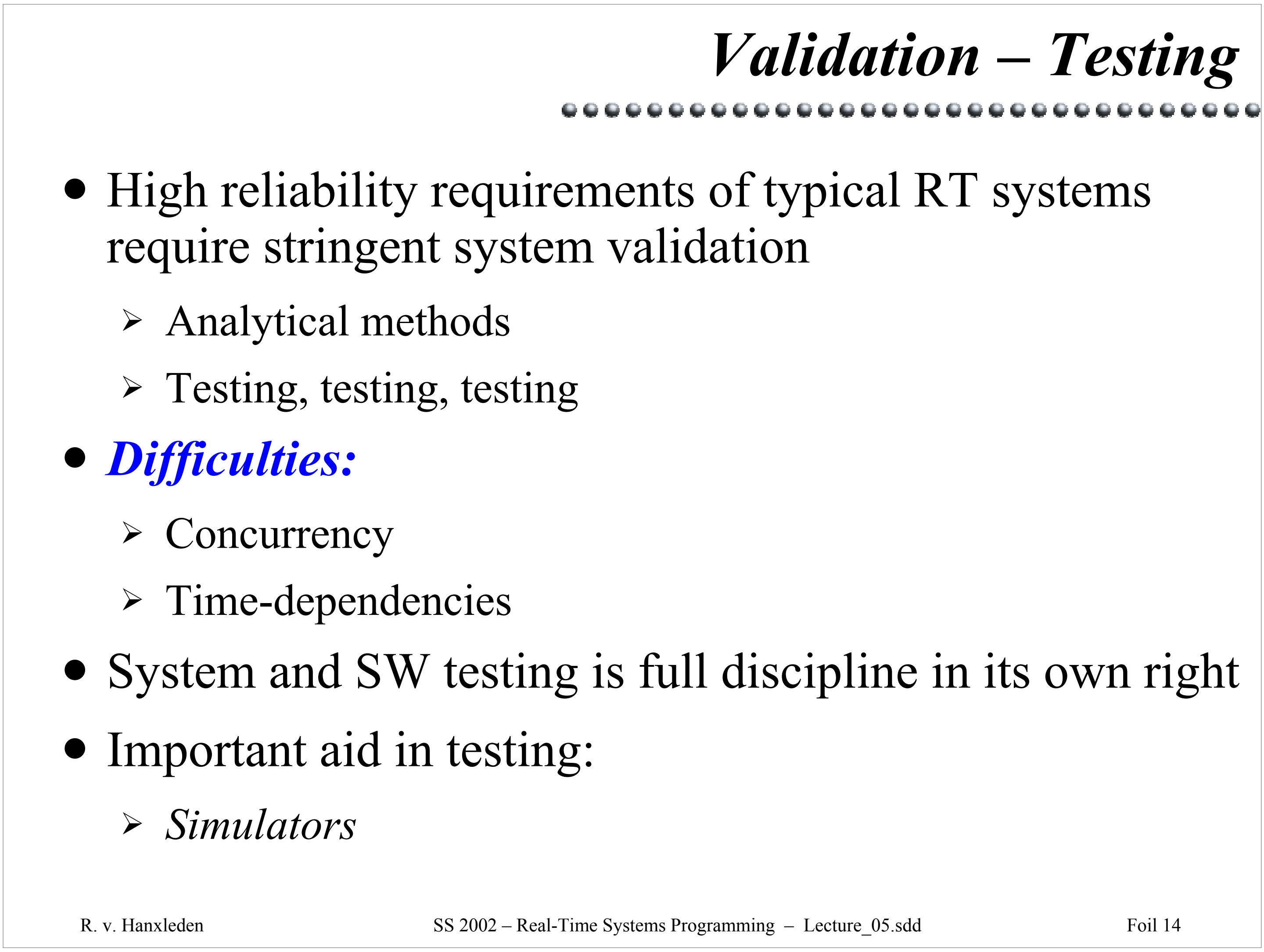
- See S. Allworth and R. Zobel, *Introduction to Real-Time Software Design*, MacMillan, 1987
- *Coincidental*
  - E.g., modules written in same month
- *Logical:*
  - Elements related in terms of overall system, but not in terms of actual SW (e.g., all device drivers)
- *Temporal*
  - Elements executed at similar times, e.g. start-up routines
- *Procedural*
  - Elements used in same program section; e.g., user interface
- *Communicational*
  - Elements working on same data structure
- *Functional*
  - Contribute to single system function

Coupling

- ***Coupling:***
  - Measure of interdependence of program modules
- Modules exchanging control information:
  - *High/tight* coupling
- Modules exchanging data:
  - *Loose* coupling
- Degree of coupling typically also expresses how easy it is to replace a component within system

Implementation

- System design should lead naturally to implementation
- However, proper design in practice still requires knowledge of what is possible at implementation level
    - ➢ This also true when using auto-coding!
- Implementation languages for real-time systems are a focus of this course
    - ➢ Will subsequently give language overview
- ***One aim:*** To sharpen your vision to distinguish the essentials from syntactic embellishments



Validation – Testing

- High reliability requirements of typical RT systems require stringent system validation
  - Analytical methods
  - Testing, testing, testing
- ***Difficulties:***
  - Concurrency
  - Time-dependencies
- System and SW testing is full discipline in its own right
- Important aid in testing:
  - *Simulators*

- *See* http://www.mtsu.edu/~storm/

Simulators

- ... are programs that imitate environment in which RT SW is embedded
  - I/O
  - Interrupts
- ***Advantages:***
  - Reproducibility
  - Can stop and resume operations
  - Safety
- Costs are often significant

Prototyping

- ... is the construction of a “mock-up” of the final system
  - Must be cheaper than building final system
  - Often does not exhibit dependability characteristics of final system
- Helps to ensure that requirements specification is ...
  - ... really what customer desired
  - ... complete

Summary

- The *requirements specification* is a critical phase in system development
  - For RT systems, requirements should include their *temporal* behavior, *dependability* requirements, and the behavior in case of component *failure*
- The *architectural design* of a system should result in a decomposition that exhibits *strong coherence* and *loose coupling*
- The *validation* of a RT system is often complicated by their *concurrent nature* and their RT dependencies
- *Testing* is a crucial part of validation, often aided by *simulators*

To Go Further

- ***System Design***
  - ☞ [Burns and Wellings 2001] – Chapter 2
- ***Software Testing***
  - ☞ http://www.mtsu.edu/~storm/