2IS55 Software Evolution

Requirements Evolution

Alexander Serebrenik

Technische Universiteit Eindhoven University of Technology

Where innovation starts

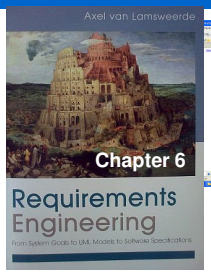
Assignment 1: Reminder

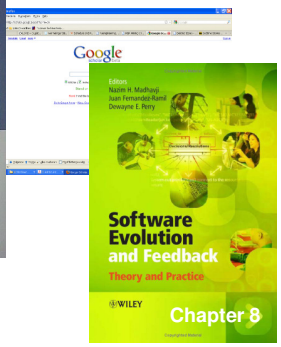
- Deadline: Today, 23:59
- Individual

- Preference: PDF
- How to submit: Peach
  - http://peach.win.tue.nl/

- Assignment 2
  - Is already open
  - Deadline: February 22, 23:59
  - Individual

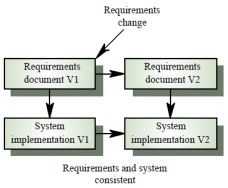
Sources



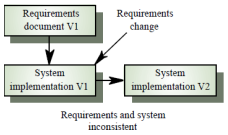


Requirements Evolution

- Requirements are "just a piece of paper"…
- Tend to be forgotten during the evolution



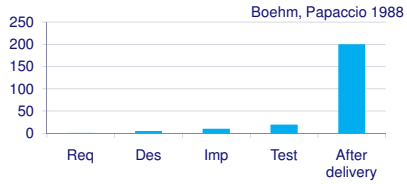
Sommerville 1996



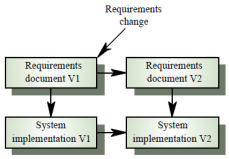
This is how it should be… this is how it often is.

Why requirements?

- Errors in requirements are:
  - common:
    - 25% of all the errors (Jones '91)
    - 1 error per function point (~ 80 LOC Java; Jones '95)
  - expensive



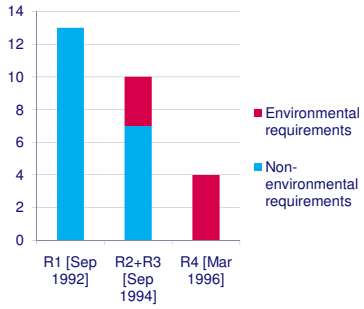
Questions



- Why do the requirements evolve?
- How suited is a given requirements document for evolution?
- How do the requirements evolve and co-evolve?

Why do the requirements evolve?

- Environment changes
- [Nanda, Madhavji]
  - Congruence Evaluation System
  - Research prototype



Suitability for evolution

- When is evolution difficult?
  - Per requirement:
    - "Bad requirements": vague, subjective, weak, underspecified, overtly complex, unreadable…
    - Volatile requirements
      - Related to dependencies between the requirements
  - Per requirements document:
    - Missing requirements
    - Inconsistent requirements

Bad requirements: Check lists

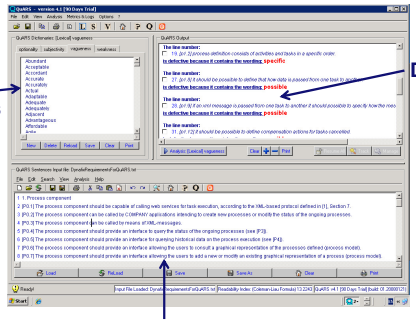
- Industrial approach: guidelines, checklists, templates
- Manual verification
  - "Each requirement is testable" (SMART)
  - "Each requirement should state consequences of losses of availability and breaches of security" (European eGovernment program)
- Assessment
  - is subjective
  - requires training and experience

Bad requirements: More automation?

Problem	Indicators (examples)
Vagueness	clear, significant, useful, adequate, good, bad
Subjectivity	similar, as … as possible, taking … into account
Optionality	possibly, if needed, if appropriate, eventually
Weakness	could, might
Underspecification	(write/read) access, (data/control) flow, "TBD"
Multiplicity	and, or
Implicity	Anaphora (it, these, previous, above)

Fabbrini, Fusani, Gnesi, Lami, 2001.

How to make the requirements better?



Readability measurement

- Requirements from a student project (Horus 2007)
  A. An account is an administrator account, a scientist account or an observer account.
  B. An administrator shall be able to configure whether multiple experiments may be executed simultaneously on a particular satellite.
  C. Experiment data can be retrieved from the system.
- Which one is more difficult to read?
- Flesch-Kincaid grade level:
  - A – 11.2, B – 20.2, C – 8.1

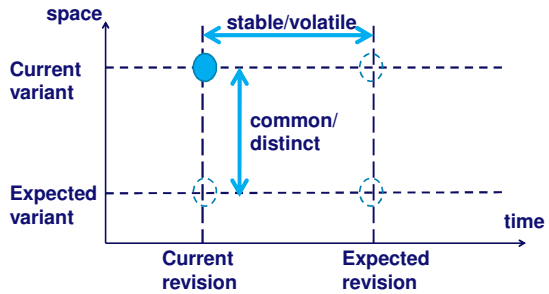
Flesch-Kincaid grade level

- Number of years of (US) education required to understand the text.

$$0.39\left(\frac{\text{total words}}{\text{total sentences}}\right)+11.8\left(\frac{\text{total syllables}}{\text{total words}}\right)-15.59$$

- Might be misleading for smaller texts
  - Use for features instead of individual requirements
  - Feature = group of related requirements
- The NASA study (Wilson,Rosenberg,Hyatt 1997)
  - Mean = 10.76, std dev = 1.59

Second problem: Volatile requirements



- Variants – adaptations to different users or environments
- Revisions – subsequent versions of one product

How can we identify volatile requirements?

- Feature = group of related requirements
  - Features should separate more and less stable requirements
  - Intuition: More stable requirements should not depend on less stable ones
- Problems:
  - We cannot predict future change
  - Analysis of natural language requirements is difficult

Relative stability

- "Relative stability" – one requirement is more stable (>) than another one.
- Example: meeting schedule system
- Notify the participants vs. Notify the participants by SMS
  - Intention or concept > operation or fact
- Notify the participants vs. Arrange recurrent meetings
  - Core (in any variant/revision) > others
- Notify the participants vs. The system should have an MS Windows "look and feel"
  - Functional > non-functional
- NB: Conflicts and choices among different options are usually quite volatile

How can we address volatility?

- At requirements engineering time:
  - Try to find a more stable alternative
  - Put special attention to traceability (backwards – rationale, forwards – design, implementation, tests)
  - Anticipate and record responses for future changes
- At design time:
  - Encapsulate volatile requirements in separate modules

Volatility and dependencies

- "More stable requirements should not depend on less stable ones"
- A affects B (B depends on A) if changing A might require changing B.

Types of dependencies (examples)

- **Use**
  - A explicitly refers to B
  - "IMSETY shall adhere to Table 2.1 for user rights"
- **Generalization/refinement**
  - A is a more general case of B
  - "Observers shall not be authorized to manipulate experiments."

Entities	Users: Administrator	Scientist	Observer
Payload	CRUD	R	R
Satellite	CRUD	-	-
User	CRUD	RU	-
Payload command list	CRUD	R	-
Experiment	CRUD	CRUD	R
Observation	RD	R	R
Representation	-	CRD	CRD

Table 2.1: CRUD matrix

Types of dependencies (examples, continued)

- **Temporal**
  - Satisfaction of A should precede/follow satisfaction of B
  - "IMSETY shall require users to be logged in before they can use any of the system's functionality."
- **Satisfiability**
  - Satisfaction of A implies satisfaction of B
  - More general than "generalization/refinement"
  - But also
    - "The system shall interface with an MCS for communication with satellites."
    - "IMSETY shall log all communications with the MCSes."

How can we derive dependency relations?

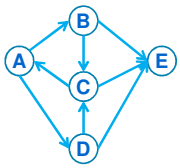
- Manually
- If requirements are formalized (à la RADV) – formal techniques, e.g., using model checking
- Using transitivity
- Keyword-based [Huffman Hayes, Dekhtyar, Osborne 2003]:
  - At any moment, only one scientist is allowed to compose an experiment on a single payload.
  - A scientist shall be able to request the scheduling of the execution of experiments on a predefined moment.

Problems (and solutions) with keyword-based

- Terminology vs. regular use
  - scientist, experiment vs. moment
  - solution: domain dictionary
- Synonyms (solution: thesaurus)
- Some requirements are more "essential" for the keyword than others.
- Lexical correlation vs. dependency
  - Which type?

Dependency analysis

- Traceability graph
  - Vertices: requirements
  - Arcs: dependency relations



- What do you think about the requirements document right?
- What does this mean for evolution?
- How would the quality information influence your interpretation?
- What are the limitations of the traceability graph approach?

Inconsistent requirements

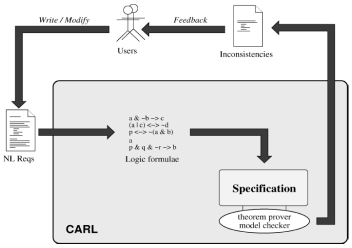
- Different kinds of requirements: use cases, process models, natural language requirements
- Different sources of requirements: multiple documents, multiple stakeholders
- Different types of inconsistencies:
  - Terminological (synonyms, different interpretations of the same term): data dictionary, glossary, ontology
  - Logical (strong) – conjunction of the requirements is *false*
  - Logical (weak) – under some condition conjunction of the requirements is *false*

Logical inconsistencies: Heuristics

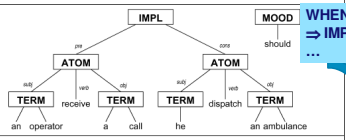
- Logical inconsistencies [van Lamsweerde]
  - Heuristic: scrutinize dependent requirements
  - Heuristic: public availability vs. confidentiality
    - Grades should be publically available
    - Students should not have access to other students' grades
  - Heuristic: increases vs. decreases
    - Increase access to books and journals
    - Reduce operational costs
  - Heuristic: security vs. user-friendliness

Inconsistent requirements: Linguistics+Logics

- CARL [Gervasi. Zowghi 2005]:
  - Translate nat. lang. requirements to logical formulae
  - Analyse consistency



CARL: From text to formula

Original requirement	When an operator receives a call, he should dispatch an ambulance.
After morpho-syntactic analysis	When/CC/WRB an/DT operator/NN receive/VB/Z a/DT call/NN he/PP should/MD dispatch/VB an/DT ambulance/NN
Parse tree, as produced by the CICO algorithm ($\mathcal{P}$)	
Equivalent logic formula ($\mathcal{T}$)	receive(operator,call) → dispatch(operator,ambulance) (with priority set to "optional")

WHEN a/SENT b/SENT
⇒ IMP $a $b
…

- Now CARL can check for (weak) inconsistencies, resolve ambiguities and even "invent" unexpected scenario's.

CARL: Detect inconsistency

1. A medical emergency is either an illness or an accident.
2. When an operator receives a phone call concerning a medical emergency, (s)he should dispatch a nearby available ambulance.
3. When an operator receives a phone call concerning a nonmedical emergency, the operator should not dispatch an ambulance, and he should transfer the phone call to another service.
4. When an operator receives a phone call, if an ambulance is not nearby or not available, then the operator should not dispatch that ambulance.
5. When an operator receives a phone call, (s)he should dispatch a nearby available ambulance.

How can we address inconsistency?

- Weaken or drop one of the conflicting statements
- Specialize the requirement such that the conflict disappears.
  - When an operator receives a phone call *concerning medical emergency*, (s)he should dispatch a nearby available ambulance.
- For weak logical inconsistencies: avoid the condition
  - Logical (weak): under some condition conjunction of the requirements is *false*
- Evaluate different options and choose the "best" one
  - NB: Source of volatility

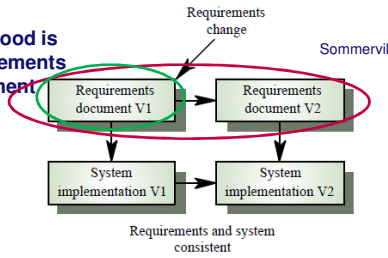
Summary so far…

- Requirements evolution can be hindered by
  - "Bad requirements": vague, subjective, weak, underspecified, overtly complex, unreadable…
  - Volatile requirements
    - Related to dependencies between the requirements
  - Missing requirements
  - Inconsistent requirements

So far…

Next…

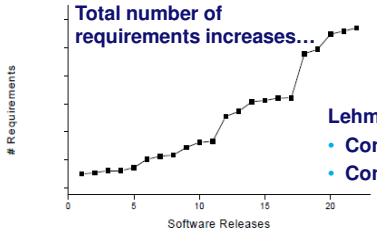
How good is requirements document v1?



Sommerville 1996

How do the requirements evolve?

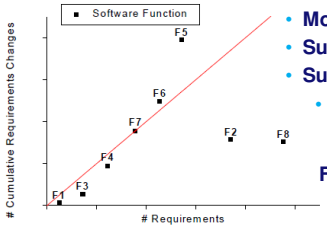
- Are Lehman's laws applicable?
- [Anderson, Felici 2000]: avionics software



Lehman's laws
- Continuing change
- Continuing growth

Evolution and volatility

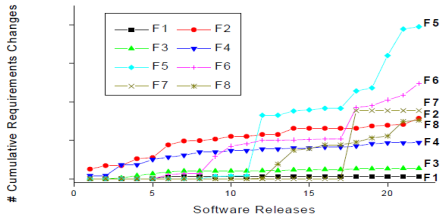
- Volatility = subject to change?
- Eight functions, different documents



- Mostly linear correlation
- Sublinear: F2, F8
- Superlinear: F5
  - Most likely to change

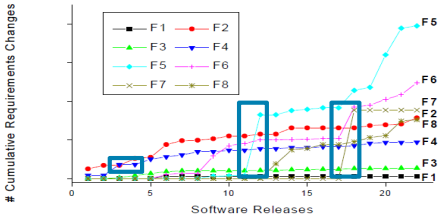
F1 *seems* to be stable

Closer look at the 8 functions (1)



- F1 is indeed stable.
- F1 is about system architecture
- Conjecture: system architecture is stable

Closer look at the 8 functions (2)



- Different functions are likely to change at different times.

How do the req. evolve – what have we done?

- Calculated
  - the number of requirements
  - the number of changes
  - the cumulative number of changes
- Studied
  - how these values change with time
- Last week something similar for size/complexity/…

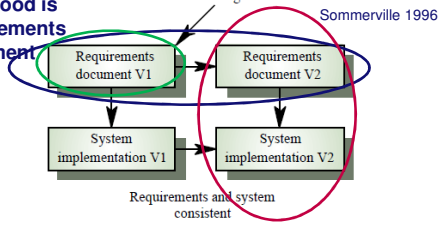
- Generic approach
  - Metrics: function from software artefacts to numbers
  - Time series: sequence of measurements at successive times

So far…

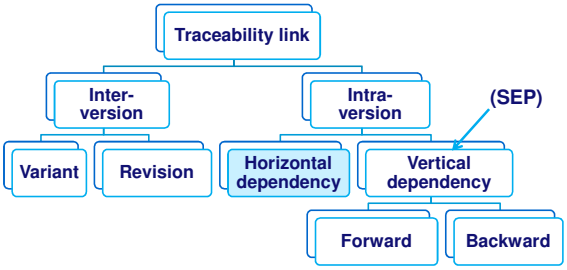
How do the requirements evolve?

Next…

How good is requirements document v1?



Co-evolution: Traceability links



Design, implementation, tests

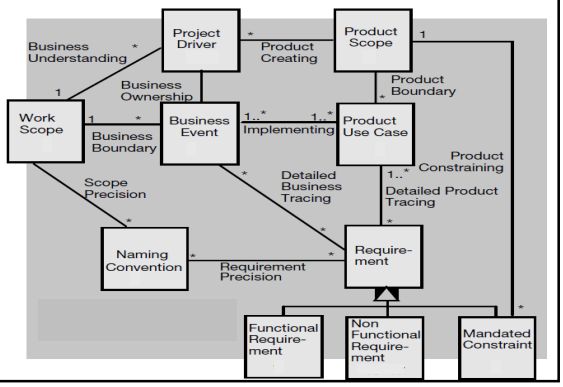
Rationale, business needs

Why do we need traceability?

[Wiegers 2003]

- (Co-)evolution
  - Change impact analysis
  - Maintenance
  - Reengineering
- Certification
- Project tracking
- Reuse
- Risk reduction
- Testing

Backward dependencies [Robertson]



Traceability matrix

- Means of expressing traceability information

User req.	SW req.	Design Elem.	Func	Test Case
UC-28	SR-28, SR-15	Class catalog	sort	7, 8
UC-29	SR-44	Class catalog	import check	12, 13

Two popular techniques

User req.	Use Case		
	UC-1	UC-2	UC-3
UR-1	*		
UR-2	*		
UR-3		*	*
UR-4			*

What are their advantages and disadvantages?

We need tools!

- Large amount of information:
  - requirements, components, traceability links
  - database technology!
- Many commercial/OS tools are available
  - OS requirements management tool: http://sourceforge.net/projects/osrmt/
  - http://requirements.tigris.org/
- You might like to try them!

Conclusions

- Requirements often evolve due to environmental changes
- Suitability for evolution: quality, volatility, dependencies, inconsistency
- Evolution:
  - Continuous change and growth
  - System architecture is “almost” stable
- Co-evolution
  - Need for backward and forward traceability

Assignment 2

- Organizational:
  - Is already open
  - Deadline: February 22, 23:59
  - Individual
  - Please submit in PDF
- Given a set of requirements you’ll assess their quality, study dependencies between them and discuss the implications of your findings on the requirements evolution.