Lecture 8: Communicating Requirements

Last Week:
Modeling and Analysis (III)
Formal Modeling Techniques
Program Spec. vs. Reqts Modeling
RSML, SCR, RML, Telos, Albert II
Lightweight formal modeling

This Week:
Communicating Requirements
the Software Requirements Specification (SRS)
Documentation Standards
Requirements Traceability

Next Week:
Agreeing Requirements (I)
Validation
Reviews and Inspections
Prototyping

Software Requirements Specification

- **How do we communicate the Requirements to others?**
  - **It is common practice to capture them in an SRS**
    - But an SRS doesn't need to be a single paper document...
- **Purpose**
  - Communicates an understanding of the requirements
    - explains both the application domain and the system to be developed
  - Contractual
    - May be legally binding!
    - Expresses an agreement and a commitment
  - Baseline for evaluating subsequent products
    - supports system testing, verification and validation activities
    - should contain enough information to verify whether the delivered system meets requirements
  - Baseline for change control
    - requirements change, software evolves
- **Audience**
  - Users, Purchasers
    - Most interested in system requirements
    - Not generally interested in detailed software requirements
  - Systems Analysts, Requirements Analysts
    - Write various specifications that inter-relate
  - Developers, Programmers
    - Have to implement the requirements
  - Testers
    - Determine that the requirements have been met
  - Project Managers
    - Measure and control the analysis and development processes

Appropriate Specification

Source: *Adapted from Blum 1992, p154-5*

→ Consider two different projects:

A) Small project, 1 programmer, 6 months work

programmer talks to customer, then writes up a 5-page memo

B) Large project, 50 programmers, 2 years work

team of analysts model the requirements, then document them in a 500-page SRS

	Project A	*Project B*
Purpose of spec?	Crystalizes programmer's understanding; feedback to customer	Build-to document; must contain enough detail for all the programmers
Management view?	Spec is irrelevant; have already allocated resources	Will use the spec to estimate resource needs and plan the development
Readers?	**Primary**: Spec author; **Secondary**: Customer	**Primary**: all programmers + V&V team, managers; **Secondary**: customers

A complication: Procurement

→ An 'SRS' may be written by…

- …the procurer:
  - so the SRS is really a call for proposals
  - Must be general enough to yield a good selection of bids…
  - …and specific enough to exclude unreasonable bids
- …the bidders:
  - Represents a proposal to implement a system to meet the CfP
  - must be specific enough to demonstrate feasibility and technical competence
  - …and general enough to avoid over-commitment
- …the selected developer:
  - reflects the developer's understanding of the customers needs
  - forms the basis for evaluation of contractual performance
- …or by an independent RE contractor!

→ Choice over what point to compete the contract

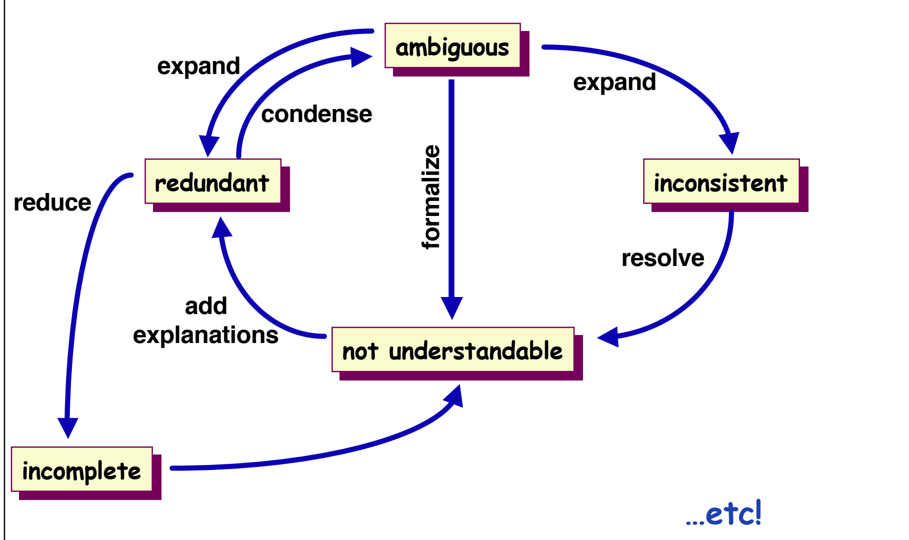
- Early (conceptual stage)
  - can only evaluate bids on apparent competence & ability
- Late (detailed specification stage)
  - more work for procurer; appropriate RE expertise may not be available in-house
- IEEE Standard recommends SRS jointly developed by procurer & developer

Desiderata for Specifications

Source: *Adapted from Blum 1992, pp164-5 and the IEEE-STD-830-1993*

- **Valid (or "correct")**
  - Expresses only the real needs of the stakeholders (customers, users,…)
- **Complete**
  - Specifies all the things the system must do
  - ...and all the things it must not do!
  - Conceptual Completeness
    - E.g. responses to all classes of input
  - Structural Completeness
    - E.g. no TBDs!!!
- **Consistent**
  - Doesn't contradict itself
    - I.e. is satisfiable
  - Uses all terms consistently
  - Note: inconsistency can be hard to detect
    - especially in timing aspects and condition logic
    - (Formal specification can help)
- **Necessary**
  - Doesn't contain anything that isn't "required"
- **Unambiguous**
  - Every statement can be read in exactly one way
  - Clearly defines confusing terms
    - E.g. in a glossary
- **Verifiable**
  - A process exists to test satisfaction of each requirement
  - *"every requirement is specified behaviorally"*
- **Understandable (Clear)**
  - E.g. by non-computer specialists
- **Modifiable**
  - Can be changed without difficulty
    - Good structure and cross-referencing
  - It must be kept up to date!

There is no Perfect SRS!



Typical mistakes

- Noise
  - the presence of text that carries no relevant information to any feature of the problem.
- Silence
  - a feature that is not covered by any text.
- Over-specification
  - text that describes a feature of the solution, rather than the problem.
- Contradiction
  - text that defines a single feature in a number of incompatible ways.
- Ambiguity
  - text that can be interpreted in at least two different ways.
- Forward reference
  - text that refers to a feature yet to be defined.
- Wishful thinking
  - text that defines a feature that cannot possibly be validated.
- Jigsaw puzzles
  - e.g. distributing requirements across a document and then cross-referencing
- Duckspeak requirements
  - Requirements that are only there to conform to standards
- Unnecessary invention of terminology
  - E.g., 'the user input presentation function', 'airplane reservation data validation function'
- Inconsistent terminology
  - Inventing and then changing terminology
- Putting the onus on the development staff
  - i.e. making the reader work hard to decipher the intent
- Writing for the hostile reader
  - There are fewer of these than friendly readers

Source: *Adapted from Kovitz, 1999*

SRS should not include…

→ Project development plans

- cost, staffing, schedules, methods, tools, etc
- Lifetime of SRS is until the software is made obsolete
- Lifetime of development plans is much shorter

→ Product assurance plans

- CM, V&V, test, QA, etc
- Different audiences
- Different lifetimes

→ Designs

- Requirements and designs have different audiences
- Analysis and design are different areas of expertise
  - I.e. requirements analysts shouldn't do design!
- *Except where application domain constrains the design*
  - e.g. limited communication between different subsystems for security reasons.

Source: *Adapted fromDavis, 1990, p183*

Text Analysis to measure Quality

- Can do textual analysis of an SRS
  - measure current practice
  - establish norms for an organisation
- E.g. NASA SEL used nine quality indicators:
  - Imperatives
    - identified by words such as "shall", "must", "is required", etc.
    - Imperatives measure how explicit a SRS is.
  - Continuances follow an imperative and introduce requirements
    - indicated by "below:", "as follows:" etc.
    - measure the structure of an SRS.
  - Option
    - indicated by words such as "can", "may", "optionally" etc.
    - measure how much latitude does an SRS leave
  - Weak phrases
    - cause uncertainty
    - e.g. "adequate", "as applicable" etc.
  - Directives
    - indicated by tables, figures etc
    - these strengthen the quality of the document
  - Size
    - …in terms of lines of text, indicators and subjects
    - roughly, the number of subjects for all the imperatives
  - Text structure
    - measures the number of statement identifiers
  - Specification depth
    - measures how deep are the subsections of the SRS (e.g., 3.2.5.1)
    - gives an indication of SRS structure.
  - Readability statistics
    - e.g average number of syllables per word, number of words per sentence etc.

Ambiguity Test

- Natural Language?
  - "The system shall report to the operator all faults that originate in critical functions or that occur during execution of a critical sequence and for which there is no fault recovery response."

    (adapted from the specifications for the international space station)
- Or a decision table?

Originate in critical functions	F	T	F	T	F	T	F	T
Occur during critical seqeunce	F	F	T	T	F	F	T	T
No fault recovery response	F	F	F	F	T	T	T	T
Report to operator?								

Source: *Adapted from Easterbrook & Callahan, 1997.*

Avoiding ambiguity

- **Review natural language specs for ambiguity**
  - use people with different backgrounds
  - include software people, domain specialists and user communities
  - Must be an independent review (I.e. not by the authors!)
- **Use a specification language**
  - E.g. a restricted subset or stylized English
  - E.g. a semi-formal notation (graphical, tabular, etc)
  - E.g. a formal specification language (e.g. Z, VDM, SCR, …)
- **Exploit redundancy**
  - Restate a requirement to help the reader confirm her understanding
  - ...but clearly indicate the redundancy
  - May want to use a more formal notation for the re-statement

SRS format and style

- **Modifiability**
  - well-structured, indexed, cross-referenced, etc.
  - redundancy should be avoided or must be clearly marked as such
  - An SRS is not modifiable if it is not traceable...
- **Traceability**
  - Backwards - the specification must be *"traced"*
    - each requirement traces back to a source or authority
    - e.g. a requirement in the system spec; a stakeholder; etc
  - Forwards - the specification must be *"traceable"*
    - each requirement will eventually trace forwards to parts of the design that satisfy it
    - Hence we will need a way of referring to each requirement
  - Note: traceability links are two-way
    - other documents will be traced into the SRS
    - Every requirement must have a unique label.
- **Useful Annotations**
  - E.g. relative necessity and relative stability

Source: *Adapted from Davis, 1990, p192-5*

Organizing the Requirements

- Need a logical organization for the document
  - IEEE standard offers different templates
- Example Structures - organize by…
  - …External stimulus or external situation
    - e.g., for an aircraft landing system, each different type of landing situation: wind gusts, no fuel, short runway, etc
  - …System feature
    - e.g., for a telephone system: call forwarding, call blocking, conference call, etc
  - …System response
    - e.g., for a payroll system: generate pay-cheques, report costs, print tax info;
  - …External object
    - e.g. for a library information system, organize by book type
  - …User type
    - e.g. for a project support system: manager, technical staff, administrator, etc.
  - …Mode
    - e.g. for word processor: page layout mode, outline mode, text editing mode, etc
  - …Subsystem
    - e.g. for Agate case study: campaign management, staff management, etc.

IEEE Standard for SRS

Source: *Adapted from IEEE-STD-830-1993* **See also**, *Blum 1992, p160*

1 Introduction
- Purpose
- Scope
- Definitions, acronyms, abbreviations
- Reference documents
- Overview

2 Overall Description
- Product perspective
- Product functions
- User characteristics
- Constraints
- Assumptions and Dependencies

3 Specific Requirements

Appendices

Index

Identifies the product, & application domain

Describes contents and structure of the remainder of the SRS

Describes all external interfaces: system, user, hardware, software; also operations and site adaptation, and hardware constraints

Summary of major functions

Anything that will limit the developer's options (e.g. regulations, reliability, criticality, hardware limitations, parallelism, etc)

All the requirements go in here (i.e. this is the body of the document). IEEE STD provides 8 different templates for this section

IEEE STD Section 3 (example)

Source: *Adapted from IEEE-STD-830-1993.* **See also**, *Blum 1992, p160*

3.1 External Interface Requirements
- 3.1.1 User Interfaces
- 3.1.2 Hardware Interfaces
- 3.1.3 Software Interfaces
- 3.1.4 Communication Interfaces

3.2 Functional Requirements
this section organized by mode, user class, feature, etc. For example:
- 3.2.1 Mode 1
  - *3.2.1.1 Functional Requirement 1.1*
  - …
- 3.2.2 Mode 2
  - *3.2.1.1 Functional Requirement 1.1*
  - …
- ...
- 3.2.2 Mode n
  - ...

3.3 Performance Requirements
Remember to state this in measurable terms!

3.4 Design Constraints
- *3.4.1 Standards compliance*
- *3.4.2 Hardware limitations*
- *etc.*

3.5 Software System Attributes
- 3.5.1 Reliability
- 3.5.2 Availability
- 3.5.3 Security
- 3.5.4 Maintainability
- 3.5.5 Portability

3.6 Other Requirements

MIL-STD-498

- MIL-STD-498 is the main US DoD standard for software development and documentation
  - replaces DOD-STD-2167A and DOD-STD7935A
- Consists of:
  - a guidebook,
  - a list of process requirements
  - 22 Data Items Descriptions (DIDs)
- DIDs are the documents produced during software development. e.g.
  - OCD - Operational Concept Description
  - SSS - System/Subsystem Specification
  - SRS - Software Requirements Specification
  - IRS - Interface Requirements Specification
  - etc

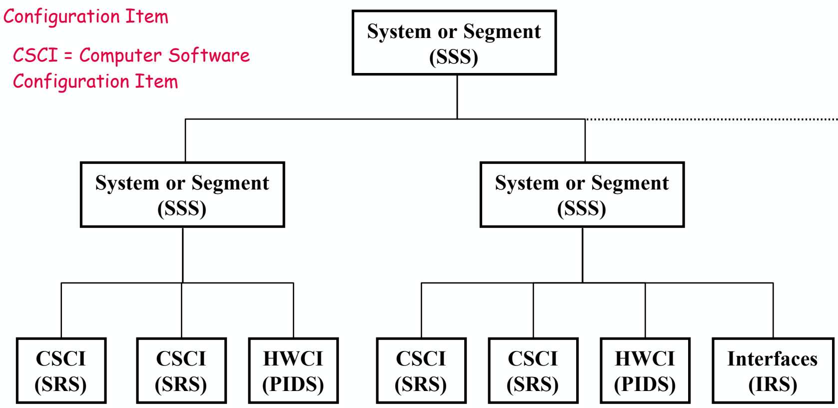
Source: *Adapted from MIL-STD-498*

System Structure

→ **MIL-STD-498 uses the following system structure:**

HWCI = Hardware Configuration Item

CSCI = Computer Software Configuration Item



Source: *Adapted from MIL-STD-498*

SRS DID from MIL-STD-498

1 Scope
- 1.1 Identification
- 1.2 System Overview
- 1.3 Document Overview

2 Referenced Documents

3 Requirements
- 3.1 Required States and Modes
- 3.2 CSCI Capability Requirements
  - *3.2.x Capability X…*
- 3.3 CSCI External Interface Requirements
  - 3.3.1 Interface Identification and diagrams
  - 3.3.x Project Unique Identifier
- 3.4 CSCI Internal Interface Requirements
- 3.5 CSCI Internal Data Requirements
- 3.6 Adaptation Requirements
- 3.7 Safety Requirements
- 3.8 Security and Privacy Requirements
- 3.9 CSCI Environment Requirements
- 3.10 Computer Resource Requirements
- 3.11 Software Quality Factors
- 3.12 Design and Implementation Constraints
- 3.13 Personnel-related Requirements
- 3.14 Training-related Requirements
- 3.15 Logistics-related Requirements
- 3.16 Other Requirements
- 3.17 Packaging Requirements
- 3.18 Precedence and criticality of Requirements

4 Qualification Provisions

5 Requirements Traceability

6 Notes

Appendices

Source: *Adapted from MIL-STD-498*

Requirements Traceability

→ **Definition (DOD-STD-2167A):**

"(1) The document in question contains or implements all applicable stipulations in the predecessor document

(2) a given term, acronym, or abbreviation means the same thing in all documents

(3) a given item or concept is referred to by the same name or description in the documents

(4) all material in the successor document has its basis in the predecessor document, that is, no untraceable material has been introduced

(5) the two documents do not contradict one another"

→ **In short:**

- A demonstration of completeness, necessity and consistency
- a clear allocation/flowdown path (down through the document hierarchy)
- a clear derivation path (up through the document hierarchy)

Source: Adapted from Palmer, 1996, p 367

Importance of Traceability

→ **Verification and Validation**
- assessing adequacy of test suite
- assessing conformance to requirements
- assessing completeness, consistency, impact analysis
- assessing over- and under-design
- investigating high level behavior impact on detailed specifications
- detecting requirements conflicts
- checking consistency of decision making across the lifecycle

→ **Maintenance**
- Assessing change requests
- Tracing design rationale

→ **Document access**
- ability to find information quickly in large documents

→ **Process visibility**
- ability to see how the software was developed
- provides an audit trail

→ **Management**
- change management
- risk management
- control of the development process

Source: Adapted from Palmer, 1996, p365

Traceability Difficulties

- Cost
  - very little automated support
  - full traceability is very expensive and time-consuming
- Delayed gratification
  - the people defining traceability links are not the people who benefit from it
    - development vs. V&V
  - much of the benefit comes late in the lifecycle
    - testing, integration, maintenance
- Size and diversity
  - Huge range of different document types, tools, decisions, responsibilities,…
  - No common schema exists for classifying and cataloging these
  - In practice, traceability concentrates only on baselined requirements

Source: *Adapted from Palmer, 1996, p365-6*

Current Practice

- Coverage:
  - links from requirements forward to designs, code, test cases,
  - links back from designs, code, test cases to requirements
  - links between requirements at different levels
- Traceability process
  - Assign each sentence or paragraph a unique id number
  - Manually identify linkages
  - Use manual tables to record linkages in a document
  - Use a traceability tool (database) for project wide traceability
  - Tool then offers ability to
    - follow links
    - find missing links
    - measure overall traceability

Source: *Adapted from Palmer, 1996, p367-8*

Traceability Tools

→ **Approaches:**
- hypertext linking
  - hotwords are identified manually, tool records them
- unique identifiers
  - each requirement gets a unique id; database contains cross references
- syntactic similarity coefficients
  - searches for occurrence of patterns of words

→ **Limitations**
- All require a great deal of manual effort to define the links
- All rely on purely syntactic information, with no semantics or context

→ **Examples**
- single phase tools:
  - TeamWork (Cadre) for structured analysis
- database tools, with queries and report generation
  - RTM (Marconi)
  - SLATE (TD Technologies)
  - DOORS (Zycad Corp)
- hypertext-based tools
  - Document Director
  - Any web browser
- general development tools that provide traceability
  - RDD-100 (Ascent Logic) - documents system conceptual models
  - Foresight - maintains data dictionary and document management

Source: *Adapted from Palmer, 1996, p372*

Limitations of Current Tools

→ **Informational Problems**
- Tools fail to track *useful* traceability information
  - e.g cannot answer queries such as "who is responsible for this piece of information?"
- inadequate pre-requirements traceability
  - "where did this requirement come from?"

→ **Lack of agreement…**
- …over the quantity and type of information to trace

→ **Informal Communication**
- People attach great importance to personal contact and informal communication
  - These always supplement what is recorded in a traceability database
- But then the traceability database only tells part of the story!
  - Even so, finding the appropriate people is a significant problem

Source: *Adapted from Gotel & Finkelstein, 1993, p100*

Problematic Questions

- **Involvement**
  - Who has been involved in the production of this requirement and how?
- **Responsibility & Remit**
  - Who is responsible for this requirement?
    - who is currently responsible for it?
    - at what points in its life has this responsibility changed hands?
  - Within which group's remit are decisions about this requirement?
- **Change**
  - At what points in the life of this requirements has working arrangements of all involved been changed?
- **Notification**
  - Who needs to be involved in, or informed of, any changes proposed to this requirement?
- **Loss of knowledge**
  - What are the ramifications regarding the loss of project knowledge if a specific individual or group leaves?

Source: Adapted from Gotel & Finkelstein, 1997, p100

Contribution Structures

- **'author' attribute too weak**
  - does not adequately capture ownership of information
  - refers to person that wrote the document rather than the person who originated the content
  - fail to capture situations where many people participate
  - fail to capture changing patterns of participation
- **Contribution structures**
  - link requirements artifacts (contributions) to agents (contributors) via contribution relations
- **Roles**
  - Principal
    - who motivated the artefact (responsible for consequences)
  - Author
    - who chose the structure and content (responsible for semantics)
  - Documentor
    - who recorded/transcribed the content (responsible for appearance)