Midterm Review

The purpose of software engineering
Teamwork
Processes and project planning
Software Requirements

The "Software Crisis"

- Have been in "crisis" since the advent of "big" software (roughly 1965)
- What we want for software development
  - Low risk, predictability
  - Lower costs and proportionate costs
  - Faster turnaround
- What we have:
  - High risk, high failure rate
  - Poor delivered quality
  - Unpredictable schedule, cost, effort
  - Examples: Ariane 5, Therac 25, Mars Lander, DFW Airport, FAA ATC etc.
- Characterized by **lack of *control***

Large System Context

- Focus large, complex systems
  - Multi-person: many developers, many stakeholders
  - Multi-version: intentional and unintentional evolution
- Quantitatively distinct from small developments
  - Complexity of software rises exponentially with size
  - Complexity of communication rises exponentially
- Qualitatively distinct from small developments
  - Multi-person introduces need for organizational functions, policies, oversight, etc.
  - More stakeholders and more kinds of stakeholders

Software is Pre-Industrial

Pre-Industrial

- Craftsman builds product
  - Builds one product at a time
  - Each product is unique, parts are not interchangeable
  - Quality depends on craftsman's skill – product of training, experience
  - Many opportunities for error
- Focus on individual products
  - Customization is easy
- Scaling is difficult
  - Parts are not interchangeable
  - No economy of scale
  - **Control problems rise *exponentially* with product size!**

Post-Industrial

- Products produced by machines
  - Quality depends on machines & manufacturing process
  - Production requires little training or experience
- Focus on developing the **means of production**
  - Craftsman builds means to build product (tools, factory)
  - Customization is difficult
- Easily scales
  - Parts are interchangeable
  - Products are alike
  - Economies of scale apply

Implications

- Small system development is driven by technical issues (I.e., programming)
- Large system development is dominated by organizational issues
  - Managing complexity, communication, coordination, etc.
  - Projects fail when these issues are inadequately addressed
- Lesson #1: **programming ≠ software engineering**
  - Techniques that work for small systems fail utterly when scaled up
  - Programming alone won't get you through real developments or even this course

View of SE in this Course

- The purpose of software engineering is to *gain* and *maintain* intellectual and managerial control over the products and processes of software development.
  - "**Intellectual control**" means that we are able make rational choices based on an understanding of the downstream effects of those choices (e.g., on system properties).
  - **Managerial control** means we control development *resources* (budget, schedule, personnel).

Meaning of "Control"

- Both are necessary for success!
- Intellectual control implies (as an ideal)
  - We understand what properties we want for the software (functional behavior and system qualities)
  - Can distinguish good choices from bad
  - We can reliably and predictably build a system with the desired qualities
- Managerial control implies
  - We make accurate estimations
  - We deliver on schedule and within budget
- Assertion: *Managerial control is not really possible without intellectual control*

Course Approach

- Will learn methods for acquiring and maintaining control of software projects
- Managerial control (most of focus to date)
  - People management and team organization
  - Organizing people and tasks
  - Planning and guiding development
- Intellectual control
  - Choosing appropriate order for decisions and ensuring feedback/correction
  - Establishing and communicating exactly what should be built

Teamwork and Group Dynamics

What is a Great Team?

- Diverse Skills
  - People skills, communication and writing skills, design skills, implementation skills and knowledge
- Coherence
  - Ability to build and maintain a shared vision
  - Shared expectations
- Mutual Respect and Responsibility
  - You don't *have* to like each other, but you *need* to trust and respect each other — and to earn your teammates trust and respect
  - This is an enduring part of professionalism in the real world

Team Roles

- Manager: responsible for schedule
- System architect
- Programmer
- Quality control
- Technical documentation
- User documentation
- User interface design/build
- Configuration control (build-master)

Lessons Learned:

- *Assigning people to roles ensure someone is personally responsible for each deliverable*

What do software developers do?

- Most roles are not coding
- So how do they spend their time?
- IBM study (McCue, 1978):
  - 50% team interactions
  - 30% working alone
  - 20% not directly productive

-Technical excellence is not enough

"Egoless" design

(Weinberg, Psychology of Computer Programming)

- Investing ego in group
- "Letting go" of ego investment in code, design, ideas
  - No winning or losing design debates (focus on improving the product)
  - Once contributed, ideas belong to the group
  - Criticism is aimed at concepts, not people
- The best designers criticize their own designs!
  - Our own assumptions are the hardest to critique
  - Corollary: A conscientious critic is your best ally

Being a Good Team Member

- Attributes most valued by other team members
  - Dependability
    - When you say you'll do something, you do it
    - Correctly
    - On time
  - Carrying your own weight (doing a fair share of the work)
- People will overlook almost everything else if you do these

The Software Lifecycle

Introduction

Need to Organize the Work

- Nature of a software project
  - Software development produces a set of interlocking, interdependent work products
    - E.g. Requirements -> Design -> Code
  - Implies dependencies between tasks
  - Implies dependencies between people
- Must organize the work such that:
  - Every task gets done
  - Tasks get done in the right order
  - Tasks are done by the right people
  - The product has the desired qualities
  - The end product is produced on time

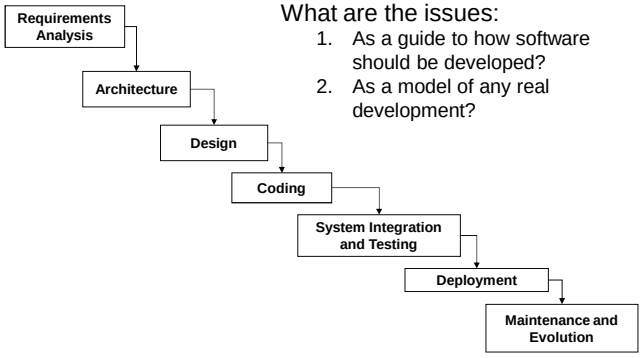
Usefulness of Life Cycle Models

- Application of "divide-and-conquer" to software processes and products
  - Goal: identify distinct and relatively independent phases and products
  - Can then address each somewhat separately
- Intended use
  - Provide guidance to developers in what to produce and when to produce it
  - Provide a basis for planning and assessing development progress
- Never an accurate representation of what really goes on

Common Models

Waterfall
Prototyping
Iterative
Spiral
Agile

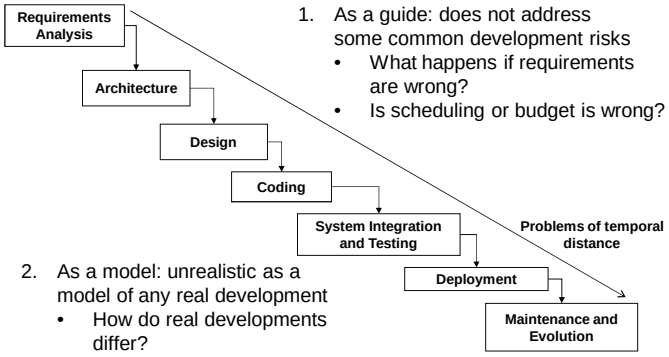
A "Waterfall" Model



What are the issues:

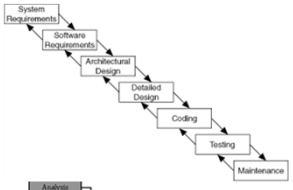
1. As a guide to how software should be developed?
2. As a model of any real development?

A "Waterfall" Model

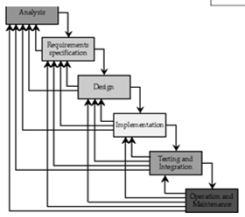


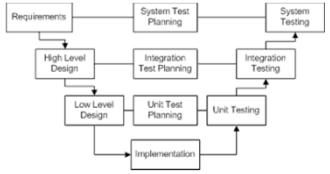
1. As a guide: does not address some common development risks
   - What happens if requirements are wrong?
   - Is scheduling or budget is wrong?
2. As a model: unrealistic as a model of any real development
   - How do real developments differ?
   - Models are abstractions of reality

Waterfall Model Variations



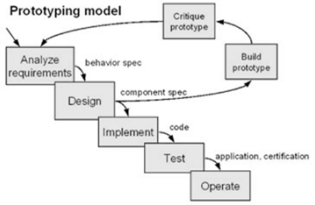
There have been many variations attempting to address these issues





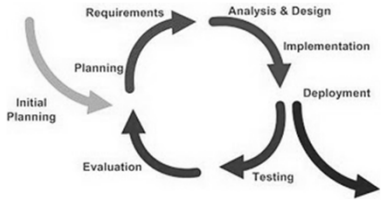
Characteristic Model: Prototyping

- Waterfall variation
- First system versions are prototypes, either:
  - Interface
  - Functional
- Attempts to address risk of building the wrong system



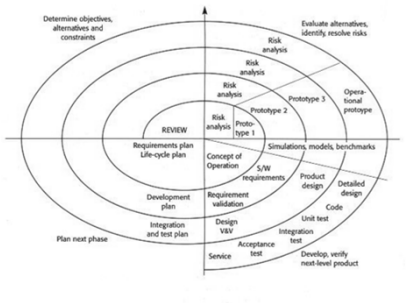
Characteristic Processes: The Iterative Model

- Process is a sequence of iterations, each producing an increment of the working software (sequence of waterfalls). Addresses
  - Risk that software cannot be completed – build incremental subsets
  - Risk of building the wrong system – stakeholder have opportunities to see the software
  - Also, feasibility, schedule, budget and others to some extent



Characteristic Processes: The Spiral Model

- Process viewed as repeating cycles of increasing scale
- Identify risks and determine (next set of) requirements, build next version by extension, increasing scale each time



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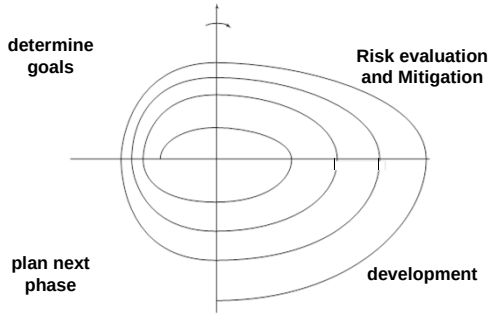
Spiral Model

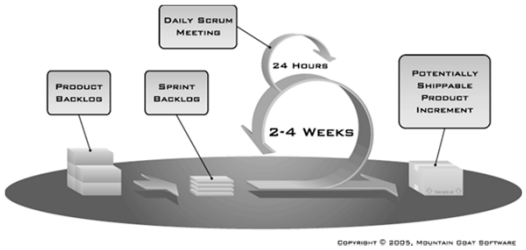


Spiral Model Goals

- Response lack of risk analysis and risk mitigation in “waterfall” process
  - Make risk analysis standard part of process
  - Address risk issues early and often
- Explicit risk analysis at each phase
- Framework for explicit risk-mitigation strategies
  - E.g., prototyping
- Explicit Go/No-Go decision points in process

Characteristic Processes: Agile (scrum, RAD, XP)

- Process viewed as nested sequence of short builds (sprints)
  - Even tighter timing loop
  - Addresses rapidly changing or emerging requirements
  - Code-driven, little planning or documentation



How do we choose a development process?

Goals vs. Risks

- Balance goals and risks
- Goal: proceed as rationally and systematically as possible from a statement of goals to a design that demonstrably meets those goals
  - Understand that any process description is an abstraction
  - Always must compensate for deviation from the ideal (e.g., by iteration)
- Risk: Anything that might lead to a loss of control is a project risk
  - E.g., won't meet the schedule, will overspend budget, will fail to deliver the proper functionality

A Software Engineering Perspective

- Choose processes, methods, notations, etc. to provide *an appropriate level of control* for the given *product* and *context*
  - Sufficient control to achieve results
  - No more than necessary to contain cost and effort

Example

- Project 1 assumptions
  1. Deadline and resources (time, personnel) are fixed
  2. Delivered functionality and quality can vary (though they affect the grade)
  3. Risks:
     1. Missing the deadline
     2. Technology problems
     3. Inadequate requirements
- Process model
  - All of these risks can be addressed to some extent by building some version of the product, then improving on it as time allows (software & docs.)
  - Technology risk requires building/finding software and trying it (prototyping)
  - Most forms of incremental development will address these

Project Planning and Management

From Process to Plan

- Process definition manifests itself in the project plan
  - Process definition is an abstraction
  - Many possible ways of implementing the same process
- Project plan makes process concrete, it assigns
  - People to roles
  - Artifacts to deliverables and milestones
  - Activities to tasks over time
- Looked at several techniques for documenting these

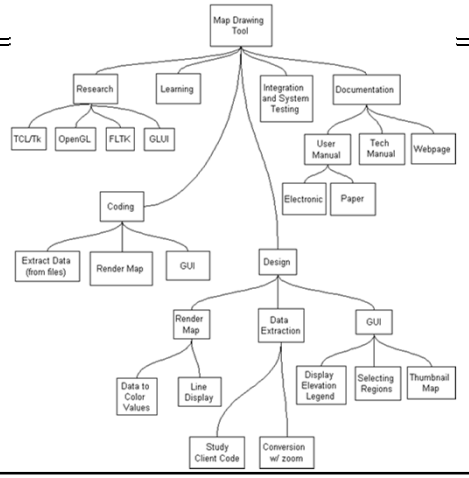
Document Types and Purposes

- Management documents
  - Basis for managerial control of resources
    - Calendar time, skilled man-hours budget
    - Other organizational resources
  - Project plan, WBS, Development schedule
  - Use: allows managers to track actual against expected consumption of resources
- Development documents
  - Basis for product development (intellectual control)
  - ConOps, Requirements (SRS), Architecture, Detail design, etc.
  - Uses:
    - Making and recording development decisions
    - Allows developers to track decisions from stakeholder needs to implementation

Work Breakdown Structure

- This is a technique to analyze the content of work and cost by breaking it down into its component parts. It is produced by :
  - Identifying the key tasks
  - Breaking each task down into component parts
  - Continuing to breakdown until manageable work packages have been identified. These can then be allocated to the appropriate person
- The WBS is used to allocate responsibilities

Work Breakdown Structure



Lessons Learned from Projects

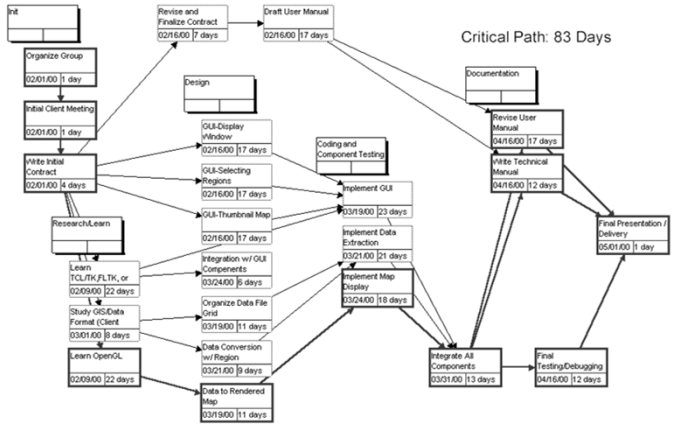
- The work breakdown defines the specific tasks team members must accomplish
- Results of inadequate work breakdown and task definitions
  - If incomplete, some tasks may not be done
  - If imprecise, people do not know exactly what to do. May do too little or the wrong thing.
  - Without a complete set of tasks, schedules are unrealistic

Milestone Planning

- Milestone planning is used to show the major steps that are needed to reach the goal on time
- Milestones typically mark completion of key deliverables or establishment of baselines
- Often associated with management review points
  - Baseline: when a work product is put under configuration management and all changes are controlled
  - E.g., Requirements baseline, project plan complete, code ready to test

Pert Chart

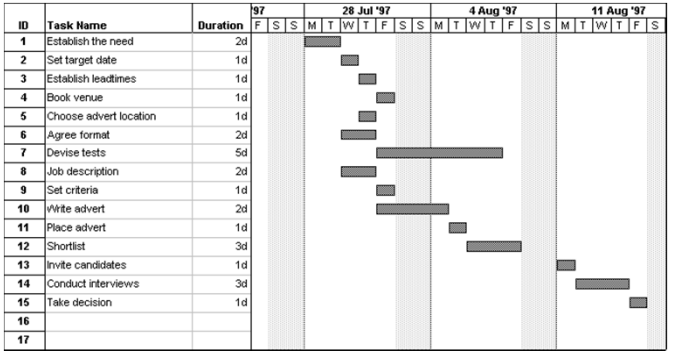
- Network analysis or PERT is used to analyze the inter-relationships between the tasks identified by the work breakdown structure and to define the dependencies of each task
- Helps identify where ordering of tasks may cause problems because of precedence or resource constraints
  - Where one person cannot do two tasks at the same time
  - Where adding a person can allow tasks to be done in parallel, shortening the project



Gantt Charts

- Method for visualizing a project schedule showing
  - The set of tasks
  - Start and completion times
  - Task dependencies
  - Responsibilities
- PERT charts can be reformatted as Gantt charts

Example Gantt Chart



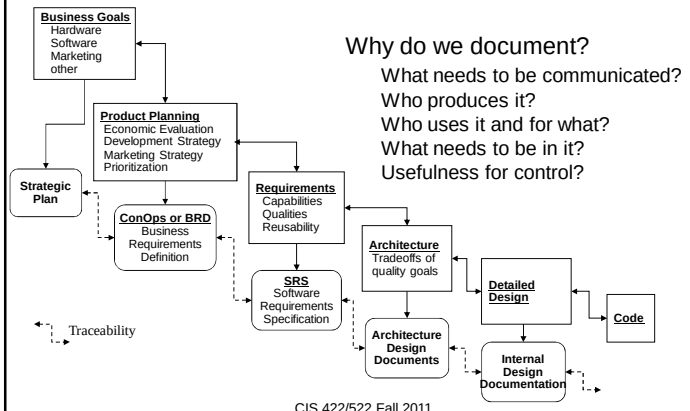
ID	Task Name	Duration
1	Establish the need	2d
2	Set target date	1d
3	Establish leadtimes	1d
4	Book venue	1d
5	Choose advert location	1d
6	Agree format	2d
7	Devise tests	5d
8	Job description	2d
9	Set criteria	1d
10	Write advert	2d
11	Place advert	1d
12	Shortlist	3d
13	Invite candidates	1d
14	Conduct interviews	3d
15	Take decision	1d
16		
17		

http://www.spottydog.u-net.com/guides/faq/faq.html

Development Documents

Making and recording engineering decisions

Product Development Cycle



Why do we document?

- What needs to be communicated?
- Who produces it?
- Who uses it and for what?
- What needs to be in it?
- Usefulness for control?

Document Types and Purposes

- **Management documents**
  - **Basis for project management (managerial control of resources)**
    - **Calendar time, skilled man-hours budget**
    - **Other organizational resources**
  - **Project plan, WBS, Development schedule**
  - **Use: allows managers to track actual against expected consumption of resources**
- Development documents
  - Basis for intellectual control
    - Used for making and communicating engineering decisions (requirements, design, implementation, verification, etc.)
    - Allows developers to track decisions from stakeholder needs to implementation
  - ConOps, SRS, Architecture, Detail design, etc.

Requirements

Problem Analysis

Requirements Specification

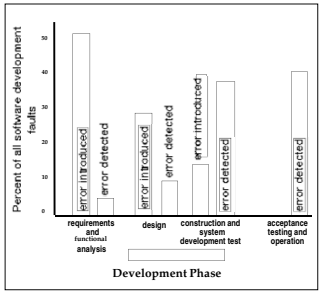
What is a "software requirement?"

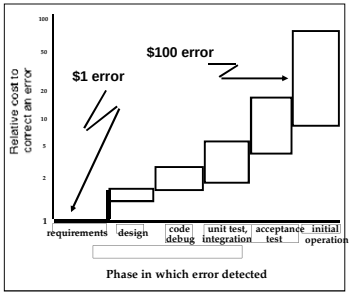
- A description of something the software must do or property it must have
- The set of system requirements denote the problem to be solved and any constraints on the solution
  - Ideally, requirements specify precisely what the software must do without describing how to do it
  - Any system that meets requirements should be an acceptable implementation

Importance of Getting Requirements Right

1. The majority of software errors are introduced early in software development

2. The later that software errors are detected, the more costly they are to correct





Requirements Phase Goals

- What does “getting the requirements right” mean in the systems development context?
- Only three goals
  1. Understand precisely what is required of the software
  2. Communicate that understanding to all of the parties involved in the development (stakeholders)
  3. Control production to ensure the final system satisfies the requirements
- Sounds easy but hard to do in practice, observed this and the resulting problems in projects
- Understanding what makes these goals difficult to accomplish helps us understand how to mitigate the risks

What makes requirements difficult?

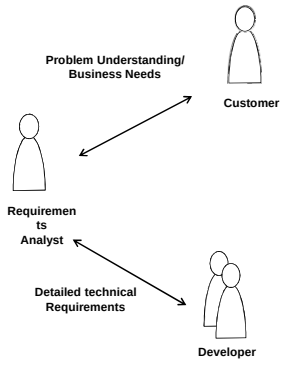
- Comprehension (understanding)
  - People don’t (really) know what they want (…until they see it)
  - Superficial grasp is insufficient to build correct software
- Communication
  - People work best with regular structures, conceptual coherence, and visualization
  - Software’s conceptual structures are complex, arbitrary, and difficult to visualize
- Control (predictability, manageability)
  - Difficult to predict which requirements will be hard to meet
  - Requirements change all the time
  - Together can make planning unreliable, cost and schedule unpredictable
- Inseparable Concerns
  - Many requirements issues cannot be cleanly separated (I.e., decisions about one necessarily impact another)
  - Difficult to apply “divide and conquer”
  - Must make tradeoffs where requirements conflict

Purposes and Stakeholders

- Many potential stakeholders using requirements for different purposes
  - Customers: the requirements document what should be delivered
  - Managers: provides a basis for scheduling and a yardstick for measuring progress
  - Software Designers: provides the “design-to” specification
  - Coders: defines the range of acceptable implementations
  - Quality Assurance: basis for validation, test planning, and verification
  - Also: potentially Marketing, regulatory agencies, etc.

Needs of Different Audiences

- Customer/User
  - Focus on problem understanding
  - Use language of problem domain
  - Technical if problem space is technical
- Development organization
  - Focus on system/software solutions
  - Use language of solution space (software)
  - Precise and detailed enough to write code, test cases, etc.



Documentation Approaches

- ConOps: informal requirements to describe the system's capabilities from the customer/user point of view
  - Answer the questions, "What is the system for?" and "How will the user use it?"
  - Tells a story: "What does this system do for me?"
  - Helps to use a standard template
- SRS: formal, technical requirements for development team
  - Purpose is to answer specific technical questions about the requirements quickly and precisely
    - Answers, "What should the system output in this circumstance?"
    - Reference, not a narrative, does not "tell a story"
  - Precise, unambiguous, complete, and consistent as practical

Informal Techniques

- Most requirements specification methods are informal
  - Natural language specification
  - Use cases
  - Mock-ups (pictures)
  - Story boards
- Benefits
  - Requires little technical expertise to read/write
  - Useful for communicating with a broad audience
  - Useful for capturing intent (e.g., how does the planned system address customer needs, business goals?)
- Drawbacks
  - Inherently ambiguous, imprecise
  - Cannot effectively establish completeness, consistency
  - However, can add rigor with standards, templates, etc.
- Exemplified by discussion of use cases

Scenario Analysis and Use Cases

- Applying scenario analysis in the development process
- Requirements Elicitation
  - Identify stakeholders who interact with the system
  - Collect "user stories" - how people would interact with the system to perform specific tasks
- Requirements Specification
  - Record as use-cases with standard format
  - Use templates to standardize, drive elicitation
- Requirements verification and validation
  - Review use-cases for consistency, completeness, user acceptance
  - Apply to support prototyping
  - Verify against code (e.g., use-case based testing)

Use Cases

1 Use Case: Manage Reports

1.1 Description

This Use Case describes operation for Creating, Saving, Deleting, Printing, Exiting and Displaying reports.

1.2 Actors

User
Project database

1.3 Triggers

Program Manager selects operations from menu.

1.4 Flow of events

1.4.1 Basic Flow

1. User chooses desired report by selecting "Report" -> "Open" from the menu bar
2. System displays report to screen
3. User selects desired report layout using Use Case Specify Report
4. Steps 2 and 3 are repeated until user is satisfied
5. User can Save or Print report using use case Save Report or Print Report
6. User Exits report by selecting "Exit" from the "File" menu

1.4.2 Alternative Flows

1.4.2.1 Create New Report

1. User selects "Create New Report" from file menu
2. ...

1.4.2.2 Delete Report

.....

1.4.3 Preconditions

etc

A systematic approach to use cases

- **Uses a standard template**
- **Easier to check, read**
- **Still informal**

Benefits and Drawbacks

- Use cases can be an effective tool for:
  - Identifying key users and their tasks
  - Characterizing how the system should work from each user's point of view
  - Communicating to non-technical stakeholders
- Generally inadequate for detailed technical requirements
  - Difficult to find specific requirements
  - Inherently ambiguous and imprecise
  - Cannot establish completeness or consistency
  - Possible exception: applications doing simple user-centric tasks with little computation (e.g., your project)

Technical Specification

The SRS

The role of rigorous specification

Requirements Documentation

- Is a detailed requirements specification necessary?
- How do we know what "correct" means?
  - How do we decide exactly what capabilities the modules should provide?
  - How do we know which test cases to write and how to interpret the results?
  - How do we know when we are done implementing?
  - How do we know if we've built what the customer asked for (may be distinct from "want" or "need")?
  - Etc…
- Correctness is a *relation* between a spec and an implementation (M. Young)
- Implication: until you have a spec, you have no standard for "correctness"

Technical Requirements

- Focus on developing a technical specification
  - Should be straight-forward to determine acceptable inputs and outputs
  - Can systematically check completeness consistency
- Provides
  - Detailed specification of precisely what to build
  - Design-to specification
  - Build-to specification for coders
  - Characterizes expected outputs for testers

Desirable SRS Properties

Semantic Properties*	Packaging Properties+
• Complete • Consistent • Unambiguous • Verifiable • Implementation independent	• Modifiable • Readable • Organized for reference and review • Reusable
* Properties of the specification's semantics (what it says) independently of how it's said	+ Properties arising from the way the specification is written (organization, formats, notations)

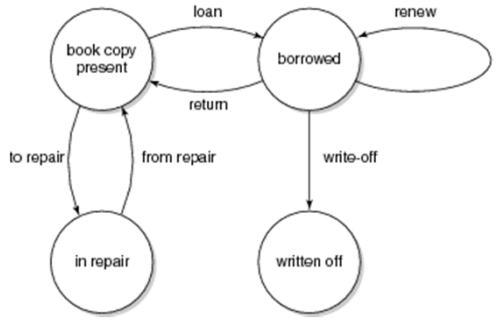
The Formal Methods Dilemma

- Standard approaches (e.g., prose specs) lack sufficient rigor to meet high-assurance goals
- Formal requirements methods have desired technical virtues viewed as impractical for large, complex systems
  - Capability for unambiguous specification, precision, testability, and analyzability
  - Industry concern for practicality
    - Concern for difficulty to write/read, required expertise, ability to scale
    - Concern for real-world issues of fuzzy or changing requirements
    - Concern for fit with industrial development context
    - Adds up to perceived cost/schedule risk
- Implication: Need for Practical Formal Methods

The Good News

- A little rigor in the right places can help a lot
  - Adding formality is not an all-or-none decision
  - Use it where it matters most to start (critical parts, potentially ambiguous parts)
  - Often easier, less time consuming than trying to say the same thing in prose
- E.g. in describing conditions or cases
  - Use predicates (i.e., basic Boolean expressions)
  - Use tables where possible

Graphic Notations for Simple Machines

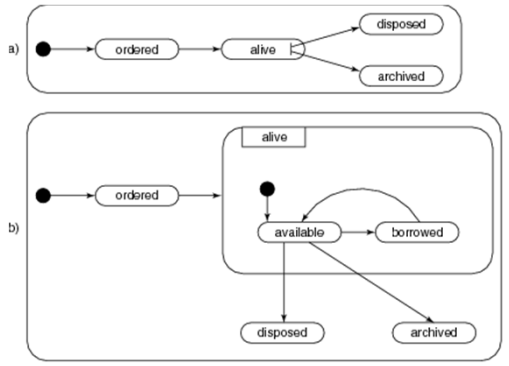


Tabular for Larger Machines

HeatCycle State Transition Function

Source Mode(s)	Events	Destination Mode
Off	@T(HeatSwitch = on) WHEN (NOT NeedHeat)	Standby
Off	@T(HeatSwitch = on) WHEN NeedHeat	Ignition
Standby	@T(HeatSwitch = off)	Off
Standby	@T(NeedHeat)	Ignition
Ignition	@T(Combustion = ignited)	Running
Ignition	@T(HeatSwitch = off) WHEN (Combustion = notignited)	Shutdown
Running	@F(NeedHeat)	Shutdown
Running	@T(HeatSwitch = off)	Shutdown
Shutdown	@F(BlowerUptoSpeed)	Standby
FaultShutdown	@T(FaultReset)	Standby
Description		
Allowed state transitions for the Home Heating System		

State Charts for Concurrent and Hierarchical Machines



***Careful since there are many possible semantics**

Tables Express Cases

WaterPump Condition Function

Modes for HeatCycle	Conditions	
Running	HeatAvail	NOT HeatAvail
Off, Standby, Ignition, Shutdown, FaultShutdown	FALSE	TRUE
WaterPump =	on	off
Description		
WaterPump defines the rules for when the pump circulating heated water to the radiators should be turned on and when it should be turned off.		

Is a "Good" SRS Achievable?

- A qualified "yes"
  - Mutual satisfaction of some goals is difficult
  - Want completeness but users don't know what they want and requirements change.
  - Many audiences and purposes, only one possible organization and language
  - Want formality (precision, verifiability, analyzability) but need readability.
- Tradeoffs and compromises are inevitable
  - Usefulness of establishing document purpose in advance.
  - Make them by choice not chance!
- It isn't easy
  - Effort, expertise, technique

Requirements Summary

- Requirements characterize “correct” system behavior
- Being in control of development requires:
  - Getting the right requirements
  - Communicating them to the stakeholders
  - Using them to guide development
- Requirements activities must be incorporated in the project plan
  - Requirements baseline
  - Requirements change management

Real meaning of “control”

- What does “control” really mean?
- Can we really get everything under control then run on autopilot?
- Rather, does control mean a continuous feedback loop?
  1. Define ideal
  2. Make a step
  3. Measure deviation from idea
  4. Correct direction or redefine ideal and go back to 2

Questions?