Lecture 3: Software Life Cycles

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Foundations of Software Engineering

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Today's Lecture

- Briefly Review Software Life Cycles
- Discuss problems associated with them

Software Lifecycle

- A series of steps marking the progress of a software product
- Lifetimes range from days to years
- Consists of
  - people!
  - overall process
  - intermediate products
  - stages of the process

Intermediate Software Products

- Objectives
  - Demarcate end of phases
  - Enable effective reviews
  - Specify requirements for next phase
- Form
  - Rigorous
  - Machine processible (highly desirable)
- Content
  - Specifications, Tests, Documentation

Example Artifacts

- Options Document
  - Problem Definition
  - Potential Solutions
  - Proposed System
- Cost-Benefit Analysis
  - Benefits
    - Achievable Goals
  - Costs
    - Development & Maint.
  - Analysis
    - Net improvement
- Requirements
  - Boilerplate
  - Project scope
  - Project history
  - Current System
  - New System
  - Requirements
- Preliminary Plan
  - Statement of Work
    Mgmt, Docs, Testing Plans
  - Schedules

Phases of a Software Lifecycle

- Standard Phases
  - Requirements Analysis & Specification
  - Design
  - Implementation and Integration
  - Operation and Maintenance
  - Change in Requirements
  - Testing throughout!
- Phases promote manageability and provide organization

Requirements Analysis and Specification

- Problem Definition —> Requirements Specification
  - determine exactly what client wants and identify constraints
  - develop a contract with client
  - Specify the product's task explicitly
- Difficulties
  - client asks for wrong product
  - client is computer/software illiterate
  - specifications may be ambiguous, inconsistent, incomplete
- Validation
  - extensive reviews to check that requirements satisfy client needs
  - look for ambiguity, consistency, incompleteness
  - check for feasibility, testability
  - develop system/acceptance test plan

Design

- Requirements Specification —> Design
  - develop architectural design (system structure)
    - decompose software into modules with module interfaces
  - develop detailed design (module specifications)
    - select algorithms and data structures
  - maintain record of design decisions
- Difficulties
  - miscommunication between module designers
  - design may be inconsistent, incomplete, ambiguous
- Verification
  - extensive design reviews (inspections) to determine that design conforms to requirements
  - check module interactions
  - develop integration test plan

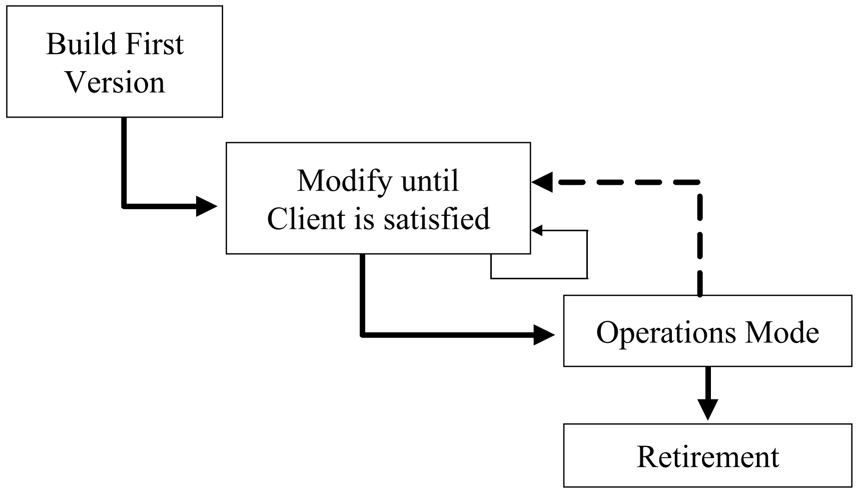
Implementation and Integration

- Design —> Implementation
  - implement modules and verify they meet their specifications
  - combine modules according to architectural design
- Difficulties
  - module interaction errors
  - order of integration has a critical influence on product quality
- Verification and Testing
  - code reviews to determine that implementation conforms to requirements and design
  - develop unit/module test plan: focus on individual module functionality
  - develop integration test plan: focus on module interfaces
  - develop system test plan: focus on requirements and determine whether product as a whole functions correctly

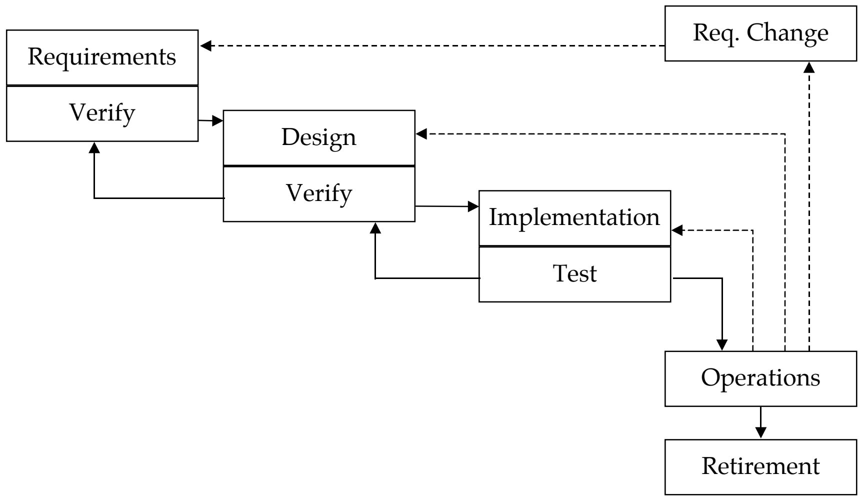
Operation and Maintenance

- Operation —> Change
  - maintain software after (and during) user operation
  - determine whether product as a whole still functions correctly
- Difficulties
  - design not extensible
  - lack of up-to-date documentation
  - personnel turnover
- Verification and Testing
  - review to determine that change is made correctly and all documentation updated
  - test to determine that change is correctly implemented
  - test to determine that no inadvertent changes were made to compromise system functionality (check that no affected software has regressed)

Build-and-Fix



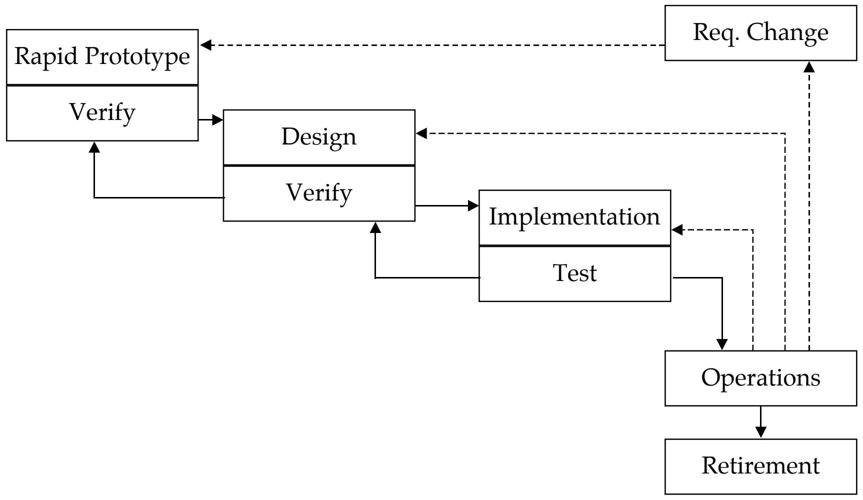
Waterfall Model



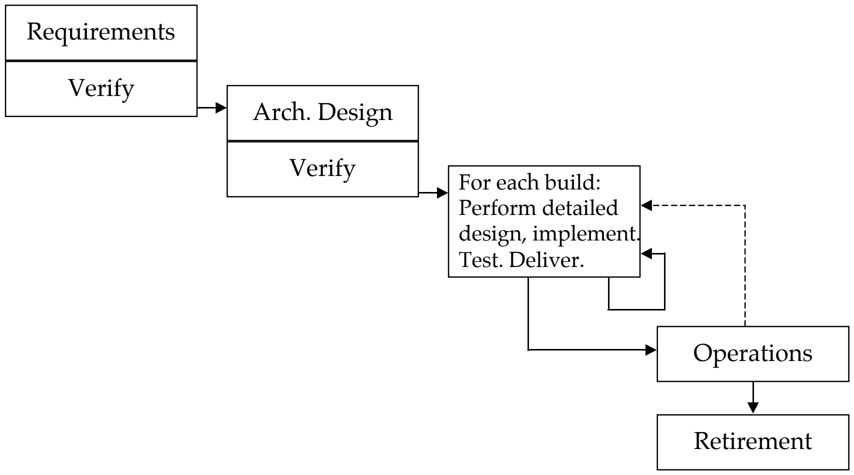
Two views on Waterfall

- Business Systems
  - Enterprise Initiatives lead to Feasibility Studies
    - This starts the waterfall in motion
- Engineering Applications
  - Waterfall starts much later in the process
  - Software may not be considered until
    - after concept exploration and experimental prototyping of global engineering system

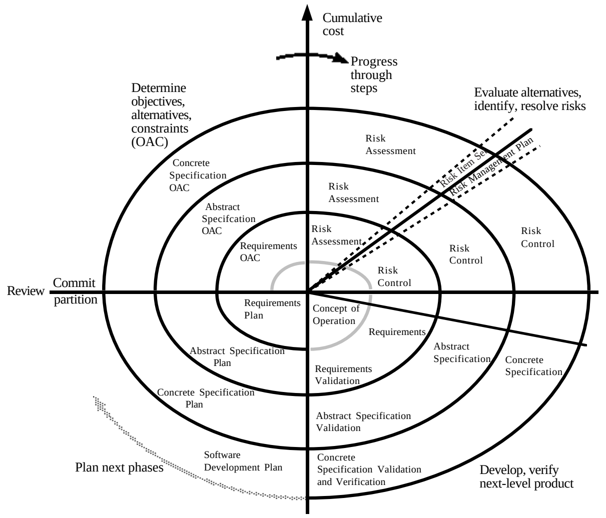
Rapid Prototyping



Incremental



The Spiral Model [Boehm,1988]


Cumulative cost
Progress through steps
Determine objectives, alternatives, constraints (OAC)
Evaluate alternatives, identify, resolve risks
Risk Assessment
Risk Assessment
Risk Assessment
Risk Item Set
Risk Management Plan
Concrete Specification OAC
Abstract Specifcation OAC
Requirements OAC
Risk Control
Risk Control
Risk Control
Review
Commit partition
Requirements Plan
Concept of Operation
Requirements
Abstract Specification
Concrete Specification
Abstract Specification Plan
Requirements Validation
Concrete Specification Plan
Abstract Specification Validation
Plan next phases
Software Development Plan
Concrete Specification Validation and Verification
Develop, verify next-level product

Object-Oriented Life Cycles

- Obtain customer requirements for the OO System
  - Identify scenarios or use cases
  - Build a requirements model
- Select classes and objects using basic requirements
- Identify attributes and operations for each object
- Define structures and hierarchies that organize classes
- Build an object-relationship model
- Build an object-behavior model
- Review the OO analysis model against use cases

Life Cycle Problems

- The user's view of software development
  - The waterfall is not "real" to them
- Consider Construction of a House
  - Decisions are visible
    - The lot
    - The position of the house on the lot
    - Landscaping
    - Pouring the Foundation

Constructing a House, continued

- As each decision is made, the "user" can see its effects
  - Its easy to see that making a change to the position of the house on the lot is expensive after the foundation is poured
- Its harder to determine what events in a software life cycle "casts things in concrete!"

Software-based Example

```
if (employee_age > 60) then
   …
end if;
```

Imagine the implications if the actual retirement age changed to 59.5

Consequences of the Change

- Integer to Rational
  - Or to stay with integers
    - change all values to months (round up or down?)
- Was "60" used for other purposes?
  - If so, you must ensure that the code isn't intertwined
- Update all requirements documents, design documents, specifications, etc.

Life cycle Problems

- Requirements are incomplete
- Waterfall is expensive
- It takes too long
- Too many variations
- Communications Gap
- Assumes "What" can be separated from "How"
- Error Management

Requirements are Incomplete

- Boehm reports that incomplete requirements cause downstream costs to increase exponentially!
- Issues
  - Computerization affects Environment
  - "Report Effect"
  - Lack of Visibility
  - People are not used to attaining completeness
    - Consider the construction of an airplane
      - Many details are covered by standards…

It costs too much!

- The waterfall was introduced when
  - computer time more expensive than person time
    - forced extensive desk planning
    - use of time and space optimized
- Now, computer time is extremely cheap
  - but our methods haven't changed!
- The management of artifacts as the life cycle progresses requires more and more resources
  - New methods must focus on this information management task

It takes too long!

- Example Waterfall (> 400 important entities)
  - 114 major tasks
  - 87 different organizations
  - 39 deliverables
  - 164 authorizations
- All of this allows people to “talk” about the project rather than “doing” the project!
- Inevitably, a project running too long, gets cut short => results in incomplete or untenable system

It takes too long! (continued)

- What to do?
  - Experience will help
  - CMM-like methods will increase the organization’s ability to predict schedules
  - Rules needed when project is shortened
    - What requirements are removed?
    - How is the system’s functionality scaled back?

Too many variations!

- Key problems
  - communication between practitioners
    - each builds large systems but use
      - different vocabulary
      - different steps
      - different deliverables
  - Difficult to assess life cycle critically
    - Problems are shared by all; but without common understanding how are root causes found?

End-User Communications Gap

“What we understand to be the conventional life cycle approach might be compared with a supermarket at which the customer is forced to provide a complete order to a stock clerk at the door of the store with no opportunity to roam the aisles–comparing prices, remembering items not on the shopping list, or getting a headache and deciding to go out for dinner…”

[McCracken and Jackson, 1982]

Communications Gap, continued

- User involvement throughout the life cycle
  - Participatory Design field
- Watch out for communications gap within the development team!
  - Horizontal Team Integration considered bad
    - Tends to be little review; no chance for self-correction
  - Vertical Teams better; maintenance still a problem

"What vs. How"

- Assumption
  - Problem description can be separated from problem solution
- Unfortunately, people don't behave this way!
  - People like to consider a range of solutions
    - What are the trade-offs?
    - A solution strategy may help clarify the problem

Error Management

- It is impossible to predict all of the errors that a software system must handle
- Thus, a module's initial design is very likely to be incomplete!
  - Some errors may exist only because of a particular implementation strategy
  - if so, an implementation choice may then impact the interface of the module (which is typically set during design)