Software Process

- What is SW process?
  - Definition, Development, Support phases
- Process models:
  - Waterfall
  - Prototyping
  - Spiral,
  - Incremental & iterative (best practices)
- UP process model
  - What is it? How does it work?

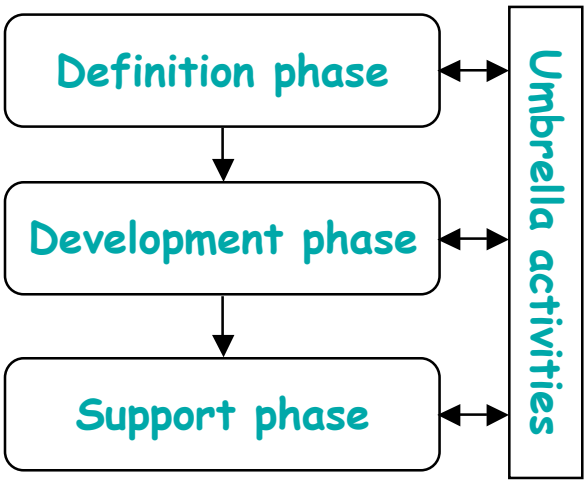
Software Process

- For a single project
  - Planning (time, resources, assignments)
  - Tracking and measuring progress
- Across multiple projects
  - Organizational planning (time, resources, etc.)
  - Hiring, training, tool acquisition, etc.
  - Process assessment and improvement
- For software engineering in general
  - Helps organize SE around 'best practices'
    - How to build software?
  - SW Process is a research area of SE

Elements of the Process

Term	Example
• Tasks	*analyze requirements*
• Work products	*requirements specification*
• Relationships	*req. specs feed design*
• Milestones	*reviewed requirements*
• People	*Alice and Bob*
• Methods	*use OO analysis with UML*
• Tools	*Rational Rose*

Generic View of Software Process



Definition Phase

- Tasks related to problem definition
  - What? - requirements, constraints, external environment, validation criteria, etc.
- Step 1: system engineering
  - Ascertain roles of hardware, software, people, databases, operational procedures, etc. in system
- Step 2: analysis of the problem
  - requirements analysis
    - Understanding what the users need and want
  - domain analysis
    - Illustrate key concepts in a set of SW systems (reuse)
- Step 3: project planning
  - Resources (e.g., people), cost, schedule

Development Phase

- Tasks related to problem solution
  - How? - architecture, components, data, algorithms, programming, testing, etc.
- Step 1: software design (the blueprint)
  - Design models that describe structure, interactions, etc.
- Step 2: code generation
- Step 3: software testing
  - Goal: uncover as many errors as possible

Support (Maintenance) Phase

- Tasks related to software evolution
  - Definition and development in the context of existing software
- Adaptation to changes in the environment
  - New hardware, changes in OS, business rules, etc.
- Correction of defects
  - e.g. Y2K problem - many billions of dollars
- Enhancements (new features, etc.)
- Reengineering: for easier future changes

Real-World Example: Cobol

- Business programming language
  - Initial spec: 1960, last spec: 2002
  - Y2K problem
  - Millions lines of code in legacy applications
  - Dozens of books and training courses
    - "Cobol for the 21 century", 10th ed

```
GetBookRankings.
  MOVE W-BookNum TO PrevBookNum
  MOVE ZEROS TO BookSalesTotal
  PERFORM UNTIL W-BookNum NOT EQUAL TO PrevBookNum
                OR EndOfWorkfile
     ADD W-Copies TO BookSalesTotal
     RETURN WorkFile
        AT END SET EndOfWorkfile TO TRUE
        END-RETURN
  END-PERFORM
```

Some Umbrella Activities

- *Project management*
  - Tracking and control of people, process, work products, schedule, cost, quality, risk, etc.
- *Quality assurance* (Q&A): activities that ensure high quality of all work products
  - Formal technical reviews of requirement specifications, designs, source code
  - Software testing
  - Keeping docs consistent with code base
- *Configuration management*
  - Controls the changes in work products: e.g., version control for source code (e.g., RCS,CVS)

Process Model

- A general pattern for a software process
  - Instantiated for each specific project
  - May have to be modified for the particular circumstances
    - Not a dogma – adjust as necessary-helps to organize the work in a manner where progress can be assessed
- The model defines tasks, work products, relationships, milestones, etc.
  - e.g. "The output of task X is input for task Y"

Observations

- Process models are idealizations
  - The real world is a very complex place
  - Provide a roadmap for SE work
- They can be difficult to execute
- They can be viewed as interfering with "real work"
- Conformance can be faked
- But they provide stability, control and organization to an activity that may become chaotic, otherwise

Code-and-Fix Process

- The first thing people tried in the 1950s
  - Beginning programmers often use it

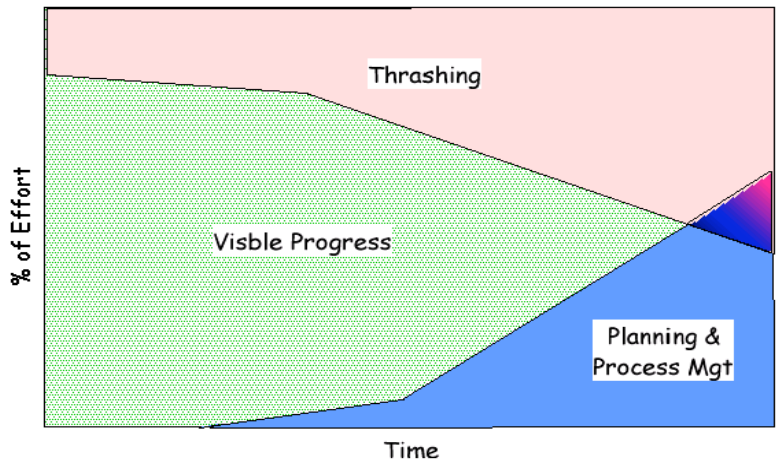
1. Write program
2. Improve it (debug, add functionality, improve efficiency, …)
3. GOTO 1

- Works for small 1-person projects and for some CS course assignments

Problems with Code-and-Fix

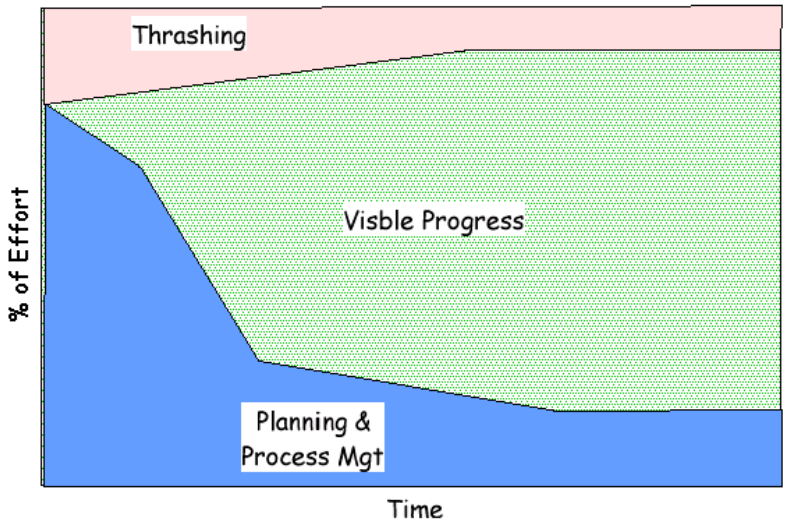
- Poor match with user needs
- Bad overall structure
  - No blueprint
- Poor reliability - no systematic testing
- Maintainability? What's that?
- What happens when the programmer quits?

Code-and-Fix Process



from McConnell, *After the Goldrush, 1999*

A More Advanced Process



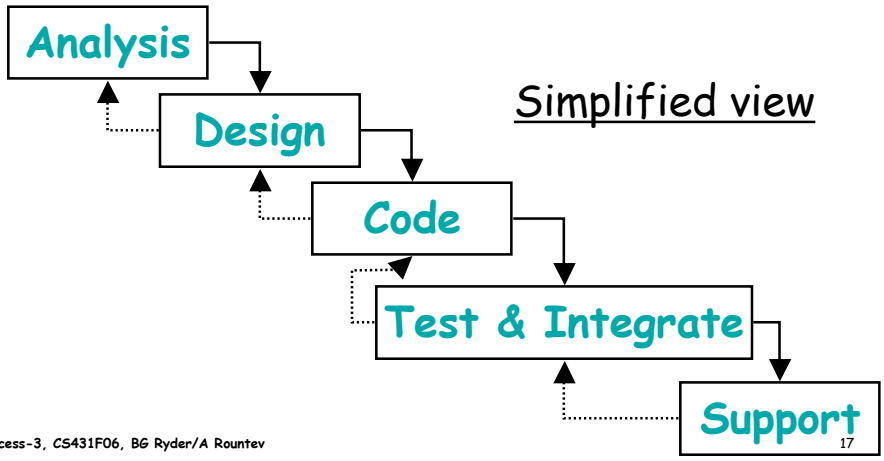
from McConnell, *After the Goldrush, 1999*

Examples of Process Models

- Waterfall model
- Prototyping model
- Spiral model (an '88 classic)
- Iterative & incremental model

Waterfall Model

- The "classic" process model since 1970s
  - Also called "software life cycle"



Waterfall Phases

- Analysis: requirements (features, etc.) and relevant domain concepts
- Design: solution blueprint for the systems and for individual components
- Individual components: implementation and testing (unit testing)
- System integration
  - with integration/system testing
- Software support and maintenance

Key Points of the Model

- The project goes through the phases sequentially
- Possible feedback and iteration across phases
  - e.g., during coding, a design problem is identified and fixed
- Typically, few or no iterations are used
  - e.g., after a certain point of time, the design is "frozen"

Waterfall Model Assumptions

- Requirements are known from the start, before design
- Requirements are stable
- The design can be done abstractly and speculatively
  - i.e., it is possible to correctly guess in advance how to make it work
- Everything will fit together when we start the integration

Pros and Cons

- Pros: widely used, systematic, good for projects with well-defined requirements
  - Makes managers happy
- Inflexible: the actual process is not so sequential
  - Limited use of iteration, problems from earlier phases are hard to fix
- Expects full requirements early
- Working program is not available early
  - *High risk issues are not tackled early enough*

Prototyping Model

- Problem: customers have general objectives but no detailed requirements
- Solution: build a prototype
  - Analysis of known requirements, plus quick-and-dirty design and implementation
- Iterations: customer evaluation followed by prototype refinements
- Goal: to understand and identify the requirements
  - The prototype is thrown away!

Pros and Cons

- Better understanding of requirements
  - Good starting point for other process models (e.g., waterfall)
- Problem: the prototype may be used as a starting point rather than being thrown away
  - Bad idea: prototypes typically have poor design that adversely affects maintainability as well as poor quality
- Bad decisions during prototyping may propagate to the real product
  - E.g., bad choice of O/S platform or PL

Spiral Model

- An evolutionary model that combines prototyping with waterfall phases
  - SW developed in series of evolutionary releases that better define/implement system while reducing risk
  - Implement increasingly more complete versions of the software
  - Do same activities as in waterfall, but cyclically, with milestones and assessment at the end of each cycle influencing the next cycle's tasks
- Developed by Barry Boehm in mid-1980's at TRW (cf IEEE Computer, May 1988)

Example of Spiral Model

TRW SW Productivity System

1. Outline initial idea for product, establish needs (2-3 months)
2. Refine outline from 1, for a product that will increase productivity two-fold over 5 years at $10K per person (12 months)
   - Suggested a testbed of 100 people for prototype environment
   - Assessed risks and established a steering group for product
3. Start new project to develop 'bare bones' version of product including an initial design
4. Iterate product through several versions of evolution and assessment
5. Later cycles enhance product to meet new needs

Pros and Cons

- Pros:
  - Realistic for large SW systems
  - Since SW is evolving, technical risks discerned by users and developers can be more easily handled in mid-stream
  - Allows prototyping to be applied during each phase of SW evolution
  - Maintains step-wise approach with 'go-backs' to earlier stages
  - Can result in non-uniform designs that focus on risky parts of the system
- Cons:
  - Requires risk-assessment expertise for success
  - Hard to convince customers that product will be finished

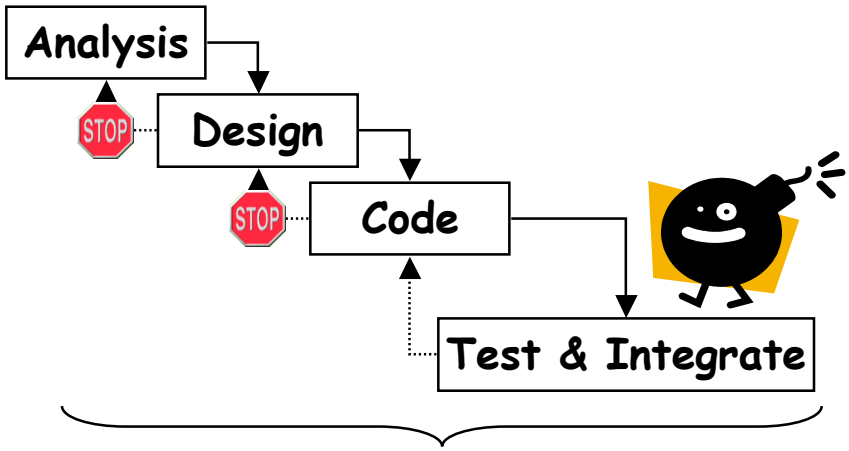
Iterative & Incremental Model

- Waterfall: single release
- Iterative: many releases (increments)
  - First increment: core functionality
  - Successive increments: add/fix functionality
  - Final increment: the complete product
- Each iteration: a short mini-project with a separate lifecycle
  - e.g., waterfall
- Increments may be built sequentially or in parallel
- Spiral was one of first iterative process models

Iterative & Incremental Model

- Outcome of each iteration: tested, integrated, executable system
- Iteration length is short and fixed
  - e.g. 2 weeks, 4 weeks, 6 weeks
- Takes many iterations to finish(e.g. 10-15)
- Does not try to "freeze" the requirements and design speculatively
  - Rapid feedback, early insight, opportunity to modify requirements and design
  - Later iterations: reqs/design become stable

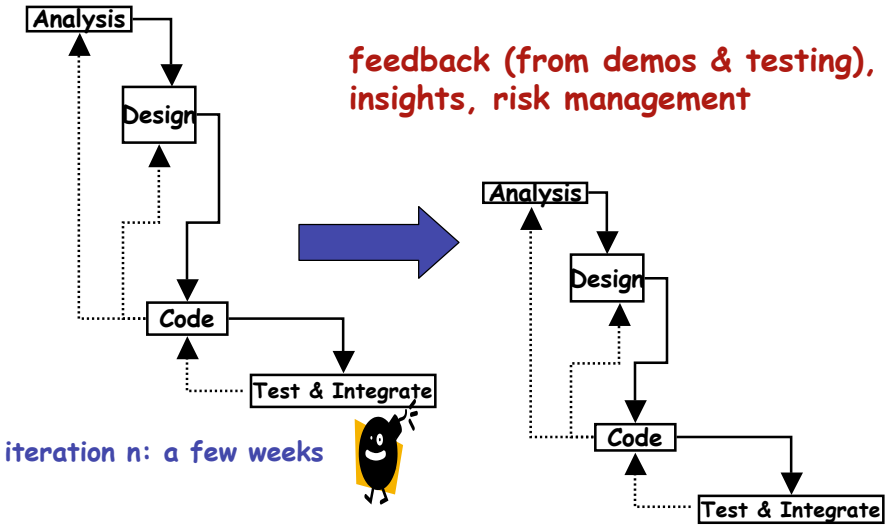
Waterfall (Sequential) Model



e.g. 1-2 years

Iterative Model

feedback (from demos & testing), insights, risk management



iteration n: a few weeks

iteration n+1: a few weeks

Iterative & Incremental Model

- Risks are addressed in early iterations
  - e.g. server application with 10,000 concurrent users and <1sec response: quickly build and evaluate components/architecture
- Continuous feedback from users
  - To build what the users want
- Early quality control: testing and reviews

Iterative vs. Waterfall - 1

- Waterfall: tries to fully specify and freeze requirements and design
  - Problem 1: the requirements may change in the future
  - Problem 2: early design decisions are speculative
- Iterative: accepts requirements change as inevitable, and allows the design to evolve

Iterative vs. Waterfall - 2

- Waterfall: inadequate risk management
  - Testing in the end, when problems are hard and expensive to fix
- Iterative: identifies high-risk issues through rapid feedback
  - At the end of each iteration, learn from users, developers, testers
    - Users try the partial system and say *"Well, the feature I wanted is actually ..."*
    - Usability testing: (e.g. the user interface)
    - Load testing

Pros and Cons - Iterative Model

Accepted as best practice

- Early discovery of high risks
  - Technical, requirements, usability, etc.
- Early visible progress
  - Customers and managers are happy
- Managed complexity: avoids long and complex analysis/design steps
  - No "analysis paralysis"
  - Smaller increments are easier to manage

Pros and Cons - Iterative Model

- Operational product is available early
  - Allows early feedback from users
    - Result: a system the users actually want
  - The market may force a limited version
- Accommodates changes
  - e.g. experience with earlier increments may be used to define/refine the requirements
- Constant changes ("feature creep") may erode system architecture

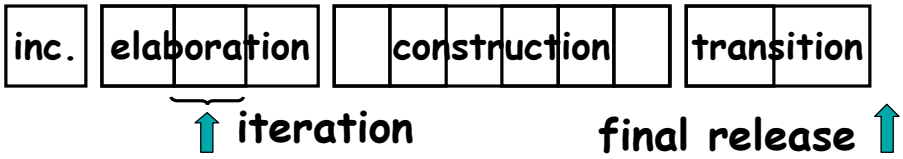
Unified Process - Overview

- The Unified Process (UP): an example of an iterative and incremental process
  - Very popular in the last few years
  - By same folks who developed UML
  - Incorporates modern principles for software development
- Will provide a context for our discussion of analysis and design
- Objectives:
  - Define the organization and practices of the UP

A Little History

- "The three amigos": Grady Booch, Ivar Jacobson, James Rumbaugh
  - Separate methodologies for object-oriented analysis and design (OOAD) in the early 90s
  - Created the Unified Modeling Language (UML) in 1996
- 1999: defined the Unified Process (UP) in Rational Software Inc.
  - Refinement: Rational Unified Process (RUP)
  - Rational makes lots of money from the RUP

Organization of the UP



- Inception: preliminary investigation
- Elaboration: analysis, design, some coding
- Construction: more coding and testing
- Transition: beta testing and deployment

Inception

- Short initial phase (e.g., about a week)
  - Investigation of purpose, scope, and feasibility: should we even bother?
- Order-of-magnitude unreliable estimates of cost and time
- Definition of some requirements (10%)
- Plan for the first iteration of elaboration
- Possibly a proof-of-concept prototype

Elaboration

- Analysis
  - Most of requirements analysis
  - Most of domain analysis (domain modeling)
- Most of the design
- Some coding
  - Iterative implementation of the core architecture and high-risk requirements
- Testing of all implemented code
- More precise estimates of time/cost

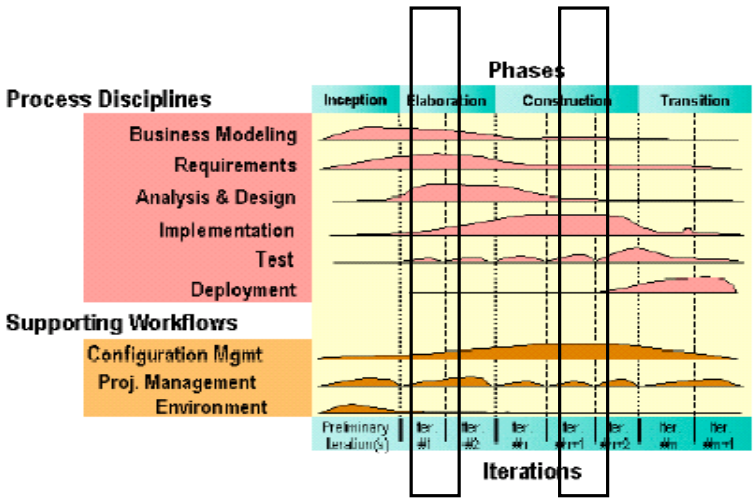
Remaining Phases

- Construction phase
  - Iterative implementation and testing of the remaining lower risk and easier aspects
  - Very little analysis or design
  - Preparation for deployment
- Transition
  - Beta testing
  - Deployment

UP Disciplines

- Discipline: a set of activities and related artifacts in one subject area
- Artifact: any kind of work product
  - e.g., code, diagrams, models, documents, ...
- We will consider three disciplines
  - Business modeling – e.g., domain analysis
  - Requirements – requirements analysis
  - Design

Effort Distribution



source: Rational. software *white paper, May 2002*

Iteration Length

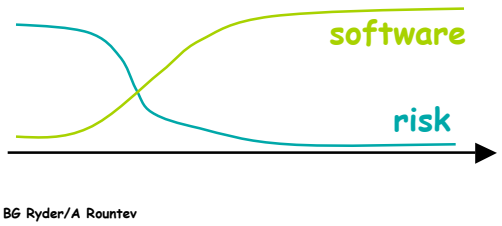
- Iterations should be short
  - Typically 2-6 weeks
  - Goal: small steps, rapid feedback, adaptation
  - Exception: massive teams with lots of communication – but no more than 3-6 months
- Iterations should be timeboxed (i.e., fixed in length)
  - The system should be integrated, tested, and stabilized by the schedule date
  - If not possible: move tasks to the next iteration

Reasons for Timeboxing

- Work expands to fill the available time
  - With a deadline two weeks away, people focus and get moving
- Encourages prioritization and decisiveness
- Team satisfaction and confidence
  - Quick and repeating sense of completion, competency, and closure
  - Also, increased confidence for customers and managers

High-risk and High-value Issues

- In the early iterations, focus on:
  - Overall architecture
  - Components for risky requirements
  - Components with high value to the customer
- Better to fail early than late
  - The process is risk-driven



Other UP Practices

- Continuously engage the customer
- Early focus on the core architecture
  - Shallow implementation: overall structure, component interfaces and responsibilities, without an "in-depth" implementation
- Verify quality early and often
  - Testing and reviews: critical for early feedback and to avoid expensive late defects
  - Unlike the waterfall model

Some Work Products

Artifact	Incep	Elab	Const	Trans
Use-Case Model	X	X		
Supplem. Spec	X	X		
Domain Model		X		
Design Model		X	X	
Implem. Model (code)		X	X	X

Requirements analysis: Use-Case Model + Supplementary Specification

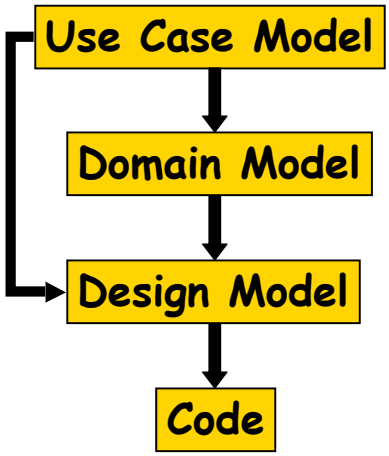
Domain analysis: Domain Model

Design: Design Model

Coding: Implementation Model

Cf Larman, p 38

Relationships Among Models



A Borrowed Joke

How many software engineers does it take to change a light bulb?

Five. Two to write the specification, one to screw it in, and two to explain why the project was late.