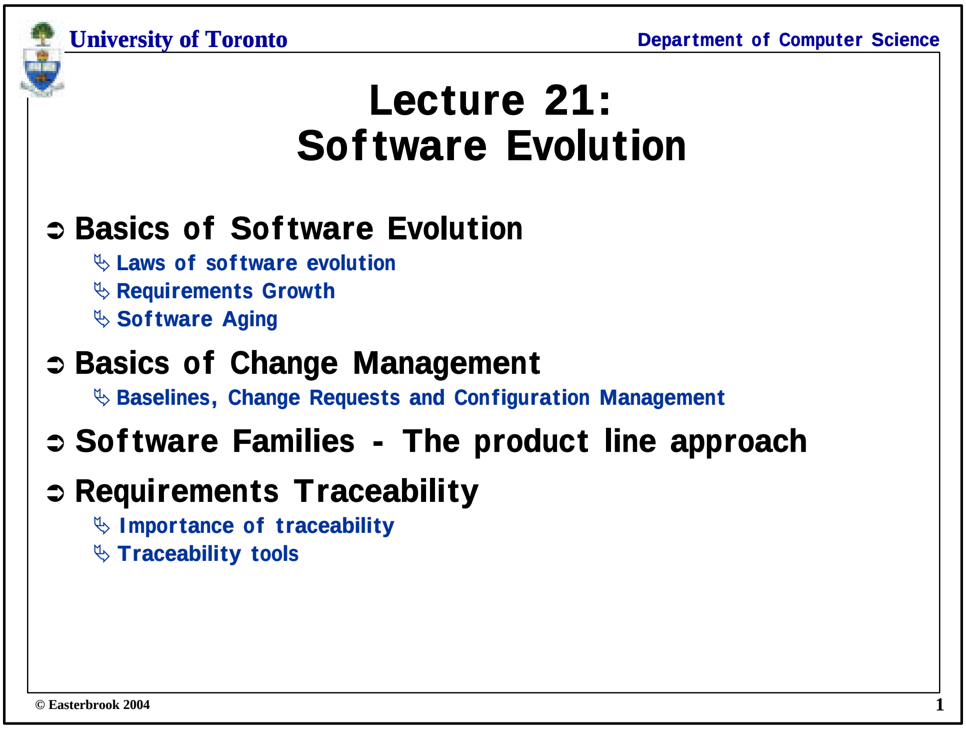
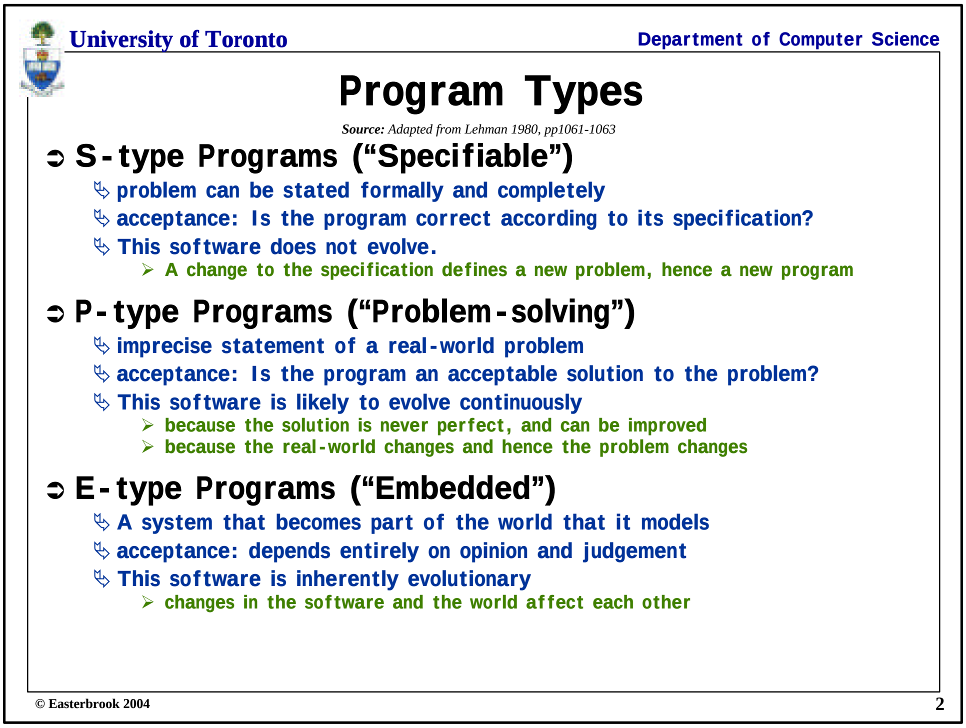


Lecture 21: Software Evolution

- ➲ **Basics of Software Evolution**
  - Laws of software evolution
  - Requirements Growth
  - Software Aging
- ➲ **Basics of Change Management**
  - Baselines, Change Requests and Configuration Management
- ➲ **Software Families - The product line approach**
- ➲ **Requirements Traceability**
  - Importance of traceability
  - Traceability tools

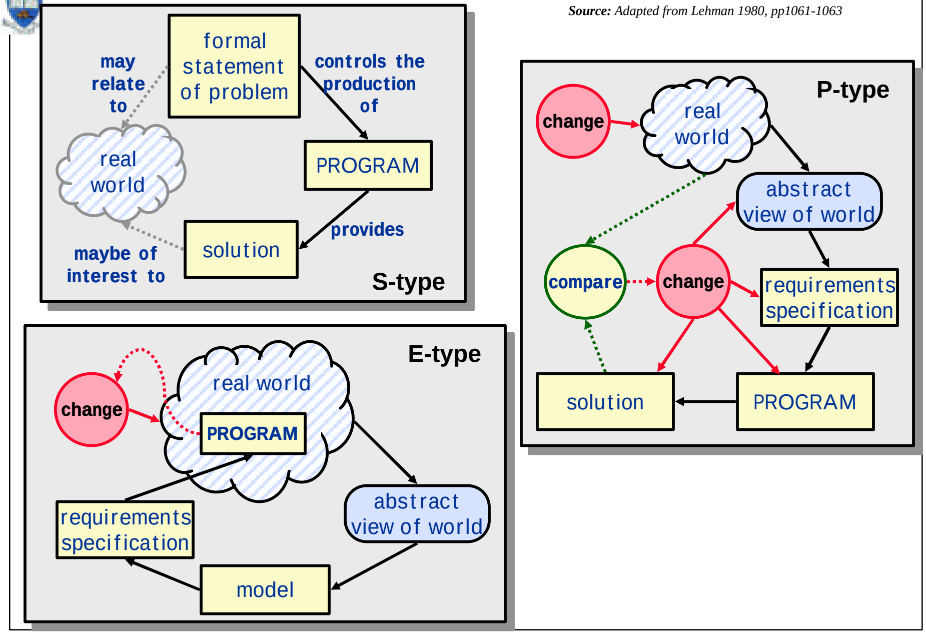


Program Types

Source: *Adapted from Lehman 1980, pp1061-1063*

- ➲ **S-type Programs (“Specifiable”)**
  - problem can be stated formally and completely
  - acceptance: Is the program correct according to its specification?
  - This software does not evolve.
    - ➢ A change to the specification defines a new problem, hence a new program
- ➲ **P-type Programs (“Problem-solving”)**
  - imprecise statement of a real-world problem
  - acceptance: Is the program an acceptable solution to the problem?
  - This software is likely to evolve continuously
    - ➢ because the solution is never perfect, and can be improved
    - ➢ because the real-world changes and hence the problem changes
- ➲ **E-type Programs (“Embedded”)**
  - A system that becomes part of the world that it models
  - acceptance: depends entirely on opinion and judgement
  - This software is inherently evolutionary
    - ➢ changes in the software and the world affect each other

Source: *Adapted from Lehman 1980, pp1061-1063*



Laws of Program Evolution

Source: *Adapted from Lehman 1980, pp1061-1063*

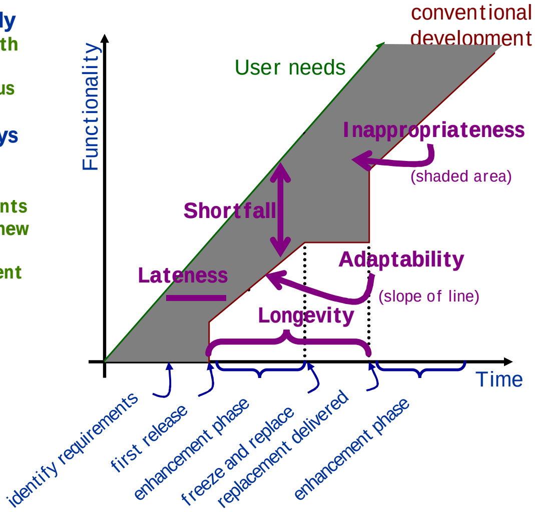
- **Continuing Change**
  - Any software that ***reflects some external reality*** undergoes continual change or becomes progressively less useful
    - change continues until it is judged more cost effective to replace the system
- **Increasing Complexity**
  - As software evolves, its ***complexity*** increases…
    - …unless steps are taken to control it.
- **Fundamental Law of Program Evolution**
  - Software evolution is self-regulating
    - …with statistically determinable trends and invariants
- **Conservation of Organizational Stability**
  - During the active life of a software system, the work output of a development project is roughly constant (regardless of resources!)
- **Conservation of Familiarity**
  - The amount of change in successive releases is roughly constant

Requirements Growth

Source: *Adapted from Davis 1988, pp1453-1455*

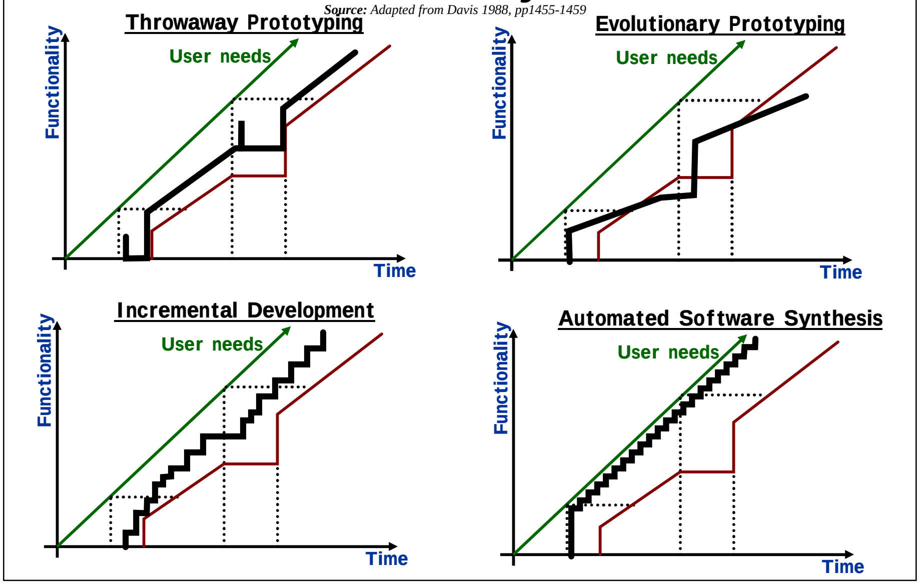
➲ **Davis's model:**

- **User needs evolve continuously**
  - Imagine a graph showing growth of needs over time
  - May not be linear or continuous (hence no scale shown)
- **Traditional development always lags behind needs growth**
  - first release implements only part of the original requirements
  - functional enhancement adds new functionality
  - eventually, further enhancement becomes too costly, and a replacement is planned
  - the replacement also only implements part of its requirements,
  - and so on...



Alternative lifecycle models

Source: *Adapted from Davis 1988, pp1455-1459*



Software "maintenance"

Source: *Adapted from Blum, 1992, p492-495*

Maintenance philosophies

- "throw-it-over-the-wall" - someone else is responsible for maintenance
  - investment in knowledge and experience is lost
  - maintenance becomes a reverse engineering challenge
- "mission orientation" - development team make a long term commitment to maintaining/enhancing the software

Basili's maintenance process models:

- Quick-fix model
  - changes made at the code level, as easily as possible
  - rapidly degrades the structure of the software
- Iterative enhancement model
  - Changes made based on an analysis of the existing system
  - attempts to control complexity and maintain good design
- Full-reuse model
  - Starts with requirements for the new system, reusing as much as possible
  - Needs a mature reuse culture to be successful

Software Aging

Source: *Adapted from Parnas, 1994*

Causes of Software Aging

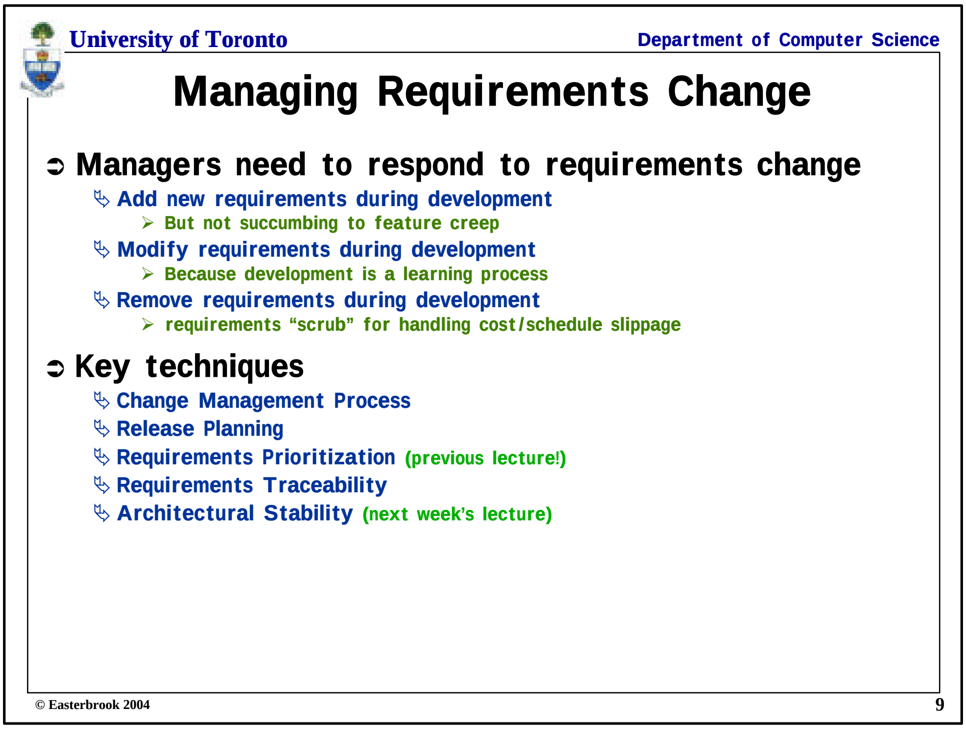
- Failure to update the software to meet changing needs
  - Customers switch to a new product if benefits outweigh switching costs
- Changes to software tend to reduce its coherence

Costs of Software Aging

- Owners of aging software find it hard to keep up with the marketplace
- Deterioration in space/time performance due to deteriorating structure
- Aging software gets more buggy
  - Each "bug fix" introduces more errors than it fixes

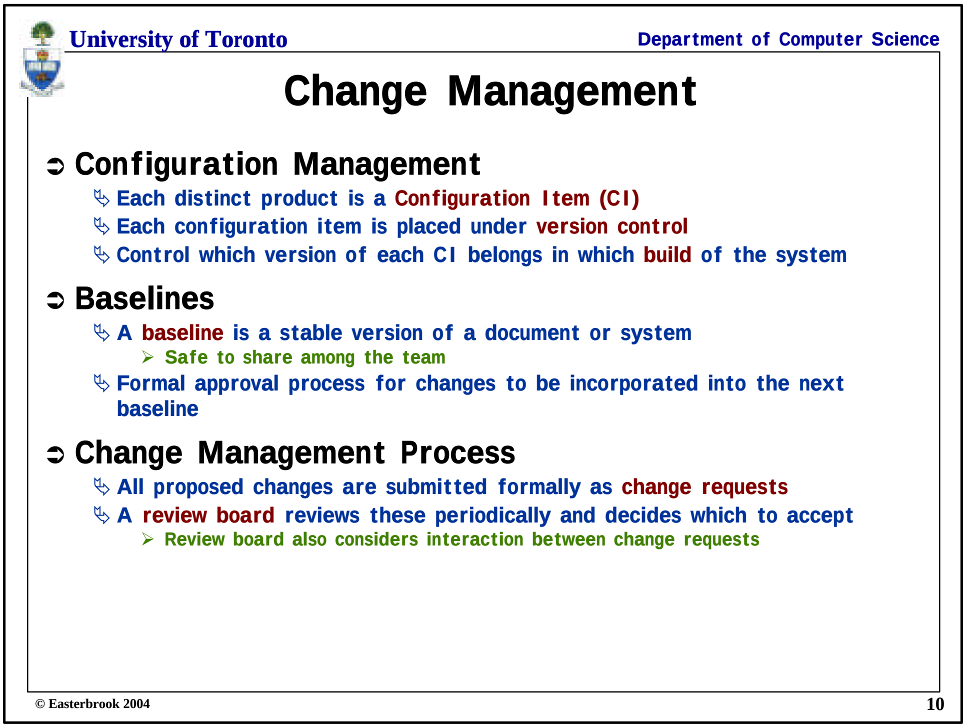
Ways of Increasing Longevity

- Design for change
- Document the software carefully
- Requirements and designs should be reviewed by those responsible for its maintenance
- Software Rejuvenation…



Managing Requirements Change

- Managers need to respond to requirements change
  - Add new requirements during development
    - But not succumbing to feature creep
  - Modify requirements during development
    - Because development is a learning process
  - Remove requirements during development
    - requirements “scrub” for handling cost/schedule slippage
- Key techniques
  - Change Management Process
  - Release Planning
  - Requirements Prioritization (previous lecture!)
  - Requirements Traceability
  - Architectural Stability (next week’s lecture)



Change Management

- Configuration Management
  - Each distinct product is a Configuration Item (CI)
  - Each configuration item is placed under version control
  - Control which version of each CI belongs in which build of the system
- Baselines
  - A baseline is a stable version of a document or system
    - Safe to share among the team
  - Formal approval process for changes to be incorporated into the next baseline
- Change Management Process
  - All proposed changes are submitted formally as change requests
  - A review board reviews these periodically and decides which to accept
    - Review board also considers interaction between change requests

Towards Software Families

- Libraries of Reusable Components
  - domain specific libraries (e.g. Math libraries)
  - program development libraries (e.g. Java AWT, C libraries)
- Domain Engineering
  - Divides software development into two parts:
    - domain analysis - identifies generic reusable components for a problem domain
    - application development - uses the domain components for specific applications.
- Software Families
  - Many companies offer a range of related software systems
    - Choose a stable architecture for the software family
    - identify variations for different members of the family
  - Represents a strategic business decision about what software to develop
  - Vertical families
    - e.g. ‘basic’, ‘deluxe’ and ‘pro’ versions of a system
  - Horizontal families
    - similar systems used in related domains

Requirements Traceability

- From IEEE-STD-830:
  - Backward traceability
    - i.e. to previous stages of development.
    - the origin of each requirement should be clear
  - Forward traceability
    - i.e., to all documents spawned by the SRS.
    - Facilitation of referencing of each requirement in future documentation
    - depends upon each requirement having a unique name or reference number.
- From DOD-STD-2167A:
  - A requirements specification is traceable if:
    - “(1) it contains or implements all applicable stipulations in 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 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”

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*

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*