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

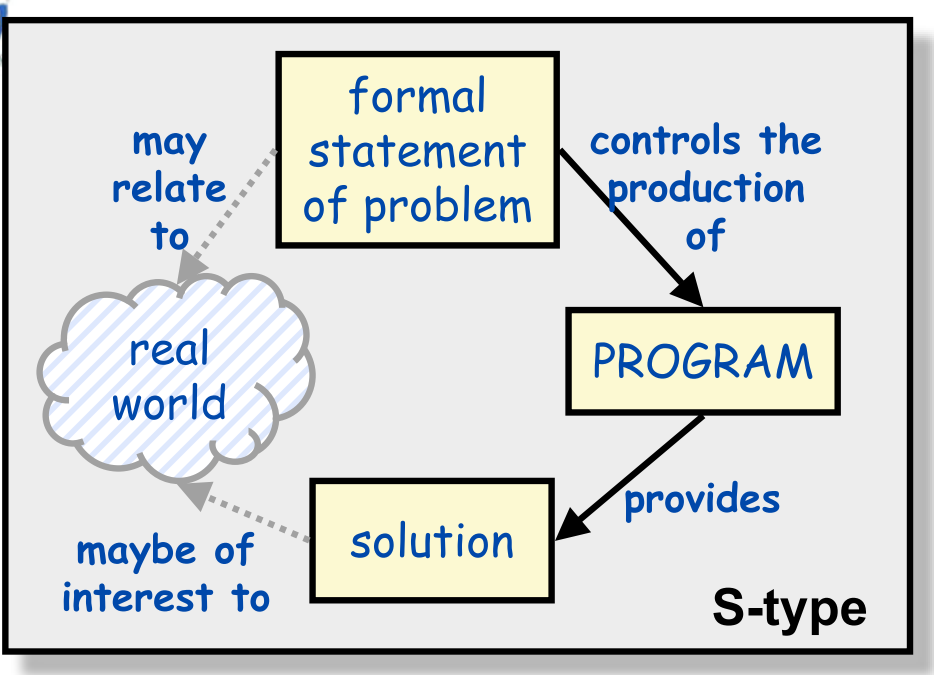
→ P-type Programs ("Problem-solving")

- 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*



S-type

formal statement of problem

controls the production of

PROGRAM

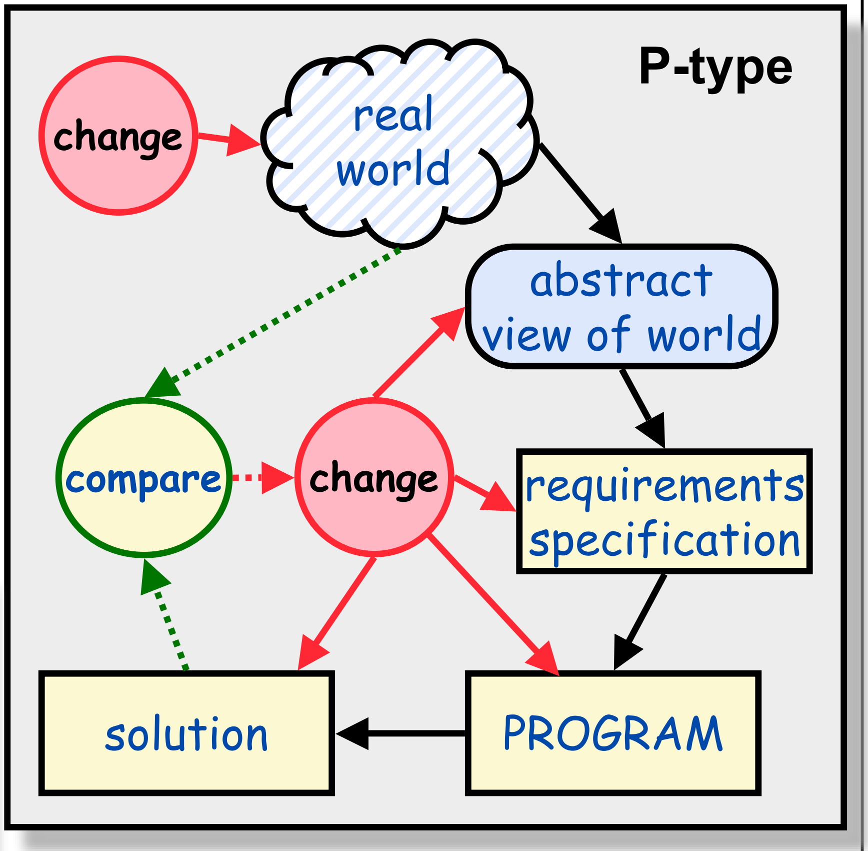
provides

solution

maybe of interest to

real world

may relate to



P-type

change

real world

abstract view of world

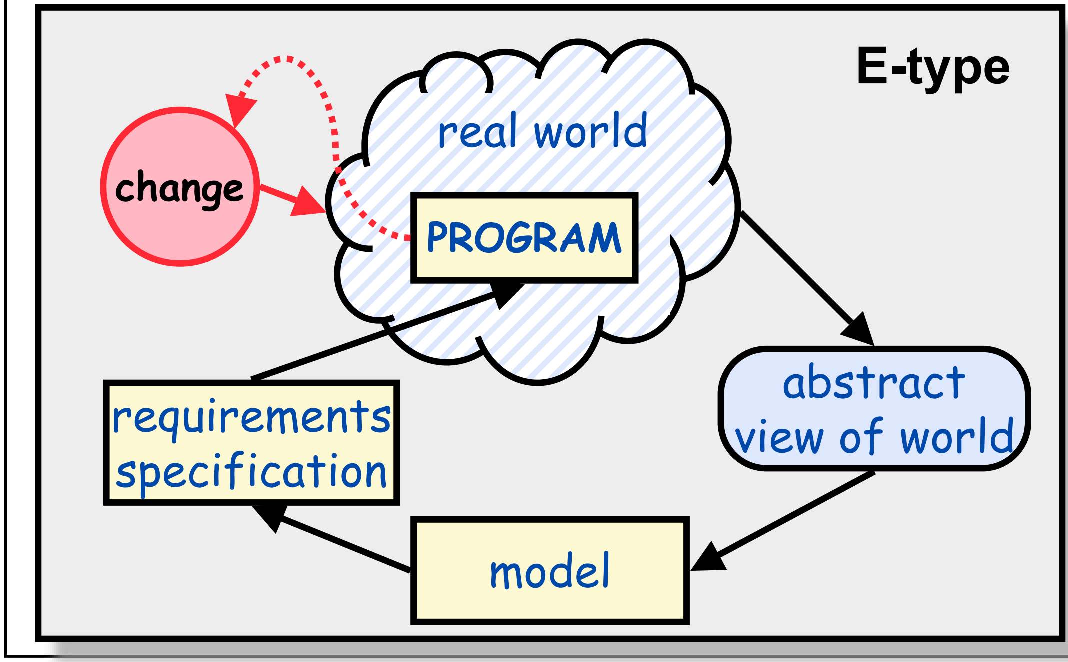
requirements specification

PROGRAM

solution

compare

change



E-type

change

real world

PROGRAM

abstract view of world

model

requirements specification

Laws of Program Evolution

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

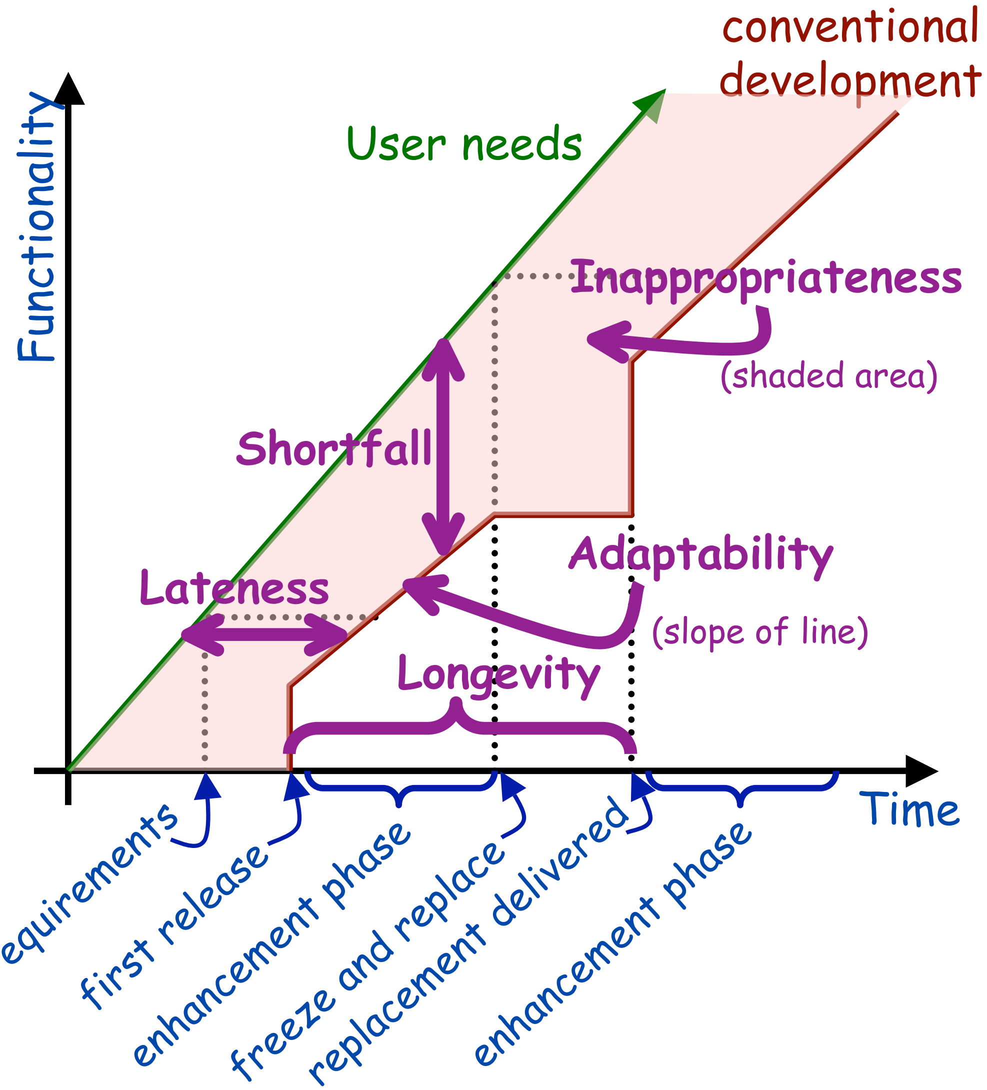
- → Continuing Change
  - ↳ Any software that reflects some external reality undergoes continual change or becomes progressively less useful
    - ➢ change continues until it is judged more cost effective to replace the system
- → Increasing Complexity
  - ↳ As software evolves, its complexity increases…
    - ➢ …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...



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…

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

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

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

- 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

Traceability Difficulties

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

- **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

Current Practice

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

→ 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

Limitations of Current Tools

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

- 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

Problematic Questions

Source: *Adapted from Gotel & Finkelstein, 1997, p100*

- **Involvement**
  - Who has been involved in the production of this requirement and how?
- **Responsibility & Remit**
  - Who is responsible for this requirement?
  - What group has authority to make decisions about this requirement?
- **Change**
  - What changes are relevant to this requirement?
    - Stakeholders' changed jobs? changed development process?
    - When has responsibility for the requirement changed hands?
- **Notification**
  - Who needs to be involved in, or informed of, any changes proposed to this requirement?
- **Loss of knowledge**
  - What loss of project knowledge is likely if a specific individual leaves?

Summary

- Software Evolution is inevitable
  - Software must evolve or become progressively less useful
  - Software becomes more complex as it evolves
  - Software evolutions follows regular patterns
- Good practice plans for evolution
  - Release management
  - Controlled requirements change process
- Traceability needed to recover knowledge
  - Backwards to originating stakeholders
  - Forwards into design and implementation
  - Still many questions traceability won't answer