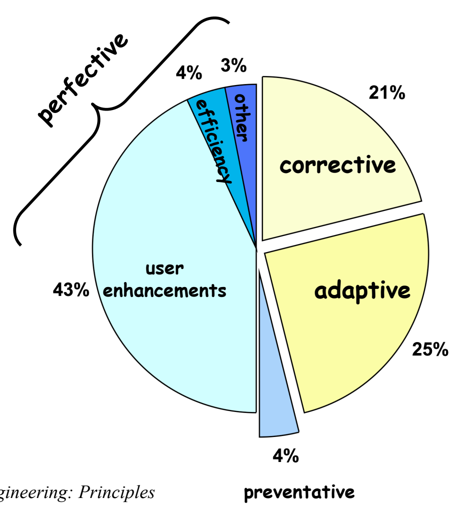
# Lecture 6: Software Re-Engineering

- → Why software evolves continuously
- → Costs of Software Evolution
- → Challenges of Design Recovery
- → What reverse engineering tools can and can't do






# Software Evolves Continuously




Data from:
van Vliet, H., *Software Engineering: Principles and Practices*, Wiley 1999, p449

# 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

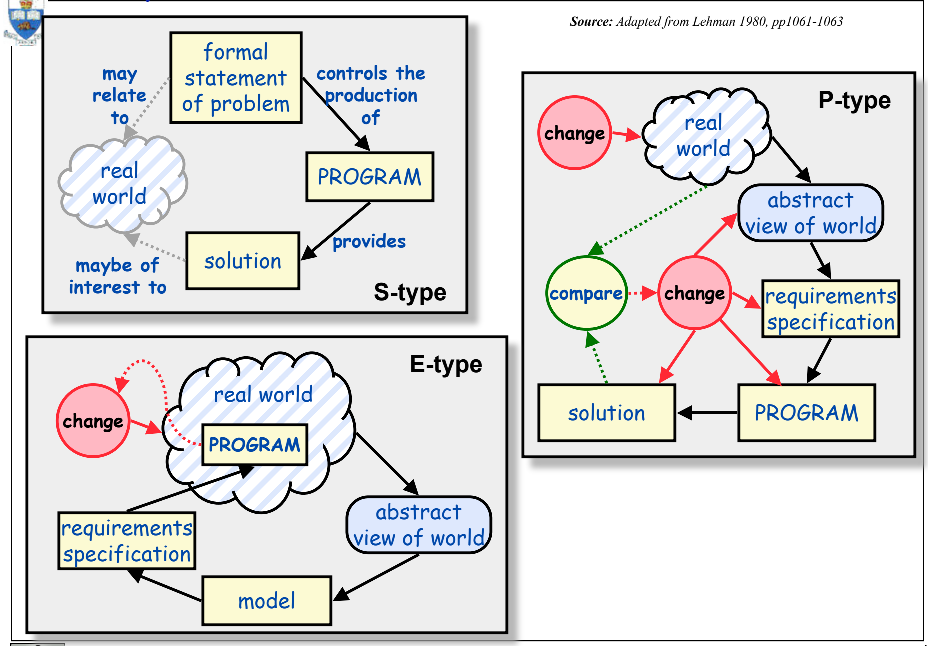
## E-type Programs ("Embedded")

- 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*



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# 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




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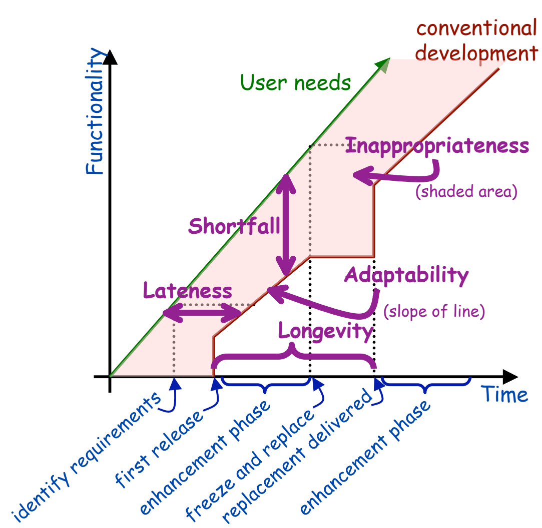
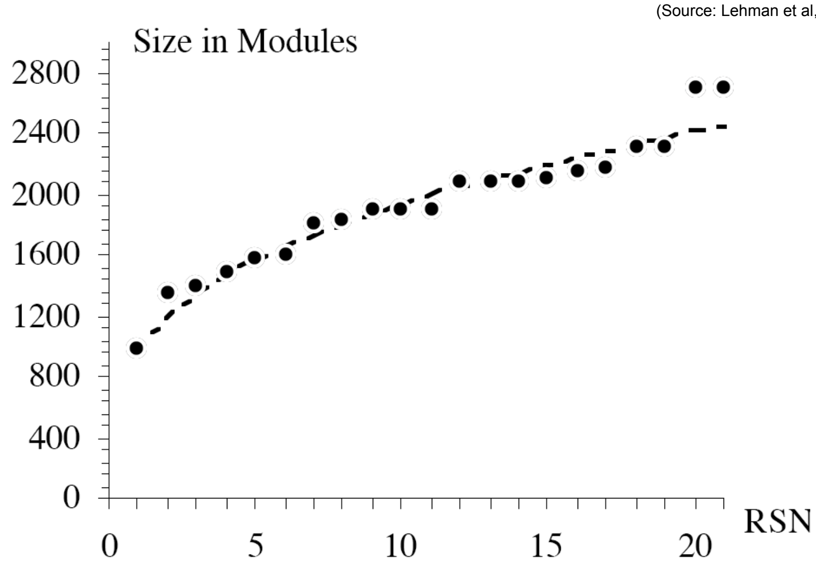
# User requirements always grow




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

# E.g. Logica Financial Software

(Source: Lehman et al, 2000)



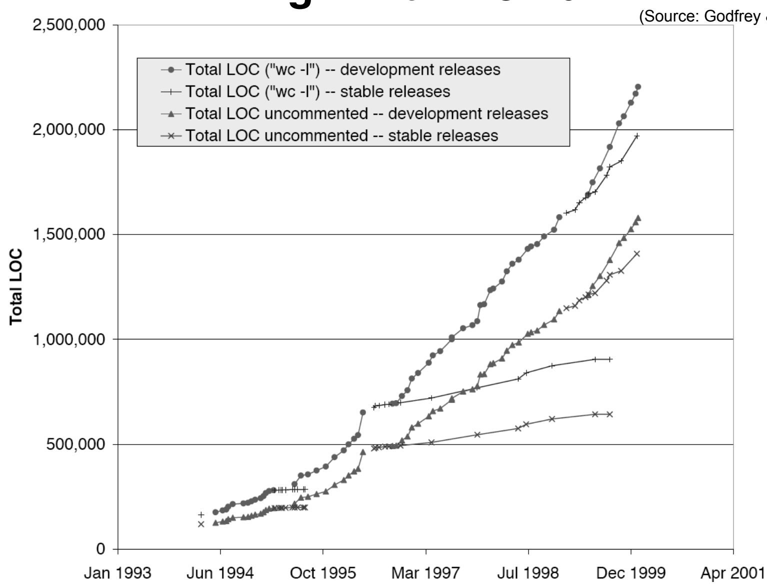




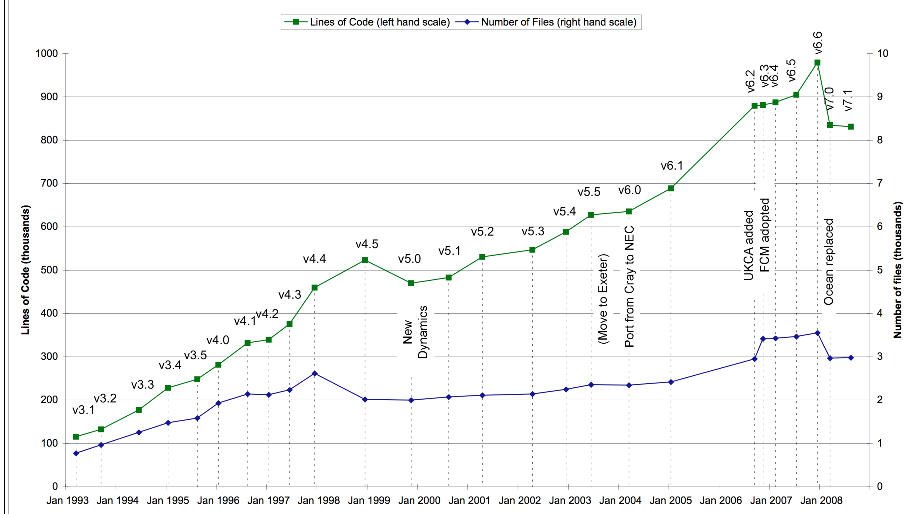


# E.g. Linux Kernal

(Source: Godfrey & Tu, 2000)



# E.g. Hadley Centre Climate Model









# Software Geriatrics

## 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 coherence & increase complexity

## 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

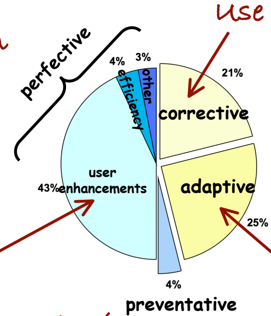
- Design for change
- Document the software carefully
- Requirements and designs should be reviewed by those responsible for its maintenance
- Software Rejuvenation…

***Source:*** *Adapted from Parnas, "Software Aging" 1996*

# Reducing Maintenance Costs

General
Modular structure
Comprehensibility
Good documentation

Higher quality code
Better testing (verification)
Use of standards




Platform independence
Design for change
Good architecture

Better requirements analysis
prototyping, iterative development
Design for change






# E.g. The Altimeter Example

```
IF not-read1(V1) GOTO DEF1;
display (V1);
GOTO C;
DEF1: IF not-read2(V2) GOTO DEF2;
display(V2);
GOTO C;
DEF2: display(3000);
C:
```

```
if (read-meter1(V1))
  display(V1);
else {
  if (read-meter2(V2))
    display(V2);
  else
    display(3000);
}
```

## Questions:

- **Should you refactor this code?**
- **Should you fix the default value?**

***Source:*** *Adapted from van Vliet 1999*

# Why maintenance is hard

## Poor code quality

- opaque code
- poorly structured code
- dead code

## Lack of knowledge of the application domain

- understanding the implications of change

## Lack of documentation

- code is often the only resource
- missing rationale for design decisions

## Lack of glamour

*Source: Adapted from van Vliet 1999*







# Rejuvenation

## Reverse Engineering

- Re-documentation (same level of abstraction)
- Design Recovery (higher levels of abstraction)

## Restructuring

- Refactoring (no changes to functionality)
- Revamping (only the user interface is changed)

## Re-Engineering

- Real changes made to the code
- Usually done as round trip:
  - design recovery -> design improvement -> re-implementation

*Source: Adapted from van Vliet 1999*

# Program Comprehension

## During maintenance:

- programmers study the code about 1.5 times as long as the documentation
- programmers spend as much time reading code as editing it

## Experts have many knowledge chunks:

- programming plans
- beacons
- design patterns

## Experts follow dependency links

- …while novices read sequentially

## Much knowledge comes from outside the code

**Source:** *Adapted from van Vliet 1999*






# Example 1

## What does this do?

```
for (i=0; i<n; i++) {
  for (j=0; j<n; j++) {
    if (A[i,j]) {
      for (k=0; k<n; k++) {
        if (A[j,k])
          A[i,k]=true;
      }
    }
  }
}
```

**Source:** *Adapted from van Vliet 1999*

# Example 2

```
procedure A(var x: w);
begin
  b(y, n1);
  b(x, n2);
  m(w[x]);
  y := x;
  r(p[x]);
end;
```

```
procedure change_window(var nw: window);
begin
  border(current_window, no_highlight);
  border(nw, highlight);
  move_cursor(w[nw]);
  current_window := nw;
  resume(process[nw]);
end;
```

***Source:*** *Adapted from van Vliet 1999*






# What tools can do

## Reformatters / documentation generators
- Make the code more readable
- Add comments automatically

## Improve Code Browsing
- E.g visualize and traverse a dependency graph

## (simple) Code transformation
- E.g. Refactoring class browsers
- E.g. Clone detectors

## (simple) Design Recovery
- E.g. build a basic class diagram
- E.g. use program traces to build sequence diagrams