Software Maintenance

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Contents

- What is Software Maintenance
- Types of Maintenance
- Evolutionary Design
- Modifying Code

1. What is Software maintenance

> "When the transition from development to evolution is not seamless, *the process of changing the software after delivery* is often called software maintenance"

- Modifying a program after it has been put into use
- Maintenance does not normally involve major changes to the system's architecture
- Changes are implemented by modifying existing components and adding new components to the system
- Maintenance requires program understanding

Importance of maintenance

- Organizations have huge investments in their software systems - they are critical business assets

- To maintain the value of these assets to the business, they must be changed and updated

- Much of the software budget in large companies is for modifying existing software

Software changes are inevitable

- We cannot avoid *changing software*
  - New requirements emerge when the software is used
  - The business environment changes
  - Faults must be repaired
  - New computers and equipment is added to the system
  - The performance or reliability of the system may have to be improved
- Software is tightly coupled with the environment
- A key problem for organizations is implementing and managing change to their existing software systems

Maintenance costs

- Usually higher than development costs (2 – 100 times depending on the application)
- Affected by both technical and non-technical factors
- Increases as software evolves
  - Maintenance corrupts the software structure, making further maintenance more difficult
- Aging software can have high support costs (old languages, compilers etc.)

Maintenance cost（workload） factors

- Team stability
  - Maintenance costs are lower if the same staff stay involved
- Contractual responsibility
  - If the developers of a system are not responsible for maintenance, there is no incentive to design for future change
- Staff skills
  - Maintenance staff are often inexperienced and don’t have much domain knowledge
- Program age and structure
  - As programs age, changes degrade the code, design, and structure and they become harder to understand and change

Additional maintenance terms

- **Maintainability** : The ease with which software can be modified
- **Ripple effect** : Changes in one software location can impact other components
- **Impact analysis** : Process of identifying how a change in terms of how a change will effect the rest of the system
- **Traceability** : The degree to which a relationship can be established between two or more software artifacts
- **Legacy systems** : A software system that is still in use but the development team is no longer active

Maintenance vs. Evolution

- Software Maintenance
  - Activities required to keep a software system operational after it is deployed

- Software Evolution
  - Continuous changes from a lesser, simpler, or worse system to a higher or better system

Software Evolution

"Software development does not stop when a system is delivered but continues throughout the lifetime of the system"

- The system changes relate to changing needs—business and user
- The system evolves continuously throughout its lifetime
- Modern agile processes emphasize getting a few functionalities running, then adding new behaviors over time

The pace of change is increasing

- Hardware advances lead to new, bigger software applications

- The rate of change (that is, new features) is increasing

How can we deal with the spiraling need to handle change ?

2. Types of Maintenance

→ **Corrective Maintenance**

- fixing latent errors
  - includes temporary patches and workarounds

→ **Adaptive Maintenance**

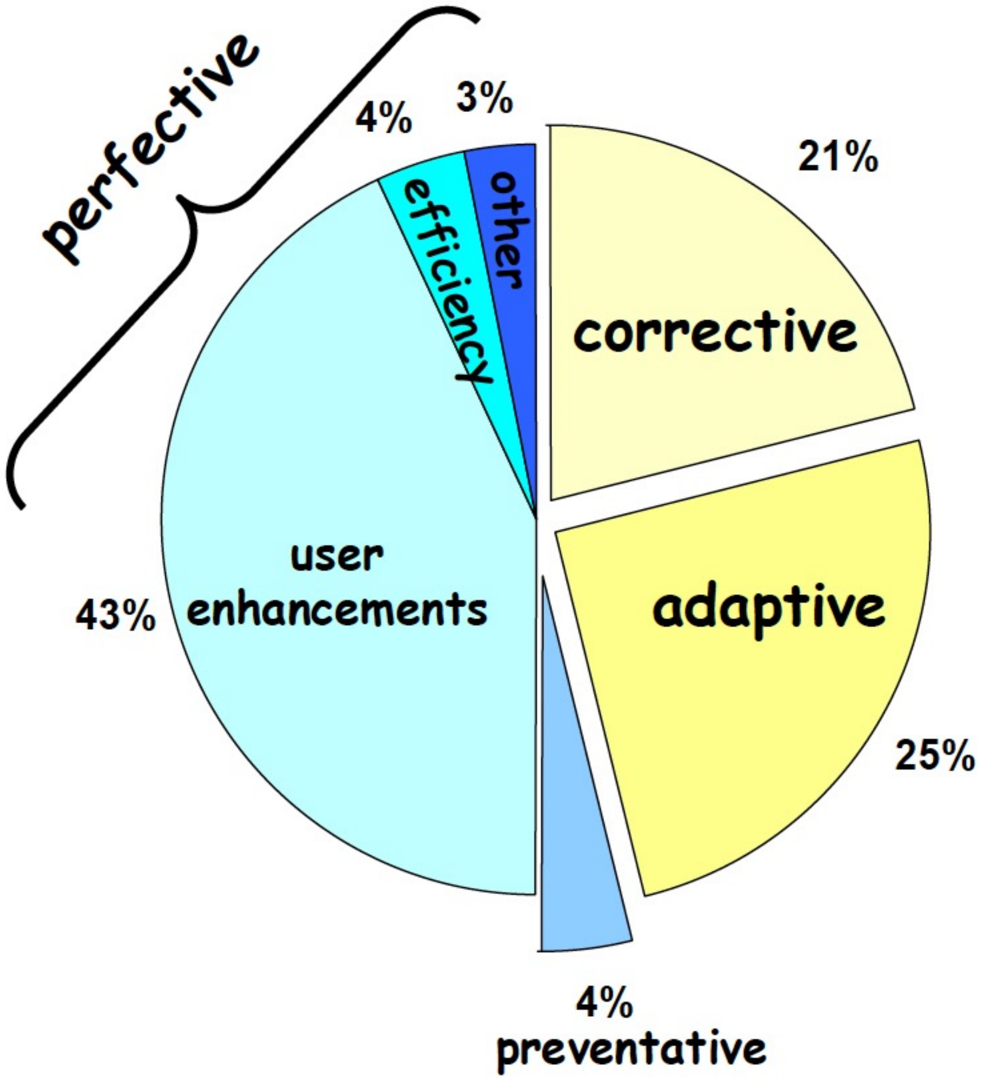
- responding to external changes
  - changes in hardware platform
  - changes in support software

→ **Perfective Maintenance**

- improving the as-delivered software
  - user enhancements
  - efficiency improvements

→ **Preventative Maintenance**

- Improves (future) maintainability
  - Documenting, commenting, etc.

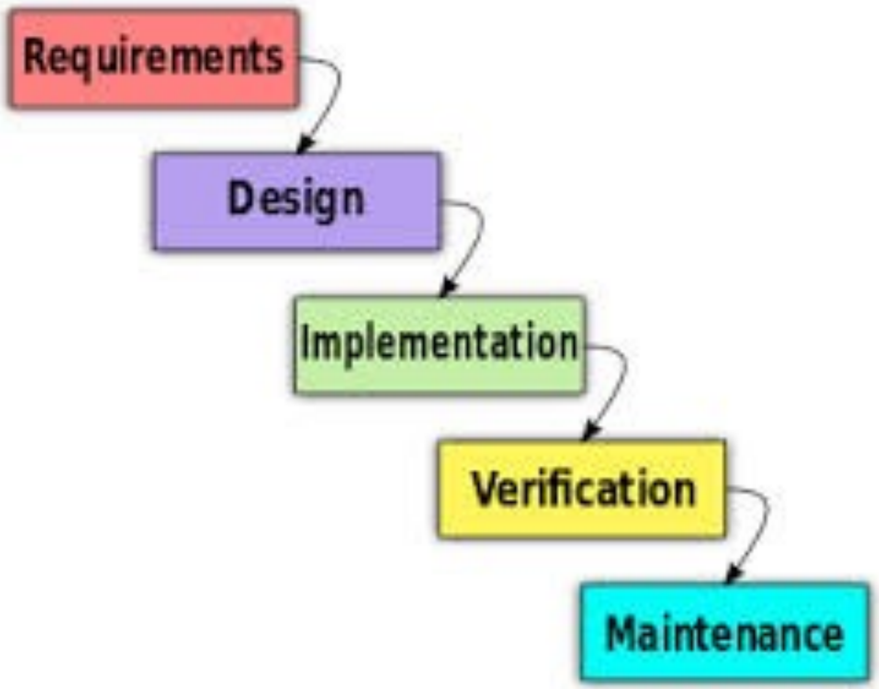


Problems facing maintainers

- **Top five problems:**
  - (Poor) quality of documentation
  - user demand for enhancements and extensions
  - competing demands for maintainers' time
  - difficulty in meeting scheduled commitments
  - turnover in user organizations
- **Limited Understanding**
  - 47% of software maintenance effort devoted to understanding the software
    - E.g. if a system has m components and we need to change k of them…
    - …there are k*(m-k) + k*(k-1)/2 interfaces to check for impact
  - also, >50% of effort can be attributed to lack of user understanding
    - I.e. incomplete or mistaken reports of errors & enhancements
- **Low morale**
  - software maintenance is regarded as less interesting than development

3. Traditional software development

- Production cost for software is very low
- Distribution cost is substantial
  - Includes marketing, sales, shipping
- Support costs escalated
- Software splits design into design and implementation
  - Both very expensive !



1900s software costs

- Millions of customers skewed costs to the back end
  - High support costs
  - High distribution costs
- New versions shipped every 4 to 6 years
  - MS Office, CAD, compilers, operating systems
- Software needed to be "perfect out of the box"
  - Very expensive design
  - Very expensive implementation—including testing more than 50% of the cost

Software evolution was very slow!

Research agenda

- The need to be “perfect out of the box” heavily influenced decades of SE research
  - Formal methods
  - Modeling the entire system at once
  - Process
  - Testing finished products
  - Maintenance in terms of years
- Much of our research focus and results assume :
  - High design costs
  - High implementation costs
  - High distribution costs
  - High support costs

Distribution costs

- In the 1980s, technology started driving down distribution costs for software …

2000s : The Web

- The web created a new way to deploy and distribute software

Traditional software deployment methods

1. Bundle
2. Shrink-wrap
3. Embed
4. Contract

A new software deployment method

5. *Web Deployment*

Distributing web software

- Desktop software can be distributed across the web
  - Zero-cost distribution
  - Instantaneous distribution
  - This allows more frequent updates
- Web applications are not distributed at all in any meaningful sense
  - Software resides on the servers
  - Updates can be made weekly … daily … hourly … continuously!
- Mobile applications allow the artisan to come into your "home" to improve that rocking chair

Evolutionary software design

- Pre-Web software design & production
  - Strived for a perfect design, expensive development
  - Deployed a new version ever 4 to 6 years
  - Evolution was very slow
- Post-Web software production
  - Initial "pretty good" design and development
  - Slowly make it bigger and better
  - Faster evolution
  - Immediate changes to web applications
    - Automatic updates of desktop applications
    - Software upgrades pushed out to mobile devices hourly

This changes all of software engineering !!

Software process

- We have already seen process changes that are a direct result of web deployment & distribution
- Agile processes goals :
  - Have a working, preliminary, version as fast as possible
  - Continue growing the software to have more functionality and better behavior
  - Easy and fast to modify
  - Adapt to sudden and frequent changes in planned behavior
- Agile processes are widely used
- Results are mixed, but use is growing quickly

How much do you know about agile processes ?

Architecture

- Software architects often assume their high level design will not change throughout development
  - And the lifetime of the system
- It is not clear how this supports software growth, rapid deployment, and instantaneous distribution
- Is this attitude compatible with agile processes ?
- How does architecture design interact with refactoring ?

Your generation needs to deal with this

Software self-responsibility

- Evolutionary design means we cannot know everything software will ever do
- Self-management means the software adapts behavior to runtime changes—crucial for evolutionary design
- Fault localization tries debug automatically, which can dramatically cut the human effort required to fix software after testing
- Automated defect repair goes one step further, and attempts to automatically fix faults

Are you ready for the adaptive software revolution ?

Software Testing

- Test-driven design uses tests to drive requirements
  - Every step is evolutionary
- We must stop thinking of regression testing as something special done "late in the process"
  - Virtually all testing is now regression testing
- Model-based testing allows test design to quickly and easily adapt to changes
- Test automation is the key to running tests as quickly as software is now changed
  - Model to implementation ?
  - Test oracle strategy ?

TDD is an important part of this class

Long term impact of evolutionary design

- The end-result of large scale manufacturing was a heavy emphasis on quantity over quality

- The web enables evolutionary design, which can allow us to focus on quality over quantity

4. Programming for maintainability

1. Understanding the Program
2. Programming for Change
3. Coding Style

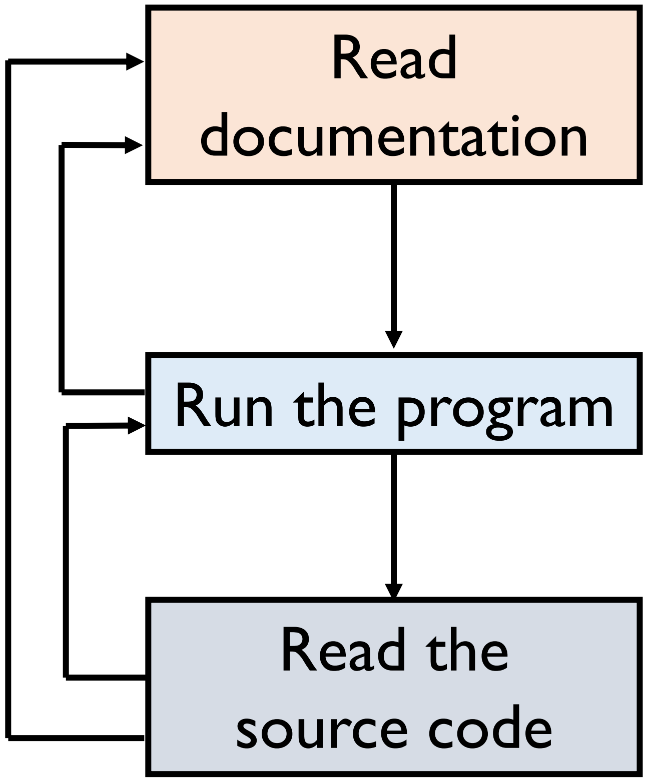
Major maintenance activities

We must understand an existing system before changing it

- How to make the change ?
- What are the potential ripple effects ?
- What skills and knowledge are required ?

- Identify the change
  - What to change, why to change it there
- Manage the process … what resources are needed?
- Understand the program
  - How to make the change, determining the ripple effect
- Make the change
- Test the change
- Document and record the change

Comprehension process



Dynamic analysis

Static analysis

What influences understanding?

- *Expertise* : Domain knowledge, programming skills
- *Program structure* : Modularity, level of nesting
- *Documentation* : Readability, accuracy, up-to-date
- *Coding conventions* : Naming style, small design patterns
- *Comments* : Accuracy, clarity, and usefulness
- *Program presentation* : Good use of indentation and spacing

Sloppy programming creates maintenance debt

Programming for maintainability

1. Understanding the Program
2. Programming for Change
3. Coding Style

Avoid unnecessary fancy tricks

- Write for humans, not compilers
  - Fully parenthesize expressions
  - Pointer arithmetic is anti-engineering
  - Clever programming techniques are for kids, not engineers
- In 1980, computers were slow and memory expensive
  - Control flow dominated the running time
  - Hence the undergraduate CS emphasis on analysis of algorithms
- Today: Make it easier to change the program
  - Readable code is easier to debug, more reliable, and more secure
  - Optimizing compilers are far better than humans
  - Overall architecture usually dominates running time

Document clearly

- Include header blocks for each method (author & version)
- Add a comment every time you stop to think
  - Why a method does something is more important than what
  - What is more important than how
- Document :
  - Assumptions
  - Variables that can be overridden by child methods
  - Reliance on default and superclass constructors
- Write pseudocode as comments, then write the method
  - Faster and more reliable
- Use a version control system with an edit history
  - Explain why each change was made clearly

Use white space effectively

- A 1960s study asked “how far should we indent”
  - 2 — 4 characters is ideal
  - Fewer is hard to see
  - More makes programs too wide
- Don’t use tabs – they look different in every editor and printer
  - Mixing tabs and spaces is even worse
- Use plenty of spaces
  - newList(x+y)=fName+space+lName+space+title;
  - newList (x+y) = fName + space + lName + space + title;
- Don’t put more than one statement per line

Write maintainable code

- **Be tidy**
  - Sloppy style looks like sloppy thinking
  - Sloppy style creates maintenance debt
- **Use clear names**
  - Long names are simpler than short names
  - Don’t make the so long they’re hard to read
- **Don’t test for error conditions you can’t handle**
  - Let them propagate to someone who does

> If you can’t develop these habits, find a non-developer job

Java-specific tips

- Implement both or neither equals() and hashCode()
  - Implementing just one can cause some very subtle faults
- Always override toString() to produce a human-readable description of the object
- If your class is cloneable, use super.clone(), not new()
  - new() will break if another programmer inherits from your class
- Threads are hard to get right and harder to modify
- Don't add error checking the VM already does
  - Array bounds, null pointers, etc

Keep it simple

- Long methods are not simple
  - Good programmers write less code, not more
- Bad designs lead to more and longer methods
- Don’t generalize unless it’s necessary
- Ten programmers …
  - deliver twice as much code
  - four times as many faults, and
  - half the functionality as
- … five programmers

Classes and objects

The point of OO design is to look at nouns (data) first, then verbs (algorithms and methods)

- Think about what it is, not what it does
  - Class names should not be verbs
- Objects are defined by state–the class defines behavior
- Lots of switch statements may mean the class is trying to do too many things
  - Use inheritance or type parameterization
- Make methods that don’t use class instance variables static
- Don’t confuse inheritance with aggregation
  - Inheritance implements “is-a”
  - Aggregation implements “has-a”

Programming for change summary

The cost of writing a program is a small fraction of the cost of **fixing and maintaining** it

…

Don't be lazy or selfish

…

Be an engineer !

Remember that

complexity

is the number one enemy of

maintainability

Programming for maintainability

1. Understanding the Program
2. Programming for Change
3. Coding Style

Using style conventions

- Select a set of style conventions
  - Follow them strictly !
- Follow the existing style when making changes
  - Even if you do not like it
- Lots of style conventions are available
  - It is more important to be consistent than to have perfect style
- Programmers need to be told to follow the team’s style

What style guides tell us

- Case for names
  - Variables, methods, classes, …
- Guidelines for choosing names
- Width, special characters, and splitting lines
- Location of statements
- Organization of methods and use of types
- Use of variables
- Control structures
- Proper spacing and white space
- Comments

Summary

- Programming habits have a major impact on readability
- Readability has a major impact on maintainability
- Maintainability determines long-term costs

The minor decisions that engineers make determine how much money the company makes

That is what engineering means !