# Software Maintenance (I)

# Software decay

Frequent failures

Overly complex structure

Running in emulation mode

Very large components

Excessive resource requirements

Deficient documentation

High personnel turnover

Different technologies in one system

# Software evolution

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.

The majority of the software budget in large companies is devoted to evolving existing software rather than developing new software.

Studies indicate that up to 75% of all software professionals are involved in some form of maintenance/evolution activity.

# Software evolution – variety of facets

- Data evolution
  - Migrating to a new database schema.
  - Verifying that the information in the existing databases is preserved.
- Runtime evolution
  - How to modify a system without stopping it.
  - Encompasses runtime reconfiguration, dynamic adaptation, dynamic upgrading.
- Language evolution
  - Dealing with changes in the programming language definition.
  - multi-language systems.
  - Designing languages to make them more robust to evolution.

# Evolution of software artifacts

- Requirements evolution
  - Managing requirements changes.
- Architecture evolution
  - Reengineering the architectures of legacy systems.
  - Migration to distributed architectures, e.g., service-oriented architectures.
  - Maintenance issues with modern architectures.
- Design evolution
  - Evolution of design models.
- Test case evolution
  - Adding and modifying test cases to verify that the system behavior was changed as intended.
- Traceability management
  - How to assure the consistency of the different artifacts.

# Software change

- Software change is inevitable:
  - New requirements emerge when the software is used;
  - The business environment changes;
  - Errors must be eliminated;
  - New computers and equipment is added to the system;
  - The performance /reliability of the system has to be improved.

A key problem for organizations is implementing and managing change to their existing software systems.

# Types of changes

- Repair software faults
  - Changing a system to correct deficiencies in the way meets its requirements.
- Adapt software to a different operating environment
  - Changing a system so that it operates in a different environment (computer, OS, etc.) from its initial implementation.
- Add to or modify the system's functionality
  - Modifying the system to satisfy new requirements.
- Improve the program structure and system performance
  - Rewriting all or parts of the system to make it more efficient and maintainable.

# Software evolution and software maintenance

- No standard definitions.
- Broad definition of evolution: Generally, software evolution refers to the study and management of the process of making changes to software over time.
  - In this definition, software evolution comprises:
    - Development activities
    - **Maintenance activities**
    - Reengineering activities
- Narrow definition of evolution: Sometimes, software evolution is used to refer to the activity of adding new functionality to existing software.
- Maintenance refers to the activity of modifying software after it has been put to use in order to maintain its usefulness.

# Types of changes

"Maintenance"

- Repair software faults
  - Changing a system to correct deficiencies in the way meets its requirements.
- Adapt software to a different operating environment
  - Changing a system so that it operates in a different environment (computer, OS, etc.) from its initial implementation.

"Evolution"

- Add to or modify the system's functionality
  - Modifying the system to satisfy new requirements.

"Reengineering"

- Improve the program structure and system performance
  - Rewriting all or parts of the system to make it more efficient and maintainable.

# History

- 1960s – 1970s
  - Inclusion of maintenance in waterfall lifecycle after delivery of the software product.
  - Perception that post-delivery activities only consisted of faults fixes and minor adjustments.
  - Did not account for the need to add functionality due to new and changed requirements.
- 1970s
  - Lehman postulated the initial laws of program evolution.
  - Stressed the need for continuous evolution due to changes in the software's operational environment.
- Late 1970s – 1980s
  - Initial process models that handled change requests.
- 1990s
  - General acceptance of software evolution.
  - Development of new process models that accounted for evolution activities: evolutionary development, spiral model, agile software development.

# Laws of program evolution (Lehman)

**Continuing change**

Any software that reflects some external reality undergoes continual change or becomes progressively less useful. The change continues until it is judged more cost effective to replace the system entirely

**Increasing complexity**

As the 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

# Laws of Program evolution (Lehman)

**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) [adding more staff does not improve output]

**Conservation of familiarity**

During the active life of a program the amount of change in successive releases is roughly constant

# Program (System) Types

**S-type (Specifiable)**

**P-type (Problem-solving)**

**E-type (Embedded)**

# Program (System) Types

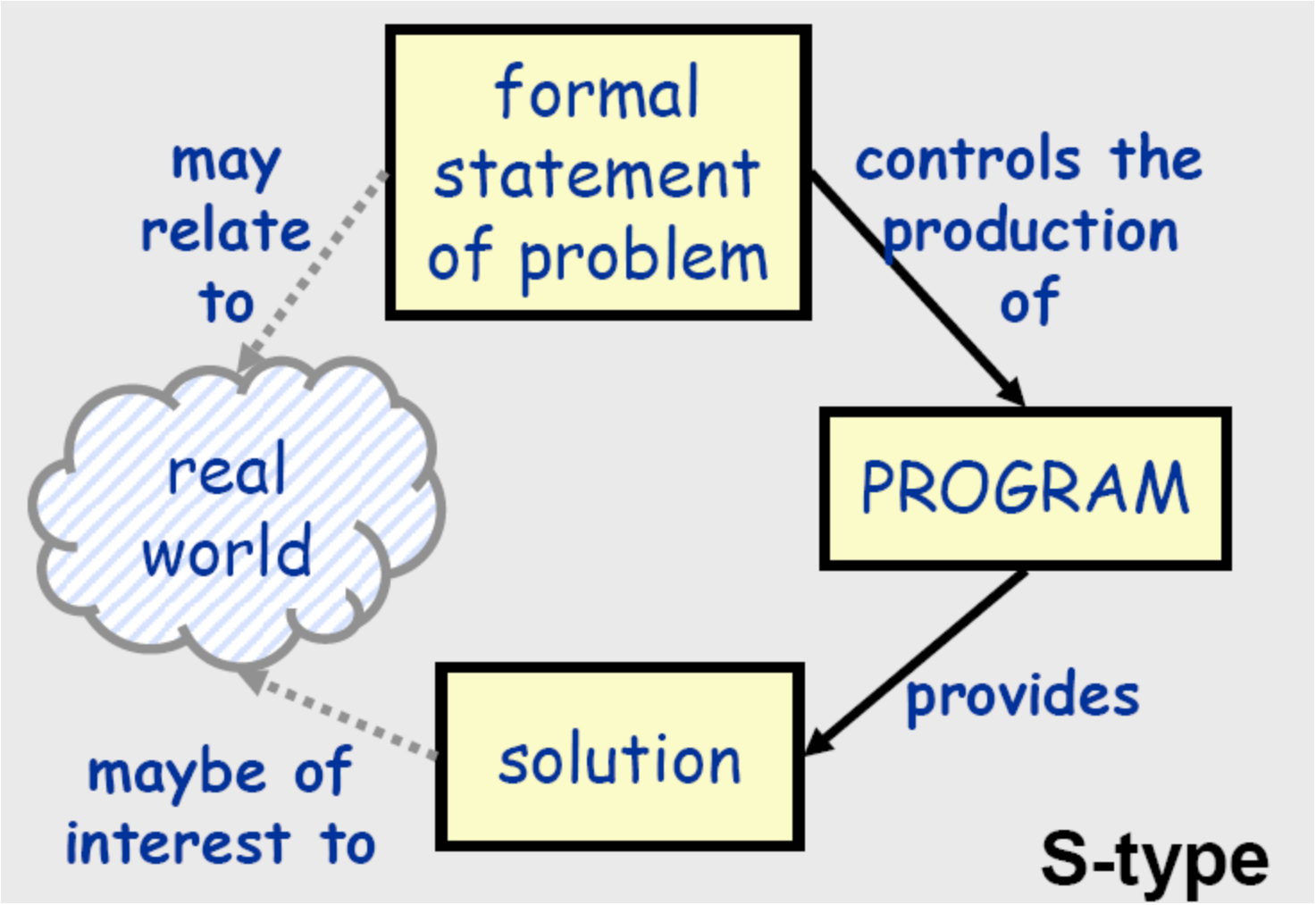
## S-type (Specifiable)

**Problem can be stated formally and completely.**
The problem is completely defined and there is a well- defined solution. We are concerned with the correctness of the implementation of the solution.

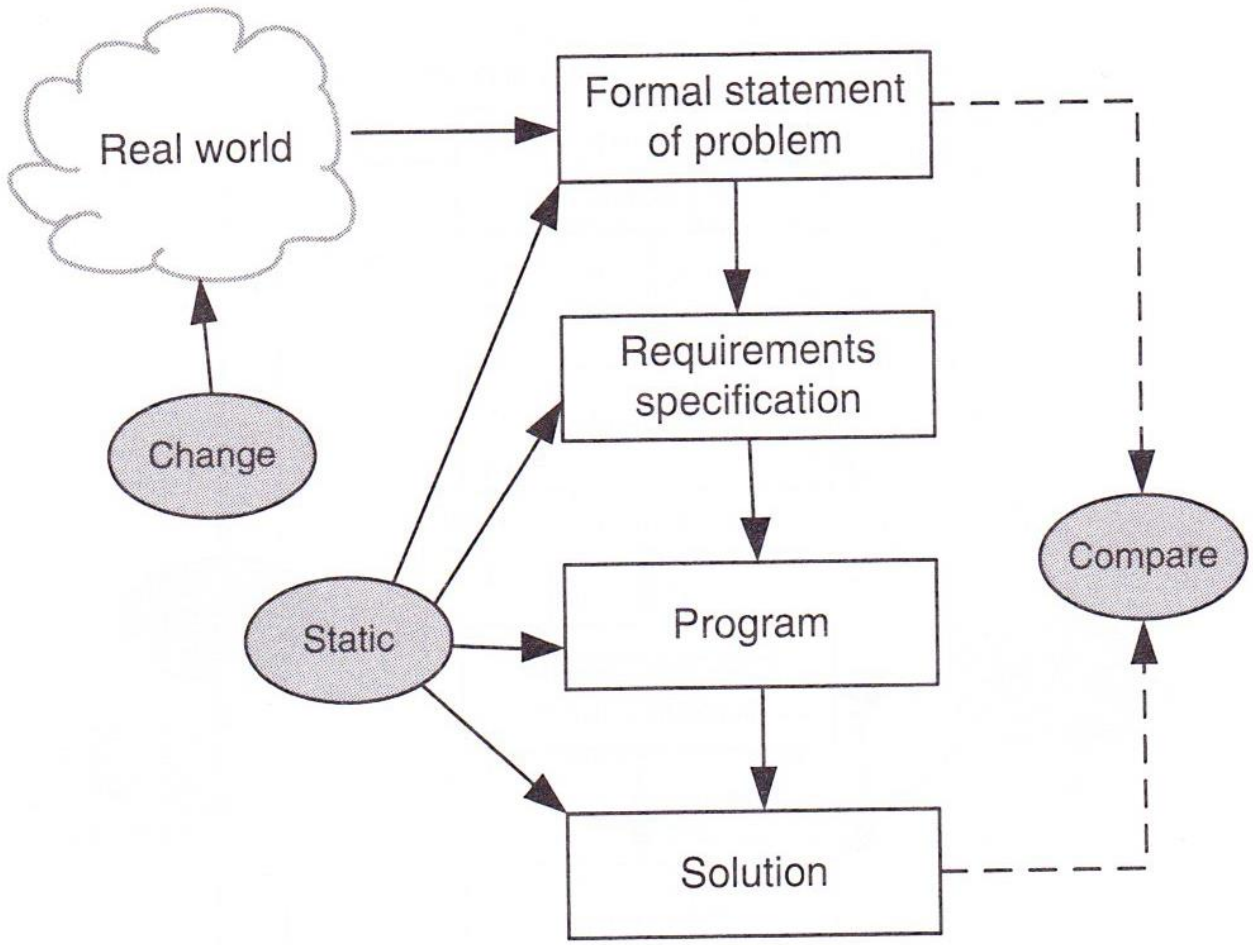
**Acceptance:**
**is the program correct according to its specification?**

**The software does not evolve**
any change in the specification defines a new problem, hence a new program

# S-Type


formal statement of problem
may relate to
controls the production of
real world
PROGRAM
provides
solution
maybe of interest to
S-type

# S-Type


Real world
Formal statement of problem
Requirements specification
Change
Static
Program
Compare
Solution

# Program (System) Types

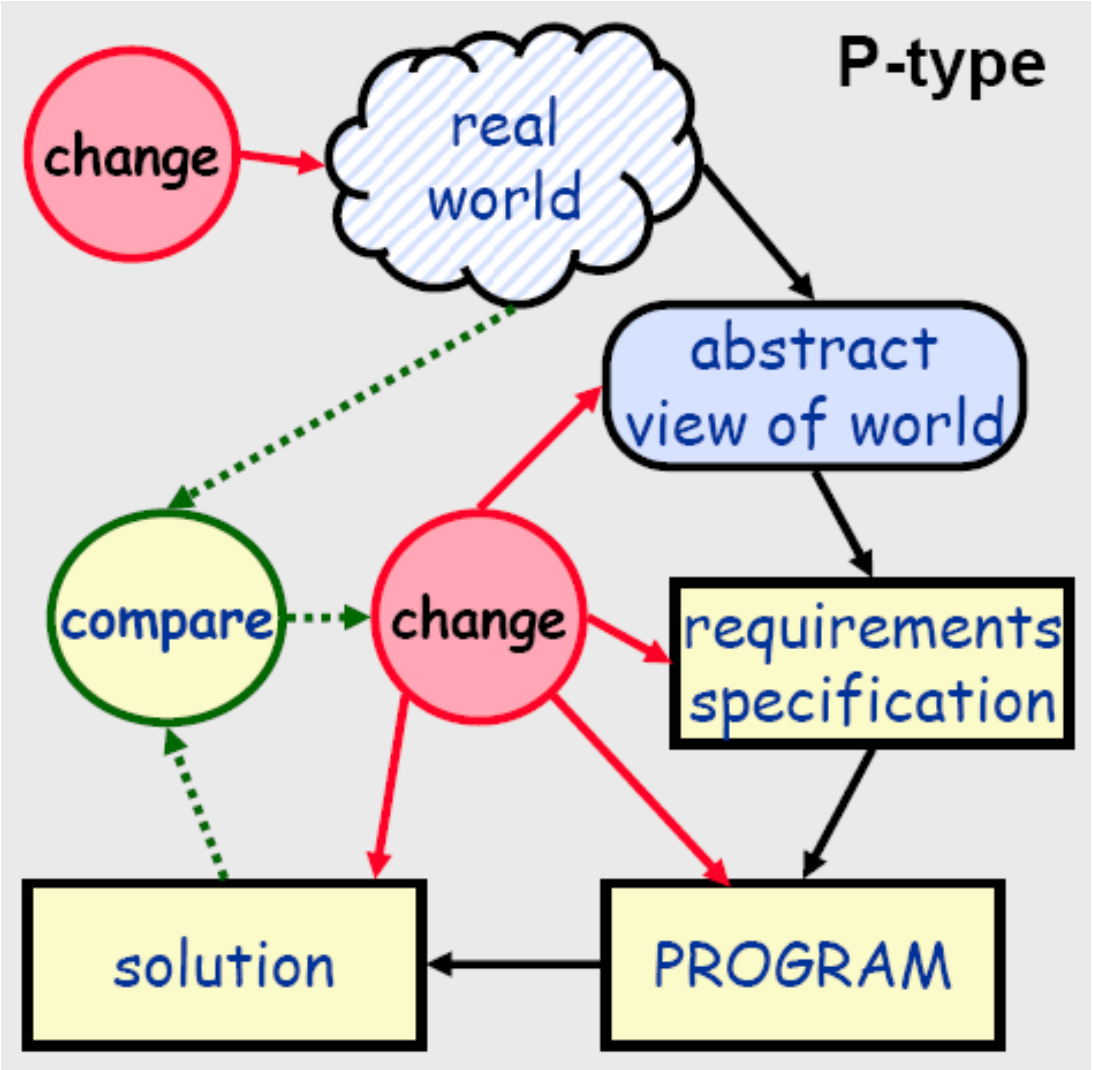
## P-type (Problem-Solving, Practical abstraction)

**Imprecise (approximate) statement of a real-world problem**
Example: chess playing

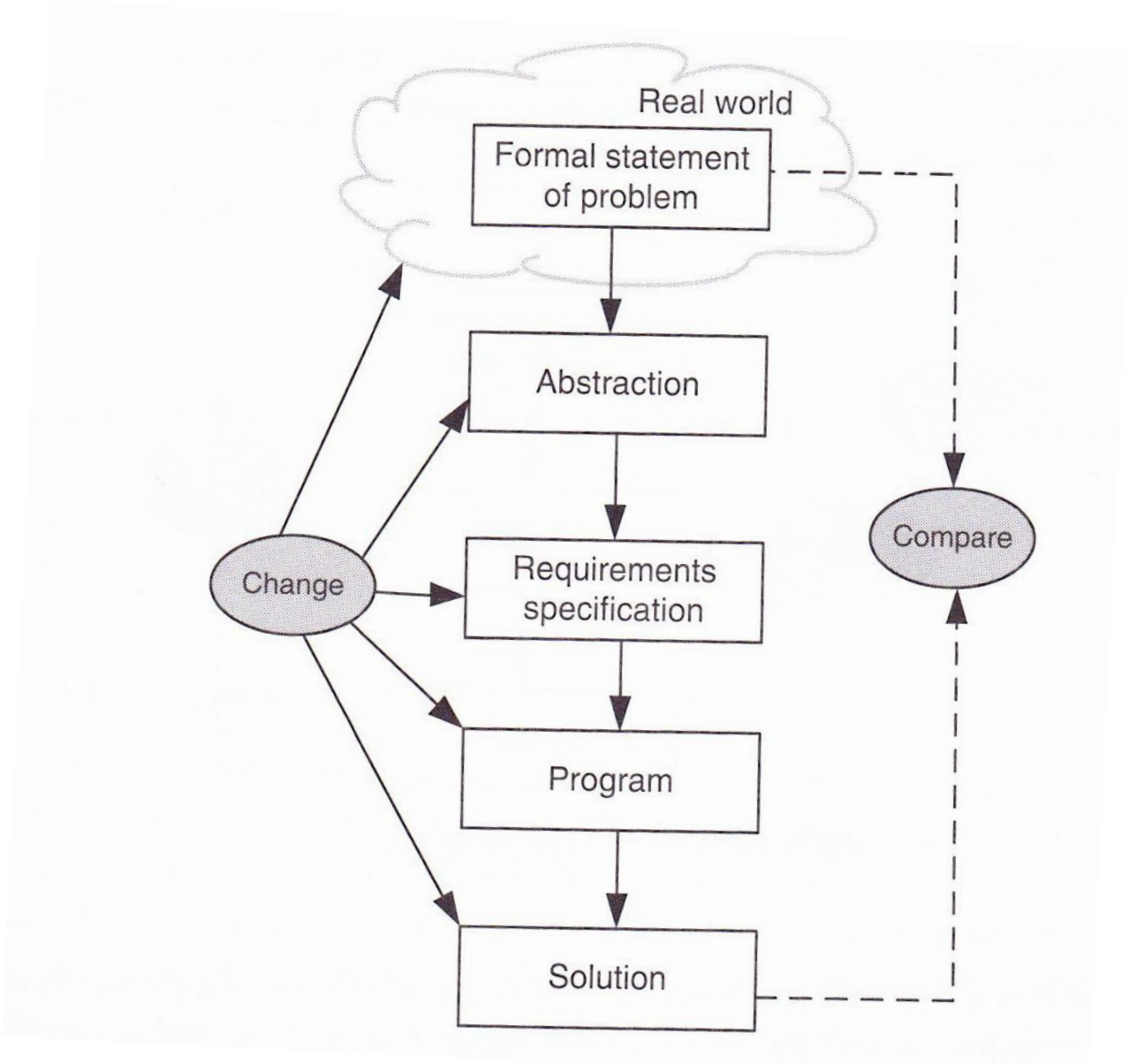
**Acceptance:**
**is the program an acceptable solution to the problem?**

**The software is likely to evolve continuously**
Solution is never perfect and can be improved
Real-world changes and hence the problem changes

# P- Type


P-type
change
real world
abstract view of world
compare
change
requirements specification
solution
PROGRAM

# P- Type


Real world
Formal statement of problem
Abstraction
Requirements specification
Program
Solution
Change
Compare

# Program (System) Types

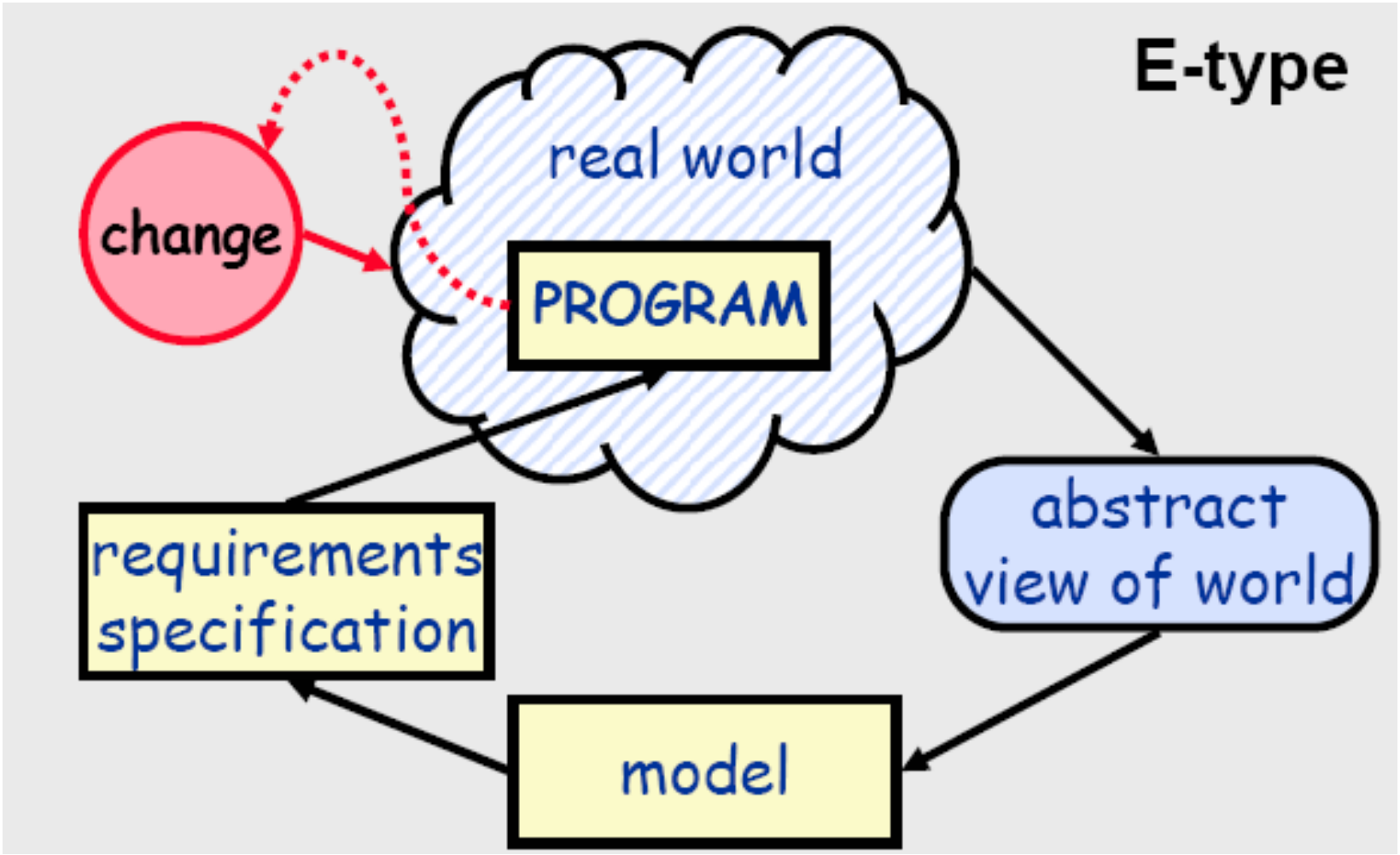
## E-type (Embedded)

**A system becomes part of the world that it models**

**Acceptance:**
**Depends entirely on opinions and judgments**

**The software is inherently evolutionary**
Changes in the software and the world affect each other

# E- Type


E-type
real world
change
PROGRAM
requirements specification
abstract view of world
model

# Software Maintenance: definitions

… the performance of those activities required to keep a software system operational and responsive after it is accepted and placed into production

Maintenance covers the life of a software system from the time it is installed until it is phased out

Modification of a software product after delivery to correct faults, to improve performance or other attributes, or to adapt the product to a modified environment [IEEE 1219 1993]

… software product undergoes modification to code and associated documentation due to a problem or the need for improvement.
The objective is to modify existing software product while preserving its integrity [ISO/IEC 12207 1995]

# Software Maintainability

The ease with which software can be maintained, enhanced, adapted, or corrected to satisfy specified requirements

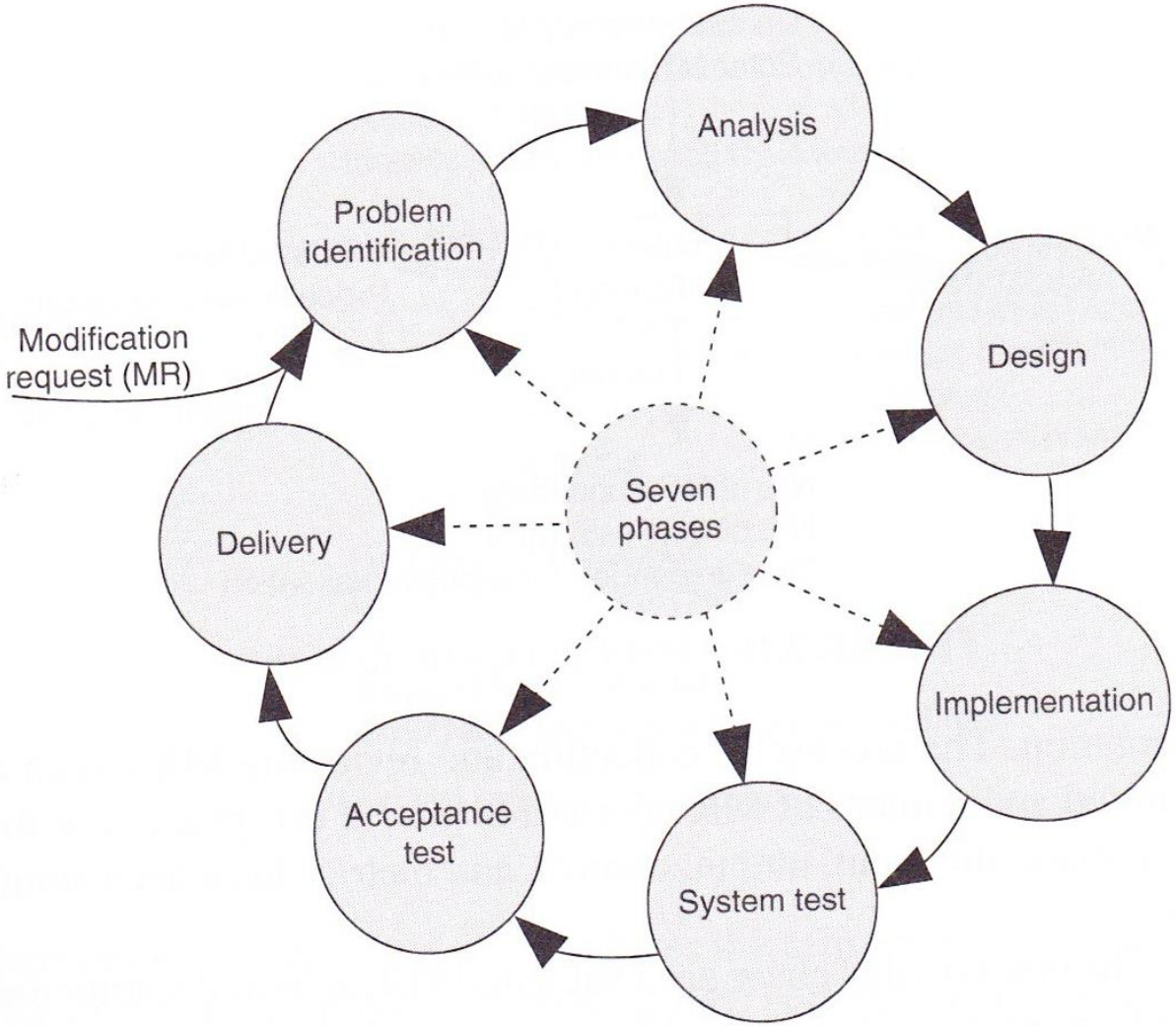
(1) The ease with which a software system or component can be modified to correct faults, improve performance or other attributes, or adapt to a changed environment, or
(2) The ease with which a hardware system or component can be retained in, restored to, a state in which it can perform its required functions

*IEEE Computer Society [ANSI/IEEE 610.12.1990]*

A set of attributes that bear on the effort needed to make specified modifications

*[ISO/IEC 8402 1986]*

# Software Maintenance Process (IEEE)



# Software Maintenance - Types

Corrective maintenance:

- Fixing faults that cause the system to fail

Adaptive maintenance:

- Making changes in existing software to accommodate a changing environment

# Software Maintenance- Types

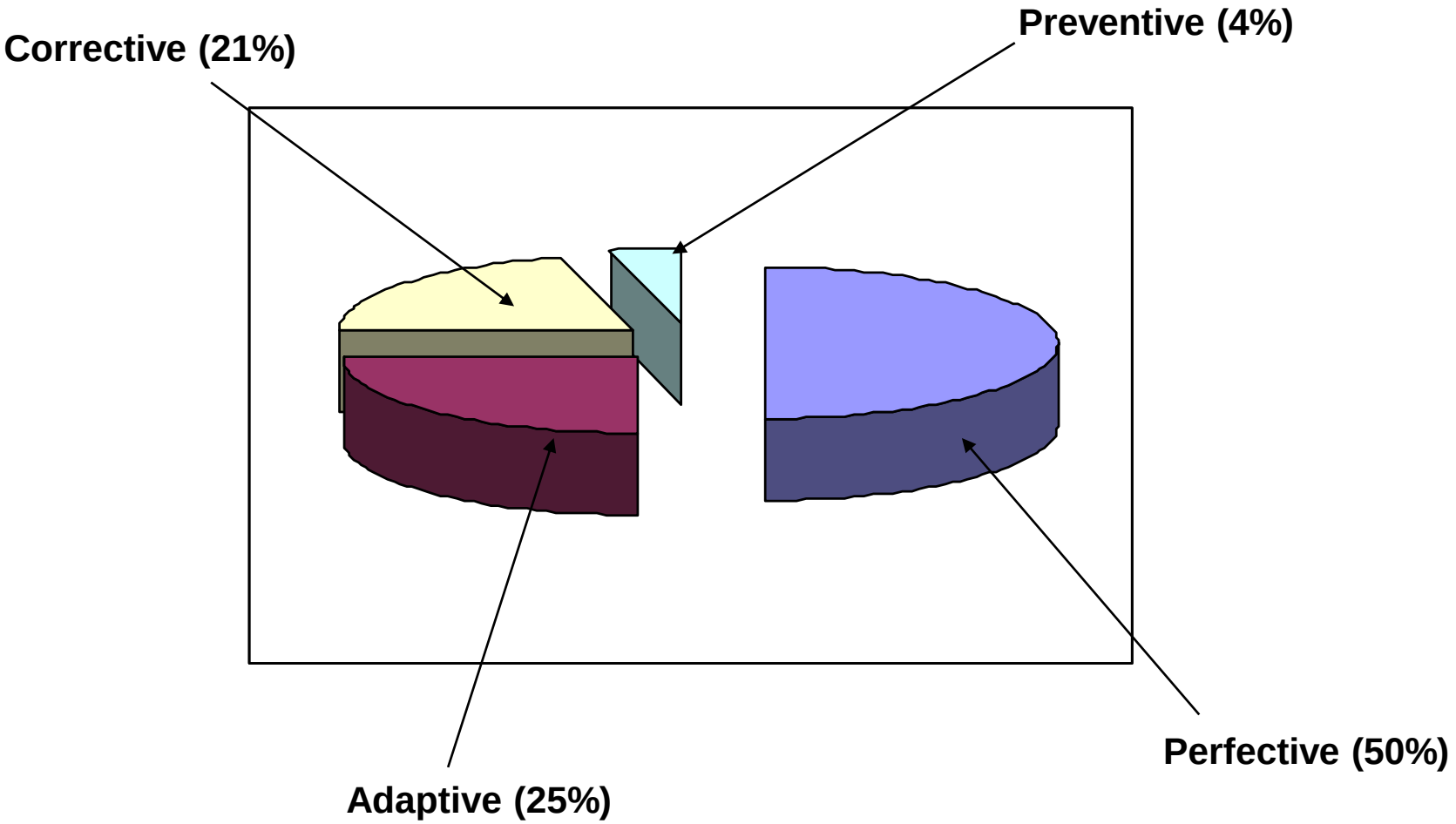
## *Perfective* maintenance

- Making improvements to the existing system without effecting end-user functionality
  - To make it easier to extend and add new features in the future
  - Also called *re-engineering*
  - *Refactoring* is a one type of perfective maintanance

## *Preventive* maintenance

- Preventing failures by fixing defects in advance of failures
- A kind of perfective maintenance
- Key examples: Y2K and Daylight Savings Time adjustments

# Types of Maintenance- stats



# Approaches to Maintenance (1)

## Maintenance philosophies:

**Throw it over-the-wall** – someone else is responsible for maintenance

- investment in knowledge and experience is lost
- maintenance becomes a challenge of reverse engineering

**Mission orientation**

Development team makes a long term commitment to maintaining the software

# Approaches to Maintenance (2) Basili's maintenance process models

**Quick-fix model**

•Changes made at the code level, as easily as possible
•Rapid degradation of 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 Maintenance- Steps (1)

- Understand the existing system
  - Study whatever form of documentation exists about the system to be modified
    - Often the only reliable source of information is the source code
  - Use tools to recover the high-level design models of the system

# Software Maintenance - Steps (2)

- Define the maintenance objectives
  - Set the requirements
- Analysis
  - Evaluate alternatives for handling the modification
    - Estimate the costs and benefits of the alternative modifications
    - Perform *impact analysis*
      - Determine the effect of the change on the rest of the system

# Software Maintenance-Steps (3)

- Design, implement, and test the changes

- Revalidate
  - Running *regression tests* to make sure that the unchanged code still works and is not adversely affected by the new changes

# Software Maintenance-Steps (4)

- Train
  - Inform users of the changes
- Convert and release
  - Generate and release/install a new version with the modified parts
  - May involve *migrating* database schema changes and data at the same time

# Program Comprehension

- Program comprehension:
  - The discipline concerned with studying the way software engineers understand programs
- Objective of those studying program comprehension:
  - design tools that will facilitate the understanding of large programs

# Program Comprehension Strategies (1)

- The bottom-up model:
  - Comprehension starts with the source code and abstracting from it to reach the overall comprehension of the system
  - Steps:
    - Read the source code
    - Mentally group together low-level programming details (*chunks*) to build higher-level abstractions
    - Repeat until a high-level understanding of the program is formed

# Program Comprehension Strategies (2)

- The top down model:
  - Comprehension starts with a general idea, or hypothesis, about how the system works
    - Often obtained from a very quick look at what components exist
  - Steps
    - First formulate hypotheses about the system functionality
    - Verify whether these hypotheses are valid or not
    - Create other hypotheses, forming a hierarchy of hypotheses
    - Continue until the low-level hypotheses are matched to the source code and proven to be valid or not

# Program Comprehension Strategies (3)

- The Integrated Model:
  - Combines the top down and bottom up approaches
  - Empirical results show that maintainers tend to switch among the different comprehension strategies depending on
    - The code under investigation
    - Their expertise with the system

# Reverse Engineering

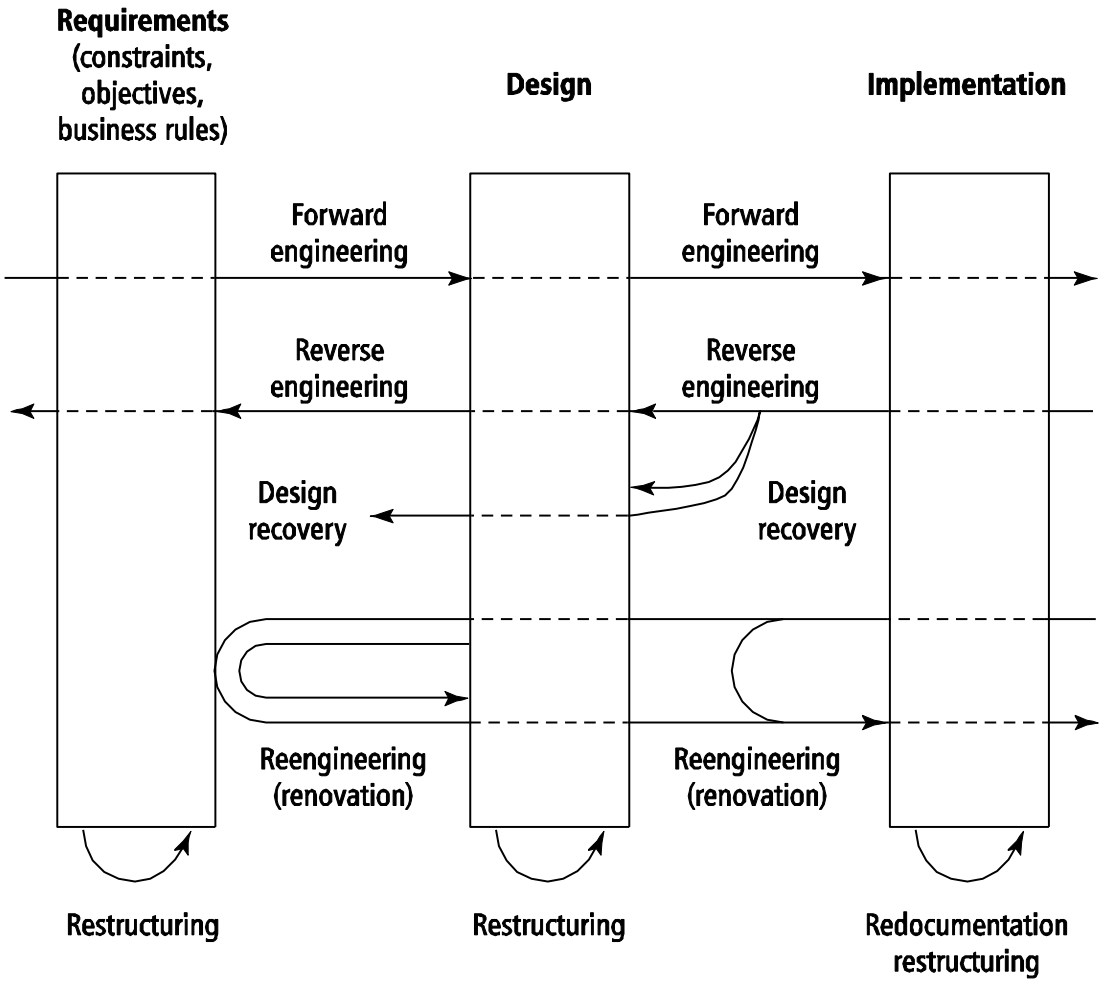
- The process of analyzing a subject system
  - to identify the system's components and their interrelationships
  - and to create representations of the system, in another form, at a higher level of abstraction"

Chikofsky and Cross

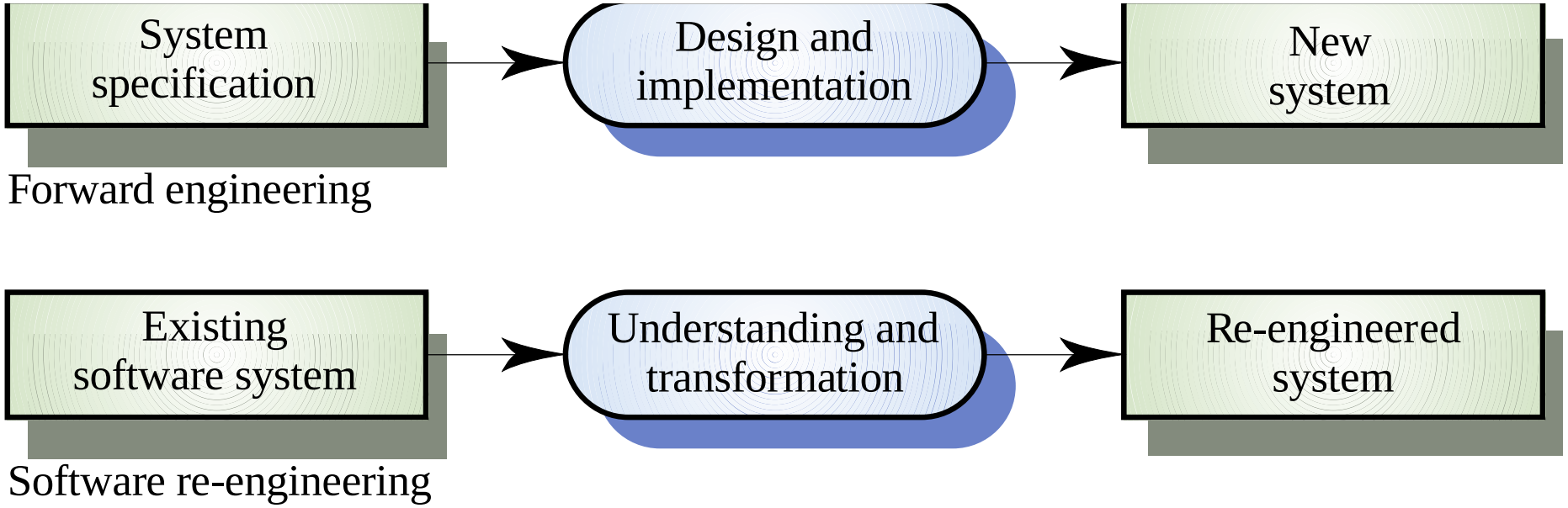
# System Reengineering

- Re-structuring or re-writing part or all of a legacy system without changing its functionality
- Applicable where some but not all sub-systems of a larger system require frequent maintenance
- Re-engineering involves adding effort to make them easier to maintain. The system may be re-structured and re-documented

# Reverse Engineering



# Forward Engineering and Re-engineering



# Main levels of reverse engineering

- Binary reverse engineering
  - Take a binary executable
    - Recover source code you can then modify
  - Useful for companies that have lost their source code
  - Used extensively by hackers
  - Can be used legally, e.g. to enable your system to interface to existing system
  - Illegal in some contexts
- Source code reverse engineering
  - Take source code
    - Recover high level design information
  - By far the most widely performed type of reverse engineering
  - Binary reverse engineers also generally do this too

# Reverse Engineering Objectives (1)

- Cope with complexity:
  - Have a better understanding of voluminous and complex systems
  - Extract relevant information and leave out low-level details
- Generate alternative views:
  - Enable the designers to analyze the system from different angles

# Reverse Engineering Objectives (2)

- Recover lost information:
  - Changes made to the system are often undocumented;
    - This enlarges the gap between the design and the implementation

# Reverse Engineering Objectives (3)

- Detect side effects:
  - Detect problems due to the effect a change may have on the system before it results in failure
- Synthesize higher-level abstractions

# Reverse Engineering Objectives (4)

- Facilitate reuse
  - Detect candidate system components that can be reused

# Advantages of reengineering

- Reduced risk
  - There is a high risk in new software development. There may be development problems, staffing problems and specification problems.
- Reduced cost
  - The cost of re-engineering is often significantly less than the costs of developing new software.