Chapter 1

What is Software Engineering

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Objectives

- What we mean by software engineering
- Software engineering’s track record
- What we mean by good software
- Why a system approach is important
- How software engineering has changed since 1970s

1.1 What is Software Engineering
Solving Problems

- Software products are large and complex
- Development requires analysis and synthesis
  - Analysis: decompose a large problem into smaller, understandable pieces
    - abstraction is the key
  - Synthesis: build (compose) a software from smaller building blocks
    - composition is challenging
1.1 What is Software Engineering
Solving Problems (continued)

• The analysis process

1.1 What is Software Engineering
Solving Problems (continued)

• The synthesis process
1.1 What is Software Engineering
Solving Problems (continued)

- **Method**: refers to a formal procedure; a formal “recipe” for accomplishing a goal that is typically independent of the tools used
- **Tool**: an instrument or automated system for accomplishing something in a better way
- **Procedure**: a combination of tools and techniques to produce a product
- **Paradigm**: philosophy or approach for building a product (e.g., OO vs structured approaches)

1.1 What is Software Engineering
Where Does the Software Engineer Fit In?

- **Computer science**: focusing on computer hardware, compilers, operating systems, and programming languages

- **Software engineering**: a discipline that uses computer and software technologies as problem-solving tools
1.1 What is Software Engineering
Where Does the SW Engineer Fit in? (continued)

- Relationship between computer science and software engineering

![Diagram showing the relationship between computer science, software engineering, and customer needs.]

1.2 How Successful Have We Been?

- Perform tasks more quickly and effectively
  - Word processing, spreadsheets, e-mail

- Support advances in medicine, agriculture, transportation, multimedia education, and most other industries

- Many good stories

- However, software is not without problems
1.2 How Successful Have We Been?

Sidebar 1.1 Terminology for Describing Bugs

- A **fault**: occurs when a human makes a mistake, called an **error**, in performing some software activities
- A **failure**: is a departure from the system’s required behaviour

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  Human Error  Fault  Failure
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Pfleeger and Atlee, Software Engineering: Theory and Practice
(edited by B. Cheng)

1.2 How Successful Have We Been?

Examples of Software Failure

- IRS hired Sperry Corporation to build an automated federal income tax form processing process
  - An **extra** $90 M was needed to enhance the original $103M product
  - IRS **lost** $40.2 M on interests and $22.3 M in overtime wages because refunds were not returned on time
- Malfunctioning code in Therac–25 killed several people
- Reliability constraints have caused cancellation of many **safety critical** systems
  - **Safety–critical**: something whose failure poses a threat to life or health

Pfleeger and Atlee, Software Engineering: Theory and Practice
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1.3 What is Good Software?

- Good software engineering must always include a strategy for producing quality software.
- Three ways of considering quality:
  - The quality of the product
  - The quality of the process
  - The quality of the product in the context of the business environment

1.3 What Is Good Software?

The Quality of the Product

- Users judge external characteristics
  - (e.g., correct functionality, number of failures, type of failures)
- Designers and maintainers judge internal characteristics (e.g., types of faults)
- Thus different stakeholders may have different criteria
- Need quality models to relate the user’s external view to developer’s internal view
1.3 What Is Good Software?
The Quality of the Product (continued)

- McCall's quality model

Factors to specify

<table>
<thead>
<tr>
<th>Correctness</th>
<th>Reliability</th>
<th>Efficiency</th>
<th>Integrity</th>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintainability</td>
<td>Testability</td>
<td>Flexibility</td>
<td>Portability</td>
<td>Reusability</td>
</tr>
</tbody>
</table>

Quality criteria to build

<table>
<thead>
<tr>
<th>Translatability</th>
<th>Completeness</th>
<th>Consistency</th>
<th>Accuracy</th>
<th>Ease of Reading</th>
<th>Execution Efficiency</th>
<th>Robustness</th>
<th>Data Accuracy</th>
<th>Access Control</th>
<th>Security</th>
<th>Reusability</th>
<th>Minimality</th>
<th>Software System Independence</th>
<th>Maintainability</th>
<th>Machine Independence</th>
<th>Communications Compatibility</th>
<th>Data-communication</th>
</tr>
</thead>
</table>

1.3 What Is Good Software?
The Quality of the Process

- Quality of the development and maintenance process is as important as the product quality
- The development process needs to be modeled
- Modeling will address questions such as
  - Where to find a particular kind of fault
  - How to find faults early
  - How to build in fault tolerance
  - What are alternative activities
1.3 What Is Good Software?
The Quality of the Process (continued)

• Models for process improvement
  – SEI’s Capability Maturity Model (CMM)
  – ISO 9000
  – Software Process Improvement and Capability dEtermination (SPICE)

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1.3 What Is Good Software?
The Quality in the Context of the Business Environment

• Business value is as important as technical value
• Business value (in relationship to technical value) must be quantified
• A common approach: return on investment (ROI) – what is given up for other purposes
• ROI is interpreted in different terms: reducing costs, predicting savings, improving productivity, and costs (efforts and resources)
1.4 Who Does Software Engineering?

- **Customer**: the company, organization, or person who pays for the software system
- **Developer**: the company, organization, or person who is building the software system
- **User**: the person or people who will actually use the system

(continued)

- Participants (stakeholders) in a software development project
Review

- What are two complementary strategies for SE-based problem solving?
- What are three ways to consider software quality?
- Who are the three key stakeholders in a software development project?

1.5 Systems Approach

- Hardware, software, interaction with people
- Identify activities and objects
- Define the system boundary
- Consider nested systems, systems interrelationship
Use–Case Diagrams (POST)

POST: Point of Sale Terminal

System Boundary

- Buy Item
- Log In
- Refund a Purchased Item

Customer
Cashier

Adapted from Larman “Applying UML and Patterns”

A Different Boundary

- Let us view the whole store as our system
1.6 Engineering Approach
Building a System

- Requirement analysis and definition
- System design
- Program design
- Writing the programs
- Unit testing
- Integration testing
- System testing
- System delivery
- Maintenance

Waterfall Process Model

Diagram showing the process model with stages:
- Requirements
- Design
- Coding
- Testing
- Maintenance
1.7 Members of the Development Team

- **Requirement analysts**: work with the customers to identify and document the requirements
- **Designers**: generate a system-level description of what the system is supposed to do
- **Programmers**: write lines of code to implement the design
- **Testers**: catch faults; detect errors
- **[Trainners]**: show users how to use the system
- **Maintenance team**: fix faults that show up later
- **[Librarians]**: prepare and store documents such as software requirements
- **Configuration management team**: maintain correspondence among various artifacts

1.7 Members of the Development Team

(continued)

- Typical roles played by the members of a development team
Why is software development so difficult?

- **Communication**
  - Between customer and developer
    - Poor problem definition is largest cause of failed software projects
  - Within development team
    - More people = more communication
    - New programmers need training

- **Project characteristics**
  - Novelty
  - Changing requirements
    - 5 x cost during development
    - up to 100 x cost during maintenance
  - Hardware/software configuration
  - Security requirements
  - Real time requirements
  - Reliability requirements

Why is software development difficult? (cont.)

- **Personnel characteristics**
  - Ability
  - Prior experience
  - Communication skills
  - Team cooperation
  - Training

- **Facilities and resources**
  - Identification
  - Acquisition

- **Management issues**
  - Realistic goals
  - Cost estimation
  - Scheduling
  - Resource allocation
  - Quality assurance
  - Version control
  - Contracts
## Capability Maturity Model (CMM)

- **Level 1**: Initial  
  - ad hoc  
  - success depends on people

- **Level 2**: Repeatable  
  - track cost, schedule, functionality

- **Level 3**: Defined  
  - use standardized processes

- **Level 4**: Managed  
  - collect detailed metrics

- **Level 5**: Optimizing  
  - continuous process improvement  
  - “built-in” process improvement

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### 1.8 How Has Software Engineering Changed?  
The Nature of the Change

- **Before 1970s**  
  - Single processors: mainframes (e.g., IBM, VAX)  
  - Designed in one of two ways  
    - as a **transformation**: input was converted to output  
    - as a **transaction**: input determined which function to apply

- **After 1970s**  
  - Run on multiple systems  
  - Perform multi–functions

- **…**

- **After 2000:**  
  - Distributed (global) development teams

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*Pfleeger and Atlee, Software Engineering: Theory and Practice (edited by B. Cheng)*
1.8 How Has SE Changed?
Wasserman's Seven Key Factors (continued)

- The key factors that have changed the software development

1.8 How Has SE Changed?
Wasserman's Discipline of Software Engineering

- Abstractions
- Analysis and design methods and notations
- User interface prototyping
- Software architecture
- Software process
- Reuse
- Measurement
- Tools and integrated environments
1.8 How Has SE Changed?

Abstraction

- A description of the problem at some level of generalization
  - Hide details

![Diagram of Electrical device, Sensor, Water sensor, Air sensor]

1.8 How Has SE Changed?

Analysis and Design Methods and Notations

- Provide documentation
- Facilitate communication
- Offer multiple views
- Unify different views
- Example: Unified Modeling Language
  - de facto standard for OO modeling
1.8 How Has SE Changed?
User Interface Prototyping

- Prototyping: building a small version of a system
  - Help users identify key requirements of a system
  - Demonstrate feasibility
- Develop good user interface

1.8 How Has SE Changed?
Software Architecture

- A system’s architecture describes the system in terms of a set of architectural units and relationships between these units
- Architectural decomposition techniques
  - Modular decomposition
  - Data-oriented decomposition
  - Event-driven decomposition
  - Outside-in-design decomposition
  - Object-oriented decomposition
- Architectural Styles:
  - Pipe and filter; client–server, star–based, p2p
Pipes-and-Filter

- The system has
  - Streams of data (pipe) for input and output
  - Transformation of the data (filter)

Ex: Pipeline Topology (Architecture)

Compiler:

- source program
- Lexical analyzer
- token stream
- Semantic analyzer
- abstract syntax tree
- Code generator
- code sequence
- Code optimizer
- object code
Ex: Star Topology
(Architecture)

Monitoring system:

- Sensors
- Control panel
- SafeHome software
- Alarm
- Telephone line

Ex: Star Topology
(Architecture)

Client–Server

- Two types of components:
  - Server components offer services
  - Clients access them using a request/reply protocol
- Client may send the server an executable function, called a callback
  - The server subsequently calls under specific circumstances
1.8 How Has SE Changed?
Software Reuse

- Commonalities between applications may allow reusing artifacts from previous developments (e.g., product lines)
  - Improve productivity
  - Reduce costs
- Potential concerns
  - It may be faster to build a smaller application than searching for reusable components
  - Generalized components take more time to build
  - Must clarify who will be responsible for maintaining reusable components
  - Generality vs specificity: always a conflict

1.11 What this Chapter Means for You

- Given a problem to solve
  - Analyze it
  - Synthesize a solution
- Understand that requirements may change
- Must view quality from several different perspectives
- Use fundamental software engineering concepts (e.g., abstractions and measurements)
- Keep system boundary in mind