Chapter 1

What is Software Engineering

Shari L. Pfleeger
Joanne M. Atlee

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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

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.

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.
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

![McCall's quality model diagram]

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)

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

Software Engineering Institute: [http://www.sei.cmu.edu/cmm/](http://www.sei.cmu.edu/cmm/)
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
1.4 Who Does Software Engineering? (continued)

- Participants (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

Use Case

Customer

Cashier

POST

Buy Item

Log In

Refund a Purchased Item

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
Prototyping Process Model

When to use prototyping?

- Help the customer pin down the requirements
  - Concrete model to “test out”
  - Often done via the user interface
- Explore alternative solutions to a troublesome component
  - e.g., determine if an approach gives acceptable performance
- Improve morale
  - Partially running system provides visibility into a project
Spiral Process Model

Process Models

• Idealized views of the process
• Different models are often used for different subprocesses
  – may use spiral model for overall development
    • prototyping for a particularly complex component
    • waterfall model for other components
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
- **[Trainers]**: 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
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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1.8 How Has SE Changed?  
Wasserman's Seven Key Factors (continued)

• The key factors that have changed the software development

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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

Abstraction

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

[Diagram showing a hierarchy of electrical device, sensor, water sensor, and 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?  
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

- Sensors status
- Control panel display information
- SafeHome software commands, data
- Alarm On/Off signals, alarm type
- Telephone line number tones

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 Process

• Many variations
• Different types of software need different processes
  – Enterprise-wide applications need a great deal of control
  – Departmental applications can take advantage of rapid development

1.8 How Has SE Changed?
Software Process (continued)

• Pictorial representation of differences in development processes

Controlled development

Rapid application development

Enterprise- or division-wide applications

Departmental applications

Single-user, desktop productivity tools

- Mission-critical
- Multiuser
- Multiplatform
- Limited scope
- High risk
- Single/multiplatform
- 1- to 2-tier development
- Packages/minimum development
- Lowcost/low risk
- Single platform
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

1.10 Real Time Example

• Ariane–5 rocket, from the European Space Agency
• June 4, 1996: functioned well for 40 seconds, then veered off course and was destroyed
• Contained four satellites: cost was $500 million
• Reused code from Ariane–4 rocket
1.10 Real Time Example
Ariane–5 Definition of Quality

- From the Lions et al report:
  - “... demonstrated the high quality of the Ariane–5 programme as regards engineering work in general and completeness and traceability of documents.”
  - “... the supplier of the SRI ... was only following the specification given to it. ... The exception which occurred was not due to random failure but a design error.”

1.11 What this Module 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