Joint Degree Program of Fudan University and University College Dublin (UCD)

SOFT620020.02

Advanced Software Engineering

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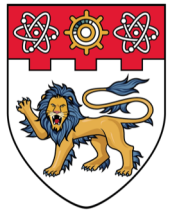
About Me

- BSc and PhD from Fudan
- Postdoc from NTU
- Pre-Tenure Assoc. Prof. at Fudan



NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

- No teaching experience 🤫

- Software Engineering
- Program Analysis
- Software Testing
- Software Security

Course Structure

- In-Class Teaching and **Discussion** (Every Monday 11-13)
- No After-Class Assignments

- Discussion (30%): a range of topics
- Survey or New Ideas Presentation (30%): 13 + 2 minutes
- Survey or New Ideas Paper (40%): Jan. 11, 2019

Course Communication

- All materials are available at the course website https://chenbihuan.github.io/course/ase/

- Email: bhchen@fudan.edu.cn
- Office: Room 403, Software Building, Zhangjiang Campus (make an appointment via email first)
- WeChat group for course announcement

QR Code of WeChat Group

A Quick Journey through Software Engineering

A Warm-Up Questionnaire

- Did you take the course about software engineering?
- Did you have programming experience of ≥ two years?

- Did you participate in the development of a project?
- Did you write and manage tests for your projects?
- Did you have a debugging nightmare for your projects?
- Did you use any automatic tools to help you test or debug?

- Did you submit bug reports for open-source projects?
- Can you prove that your program is correct?

Discussion 1 – Software and SE

- What is software?
- What are the attributes of good software?
- What is software engineering?

- Software: computer **programs** and associated **documents**
- Good software: deliver the required **functionalities** and **performance** to users, be **maintainable**, **dependable** and **usable**
- Software engineering: an engineering **discipline** that is concerned with **all** aspects of software production

Discussion 2 – Challenges and Costs

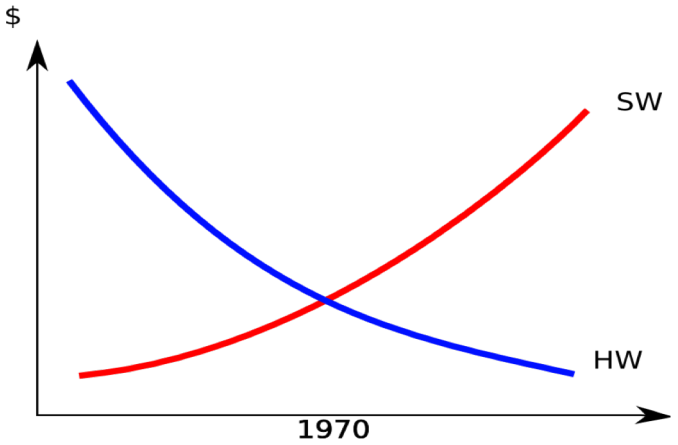
- What are the key challenges facing software engineering?
- What are the main costs of software engineering?

- Challenges: coping with increasing **diversity**, demands for **reduced delivery times** and developing **trustworthy** software

- Costs: 60% of costs are **development costs**, 40% are **testing costs**, and **evolution costs** often exceed development costs

Software Crisis

- Projects ran over-budget
- Projects ran over-time
- Software was very inefficient
- Software was of low quality

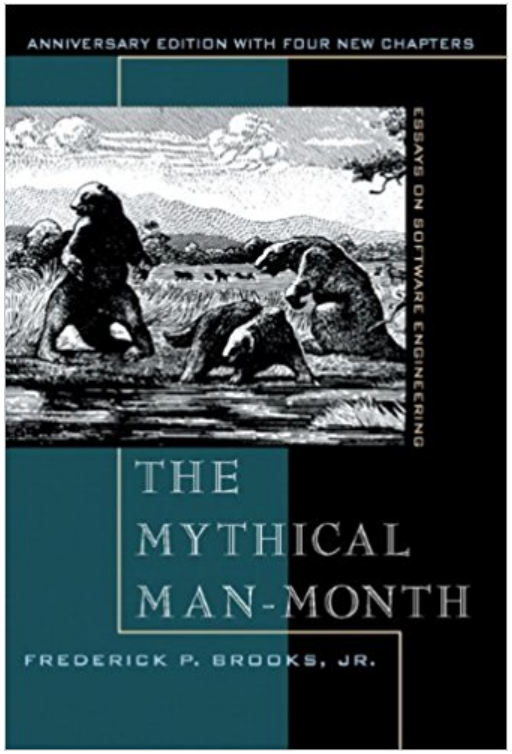


- Software often did not meet requirements
- Projects were unmanageable
- Code was difficult to maintain
- Software was never delivered
- …

IBM's System/360 Operating System

- Development period: 1963 – 1966
- Manpower: 5,000 man-year
- Code: one million lines of code
- Costs: hundreds of millions of dollars

- Delivery was delayed
- Cost was several orders of magnitude higher
- More memory was needed as planned
- The first release did not work well
- The system worked well after several releases
- Each release fixed thousands of bugs



Frederick Brooks

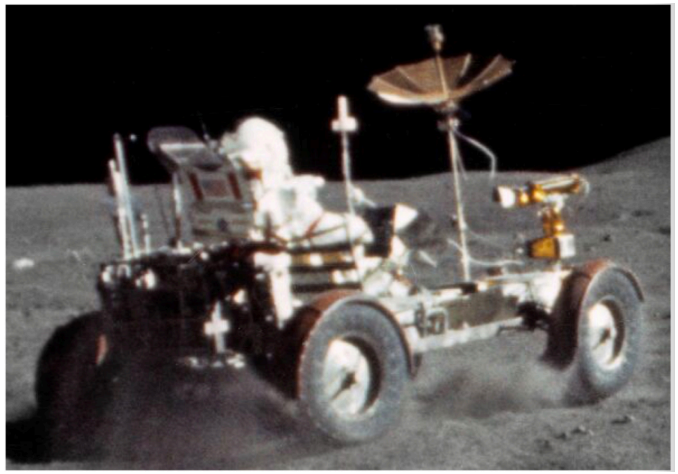
"Adding manpower to a late software project makes it later"

The Idea of Software Engineering

https://www.youtube.com/watch?v=ZbVOF0Uk5lU

- **Margaret Hamilton**, the lead Apollo flight software designer

"When I first came up with the term, no one had heard of it before, at least in our world. It was an ongoing joke for a long time. They liked to kid me about my radical ideas."



The Apollo 11 on the moon

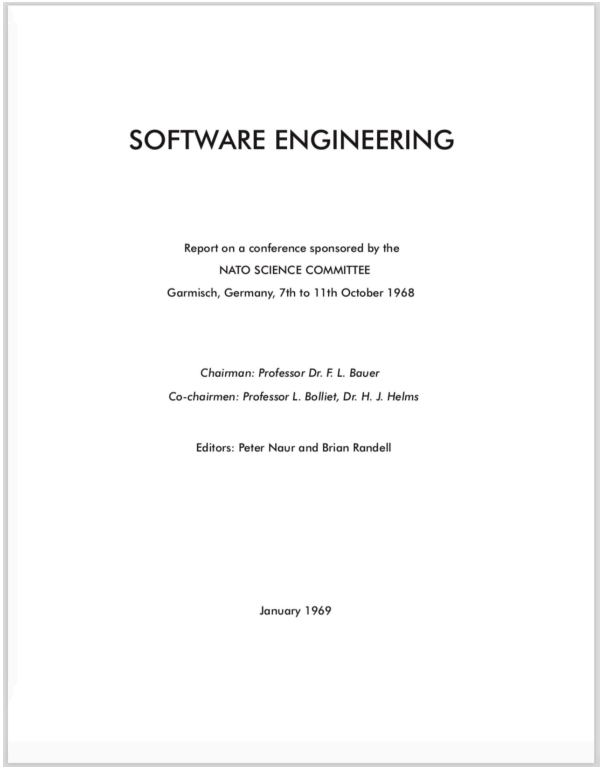
Standing next to listings of the software

Her concepts (e.g., asynchronous software, priority scheduling and software reuse) became the foundation for ultra-reliable software design

The Birth of Software Engineering

- **Fritz Bauer**, at NATO in 1968
- Suggest the term “Software Engineering” as a way to conceive both the problem and the solution of software crisis

- *“The establishment and use of sound engineering principles in order to obtain economically software that is reliable and works efficiently on real machines”*



SOFTWARE ENGINEERING

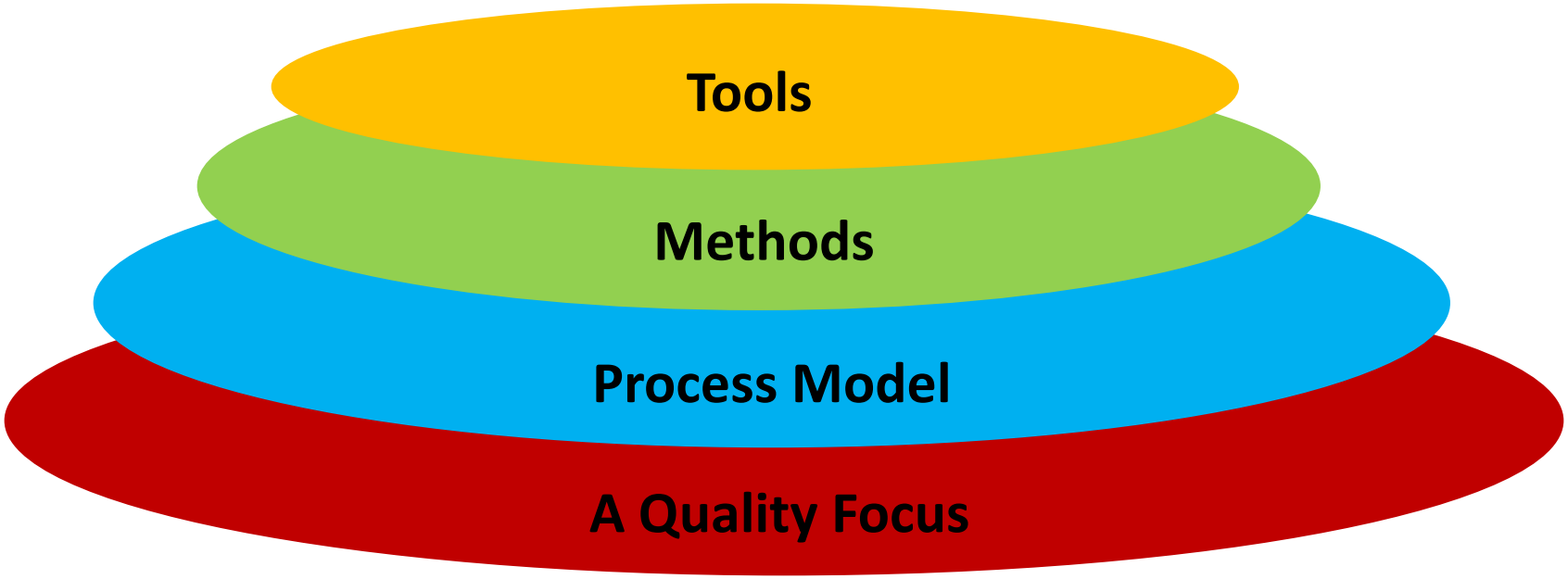
Report on a conference sponsored by the
NATO SCIENCE COMMITTEE
Garmisch, Germany, 7th to 11th October 1968

Chairman: Professor Dr. F. L. Bauer
Co-chairmen: Professor L. Bolliet, Dr. H. J. Helms

Editors: Peter Naur and Brian Randell

January 1969

SE: A Layered Technology



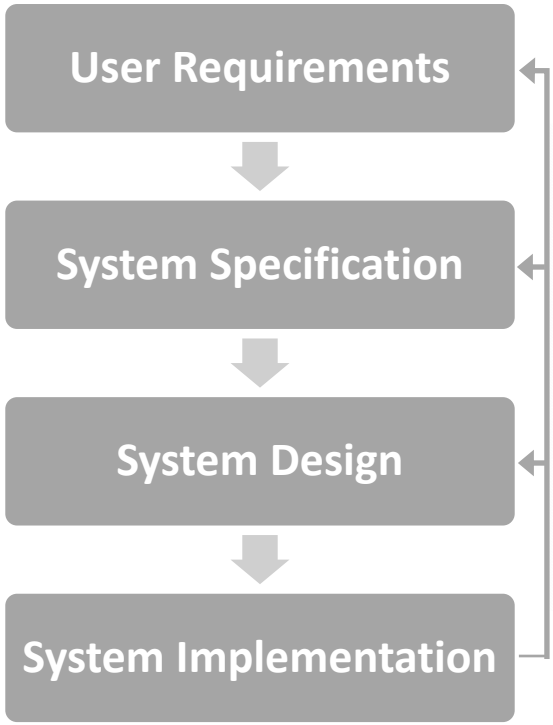
Activities in Software Engineering

Do we get the right requirements?

Is the specification equivalent to requirements?

Does the design satisfy the specification?

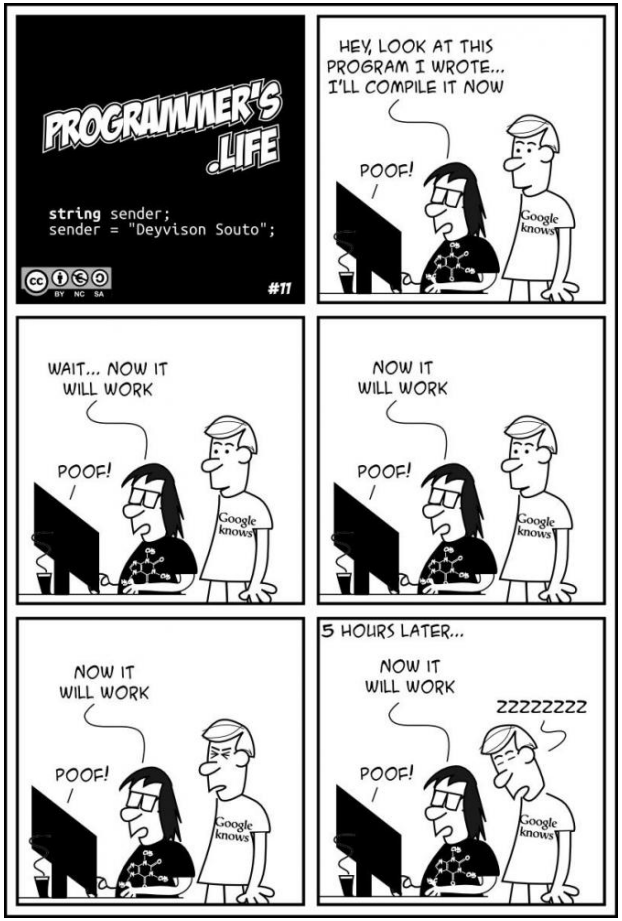
Is the design correctly implemented?

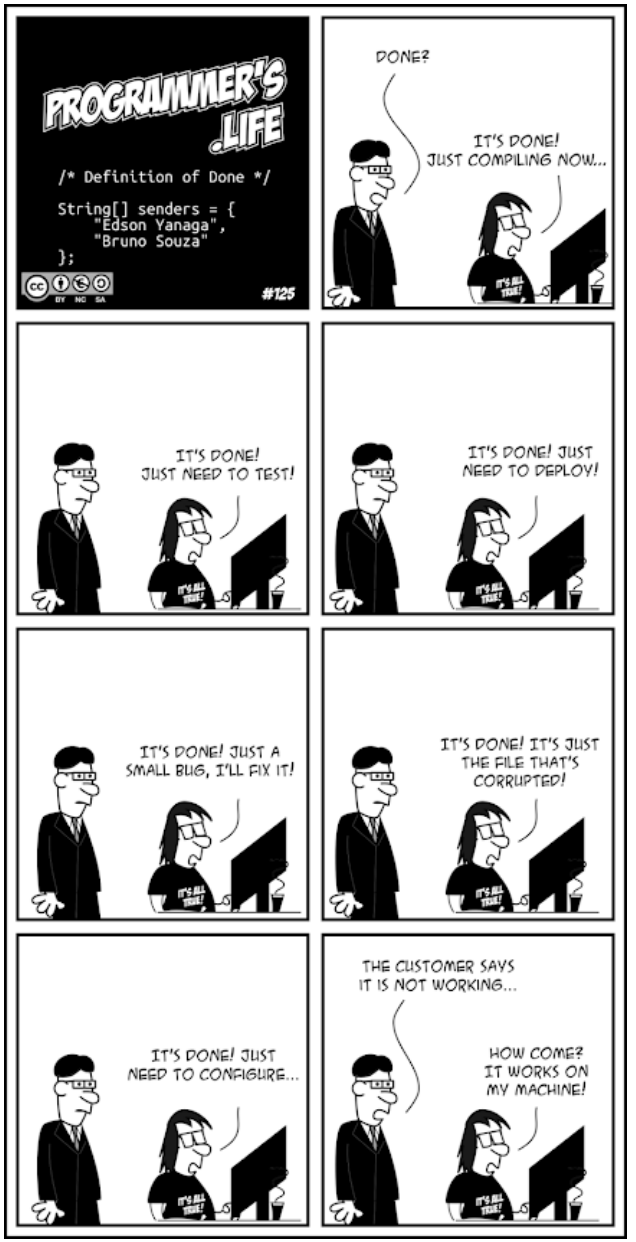


System Evolution

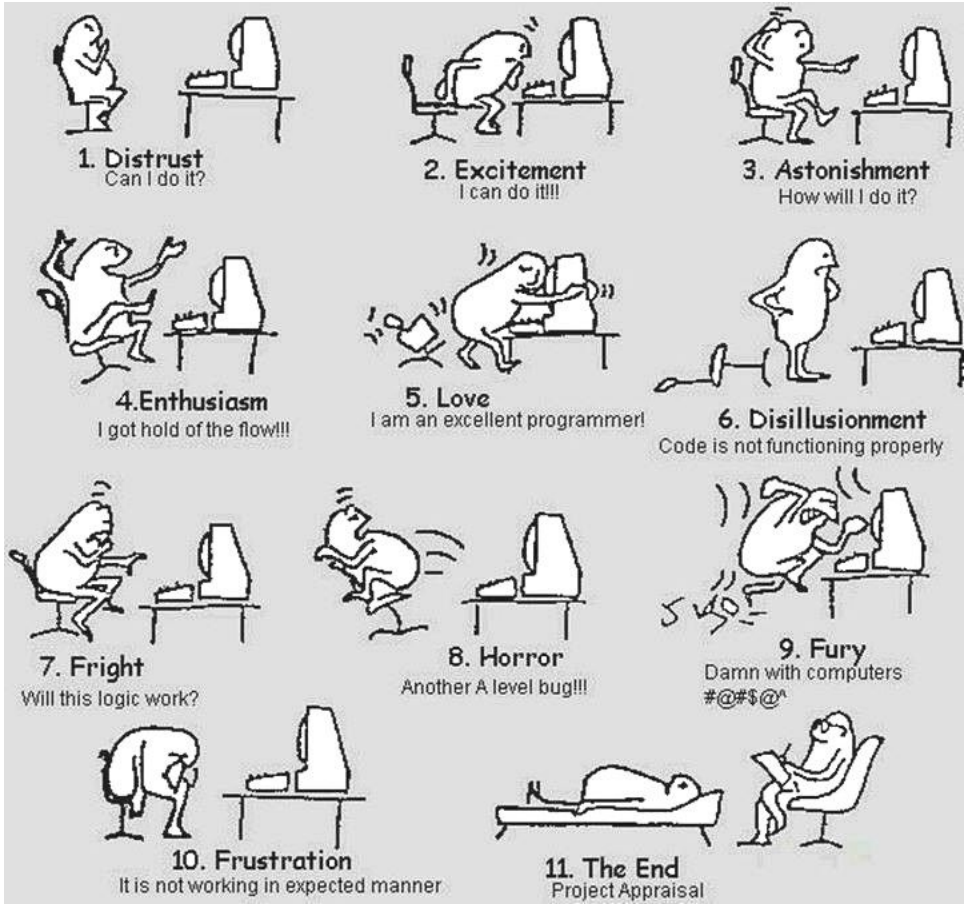
The Species We Call Programmers

A Programmer's Life



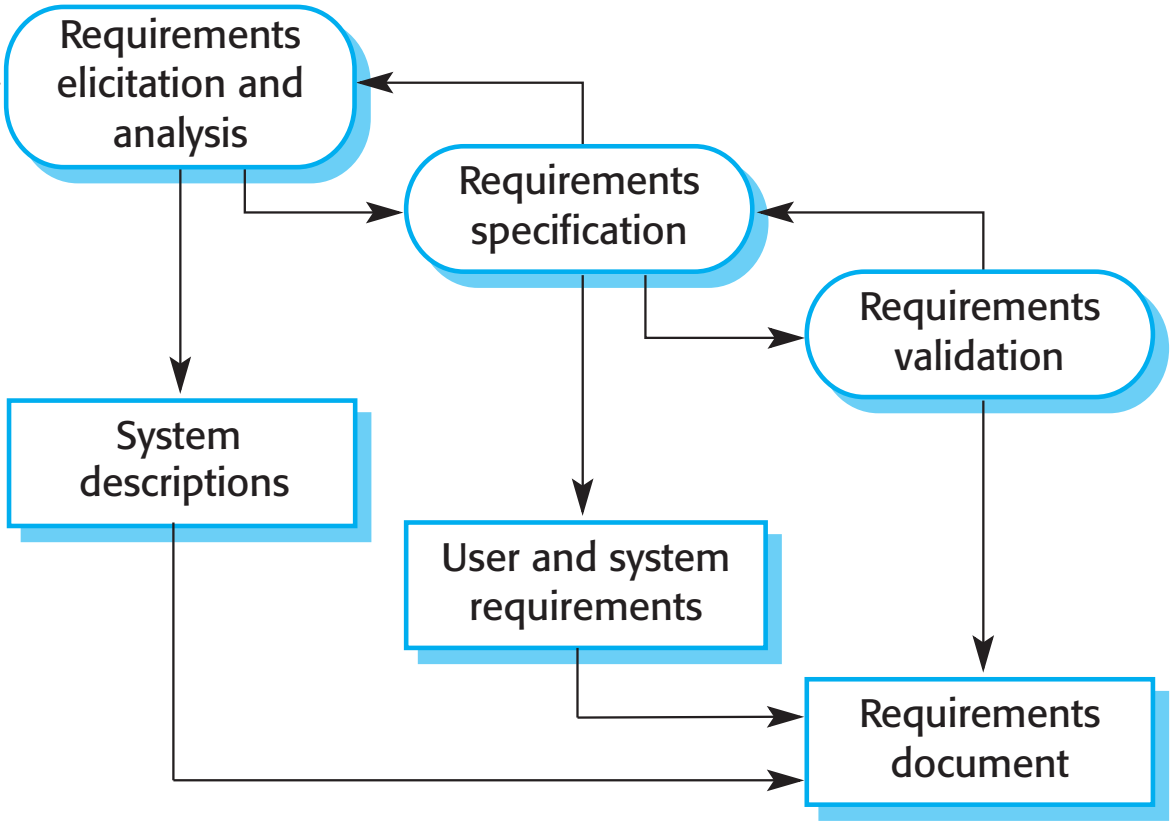


A Programmer's Life (cont.)



Requirements and Specification

- **Establish the required services and the constraints on the system's operation and development**



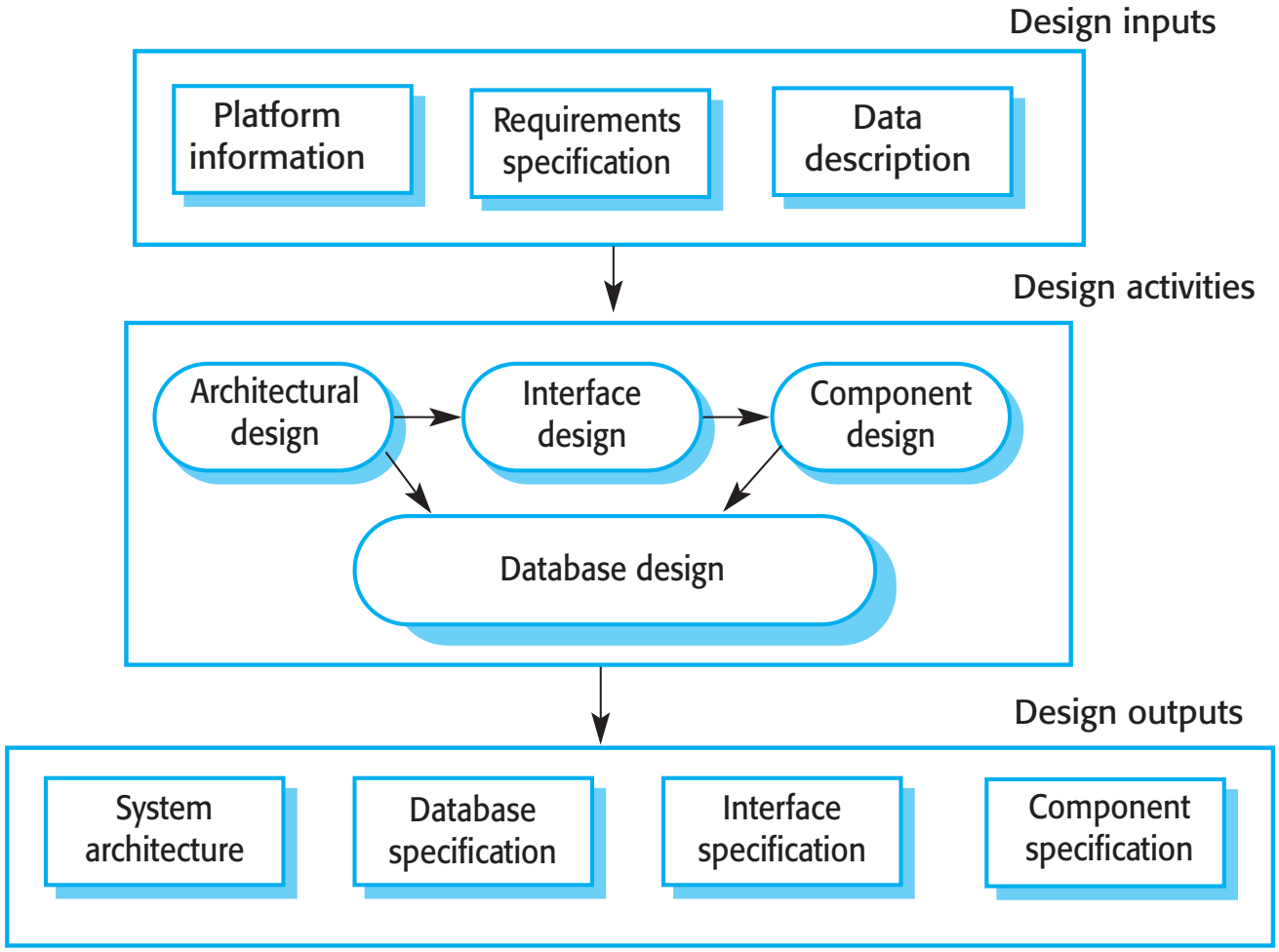
Requirements and Specification (cont.)

- Example: sort an array of integers within certain time
  - Red: functional requirement
  - Green: quality requirement

- Formal specification languages
  - The Z language, VDM, the B language, etc.
  - CSP, CCS, etc.

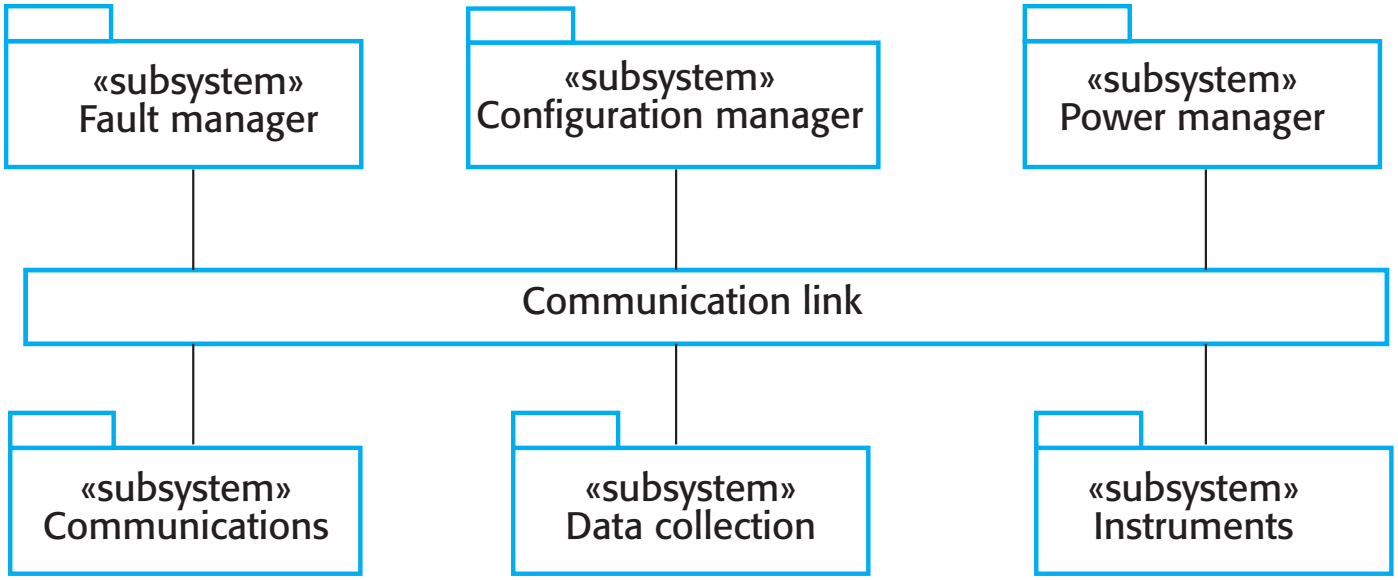
System Design

- **Design a software structure that realizes the specification**



System Design (cont.)

- Example: high-level architecture of a weather station system



System Implementation

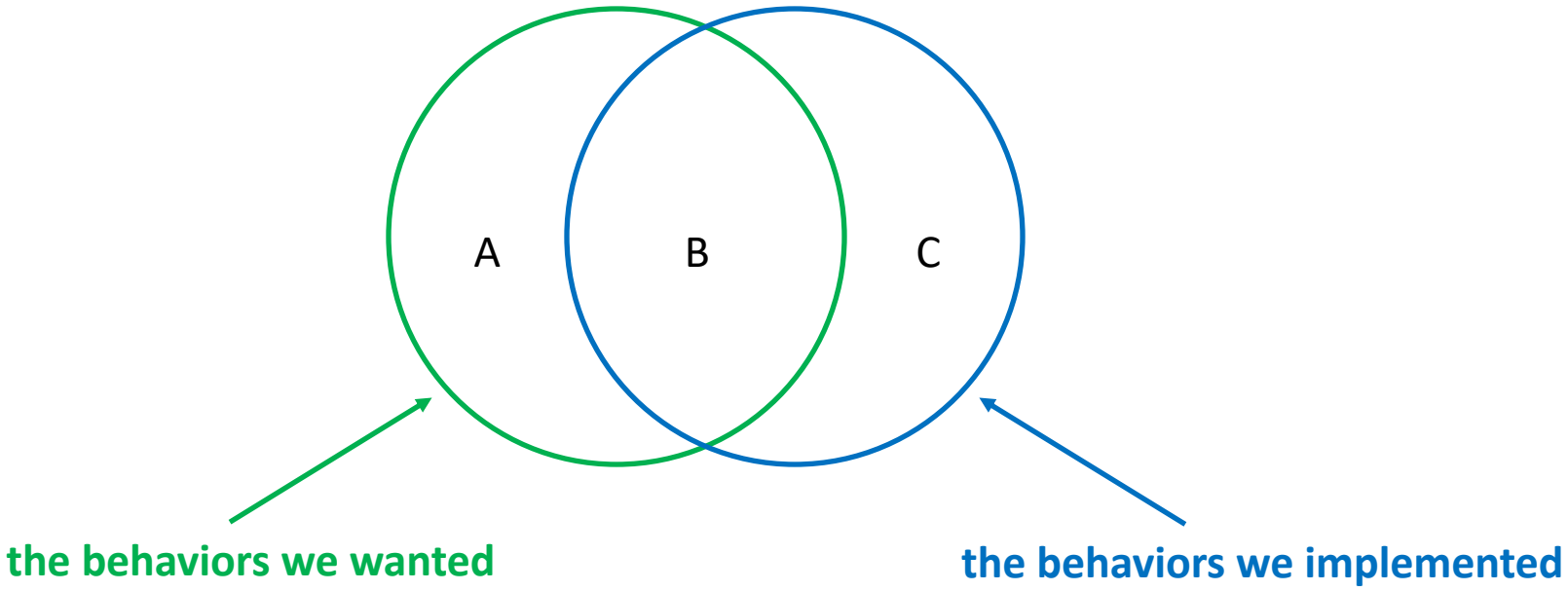
- **Translate the software structure into an executable program**

- The focus here is not on programming but on other implementation issues
  - Reuse
  - Configuration management
  - Host-target development
  - …

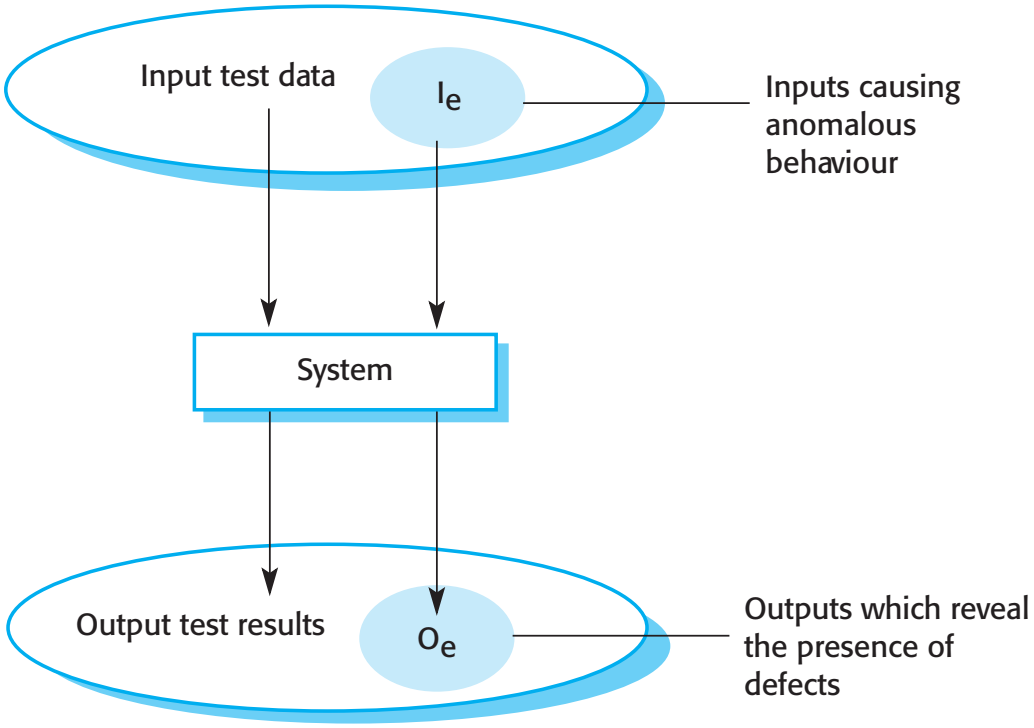
- The activities of implementation and testing are often closely related and may be interleaved

Testing

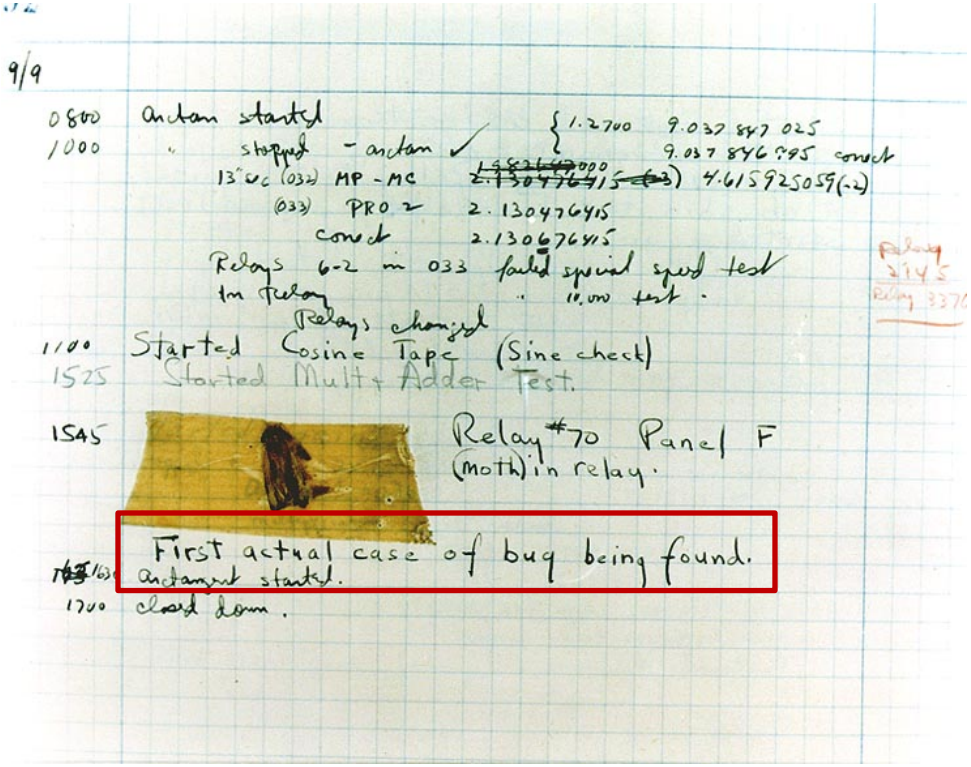
- **Testing is the most commonly used verification and validation activity**



Testing (cont.)



The Origins of Bug



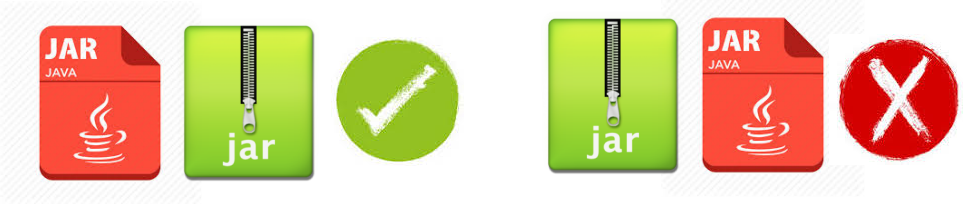
Grace M. Hopper's associates discovered a **moth** that was stuck in a relay; and the moth impeded the operation of the relay

Discussion 3 – Bug

- unexpected program behaviours manifested as crashes, errors, loss of data, denial of service, poor performance, high energy consumption, etc.

What kinds of bugs did you encounter?

The red and green library contains a class with same name but different function, and I needed the class in the red library



Computer A Computer B

Root cause: use **File.listFiles** to load the two libraries, which has no guarantee of any specific order.

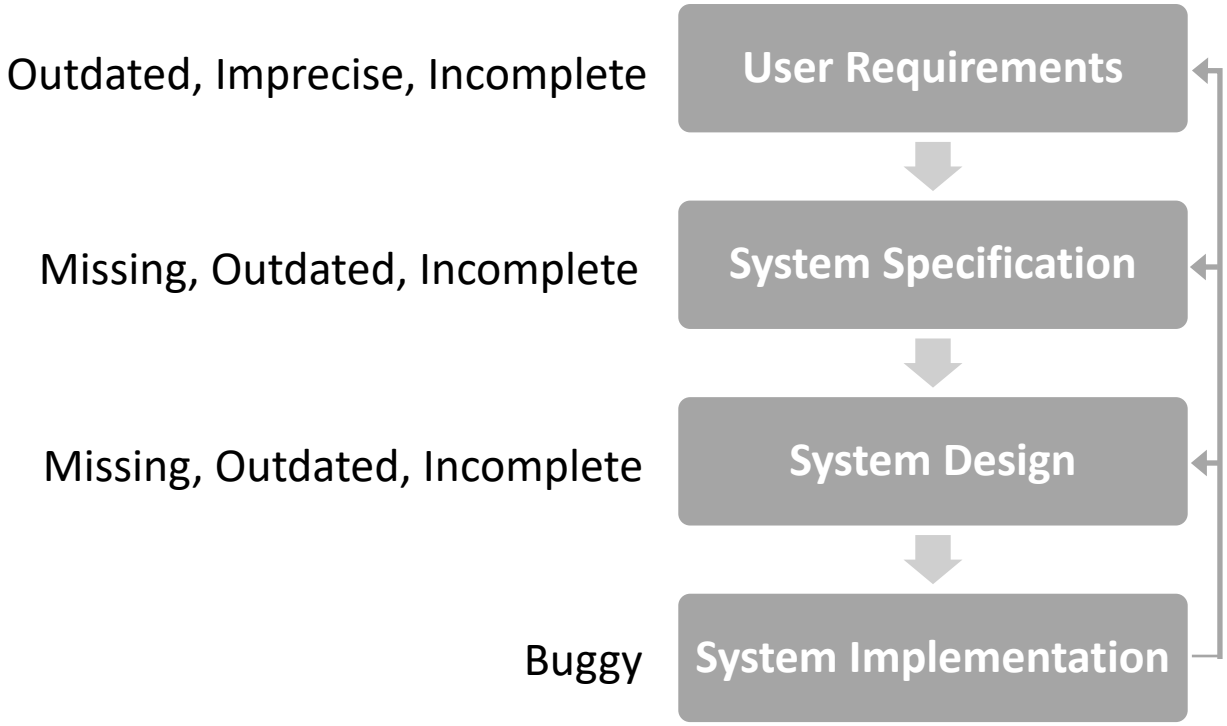
Discussion 4 – Debugging

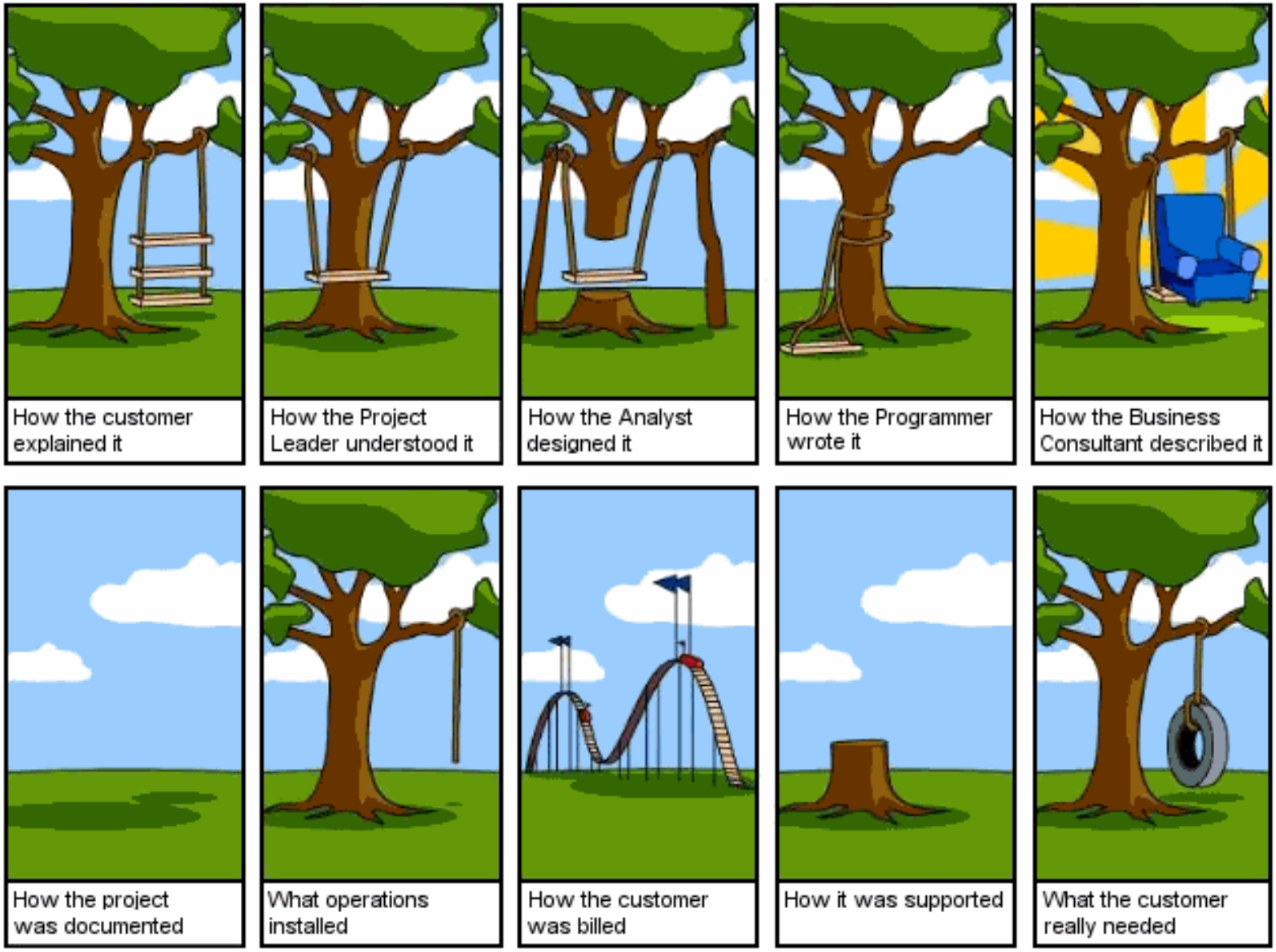
How do you debug the following buggy sort?

```
class BuggySort {
    public static void sort (int[] input) {
        int n = input.length;
        for (int i = 1; i < n - 1; i++) {
            for (int j = i; j < n - 1; j++) {
                if (input[j] > input[j+1]) {
                    int tmp = input[j];
                    input[j] = input[j+1];
                    input[j+1] = tmp;
                }
            }
        }
    }
}
```

```
class CorrrectSort {
    public static void sort (int[] input) {
        int n = input.length;
        for (int i = 0; i < n - 1; i++) {
            for (int j = 0; j < n - i - 1; j++) {
                if (input[j] > input[j+1]) {
                    int tmp = input[j];
                    input[j] = input[j+1];
                    input[j+1] = tmp;
                }
            }
        }
    }
}
```

Software Engineering




How the customer explained it
How the Project Leader understood it
How the Analyst designed it
How the Programmer wrote it
How the Business Consultant described it
How the project was documented
What operations installed
How the customer was billed
How it was supported
What the customer really needed

Course Planning

Course Outline

Date	Topic
Sep. 10	Introduction
Sep. 17	Testing Overview
Sep. 24	Holiday
Oct. 01	Holiday
Oct. 08	Guided Random Testing
Oct. 15	Search-Based Testing
Oct. 22	Security Testing
Oct. 29	Performance Analysis

Date	Topic
Nov. 05	Compiler Testing
Nov. 12	Mobile Testing
Nov. 19	Bug Prediction
Nov. 26	Bug Localization
Dec. 03	Delta Debugging
Dec. 10	Automatic Repair
Dec. 17	Symbolic Execution
Dec. 24	Presentation

For each topic, I will introduce two or three approaches proposed in the literature, and organize multiple discussions.

Presentation and Paper

Survey

- At Least 3 Papers
- Problem Statements
- **Critical Approach Analysis**
- **Pros and Cons**
- Possible Future Directions

New Ideas

- Problem Statement
- **Motivating Example**
- **Detailed Approach**
- Evaluation (Optional)
- Related Work

New Ideas Papers are favored over survey papers, and have a high chance of getting high marks.

Q&A?

Discussion 5 – AI Developers

Do you believe that AI can replace human developers?