Curriculum

- Software development lifecycle
- Capture software requirements using UML
- Strike a balance: risk management
- Early bug-finding using model checking
- Maintain traceability in model-based software design
- Software testing

Logistics

- TA
  - 陈光耀: chengy2@shanghaitech.edu.cn
  - 王文滔: wangwt1@shanghaitech.edu.cn
  - 何沛霖: hepl@shanghaitech.edu.cn
- Office Hour (Starting from Week 3)

江智浩	Tue 4-5pm	3-424
陈光耀	Mon 4-5pm	3-403B
王文滔	Thu 5-6pm	1b105
何沛霖	Wed 6-7pm	1b105

“In a software engineering course, you PREACH, not TEACH.”

-- Frederick P. Brooks, Jr.
UNC Chapel Hill

Why preach instead of teach

- What can be taught?
  - Tools and methodologies
  - Which are different in different industries, and change over time

- Religions are ways of interpreting the world
  - Preaching principles which can change your behavior
  - i.e. You will go to Hell if you don’t donate 1/10 of your wealth (Tithe)
  - Which do not change over time

Key Challenges in Software Engineering

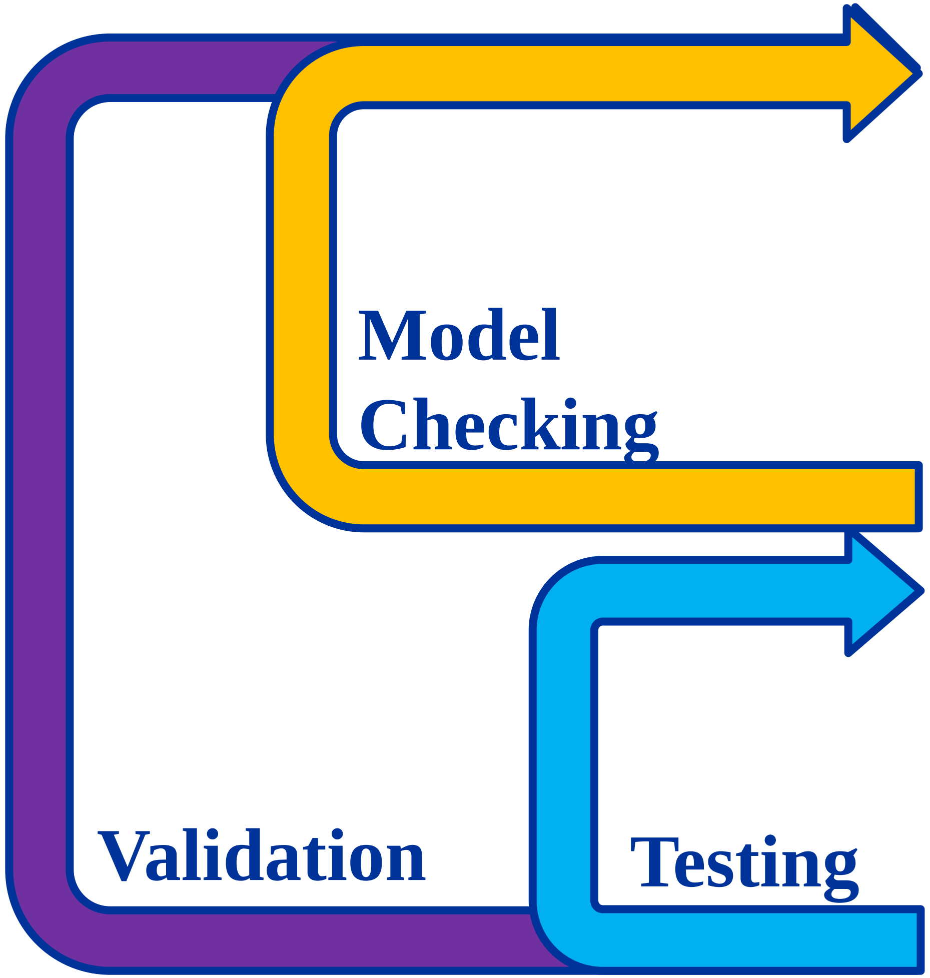
1. Effective communication
   - Between the engineering team and other stakeholders
   - Within the engineering team

2. Risk Management
   - How to balance conflicting judging criteria?

3. Validation
   - How do you know the software is effective/safe/secure?

Lecture 2: Software Life Cycle

Three Most Important Artifacts



Model Checking

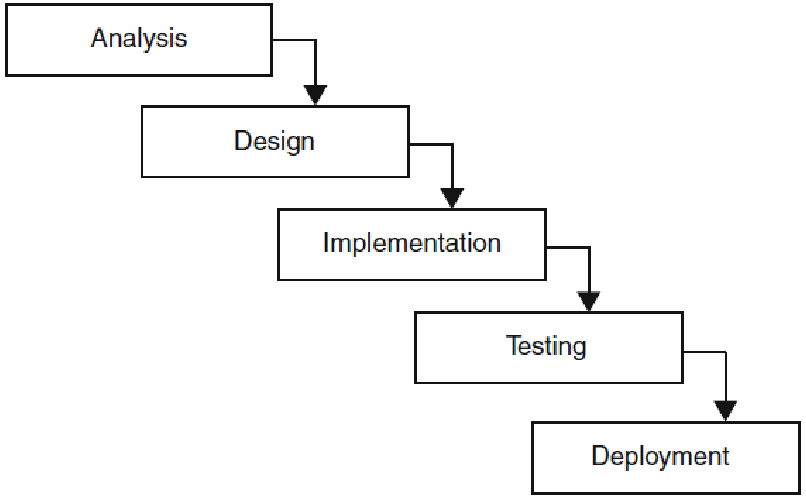
Validation

Testing

- Requirements **What**
  - i.e. the vehicle should not crash with any other objects
- Specifications **How**
  - i.e. when the vehicle detects an object on its path, apply brake
- Implementation

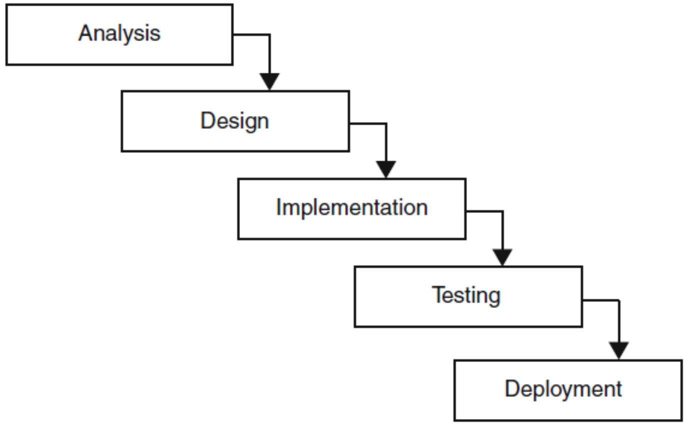
Waterfall Software Development Model

- A new phase begins only when the previous phase has been fully completed
- Intend to ensure full attention on one stage at a time X



Cons: Waterfall Software Development Model

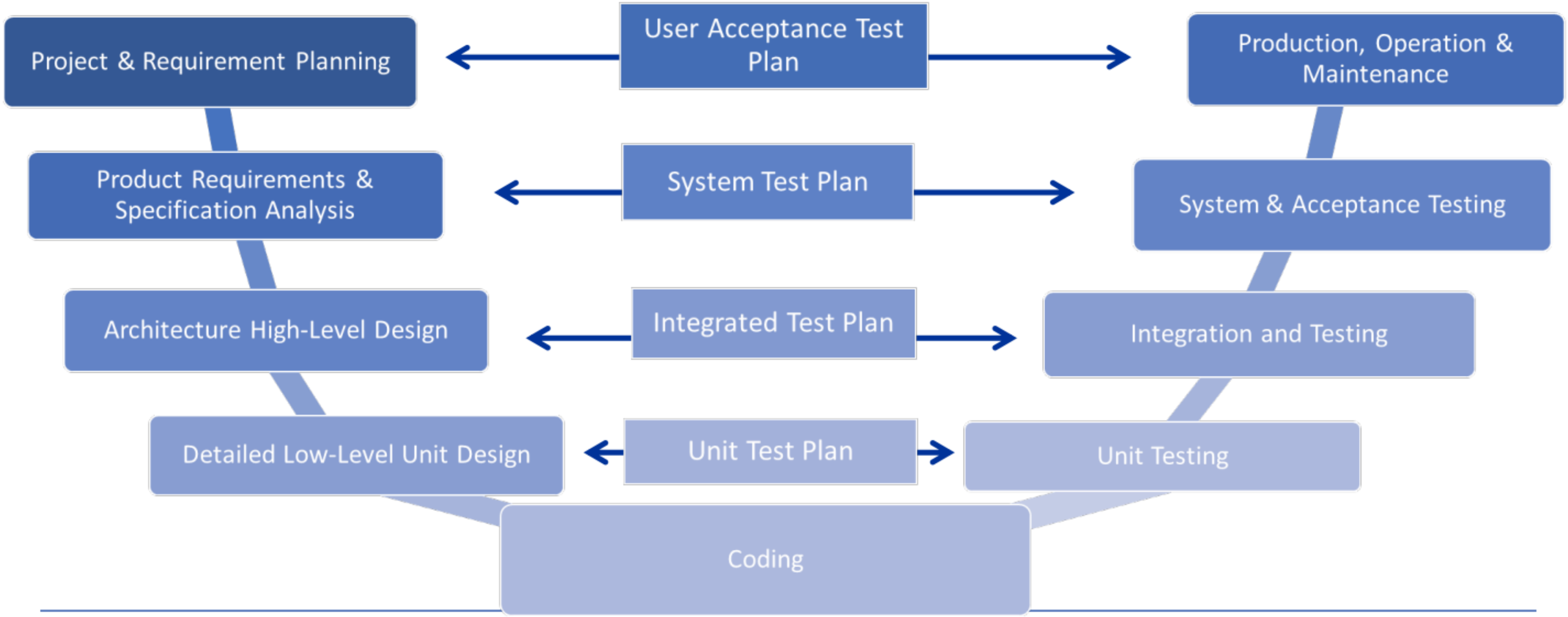
- Inflexible: Assume ideal situation which does not consider
  - Communication failures
  - Human errors
  - Change of requirements
- No feedback: No tangible product available for assessment until very late



When to use the Waterfall model?

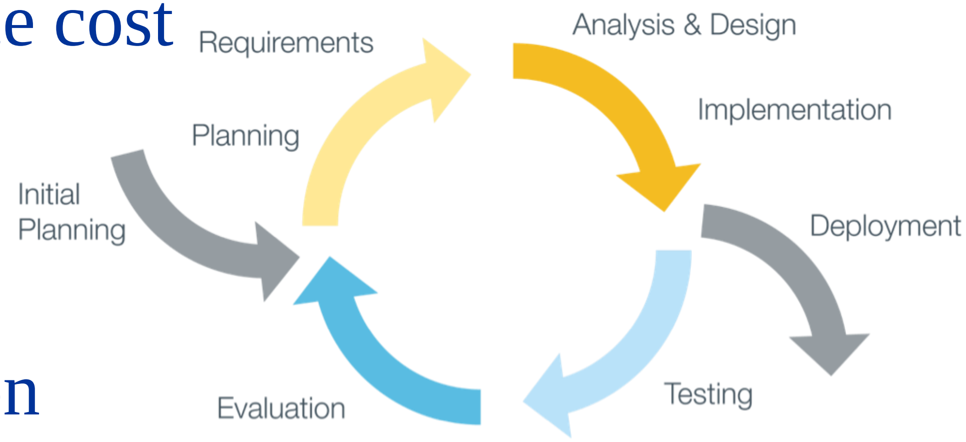
- When the requirements are established hand-on and well known to the team;
- When the technology is mastered by the team;
- The project has a stable plan and product definition;
- When updating or creating a new version of an existing product;
- When porting an existing product to a new platform

V-shape Model


Project & Requirement Planning
User Acceptance Test Plan
Production, Operation & Maintenance
Product Requirements & Specification Analysis
System Test Plan
System & Acceptance Testing
Architecture High-Level Design
Integrated Test Plan
Integration and Testing
Detailed Low-Level Unit Design
Unit Test Plan
Unit Testing
Coding

The Importance of Intermediate Artifacts

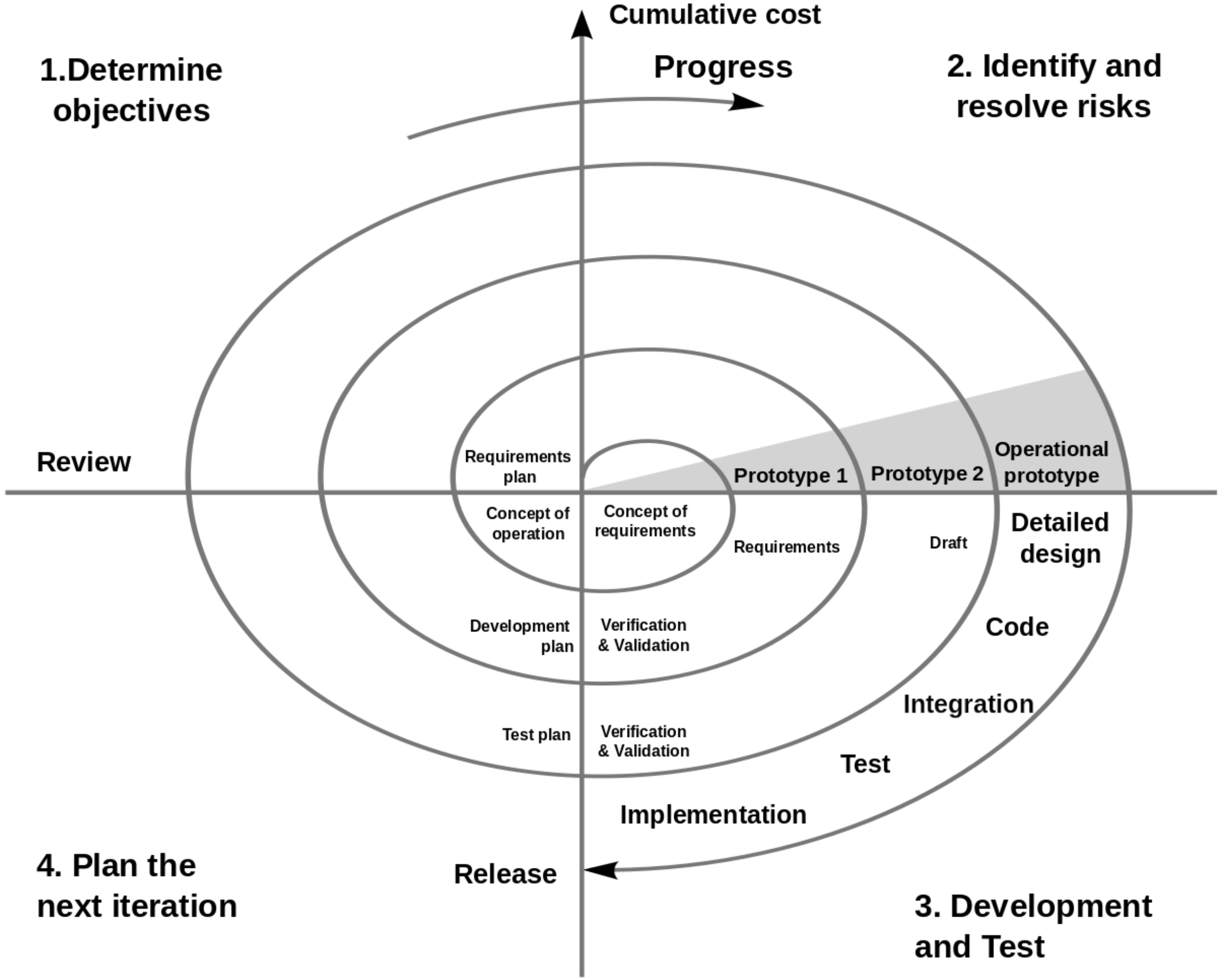
- Find problems early can significantly reduce cost
  - Tools and methodologies available to analyze intermediate artifacts



- Reduce ambiguity due to miscommunication
  - An executable product is the best communication tool
- What’s in the first prototype?
  - What should be added in each iteration?

Spiral software development model

- Each cycle represents an iteration in the development process
- Client feedback after each iteration
- Iterations guided using risk management



Agile Development

- Individuals and interactions over processes and tools;
- Working software over comprehensive documentation;
- Customer collaboration over contract negotiation;
- Responding to change over following a plan

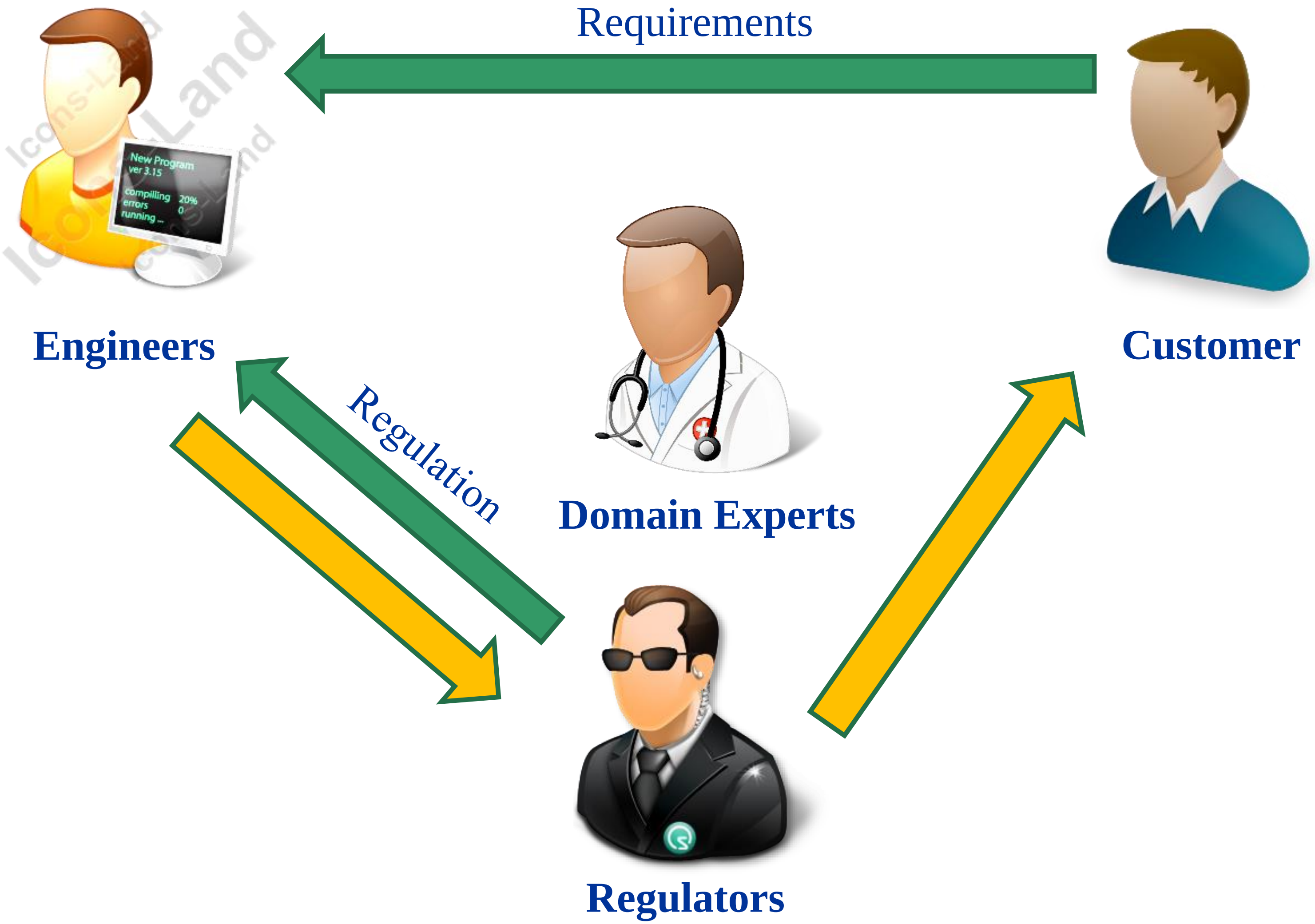
My Experience in Software Engineering

- Safe software for autonomous medical devices (UPenn)
  - Developed tools and methodologies for software validation
  - Proposed model-based design framework for medical device software
  - Identified physiological requirements with physicians (domain experts)
  - Studied certification of medical device software with regulators

- Software and systems for connected cars (Toyota ITC)
  - Learned the business perspective of software products.
    - Learned how to convert company vision to concrete projects
  - How legacy tools and best-practice affect software design
  - How risk management is used when developing a product
  - How does R&D work? From research to advanced development to production

Step 1: Software Requirement

Stakeholders for software



Composition of an Engineering Team

- Business analyst
  - In charge of developing requirements
  - Interacts with customer and domain experts
- Developer
  - In charge of developing specifications that satisfy the requirements
- Tester
  - In charge of validating the design and implementation
  - Interacts with regulators

Software Requirement

- Requirements: expected services of the system and constraints that the system must obey

- Functional Requirements
  - What the system must achieve

- Non-functional Requirements
  - Software quality: How well the system can do its job, etc

- Domain Requirements
  - Easy to omit as domain experts may think they are “obvious”

Functional Requirements

- Functions, tasks, or behaviors the system must fully support.
  - How user of the system use the system
- The “skeleton” of the system requirements
  - Should be captured in early iterations
- Need to distinguish “core functions” from “features”

Non-Functional Requirements

- Constraints placed on various attributes of system functions or tasks
- Equally important compared to functional requirements
  - Separate software products from software practices
- Sources
  - Domain: i.e. Human can tolerate up to 150ms delay in voice communication
  - Legacy: i.e. QWERTY keyboard
  - User: i.e. User want to operate the interface with one hand
  - Regulation: The system should switch to backup and resume within 1ms after the primary program crashes

Examples of Non-Functional Requirements

- User interface and human factors:
  - What type of user will be using the system?
  - Will more than one type of user be using the system?
  - What sort of training will be required for each type of user?
  - Is it particularly important that the system be easy to learn?
  - Is it particularly important that users be protected from making errors?
  - What sort of input/output devices for the human interface are available, and what are their characteristics?

Examples of Non-Functional Requirements

- Performance characteristics
  - Are there any speed, throughput, or response time constraints on the system?
  - Are there size or capacity constraints on the data to be processed by the system?
- Error handling and extreme conditions
  - How should the system respond to input errors?
  - How should the system respond to extreme conditions?

Examples of Non-Functional Requirements

- Quality issues
  - What are the requirements for reliability?
  - Must the system trap faults?
  - What is the maximum time for restarting the system after a failure?
  - Is it important that the system be portable (able to move to different hardware or operating system environments)?
- System Modifications
  - What parts of the system are likely candidates for later modification?
  - What sorts of modifications are expected (levels of adaptation)?
  - Might unwary adaptations lead to unsafe system states?

Identifying Non-functional Requirements

- Certain constraints are related to the design solution that are unknown at the requirements stage.
- Certain constraints are highly subjective and can only be determined through complex, empirical evaluations.
- Non-functional requirements tend to conflict and contradict.
- There is no ‘universal’ set of rules and guidelines for determining when nonfunctional requirements are optimally met.

Requirement Elicitation

- Step 1: (Business analyst) develops common understanding of the problem domain with (customers) and (domain experts)
- Step 2: (Business analyst) explains the problem to (the development team) and develop a design strategy
- Step 3: (Business analyst) presents the design strategy to the customer, and agree on technical solutions

Business analysts

- Need to be familiar with the problem domain and development techniques
- The bridge between the customers and the development team
  - To the customers:
    - Explain in domain language what can/cannot be achieved with existing constraints
    - Hide technical details when explaining the technical solution to the customers
    - Create user manual
  - To the development team:
    - Reformulate the domain problem as mathematical problems

Common Problems During Requirement Elicitation

- Problem of scope
  - What environmental condition the system will operate in?

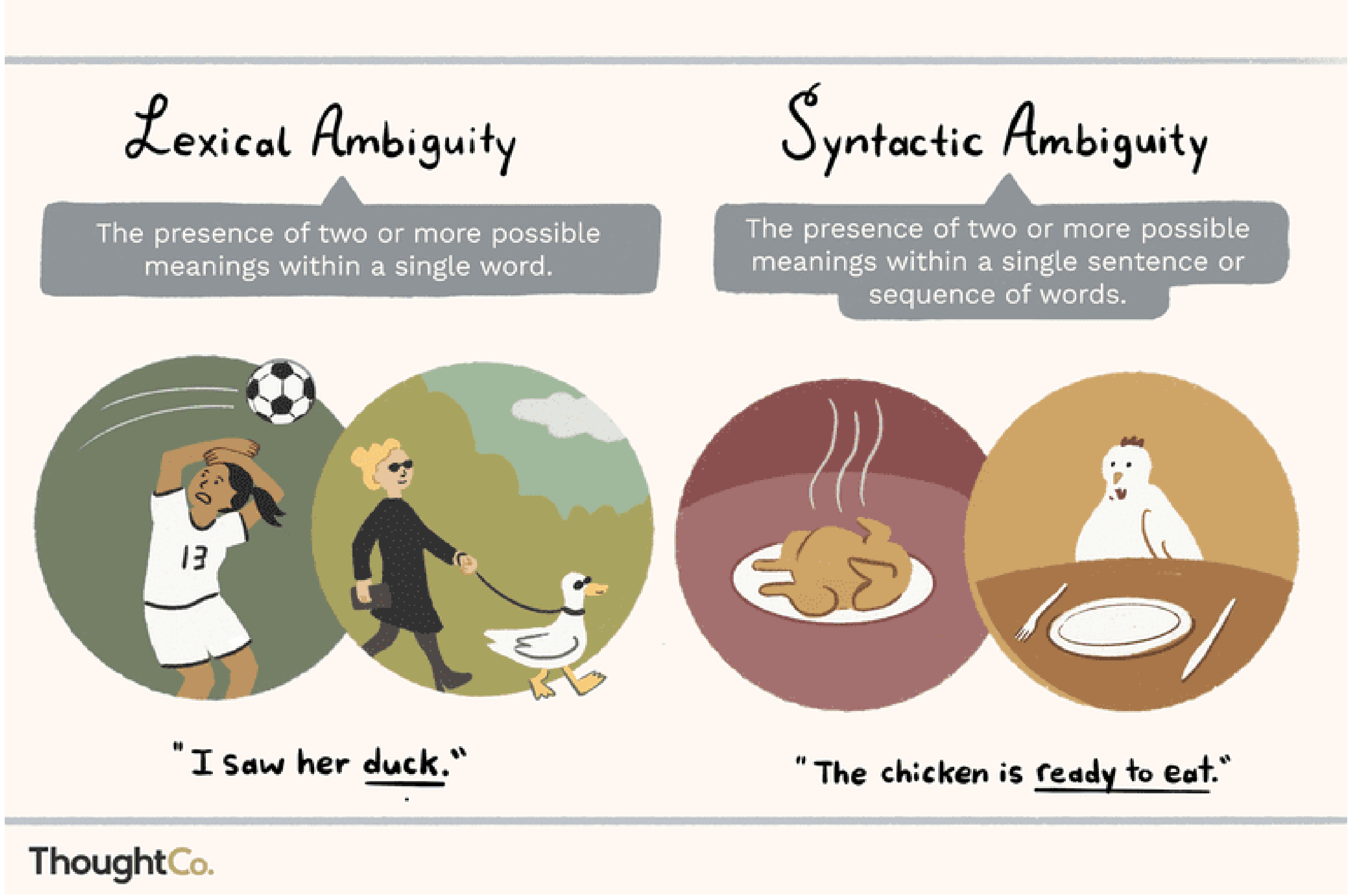
- Problem of understanding

- Problem of volatility
  - User needs evolve over time

Problem of Understanding

- The customer fails to explain their needs well.
  - Need a common language
- The analyst may not understand the customer's need.
  - Need to study the problem domain
- The customer may not know what he/she wants
  - The team should identify customer needs from the problem domain
- The analyst may not clearly convey the requirements to the development team
  - Problem abstraction

Natural Languages Are Prone to Ambiguities



Lexical Ambiguity

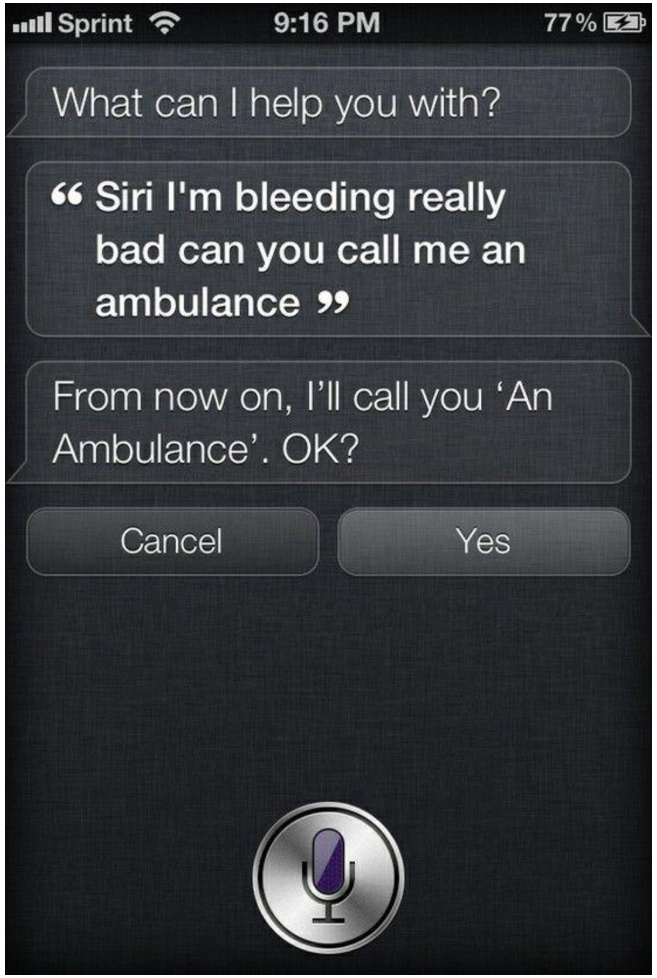
The presence of two or more possible meanings within a single word.

"I saw her duck."

Syntactic Ambiguity

The presence of two or more possible meanings within a single sentence or sequence of words.

"The chicken is ready to eat."



What can I help you with?

“ Siri I'm bleeding really bad can you call me an ambulance ”

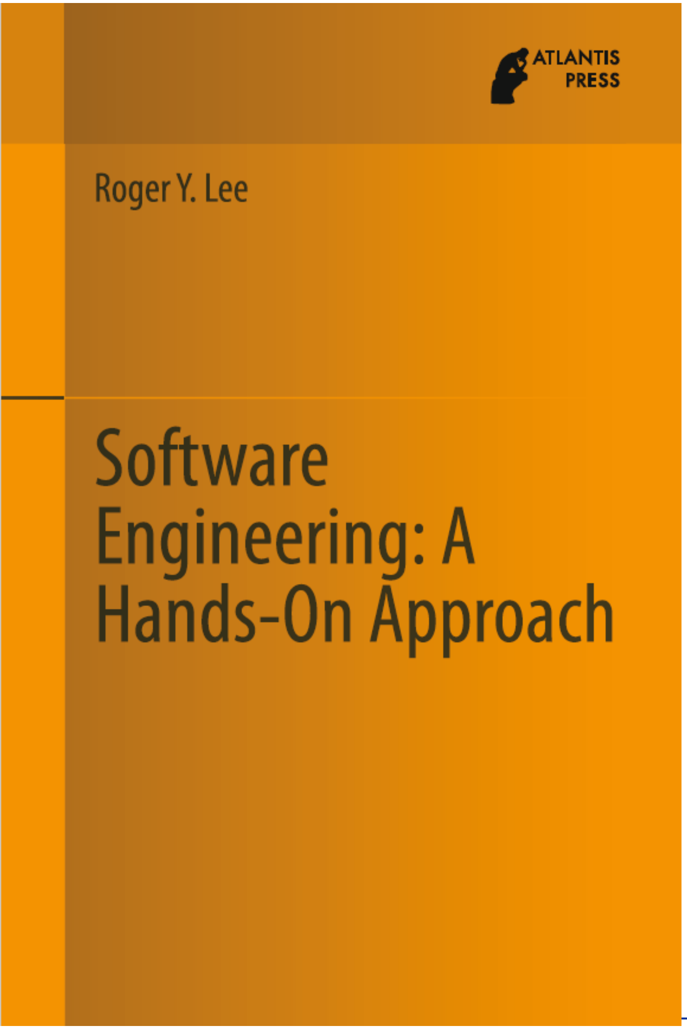
From now on, I’ll call you ‘An Ambulance’. OK?

We need a widely used formal language

Communications among various stakeholders

- Need a common language for communication
- Unified Modeling Language (UML)
- Recognized as an international standard
- It’s just a tool, not a solution

Reference Book



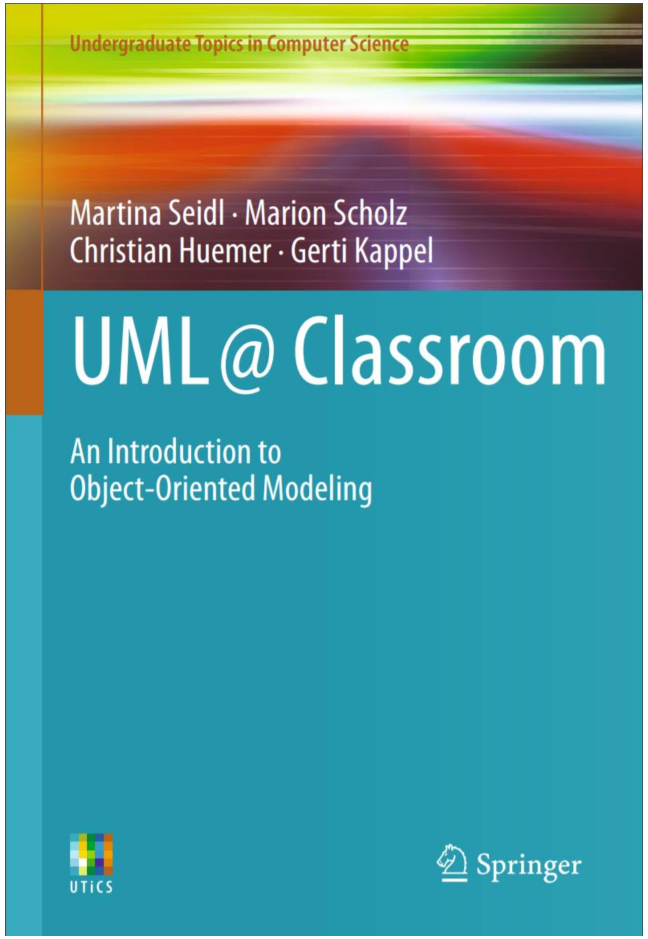
ATLANTIS PRESS

Roger Y. Lee

Software Engineering: A Hands-On Approach

Reference for UML

- Freely available online
- Search from our library website



Undergraduate Topics in Computer Science

Martina Seidl · Marion Scholz
Christian Huemer · Gerti Kappel

UML @ Classroom

An Introduction to
Object-Oriented Modeling

UTiCS

Springer

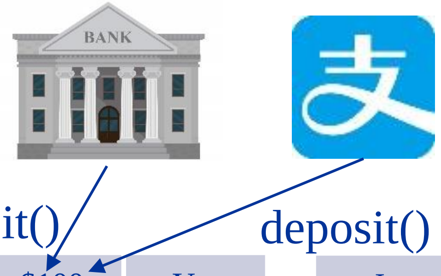
Procedure-Oriented Software Design

- Describe problems in terms of functions: y=f(x)
- Behaviors hard to describe as procedure

Procedure-Oriented Software Design

- Sensitive to requirement changes
- Nothing reusable
- Less intuitive (Communication problems)
- No information hiding

```
graduate()
{
    returnCafe();
    dropClass();
    returnBook();
}
```



deposit()

deposit()

Joe	202001	$100	Yes
Jane	202002	$200	No

Joe	202001	CS132
Jane	202002	CS233

Joe	202001	Book 1
Jane	202002	Book 2

DIY Community in Electrical Engineering

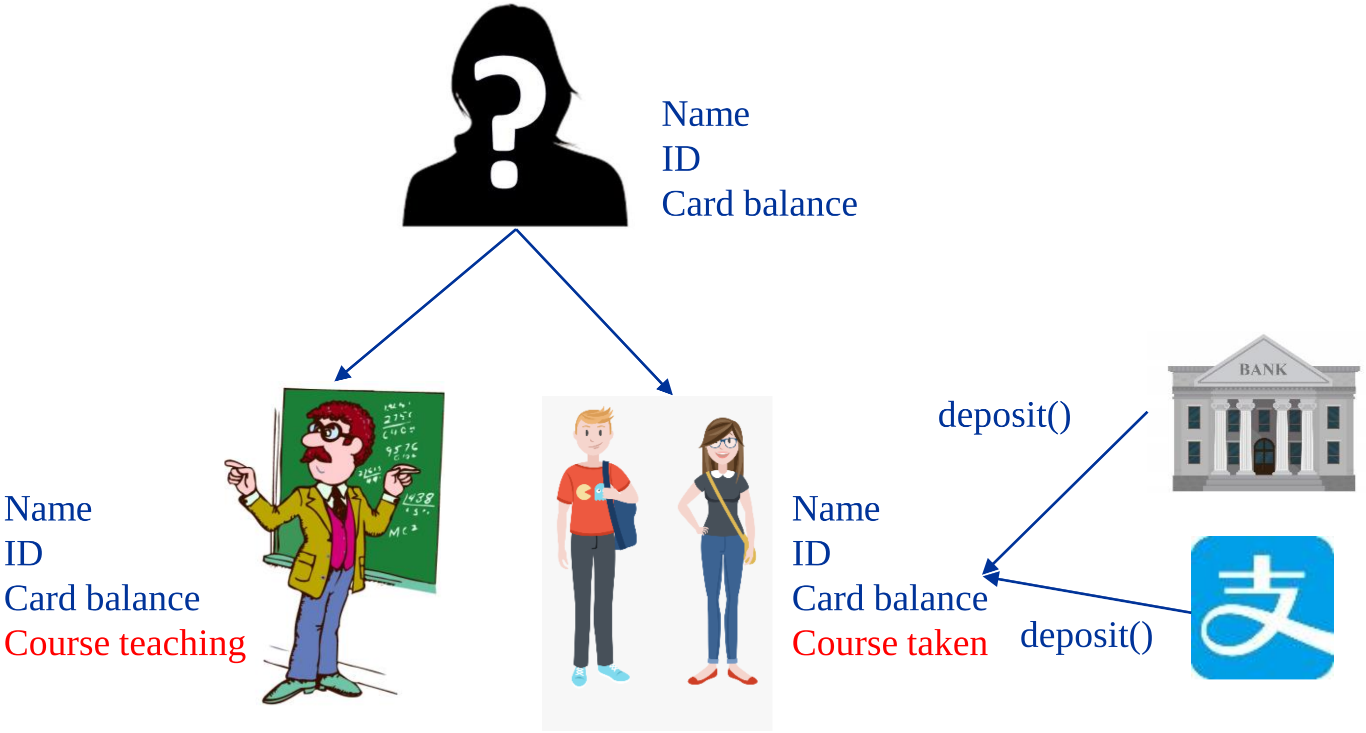
- Standardized “building blocks”
  - Easily accessible

- Standardized interface
  - Interchangeable components

- Can we define a software system as a collection of objects of various types that interact with each other through well-defined interfaces?

Object-Oriented Software Design

- Describe problems as objects and interactions between objects
- Much more intuitive



Name
ID
Card balance

Name
ID
Card balance
Course teaching

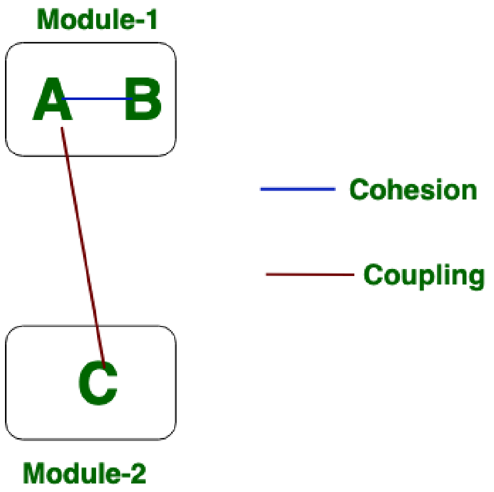
Name
ID
Card balance
Course taken

deposit()

deposit()

Benefits of OO

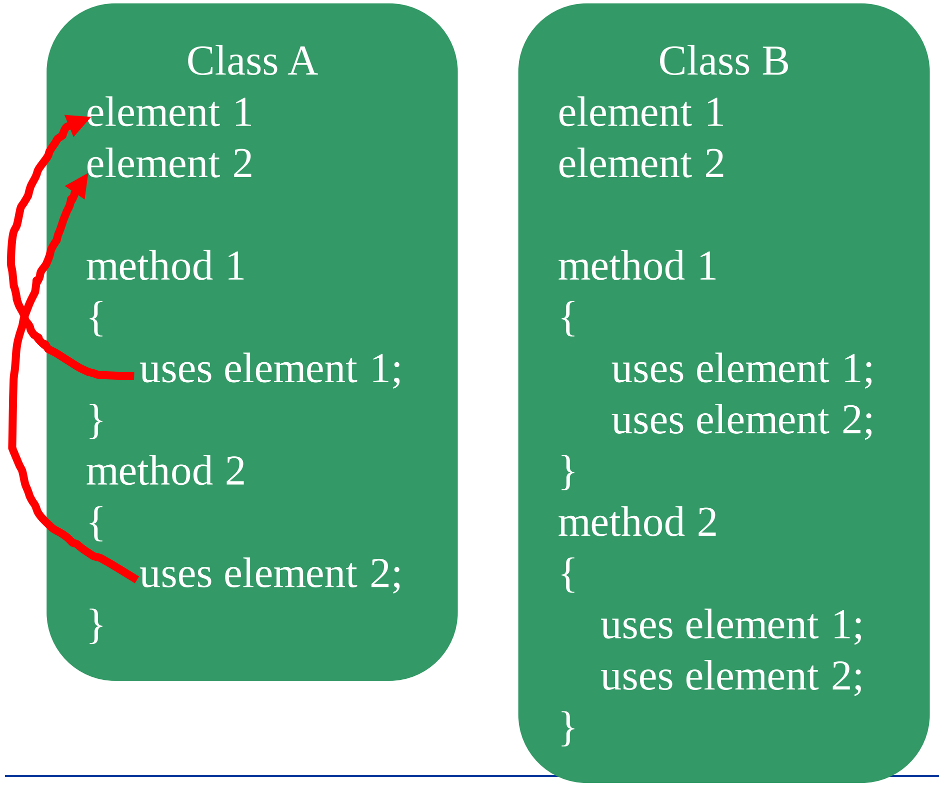
- Modularity: Decompose a system into a set of cohesive and loosely coupled modules
  - Reusability
    - Accidental vs. deliberate reuse
  - Encapsulation and information hiding
    - Interfaces
  - Access levels
    - Reduce coupling



- Inheritance: a relationship between different classes in which one class shares attributes of one or more different classes

Cohesion vs. Coupling

- Low vs. high cohesion



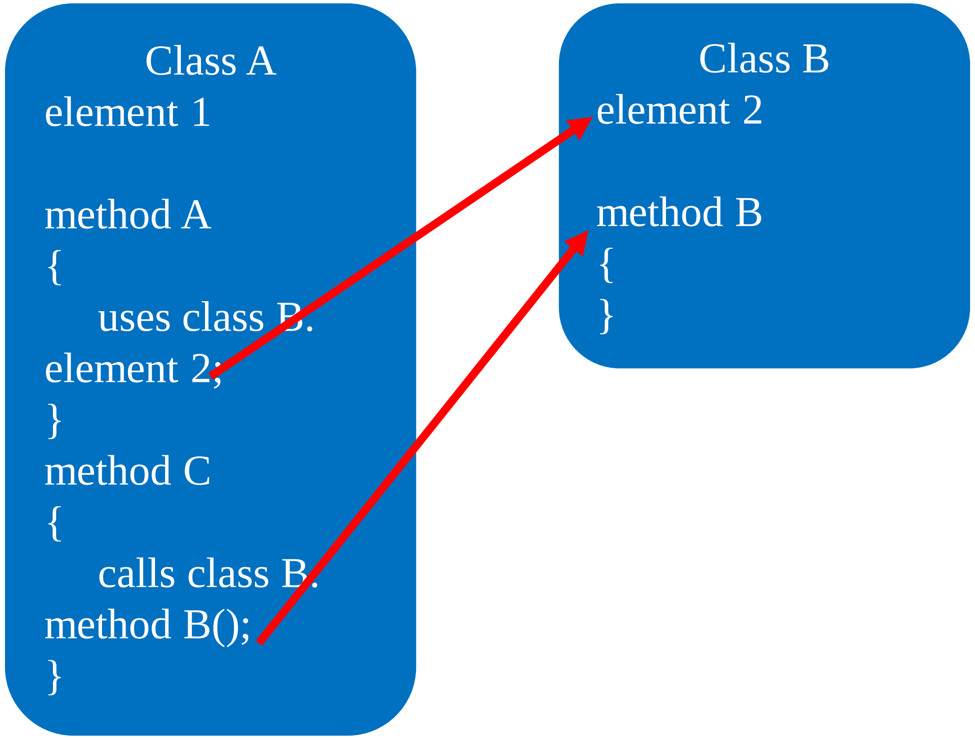
```
Class A
element 1
element 2

method 1
{
    uses element 1;
}
method 2
{
    uses element 2;
}
```

```
Class B
element 1
element 2

method 1
{
    uses element 1;
    uses element 2;
}
method 2
{
    uses element 1;
    uses element 2;
}
```

- Tight Coupling (avoid)



```
Class A
element 1

method A
{
    uses class B.
element 2;
}
method C
{
    calls class B.
method B();
}
```

```
Class B
element 2

method B
{
}
```

Design Choices

- A method of an object may only call methods of:
  - The object itself.
  - An argument of the method.
  - Any object created within the method.
  - Any direct properties/fields of the object.

- Don’t talk to strangers!

- When one wants a dog to walk, one does not command the dog’s legs to walk directly; instead one commands the dog which then commands its own legs.