# CS 520

Theory and Practice of Software Engineering
Fall 2026

**Software architecture and design**

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## Recap: Software Engineering

**What is Software Engineering?**
The complete process of specifying, designing, developing, analyzing, deploying, and maintaining a software system.

**Why is it important?**
- Software is everywhere and complex.
- Software defects are expensive (and annoying).

**Goals**
- Decompose a complex engineering problem.
- Organize processes and effort.
- Improve software reliability.
- Improve developer productivity.

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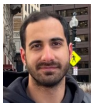
## The CS 520 Teaching Assistants



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## What's coming up?

- Homework 1 posted
  due Sept 29
- Project selection assignment posted
  due Sept 24

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## Today

- Modeling and abstraction
- Software architecture vs. software design
- (very very short) UML crash course

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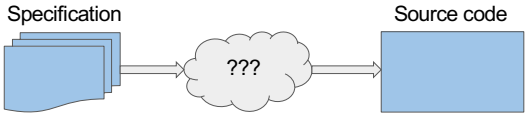
## Software development: the high-level problem

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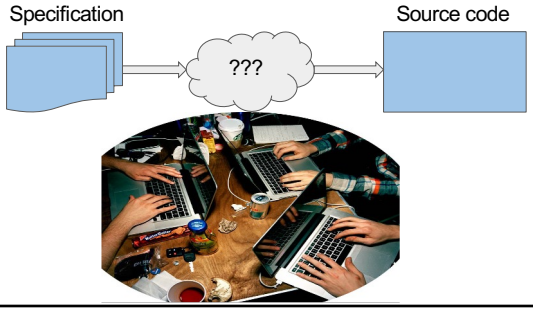
## Software development: the high-level problem

**One solution:** "*Here happens a miracle*"

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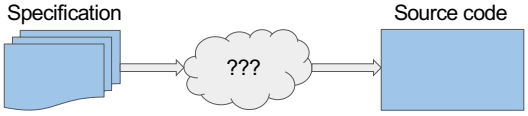
## Software development: the high-level problem

**Another solution:** Modeling the architecture and design

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## What is modeling?

**Building an abstract representation of reality**

- Ignoring (insignificant) details.
- Level of abstraction depends on viewpoint and purpose:
  - Communication
  - Verification
  - Code generation
- Focusing on the most important aspects/properties.

Is abstraction == simplification?

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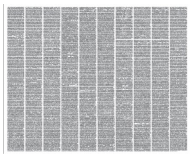
## Different levels of abstraction

Source code



**Example: Linux Kernel**

- 16 million Lines of Code!
- What does the code do?
- Are there dependencies?
- Are there different layers?

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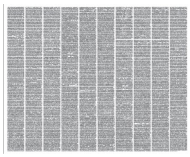
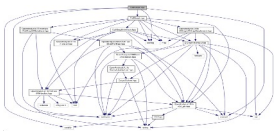
## Different levels of abstraction

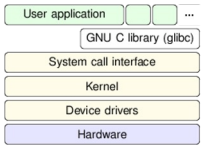
Source code



Call graph



Layer diagram




**Example: Linux Kernel**

- 16 million Lines of Code!
- What does the code do?
- Are there dependencies?
- Are there different layers?

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So, what's the difference between architecture and design?

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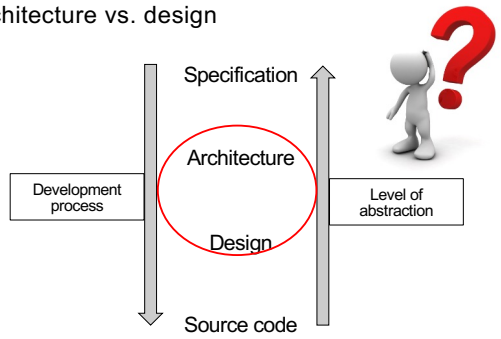
## Architecture vs. design




What's the difference?

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## Software architecture vs. design

**Architecture (what components are developed?)**

- Considers the system as a whole:
  - High-level view of the overall system.
  - What components exist?
  - What type of storage, database, communication, etc?

**Design (how are the components developed?)**

- Considers individual components:
  - Data representation
  - Interfaces, Class hierarchies
  - …

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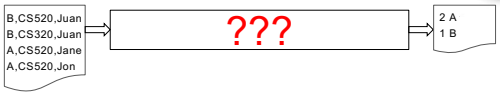
## A first example




Goal: group and count CS520 grades.

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## Architecture or design pattern?


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## Software architecture: Pipe and Filter


The architecture doesn't specify the design or implementation details of the individual components (filters)!

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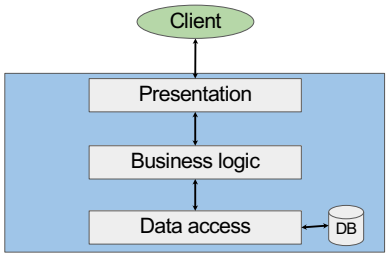
## Software architecture: Client-server / n-tier




Simplifies reusability, exchangeability, and distribution.

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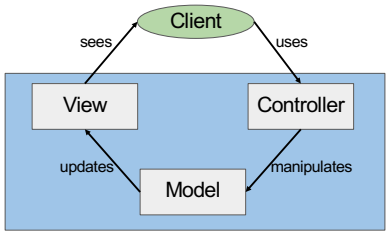
## Software architecture: **M**odel **V**iew **C**ontroler




Separates data representation (Model),
visualization (View), and client interaction (Controller)

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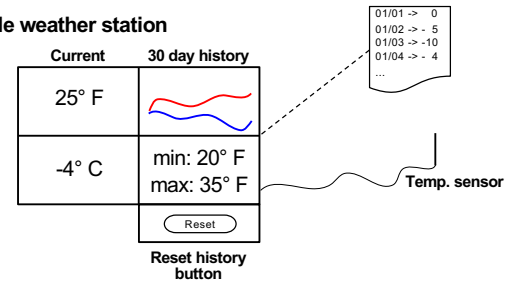
## Model View Controler: example

**Simple weather station**

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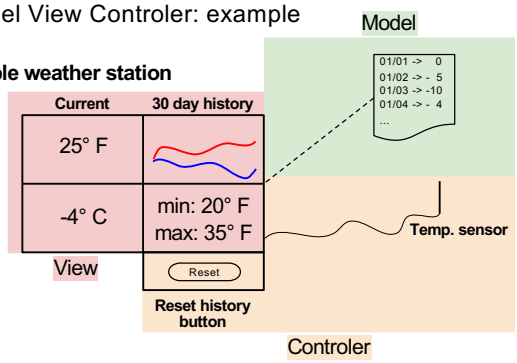


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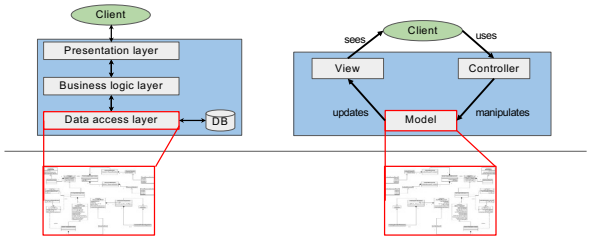
## Summary: Software architecture vs. design




**Architecture and design goals**

- Lower complexity: separation of concerns, well defined interfaces
- Simplify communication
- Allow effort estimation and progress monitoring

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## UML crash course

**The main questions**

- What is UML?
- Is it useful, why bother?
- When to (not) use UML?

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## What is UML?

- Unified Modeling Language.
- Developed in the mid 90's, improved since.
- Standardized notation for modeling OO systems.
- A collection of diagrams for different viewpoints:
  - Use case diagrams
  - Component diagrams
  - Class and Object diagrams
  - Sequence diagrams
  - Statechart diagrams
  - ...

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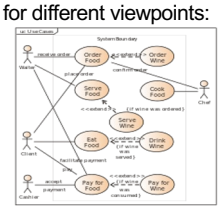

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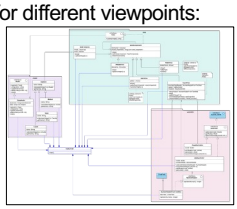

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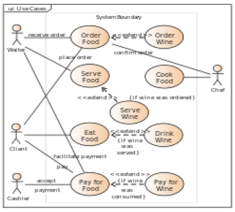
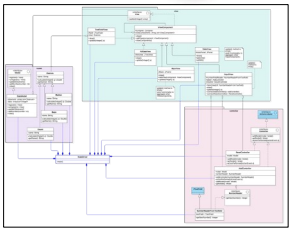
## Are UML diagrams useful?





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## Are UML diagrams useful?

**Communication**

- Forward design (before coding)
  - Brainstorm ideas (on whiteboard or paper).
  - Draft and iterate over software design.

**Documentation**

- Backward design (after coding)
  - Obtain diagram from source code.

**Code generation**

- Generating source code from diagrams is challenging.
- Code generation may be useful for skeletons.

In this class, we will use UML class diagrams mainly for visualization and discussion purposes.

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## Classes vs. objects

**Class**

- Grouping of similar objects.
  - Student
  - Car
- Abstraction of common properties and behavior.
  - Student: Name and Student ID
  - Car: Make and Model

**Object**

- Come from the real world.
- Instance of a class
  - Student: Juan (4711), Jane (4712), …
  - Car: Audi A6, Honda Civic, Tesla S,...

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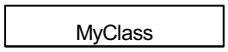
## UML class diagram: basic notation

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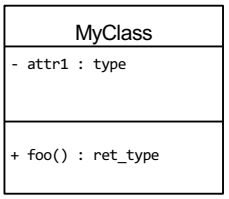


**Name**

**Attributes**

*<visibility> <name> : <type>*

**Methods**

*<visibility> <name>(<param>*) : <return type>*
*<param> := <name> : <type>*

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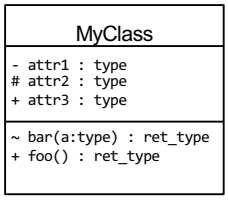


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**Visibility**

*- private*
*~ package-private*
*# protected*
*+ public*

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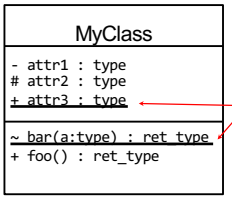


*Static attributes or methods are underlined*

**Name**

**Attributes**

*<visibility> <name> : <type>*

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*<visibility> <name>(<param>*) : <return type>*
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**Visibility**

*- private*
*~ package-private*
*# protected*
*+ public*

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## UML class diagram: concrete example

```
public class Person {
  ...
}
```

**Person**

```
public class Student
    extends Person {
  private int id;
  public Student(String name,
                 int id) {
    ...
  }

  public int getId() {
    return this.id;
  }
}
```

**Student**

```
- id : int
+ Student(name:String, id:int)
+ getId() : int
```

So why bother with UML when you have code?

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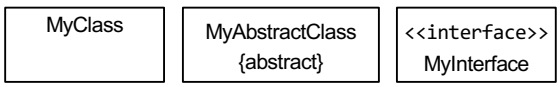
## Classes, abstract classes, and interfaces

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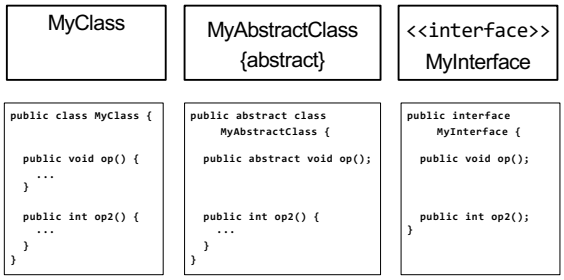


Level of detail in a given class or interface may vary and depends on context and purpose.

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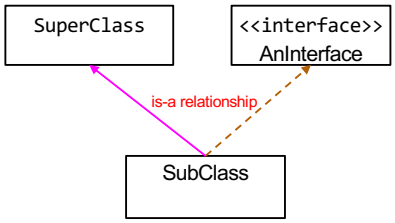
## UML class diagram: Inheritance




```
public class SubClass extends SuperClass implements AnInterface
```

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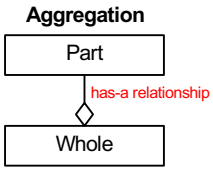
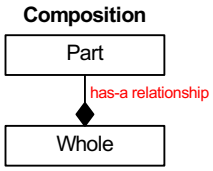
## UML class diagram: Aggregation and Composition




- Existence of Part does not depend on the existence of Whole.
- Lifetime of Part does not depend on Whole.
- No single instance of whole is the unique owner of Part (might be shared with other instances of Whole).




- Part cannot exist without Whole.
- Lifetime of Part depends on Whole.
- One instance of Whole is the single owner of Part.

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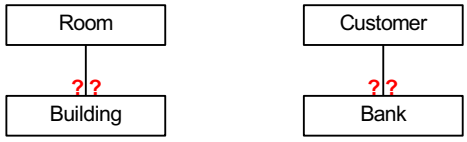
## Aggregation or Composition?

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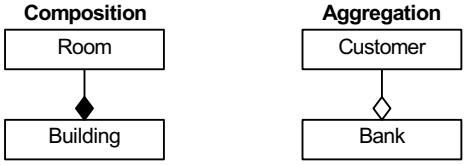
## Aggregation or Composition?




What about class and students or body and body parts?

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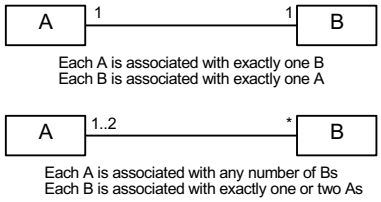
## UML class diagram: multiplicity

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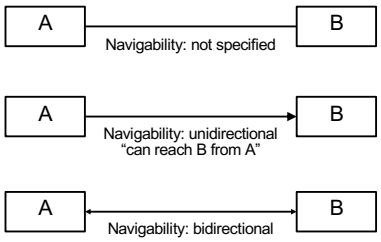
## UML class diagram: navigability

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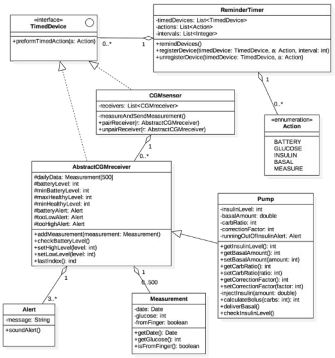
## UML class diagram: example

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## Summary: UML

- Unified notation for modeling OO systems.
- Allows different levels of abstraction.
- Suitable for design discussions and documentation.
- Generating code from diagrams is challenging.

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