CS 520

Theory and Practice of Software Engineering
Fall 2019

Software architecture and design/UML crash course

September 10, 2019

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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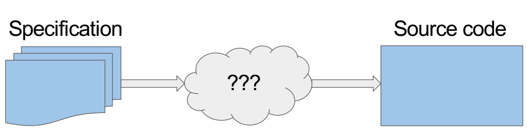
Today

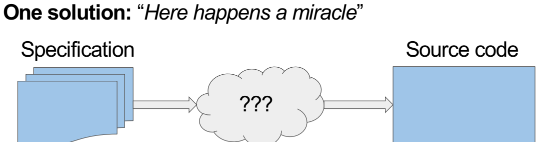
- Modeling and abstraction
- Software architecture vs. software design
- UML crash course

Software development: the high-level problem



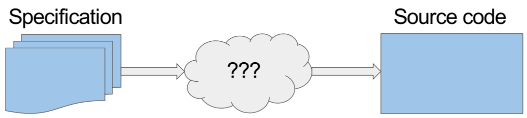
Software development: the high-level problem

One solution: "*Here happens a miracle*"



Software development: the high-level problem

Another solution: Modeling the architecture and design



What is modeling?

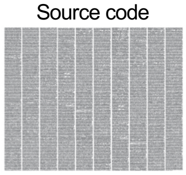
Building an abstract representation of reality

- 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?

Different levels of abstraction

Source code

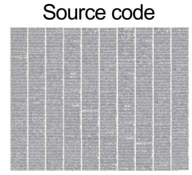


Example: Linux Kernel

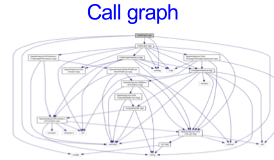
- 16 million Lines of Code!
- What does the code do?
- Are there dependencies?
- Are there different layers?

Different levels of abstraction

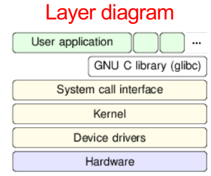
Source code



Call graph



Layer diagram



Example: Linux Kernel

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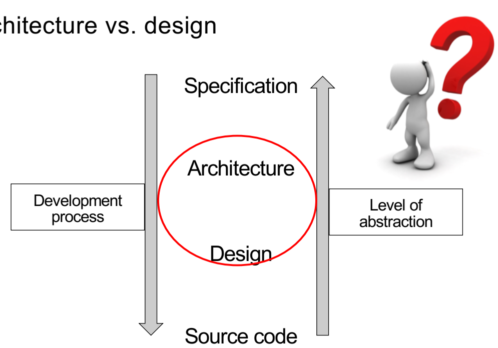
Architecture vs. design



What's the difference?

Software architecture vs. design

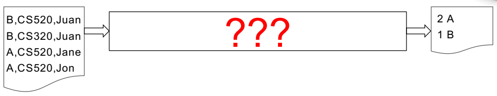
Architecture (what components are developed?)

- 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
  - …

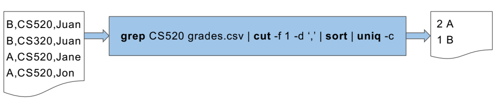
A first example



Goal: group and count CS520 grades.

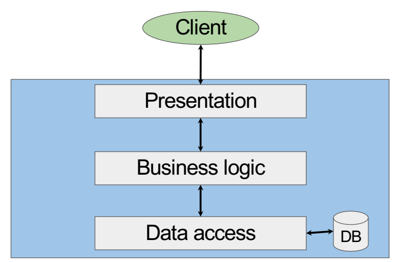
Architecture or design pattern?

Software architecture: Pipe and Filter



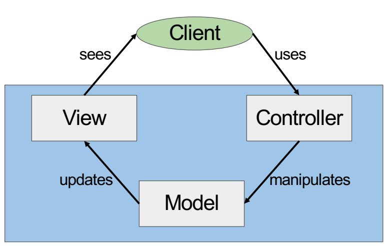
The architecture doesn't specify the design or implementation details of the individual components (filters)!

Software architecture: Client-server / n-tier



Simplifies reusability, exchangeability, and distribution.

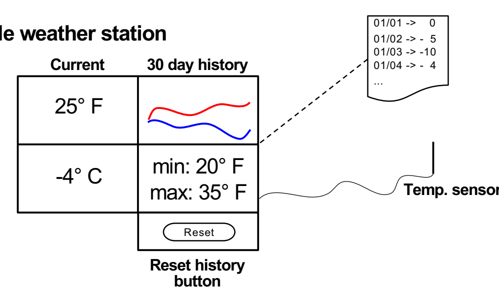
Software architecture: **M**odel **V**iew **C**ontroler



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

Model View Controler: example

Simple weather station



Model View Controler: example

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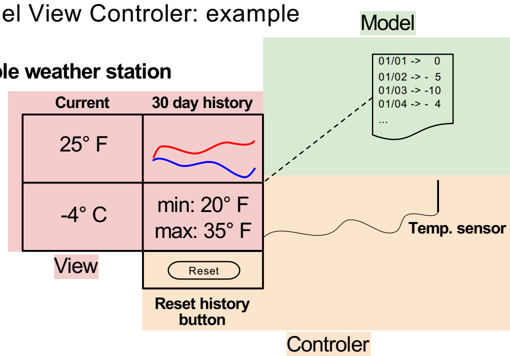
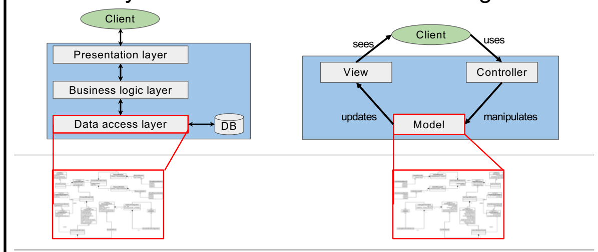


Summary: Software architecture vs. design



Architecture and design goals

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

UML crash course

The main questions

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

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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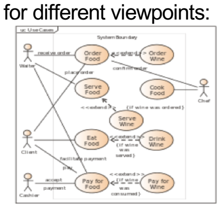

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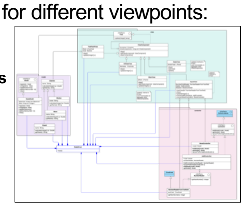
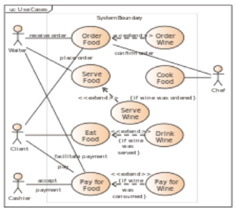
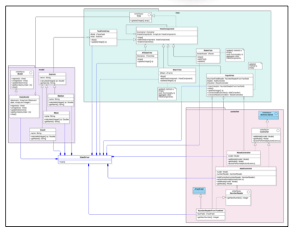


Are UML diagrams useful?





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.

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,...

UML class diagram: basic notation

MyClass

UML class diagram: basic notation

MyClass
- attr1 : type
+ foo() : ret_type

Name

Attributes
<visibility> <name> : <type>

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

UML class diagram: basic notation

MyClass
- attr1 : type # attr2 : type + attr3 : type
~ bar(a:type) : ret_type + foo() : ret_type

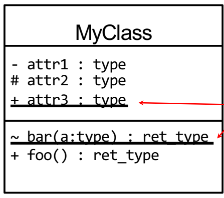
Name

Attributes
<visibility> <name> : <type>

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

Visibility
- private
~ package-private
# protected
+ public

UML class diagram: basic notation



Name

Attributes

<visibility> <name> : <type>

Static attributes or methods are underlined

Methods

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

<param> := <name> : <type>

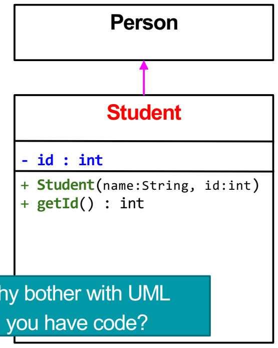
Visibility

- private
~ package-private
 # protected
+ public

UML class diagram: concrete example

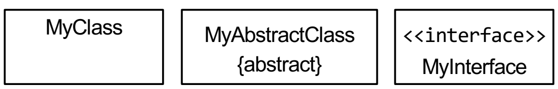
```
public class Person {
  ...
}
```

```
public class Student
     extends Person {

  private int id;
  public Student(String name,
                 int id) {
    ...
  }

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

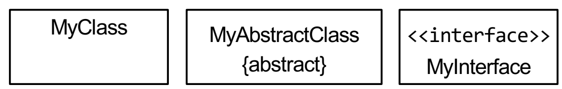


So why bother with UML when you have code?

Classes, abstract classes, and interfaces



Classes, abstract classes, and interfaces



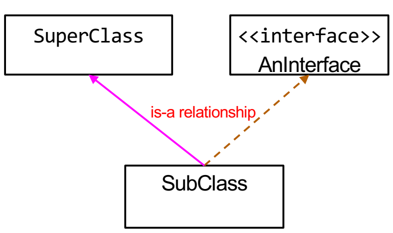

```
public class MyClass {

  public void op() {
    ...
  }

  public int op2() {
    ...
  }
}
```

```
public abstract class
    MyAbstractClass {

  public abstract void op();

  public int op2() {
    ...
  }
}
```

```
public interface
    MyInterface {

  public void op();

  public int op2();
}
```

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

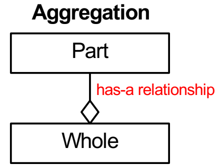
UML class diagram: Inheritance




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

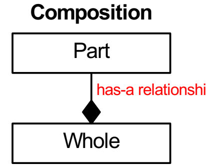
UML class diagram: Aggregation and Composition

Aggregation



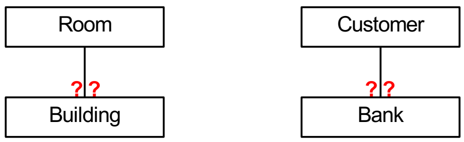
- Existence of Part does not depend on the existence of Whole.
- Lifetime of Part does not depend on Whole.
- No single instance of whole is the unique owner of Part (might be shared with other instances of Whole).

Composition

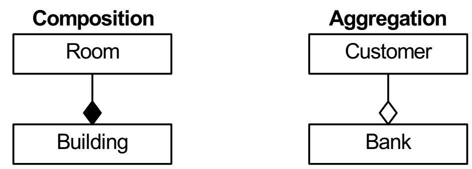


- Part cannot exist without Whole.
- Lifetime of Part depends on Whole.
- One instance of Whole is the single owner of Part.

Aggregation or Composition?

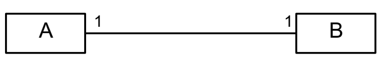


Aggregation or Composition?

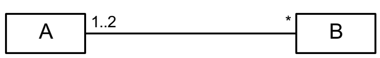


What about class and students or body and body parts?

UML class diagram: multiplicity

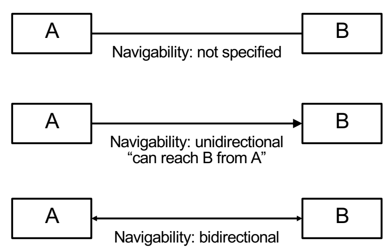


Each A is associated with exactly one B
Each B is associated with exactly one A

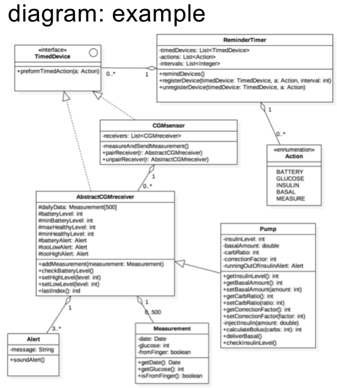


Each A is associated with any number of Bs
Each B is associated with exactly one or two As

UML class diagram: navigability



UML class diagram: example



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.