CMSC 132:
Object-Oriented Programming II

Unified Modeling Language (UML)

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UML (Unified Modeling Language)

- UML is a modeling language for
  - Specifying
  - Visualizing
  - Constructing
  - Documenting

object-oriented software
Motivation

- Software growing larger & complex
  - Difficult to describe and analyze

- Use UML to help
  - Visualize design of software
  - Provide abstract model of software
Goals

- Provide a software “blueprint”
  - Simple yet clear abstraction for software

- Describe software design
  - Clearly
  - Concisely
  - Correctly
History of UML

- Started in 1994

- Combines 3 leading OO methods
  - OMT (James Rumbaugh)
  - OOSE (Ivar Jacobson)
  - Booch (Grady Booch)
UML diagrams

UML provides a number of **diagrams** that

- Describe a **model** of all or part of system
- From a particular point of **view**
- With varying level of abstraction
- Using certain set of notations
Class Diagram

- Represents (static) structure of system

- A class diagram displays
  - Information for class
  - Relationships between classes
Class diagrams represent structure of system.
Class Diagrams

Information for class contains
- Name
- State
- Behavior

```
<table>
<thead>
<tr>
<th>Clock</th>
</tr>
</thead>
<tbody>
<tr>
<td>seconds: int</td>
</tr>
<tr>
<td>minutes: int</td>
</tr>
<tr>
<td>hours: int</td>
</tr>
<tr>
<td>start()</td>
</tr>
<tr>
<td>adjustTime()</td>
</tr>
<tr>
<td>reset()</td>
</tr>
</tbody>
</table>
```
Class Diagram

- Class name is required
- Other information optional
  - State, behavior
  - Types, visibility...

(a) Clock

<table>
<thead>
<tr>
<th>List of States and Behaviors</th>
</tr>
</thead>
<tbody>
<tr>
<td>secs:int</td>
</tr>
<tr>
<td>mins:int</td>
</tr>
<tr>
<td>hours:int</td>
</tr>
<tr>
<td>setTime()</td>
</tr>
<tr>
<td>adjustTime()</td>
</tr>
<tr>
<td>reset()</td>
</tr>
</tbody>
</table>

(b) Clock

<table>
<thead>
<tr>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>secs:int</td>
</tr>
<tr>
<td>mins:int</td>
</tr>
<tr>
<td>hours:int</td>
</tr>
</tbody>
</table>

(c) Clock

<table>
<thead>
<tr>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>secs:int</td>
</tr>
<tr>
<td>mins:int</td>
</tr>
<tr>
<td>hours:int</td>
</tr>
<tr>
<td>setTime()</td>
</tr>
<tr>
<td>adjustTime():void</td>
</tr>
<tr>
<td>reset():void</td>
</tr>
</tbody>
</table>
UML Class Diagrams ↔ Java Code

- Different representation of same information
  - Name, state, behavior of class
  - Relationships between classes
- Should be able to derive one from the other

Motivation

- **UML ⇒ Java**
  - Implement code based on design written in UML
- **Java ⇒ UML**
  - Create UML to document design of existing code
Java → UML : Clock Example

Java

class Clock {
    // name
    // state
    int seconds;
    int minutes;
    int hours;
    // behavior
    void start();
    void adjustTime();
    void reset();
}

Java Code

Class Diagram
UML Class Diagram Notation

- **Type** ⇒ type name preceded by colon :
- **Visibility** ⇒ prefix symbol
  - + public
  - – private
  - # protected
  - ~ package
- **Static** ⇒ underline
- **Types of relationships**
  - **Generalization**
    - Inheritance
    - Implementation
  - **Association**
    - Dependency
Java → UML : Clock Example

Java Code

```java
class Clock {
    // name

    // state
    private int seconds;
    private int minutes;
    private int hours;

    // behavior
    public void setTime( );
    public void adjustTime(int value);
    public void reset( );
}
```

Class Diagram

```
Clock
- seconds : int
- minutes : int
- hours : int
+ setTime( ) : void
+ adjustTime( ) : void
+ reset( ) : void
```
Generalization

- Denotes inheritance between classes
  - Can view as “is a” relationship

- Example
  - Lecturer is a person (Lecturer extends Person class)

- Types of generalization
  - Subclass extends superclass
    - Solid line ending in (open) triangle
  - Class implements interface
    - Dotted line ending in (open) triangle
Generalization Example

Inheritance

Laptop, Desktop, PDA inherit state & behavior from Computer
Generalization Example

- Abstract Classes are represented by italicizing the name

  Abstract class Shape

- Interfaces are prefaced with <<interface>>

  Laptop implements DVDplayer interface
Association

- Denotes interaction between two classes

Example

- **Lecturer teaches course**
  - Indicates relationship between Lecturer & Course
Association w/ Navigation

Navigation information

- Relationship between classes may be directional
  - Only class A can send messages to class B
- Arrowhead indicates direction of relationship

Example

```java
class Course {
    Lecturer TheBoss;
}
```

```java
class Lecturer {
    ...
}
```
Association w/o Navigation

- Undirected edge
  - Relationship between classes may be bi-directional
  - Direction of relationship may be unknown

- Examples

```java
class Course {
    Lecturer TheBoss;
}
class Lecturer {
    Course [ ] class;
}
class Foo

class Bar
```
Permanent Association

Permanent / structural association
- Class A contains reference to class B in data field
- Can view as “has a” relationship
- Also referred to as composition

Example

```java
class A {
    B x;
}
class B {
    ...
}
```

A has a B
Temporary Association (Dependency)

- A transitory relationship between classes
  - Always directed (class A depends on B)
  - Indicates change in class B may affect class A
  - Can view as “uses a” relationship
  - Represented by dotted line with arrowhead

Example

A depends on B
Dependency

Dependence may be caused by

- Local variable
- Parameter
- Return value

Example

class A {
    B foo(B x) {
        B y = new( );
        ...
    }
}

class B {
    ...
    ...
}

Inner/Nested Classes

Anchor (cross inside a circle) associated with enclosing class
UML Examples

- Read UML class diagram
  - Try to understand relationships
  - Practice converting to / from Java code

- Examples
  - Computer disk organization
  - Banking system
  - Home heating system
  - Printing system
UML Example – Computer System

Try to read & understand UML diagram

- CPU is associated with Controllers
- DiskDrive is associated with SCSIController
- SCSIController is a (type of) Controller
- Bank associated with Accounts
- Checking, Savings, MoneyMarket are type of Accounts
• Thermostat associated with (has a) Room
• Thermostat associated with (has a) Heater
• ElectricHeater is a specialized Heater
• AubeTH101D is a specialized Thermostat
Try to read & understand UML diagram

- Books are associated with (has some) Pages
- Patron & Shelf depend on (temporarily use) Books
**UML → Java : Computer System**

- **UML**
  
  ![UML Diagram](image)

- **Java**
  ```java
  class Controller {
  }
  
  class SCSIController extends Controller {
  }
  ```
Design code using all available information in UML…
Java

class CPU {
    Controller myCtlrs[];
}
class Controller {
    CPU myCPU;
}
class SCSIController extends Controller {
    DiskDrive myDrive[4];
}
Class DiskDrive {
    SCSIController mySCSI;
}
Java → UML : Printing System

Java

class Registry {
    PrintQueue findQueue();
}
class PrintQueue {
    List printJobs;
    Printer myPrinter;
    Registry myRegistry;
    void newJob();
    int length();
    Resources getResource();
}
Java → UML: Printing System

Java

```java
Class Printer {
    Resources myResources;
    Job curJob;
    void print();
    boolean busy();
    boolean on();
}

class Job {
    Job(Registry r) {
        ...
    }
}
```
Java - UML: Printing System

Java

All together
UML Tools

- Can automatically generate UML diagrams from code
- Code from UML diagrams

Examples
- AmaterasUML
- Violet
Drag-n-drop classes into UML diagram
- Auto creates class w/ attributes & methods
- Add links manually
- No directed associations
- Use undirected association + directed dependency together
Drag-n-drop classes into UML diagram
- Auto creates class with attributes & methods
- Add links manually
  - No undirected associations
  - Use directed association in both directions instead
Violet UML Editor – Eclipse Plugin
UML Summary

- UML → modeling language
- Visually represents design of software system
- We focused on class diagrams
  - Contents of a class
  - Relationship between classes
- You should be able to
  - Draw UML class diagram given Java code
  - Write Java code given UML class diagram