Lecture 8

Game Architecture Revisited
Recall: The Game Loop

**Update**
- Receive player input
- Process player actions
- Process NPC actions
- Interactions (e.g. physics)

**Draw**
- Cull non-visible objects
- Transform visible objects
- Draw to backing buffer
- Display backing buffer

60 times/s = 16.7 ms
Almost everything is in loop
- Except asynchronous actions
- Is enough for simple games

How do we organize this loop?
- Do not want spaghetti code
- Distribute over programmers
Model-View-Controller Pattern

Controller
- Updates model in response to events
- Updates view with model changes

Model
- Defines/manages the program data
- Responds to the controller requests

View
- Displays model to the user/player
- Provides interface for the controller

Controller calls the methods of the model.
The Game Loop and MVC

• **Model**: The game state
  • Value of game resources
  • Location of game objects

• **View**: The draw phase
  • Rendering commands only
  • Major computation in update

• **Controller**: The update phase
  • Alters the game state
  • Vast majority of your code
Structure of a CUGL Application

Main → Application

- Scene
  - Models
  - Root Node
- Scene
  - Models
  - Root Node

Architecture Revisited
Structure of a CUGL Application

Main

Application

Memory policy (future lecture)

App Configuration

Scene

Models

Root Node

Scene

Models

Root Node

Architecture Revisited
Structure of a CUGL Application

Main → Application
→ Active
→ Scene
→ Models
→ Root Node
→ Dormant
→ Scene
→ Models
→ Root Node
The Application Class

onStartup()

- Handles the game assets
  - Attaches the asset loaders
  - Loads immediate assets
- Starts any global singletons
  - Example: AudioEngine
- Creates any player modes
  - But does not launch yet
  - Waits for assets to load
  - Like GDXRoot in 3152

update()

- Called each animation frame
- Manages gameplay
  - Converts input to actions
  - Processes NPC behavior
  - Resolves physics
  - Resolves other interactions
- Updates the scene graph
  - Transforms nodes
  - Enables/disables nodes
The Application Class

**onStartup()**

- Handles the game assets
- Attaches the asset loaders
- Loads immediate assets
- Starts any player modes
- But does not launch yet
- Waits for assets to load
- Like `GDXRoot` in 3152

**onShutdown()**

- Cleans this up

**update()**

- Called each animation frame
- Manages gameplay
- Converts input to actions
- Processes NPC behavior
- Resolves physics
- Resolves other interactions
- Updates the scene graph
- Transforms nodes
- Enables/disables nodes

**Does not draw!**

Handled separately
Application Structure

Ownership

Collaboration

Architecture Revisited
Application Structure

Ownership

Collaboration
- Must import class/interface
- Instantiates an object OR
- Calls the objects methods

Ownership
- Instantiated the object
- Responsible for disposal
- Superset of collaboration

Collaboration
Avoid Cyclic Collaboration

Controller

Y

Z

collaborates with

collaborates with

collaborates with

X

Y

X
Scene Structure

Scene

Subcontroller

Model

Subcontroller

Model

Subcontroller

Model

View

?
The Problem: Physics
The Problem: Physics

How big is that scene graph?
CUGL Views: Scene Graphs

Architecture Revisited
CUGL Views: Scene Graphs

Architecture Revisited
CUGL Views: Scene Graphs

Topic for Another Lecture
# Model-Controller Separation (Standard)

<table>
<thead>
<tr>
<th>Model</th>
<th>Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Store/retrieve <strong>object data</strong></td>
<td>• Process <strong>user input</strong></td>
</tr>
<tr>
<td>• Limit access (getter/setter)</td>
<td>• Determine action for input</td>
</tr>
<tr>
<td>• Preserve any invariants</td>
<td>• <strong>Example</strong>: mouse, gamepad</td>
</tr>
<tr>
<td>• Only affects this object</td>
<td>• Call action in the model</td>
</tr>
<tr>
<td>• Implements <strong>object logic</strong></td>
<td></td>
</tr>
<tr>
<td>• Complex actions on model</td>
<td></td>
</tr>
<tr>
<td>• May affect multiple models</td>
<td></td>
</tr>
<tr>
<td>• <strong>Example</strong>: attack, collide</td>
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**Traditional controllers are “lightweight”**
Classic Software Problem: Extensibility

• **Given**: Class with some base functionality
  • Might be provided in the language API
  • Might be provided in 3\text{rd} party software

• **Goal**: Object with *additional* functionality
  • Classic solution is to subclass original class first
  • **Example**: Extending GUI widgets (e.g. Swing)

• But subclassing does not always work…
  • How do you extend a *Singleton* object?
Problem with Subclassing

- Games have *lots* of classes
  - Each game entity is different
  - Needs its own functionality (e.g. object methods)
- Want to avoid *redundancies*
  - Makes code hard to change
  - Common source of bugs
- Might be tempted to *subclass*
  - Common behavior in parents
  - Specific behavior in children
Problem with Subclassing

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Model-Controller Separation (Standard)

Model

- Store/retrieve **object data**
  - Limit access (getter/setter)
  - Preserve any invariants
  - Only affects this object
- Implements **object logic**
  - Complex actions on model
  - May affect multiple models
  - **Example**: attack, collide

Redundant Behavior
Model-Controller Separation (Alternate)

### Model
- Store/retrieve **object data**
  - Limit access (getter/setter)
  - Preserve any invariants
  - Only affects this object

### Controller
- Process **game actions**
  - Determine from input or AI
  - Find *all* objects effected
  - Apply action to objects

- Process **interactions**
  - Look at current game state
  - Look for “triggering” event
  - Apply interaction outcome

In this case, models are lightweight
Does Not Completely Solve Problem

- Code **correctness** a concern
  - Methods have specifications
  - Must use according to spec
- Check correctness via **typing**
  - Find methods in object class
  - **Example**: orc.flee()
  - Check type of parameters
  - **Example**: force_to_flee(orc)
- **Logical** association with type
  - Even if not part of class

Can I **flee?**
Issues with the OO Paradigm

- Object-oriented programming is very noun-centric
  - All code must be organized into classes
  - Polymorphism determines capability via type

- OO became popular with traditional MVC pattern
  - Widget libraries are nouns implementing view
  - Data structures (e.g. CS 2110) are all nouns
  - Controllers are not necessarily nouns, but lightweight

- Games, interactive media break this paradigm
  - View is animation (process) oriented, not widget oriented
  - Actions/capabilities only loosely connected to entities
Programming and Parts of Speech

Classes/Types are Nouns

- Methods have verb names
- Method calls are sentences
  - subject.verb(object)
  - subject.verb()
- Classes related by *is-a*
  - Indicates class a subclass of
  - Example: String *is-a* Object
- Objects are class *instances*

Actions are Verbs

- Capability of a game object
- Often just a simple function
  - damage(object)
  - collide(object1,object1)
- Relates to objects via *can-it*
  - Example: Orc *can-it* attack
  - Not necessarily tied to class
  - Example: swapping items
Duck Typing: Reaction to This Issue

- “Type” determined by its
  - Names of its methods
  - Names of its properties
  - If it “quacks like a duck”
- Python has this capability
  - `hasattr(<object>,<string>)`
  - True if object has attribute or method of that name
- This has many **problems**
  - Correctness is a **nightmare**

**Java:**

```java
public boolean equals(Object h) {
    if (!(h instanceof Person)) {
        return false;
    }
    Person ob = (Person)h;
    return name.equals(ob.name);
}
```

**Python:**

```python
def __eq__(self,ob):
    if (not (hasattr(ob,'name')))
        return False
    return (self.name == ob.name)
```
Duck Typing: Reaction to This Issue

- “Type” determined by its
  - Names of its methods
  - Names of its properties
  - If it “quacks like a duck”

Python has this capability
- hasattr(<object>,<string>)
  - True if object has attribute or method of that name

This has many problems
- Correctness is a nightmare

Java:

- What do we really want?
  - Capabilities over properties
  - Extend capabilities without necessarily changing type
  - Without using new languages

Again, use software patterns

- public boolean equals(Object h) {
  if (!(h instanceof Person)) {
    return false;
  }
  Person ob = (Person)h;
  return name.equals(ob.name);
}

- def __eq__(self, ob):
  if (not (hasattr(ob, 'name')))
    return False
  return (self.name == ob.name)

- return False
- return (self.name == ob.name)
Possible Solution: Decorator Pattern

Request → Decorator Object → Original Object

New Functionality

Original Functionality
Java I/O Example

```java
InputStream input = System.in;
Reader reader = new InputStreamReader(input);
BufferedReader buffer = new BufferedReader(reader);
```

- **Built-in console input**
- **Make characters easy to read**
- **Read whole line at a time**

Most of `java.io` works this way.
Alternate Solution: Delegation Pattern

Inversion of the Decorator Pattern
Alternate Solution: Delegation Pattern

Inversion of the Decorator Pattern
Example: Sort Algorithms

```java
public class SortableArray extends ArrayList {

    private Sorter sorter = new MergeSorter();
    new QuickSorter();

    public void setSorter(Sorter s) { sorter = s; }

    public void sort() {
        Object[] list = toArray();
        sorter.sort(list);
        clear();
        for (o:list) { add(o); }
    }
}
```

```java
public interface Sorter {
    public void sort(Object[] list);
}
```
### Comparison of Approaches

<table>
<thead>
<tr>
<th><strong>Decoration</strong></th>
<th><strong>Delegation</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Pattern applies to <em>decorator</em></td>
<td></td>
</tr>
<tr>
<td>• Given the original object</td>
<td></td>
</tr>
<tr>
<td>• Requests through decorator</td>
<td></td>
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<tr>
<td>• Monolithic solution</td>
<td></td>
</tr>
<tr>
<td>• Decorator has all methods</td>
<td></td>
</tr>
<tr>
<td>• “Layer” for more methods</td>
<td></td>
</tr>
<tr>
<td>(e.g. Java I/O classes)</td>
<td></td>
</tr>
<tr>
<td>• Works on <em>any</em> object/class</td>
<td></td>
</tr>
<tr>
<td>• Applies to <em>original object</em></td>
<td></td>
</tr>
<tr>
<td>• You designed object class</td>
<td></td>
</tr>
<tr>
<td>• All requests through object</td>
<td></td>
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<tr>
<td>• Modular solution</td>
<td></td>
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<tr>
<td>• Each method can have own delegate implementation</td>
<td></td>
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<tr>
<td>• Like higher-order functions</td>
<td></td>
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<tr>
<td>• Limited to classes you make</td>
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</tbody>
</table>
The Subclass Problem Revisited

Redundant Behavior

Delegates?

NPC

Human

Warrior

Orc

Human

Archer

Orc

Warrior

Orc

Archer

Human

Warrior

Archer

Orc

NPC

Slot

Slot

Slot
A C++ Solution: Mix-Ins

- **Orthogonal class design**
- Start with common base
- Only one level of superclass
- Other classes can combine

- **Needs C++ templates**
- Templatize base class
- Nest templates to mix

- **Builds an inheritance tree**
- But tree details not needed
- Stacking is commutative

```cpp
class Number {
    int n;
    void set(int v) { n = v; }
    int get() const { return n; }
};

template <typename BASE>
class Undo : public BASE {
    int pre;
    void set(int v) { pre = BASE::get(); BASE::set(v); }
    void undo() { BASE::set(pre); }
};

template <typename BASE>
class Redo : public BASE {
    int post;
    void set(int v) { post = v; BASE::set(v); }
    void redo() { BASE::set(post); }
};

typedef Redo< Undo<Number> > ReUndoNumber;
```
Summary

- Games naturally fit a **specialized MVC** pattern
  - Want *lightweight* models (mainly for serialization)
  - Want *heavyweight* controllers for the game loop
  - View is specialized rendering with few widgets

- Proper design leads to unusual OO patterns
  - Subclass hierarchies are unmanageable
  - **Component-based design** better models actions
  - More advanced patterns supported by C++.