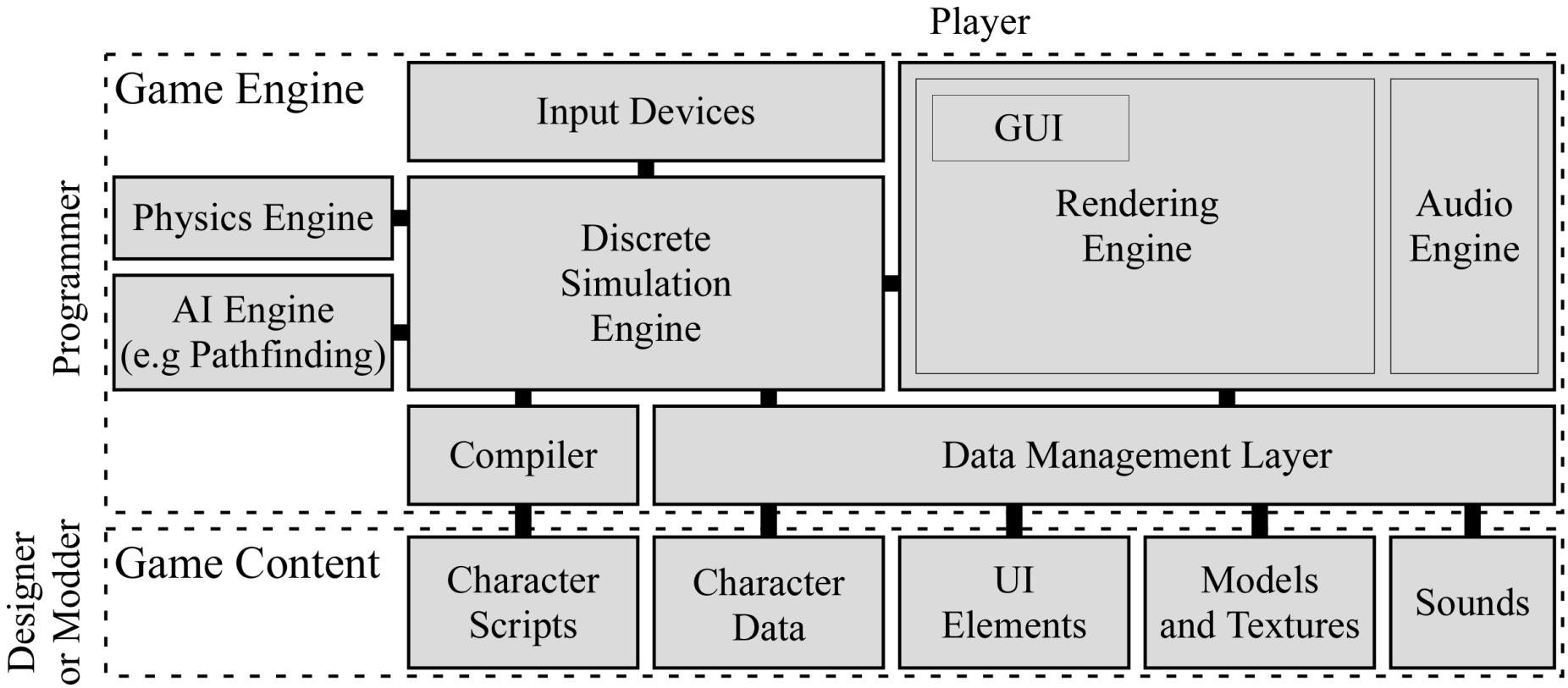
the gamedesigninitiative at cornell university

Lecture 11

Architecture Patterns

Architecture: The Big Picture



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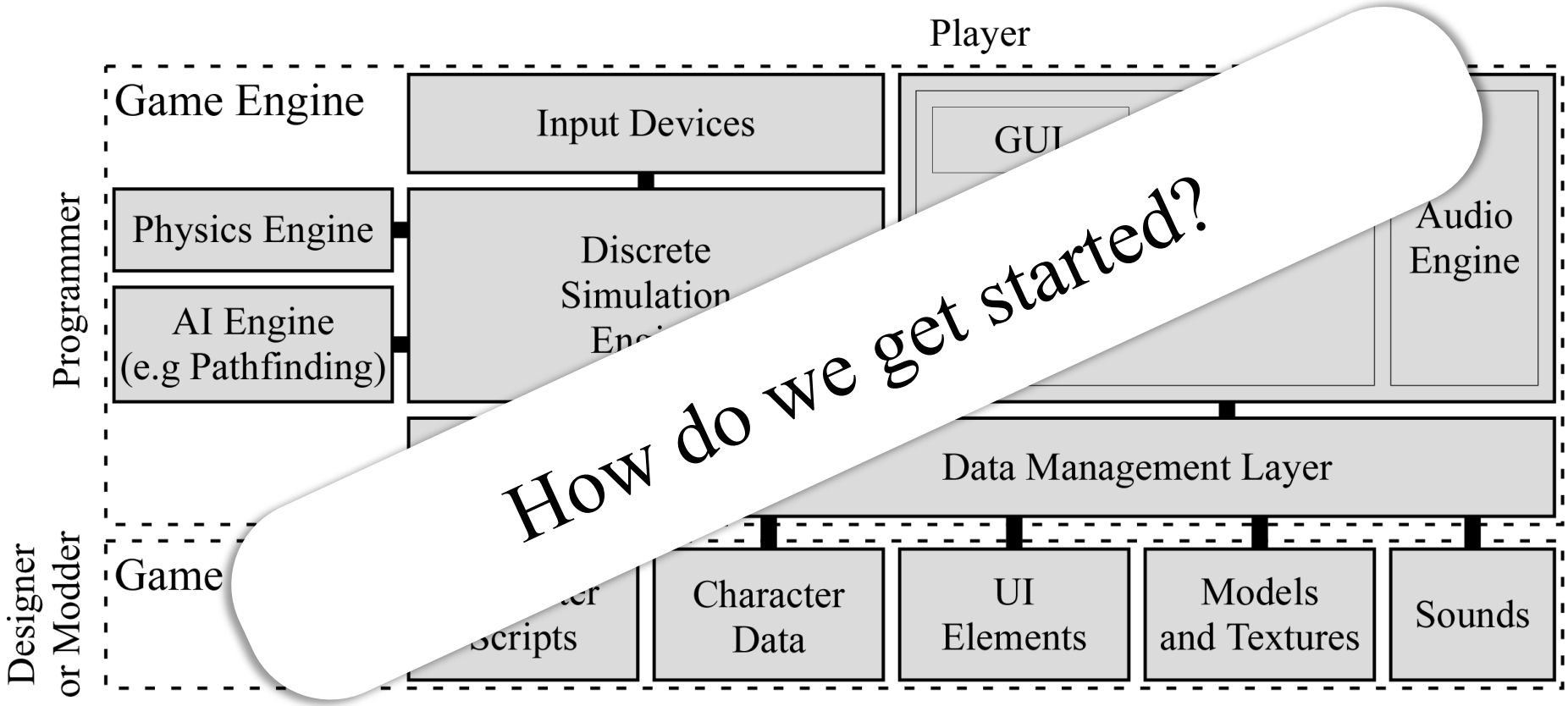

Utilizing Software Patterns

- **Pattern**: reusable solution to a problem
  - Typically a template, not a code library
  - Tells you how to design your code
  - Made by someone who ran into problem first
- In many cases, pattern gives you the interface
  - List of headers for non-hidden methods
  - Specification for non-hidden methods
  - Only thing missing is the implementation

2110 all over again

Example: Singletons

- **Goal**: Want to limit class to a single instance
  - Do not want to allow users to construct new objects
  - But do want them to access the single object
- **Application**: Writing to the console/terminal
  - Want a unique output stream to write to console
  - Many output streams would conflict w/ each other
  - Given by a unique object in Java (System.out)
  - A class with static methods in C# (not a singleton)

Creating a Singleton in Java

```
public class Singleton {

    public static final Singleton instance = new Singleton();

    private Singleton() {
        // Initialize all fields for instance
    }

    public static Singleton getInstance() {
        return instance;
    }
}
```

Creating a Singleton in Java

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public class Singleton {

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}
```

Keep user from instantiating

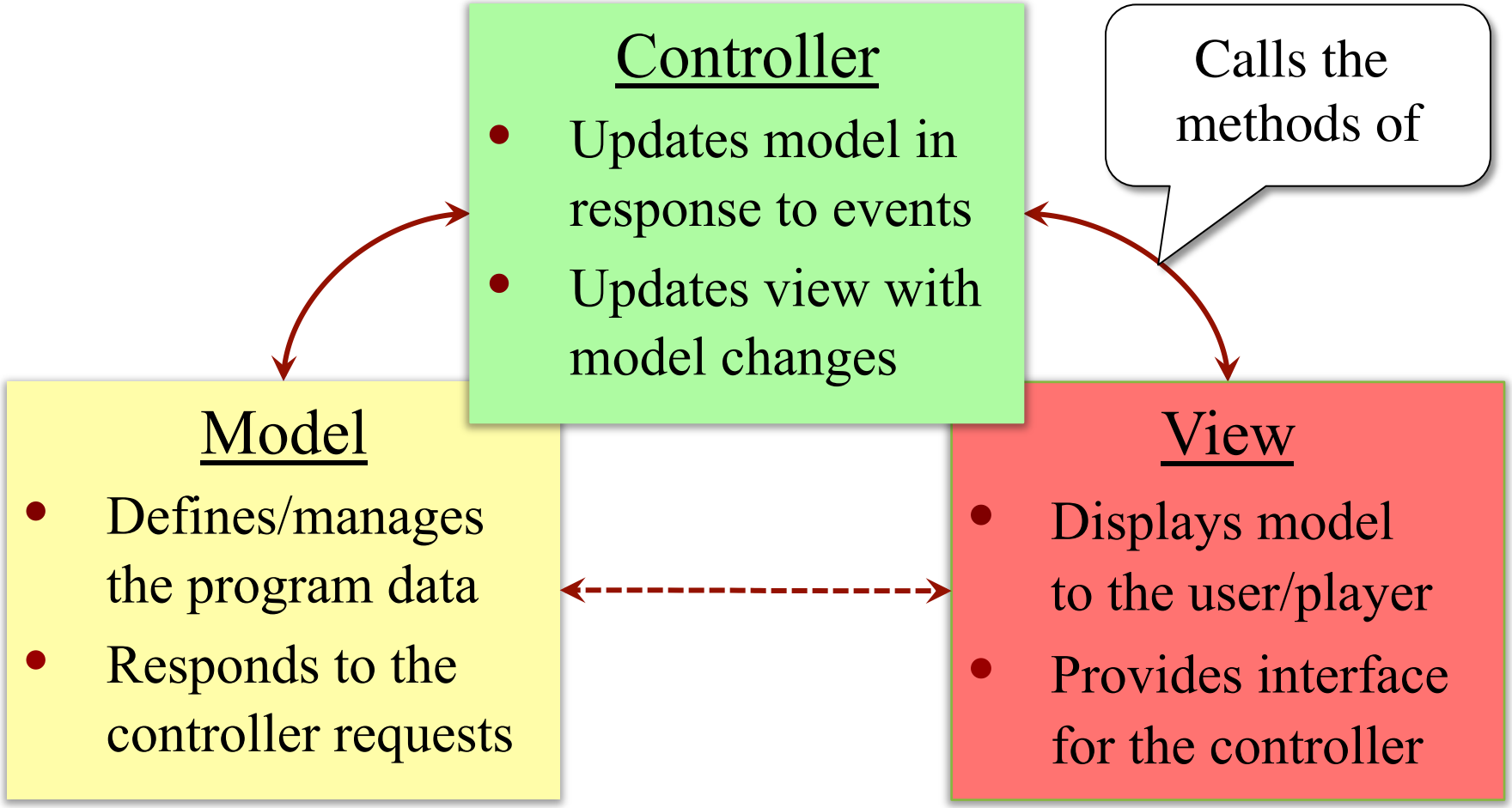
Provide as an immutable constant

Static method is an alternative to providing access with a constant

Architecture Patterns

- Essentially same idea as **software pattern**
  - Template showing how to organize code
  - But does not contain any code itself
- Only difference is **scope**
  - **Software pattern**: simple functionality
  - **Architecture pattern**: complete program
- Classic pattern: Model-View-Controller (MVC)
  - Most popular pattern in *single client* applications

Model-View-Controller Pattern



Example: Temperature Converter

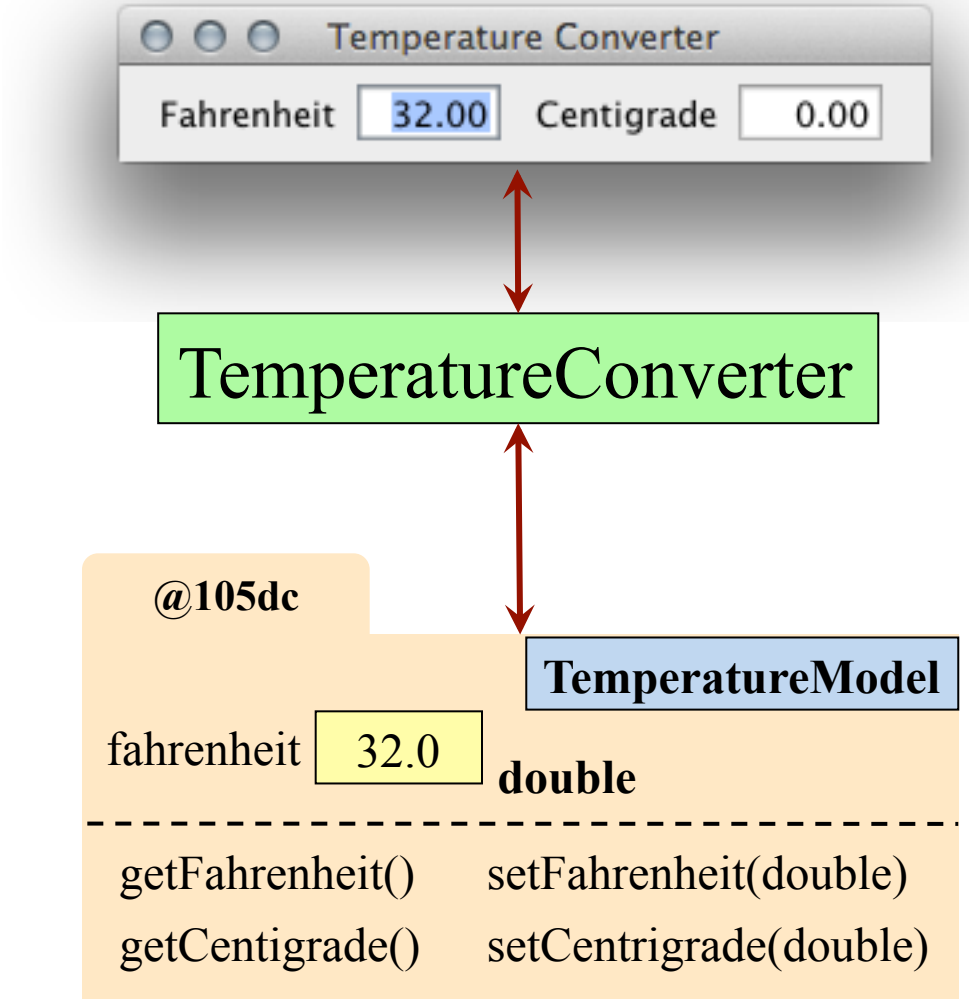
- Model: (TemperatureModel.java)
  - Stores one value: fahrenheit
  - But the methods present two values
- View: (TemperatureView.java)
  - Constructor creates GUI components
  - Recieves user input but does not "do anything"
- Controller: (TemperatureConverter.java)
  - **Main class**: instantiates all of the objects
  - "Communicates" between model and view

TemperatureConverter Example

View

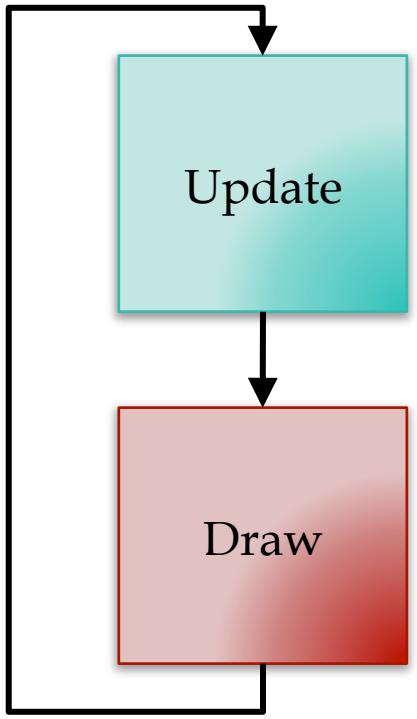
Controller

Model



The Game Loop and MVC

- Model: The game state
  - Value of game resources
  - Location of game objects
- View: The draw phase
  - Focus of upcoming lectures
- Controller: The update phase
  - Alters the game state
  - Topic of previous lecture



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

Controller

- Process **user input**
  - Determine action for input
  - **Example**: mouse, gamepad
  - Call action in the model

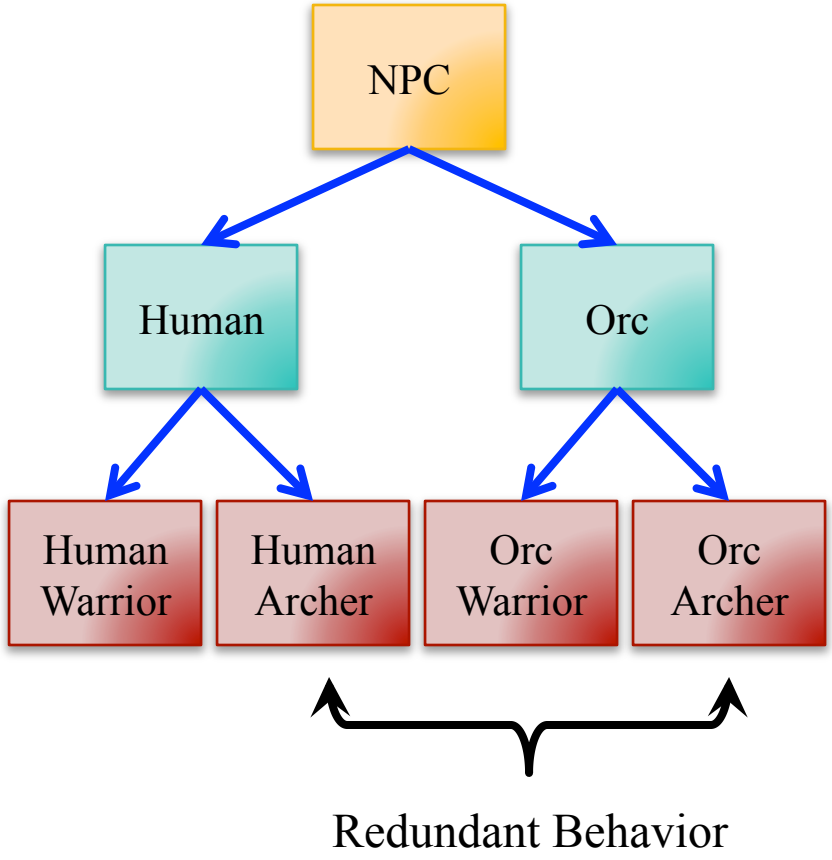
Traditional controllers are "lightweight"

Classic Software Problem: Extensibility

- **Given**: Class with some base functionality
  - Might be provided in the language API
  - Might be provided in 3rd 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



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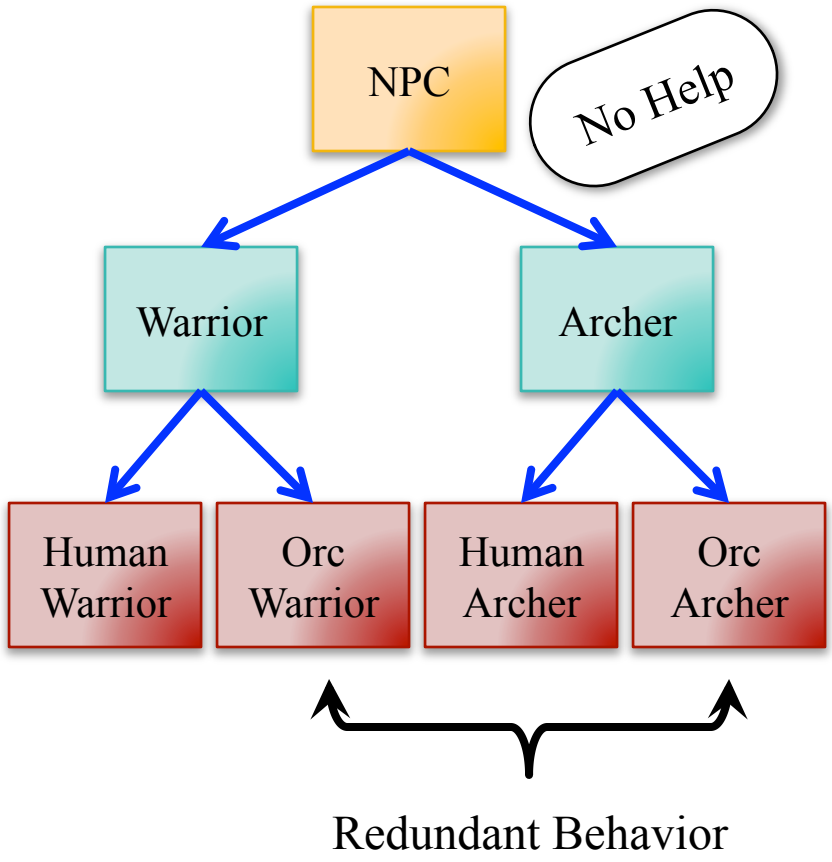

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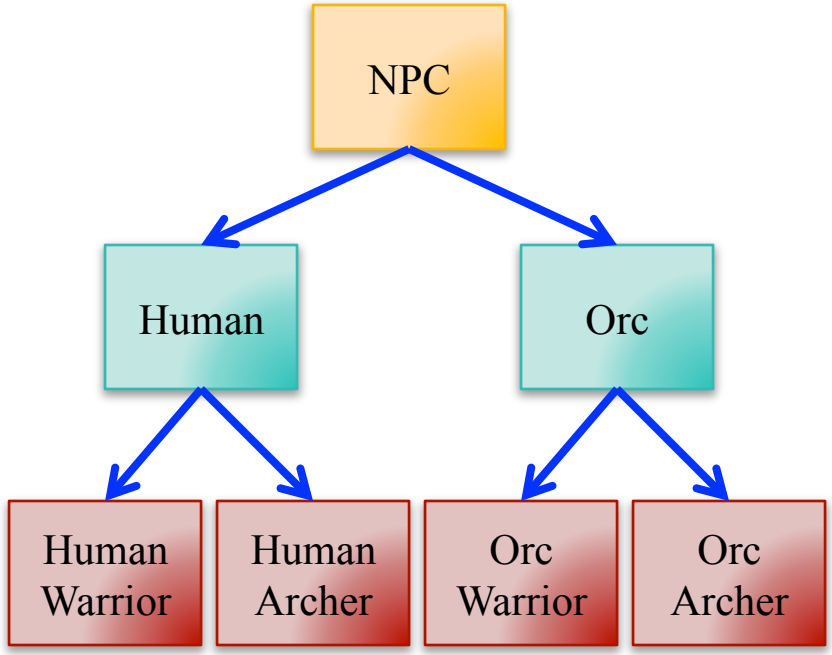

Redundant Behavior

Model-Controller Separation (Alternate)

Model

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

In this case, models are lightweight

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

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

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 flee
  - 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:

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

Python:

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

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                                ob.name);
                                name'))
  return False
return (self.name == ob.name)
```
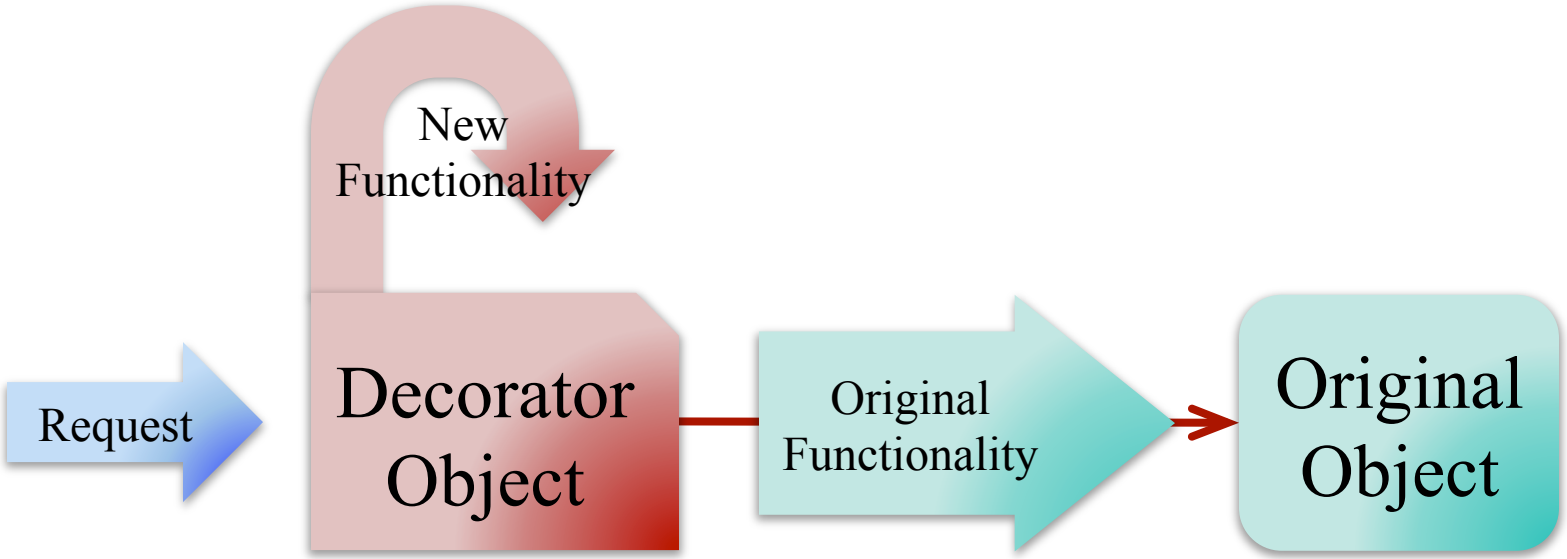

- What do we really want?
  - Capabilities over properties
  - Extend capabilities without necessarily changing type
  - Without using new languages
- Again, use a *software pattern*

Possible Solution: Decorator Pattern



Java I/O Example

```
InputStream input = System.in;
```

Built-in console input

```
Reader reader = new InputStreamReader(input);
```

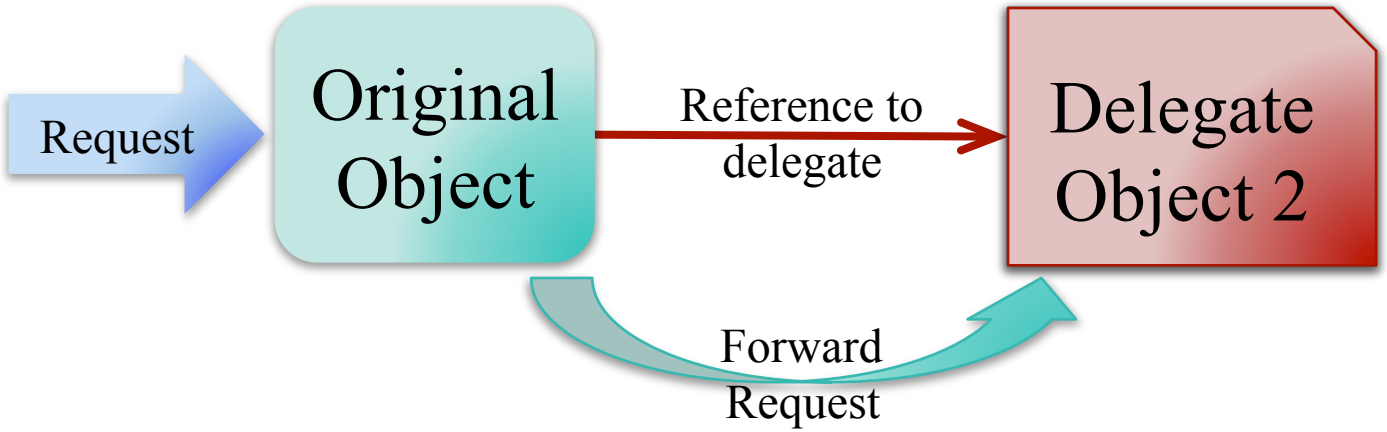
Make characters easy to read

```
BufferedReader buffer = new BufferedReader(reader);
```

Read whole line at a time

Most of java.io works this way

Alternate Solution: Delegation Pattern



Inversion of the Decorator Pattern

Example: Sort Algorithms

```
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); }
    }
}
```

```
public interface Sorter {
    public void sort(Object[] list);
}
```

Comparison of Approaches

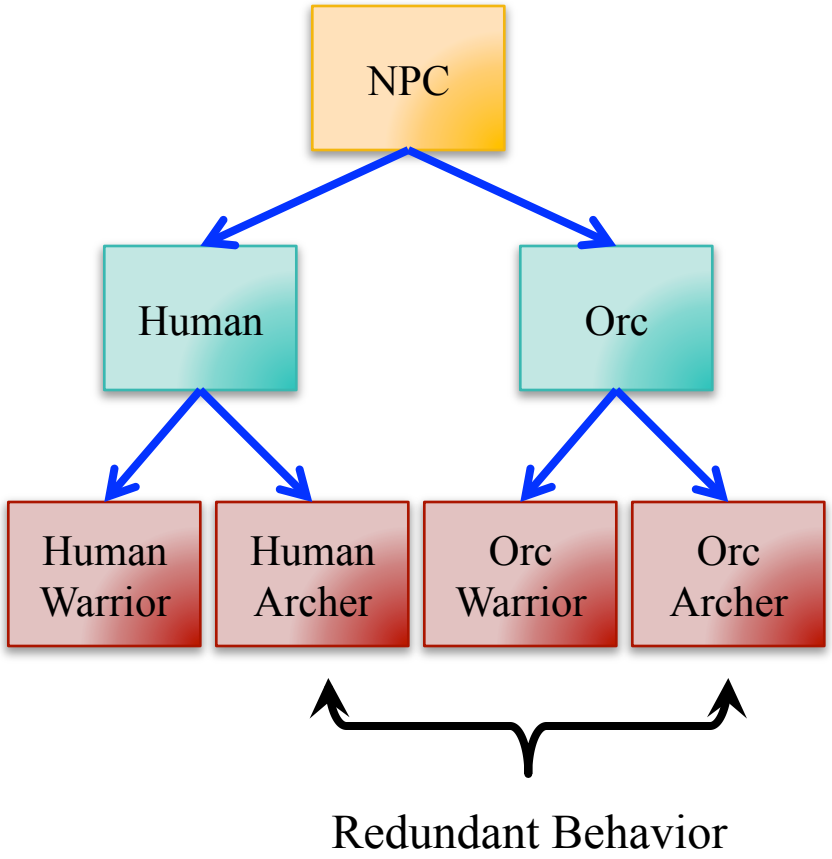
Decoration

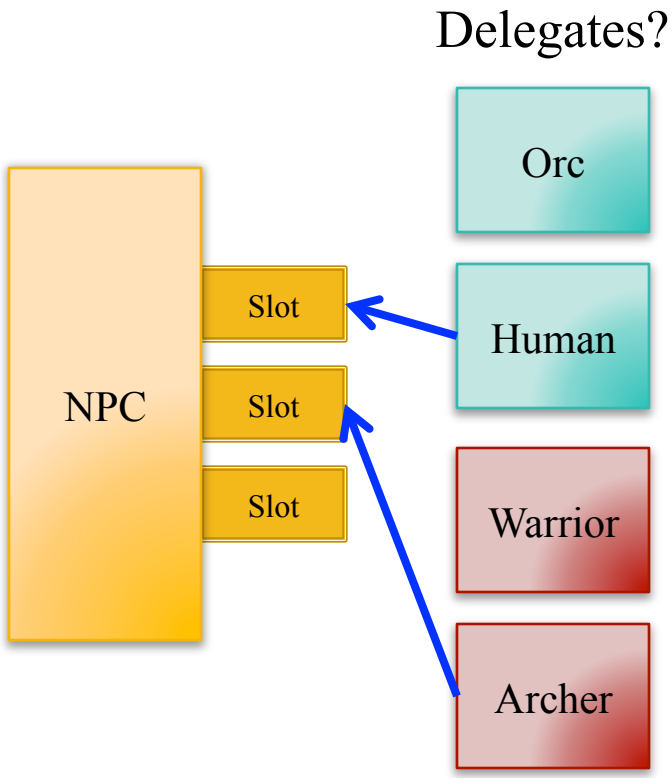
- Pattern applies to *decorator*
  - Given the original object
  - Requests through decorator
- **Monolithic** solution
  - Decorator has all methods
  - "Layer" for more methods (e.g. Java I/O classes)
- Works on *any* object/class

Delegation

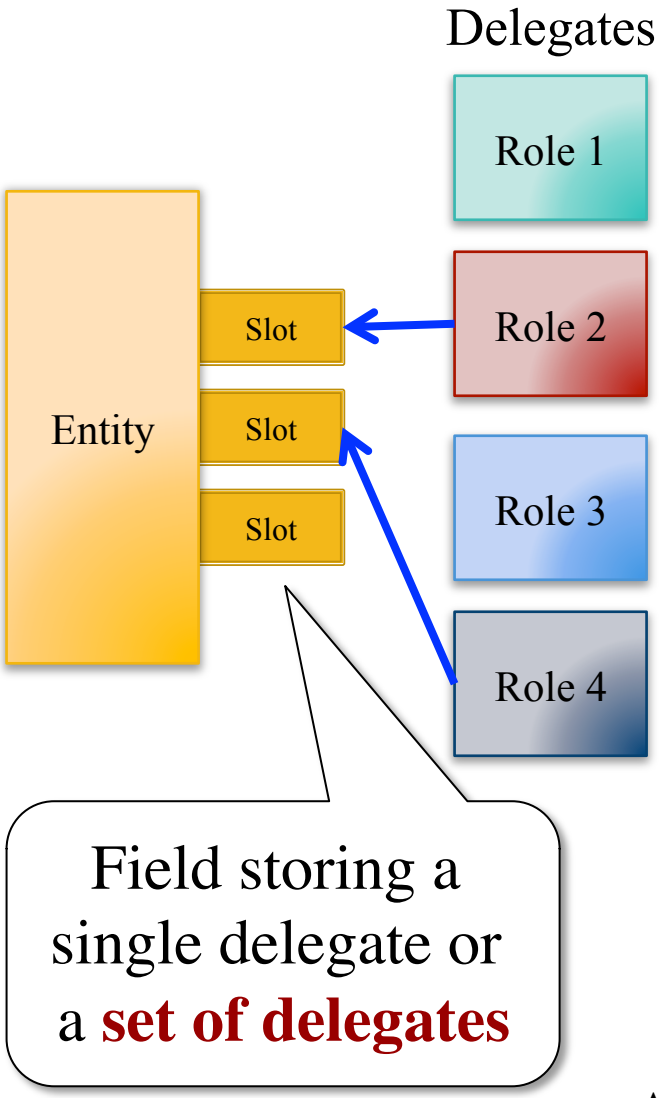
- Applies to *original object*
  - You designed object class
  - All requests through object
- **Modular** solution
  - Each method can have own delegate implementation
  - Like higher-order functions
- Limited to classes you make

The Subclass Problem Revisited





Component-Based Programming



- **Role**: Set of capabilities
  - Class with very little data
  - A collection of methods
- Add it to object as delegate
  - Object gains those methods
  - Acts as a "function pointer"
- *Can-it*: search object roles
  - Check class of each role
  - Better than duck typing
  - Possible at compile time?

Entities Need Both Is-a and Can-it

Table

Chair

Objects share same capabilities *in theory*.

But certain actions are **preferred** on each.

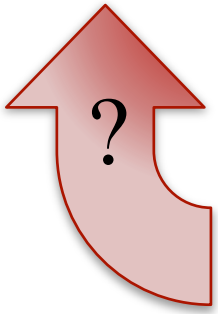
Model-Controller Separation Revisited

Model

- Store/retrieve **object data**
  - Preserve any invariants
  - Data may include delegates
  - Determines `is-a` properties

Controller

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

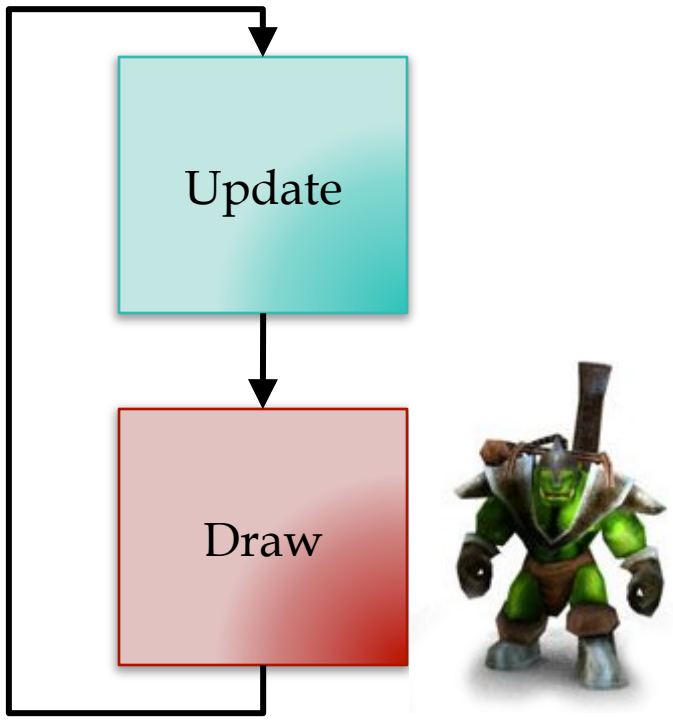


Components

- Process **game actions**
  - Attached to a entity (model)
  - Uses the model as context
  - Determines `can-it` properties

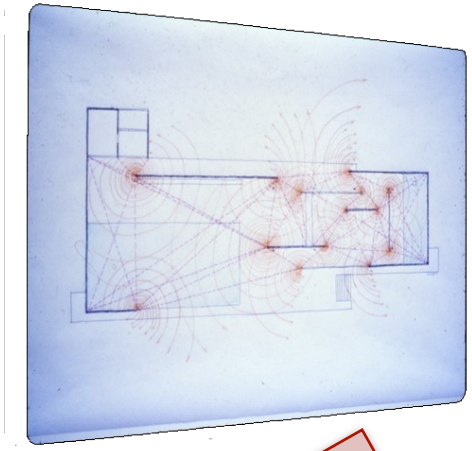
What about the View?

- Way too much to draw
  - Backgrounds
  - UI elements
  - Individual NPCs
  - Other moveable objects
- Cannot cram all in Draw
- Put it in game object?
  - But objects are models
  - Violates MVC **again**



Solution: A Drawing Canvas

- Treat display as a **container**
  - Often called a canvas
  - Cleared at start of frame
  - Objects added to container
  - Draw contents at frame end
- Canvas abstracts *rendering*
  - Hides animation details
  - Like working with widget
- Implement `draw(c)` in model
  - Classic heavyweight model
  - No problems with extension



Passed as reference

```
void draw(Canvas c) {
    // Specify perspective
    // Add to canvas
}
```

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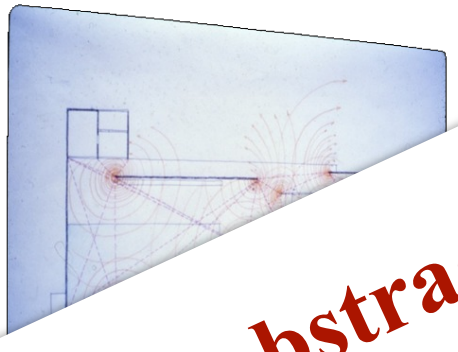

Like SpriteBatch but more **abstract**

Passed as reference

```
void draw(Canvas c) {
    // Specify perspective
    // Add to canvas
}
```

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
  - Want **component-based design** to model actions
  - Will revisit this again when we talk about AI