the gamedesigninitiative at cornell university

Lecture 5

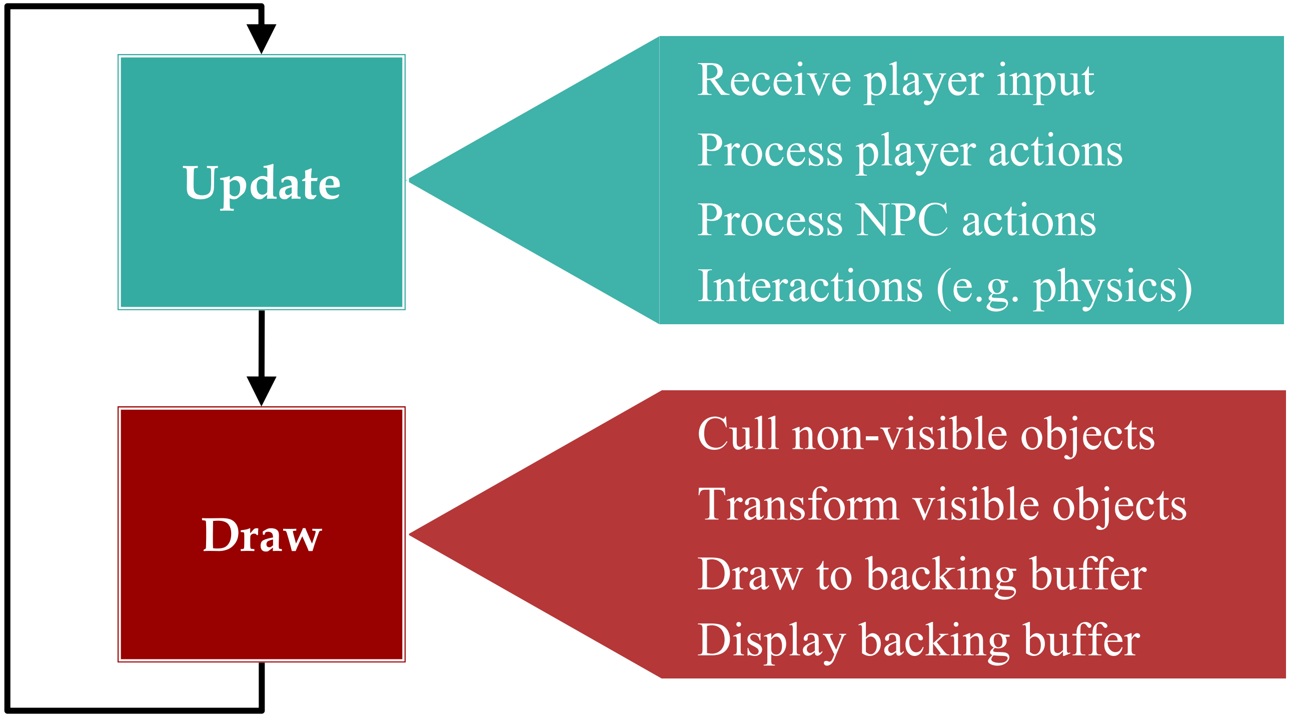
# Game Architecture Revisited

# Recall: The Game Loop

60 times/s

=

16.7 ms



Receive player input

Process player actions

Process NPC actions

Interactions (e.g. physics)

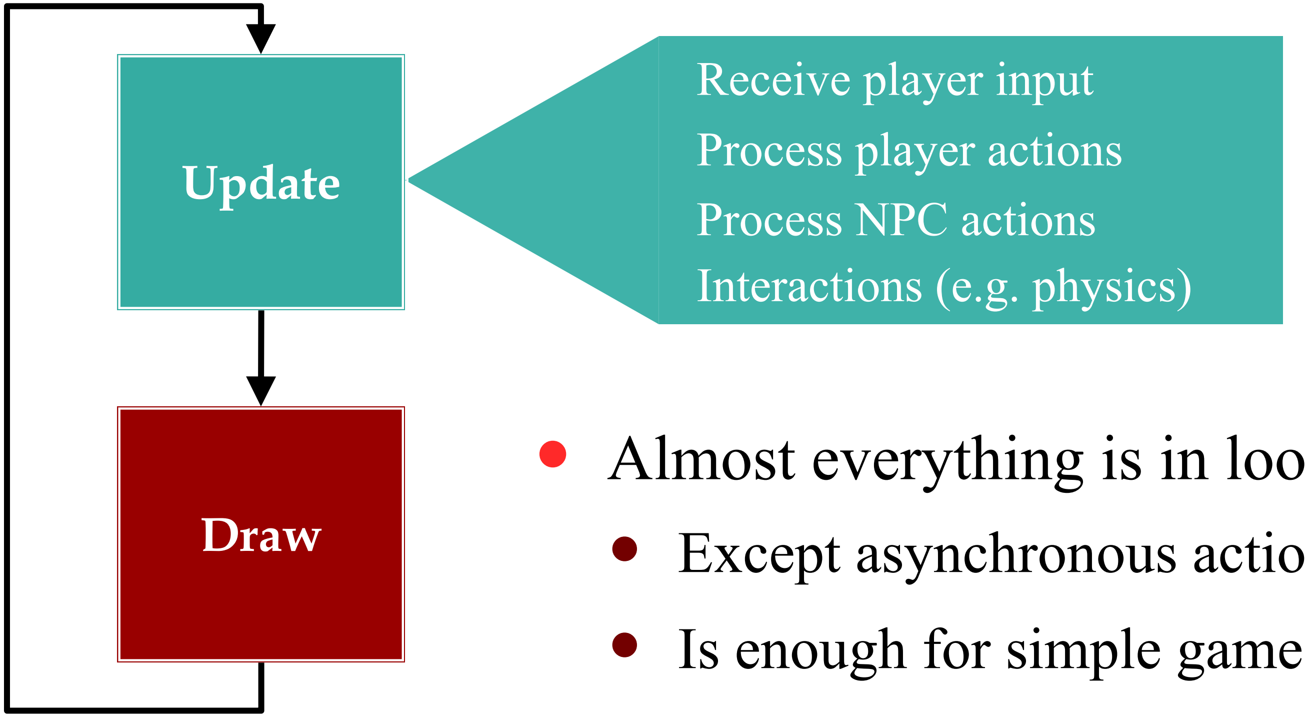
Cull non-visible objects

Transform visible objects

Draw to backing buffer

Display backing buffer

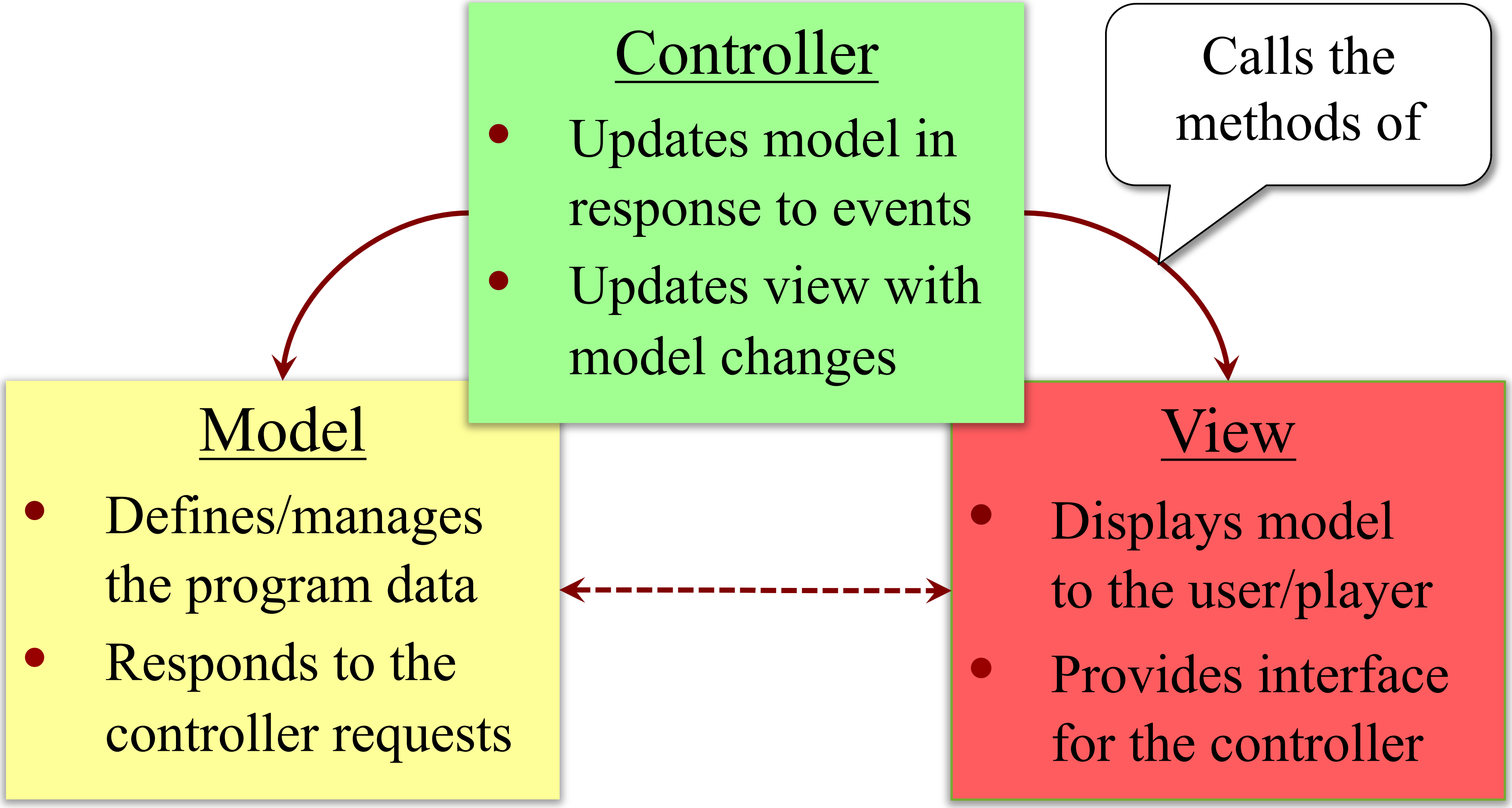
# Recall: The Game Loop



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

- 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

Calls the methods of

## Model

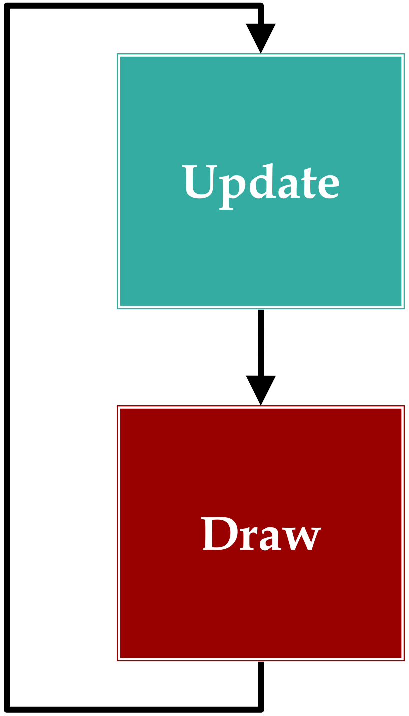
- Defines/manages the program data
- Responds to the controller requests

## View

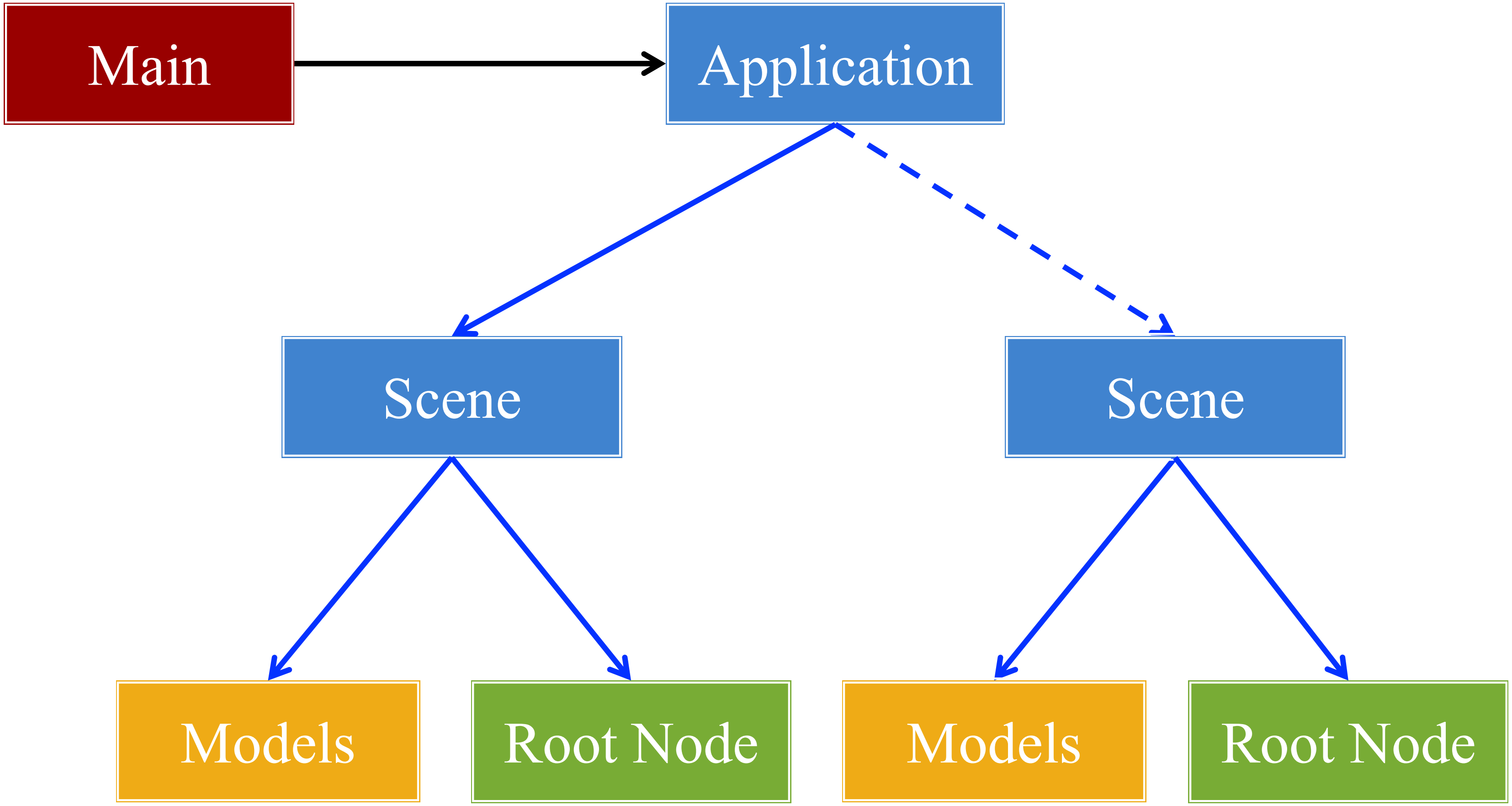
- Displays model to the user/player
- Provides interface for the controller

# 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



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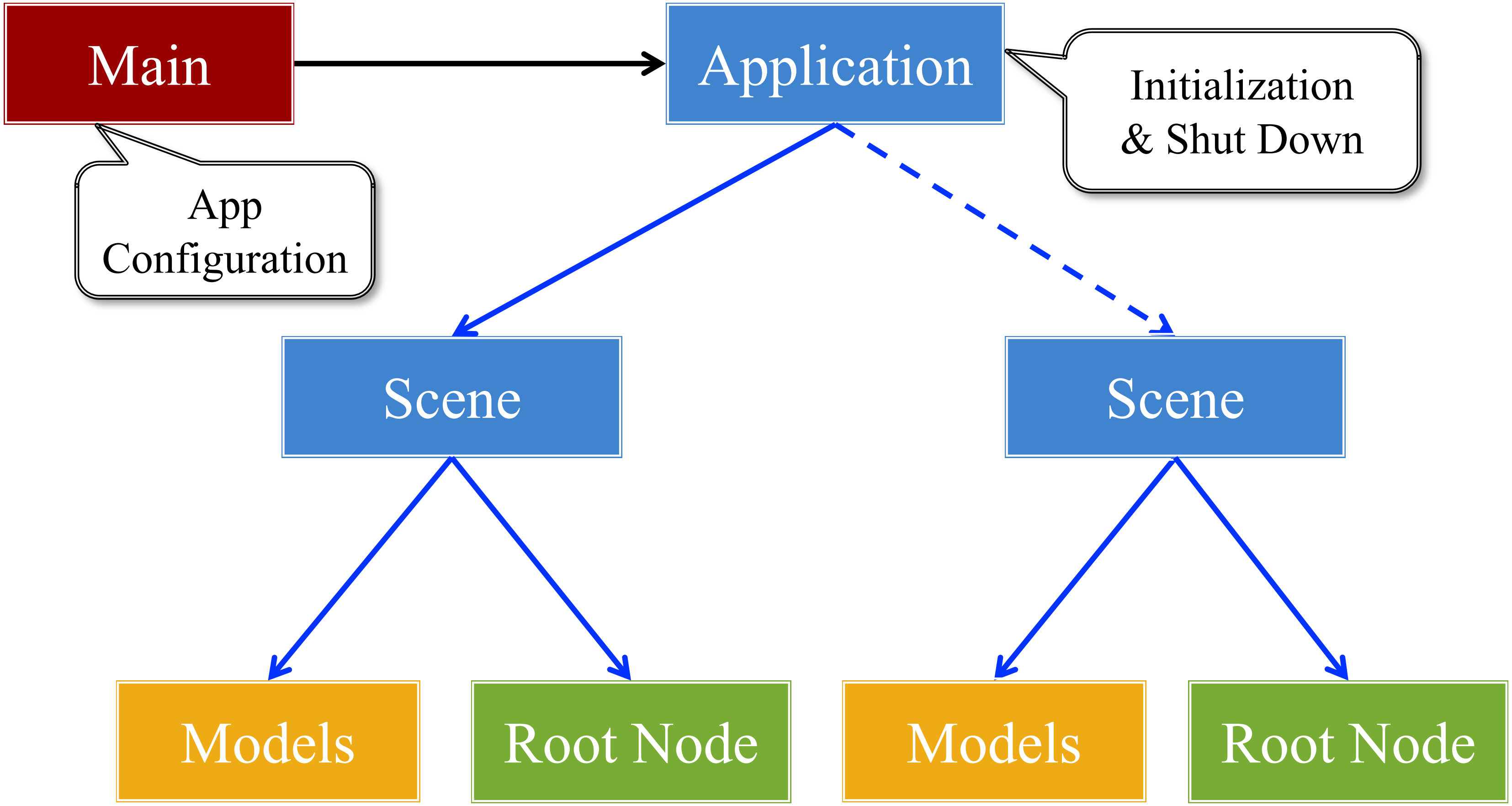

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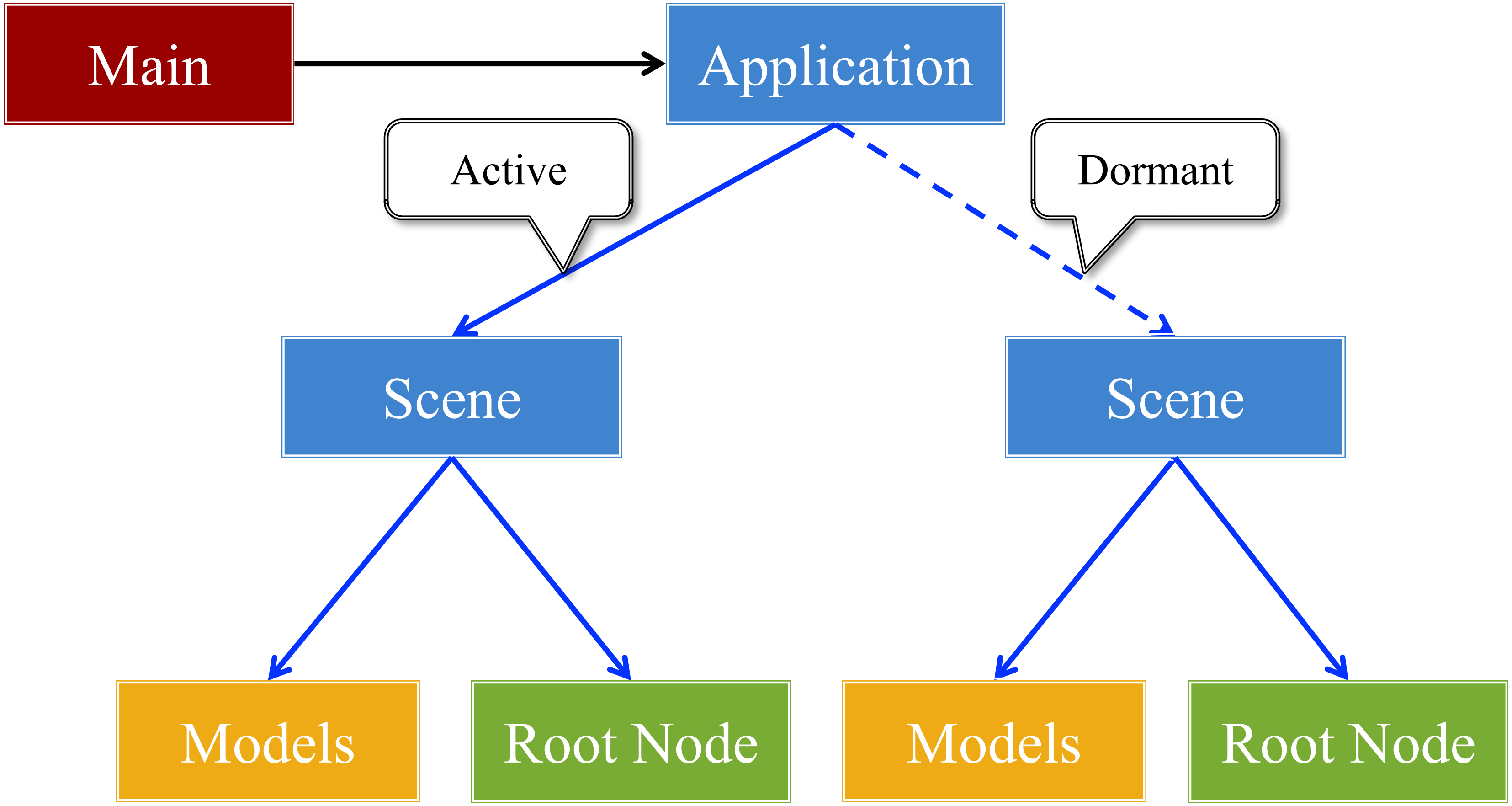

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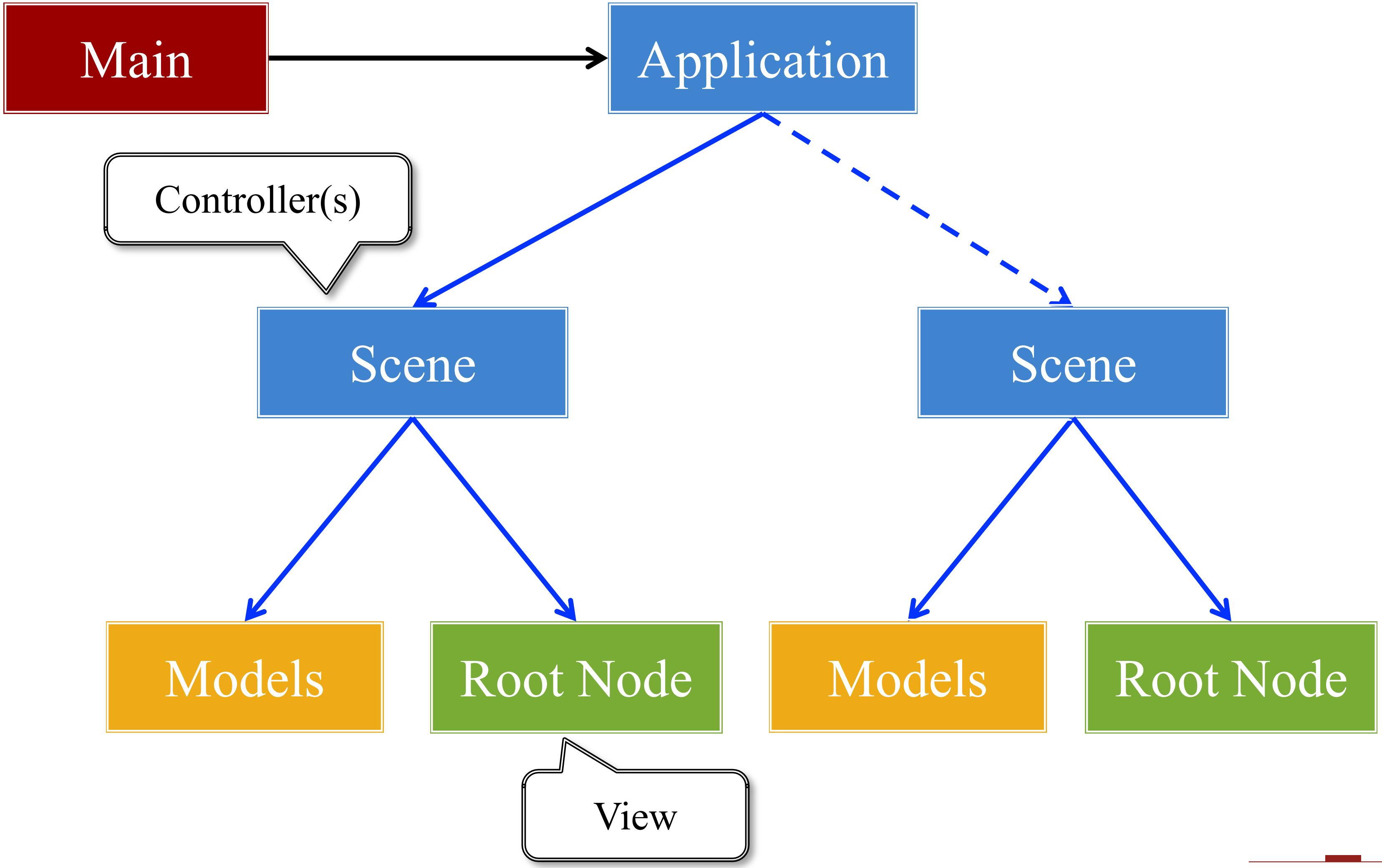

# The Application Class

## `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()

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  - Attaches the asset loaders
  - Loads immediate assets
- S… …tons
  - …els
- C… …ally player modes
  - But does not launch ***yet***
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  - Like `GDXRoot` in 3152

**onShutdown()** cleans this up

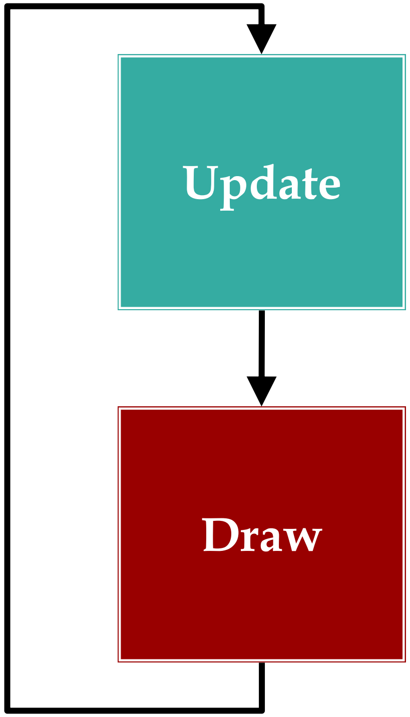
## update()

- Called each animation frame
- Manages gameplay
  - Converts in… …ons
  - …or
  - …
  - …solves other interactions
- Updates the scene graph
  - Transforms nodes
  - Enables/disables nodes

Does not draw! Handled separately

# Problems With the Game Loop

60 times/s
=
16.7 ms



- 16.7 ms **not guaranteed**!
  - Even for optimized code
  - Result of external factors
- **Regularly** see minor jitter
  - "In-between" code
  - Potential Vsync delay
- **Occasional** major jitter
  - Dynamic library loading
  - Cost of debugging tools

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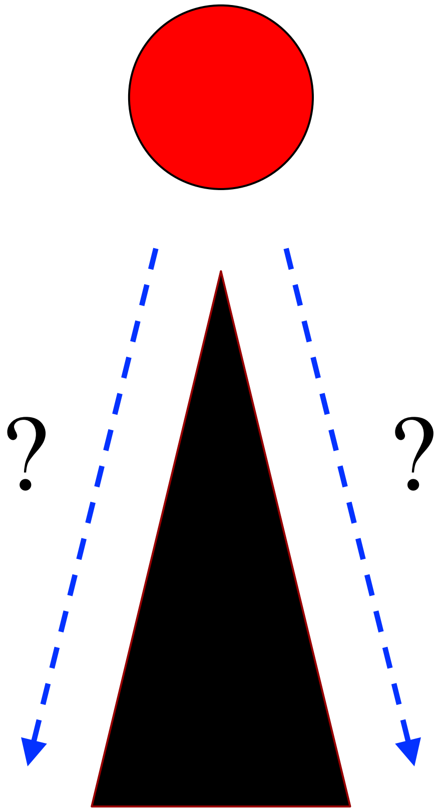
Variations mean simulations are not deterministic!

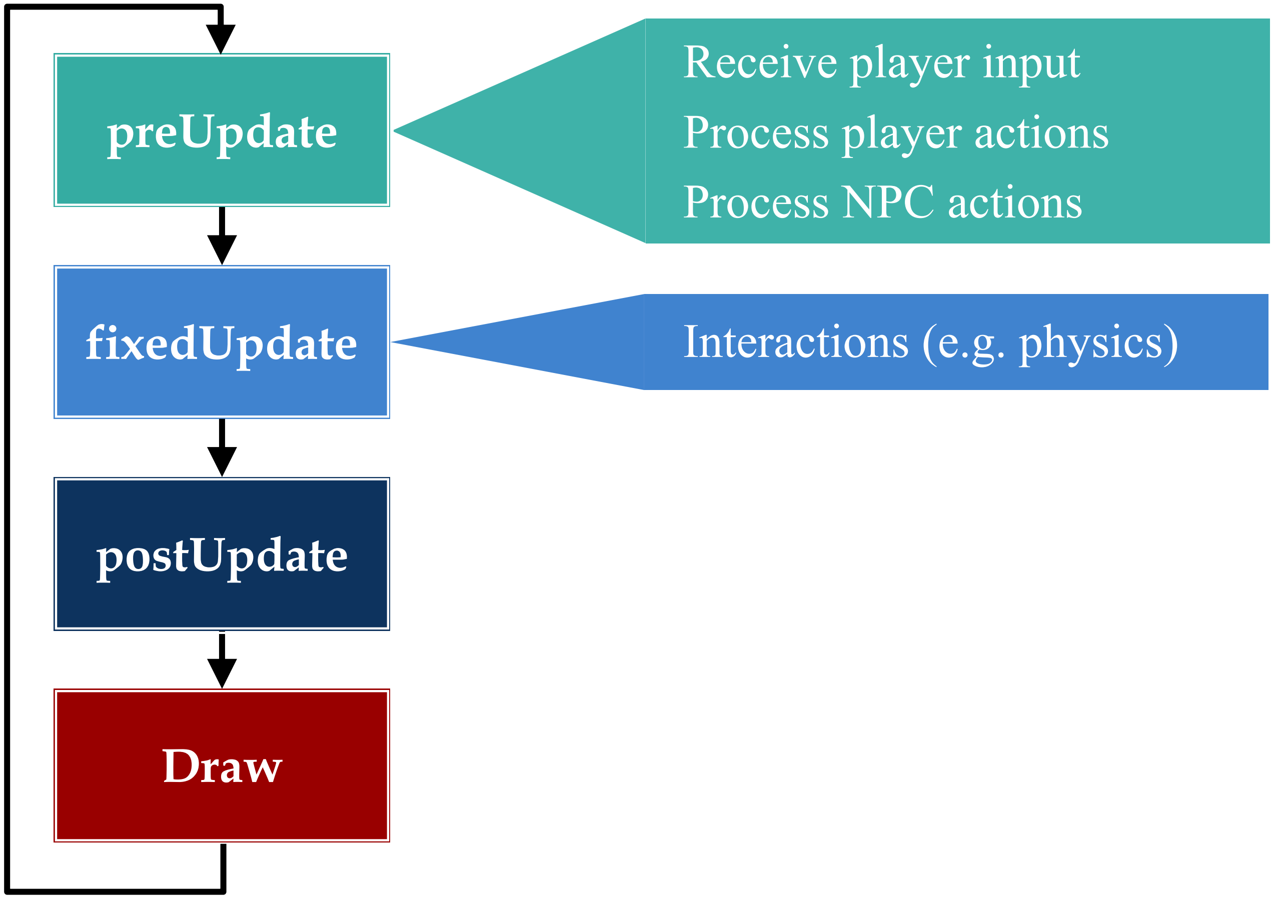
# Physics and Non-Determinism



# How To Guarantee Determinism?

- Need to **decouple simulation** from other code
  - Cannot be delayed by drawing
  - Cannot be affected by OS externalities
- Put this on a **separate thread**?
  - Thread management still has some overhead
  - Have to **synchronize** with input/drawing thread (bad!)
- Create a **separate logical loop**?
  - Simulation loop runs at its own fixed rate
  - Draw method simply draws what it has so far

# The Game Loop Revisited



Receive player input

Process player actions

Process NPC actions

Interactions (e.g. physics)

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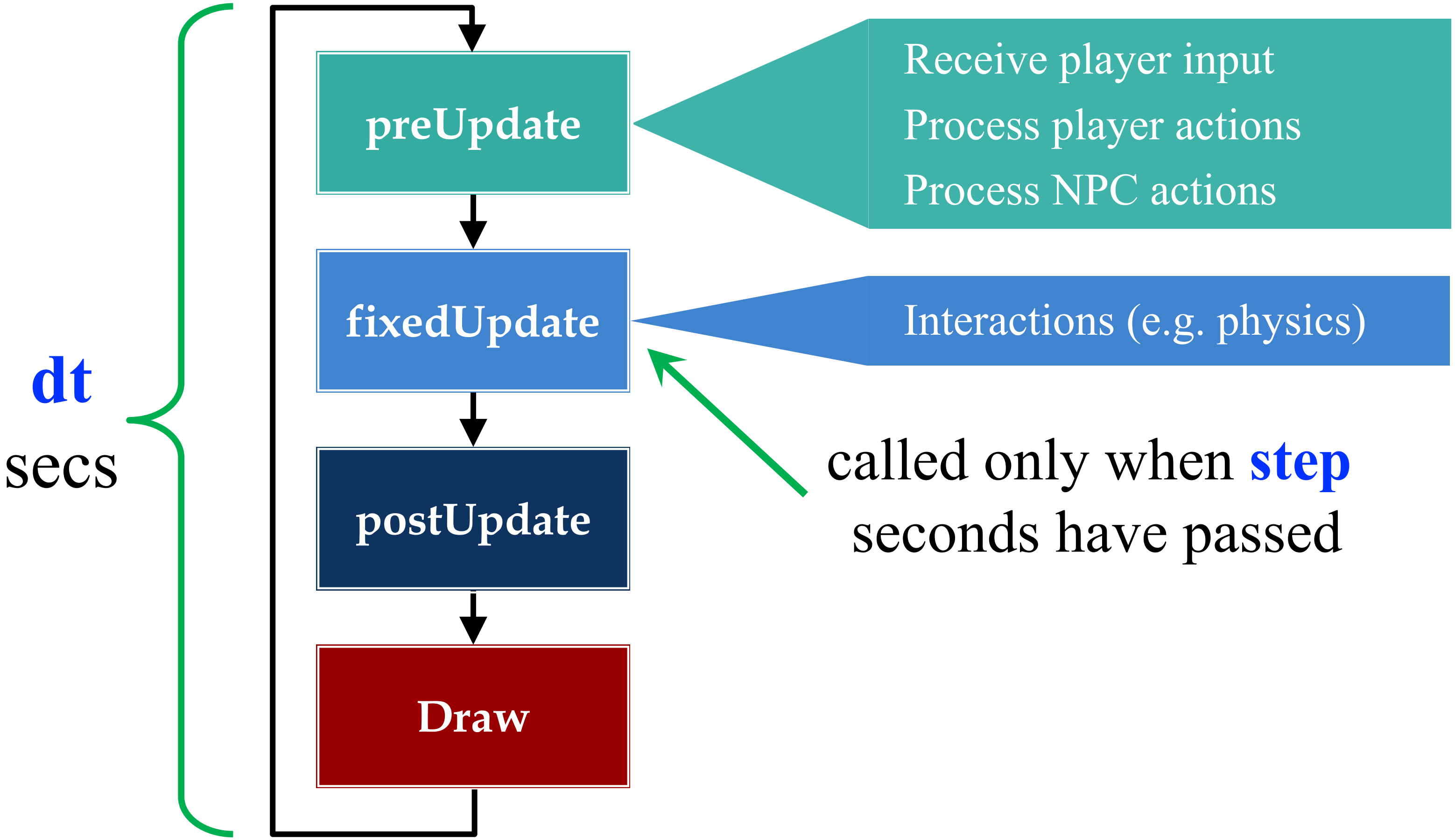
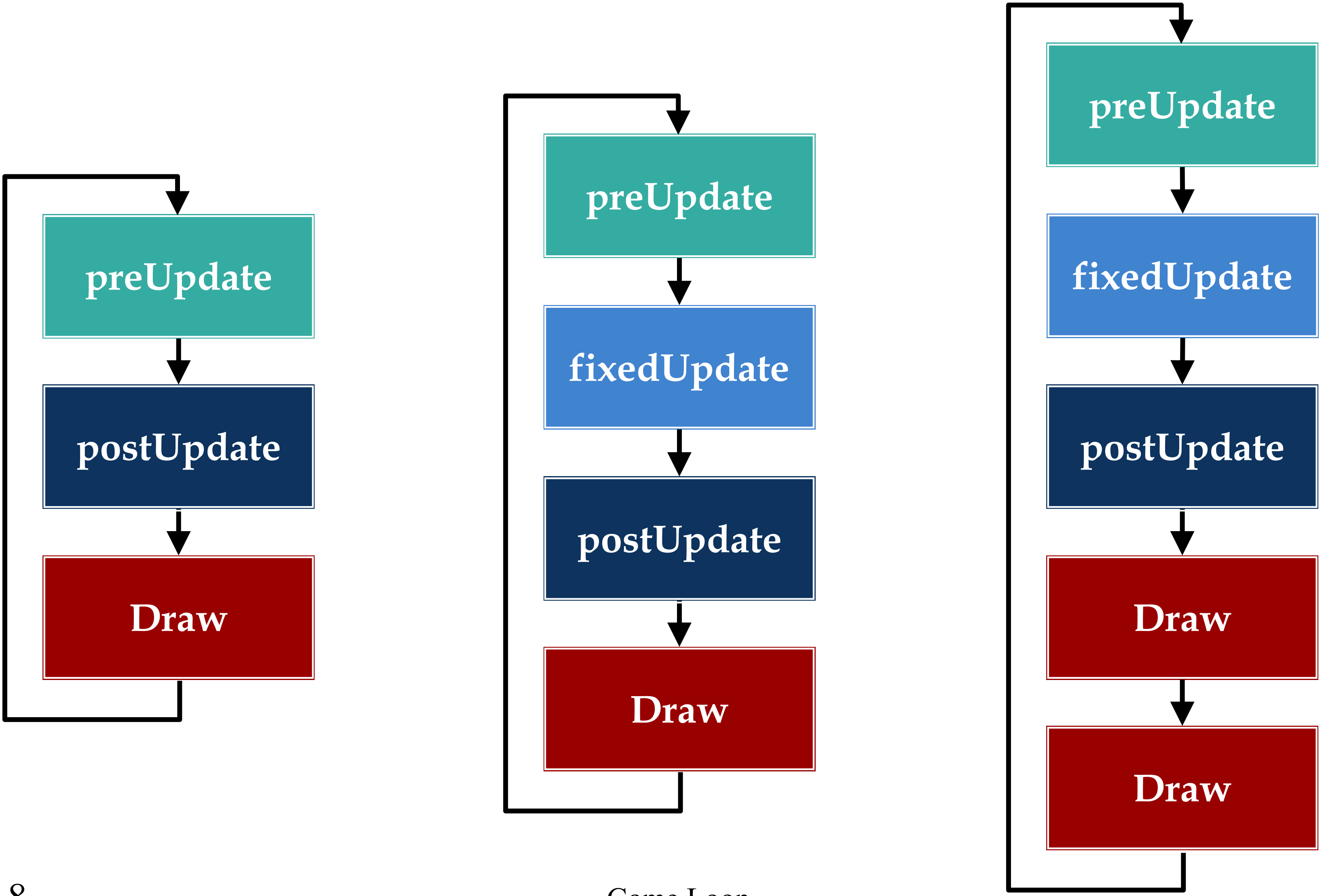


Receive player input
Process player actions
Process NPC actions

Interactions (e.g. physics)

called only when **step** seconds have passed

# These Are All Possible



preUpdate

postUpdate

Draw

preUpdate

fixedUpdate

postUpdate

Draw

preUpdate

fixedUpdate

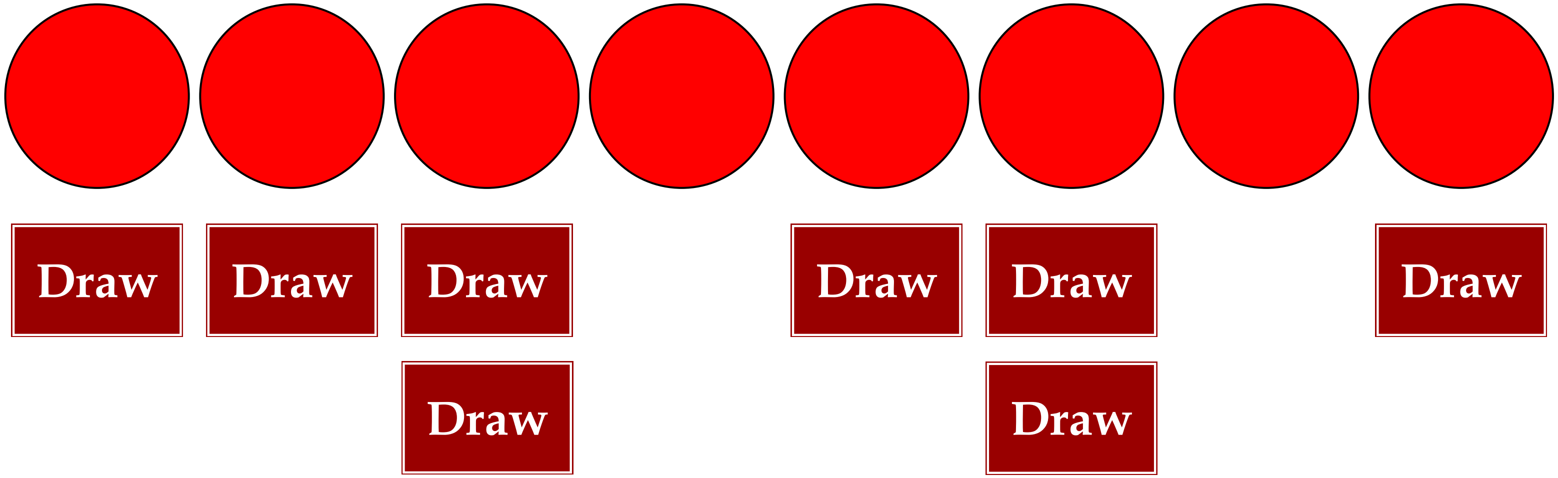
postUpdate

Draw

Draw

# Problem: Jerky Motion

Each Image is a result of `fixedUpdate`



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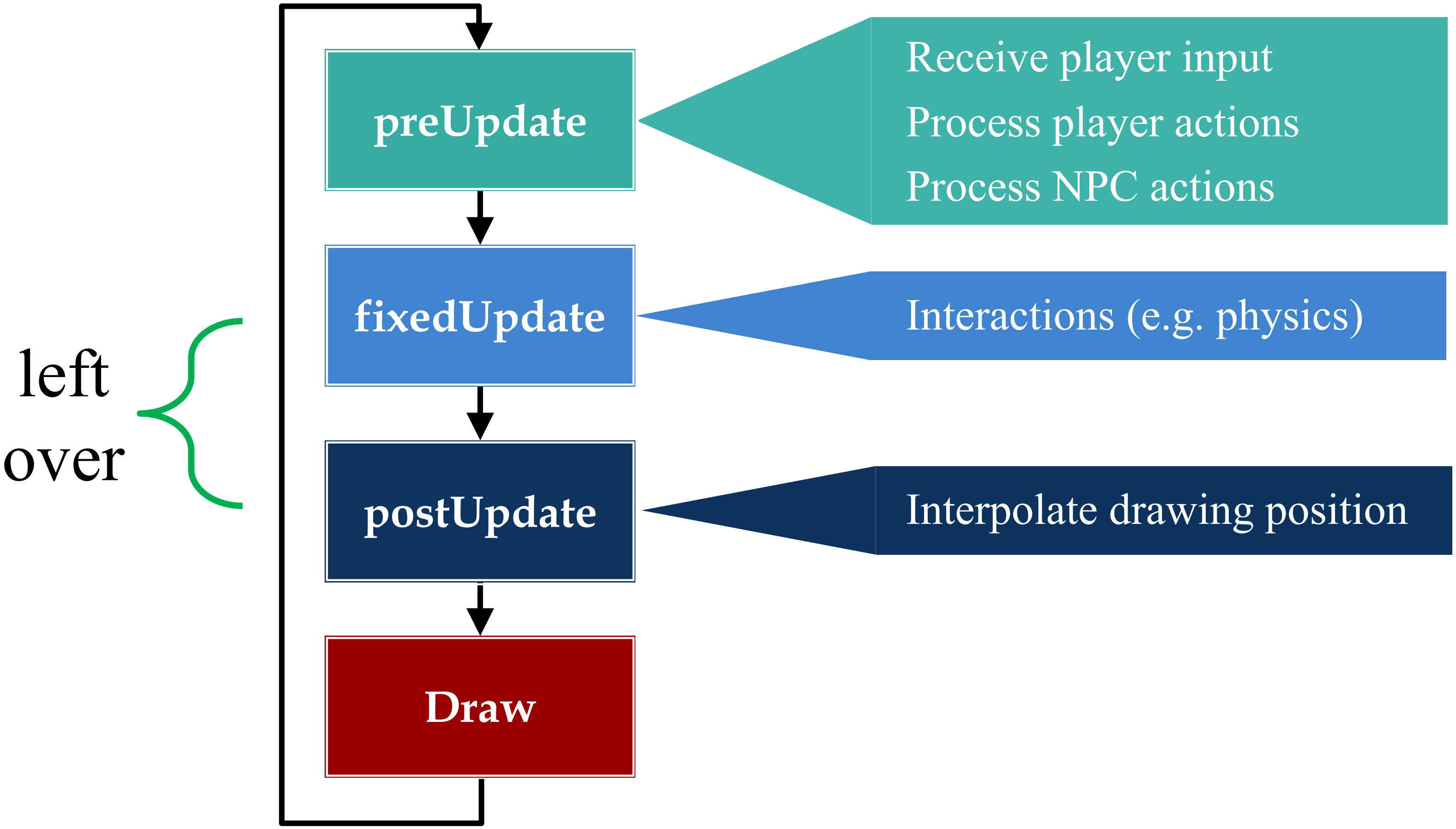


Receive player input

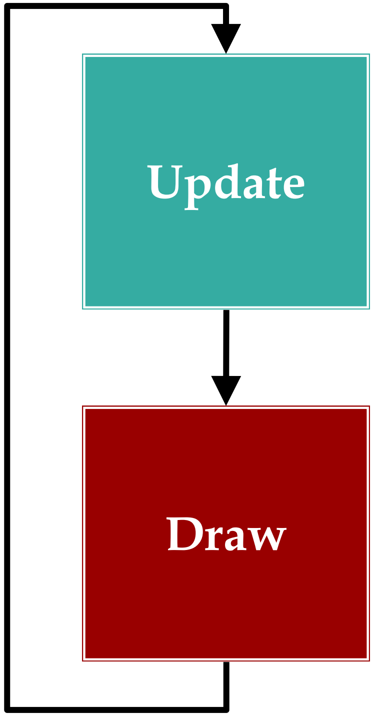
Process player actions

Process NPC actions

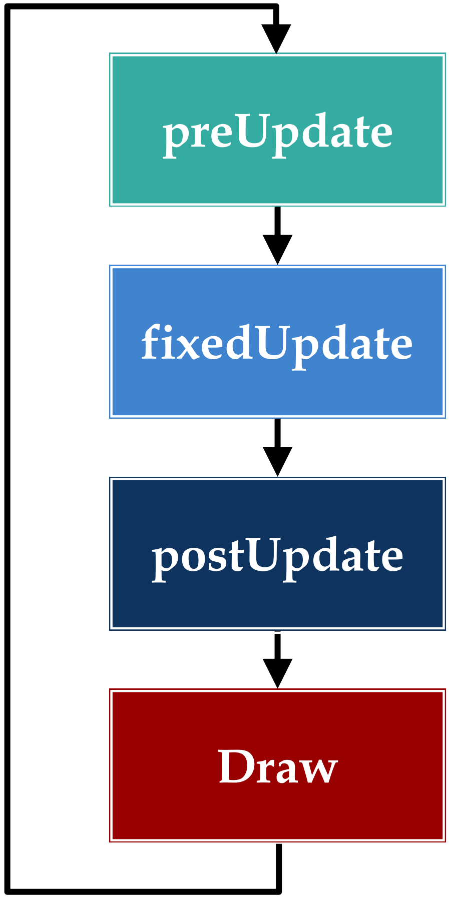
Interactions (e.g. physics)

Interpolate drawing position

# CUGL Supports Both Loops

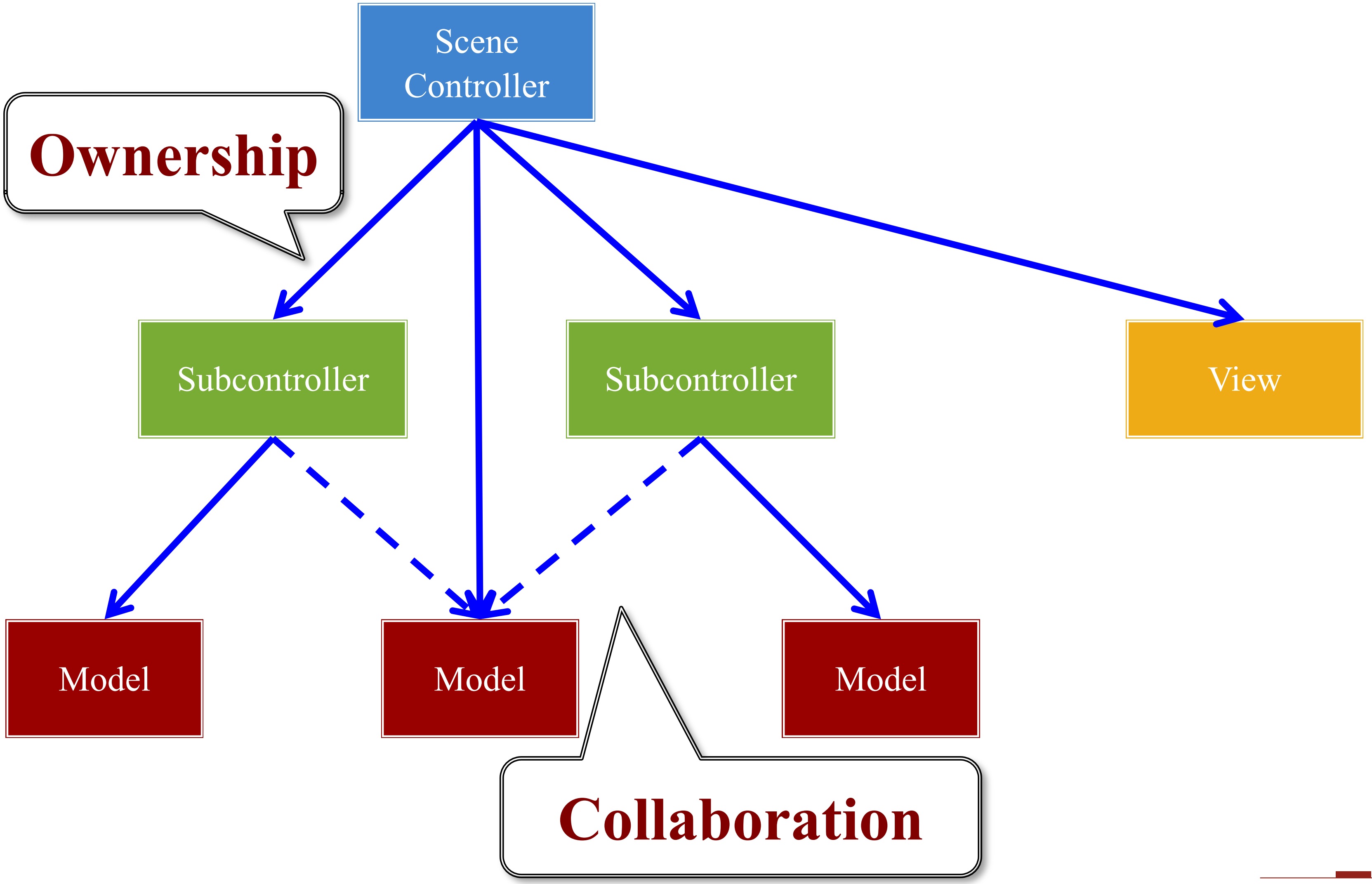


`setDeterministic(false)`



`setDeterministic(true)`

# Scene Structure



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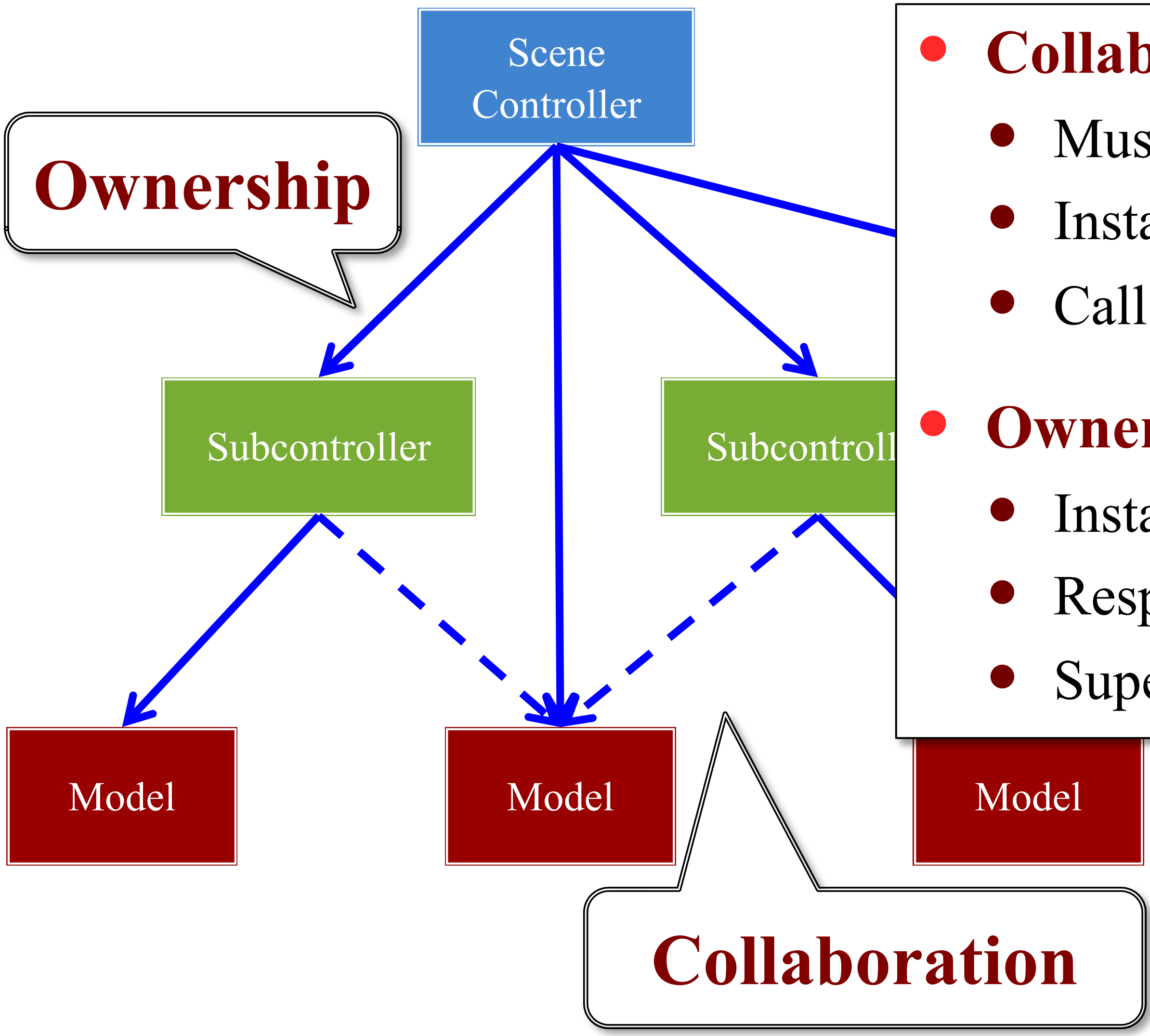
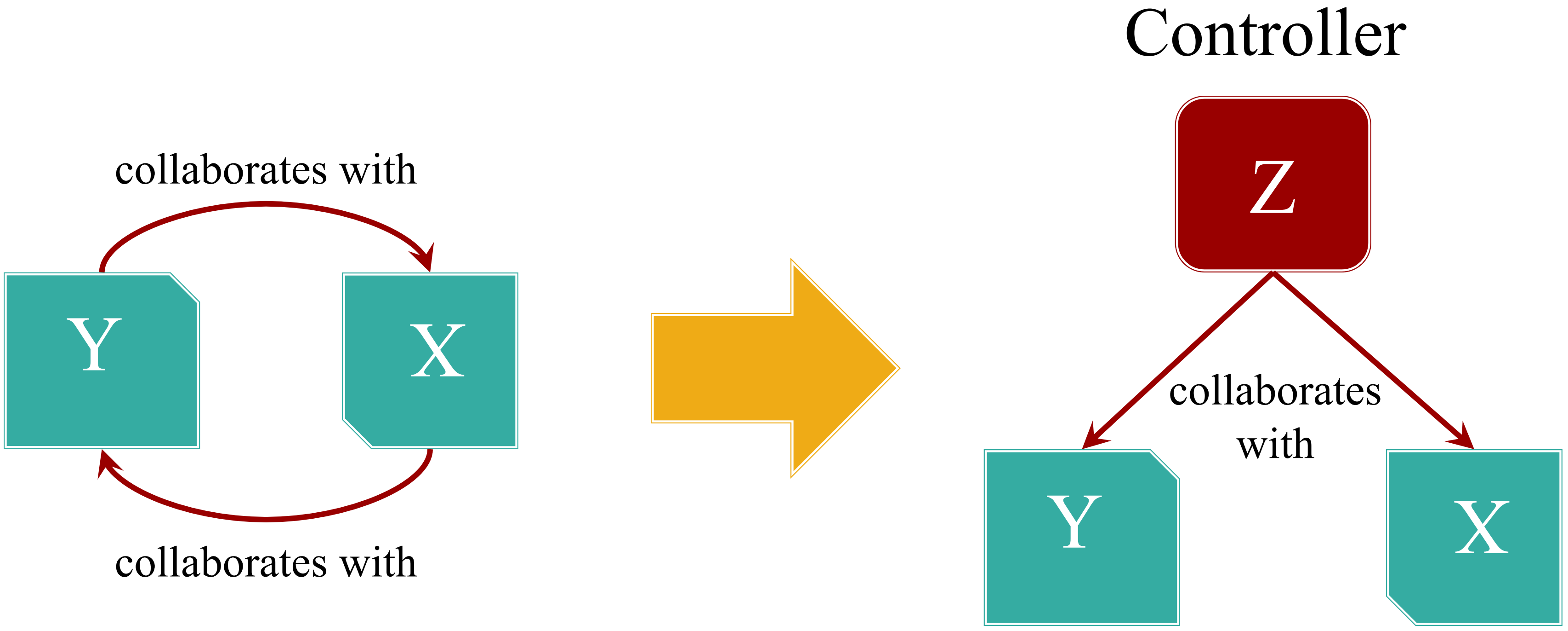


- **Collaboration**
  - Must import class/interface
  - Instantiates an object **OR**
  - Calls the objects methods
- **Ownership**
  - Instantiated the object
  - Responsible for disposal
  - Superset of collaboration

# Avoid Cyclic Collaboration



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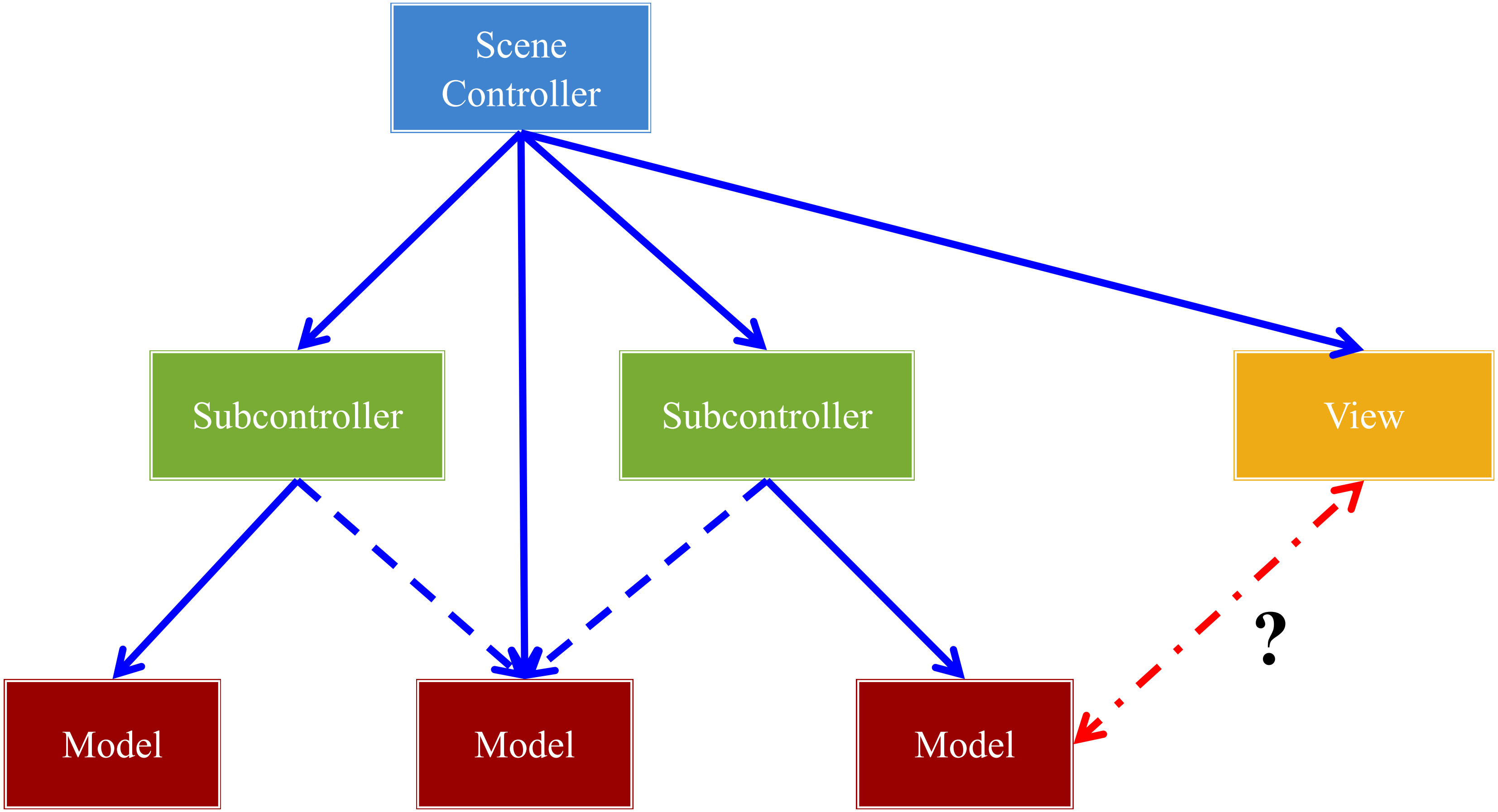
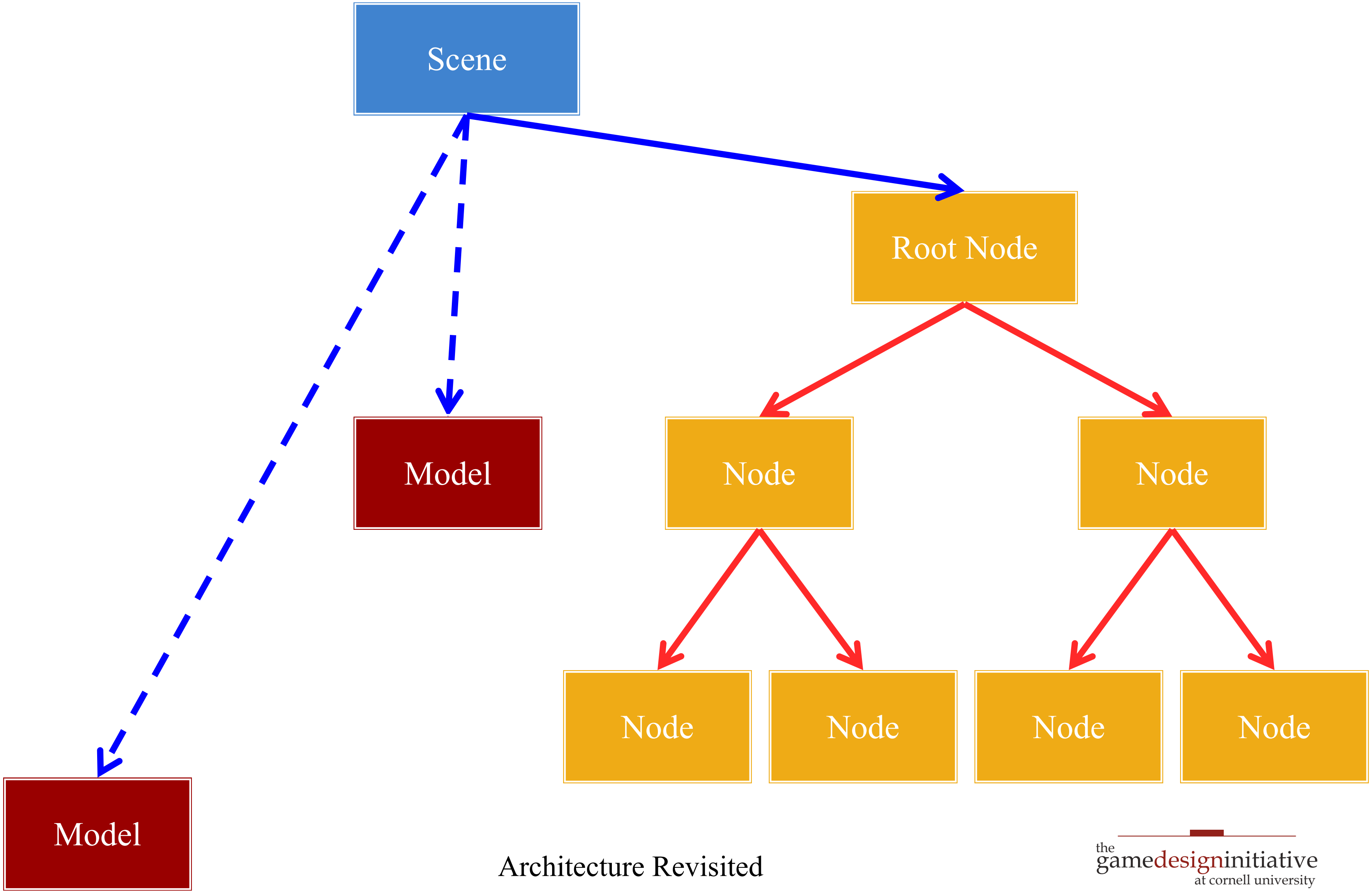


# CUGL Views: Scene Graphs



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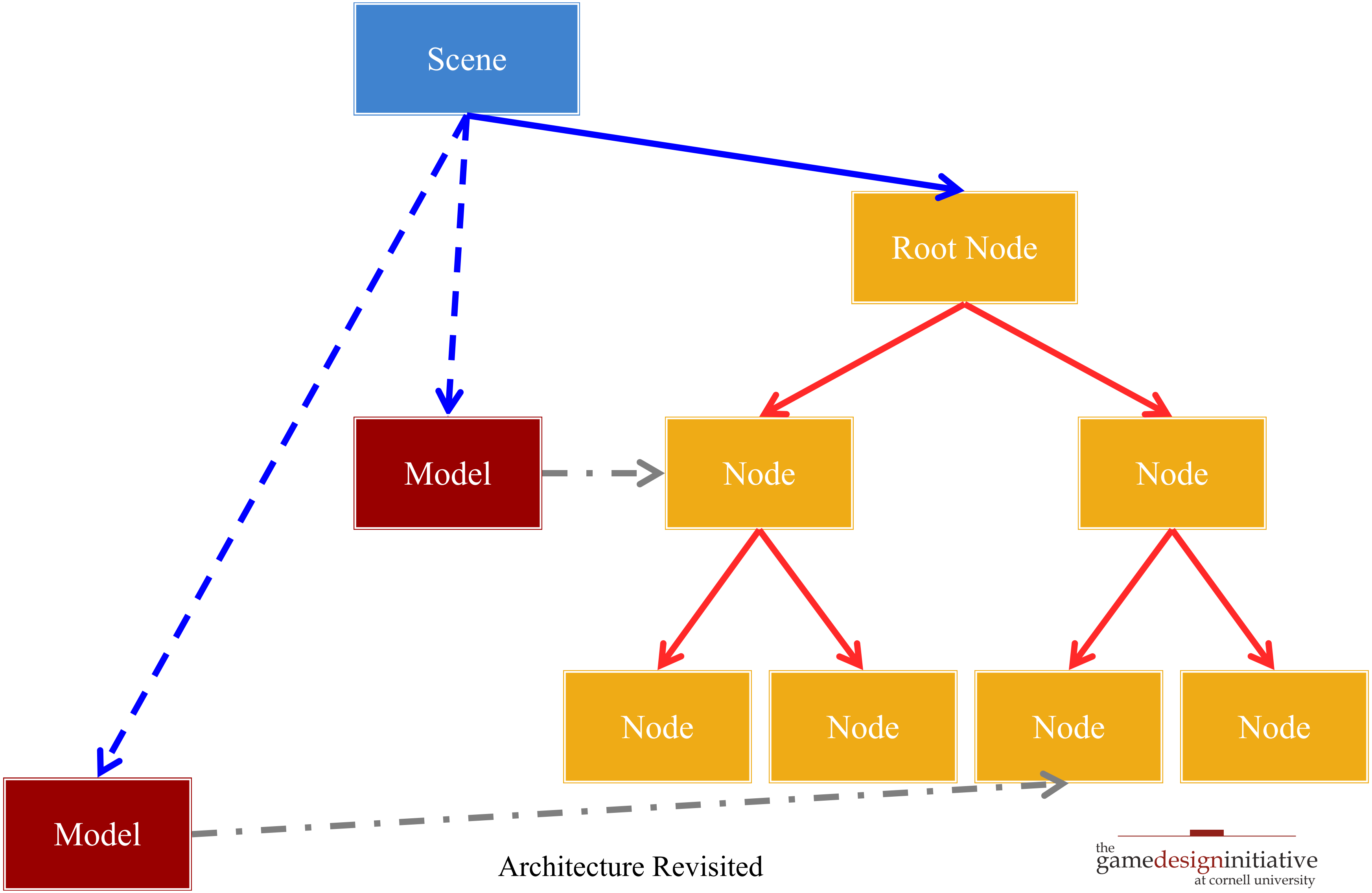

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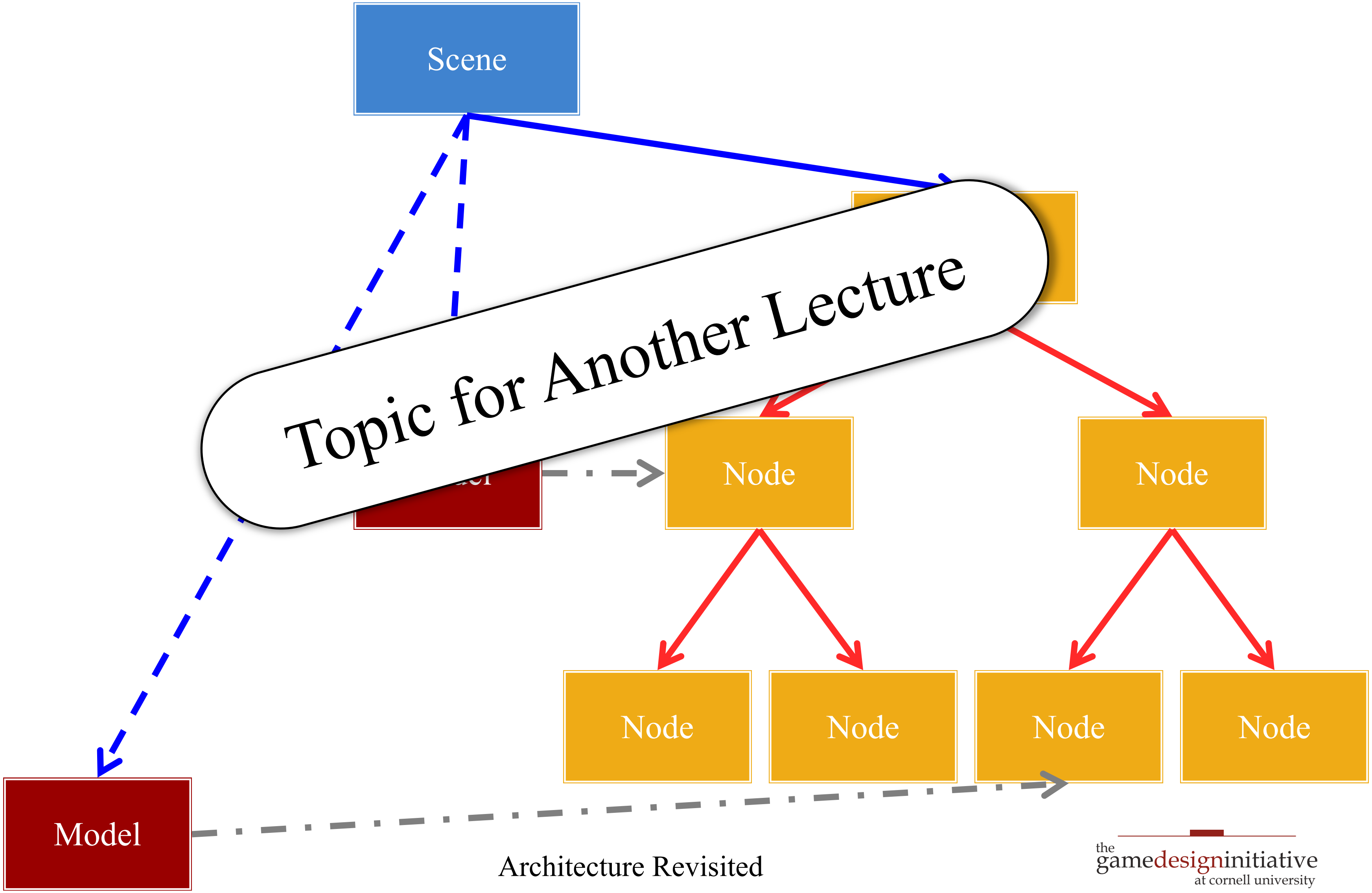


# Model-Controller Separation (Standard)

## 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

## Controller

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

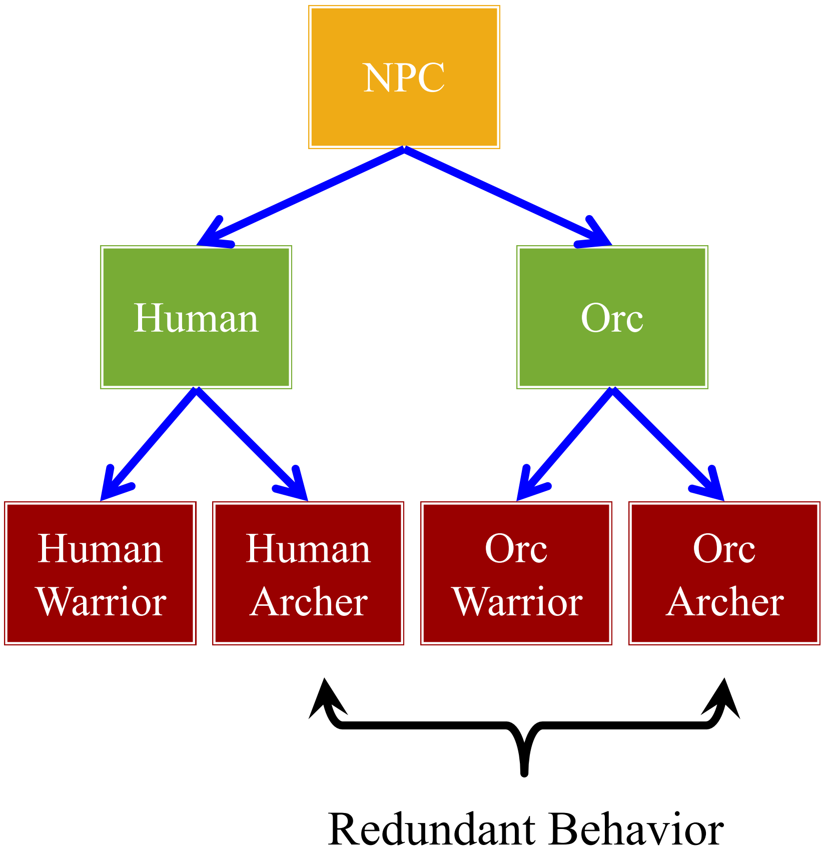
Traditional controllers are "lightweight"

# 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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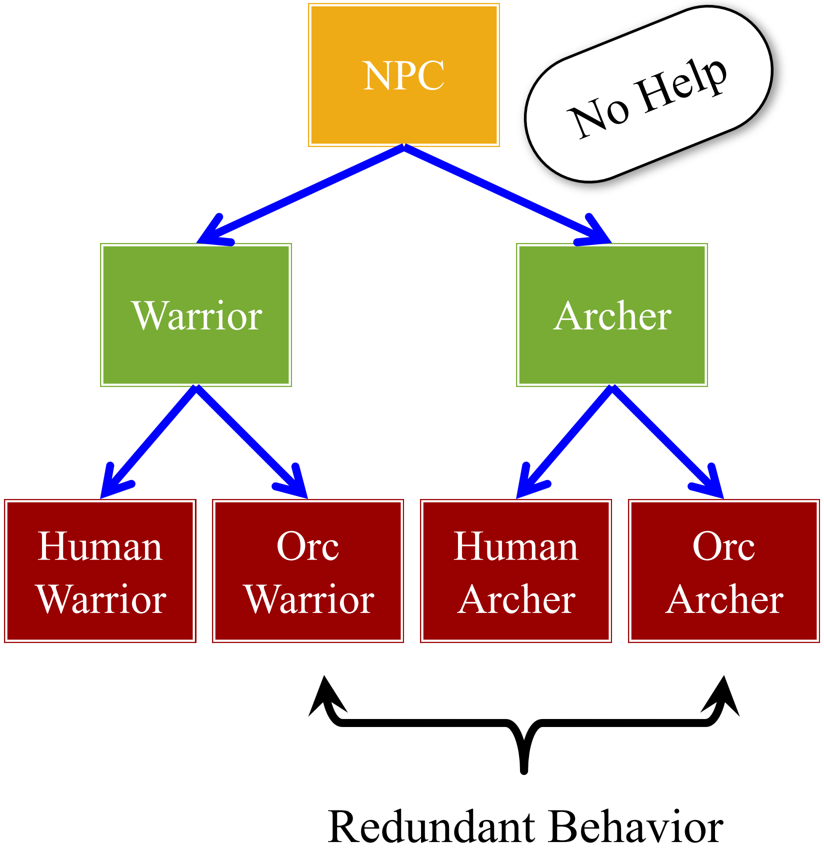

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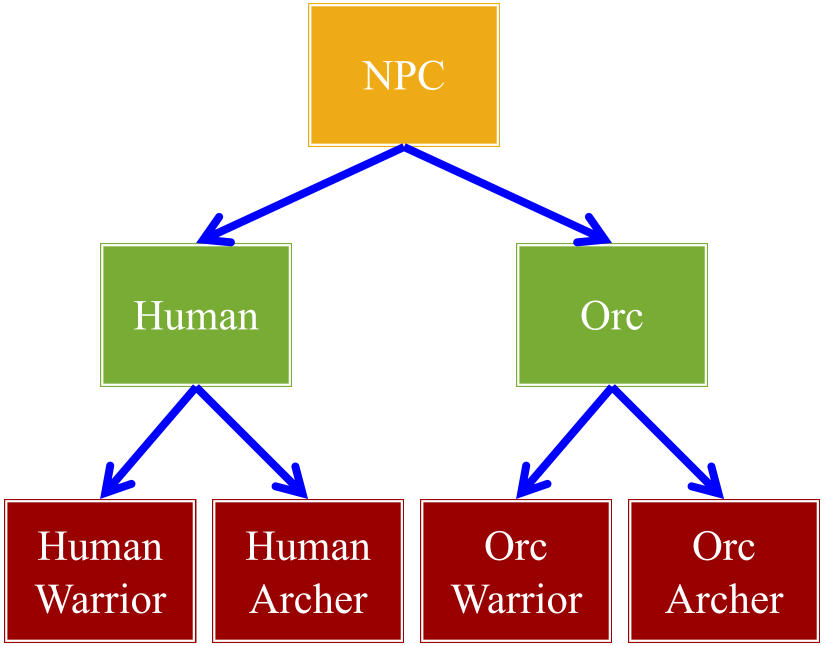

Redundant Behavior

# 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

# Model-Controller Separation (Alternate)

## Model

- Store/retrieve **object data**
  - Limit access (getter/setter)
  - Pr
  - Or

In this case, models are lightweight

## Controller

- Process **game actions**
  - Determine from input or AI
  - cted
  - ects
  - Look at current game state
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Motivation for the
Entity-Component Model

# 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 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:**

```
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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Similar to C++ templates

**Java:**

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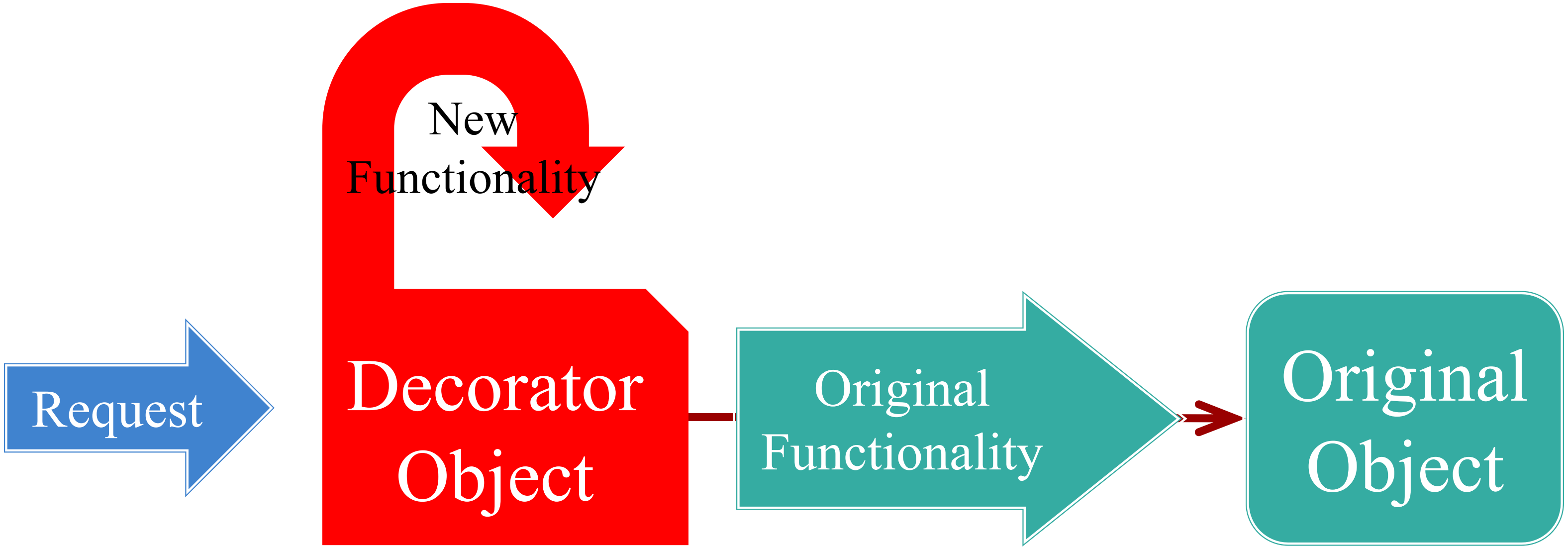

```
                                    name'))
    return False
return (self.name == ob.name)
```

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

# Possible Solution: Decorator Pattern



# Java I/O Example

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

Built-in console input

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

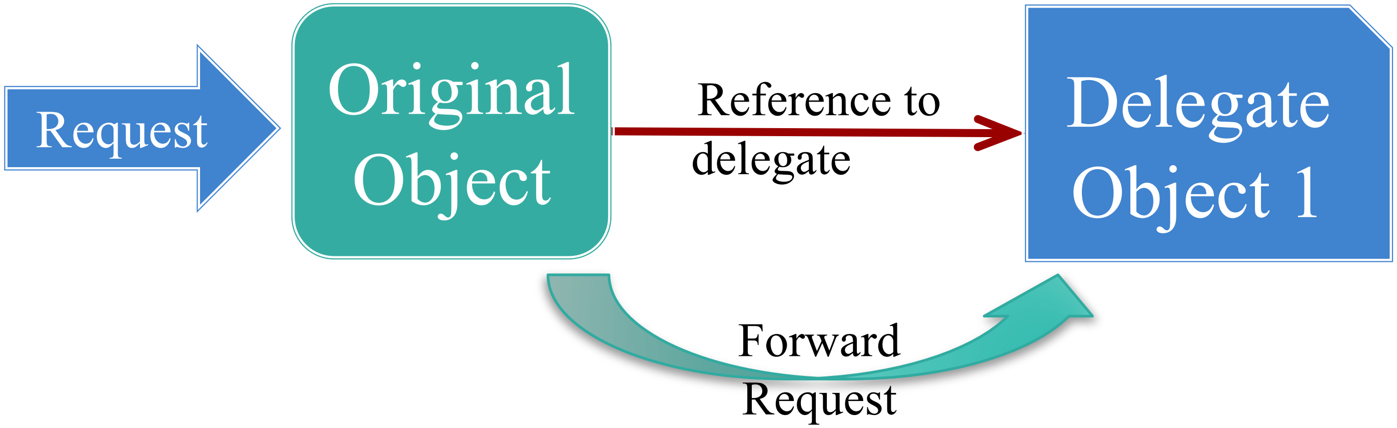
Make characters easy to read

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

Read whole line at a time

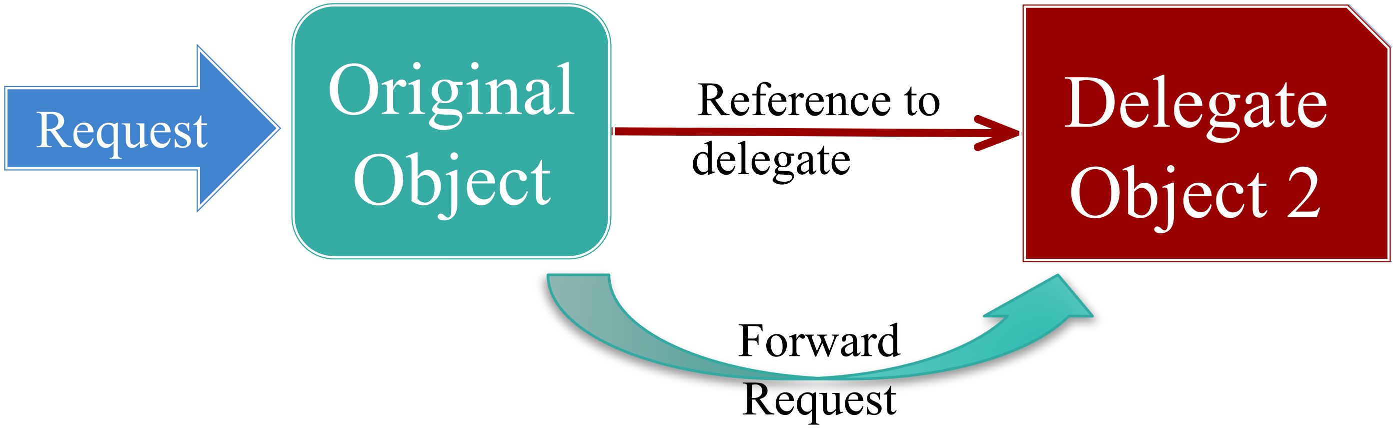
Most of java.io works this way

# Alternate Solution: Delegation Pattern



*Inversion* of the Decorator Pattern

# 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

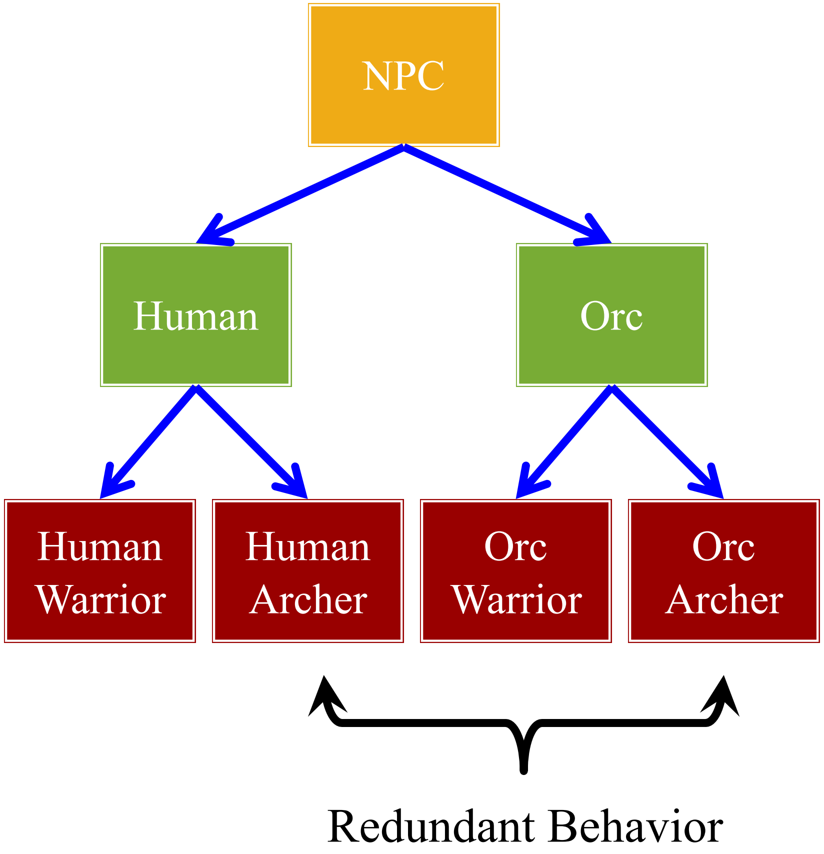
## Decoration

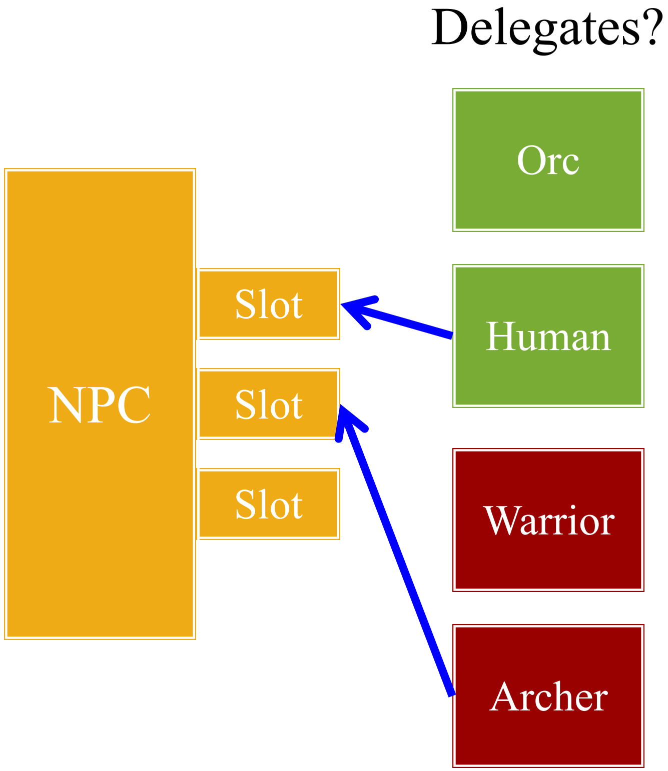
- Pattern applies to *decorator*
  - Given the original object
  - Requests through decorator
- **Monolithic** solution
  - Decorator has all methods
  - “Layer” for more methods (e.g. Java I/O classes)
- Works on *any* object/class

## 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





# 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
- CUGL view is handled in scene graphs
- Proper design leads to unusual OO patterns
  - Subclass hierarchies are unmanageable
  - **Component-based design** better models actions