CS354P

DR SARAH ABRAHAM

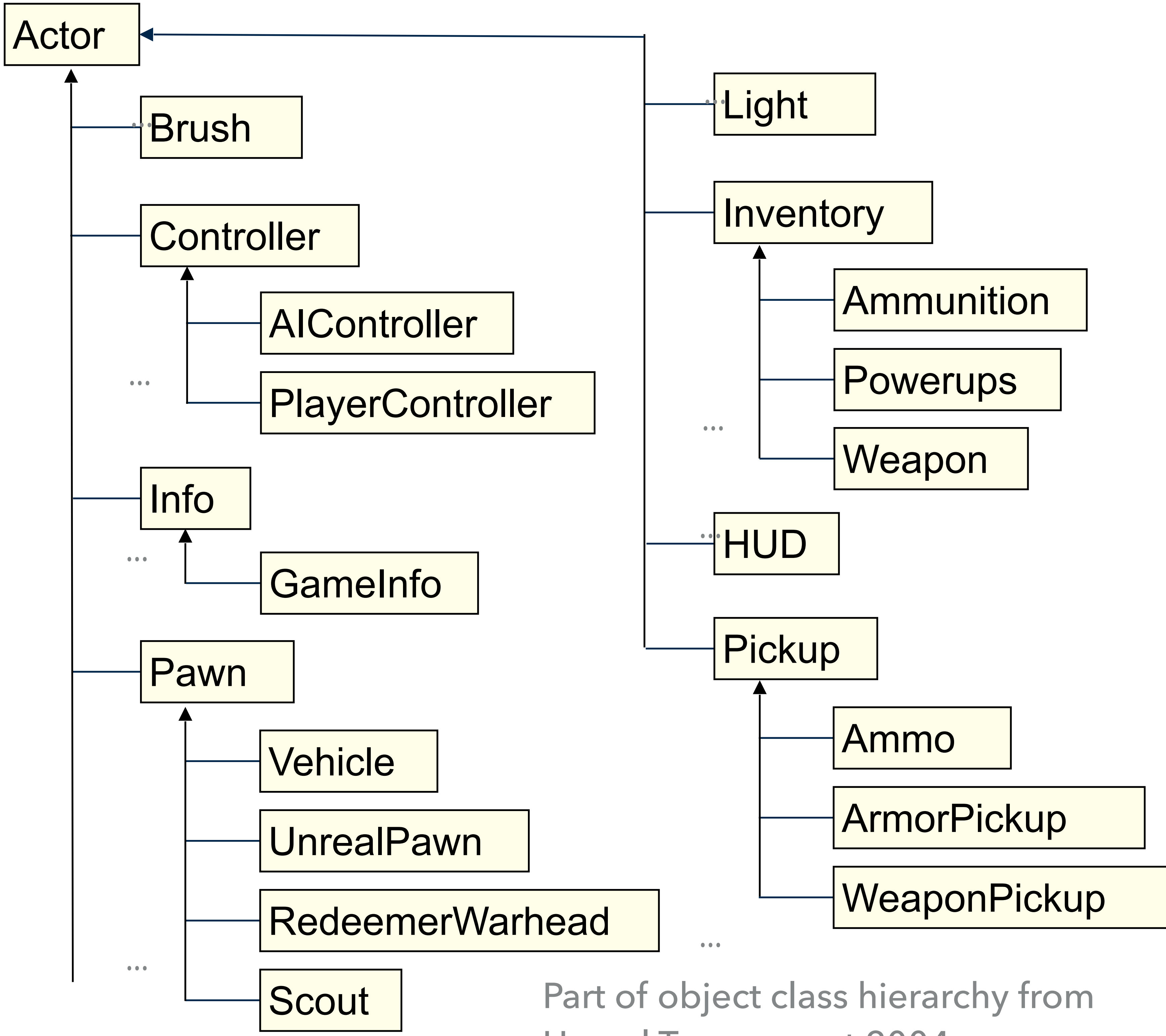
COMPONENT-ORIENTED PROGRAMMING

PROBLEMS WITH INHERITANCE

- Many complaints about OOP revolve around inheritance and its hierarchies
    - Inflexible
    - Hard to maintain
    - Hard to understand
- Causes the very problems it's trying to solve

EXAMPLE: MONOLITHIC CLASS HIERARCHIES

- Very intuitive for small simple cases
- Tend to grow ever wider and deeper
- Virtually all classes in the game inherit from a common base class



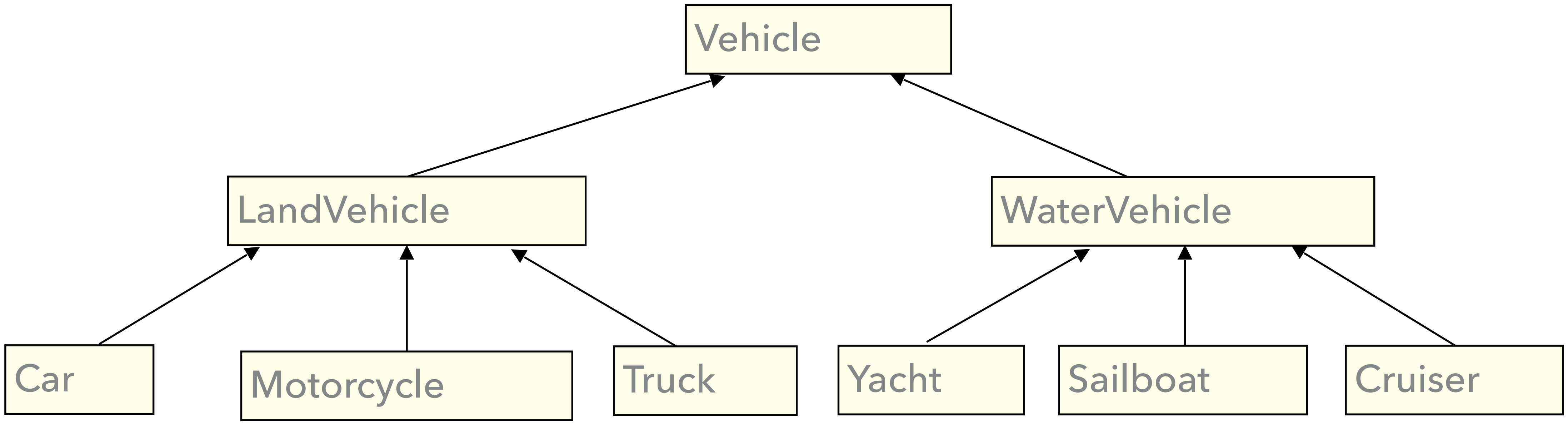
Part of object class hierarchy from Unreal Tournament 2004

WHAT MONOLITHIC GIVES US

- Inheriting from a single base class works well with dynamic programming and systems
  - One place to implement all the features (reflection, serialization, garbage collection, etc) that we may want
- Allows the creation of a natural taxonomy of objects
  - Forms a directed acyclic graph of functionality
  - Easy to reason about in many cases

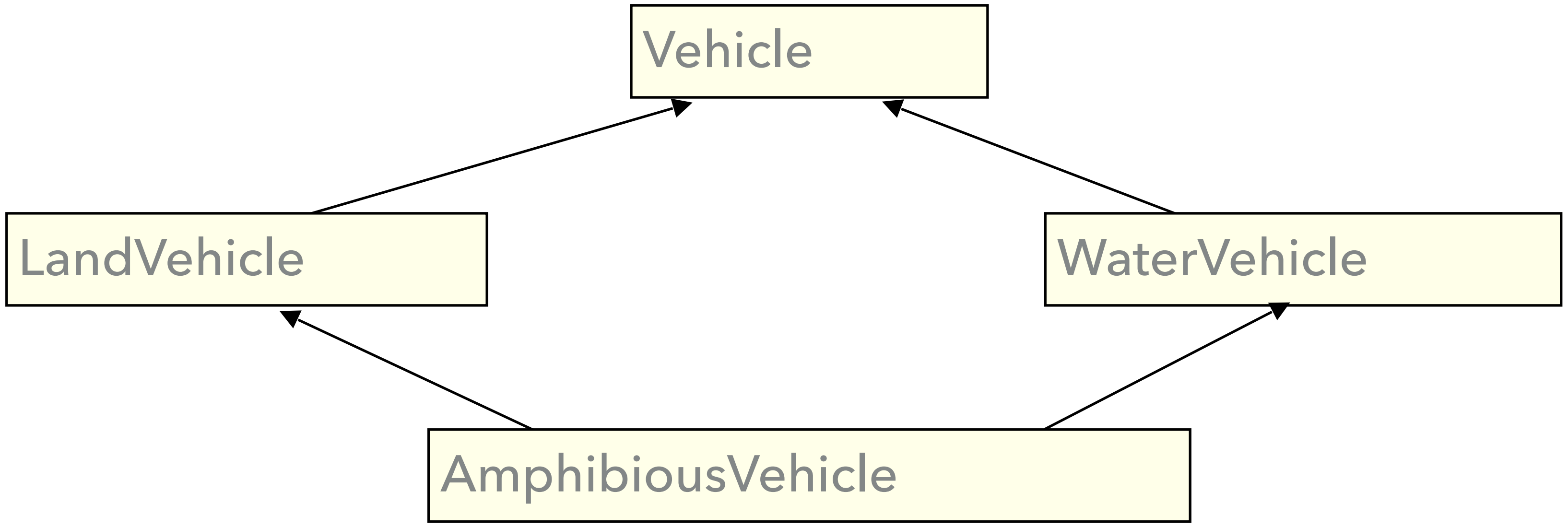
PROBLEMS WITH MONOLITHIC HIERARCHIES

- Hard to understand, maintain, and modify classes
  - Need to understand a lot of parent classes
- Hard to describe multidimensional taxonomies
  - e.g. How would you include an amphibious vehicle?



USE MULTIPLE INHERITANCE?

- NOOOO!!!!!
- There’s a reason languages like Java don’t have it
- Derived classes often end up with multiple copies of base class members
  - Compiler cannot resolve ambiguities



MULTIPLE INHERITANCE

```
class Foo: Bar {
public:
   Foo();
};

class Bar {
public:
   Bar();
};
```

- C++ allows multiple inheritance
    - Can seem quite convenient if existing taxonomy doesn't quite work in a particular case
- Problems arise since the constructor for the superclass is called when creating a derived class

When Foo() is called, copy of Bar created then copy of Foo

SO WHAT HAPPENS WHEN WE CONSTRUCT FOO NOW?

```
class Bar {

public:

   Bar();

};


class Baz: Bar {

public:

   Baz();

};
```

```
class Foo: Bar, Baz {

public:

   Foo();

};
```

1) Bar constructor called

2) Bar constructor called

3) Baz constructor called

4) Foo constructor called

THE DEADLY DIAMOND PROBLEM

- Two copies of all of Bar's members
  - Bar::Foo::function()
  - Bar::Baz::Foo::function()
- Compiler ambiguities if Bar and Baz implement the same function
  - Call on Bar::Foo::function() or Bar::Baz::Foo::function()?
- Results in a compiler error

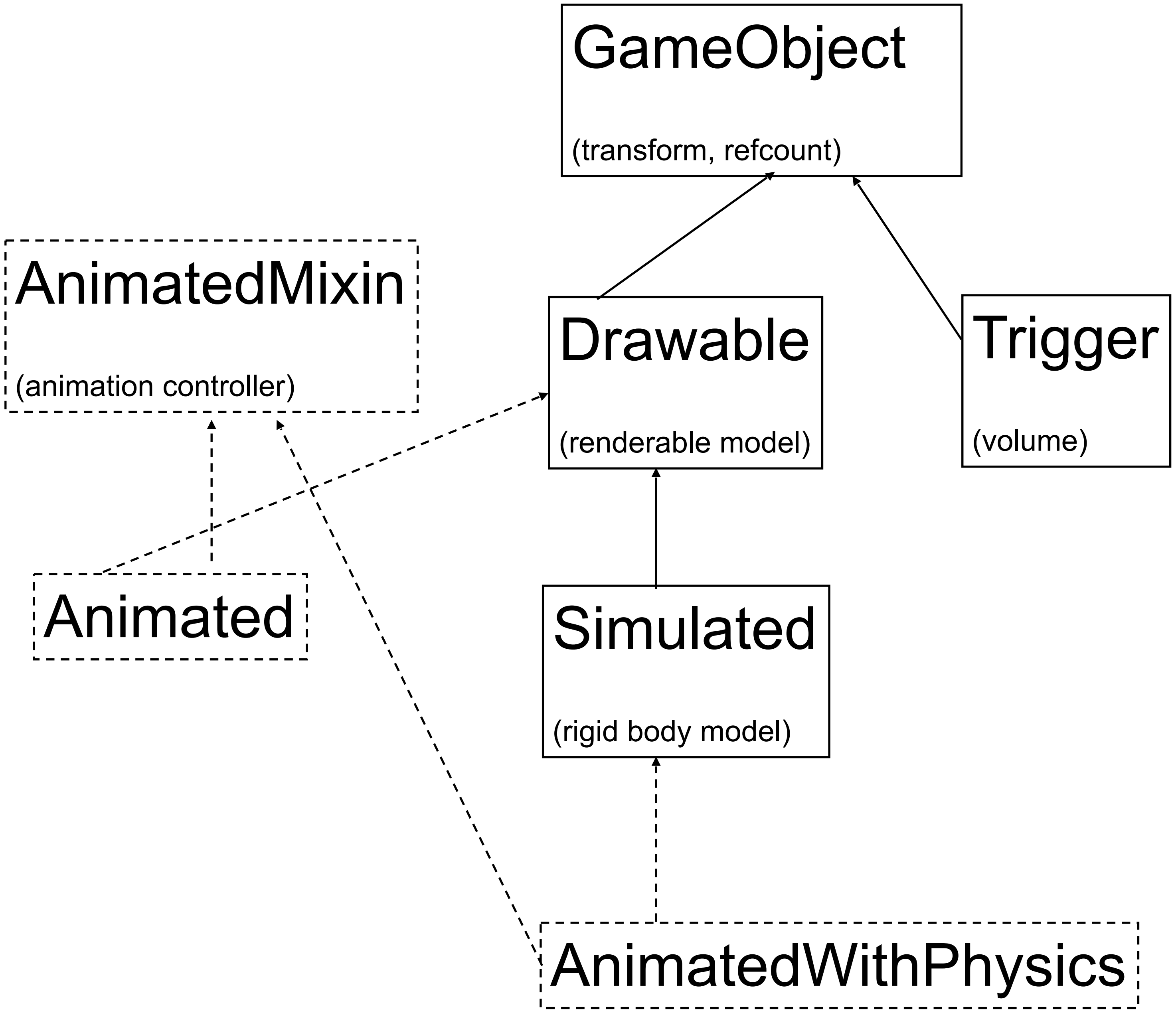
SOLVE WITH VIRTUAL INHERITANCE?

- Common C++ wisdom is use of virtual inheritance (i.e. virtual base classes) to prevent multiple copies
- Sure, but better idea: don’t use multiple inheritance
  - Assumptions about the hierarchical taxonomy may be flawed and need redesign
  - Not every object fits within a monolithic hierarchical taxonomy

INTERFACES AND MIX-INS IN OOP

- Interfaces are an abstract type that does not contain data but does contain method signatures
- Mix-ins are classes that contain functions which are useable by other classes that do not inherit from the mix-in class
- These paradigms allow for single-inheritance languages to express multiple types of functionality without multiple inheritance issues
  - High-level concepts -- actual implementation will be language-specific
- C++ does not natively support either of these
  - Create interfaces using pure virtual functions
  - Create mix-ins using…multiple inheritance…

MIX-IN EXAMPLE



GameObject

(transform, refcount)

AnimatedMixin

(animation controller)

Drawable

(renderable model)

Trigger

(volume)

Animated

Simulated

(rigid body model)

AnimatedWithPhysics

MOVING BEYOND TAXONOMIES

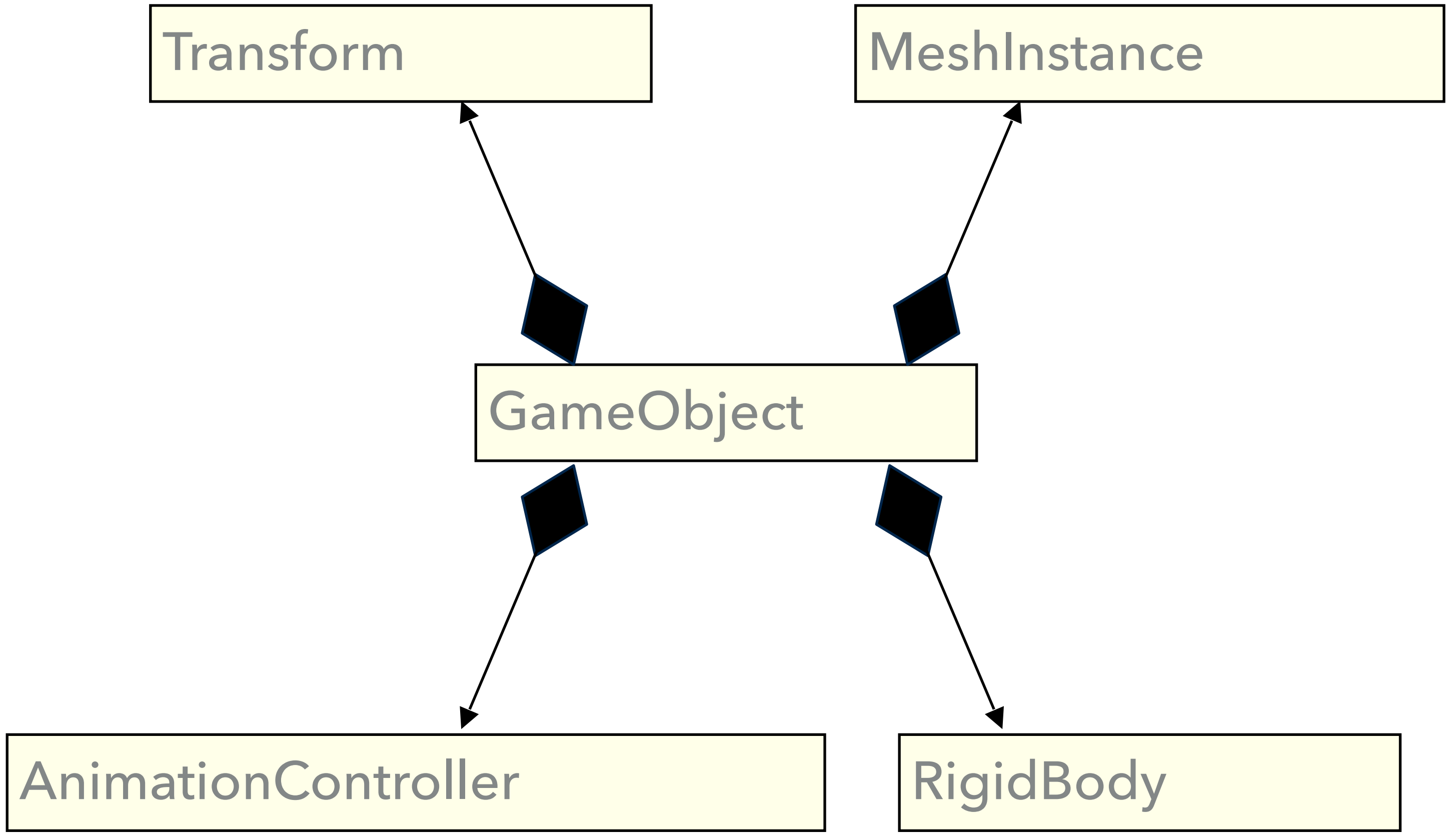
- Classical inheritance is an “is-a” relationship
  - e.g. What are the defining features of an object’s existence?
  - Allows for deep and complex taxonomy of objects
- Also possible to treat objects as a collection of other objects
  - Creates a “has-a” relationship
  - e.g. What is the functionality of the objects that an object possesses?
  - Allows for the deep and complex **composition** of objects

COMPOSITION

- Object contains subobjects that implement desired functionality
    - Composition: object can own the subobject (i.e. subobjects share main object’s life cycle)
    - Aggregation: object contains the subobject (i.e. subobject does not share main object’s life cycle)
- High level principle of how and when to split functionality
    - Can be implemented using interfaces, mix-ins, delegates, etc

COMPONENTS

- One “hub” object contains pointers to instances of various service class instances as needed (e.g. composition).



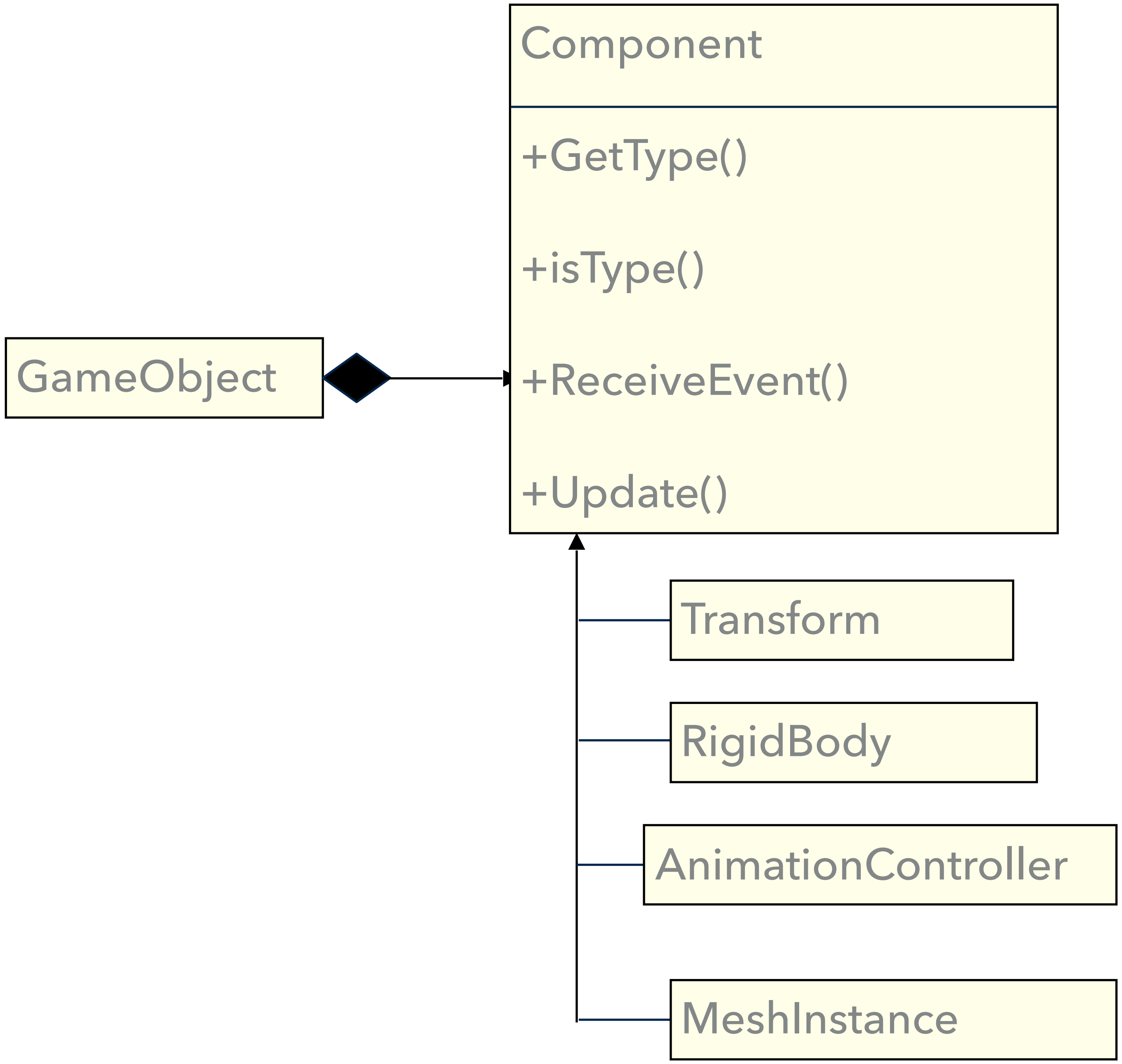
Note: Filled diamond indicates composition; unfilled diamond indicates aggregation

USING COMPOSITION

- “Hub” class owns its components and manages their lifetimes (i.e. creates and destroys them)
- Naive component creation:
  - The GameObject class has pointers to all possible components, initialized to NULL
  - Only creates needed components for a given derived class
  - Destructor cleans up all possible components for convenience
  - All optional add-on features for derived classes are in component classes

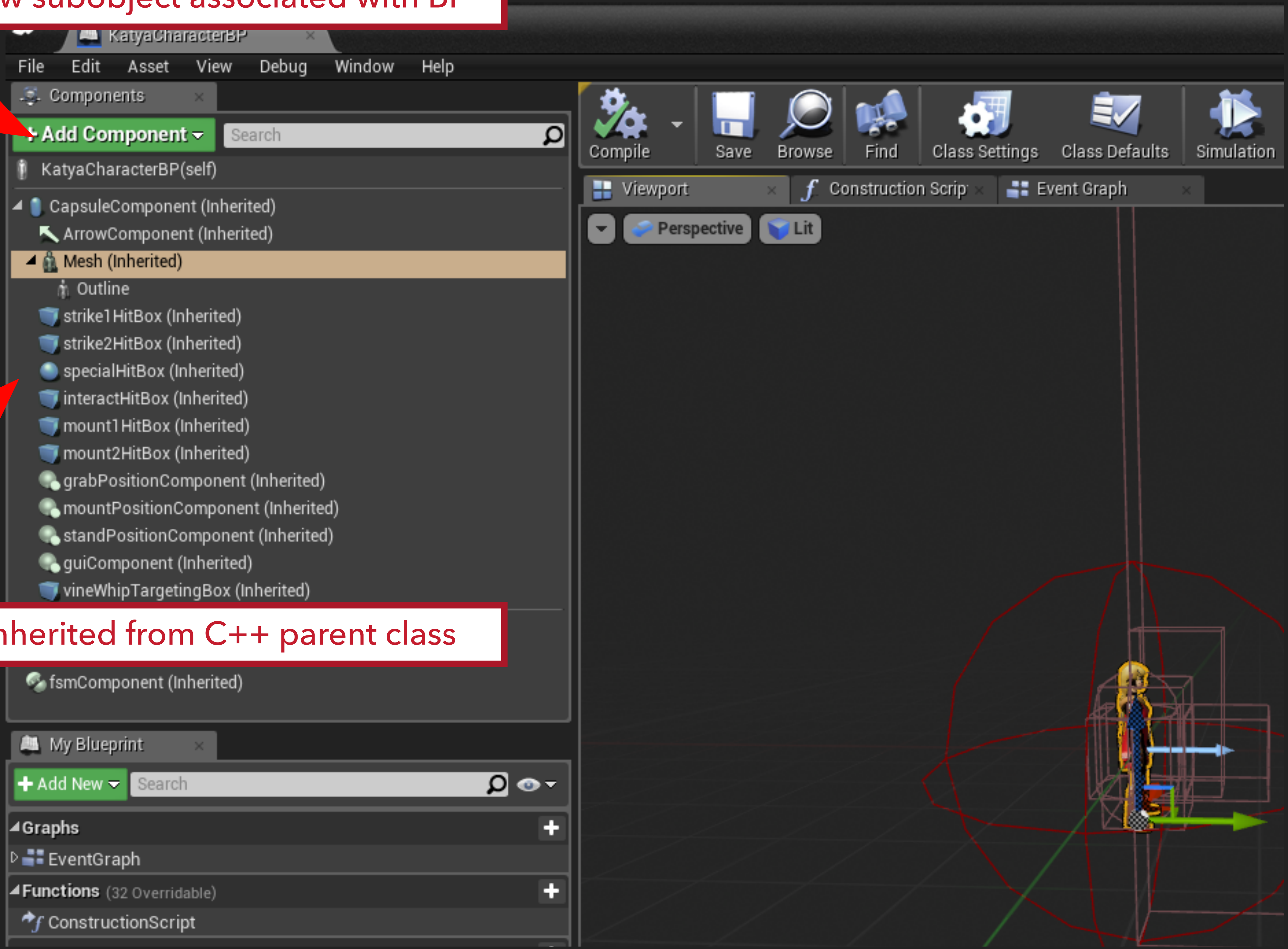
MORE FLEXIBLE (AND COMPLEX) ALTERNATIVE

- Root GameObject contains a list of generic components
- Derive specific components from the component base class
- Allows arbitrary number of instances and types of components



EXAMPLE: UE4 AND UACTORCOMPONENTS

Creates new subobject associated with BP



KatyaCharacterBP(self)

- CapsuleComponent (Inherited)
  - ArrowComponent (Inherited)
  - Mesh (Inherited)
    - Outline
  - strike1HitBox (Inherited)
  - strike2HitBox (Inherited)
  - specialHitBox (Inherited)
  - interactHitBox (Inherited)
  - mount1HitBox (Inherited)
  - mount2HitBox (Inherited)
  - grabPositionComponent (Inherited)
  - mountPositionComponent (Inherited)
  - standPositionComponent (Inherited)
  - guiComponent (Inherited)
  - vineWhipTargetingBox (Inherited)

fsmComponent (Inherited)

Graphs

- EventGraph

Functions (32 Overridable)

- ConstructionScript

Subobject inherited from C++ parent class

THINKING ABOUT OOP, COMPONENTS, AND INHERITANCE

- Consider the principles of OOP we discussed last time
  - Encapsulation
  - Abstraction
  - Inheritance
  - Polymorphism
- How useful are these in practice?
- What are the trade offs in large systems like a game engine?
- How well do the ideas of inheritance and components help or hinder these concepts?
- Are there other concepts we should be considering in game development?