
Class 2
Announcements

Text

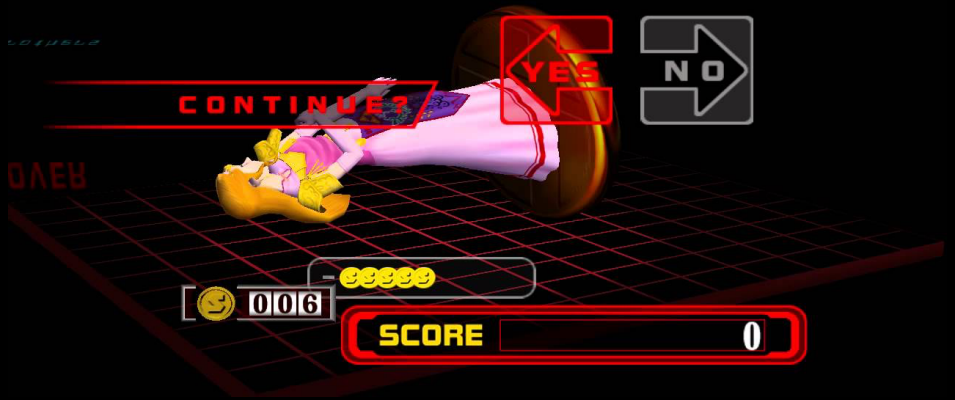
- To draw text
  - `camera->setUI(true)`
    - 1 unit = 1 pixel
    - Positions are pixel offset from bottom left of the screen
  - `g->setMaterial(...)`
  - `g->drawText("Hello, world", 100)`
- To increase font resolution
  - Change `fontResolution` variable in engine/graphics/Font.h

Handins

- Since we have had some issues with FastX, you do not need to check whether your handin compiles on the department machines
- All you need to do now is write what OS, Qt version, and compiler you are using in your README

Didn't Complete Warmup1?

- No problem – you have retries!
- Don't let the snowball begin week 1
  - Try to do your retry AND Warmup2 this week!

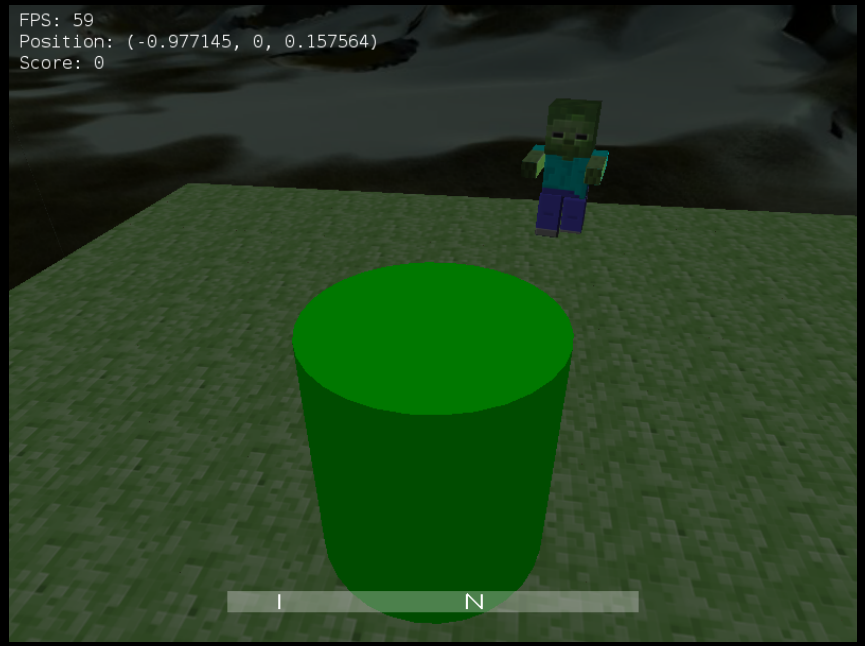


Collaboration Policy

- Remember to sign the collaboration policy on the website
- Pretty vanilla collaboration policy
  - No sharing code
  - No looking at each other's code
  - Can discuss design

Warmup2 - Your first full game!

- You'll have your first full 3D game after this week!
- Gameplay options are actually pretty diverse
  - More on this later
- Have some fun!



Announcements

QUESTIONS?


Class 2
Third Person Camera

Third-Person Camera

THE THIRD PERSON CAMERA

First Person is easy

- Field-of-view is limited
- Actions are (almost) always happening in the direction the player is looking
- It's how we see the real world

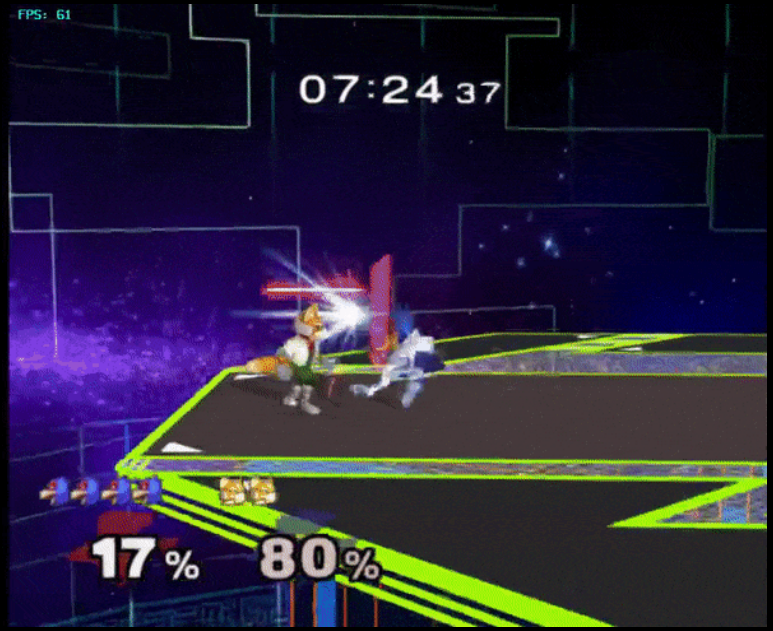
Third Person is tricky

- Field of view is ambiguous – player can often see:
  - Behind themselves
  - Around corners
  - Through walls
- Player can perform actions without turning
  - Fighting sequences
- We don't see the real world this way

What works best?

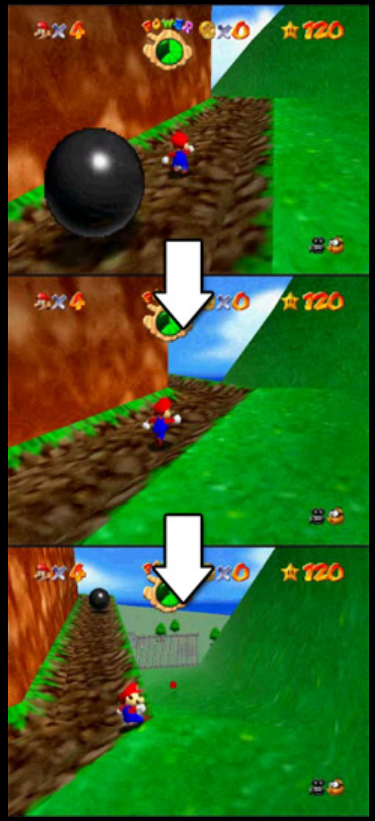
Player controls the camera?

Camera controls itself?



Combine the two?

- Camera automatically turns to keep player in focus as well as possible
- Player can manually change the camera if they want a particular camera angle



The Simplest Solution

- Take the first person camera
- Translate the eye back along the look vector
- Pros:
  - Easy to toggle between 1st and 3rd person cameras
  - Easy to change zoom level by scaling translation
- Cons:
  - Awkward camera controls (pitch and yaw don't always feel quite right)
  - Sometimes clips through walls (can use raycasting to circumvent this, but we'll get to that another day!)

Third Person Camera

QUESTIONS?


Class 2
Game World

Game World

MOTIVATION

Games are busy…

- All games involve a number of game objects
  - May be many different types of objects
  - May be many instances of the same type of object
  - Maybe both of the above
- These objects exist in their own universe
  - If our entire universe is a game, you're a game object

Games are busy…

- We need to take the burden of representing and organizing these objects off the game code
  - Otherwise, have to re-implement for every game we build

High Level Representation

The `GameObject`s

- Small collections of functionality
- Hold their **own** logic and state

The `GameWorld`

- The overarching collection of `GameObject`s
- Responsible for global logic and facilitating interactions between `GameObject`s

Game World

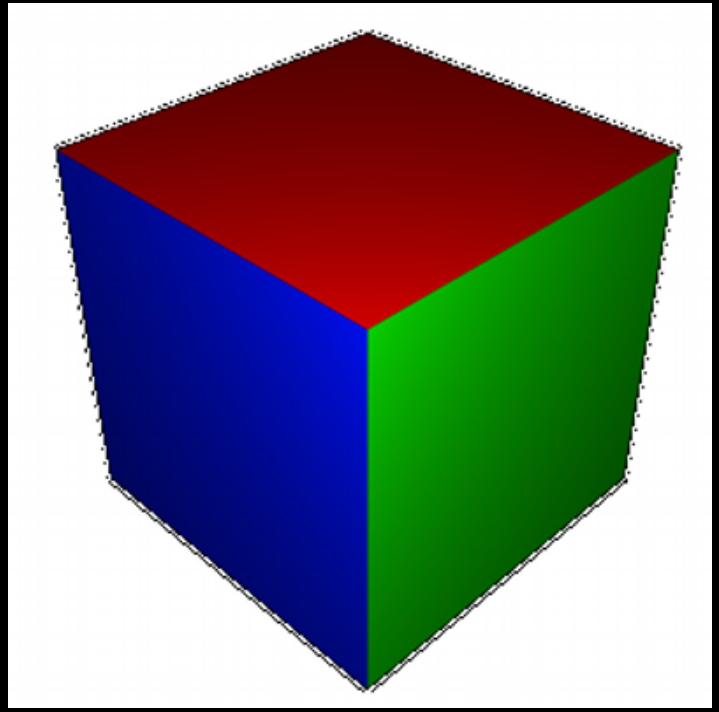
QUESTIONS?

Game World

GAME OBJECTS

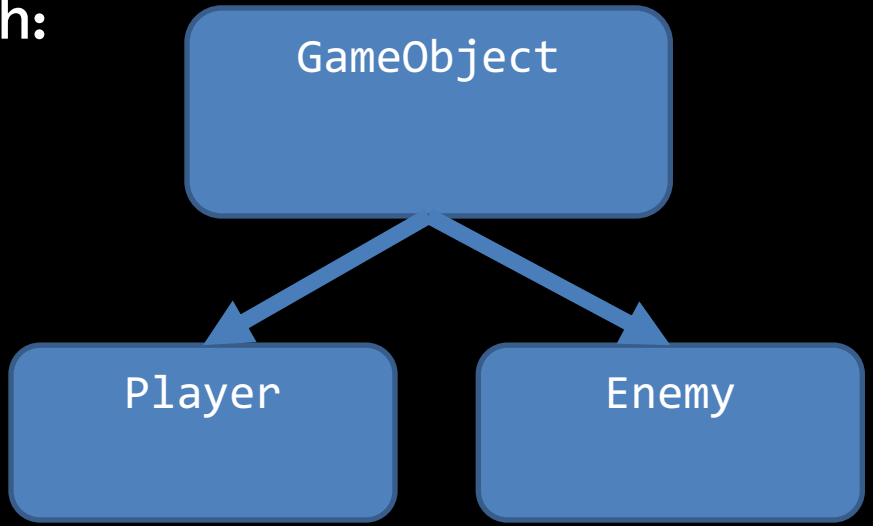
What is a `GameObject`?

- Environment
- Player
- Enemies
- Much more!
- How do we implement them?



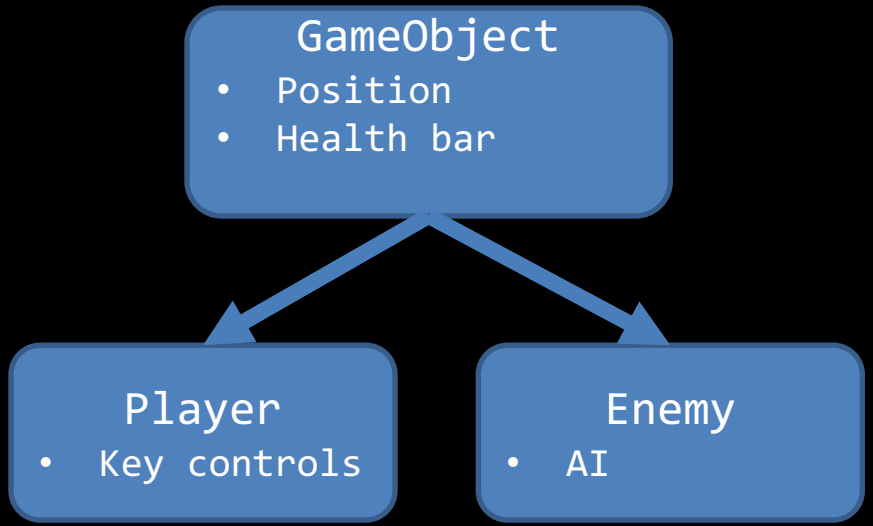
Hierarchical `GameObject` design

- Consider a simple game with:
  - Player
  - Enemies



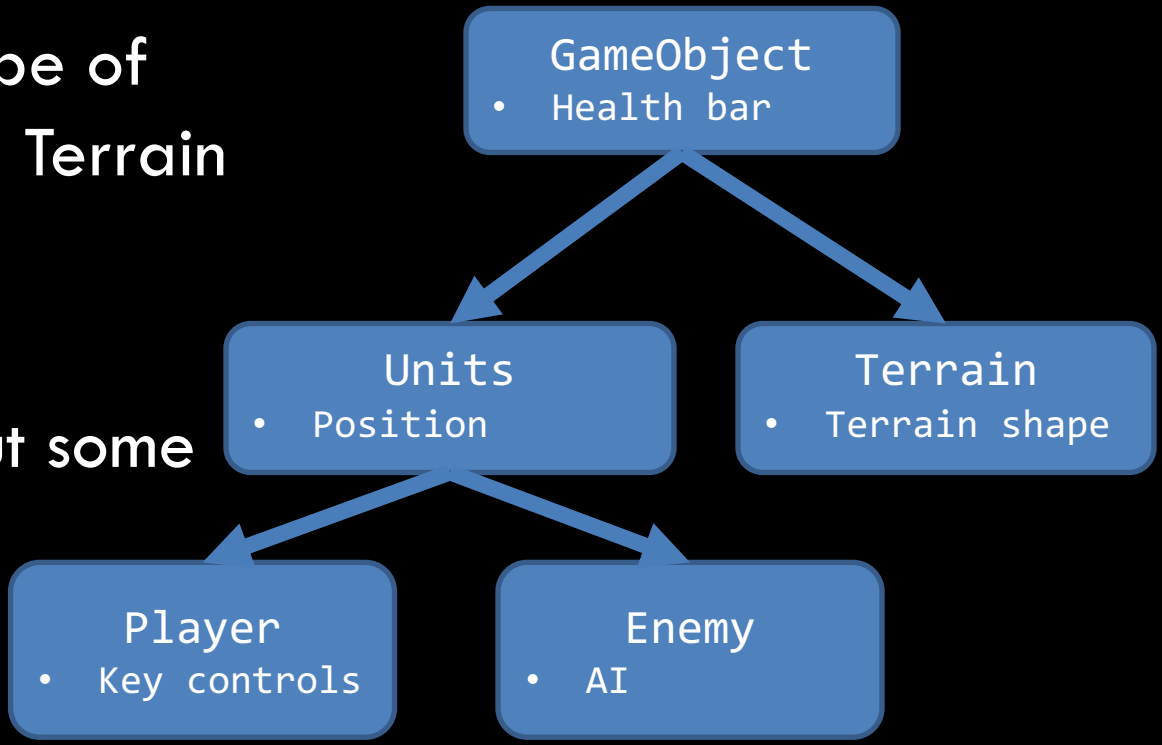
Hierarchical `GameObject` design

- They both move and have health bars
- Some behavior specific to Player
- Some behavior specific to enemies



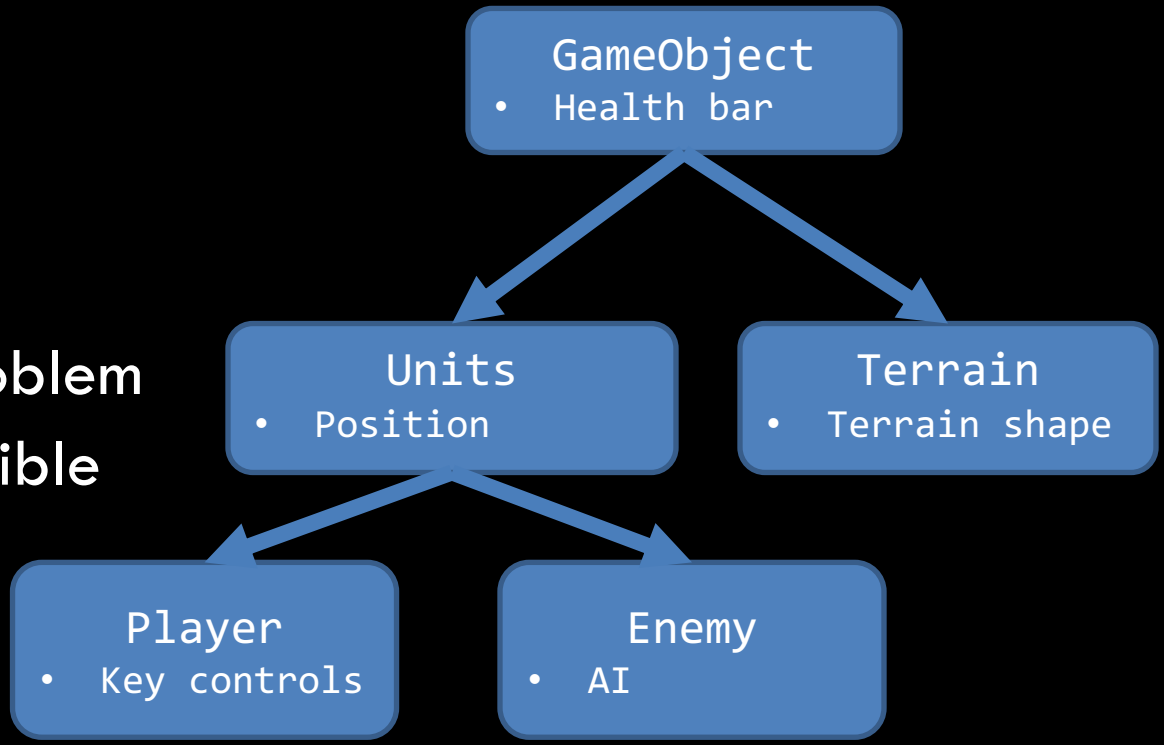
Hierarchical `GameObject` design

- Let's add a new type of object: Destructible Terrain
  - Has a health bar
  - Doesn't move
- Time to abstract out some more



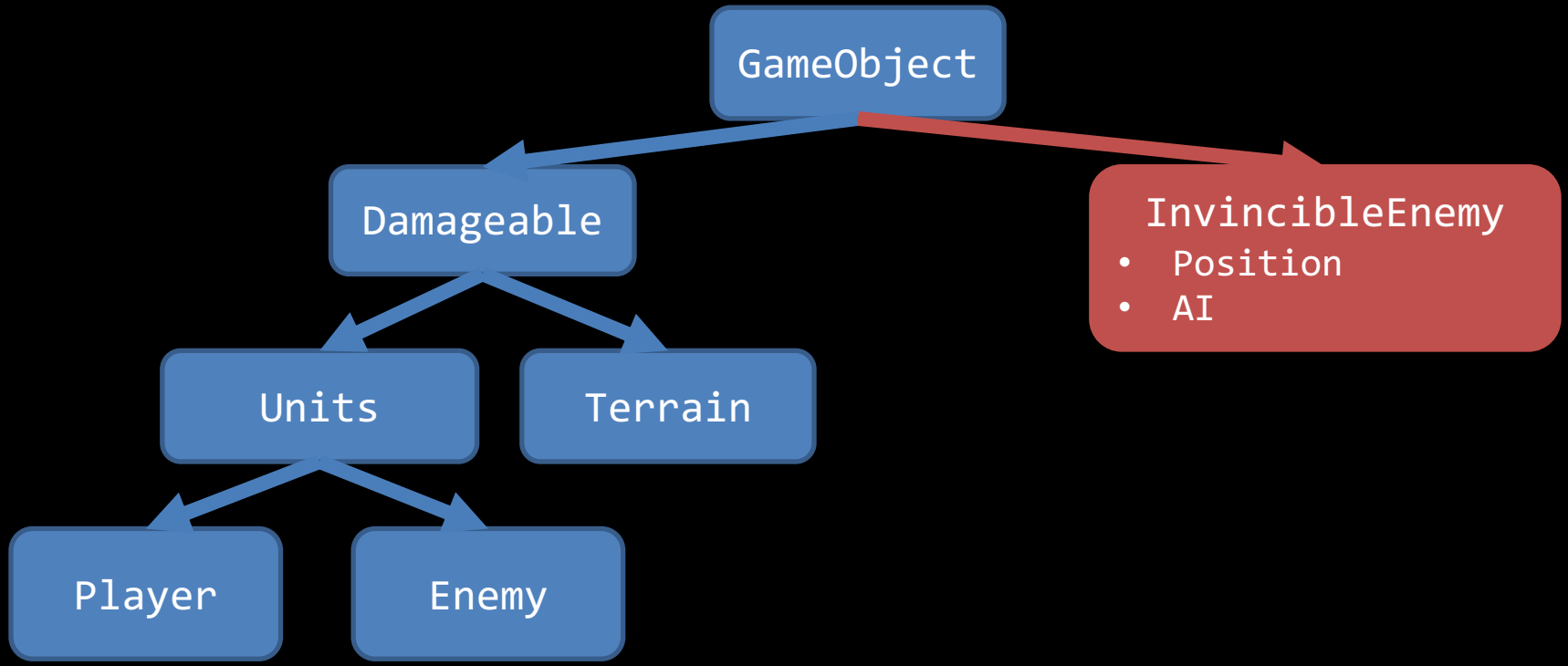
Hierarchical `GameObject` design

- Let's add Invincible Enemies
  - No health bar
  - They move
- Now we reach a problem
- Where do our invincible enemies fit in?



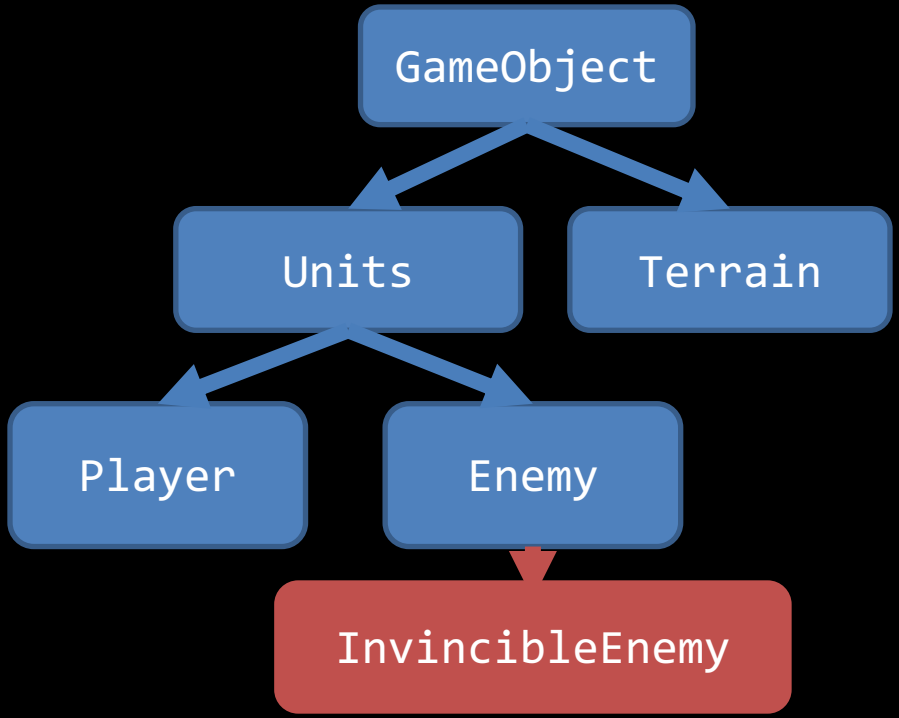
Hierarchical `GameObject` design

- Attempt 1: Can make a separate class and re-implement moving and AI



Hierarchical `GameObject` design

- Attempt 2: Can subclass enemy and add code to hide the health bar

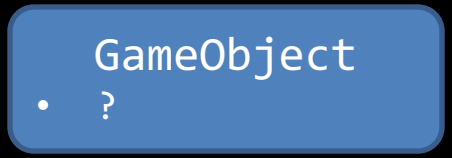


Hierarchical `GameObject` design

- Both not ideal
  - Attempt 1: Re-implementing code
  - Attempt 2: Unused superclass functionality in subclass (not good practice)
- With hierarchical design, often have to make these lose-lose design decisions

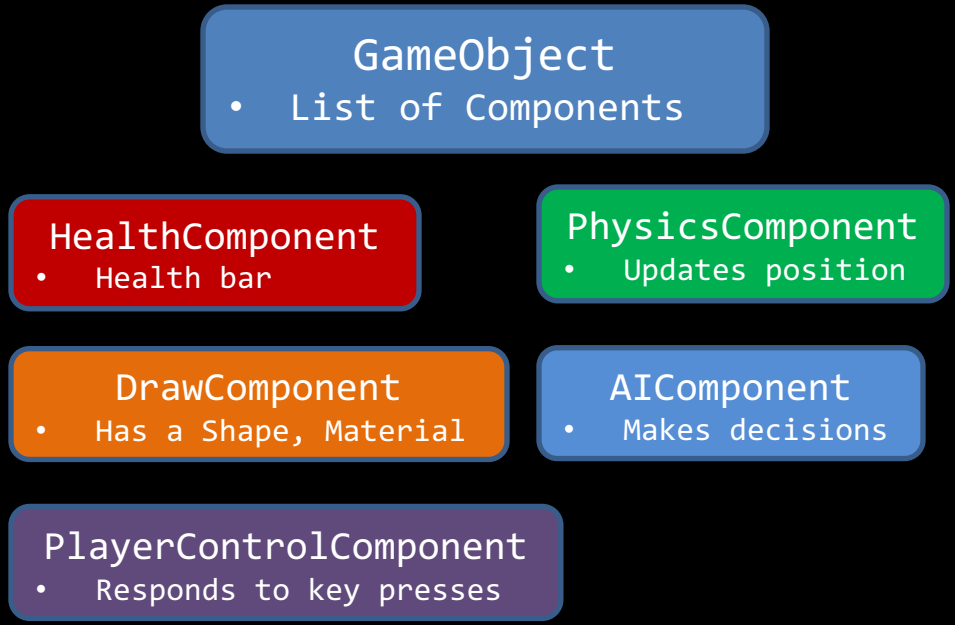
Solution

- Component-based design



Solution

- GameObjects are just lists of components
- The components implement all relevant functionality
- The appearance and logic of each object is defined by its components
  - objects can be any combination of components
- Making new objects is as easy as adding new components



`GameObject` Contract

- `GameObject`s need to do the following:
  - Add a component
  - Remove a component
  - Get a component

GameObject Contract

```
class GameObject {
public:
        void addComponent(...);
        void removeComponent(...);
        Component getComponent(...);

private:
         Container<Component> m_components;
}
```

Component Contract

- Nearly all Components need to update
  - onTick
  - Where most logic is implemented
- Some Components respond to other events
  - For example onDraw
- Components might want to access parent GameObject
  - So that they can talk to other components of the same GameObject

Component Contract

```
class Component {
public:
      void onTick(float seconds);
      // more events (possibly in subclasses)

private:
       GameObject *m_gameObject;
}
```

Game World

QUESTIONS?

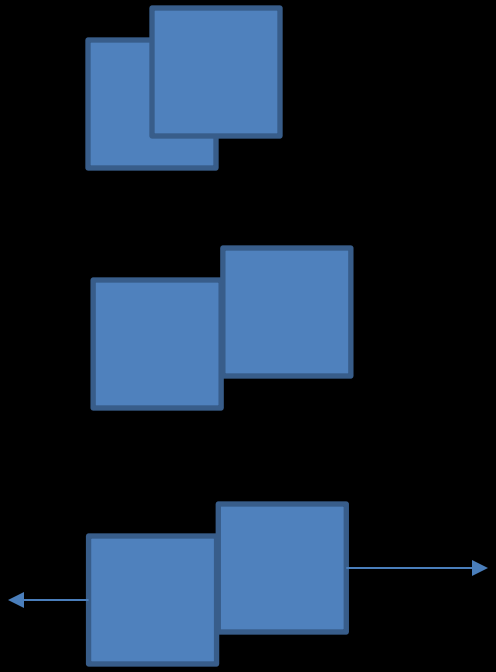

Class 2
Cylinder-Cylinder Collisions

Collisions I

CYLINDER-CYLINDER COLLISIONS

Parts of a collision

- Detection
  - Are two shapes overlapping?
- Resolution
  - Make them not overlapping anymore
- Response
  - Make them bounce off each other in some believable way

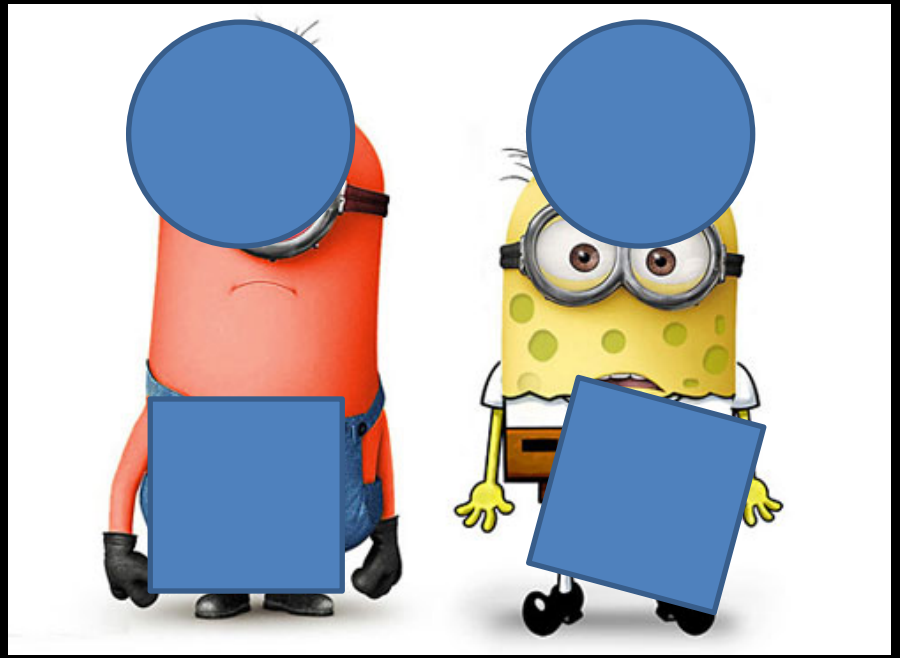


Why do we need it?

- (Almost) every 3D game uses it
- Even last week, you did this with the floor
  - Is `pos.y < 0`? (detection)
  - If so, make `pos.y = 0` (resolution)
  - Set the player's y velocity to 0 (response)

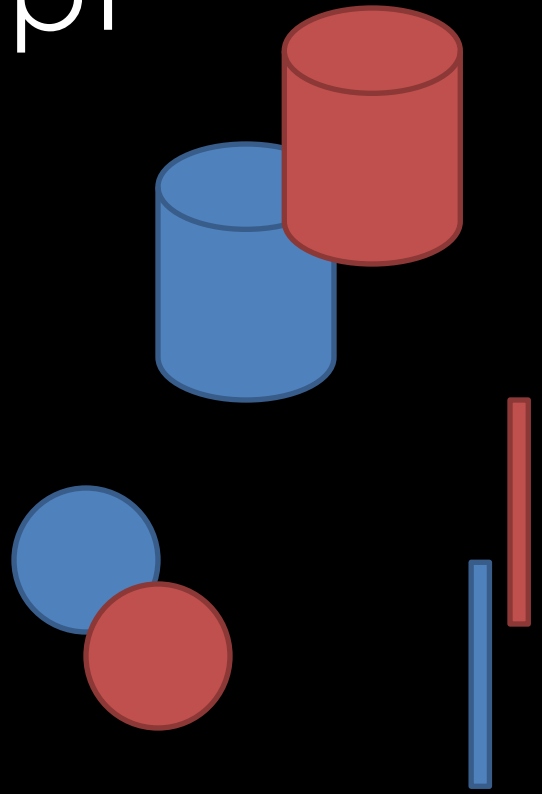
Cylinders

- Cylinders make great collision shapes
  - People are kind of cylinders
  - The math is pretty easy
  - Turning in place doesn't change your collision shape



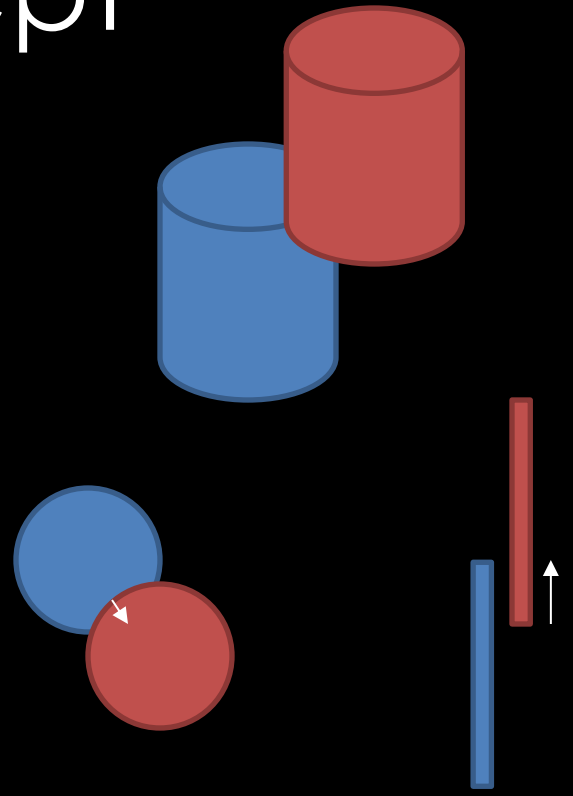
Concept

- Separate 3D problem into 2D and 1D problems
  - 2 + 1 = 3
- Overlapping if both:
  - Bases overlap in xz plane
  - Heights overlap on y axis
- Easy if your cylinder is represented by a point (bottom center) and dimension (radius, height)



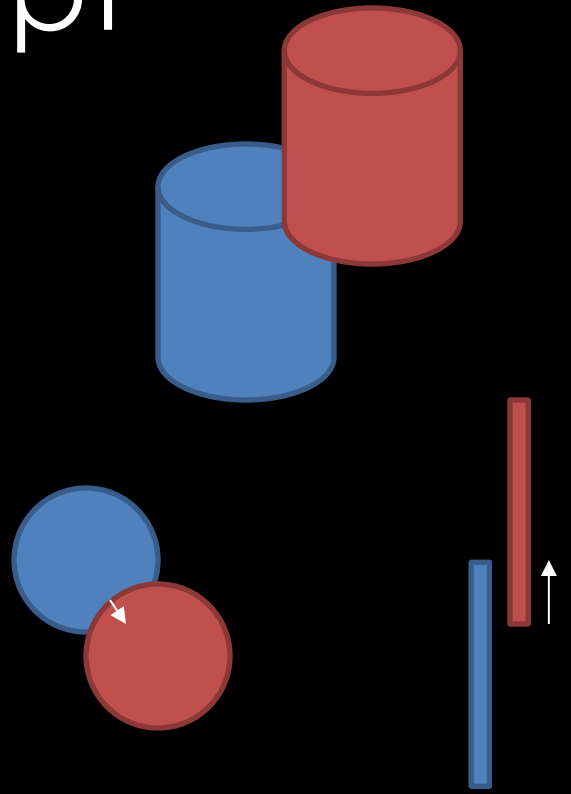
Concept

- Need to find minimum translation vector (MTV)
  - Minimum Translation Vector – shortest possible translation to get two shapes out of collision
  - With respect to one of the shapes in collision



Concept

- Either translate in xz plane or in the y direction
  - Only 2 possible MTV's
  - Pick the one that is shorter
- Translate red out by $\frac{1}{2}mtv$ and blue out by $-\frac{1}{2}mtv$
  - If your engine supports immovable game objects, the movable game object is translated out by the entire MTV



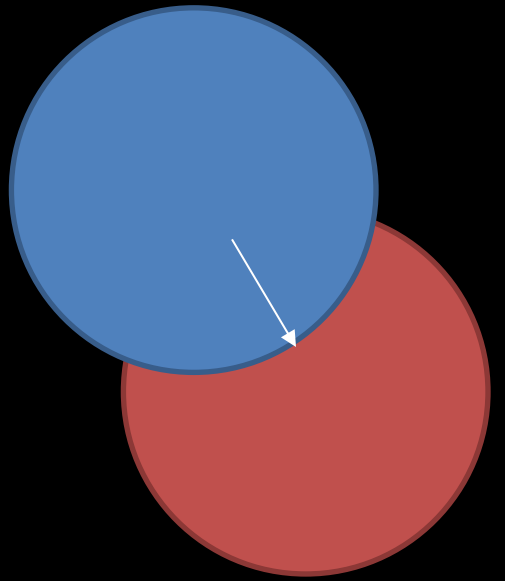
Circle Math

Two circles are overlapping if and only if:

- $(blue.pos - red.pos).length() < blue.radius + red.radius$

Avoid square root by squaring expression!

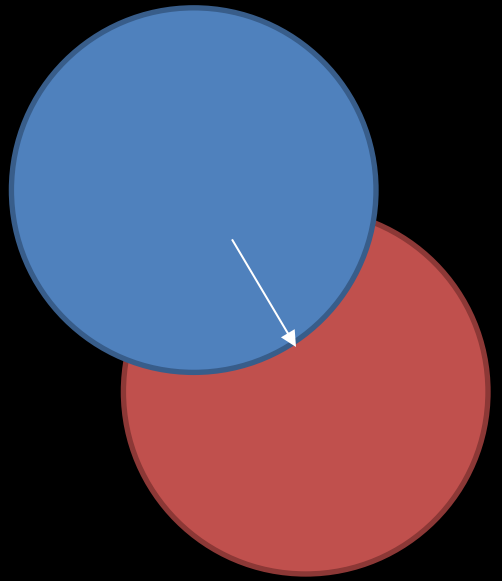
- $(blue.pos - red.pos).lengthSquared() < (blue.radius + red.radius)^2$



Computing Circle MTV

MTV (in the direction of red):

- $len = (blue.pos - red.pos).length()$
- $\frac{(red.pos - blue.pos)}{len} * \big((blue.radius + red.radius) - len\big)$



Line Math

Two 1D line segments are overlapping if and only if both of the following are true:

- $blue.min < red.max$
- $red.min < blue.max$

Computing Line MTV

```
float intervalMTV(Interval a, Interval b)
  float aRight = b.max - a.min
  float aLeft  = a.max - b.min
  if aLeft < 0 || aRight < 0
    return -1
  if aRight < aLeft
    return aRight
  else
    return -aLeft
```

Collision Response

- If objects collide, they should do something
  - Minimally, translate by ½ the MTV each
    - Adds up to 1 full MTV!
  - In almost all cases, do game-specific logic
- Example: bullet collides with player
  - Player takes damage
  - Player is moved back some by the force of the bullet
  - Bullet is destroyed

Collisions I – Cylinder-Cylinder Collisions

QUESTIONS?


Class 2
Systems

Systems

MOTIVATION

Example: Collision Logic

- We know how to detect if cylinders are overlapping
- We have a bunch of `GameObject`s
- How do we make them collide with each other?

Example: Collision Logic

- We could put collision logic in the `GameWorld`
  - `GameWorld` checks if each pair of collidable `GameObject`s is colliding
  - `GameWorld` tells `GameObject`s that they there are colliding
  - `Component`s of `GameObject`s respond appropriately
- Sounds pretty good

Global Logic

- What if your `GameObject`s play sounds?
- Should we put sound logic in the `GameWorld` too?
  - `GameWorld` tells each `GameObject` that can play a sound to do so

Global Logic

- What if other `GameObject`s require more global logic?
- We would have to add all of our logic to the `GameWorld` class
- Before long, our `GameWorld` can get pretty bloated …

Systems

- Introducing `Systems` ...
- `Systems` implement global logic
  - Each `System` stores a list of interested objects (usually `GameObjects` or `Componentss`) and calls relevant methods on each of them
- Other examples
  - `DrawSystem` calls `draw(Graphics *g)` on it's drawable components
  - `CollisionSystem` checks collisions + calls collide(`glm::vec3` mtv) on collision components
  - `SoundSystem` calls `playSound(...)` on sound components

Systems

IMPLEMENTATION

Storing `GameObject`s vs. `Component`s

- You could have your `System`s keep track of either a list of `GameObject`s *or* a list of `Component`s—it's up to you
  - Storing `GameObject`s makes it easier to access multiple `Component`s of the `GameObject` and reference `GameObject` specific state
  - Storing `Component`s avoids potential type headaches and can give you performance benefits

System Contract

```
class System {
public:
	void onTick(float seconds) {
		for(GameObject/Component obj : m_objects)
		{
			// Update objects
		}
	};

	// more events (possibly in subclasses)

private:
	Container<GameObject/Component> m_objects;
}
```

What about the GameWorld?

- GameWorld should hold Systems as well as GameObjects
- With GameObjects/Components:
  - The appearance and logic of each object is defined by its components
- With GameWorld/Systems
  - The global logic and interactions between objects in the world are defined by its systems

(Possible) GameWorld Contract

```
class GameWorld {
public:
	void tick(float seconds);
	void draw(Graphics *g);
	//...

private:
	Container<GameObject> m_objects;
	Container<System> m_systems;
}
```

Systems

QUESTIONS?


Class 2
Handling Input

Last time…

- Right now, you might be handling input like this:

```
void onKeyPressed(QKeyEvent *event) {
        if (event->key() == Qt::Key_W) //move up
        if (event->key() == Qt::Key_S) //move down
        ...
}
```

The Problem

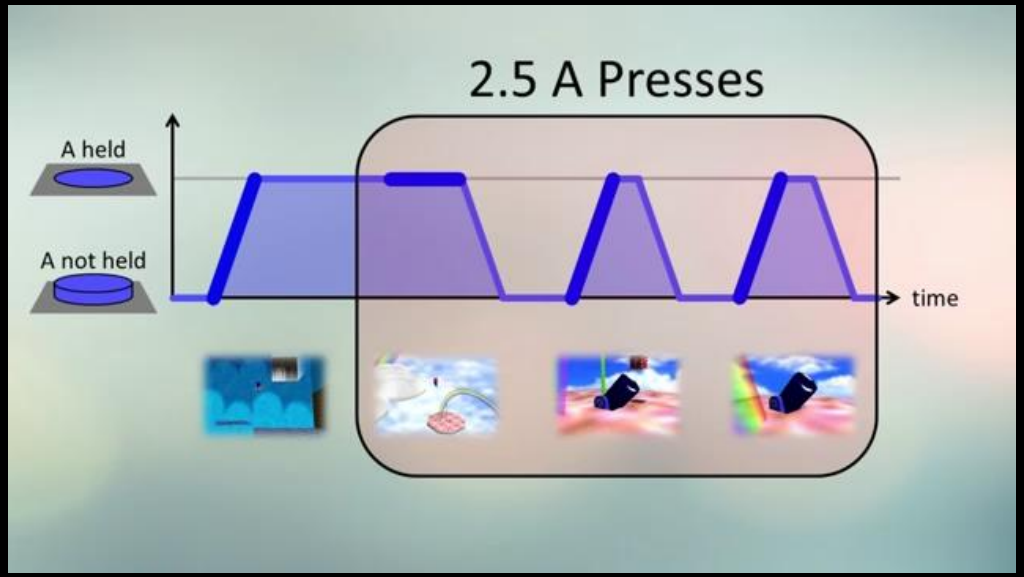
- Qt events may not act like you would expect
- The `onKeyPressed` event fires rapidly for the duration a key is held
  - Think of when you press down a letter key in Microsoft Word

The Result

- Movement happens in short bursts
  - We move a little bit every time a key event fires from the system
- Result: jerky movement—not ideal!
- What we want is something smooth and continuous

The Solution

- A key has two states: pressed and not pressed
- This is represented in the event system by `KeyPressed` and `KeyReleased` events



The Solution

- Instead of moving on every single `KeyPressed` event, just pay attention to *first* one
- Until the `KeyReleased` event, move the player every tick
- Keep track of the current state of each key in some sort of data structure of Booleans
  - For example, `Map<int, bool>`

But wait, there's more!

- In general, it's useful to access the current state of input …
  - Keys that are pressed
  - Mouse buttons that are pressed
  - Mouse position
- Not just when the current state changes
- `Input` object that stores all of this information?
- Up to you—be creative!

Input

QUESTIONS?


Class 2
Tips for Warmup 2

Warmup 2 Design

- This week, design is everything
- Many ways to approach `GameWorld`, `System`, `GameObject`, `Component` design
  - Even with the contracts we gave you
- For example …
  - `System`s can store `GameObject`s or their `Component`s
- Plan out your design, and talk it through with TAs

More Design Tips

- `GameWorld` and `GameObject`
  - Should be defined engine side
  - Should not be subclassed game side or engine side
- `System` and `Component`
  - Should be defined engine side
  - Can be subclassed game side or engine side

Your First Components (Suggested)

- `DrawableComponent`
  - Holds shape, material
- `TransformComponent`
  - Holds position, size of object
- `CollisionComponent`
  - Holds collision cylinder
- `PlayerControlComponent`
  - Responds to player input
- `Player/EnemyResponseComponent`
  - Does something in response to collision

Your First Systems (Suggested)

- `TickSystem`
  - Ticks the objects that it holds
- `DrawSystem`
  - Draws the objects that it holds
- `CollisionSystem`
  - Checks for collisions between objects
  - Notifies objects that they have collided

Destroying Game Objects

- Your Warmup 2 game needs to have a reset feature
- You must clear the gameworld when you reset
- Think about what would happen if a gameobject G managed by a `shared_ptr` called a method `destroySelf()`, which removes all `shared_ptr` references to G in the gameworld
  - The number of references to the shared pointer goes to 0, and then the shared pointer is destroyed!
  - But we are inside of one of G's methods, so we get a segfault!
- Think about what you could do to bypass this problem

Entity Component System Typemap

- Given a gameobject, what is the best way to access its components?
- We could have some function like `Component getComponent(std::string s)`
- This is okay, but if we wanted to access any methods of a `CollisionComponent` that are not virtual functions in the abstract `Component` class, we would need to cast the `Component` to the `CollisionComponent` class

Entity Component System Typemap

- We can use some C++ tricks to create a typemap
- There is a typemap implementation in src/engine/utils/TypeMap.h
- Look at this article for an explanation of the code!
  - Feel free to ask about how the typemap code works!

Entity Component System Typemap

- You can use the typemap in your GameObjects like this (assuming we have a `TypeMap<std::shared_ptr<Component>>` called `m_components`

```
template <typename Comp>
void addComponent(std::shared_ptr<Comp> &&c) {
    m_components.put<Comp>(std::forward<std::shared_ptr<Comp>>(c));
}

template <typename Comp>
void removeComponent() {
    m_components.remove<Comp>();
}

template <typename Comp>
std::shared_ptr<Comp> getComponent() {
    auto it = m_components.find<Comp>();
    return std::static_pointer_cast<Comp>(it->second);
}
```

Entity Component System Typemap

- And then we can ask a gameobject for its components like this…
- No casting required! (It's covered by the GameObject class)
- We can add extra assert statements to make sure our typemap is consistent

```
glm::vec3 position = m_gameobject->getComponent<TransformComponent>()->getPos();
```

Cylinders

- What are they good for?
- ~~Absolutely nothing~~

Tips for Warmup2

QUESTIONS?


Class 2
C++ Tip of the Week

C++ Tip of the Week

FORWARD DECLARATIONS

Forward Declarations

- What is declaration (as opposed to definition)?
  - Just enough information to tell the compiler 'this exists'
    - For a function, it would be the type signature:

      ```
      int add(int a, int b);
      ```

    - For a class, it's just the name:

      ```
      class Number;
      ```

- When you #include a header, you're defining that class

Forward Declarations

- When do we actually *need* to #include a class?
  - If this class extends that class
  - If it has a non-pointer member variable to that class
- That means we don't need to #include classes of:
  - Pointer member variables
  - Function arguments & return types (pointer or non-pointer)

Forward Declarations

- When should we use forward declarations?
  - For every class, in every header file, that you possibly can
  - There is no benefit to including a whole class when you only need the declaration
  - You can put the #include in the .cpp file instead

Benefits of Forward Declaration

- Fewer circular dependencies
  - These happen when two classes rely on each other, and both attempt to define the other by #including headers
  - If the link is indirect, it will take much longer to track
- Significantly reduced build times
  - Every time you #include a header, it also then #includes all the headers #included by that header, and so on
  - Game engines are huge, and this problem multiplies per file

C++ Tip of the Week

QUESTIONS?

Next Week...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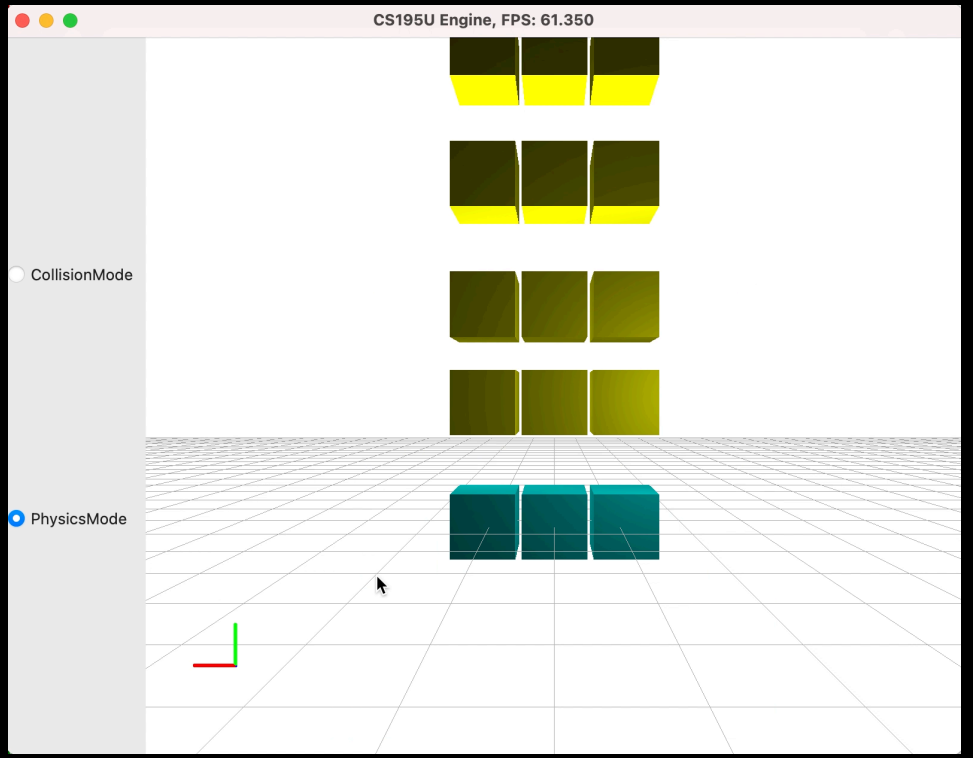
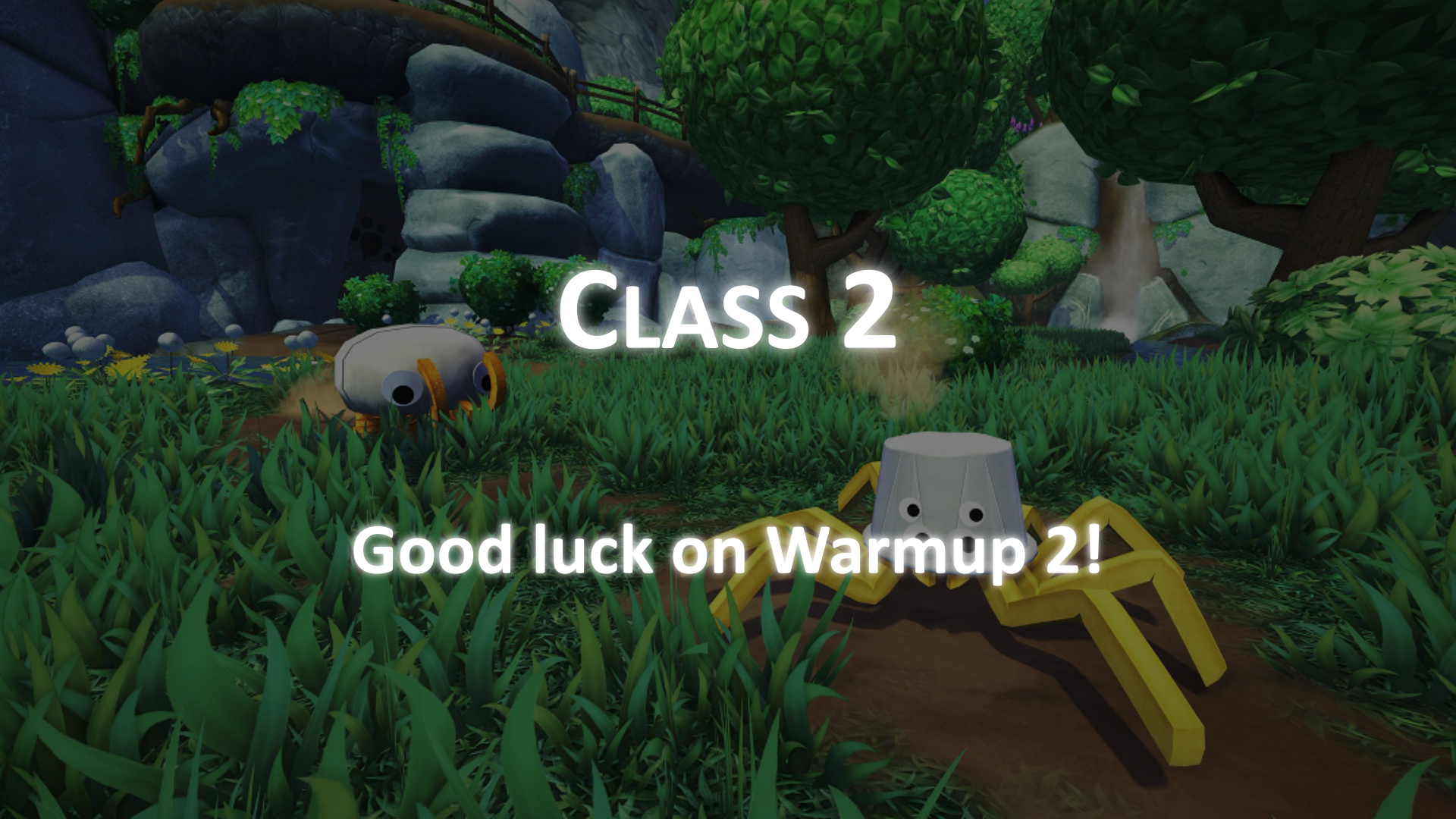
×11
×68


CS195U Engine, FPS: 61.350
CollisionMode
PhysicsMode


Class 2
Good luck on Warmup 2!