Week 4

Scene Rendering

Hooman Salamat

2019-01-26

Objectives

- Examine entity systems in concept and practice
- Explore the viewable area of our world and scrolling
- Implement tree-based scene graphs, rendering and updating of many entities
- Implement the composition of all elements to shape the world

The `Entity` Class

- An entity represents some game element in the world
  - Other planes (friendly and enemy)
  - Projectiles (bullets and missiles)
  - Pickups
- Basically what the player can interact with
- Going to have a `velocity` attribute
- Let's see what the definition looks like…

The Entity Class

```
class Entity
{
public:
  void setVelocity(sf::Vector2f velocity);
  void setVelocity(float vx, float vy);
  sf::Vector2f getVelocity() const;
private:
  sf::Vector2f mVelocity;
};
```

- Vector2f has a default constructor that sets x and y to zero

The Entity Class

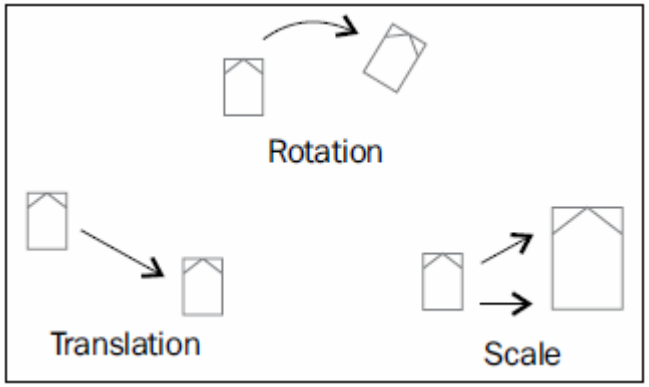
```
void Entity::setVelocity(sf::Vector2f velocity)
{
   mVelocity = velocity;
}

void Entity::setVelocity(float vx, float vy)
{
   mVelocity.x = vx;
   mVelocity.y = vy;
}

sf::Vector2f Entity::getVelocity() const
{
   return mVelocity;
}
```

Aircraft Class

```
class Aircraft : public Entity
{
public:
   enum Type
   {
     Eagle,
     Raptor,
   };
public:
   explicit Aircraft(Type type);
private:
   Type mType;
};
```

Transforms

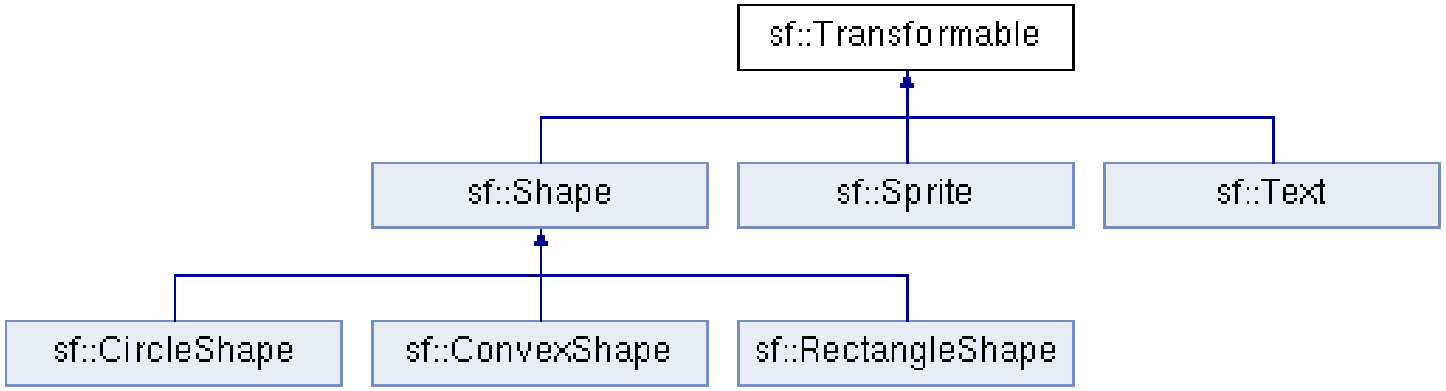
- A geometrical transform specifies the way an object is represented on screen
  - Translation -> position
  - Rotation -> orientation
  - Scale -> size



- SFML provides these in a class called sf::Transformable

Sf::Transformable

- Decomposed transform defined by a position, a rotation and a scale.
- In addition to the position, rotation and scale, sf::Transformable provides an "origin" component, which represents the local origin of the three other components.



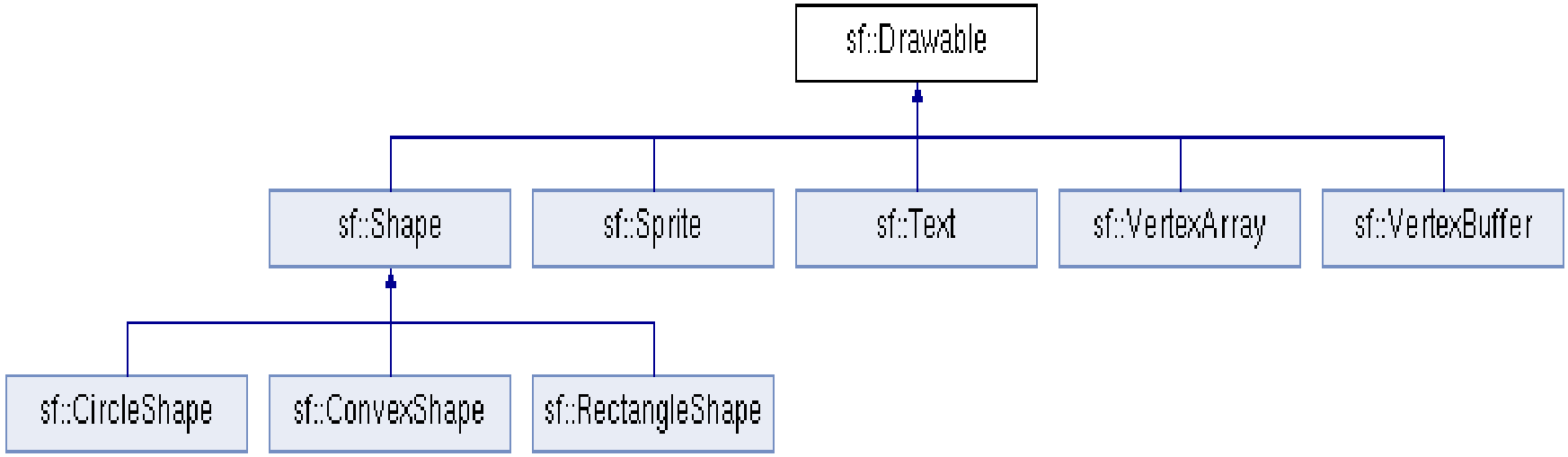
sf::Transformable

- Accessors (getters/setters):
  - setPosition (), move(), rotate(), getScale()
  - setOrigin(), getOrigin()

- High-level classes such as `Sprite`, `Text` and `Shape` are derived from `Transformable` and `Drawable`

Sf::Drawable

- Abstract base class for objects that can be drawn to a render target
- sf::Drawable is a very simple base class that allows objects of derived classes to be drawn to a sf::RenderTarget.
- All you have to do in your derived class is to override the draw virtual function.
- Note that inheriting from sf::Drawable is not mandatory, but it allows this nice syntax "window.draw(object)" rather than "object.draw(window)", which is more consistent with other SFML classes.



Sf::Drawable

- sf::Drawable is a stateless interface and provides only a pure virtual function with the following signature:

virtual void Drawable::draw(sf::RenderTarget& target,sf::RenderStates states) const = 0

- The first parameter specifies, where the drawable object is drawn to. Mostly, this will be a sf::RenderWindow. The second parameter contains additional information for the rendering process, such as blend mode (how pixel of the object are blended, or transformed (how the object is positioned/rotated/scaled), the used texture (what image is mapped to the object), or shader (what custom effect is applied to the object).
- SFML's high-level classes Sprite, Text, and Shape are all derived fromTransformable and Drawable.

Scene Graphs

- A scene graph is developed to transform the hierarchies
  - Consists of multiple nodes called scene nodes
  - Each node can store an object that is drawn
  - Represented by class called `SceneNode`
  - To store the children, we use vector container `std::vector<SceneNode>`

SceneNode Class

```
class SceneNode
{
public:
  typedef std::unique_ptr<SceneNode> Ptr;
public:
  SceneNode();
private:
  std::vector<Ptr> mChildren;
  SceneNode* mParent;
};
```

SceneNode Class

- We provide an interface to insert and remove child nodes:

```
void attachChild(Ptr child);
Ptr detachChild(const SceneNode& node);
```

SceneNode Class

```
void SceneNode::attachChild(Ptr child)
{
   child->mParent = this;
   mChildren.push_back(std::move(child));
}

SceneNode::Ptr SceneNode::detachChild(const SceneNode& node)
{
   auto found = std::find_if(mChildren.begin(), mChildren.end(),
   [&] (Ptr& p) -> bool { return p.get() == &node; });

   assert(found != mChildren.end());
   Ptr result = std::move(*found);
   result->mParent = nullptr;
   mChildren.erase(found);
   return result;
}
```

SceneNode Class Updated

```
class SceneNode : public sf::Transformable, public sf::Drawable,
                  private sf::NonCopyable
{
public:
   typedef std::unique_ptr<SceneNode> Ptr;
public:
   SceneNode();
   void attachChild(Ptr child);
   Ptr detachChild(const SceneNode& node);
private:
   virtual void draw(sf::RenderTarget& target,
                     sf::RenderStates states) const;
   virtual void drawCurrent(sf::RenderTarget& target,
                            sf::RenderStates states) const;
private:
   std::vector<Ptr> mChildren;
   SceneNode* mParent;
};
```

SceneNode Class Updated

- The class can then be used thus:

```
sf::RenderWindow window(...);
SceneNode::Ptr node(...);
window.draw(*node); // note: no node->draw(window) here!
```

Aircraft Revisited

```
class Aircraft : public Entity // inherits indirectly SceneNode
{
public:
   explicit Aircraft(Type type);
   virtual void drawCurrent(sf::RenderTarget& target,
                            sf::RenderStates states) const;
private:
   Type mType;
   sf::Sprite mSprite;
};

void Aircraft::drawCurrent(sf::RenderTarget& target,
                           sf::RenderStates states) const
{
   target.draw(mSprite, states);
}
```

Resetting the Origin

- By default, the origin of sprites is in their upper-left corner
  - For alignment or rotation, it might be better to work with their center, and we can set it thus:

```
sf::FloatRect bounds = mSprite.getLocalBounds();
mSprite.setOrigin(bounds.width / 2.f, bounds.height / 2.f);
```

Scene Layers

- Different nodes must be rendered in a certain order
  - Can't have ground above sky, for example
  - Common sense
  - UI as top layer

```
enum Layer
{
   Background,
   Air,
   LayerCount
};
```

Updating the Scene

- During an update, entities move and interact, collisions are checked and projectiles are launched
- We can add the following to `SceneNode`

```
public:
  void update(sf::Time dt);
private:
  virtual void updateCurrent(sf::Time dt);
  void updateChildren(sf::Time dt);
```

Updating the Scene

```
void SceneNode::update(sf::Time dt)
{
   updateCurrent(dt);
   updateChildren(dt);
}

void SceneNode::updateCurrent(sf::Time)
{
}

void SceneNode::updateChildren(sf::Time dt)
{
   FOREACH(Ptr& child, mChildren)
       child->update(dt);
}
```

Updating the Scene

- We also have to make the following additions to the `Entity` class:

```
private:
   virtual void updateCurrent(sf::Time dt);

...

void Entity::updateCurrent(sf::Time dt)
{
   move(mVelocity * dt.asSeconds());
}
```

Updating the Scene

- We also have to make the following additions to the `Entity` class:

```
private:
   virtual void updateCurrent(sf::Time dt);

...

void Entity::updateCurrent(sf::Time dt)
{
   move(mVelocity * dt.asSeconds());
}
```

Absolute Transforms

- In order to find out if two objects collide, we have to look at their world transform, not local or relative transforms
- We perform the following absolute transform:

```
sf::Transform SceneNode::getWorldTransform() const
{
   sf::Transform transform = sf::Transform::Identity;
   for (const SceneNode* node = this; node != nullptr;
        node = node->mParent)
       transform = node->getTransform() * transform;
   return transform;
}

sf::Vector2f SceneNode::getWorldPosition() const
{
   return getWorldTransform() * sf::Vector2f();
}
```

The View

- In our case, a view is a rectangle that represents the subset of our world that we want to render at a particular time
- We are provided a class called `sf::View`
- With the view, we can scroll, zoom and rotate with ease
- Since our game's action occurs in a vertical corridor, we scroll the view at a constant speed towards the negative y
  - mView(0.f, -40 * dt.asSecond());
- sf::View::zoom(float factor) function to easily approach or move away from the center of the view
  - mView.zoom(0.2);
- sf::View::rotate(float degree) to add a rotation angle to the current one
- sf::View::setRotation(float degrees) to set the rotation of the view to an absolute value
  - mView.rotate(45);

View Examples

```
// create a view with the rectangular area of the 2D
world to show
sf::View view1(sf::FloatRect(200.f, 200.f, 300.f,
200.f));
// create a view with its center and size
sf::View view2(sf::Vector2f(350.f, 300.f),
sf::Vector2f(300.f, 200.f));
```

- The above two definitions are equivalent

```
sf::View view1;
view1.reset(sf::FloatRect(200.f, 200.f, 300.f, 200.f));

sf::View view2;
view2.setCenter(sf::Vector2f(350.f, 300.f));
view2.setSize(sf::Vector2f(200.f, 200.f));
```

Moving (Scrolling) View

- Unlike drawable entities, such as sprites or shapes whose positions are defined by their top-left, views are always manipulated by their center

```
// move the view at point (200, 200)
view.setCenter(200.f, 200.f);

// move the view by an offset of (100, 100) (so its final position is (300, 300))
view.move(100.f, 100.f);
```

Rotating a view

```
// rotate the view at 20 degrees
view.setRotation(20.f);

// rotate the view by 5 degrees
relatively to its current
orientation (so its final
orientation is 25 degrees)
view.rotate(5.f);
```

Zooming a view

Zooming in(or out) a view is done by resizing it, so the function to use is setSize.

```
// resize the view to show a
1200x800 area (we see a bigger
area, so this is a zoom out)
view.setSize(1200.f, 800.f);

// zoom the view relatively to its
current size (apply a factor 0.5,
so its final size is 600x400)
view.zoom(0.5f);
```

Viewport

- Now that you've defined which part of the 2D world is seen in the window, let's define *where* it is shown
- Give us control over how to map the viewing rectangle to the actual application window
- By default, the viewed contents occupy the full window. If the view has the same size as the window, everything is rendered 1:1. If the view is smaller or larger than the window, everything is scaled to fit in the window.

viewport

- To split the screen in a multiplayer game, you may want to use two views which each only occupy half of the window.
- You can also implement a minimap by drawing your entire world to a view which is rendered in a small area in a corner of the window.
- The area in which the contents of the view is shown is called the *viewport*.

setViewport

- To set the viewport of a view, you can use the setViewport function.
- The viewport is not defined in pixels, but instead as a ratio of the window size.

```
// define a centered viewport, with half the size of the window
view.setViewport(sf::FloatRect(0.25f, 0.25, 0.5f, 0.5f));
```

Splitting a View in Multiplayer games

- Use a viewport to split the screen for multiplayer games:

```
// player 1 (left side of the screen)
player1View.setViewport(sf::FloatRect(0.
f, 0.f, 0.5f, 1.f));

// player 2 (right side of the screen)
player2View.setViewport(sf::FloatRect(0.
5f, 0.f, 0.5f, 1.f));
```

Mini-map

```
// the game view (full window)
gameView.setViewport(sf::FloatRect(
0.f, 0.f, 1.f, 1.f));

// mini-map (upper-right corner)
minimapView.setViewport(sf::FloatRe
ct(0.75f, 0.f, 0.25f, 0.25f));
```

Using a view

```
// let's define a view
sf::View view(sf::FloatRect(0.f, 0.f,
1000.f, 600.f));

// activate it
window.setView(view);

// draw something to that view
window.draw(some_sprite);

// want to do visibility checks? retrieve
the view
sf::View currentView = window.getView();
...
```

Default view

When you call setView, the render - target makes a copy of the view, and doesn't store a pointer to the one that is passed. This means that whenever you update your view, you need to call setView again to apply the modifications.

```
// create a view half the size of the
default view
sf::View view = window.getDefaultView();
view.zoom(0.5f);
window.setView(view);

// restore the default view
window.setView(window.getDefaultView());
```

Window Resizing

when the window is resized, everything is squeezed / stretched to the new size.If, instead of this default behavior, you'd like to show more/less stuff depending on the new size of the window, all you have to do is update the size of the view with the size of the window.

```
// the event loop
sf::Event event;
while (window.pollEvent(event))
{
...

// catch the resize events
if (event.type == sf::Event::Resized)
{
// update the view to the new size of the window
sf::FloatRect visibleArea(0.f, 0.f, event.size.width,
event.size.height);
window.setView(sf::View(visibleArea));
}
}
```

Coordinate Conversions

- When you use a custom view, or when you resize the window without using the code in the last page, pixels displayed on the target no longer match units in the 2D world.For example, clicking on pixel(10, 50) may hit the point(26.5, -84) of your world.You end up having to use a conversion function to map your pixel coordinates to world coordinates : mapPixelToCoords.

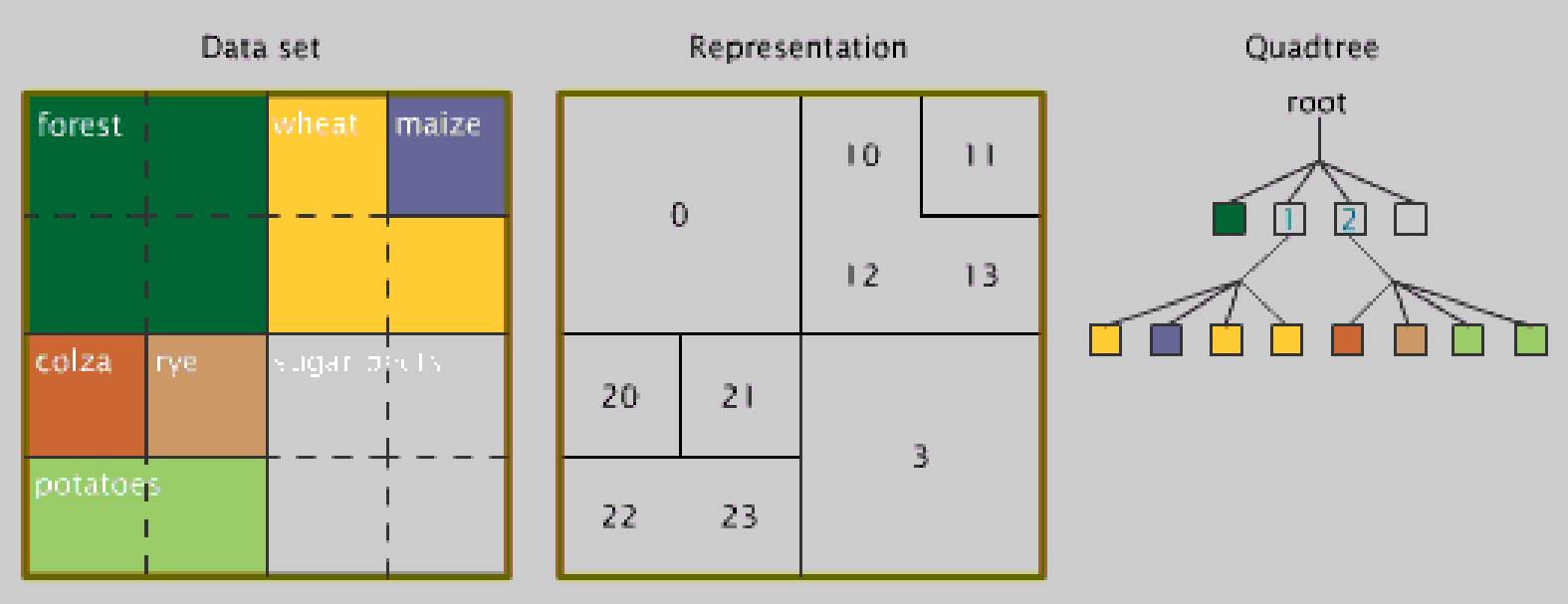
```
// get the current mouse position in the window
sf::Vector2i pixelPos =
sf::Mouse::getPosition(window);

// convert it to world coordinates
sf::Vector2f worldPos =
window.mapPixelToCoords(pixelPos);
```

View Optimization

- A Draw call is an expensive operation. We use culling to check if objects are within the viewing rectangle and then draw them.
- Game developers implement spatial subdivision: Dividing scene in multiple cells, which group all objects that reside within that given cell
- Cull a group of objects that are not in the view
- Quad Tree and Circle tree are two famous ways to subdivide space.

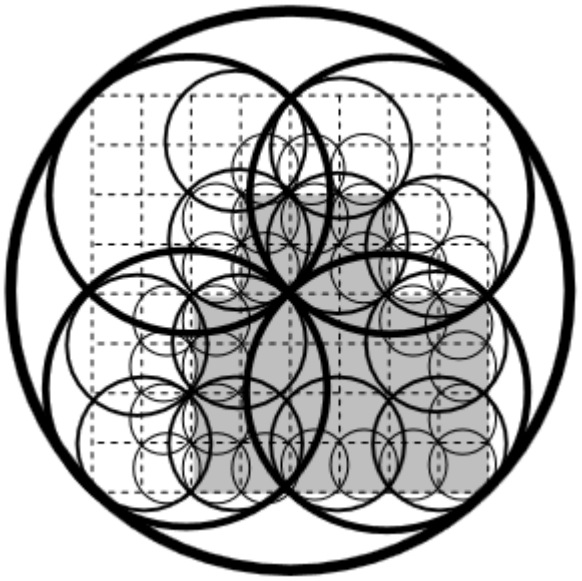
Quad Tree

- A quad tree is a hierarchical tree of cells. Only leaf nodes can contain objects and subdivide when a predetermined number of objects are present.



Circle Tree

- Similar to the quad tree, but instead each cell is a circle.
- Allows a different distribution of the objects



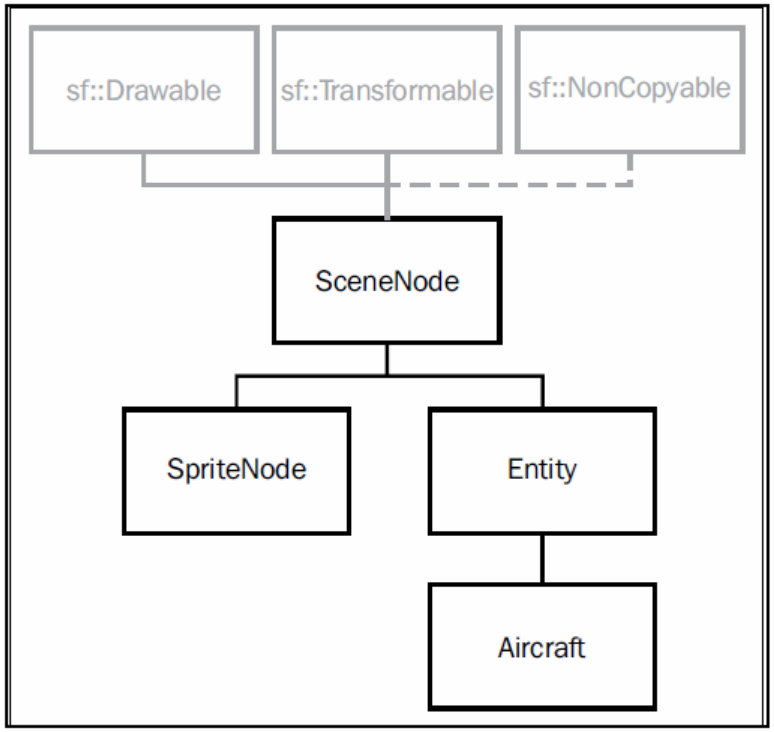
The SpriteNode Class

- The `SpriteNode` class represents a background sprite

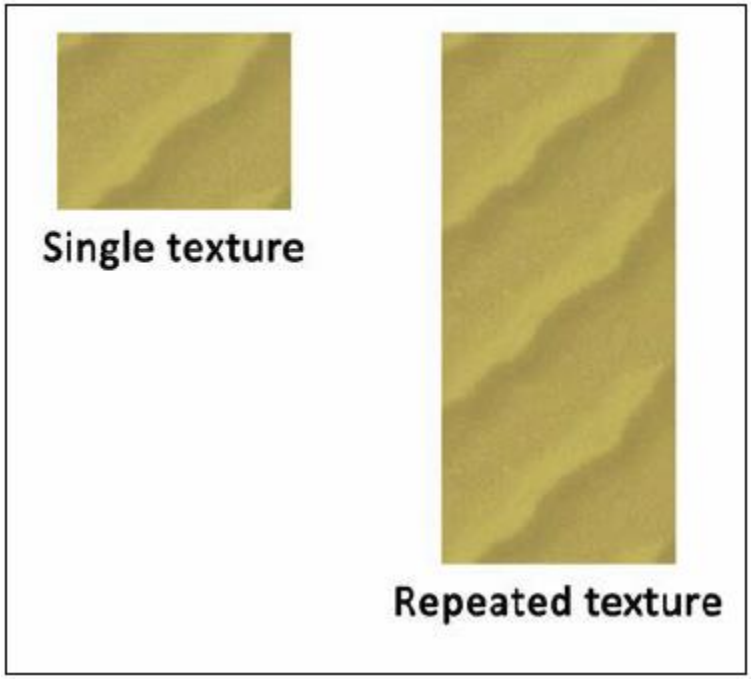
```
class SpriteNode : public SceneNode
{
public:
   explicit SpriteNode(const sf::Texture& texture);
   SpriteNode(const sf::Texture& texture, const sf::IntRect& rect);
private:
   virtual void drawCurrent(sf::RenderTarget& target,
                            sf::RenderStates states) const;
private:
   sf::Sprite mSprite;
};
```

The SpriteNode Class

- In the diagram below, the grey classes are part of SFML and the black ones are ours



Texture Repeating



- Every `sf::Texture` comes along with the option to enable repeating along both axis with the `sf::Texture::setRepeated(bool)` function

Composing the World

- The `World` class must contain all rendering data:
  - A reference to the render window
  - The world's current view
  - A texture holder with all the textures needed inside the world
  - The scene graph

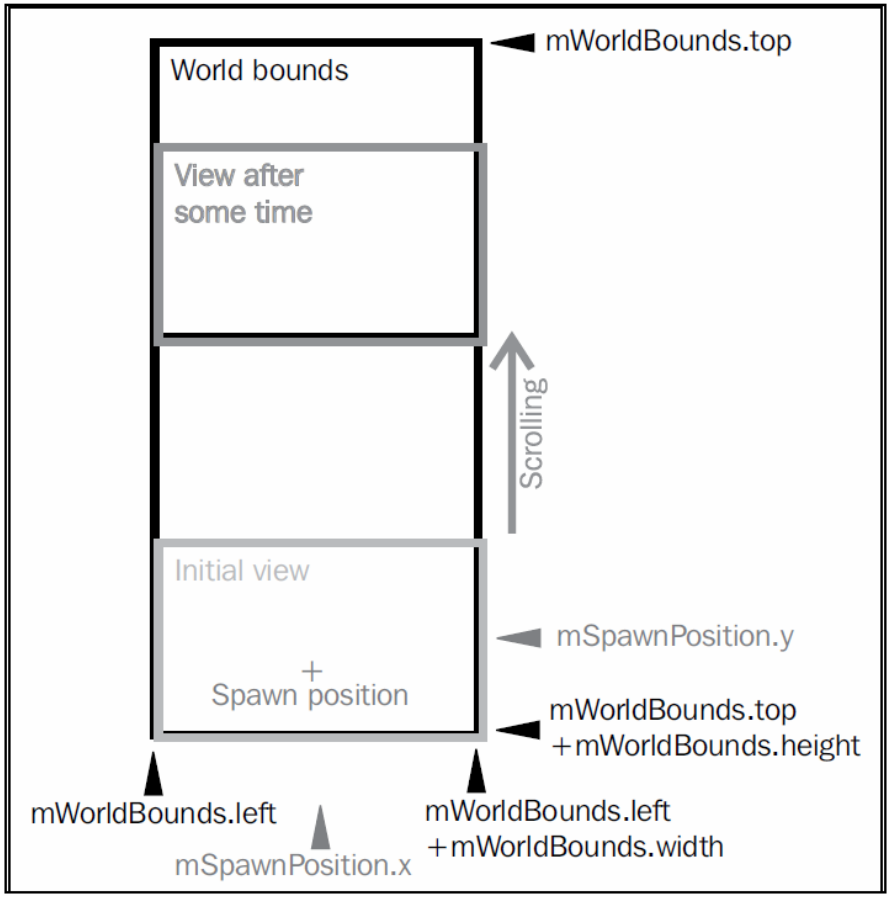
  - Some pointers to access the scene graph's layer nodes
  - The bounding rectangle of the world, storing its dimensions
  - The position where the player's plane appears in the beginning
  - The speed with which the world is scrolled
  - A pointer to the player's aircraft

The World Class

```
class World : private sf::NonCopyable
{
public:
    explicit World(sf::RenderWindow& window);
    void update(sf::Time dt);
    void draw();
private:
    void loadTextures();
    void buildScene();
    private:
    enum Layer
    {
         Background,
         Air,
    LayerCount
    };
private:
    sf::RenderWindow& mWindow;
    sf::View mWorldView;
    TextureHolder mTextures;
    SceneNode mSceneGraph;
    std::array<SceneNode*, LayerCount> mSceneLayers;
    sf::FloatRect mWorldBounds;
    sf::Vector2f mSpawnPosition;
    float mScrollSpeed;
    Aircraft* mPlayerAircraft;
};
```

Composing the World

- The following diagram represents the world dimensions:



Loading the Textures

```
void World::loadTextures()
{
   mTextures.load(Textures::Eagle, "Media/Textures/Eagle.png");
   mTextures.load(Textures::Raptor, "Media/Textures/Raptor.png");
   mTextures.load(Textures::Desert, "Media/Textures/Desert.png");
}
```

What's Left?

- Remember that the main() function is our entry point
- We can start to look at everything from there, including all the classes we've looked at
- The scene is built in the `World::buildScene()` method
- The update() and draw() methods of World encapsulate scene graph functionality
- The run() function in main gets everything going