Game Engine Development II

Week3

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Scene Rendering

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

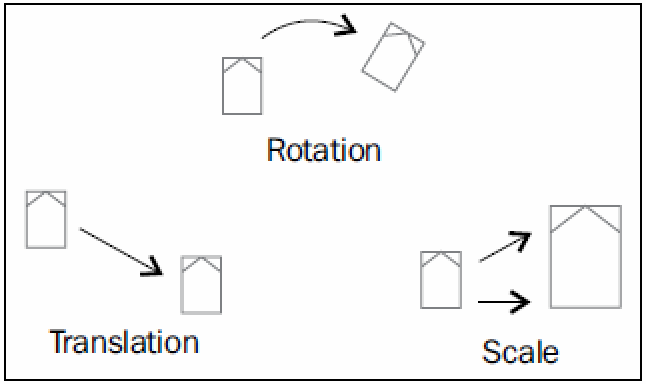
```
void Entity::setVelocity(sf::Vector2f velocity)
{
   mVelocity = velocity;
}

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 c
  sf::Transformable

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

- 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 blened, transform (how the object is positioned/rotated/scaled), the used texture (what image is mapped to the object), or shader (what custom effectis 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

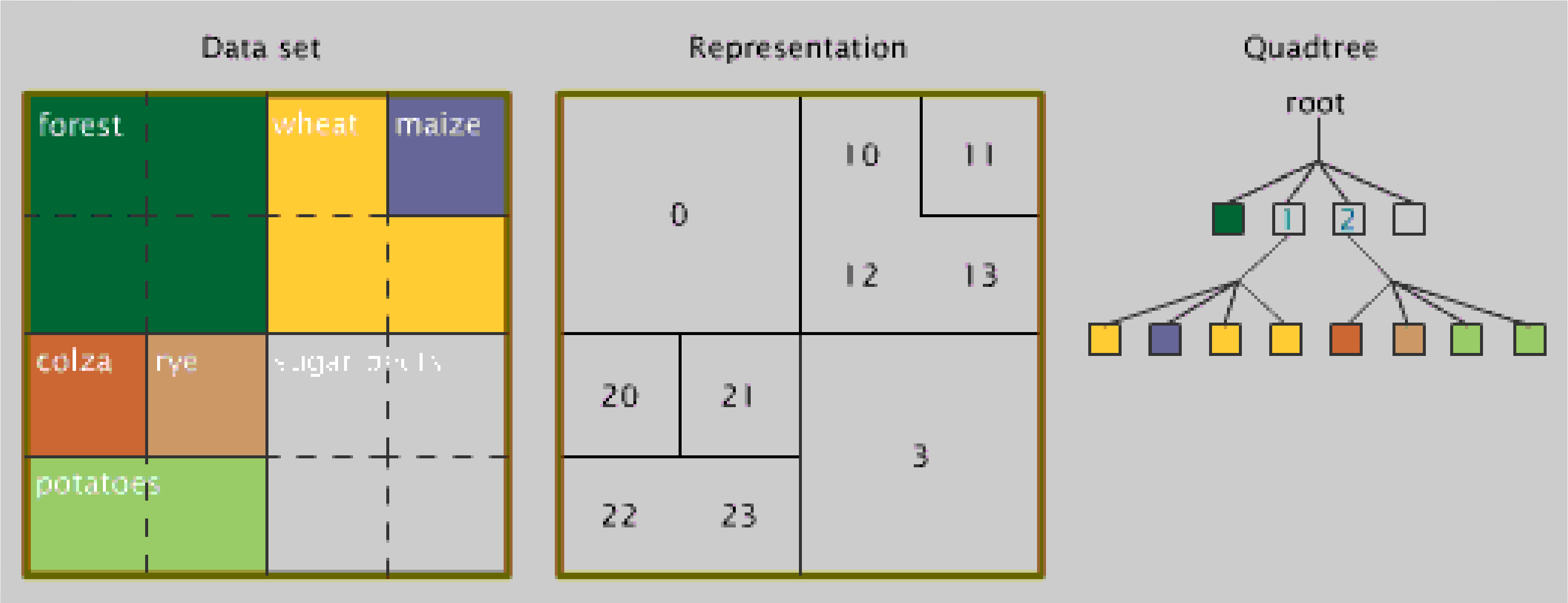
- In our case, a view is a rectangle that represents the subset of our world that we want to render at a particular time
- We are provided a class called `sf::View`
- With the view, we can scroll, zoom and rotate with ease
- Since our game's action occurs in a vertical corridor, we scroll the view at 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 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.

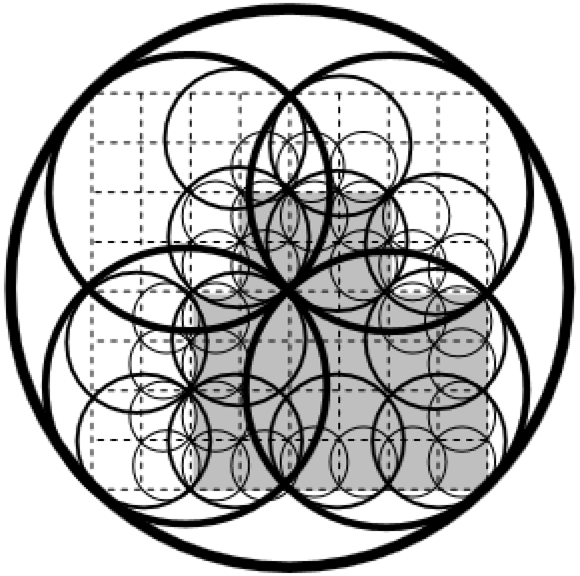
Quad Tree

- 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



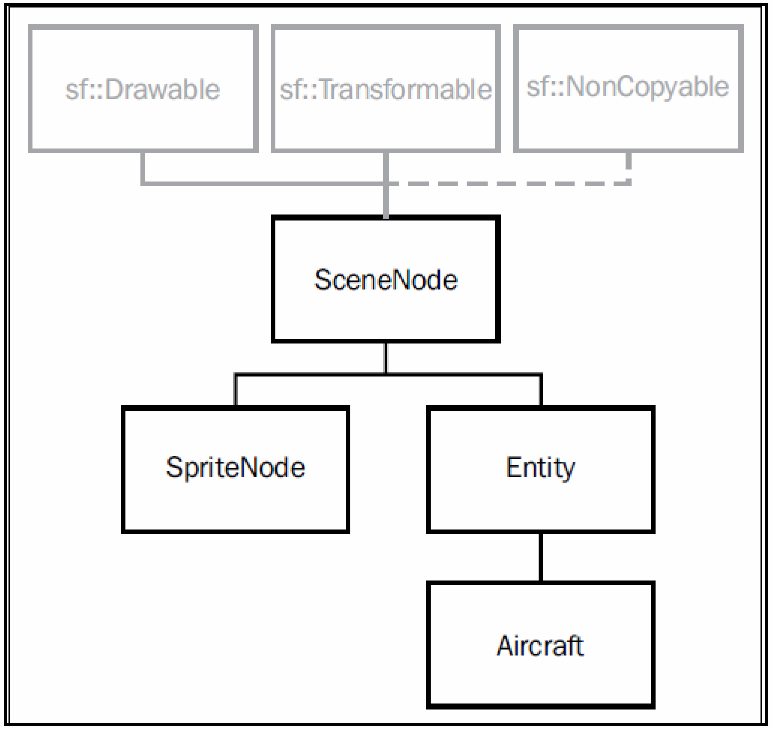
The `SpriteNode` Class

- The `SpriteNode` class represents a background sprite

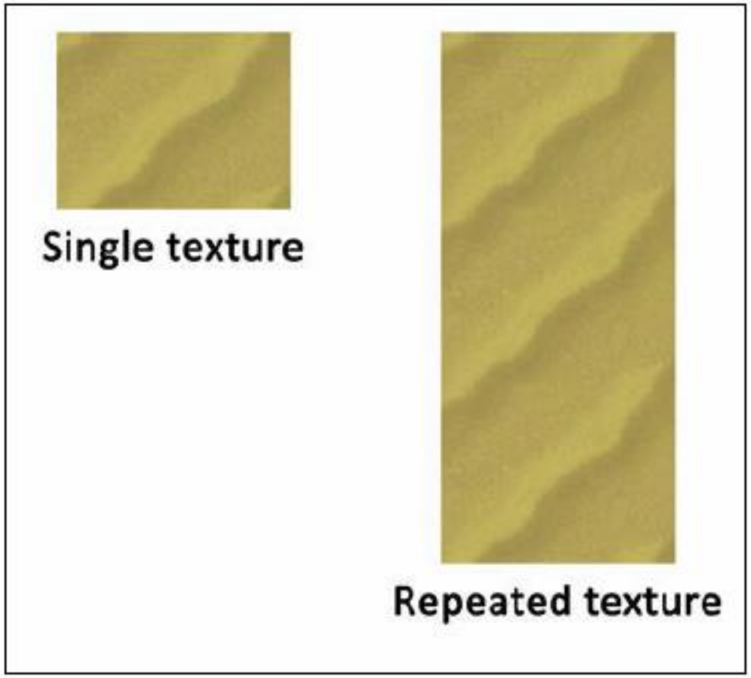
```
class SpriteNode : public SceneNode
{
public:
   explicit SpriteNode(const sf::Texture& texture);
   SpriteNode(const sf::Texture& texture, const sf::IntRect& rect);
private:
   virtual void drawCurrent(sf::RenderTarget& target,
                            sf::RenderStates states) const;
private: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

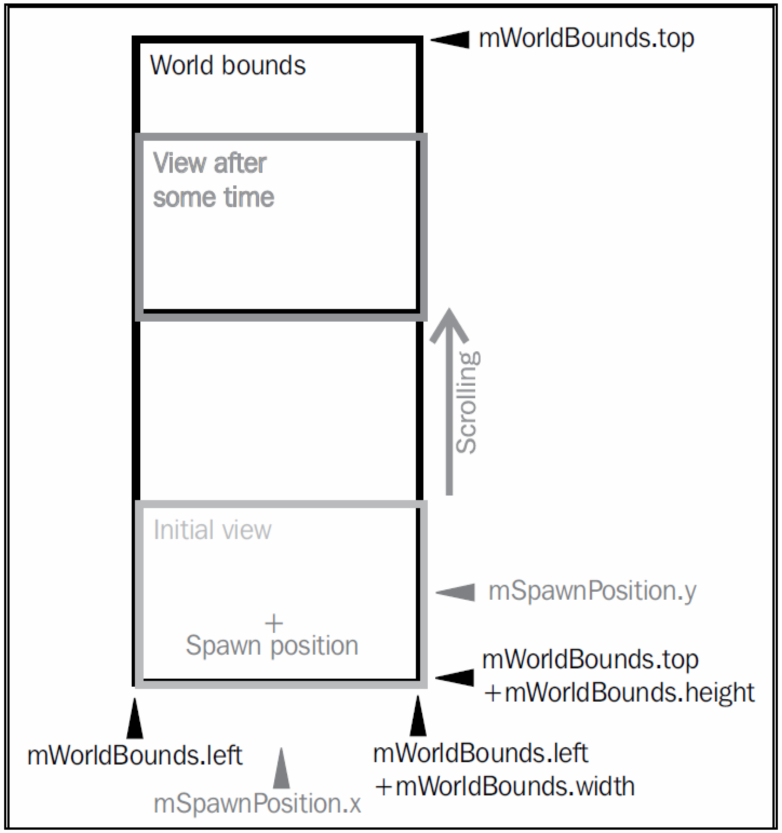
The `World` Class

```
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