

Game Engine Development II

Week 10

Hooman Salamat

AI Projectiles and Collision

Objectives

- Examine enemies controlled by simple AI
- Implement projectiles
- Implement pickups that improve the player
- Examine collision detection and response
- Examine the world's update cycle and cleanup of entities

Introducing Hitpoints

- We add hitpoints to our Entity class:

```
class Entity : public SceneNode
{
public:
    explicit Entity(int hitpoints);
    void repair(int points);
    void damage(int points);
    void destroy();
    int getHitpoints() const;
    bool isDestroyed() const;
    ...
private:
    int mHitpoints;
    ...
};
```

Introducing Hitpoints (cont'd.)

- The `repair()`, `damage()` and `destroy()` methods of the `Entity` class all affect hitpoints in the expected way

AircraftData Structure

- To handle stats of all aircraft, we have a simple and handy structure:

```
struct AircraftData
{
    int hitpoints;
    float speed;
    Textures::ID texture;
};
```

AircraftData Structure

- With the struct in place, we define a function that initializes a table of data for the aircraft:

```
std::vector<AircraftData> initializeAircraftData()  
{  
    std::vector<AircraftData> data(Aircraft::TypeCount);  
    data[Aircraft::Eagle].hitpoints = 100;  
    data[Aircraft::Eagle].speed = 200.f;  
    data[Aircraft::Eagle].texture = Textures::Eagle;  
    data[Aircraft::Raptor].hitpoints = 20;  
    data[Aircraft::Raptor].speed = 80.f;  
    data[Aircraft::Raptor].texture = Textures::Raptor;  
    ...  
    return data;  
}
```

AircraftData Structure

- With the struct in place, we define a function that initializes a table of data for the aircraft:

```
std::vector<AircraftData> initializeAircraftData()  
{  
    std::vector<AircraftData> data(Aircraft::TypeCount);  
    data[Aircraft::Eagle].hitpoints = 100;  
    data[Aircraft::Eagle].speed = 200.f;  
    data[Aircraft::Eagle].texture = Textures::Eagle;  
    data[Aircraft::Raptor].hitpoints = 20;  
    data[Aircraft::Raptor].speed = 80.f;  
    data[Aircraft::Raptor].texture = Textures::Raptor;  
    ...  
    return data;  
}
```


AircraftData Structure (cont'd.)

- `initializeAircraftData()` is declared in `DataTables.hpp` and defined in `DataTables.cpp`
- In order to avoid name collisions in other files, we use an anonymous namespace

```
namespace
{
    const std::vector<AircraftData> Table = initializeAircraftData();
}
```

Displaying Text

- We create a `TextNode` class which inherits `SceneNode` as shown in the following:

```
class TextNode : public SceneNode
{
public:
    explicit TextNode(const FontHolder& fonts,
        const std::string& text);
    void setString(const std::string& text);
private:
    virtual void drawCurrent(sf::RenderTarget& target,
        sf::RenderStates states) const;
private:
    sf::Text mText;
};
```

Displaying Text (cont'd.)

```
TextNode::TextNode(const FontHolder& fonts, const std::string& text)
{
    mText.setFont(fonts.get(Fonts::Main));
    mText.setCharacterSize(20);
    setString(text);
}
```

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

```
void TextNode::setString(const std::string& text)
{
    mText.setString(text);
    centerOrigin(mText);
}
```

Aircraft Changes

- In the Aircraft constructor:
 - We create a text node and attach it to the aircraft itself
 - We keep a pointer `mHealthDisplay` as a member variable

```
std::unique_ptr<TextNode> healthDisplay(new TextNode(fonts, ""));  
mHealthDisplay = healthDisplay.get();  
attachChild(std::move(healthDisplay));
```

- In the Aircraft update:

```
mHealthDisplay->setString(toString(getHitpoints()) + " HP");  
mHealthDisplay->setPosition(0.f, 50.f);  
mHealthDisplay->setRotation(-getRotation());
```

Movement

- Enemies are instances of the `Aircraft` class
- Their behavior is simple:
 - Appear at the top of the screen and move down
 - We've defined a `Direction` struct that has an angle and distance:

```
struct Direction
{
    Direction(float angle, float distance);
    float angle;
    float distance;
};
```

Movement (cont'd.)

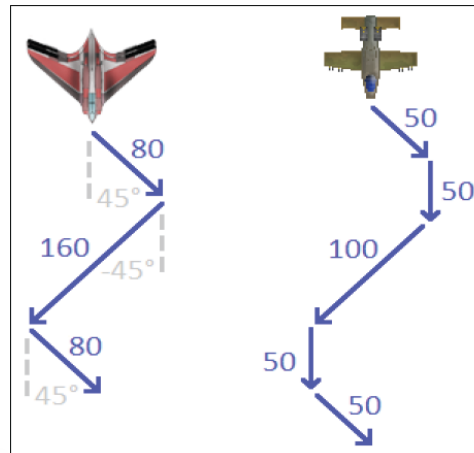
```
struct AircraftData
{
    int hitpoints;
    float speed;
    Textures::ID texture;
    std::vector<Direction> directions;
};

data[Aircraft::Raptor].directions.push_back(Direction( 45, 80));
data[Aircraft::Raptor].directions.push_back(Direction(-45, 160));
data[Aircraft::Raptor].directions.push_back(Direction( 45, 80));
```

Adding a simple AI to handle Movement

- The Avenger airplane also includes diagonal movement:

```
data[Aircraft::Avenger].directions.push_back(Direction(+45, 50));  
data[Aircraft::Avenger].directions.push_back(Direction( 0, 50));  
data[Aircraft::Avenger].directions.push_back(Direction(-45, 100));  
data[Aircraft::Avenger].directions.push_back(Direction( 0, 50));  
data[Aircraft::Avenger].directions.push_back(Direction(+45, 50));
```



Movement (cont'd.)

```
void Aircraft::updateMovementPattern(sf::Time dt)
{
    const std::vector<Direction>& directions = Table[mType].directions;
    if (!directions.empty())
    {
        float distanceToTravel = directions[mDirectionIndex].distance;
        if (mTravelledDistance > distanceToTravel)
        {
            mDirectionIndex = (mDirectionIndex + 1) % directions.size();
            mTravelledDistance = 0.f;
        }
        float radians = toRadian(directions[mDirectionIndex].angle + 90.f);
        float vx = getMaxSpeed() * std::cos(radians);
        float vy = getMaxSpeed() * std::sin(radians);
        setVelocity(vx, vy);
        mTravelledDistance += getMaxSpeed() * dt.asSeconds();
    }
}
```


Enemy Spawning

```
struct SpawnPoint
{
    SpawnPoint(Aircraft::Type type, float x, float y);
    Aircraft::Type type;
    float x;
    float y;
};
```

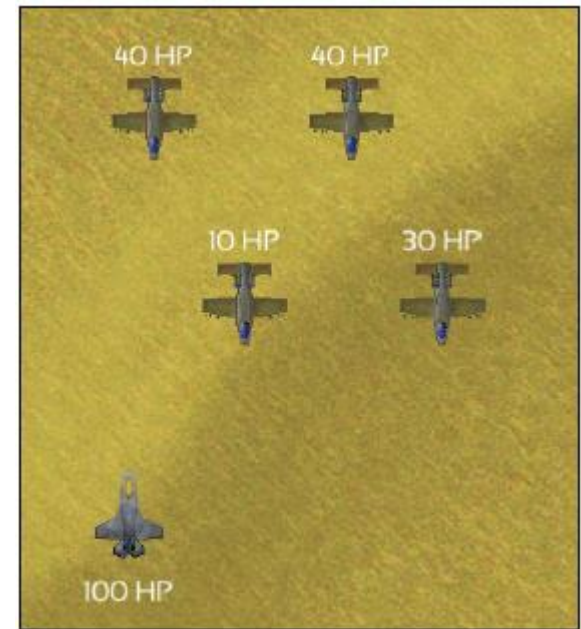
- A member variable `World::mEnemySpawnPoints` of type `std::vector<SpawnPoint>` holds all future spawn points

Enemy Spawning (cont'd.)

```
void World::spawnEnemies()
{
    while (!mEnemySpawnPoints.empty() && mEnemySpawnPoints.back().y
> getBattlefieldBounds().top)
    {
        SpawnPoint spawn = mEnemySpawnPoints.back();
        std::unique_ptr<Aircraft> enemy( new Aircraft(spawn.type,
            mTextures, mFonts));
        enemy->setPosition(spawn.x, spawn.y);
        enemy->setRotation(180.f);
        mSceneLayers[Air]->attachChild(std::move(enemy));
        mEnemySpawnPoints.pop_back();
    }
}
```

Enemy Spawning (cont'd.)

```
void World::addEnemies()  
{  
    addEnemy(Aircraft::Raptor, 0.f, 500.f);  
    addEnemy(Aircraft::Avenger, -70.f, 1400.f);  
    ...  
    std::sort(mEnemySpawnPoints.begin(), mEnemySpawnPoints.end(),  
    [] (SpawnPoint lhs, SpawnPoint rhs)  
    {  
        return lhs.y < rhs.y;  
    });  
}
```



Projectiles

```
class Projectile : public Entity
{
public:
    enum Type
    {
        AlliedBullet,
        EnemyBullet,
        Missile,
        TypeCount
    };
public:
    Projectile(Type type,
        const TextureHolder& textures);
    void guideTowards(sf::Vector2f position);
    bool isGuided() const;
    virtual unsigned int getCategory() const;
    virtual sf::FloatRect getBoundingRect() const;
    float getMaxSpeed() const;
    int getDamage() const;
```

Projectiles (cont'd.)

```
private:
    virtual void updateCurrent(sf::Time dt, CommandQueue& commands);
    virtual void drawCurrent(sf::RenderTarget& target, sf::RenderStates states) const;

private:
    Type mType;
    sf::Sprite mSprite;
    sf::Vector2f mTargetDirection;
};
```

- Constructor:

```
Projectile::Projectile(Type type, const TextureHolder& textures) : Entity(1)
    , mType(type), mSprite(textures.get(Table[type].texture))
{
    centerOrigin(mSprite);
}
```

Firing Projectiles

```
Player::Player()
{
    // Set initial key bindings
    mKeyBinding[sf::Keyboard::Left] = MoveLeft;
    mKeyBinding[sf::Keyboard::Right] = MoveRight;
    mKeyBinding[sf::Keyboard::Up] = MoveUp;
    mKeyBinding[sf::Keyboard::Down] = MoveDown;
    mKeyBinding[sf::Keyboard::Space] = Fire;
    mKeyBinding[sf::Keyboard::M] = LaunchMissile;
    // ...
}

void Player::initializeActions()
{
    // ...
    mActionBinding[Fire].action = derivedAction<Aircraft>(
        std::bind(&Aircraft::fire, _1));
    mActionBinding[LaunchMissile].action = derivedAction<Aircraft>(
        std::bind(&Aircraft::launchMissile, _1));
}
```

Firing Projectiles (cont'd.)

```
void Aircraft::checkProjectileLaunch(sf::Time dt, CommandQueue&
commands)
{
    if (mIsFiring && mFireCountdown <= sf::Time::Zero)
    {
        commands.push(mFireCommand);
        mFireCountdown += sf::seconds(1.f / (mFireRateLevel+1));
        mIsFiring = false;
    }
    else if (mFireCountdown > sf::Time::Zero)
    {
        mFireCountdown -= dt;
    }
    if (mIsLaunchingMissile)
    {
        commands.push(mMissileCommand);
        mIsLaunchingMissile = false;
    }
}
```

Firing Projectiles (cont'd.)

```
bool Player::isRealtimeAction(Action action)
{
    switch (action)
    {
        case MoveLeft:
        case MoveRight:
        case MoveDown:
        case MoveUp:
        case Fire:
            return true;
        default:
            return false;
    }
}
```


Firing Projectiles (cont'd.)

```
Aircraft::Aircraft(Type type, const TextureHolder& textures)
{
    mFireCommand.category = Category::SceneAirLayer;
    mFireCommand.action = [this, &textures] (SceneNode& node,
        sf::Time)
    {
        createBullets(node, textures);
    };

    mMissileCommand.category = Category::SceneAirLayer;
    mMissileCommand.action = [this, &textures] (SceneNode& node,
        sf::Time)
    {
        createProjectile(node, Projectile::Missile, 0.f, 0.5f,
            textures);
    };
}
```

Firing Projectiles (cont'd.)

```
void Aircraft::createBullets(SceneNode& node, const TextureHolder& textures) const
{
    Projectile::Type type = isAllied() ? Projectile::AlliedBullet :
        Projectile::EnemyBullet;
    switch (mSpreadLevel)
    {
        case 1:
            createProjectile(node, type, 0.0f, 0.5f, textures);
            break;
        case 2:
            createProjectile(node, type, -0.33f, 0.33f, textures);
            createProjectile(node, type, +0.33f, 0.33f, textures);
            break;
        case 3:
            createProjectile(node, type, -0.5f, 0.33f, textures);
            createProjectile(node, type, 0.0f, 0.5f, textures);
            createProjectile(node, type, +0.5f, 0.33f, textures);
            break;
    }
}
```

Firing Projectiles (cont'd.)

```
void Aircraft::createProjectile(SceneNode& node,
    Projectile::Type type, float xOffset, float yOffset,
    const TextureHolder& textures) const
{
    std::unique_ptr<Projectile> projectile(
        new Projectile(type, textures));
    sf::Vector2f offset(
        xOffset * mSprite.getGlobalBounds().width,
        yOffset * mSprite.getGlobalBounds().height);
    sf::Vector2f velocity(0, projectile->getMaxSpeed());

    float sign = isAllied() ? -1.f : +1.f;
    projectile->setPosition(getWorldPosition() + offset * sign);
    projectile->setVelocity(velocity * sign);
    node.attachChild(std::move(projectile));
}
```

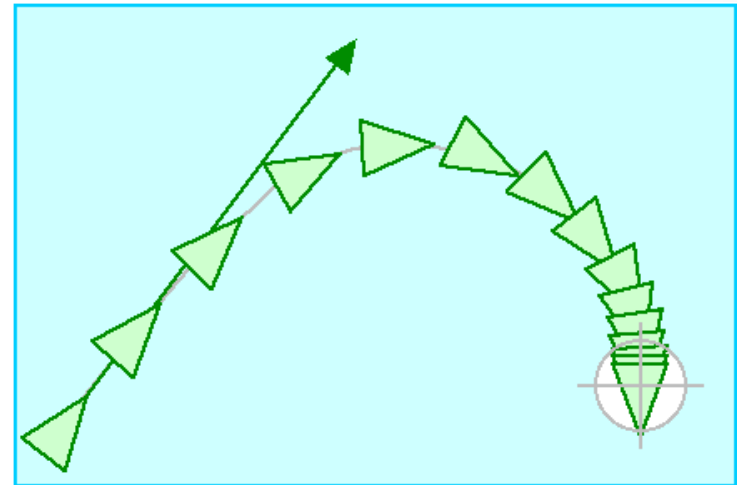
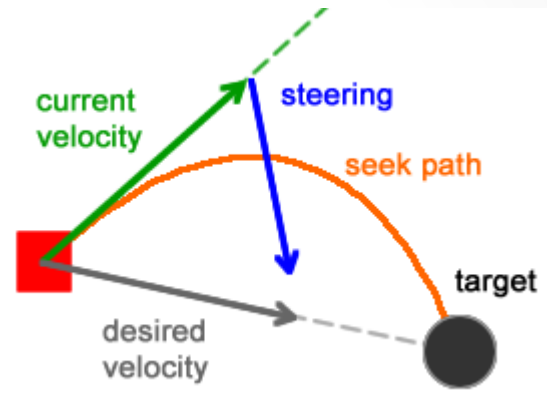
Homing Missiles

```
bool Projectile::isGuided() const
{
    return mType == Missile;
}

void Projectile::guideTowards(sf::Vector2f position)
{
    assert(isGuided());
    mTargetDirection = unitVector(position - getWorldPosition());
}
```

AI: What is the seeking behavior?

- The seeking behavior is the idea that an AI agent "seeks" to have a certain velocity (vector).
- To start, we'll need to have 2 things:
 - An initial velocity (a vector)
 - A desired velocity (also a vector)
- First, we need to find the velocity needed for our agent to reach a desired point...
 - This is usually a subtraction of the current position of the agent and the desired position.
- Secondly, we must also find the agent's current velocity, which is usually already available in most game engines.
- Next, we need to find the vector difference between the desired velocity and the agent's current velocity.
 - it literally gives us a vector that gives the desired velocity when we add it to that agent's current velocity. We will call it "steering velocity".



atan2

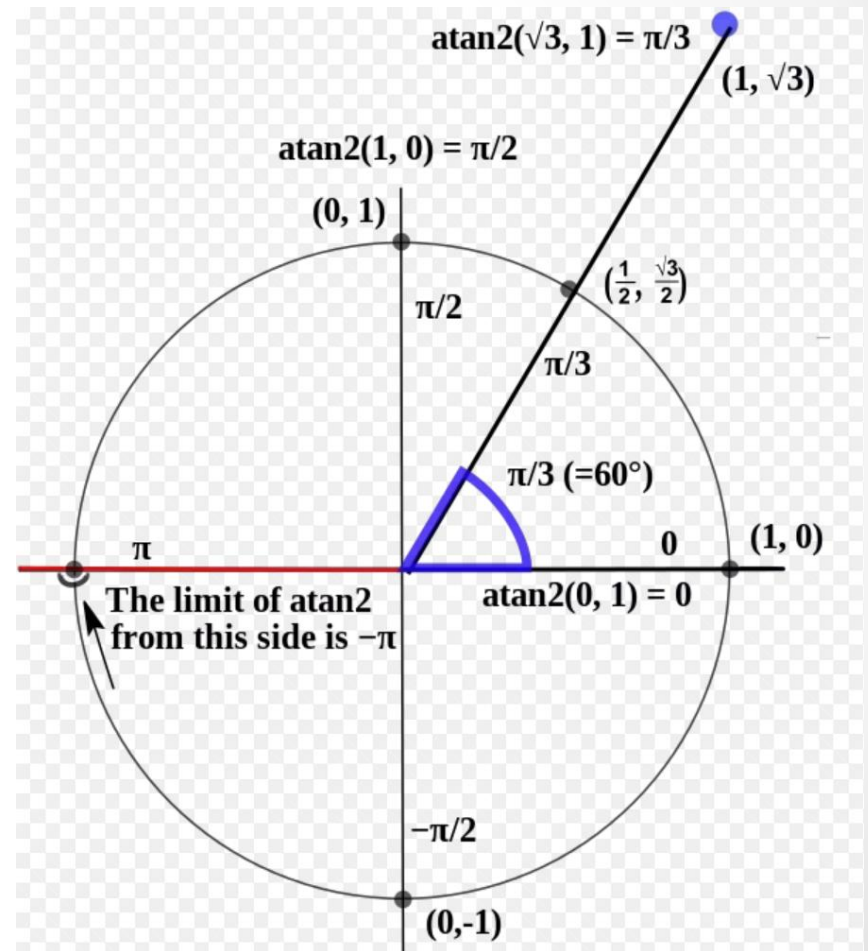
Hypot is a mathematical function defined to calculate the length of the [hypotenuse](#) of a right-angle triangle. It was designed to avoid errors arising due to limited-precision calculations performed on computers.

```
#include <iostream>
#include <cmath>

int main()
{
    // normal usage: the signs of the two arguments determine the quadrant
    std::cout << "(x:+1,y:+1) cartesian is (r:" << hypot(1,1)
        << ",phi:" << atan2(1,1) << ") polar\n" // atan2(1,1) = +pi/4, Quad I
        << "(x:-1,y:+1) cartesian is (r:" << hypot(1,-1)
        << ",phi:" << atan2(1,-1) << ") polar\n" // atan2(1, -1) = +3pi/4, Quad II
        << "(x:-1,y:-1) cartesian is (r:" << hypot(-1,-1)
        << ",phi:" << atan2(-1,-1) << ") polar\n" // atan2(-1,-1) = -3pi/4, Quad III
        << "(x:+1,y:-1) cartesian is (r:" << hypot(-1,1)
        << ",phi:" << atan2(-1,1) << ") polar\n"; // atan2(-1, 1) = -pi/4, Quad IV
    // special values
    std::cout << "atan2(0, 0) = " << atan2(0,0)
        << " atan2(0,-0) = " << atan2(0,-0.0) << '\n'
        << "atan2(7, 0) = " << atan2(7,0)
        << " atan2(7,-0) = " << atan2(7,-0.0) << '\n';
}
```

Std:atan2

- Computes the arc tangent of y/x using the signs of arguments to determine the correct quadrant.



Homing Missiles (cont'd.)

```
void Projectile::updateCurrent(sf::Time dt,
    CommandQueue& commands)
{
    if (isGuided())
    {
        const float approachRate = 200.f;
        sf::Vector2f newVelocity = unitVector(approachRate
            * dt.asSeconds() * mTargetDirection + getVelocity());
        newVelocity *= getMaxSpeed();
        float angle = std::atan2(newVelocity.y, newVelocity.x);
        setRotation(toDegree(angle) + 90.f);
        setVelocity(newVelocity);
    }
    Entity::updateCurrent(dt, commands);
}
```


Homing Missiles (cont'd.)

```
void World::guideMissiles()
{
    Command enemyCollector;
    enemyCollector.category = Category::EnemyAircraft;
    enemyCollector.action = derivedAction<Aircraft>(
        [this] (Aircraft& enemy, sf::Time)
        {
            if (!enemy.isDestroyed())
                mActiveEnemies.push_back(&enemy);
        });

    Command missileGuider;
    missileGuider.category = Category::AlliedProjectile;
    missileGuider.action = derivedAction<Projectile>(
        [this] (Projectile& missile, sf::Time)
        {
            // Ignore unguided bullets
            if (!missile.isGuided())
                return;
        });
}
```

Homing Missiles (cont'd.)

```
float minDistance = std::numeric_limits<float>::max();
Aircraft* closestEnemy = nullptr;
FOREACH(Aircraft* enemy, mActiveEnemies)
{
    float enemyDistance = distance(missile, *enemy);
    if (enemyDistance < minDistance)
    {
        closestEnemy = enemy;
        minDistance = enemyDistance;
    }
}
if (closestEnemy)
    missile.guideTowards(closestEnemy-
        >getWorldPosition());
});
```

Pickups

```
class Pickup : public Entity
{
public:
    enum Type
    {
        HealthRefill,
        MissileRefill,
        FireSpread,
        FireRate,
        TypeCount
    };
public:
    Pickup(Type type, const TextureHolder& textures);
    virtual unsigned int getCategory() const;
    virtual sf::FloatRect getBoundingRect() const;
    void apply(Aircraft& player) const;
protected:
    virtual void drawCurrent(sf::RenderTarget& target, sf::RenderStates states) const;
private:
    Type mType;
    sf::Sprite mSprite;
};
```

Collisions

- Collisions for the game will deal with bounding rectangles
- Below is an example where `getWorldTransform()` multiplies `sf::Transform` objects from the scene root to the leaf
 - `sf::Transform::transformRect()` transforms a rectangle
 - May enlarge it if there is a rotation
 - `sf::Sprite::getGlobalBounds()` returns the sprite's bounding rectangle
 - Relative to the aircraft

```
sf::FloatRect Aircraft::getBoundingRect() const
{
    return
        getWorldTransform().transformRect(mSprite.getGlobalBounds());
}
```

Finding Collision Pairs

```
void SceneNode::checkNodeCollision(SceneNode& node, std::set<Pair>&
collisionPairs)
{
    if (this != &node && collision(*this, node) && !isDestroyed() && !node.isDestroyed())
        collisionPairs.insert(std::minmax(this, &node));
    FOREACH(Ptr& child, mChildren)
        child->checkNodeCollision(node, collisionPairs);
}

void SceneNode::checkSceneCollision(SceneNode& sceneGraph, std::set<Pair>& collisionPairs)
{
    checkNodeCollision(sceneGraph, collisionPairs);
    FOREACH(Ptr& child, sceneGraph.mChildren)
        checkSceneCollision(*child, collisionPairs);
}
```

Reacting to Collisions

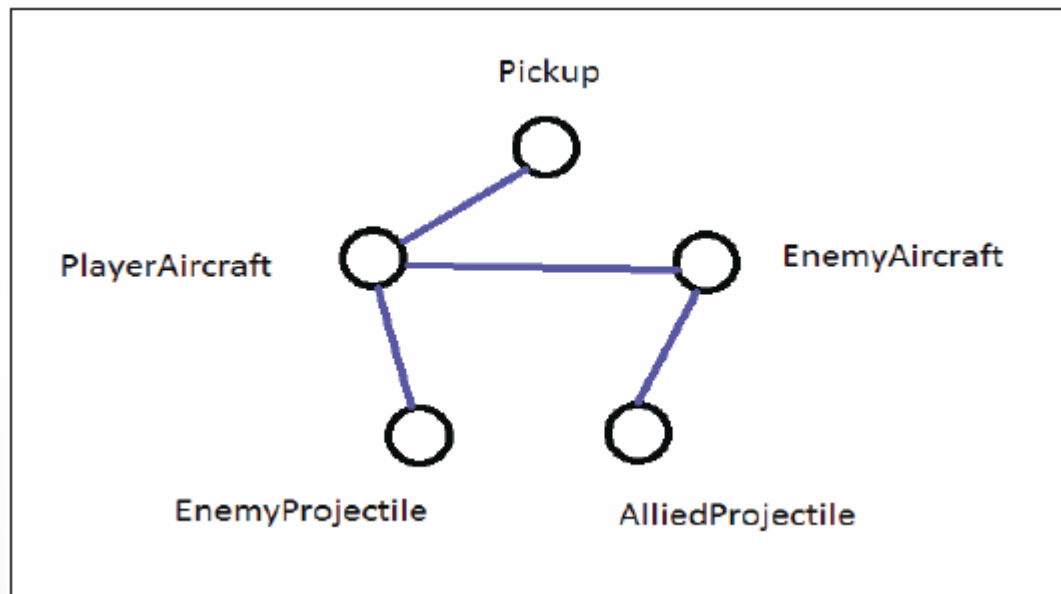
```
bool matchesCategories(SceneNode::Pair& colliders,  
    Category::Type type1, Category::Type type2)  
{  
    unsigned int category1 = colliders.first->getCategory();  
    unsigned int category2 = colliders.second->getCategory();  
    if (type1 & category1 && type2 & category2)  
    {  
        return true;  
    }  
    else if (type1 & category2 && type2 & category1)  
    {  
        std::swap(colliders.first, colliders.second);  
        return true;  
    }  
    else  
    {  
        return false;  
    }  
}
```

Reacting to Collisions

```
void World::handleCollisions()
{
    std::set<SceneNode::Pair> collisionPairs;
    mSceneGraph.checkSceneCollision(mSceneGraph, collisionPairs);
    FOREACH(SceneNode::Pair pair, collisionPairs)
    {
        if (matchesCategories(pair,
            Category::PlayerAircraft, Category::EnemyAircraft))
        {
            ... // React to player-enemy collision
        }
    }
}
```

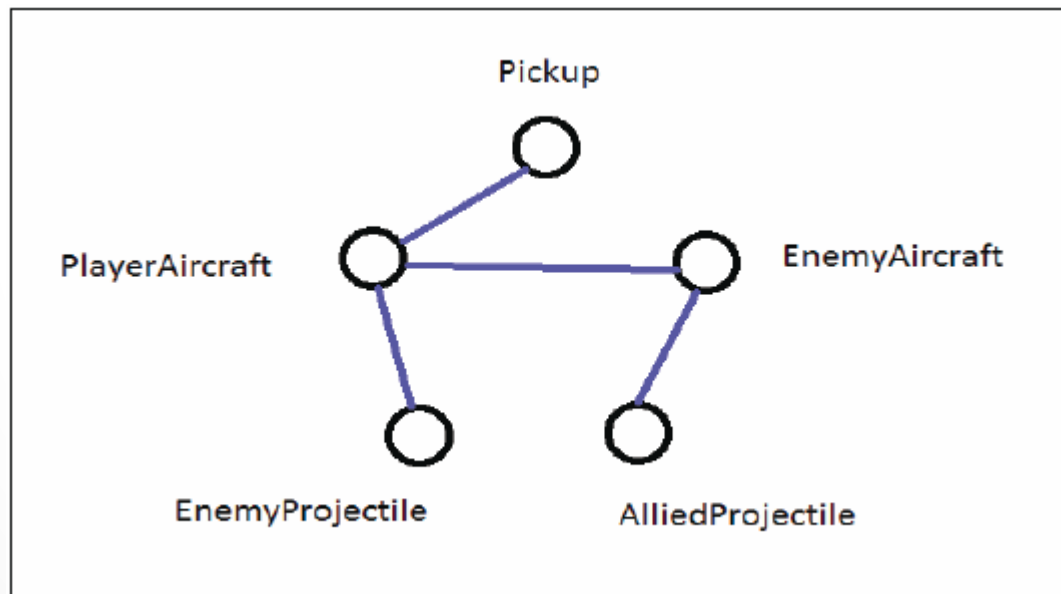
Reacting to Collisions

- We have four combinations of categories which trigger a collision, as shown in the following diagram:



Reacting to Collisions

- We have four combinations of categories which trigger a collision, as shown in the following diagram:



Reacting to Collisions

- We need four calls to `matchesCategories()` in order to react to all possible combinations
 - Code goes in the 'React to player-enemy collision' part of previous code

```
if (matchesCategories(pair, Category::PlayerAircraft, Category::EnemyAircraft))
{
    auto& player = static_cast<Aircraft&>(*pair.first);
    auto& enemy = static_cast<Aircraft&>(*pair.second);
    player.damage(enemy.getHitpoints());
    enemy.destroy();
}
```

```
else if (matchesCategories(pair, Category::PlayerAircraft, Category::Pickup))
{
    auto& player = static_cast<Aircraft&>(*pair.first);
    auto& pickup = static_cast<Pickup&>(*pair.second);
    pickup.apply(player);
}
```

Reacting to Collisions

```
else if (matchesCategories(pair, Category::EnemyAircraft, Category::AlliedProjectile)
        || matchesCategories(pair,
Category::PlayerAircraft, Category::EnemyProjectile))
{
    auto& aircraft = static_cast<Aircraft&>(*pair.first);
    auto& projectile = static_cast<Projectile&>(*pair.second);
    aircraft.damage(projectile.getDamage());
    projectile.destroy();
}
```

Cleaning Up

```
bool Entity::isDestroyed() const
{
    return mHitpoints <= 0;
}

bool SceneNode::isMarkedForRemoval() const
{
    return isDestroyed();
}

bool Aircraft::isMarkedForRemoval() const
{
    return mIsMarkedForRemoval;
}

void SceneNode::removeWrecks()
{
    auto wreckfieldBegin = std::remove_if(mChildren.begin(),
    mChildren.end(), std::mem_fn(&SceneNode::isMarkedForRemoval));
    mChildren.erase(wreckfieldBegin, mChildren.end());
    std::for_each(mChildren.begin(), mChildren.end(),
    std::mem_fn(&SceneNode::removeWrecks));
}
```

Cleaning Up (cont'd.)

```
void World::destroyEntitiesOutsideView()
{
    Command command;
    command.category = Category::Projectile | Category::EnemyAircraft;
    command.action = derivedAction<Entity>([this] (Entity& e, sf::Time)
    {
        if (!getBattlefieldBounds().intersects(e.getBoundingRect()))
            e.destroy();
    });

    mCommandQueue.push(command);
}
```

Final Update

```
void World::update(sf::Time dt)
{
    mWorldView.move(0.f, mScrollSpeed * dt.asSeconds());
    mPlayerAircraft->setVelocity(0.f, 0.f);

    destroyEntitiesOutsideView();
    guideMissiles();

    while (!mCommandQueue.isEmpty())
        mSceneGraph.onCommand(mCommandQueue.pop(), dt);
    adaptPlayerVelocity();
    handleCollisions();
    mSceneGraph.removeWrecks();
    spawnEnemies();

    mSceneGraph.update(dt, mCommandQueue);
    adaptPlayerPosition();
}
```