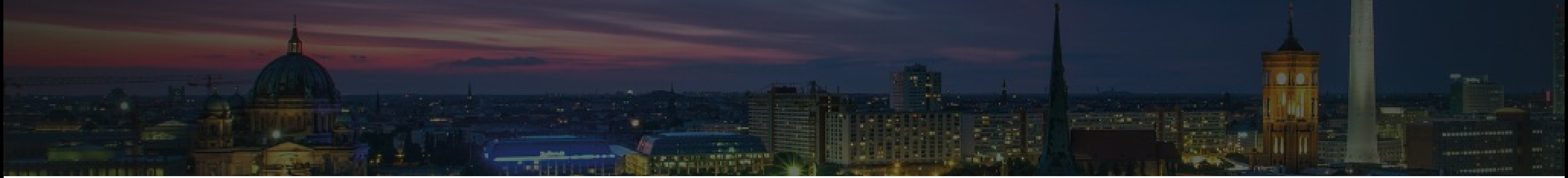


Qt 3D Basics

Kévin Ottens, Software Craftsman at KDAB

Qt 3D Basics

- Feature Set
- Entity Component System? Kezaco?
- Hello Donut
- Qt 3D ECS Explained
- Input Handling
- Drawing Basics
- Beyond the Tip of the Iceberg
- The Future of Qt 3D

Qt 3D Basics

- **Feature Set**
- Entity Component System? Kezaco?
- Hello Donut
- Qt 3D ECS Explained
- Input Handling
- Drawing Basics
- Beyond the Tip of the Iceberg
- The Future of Qt 3D

What is Qt 3D?

- It is not about 3D!
- Multi-purpose, not just a game engine
- Soft real-time simulation engine
- Designed to be scalable
- Extensible and flexible

Simulation Engine

- The core is not inherently about 3D
- It can deal with several domains at once
  - AI, logic, audio, etc.
  - And of course it contains a 3D renderer too!
- All you need for a complex system simulation
  - Mechanical systems
  - Physics
  - ... and also games

Scalability

- Frontend / backend split
  - Frontend is lightweight and on the main thread
  - Backend executed in a secondary thread
    - Where the actual simulation runs
- Non-blocking frontend / backend communication
- Backend maximizes throughput via a thread pool

Extensibility and Flexibility

- Domains can be added via independent aspects
  - ... only if there's not something fitting your needs already
- Provide both C++ and QML APIs
- Integrates well with the rest of Qt
  - Pulling your simulation data from a database anyone?
- Entity Component System is used to combine behavior in your own objects
  - No deep inheritance hierarchy

Qt 3D Basics

- Feature Set
- **Entity Component System? Kezaco?**
- Hello Donut
- Qt 3D ECS Explained
- Input Handling
- Drawing Basics
- Beyond the Tip of the Iceberg
- The Future of Qt 3D

ECS: Definitions

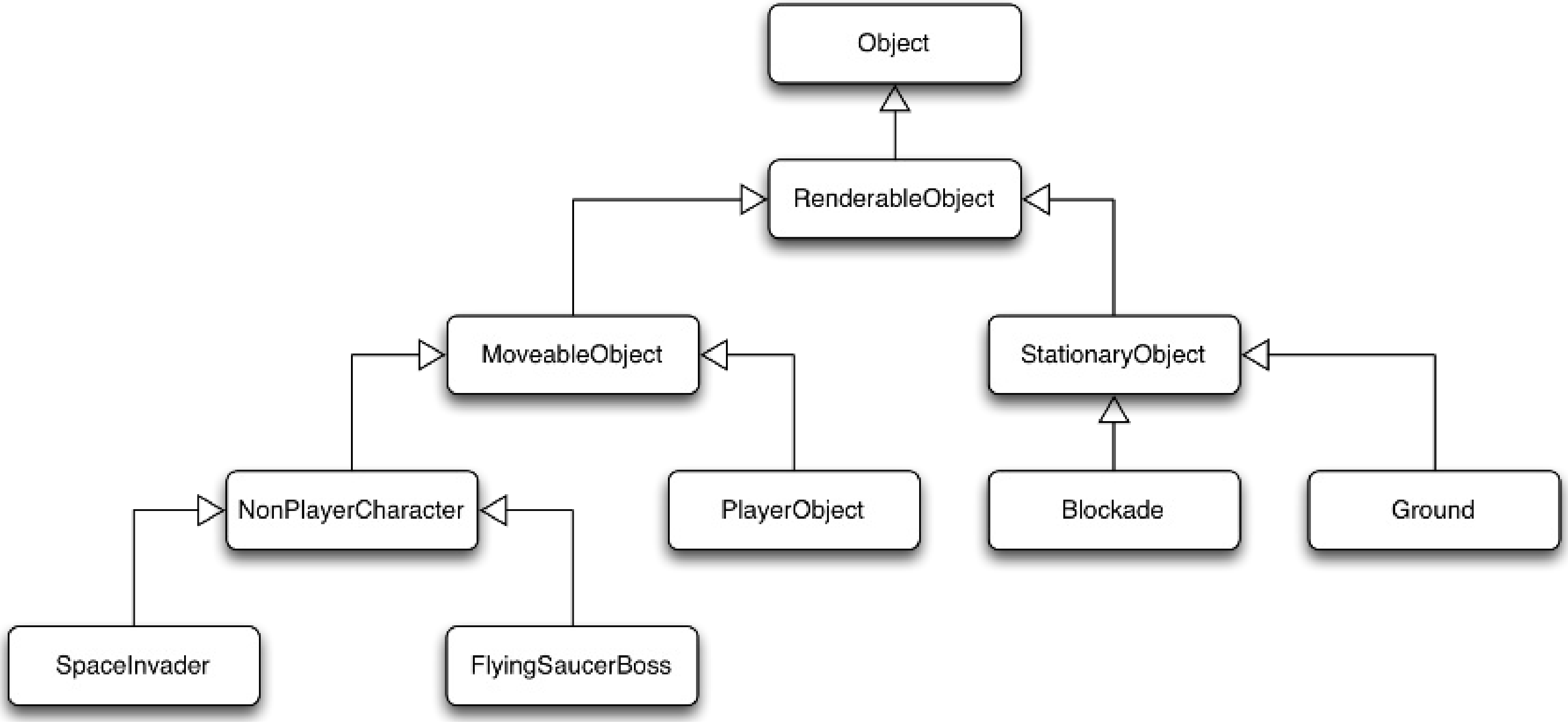
- ECS is an architectural pattern
  - Popular in game engines
  - Favors composition over inheritance
- An entity is a general purpose object
- An entity gets its behavior by combining data
- Data comes from typed components

Composition vs Inheritance

- Let's analyse a familiar example: Space Invaders

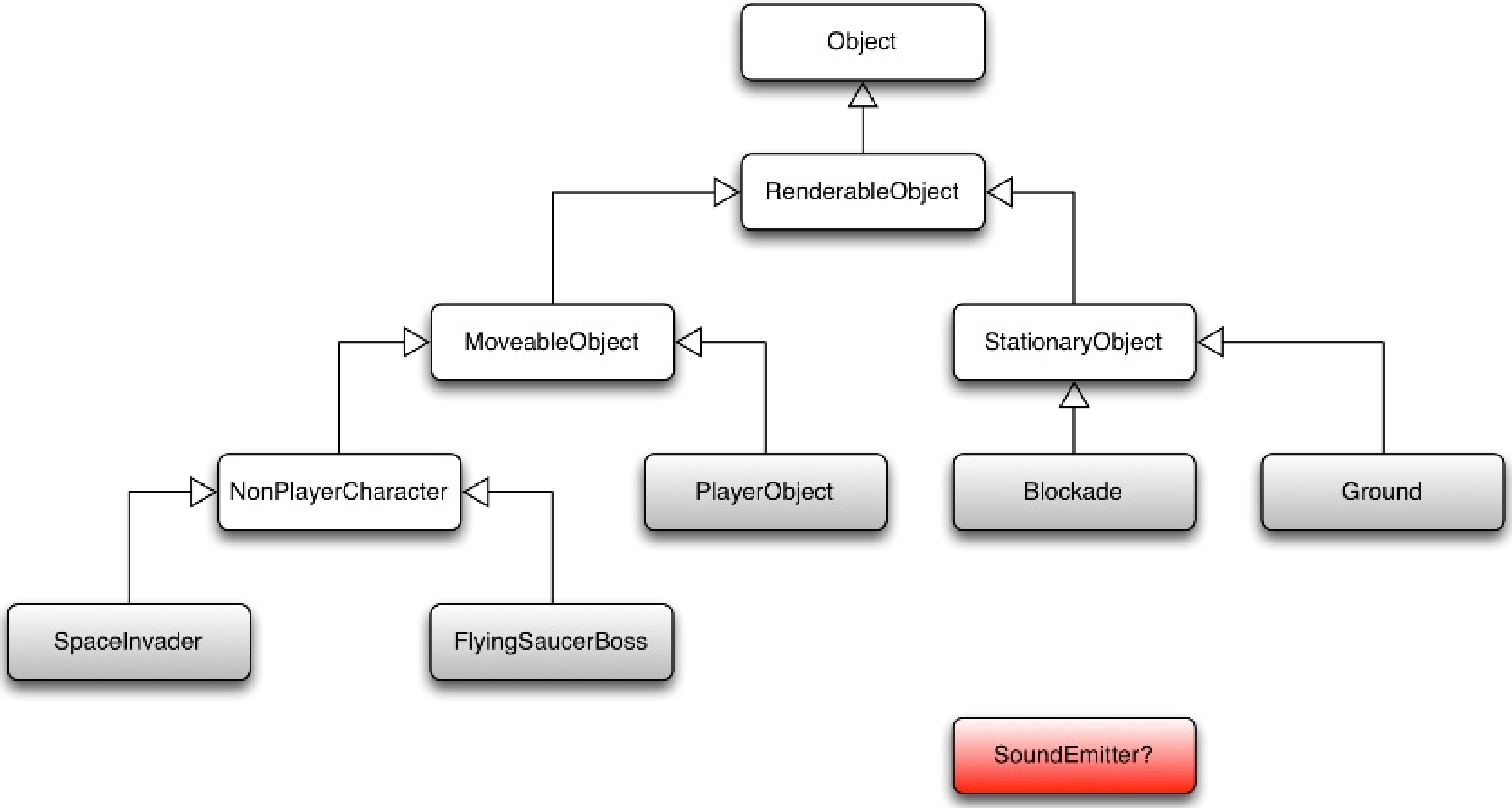
Composition vs Inheritance cont'd

- Typical inheritance hierarchy



Composition vs Inheritance cont'd

- All fine until customer requires new feature:



Object

RenderableObject

MoveableObject

StationaryObject

NonPlayerCharacter

PlayerObject

Blockade

Ground

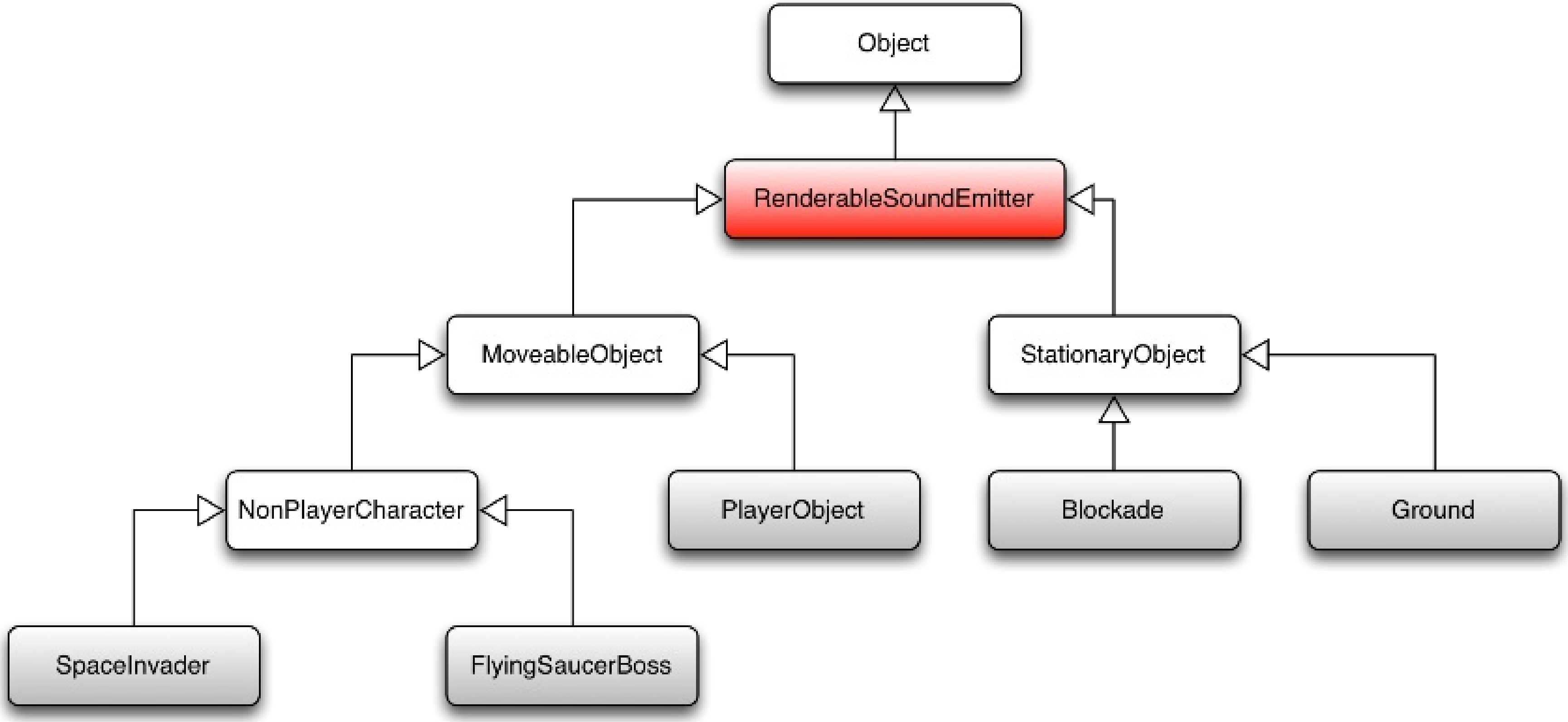
SpaceInvader

FlyingSaucerBoss

SoundEmitter?

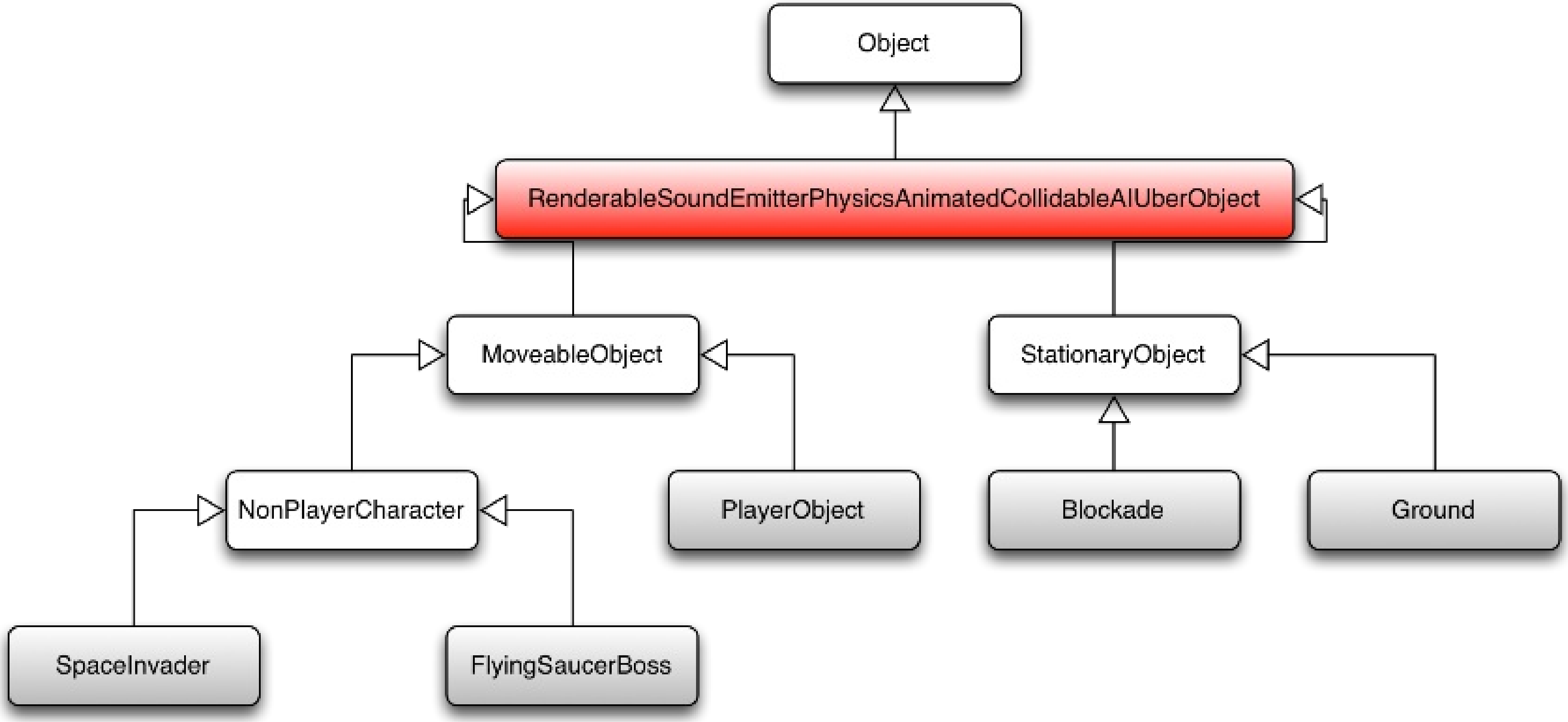
Composition vs Inheritance cont'd

- Typical solution: Add feature to base class



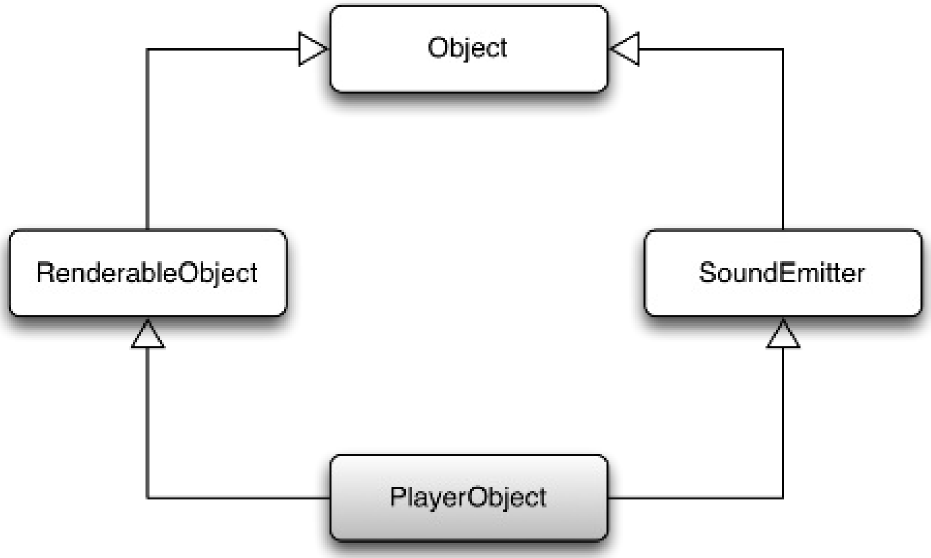
Composition vs Inheritance cont'd

- Doesn't scale:



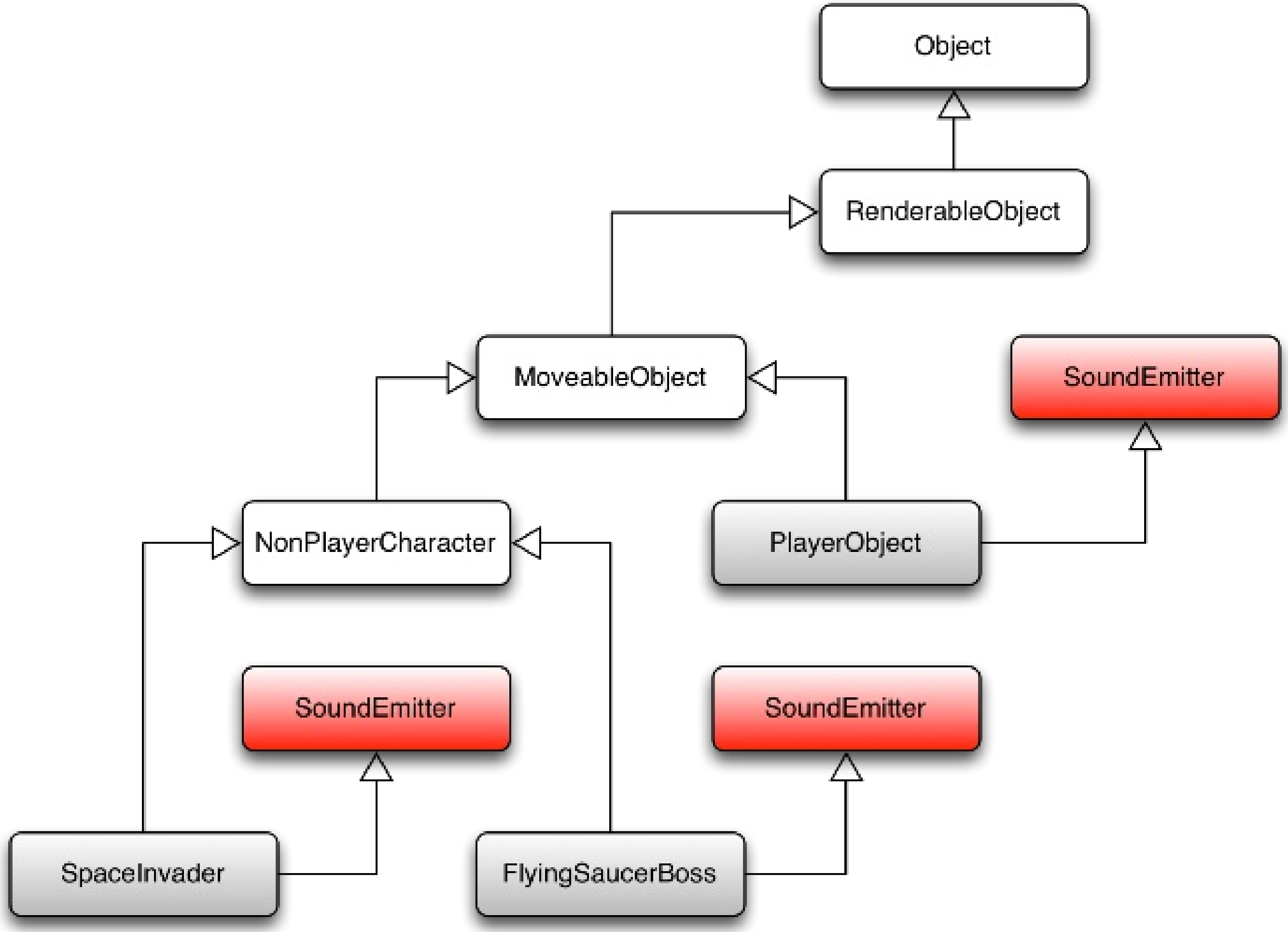
Composition vs Inheritance cont'd

- What about multiple inheritance?



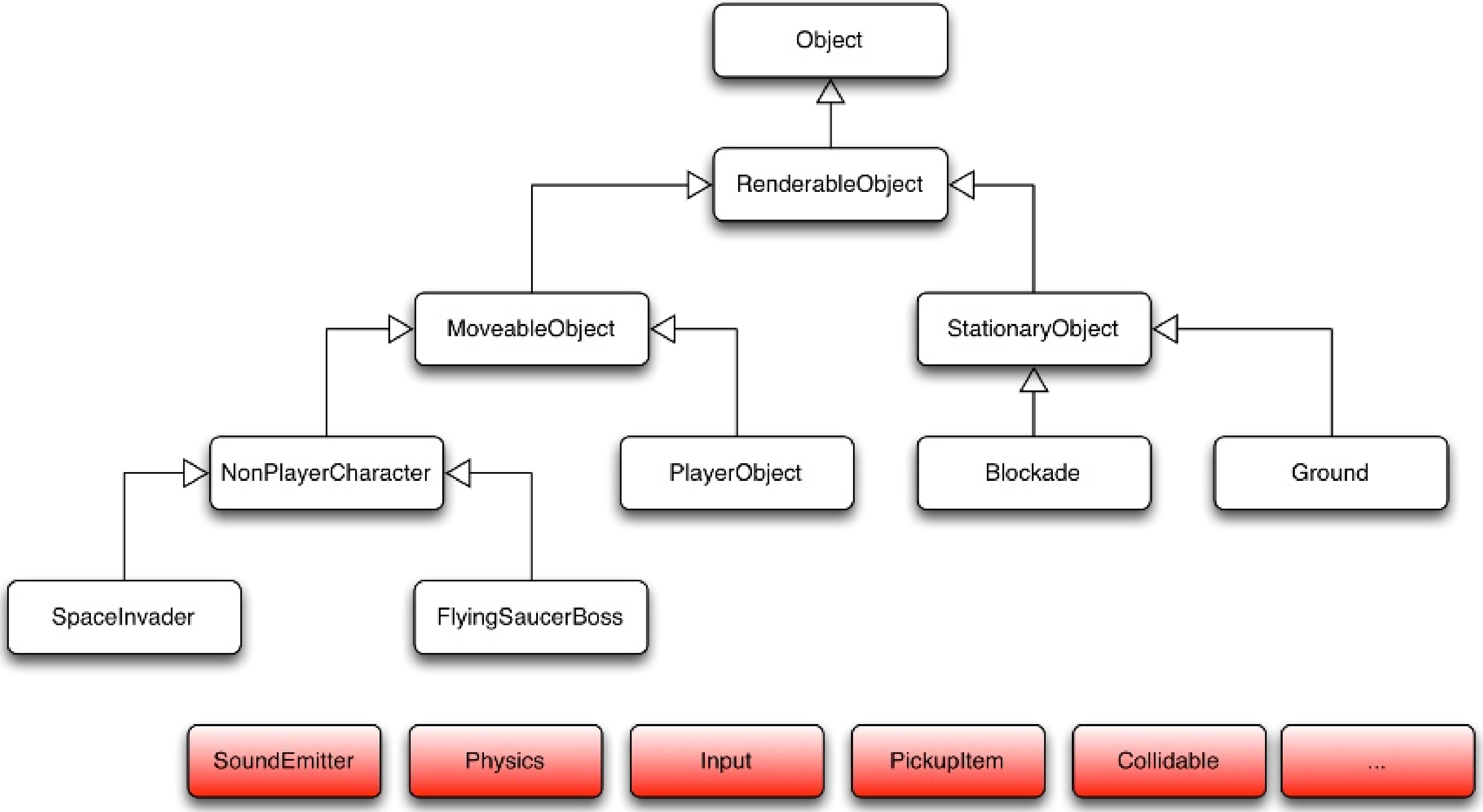
Composition vs Inheritance cont'd

- What about mix-in multiple inheritance?



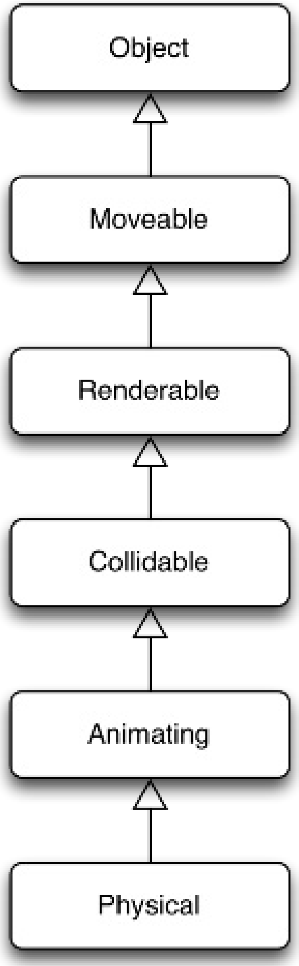
Composition vs Inheritance cont'd

- Does it scale?



Composition vs Inheritance cont'd

- Is inheritance flexible enough?



Composition vs Inheritance cont'd

- Inheritance:
  - Relationships baked in at design time.
  - Complex inheritance hierarchies: deep, wide, multiple inheritance
  - Features tend to migrate to base class
- Entity Component System
  - Allows changes at runtime
  - Avoids inheritance limitations
  - Has additional costs:
    - More QObjects
    - Different to most OOP developer's experience
  - We don't have to bake in assumptions to Qt 3D that we can't later change when adding features.

Qt 3D Basics

- Feature Set
- Entity Component System? Kezaco?
- **Hello Donut**
- Qt 3D ECS Explained
- Input Handling
- Drawing Basics
- Beyond the Tip of the Iceberg
- The Future of Qt 3D

Hello Donut (QML)

- Good practice having root `Entity` to represent the scene
- One `Entity` per "object" in the scene
- Objects given behavior by attaching component subclasses
- For an `Entity` to be drawn it needs:
  - A mesh geometry describing its shape
  - A material describing its surface appearance

Demo qt3d/ex-hellodonut-qml

C++ API vs QML API

- QML API is a mirror of the C++ API
- C++ class names like the rest of Qt
- QML element names just don't have the Q in front
  - `Qt3DCore::QNode` vs `Node`
  - `Qt3DCore::QEntity` vs `Entity`
  - ...

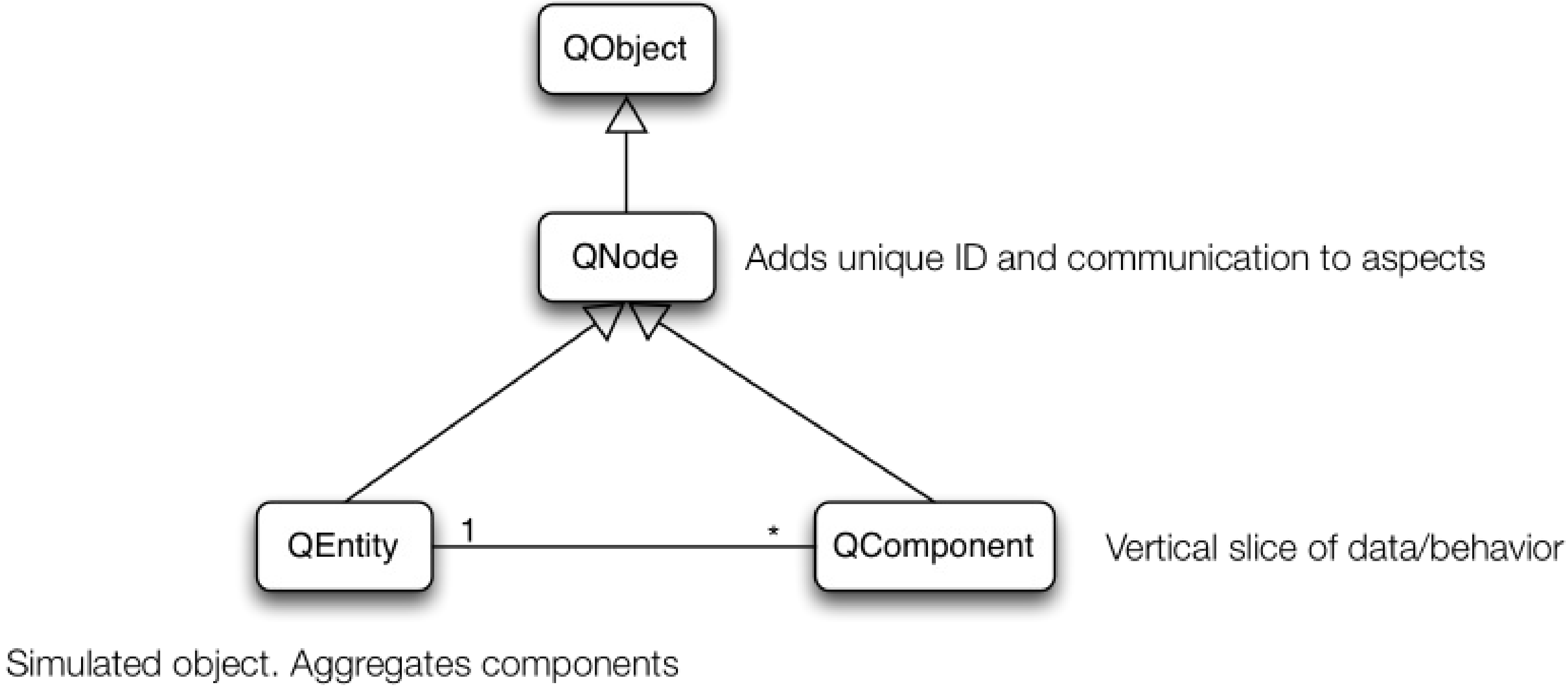
Qt 3D Basics

- Feature Set
- Entity Component System? Kezaco?
- Hello Donut
- **Qt 3D ECS Explained**
- Input Handling
- Drawing Basics
- Beyond the Tip of the Iceberg
- The Future of Qt 3D

Everything is a QNode

- `Qt3DCore::QNode` is the base type for everything
  - It inherits from `QObject` and all its features
  - Internally implements the frontend/backend communication
- `Qt3DCore::QEntity`
  - It inherits from `Qt3DCore::QNode`
  - It just aggregates `Qt3DCore::QComponents`
- `Qt3DCore::QComponent`
  - It inherits from `Qt3DCore::QNode`
  - Actual data is provided by its subclasses
    - `Qt3DCore::QTransform`
    - `Qt3DRender::QMesh`
    - `Qt3DRender::QMaterial`
    - ...

Everything is a QNode cont'd


QObject
QNode
Adds unique ID and communication to aspects
QEntity
1
*
QComponent
Vertical slice of data/behavior
Simulated object. Aggregates components

You Still Need a System

- The simulation is executed by `Qt3DCore::QAspectEngine`
- `Qt3DCore::QAbstractAspect` subclass instances are registered on the engine
  - Behavior comes from the aspects processing component data
  - Aspects control the domains manipulated by your simulation
- Qt 3D provides
  - `Qt3DRender::QRenderAspect`
  - `Qt3DInput::QInputAspect`
  - `Qt3DLogic::QLogicAspect`
- Note that aspects have no API of their own
  - It is all provided by `Qt3DCore::QComponent` subclasses

Qt 3D Basics

- Feature Set
- Entity Component System? Kezaco?
- Hello Donut
- Qt 3D ECS Explained
- **Input Handling**
- Drawing Basics
- Beyond the Tip of the Iceberg
- The Future of Qt 3D

Physical Devices

- To handle input we first need to generate input events
- Subclasses of `Qt3DInput::QAbstractPhysicalDevice` represent input devices
  - `Qt3DInput::QKeyboardDevice`
  - `Qt3DInput::QMouseDevice`
  - Others can be added later
- On it's own a device doesn't do much
  - Input handlers expose signals emitted in response to events

Picking

- High level picking provided by `Qt3DRender::QObjectPicker` component
  - Implicitly associated with mouse device
  - Uses ray-cast based picking
- `Qt3DRender::QObjectPicker` emits signals for you to handle:
  - `pressed(), released(), clicked()`
  - `moved()` - only when dragEnabled is true
  - `entered(), exited()` - only when hoverEnabled is true
- The containsMouse property provides a more declarative alternative to `entered(), exited()`

Physical Devices vs Logical Devices

- Physical devices provide only discrete events
- Hard to use them to control a value over time
- Logical device provides a way to:
  - Have an analog view on a physical device
  - Aggregate several physical devices in a unified device

Logical Input Action

- `Qt3DInput::QAction` provides a binary value
- It is activated by some input, can be:
  - A single button input with `Qt3DInput::QActionInput`
  - A simultaneous combination of button inputs with `Qt3DInput::QInputChord`
  - A sequence of button inputs with `Qt3DInput::QInputSequence`
- When the action state changes the active property is toggled

Demo qt3d/ex-logical-input-qml

Logical Input Axis

- `Qt3DInput::QAxis` provides an analog value between -1 and 1
- It varies over time when some input is generated, can be:
  - When a physical axis varies with `Qt3DInput::QAnalogAxisInput`
  - While a button is pressed with `Qt3DInput::QButtonAxisInput`
- When the axis state changes the value property changes

Demo qt3d/ex-logical-axes-qml

Putting it All Together: Moving Boxes

- Focus managed using tab
- Focused box appears bigger
- The arrows move the box on the plane
- Page up/down rotate the box on its Y axis
- Boxes light up when on mouse hover
- Clicking on a box gives it the focus
- Boxes can be moved around with the mouse

Demo qt3d/sol-moving-boxes-qml-step3

Qt 3D Basics

- Feature Set
- Entity Component System? Kezaco?
- Hello Donut
- Qt 3D ECS Explained
- Input Handling
- **Drawing Basics**
- Beyond the Tip of the Iceberg
- The Future of Qt 3D

The Scene Graph

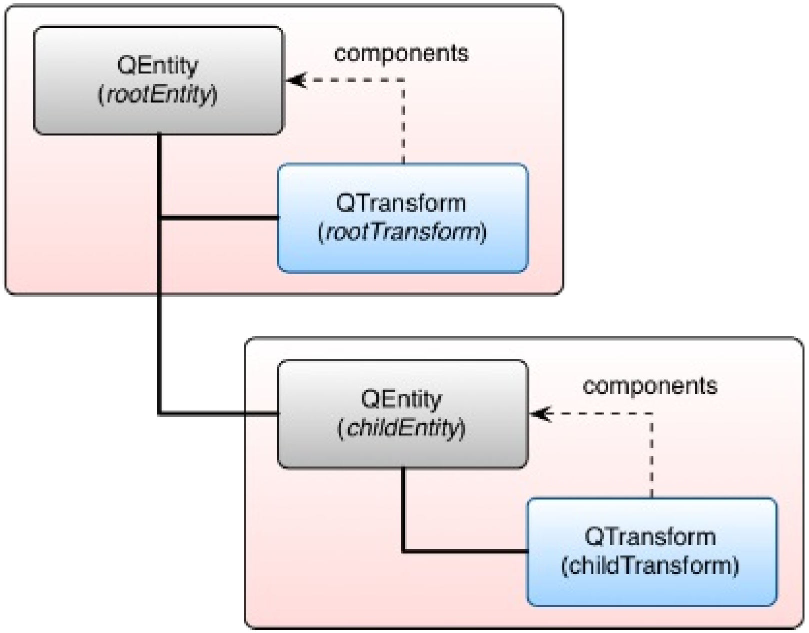
- The scene graph provides the spatial representation of the simulation
  - `Qt3DCore::QEntity`: what takes part in the simulation
  - `Qt3DCore::QTransform`: where it is, what scale it is, what orientation it has
- Hierarchical transforms are controlled by the parent/child relationship
  - Similar to `QWidget`, `QQuickItem`, etc.
- If the scene is rendered, we need a point of view on it
  - This is provided by `Qt3DRender::QCamera`

Qt3DCore::QTransform

- Inherits from `Qt3DCore::QComponent`
- Represents an affine transformation
- Three ways of using it:
  - Through properties: scale3D, rotation, translation
  - Through helper functions: `rotateAround()`
  - Through the matrix property
- Transformations are applied:
  - to objects in Scale/Rotation/Translation order
  - to coordinate systems in Translation/Rotation/Scale order
- Transformations are multiplied along the parent/child relationship

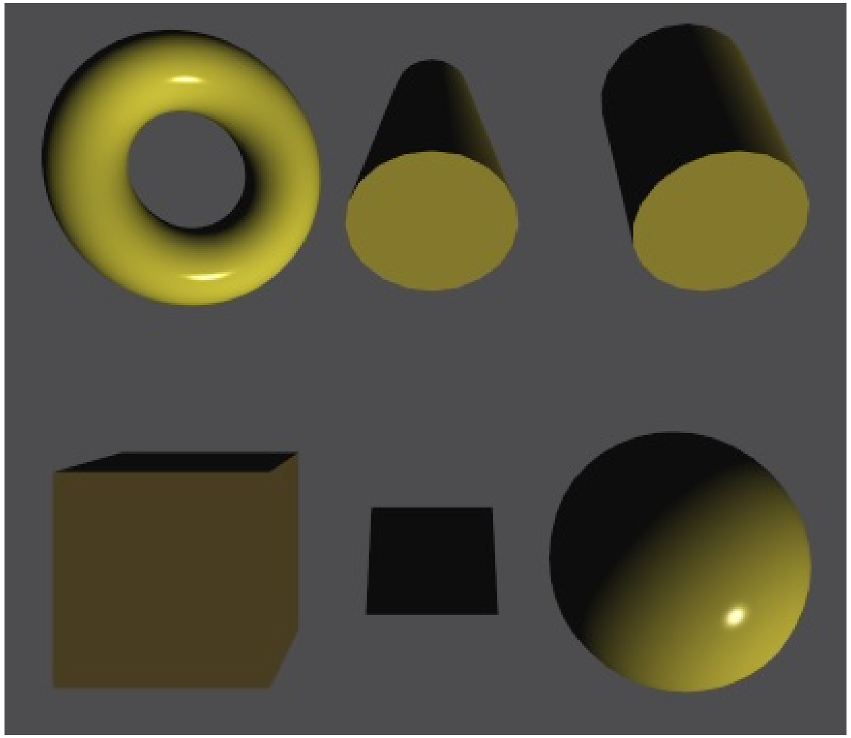
Transforms cont'd

```
import Qt3D.Core 2.0

Entity {
    components: [
        Transform {
            scale3D: Qt.vector3d(1, 2, 1.5)
            translation: Qt.vector3d(0, 0, -1)
        }
    ]

    Entity {
        components: [
            Transform { translation: Qt.vector3d(0, 1, 0) }
        ]
    }
}
```



Geometries

- `Qt3DRender::QRenderAspect` draws `Qt3DCore::QEntity`s with a shape
- `Qt3DRender::QGeometryRenderer`'s geometry property specifies the shape
- Qt 3D provides convenience subclasses of `Qt3DRender::QGeometryRenderer`:
  - `Qt3DExtras::QSphereMesh`
  - `Qt3DExtras::QCuboidMesh`
  - `Qt3DExtras::QPlaneMesh`
  - `Qt3DExtras::QTorusMesh`
  - `Qt3DExtras::QConeMesh`
  - `Qt3DExtras::QCylinderMesh`



Qt Demo examples/qt3d/basicshapes-cpp

Materials

- If a `Qt3DCore::QEntity` only has a shape it will appear black
- The `Qt3DRender::QMaterial` component provides a surface appearance
- Qt 3D provides convenience subclasses of `Qt3DRender::QMaterial`:
  - `Qt3DExtras::QPhongMaterial`
  - `Qt3DExtras::QPhongAlphaMaterial`
  - `Qt3DExtras::QDiffuseMapMaterial`
  - `Qt3DExtras::QDiffuseSpecularMapMaterial`
  - `Qt3DExtras::QGoochMaterial`
  - ...

Demo qt3d/sol-textured-scene

Lights

- Even with shapes and materials we would see nothing
- We need some lights
  - ... luckily Qt 3D sets a default one for us if none is provided
- In general we want some control of the scene lighting
- Qt 3D provides the following light types:
  - `DirectionalLight`
  - `PointLight`
  - `SpotLight`

Lab qt3d/ex-lights-qml

Qt 3D Basics

- Feature Set
- Entity Component System? Kezaco?
- Hello Donut
- Qt 3D ECS Explained
- Input Handling
- Drawing Basics
- **Beyond the Tip of the Iceberg**
- The Future of Qt 3D

Making your Own Geometries

- Using `Qt3DRender::QBuffer` we can create our own vertices
- `GeometryRenderer` controls how buffers are combined and parsed
- Useful to make you own geometries programmatically:
  - From a function
  - From data sets
  - From user interaction

Demo qt3d/ex-surface-function

Texture Composition and Filtering

- Possible to sample several textures in a single material
- Also easy to reuse stock lighting model
- Then you can blend as you see fit in the shader

Demo qt3d/sol-earth

Procedural Textures

- Lots of examples available on the Internet
  - `https://www.shadertoy.com/`
  - Usually written for WebGL or OpenGL ES 2
  - May require some adaptation
  - Many are far from simple!
- But they are easy to plug in the `Material` system and to parameterize

Demo qt3d/ex-plasma

Integrating with QtQuick using Scene3D

- Provided by the `QtQuick.Scene3D` module
- Takes an `Entity` as child which will be your whole scene
- Loaded aspects are controlled with the aspects property
- Hover events are only accepted if the hoverEnabled property is true

Demo qt3d/ex-controls-overlay

And more...

- Layer management
- Own materials and lighting models
- Texture mipmaps
- Cube Maps
- Portability of your code accross several OpenGL versions
- Complete control over the rendering algorithm
- Loading complete objects or scenes from files (3ds, collada, qml...)
- Post-processing effects (single or multi-pass)
- Instanced rendering
- etc.

Demo qt3d/ex-multiple-effects

Demo qt3d/sol-asteroids

Qt 3D Basics

- Feature Set
- Entity Component System? Kezaco?
- Hello Donut
- Qt 3D ECS Explained
- Input Handling
- Drawing Basics
- Beyond the Tip of the Iceberg
- **The Future of Qt 3D**

What does the future hold for Qt 3D?

- Qt 3D Core
  - Efficiency improvemments
  - Backend threadpool and job handling improvements - jobs spawning jobs
- Qt 3D Render
  - Use Qt Quick or QPainter to render into a texture
  - Embed Qt Quick into Qt 3D including input handling
  - Level of Detail (LOD) support for meshes
  - Billboards - camera facing entities
  - Text support - 2D and 3D
  - Additional materials such as Physics Based Rendering (PBR) materials
  - Particle systems
- Qt 3D Input
  - Axis inputs that apply cumulative axis values as position, velocity or acceleration
  - Additional input device support
    - 3D mouse controllers, game controllers
  - Enumerated inputs such as 8-way buttons, hat switches or dials

What does the future hold for Qt 3D?

- New aspects:
  - Collision Detection Aspect
    - Allows to detect when entities collide or enter/exit volumes in space
  - Animation Aspect
    - Keyframe animation
    - Skeletal animation
    - Morph target animation
    - Removes animation workload from main thread
  - Physics Aspect
    - Rigid body and soft body physics simulation
  - AI Aspect, 3D Positional Audio Aspect ...
- Tooling:
  - Design time tooling - scene editor
  - Build time tooling - asset conditioners for meshes, textures etc.

Thank you!

www.kdab.com

kevin.ottens@kdab.com