# gameplay

# Development Guide

# Contents

# Overview

The gameplay framework is an open-source, cross-platform gaming framework that is designed to make it easy to learn to write 3-D mobile and desktop games using native C++. In this guide, we cover a top-down approach to teaching you the gameplay library, tools, and all the major parts of the APIs that are included in the framework. This guide covers a set of the C++ classes that you can use to write your games.

## Design goals and considerations

In creating the gameplay framework, the goal was not only to focus on creating a high performance native C++ game framework, but also on a clean, simple, and elegant architecture. The framework uses a minimal set of cross-platform external dependencies and tries to take a minimalist approach to designing the classes. This approach allows you to learn from the classes in the library and extend the framework to build your own game engine or tools. The framework is a good starting block for learning how to write 3-D cross-platform mobile and desktop games, allowing you to spend more time designing your game.

## Why write another game engine?

We actually hope it will be considered more of a gaming framework; however, in essence, it is really still just the core components of a game engine. There are several reasons why the gameplay framework was developed.

First, most modern 3-D game engines, while sometimes free or cheap, are closed source. Additionally, they usually have licensing fees. The gameplay framework is free, open-source software under the Apache 2.0 license. We want more people to learn about the fact that cross-platform is a reality and building a good base lets you move forward to writing game titles.

Secondly, a game engine is not only about rendering. Yes, it's a huge part, but equally important are other aspects of game engines, such as audio, physics, animation, UI forms, particle emitters, scripting, and math. Searching on the web and trying to find information on how to fit these things into your game engine, or games, will likely scatter you across many different places, with the chance of gaps in your learning. This framework will hopefully bring it all together for you.

Lastly, mobile is hot! The gameplay framework will have a lot of emphasis on gaming on mobile devices. Today, mobile gaming is the largest growing sector of the game industry. Additionally, we still provide support for desktop platforms for both tooling and gaming. However, we think more focus should be on mobile gaming and learning how to write games that can easily target the cross-platform mobile sector.

# Compiling framework

To build the gameplay library, tools, and samples as well as write your own games, you will have to install and use the platform specific tools listed below. These are the supported development environments for each specific operating system as a target platform.

| Desktop OS | Tool | Development environment |
|---|---|---|
| Microsoft Windows 7 | Visual Studio 2010 | Windows 7 |
| Apple Mac OS X | Xcode 4.3.2 | Mac OS X |

| Mobile OS | Tool | Development environment |
|---|---|---|
| BlackBerry PlayBook OS 2.0 | BlackBerry Native SDK 2.0 | Windows 7, Mac OS X |
| Android 2.3 | Android NDK 7 | Windows 7, Mac OS X |
| iOS 5.1 | Xcode 4.3.2 | Mac OS X |

## Project repository

Included in the project repository are the following notable folder and files:

| Folder/Files | Description |
|---|---|
| /bin | Precompiled binary tools |
| /external-deps | External dependency libraries |
| /gameplay | The gameplay library |
| /gameplay-api | Doxygen API Reference |
| /gameplay-docs | Documentation guides and tutorials |
| /gameplay-encoder | Game asset/content encoding tool |
| /gameplay-luagen | Lua script bindings generator tool |
| /gameplay-template | Game samples template project files |
| /gameplay-samples | Game samples |

| | |
|---|---|
| gameplay.xcworkspace | Xcode workspace |
| gameplay.sln | Microsoft Visual Studio solution |
| gameplay-newproject.bat/.sh | New cross-platform project script |

## Getting started on desktop

The quickest way to get started using the gameplay framework and tools is to simply start working in one of the desktop environments. You could use Microsoft Visual Studio 2010 Express, Professional on a Windows 7 operating system, or Xcode 4.3.2 on an Apple Mac OS X operating system. Then just open either the Microsoft Visual Studio solution or Xcode workspace, and build and run the projects. These solutions/workspaces are set up by default to build all the projects needed and to run the samples you have selected as active.

Voila! You now have one of several simple, interactive samples running on your desktop environment, which you can explore and become more familiar with.

## Game samples

The gameplay-docs folder contains additional tutorial documentation for our gameplay-samples. These are intended to go into more detail for designing and coding games written using the framework. They all have a good starting point but have intentionally been left incomplete. This gives you the opportunity to change the samples, and complete them to make them more fun to interact and play with. They provide good building blocks and are a basis for you to explore various features in the framework. You can utilize code snippets from the samples to help speed up the development cycle in your own games.

## API reference

We firmly believe in making a very intuitive set of APIs that are as straight-forward and as consistent as possible. However, all of the classes in the framework have been well documented with Doxygen formatting. The classes will be updated and improved iteratively throughout each release. This is to help you learn about what classes or sets of functions can be used and the recommended practices in using them.

You should consider reading the latest versions of the API reference from the pre-generated HTML Doxygen API documentation in the gameplay-api folder. This will give you a deeper understanding of the C++ gameplay framework.

# Getting started on mobile

Now that you are up and running on one of the desktop environments, we recommend you take this seriously and go mobile! In today's mobile game market, cross-platform development is a reality. It is quite simple and easy to use the gameplay framework to target a wider device audience. Start by downloading the native development kit for one of the various supported mobile operating system targets or set them all up.

# Mobile setup instructions

Listed below are the basic setup instructions for downloading and installing the supported mobile platform and development environments for gameplay.

**BlackBerry Native SDK 2.0/10 Beta (PlayBook tablets and BlackBerry 10 devices)**

1. Download and install the BlackBerry Native SDK 2.0 (for PlayBook) or BlackBerry 10 Beta (for BlackBerry 10 devices).
2. Run the QNX Momentics IDE (Eclipse CDT based) and click **File > Import > Import Existing Projects**.
3. Import all the gameplay projects by selecting the repository project folder.

4. Set the active configuration to one of the Device-XXX or Simulator-XXX profiles.
5. Build and run any of the game samples.

**Apple Xcode 4.3.2 (iPad tablets and iPhone devices)**

1. Download and install Apple Xcode 4.
2. Open the **gameplay.xc** workspace.
3. Change the active configuration to **iOS Device**, **iPhone Simulator,** or **iPad Simulator**.
4. Build and run any of the game samples.

**Android NDK 7 (Android tablets and devices)**

1. Download and install Android NDK 7, Android SDK, Apache Ant, and GNU Make for Cygwin.
    a. Setup the Android SDK.
    b. Make sure <android-sdk-path>/tools and <android-sdk-path>/platform-tools are added to PATH.
    c. Setup the Android NDK and follow these instructions.
    d. Make sure <android-ndk-path> is added to PATH.
    e. Install Apache Ant.
    f. Make sure <ant-path>/bin is added the PATH.
    g. Install Cygwin and select and add the package **make: The GNU version of the 'make' utility** during installation.
    h. Rename **awk.exe** to something else (awk_.exe for example) in <android-ndk-path>/prebuilt/windows/bin. This is to prevent the Android build system from being confused by the cygwin's awk.

2. Build the gameplay library using following steps:
    a. Open the Cygwin terminal.
    b. Change to the **<gameplay-root>/gameplay/android** folder.

c. Run the following command to generate the needed files to build the project:
   **> android.bat update project -t 1 -p . -s**
d. Run the following command to build the gameplay library:
   **> ndk-build**

3. Build a sample game(s) with following steps:
   a. Open the Cygwin terminal.
   b. Change to the:
      **<gameplay-root/gameplay-samples/sampleXX-XXXXX>/android** folder.
   c. Run the following command to generate the needed files to build the project:
      **> android.bat update project -t 1 -p . -s**
   d. Run the following command to build the gameplay sample:
      **> ndk-build**

   **Android NDK permissions errors:**

   If you see an error like `"./obj/local/armeabi/libpng.a: No such file: Permission denied"`, make sure that the `"*.a"` files have read permission by running:
   **> chmod +r obj/local/armeabi/*.a**

4. Connect the device and run the following command in the Cygwin terminal to deploy the game:
   **> ant debug install**

Note: If "ant debug install" does not work, ensure your device is being detected properly by running "adb devices". If no devices are reported, try downloading the correct USB drivers from you phone manufacturer's website. (OEM Drivers)

## Ubuntu Linux

1. **sudo apt-get install cmake libglu1-mesa-dev libogg-dev**

   **libopenal-dev**
2. **cd build**
3. **cmake ..**
4. **make**

# Mobile platform considerations

Ensure that you test early on the physical devices. Depending on the type of game you want to write and on your design ideas, you'll want to get some idea of what type of performance you'll get with the game plan and prototypes you are working towards. Be careful and do not to rely on desktop and mobile simulators as an indicator of performance or mobile device capabilities.

# Creating new projects

To create a new cross-platform game project, run the gameplay-newproject.bat/.sh script. The following is an example of running the gameplay-newproject.bat script:

```
1. Enter a name for the new project.

   This name will be given to the project
   executable and a folder with this name
   will be created to store all project files.

Project name: test


2. Enter a game title.

   On some platforms, this title is used to
   identify the game during installation and
   on shortcuts/icons.

Title: Test


3. Enter a short game description.

Description: Test Game


4. Enter a unique identifier for your project.
```

```
   This should be a human readable package name,
   containing at least two words separated by a
   period (eg. com.surname.gamename).

Unique ID: org.gameplay3d.test


5. Enter author name.

   On BlackBerry targets, this is used for
   signing and must match the developer name
   of your development certificate.

Author: My Company


6. Enter your game's main class name.

   Your initial game header and source file
   will be given this name and a class with
   this name will be created in these files.

Class name: TestGame


7. Enter the project path.

   This can be a relative path, absolute path,
   or empty for the current folder. Note that
   a project folder named test will also
   be created inside this folder.

Path: gameplay-samples

    1 file copied.
    ...
```

The simplest way to run the project on Windows is to add the Visual Studio project to the existing gameplay.sln solution, set the "gameplay" project as a dependency (right-click on the new project, click "Project Dependencies...", and select the "gameplay" project), and then build and run.

Similarly, the easiest way to run the project on BlackBerry is import the new project into a QNX Momentics IDE workspace that already contains the gameplay project, set the "gameplay" project as a dependency (right-click the new project, click "Properties", go to "Project References", and select the "gameplay" project), and then build and run. (Note: make sure that both projects are set to the same Build Configuration.)

To run the project on Mac, simply open the Xcode project and build and run.

To run the project on Android from Windows, use the steps described above for running the samples.

# Assets and authoring

Game assets are extremely important for the quality of a good game. Not only do the game assets need to be fitted for the game design, but they also need to load as quickly as possible and at the highest quality within the platform hardware limitations.

## Binary game assets

A very practical way to ensure that you're being efficient is to always bundle and load all your game assets as binary formats. Common assets include images, fonts, audio, and 3-D scenes. Most game engines will always include some sort of authoring tool to allow developers to encode and process their content to be game-ready. The gameplay framework also includes an executable tool for this called the gameplay-encoder.

## Using fonts and 3-D scenes

For fonts and 3-D scenes, you will want to support industry-standard file formats, such as TrueType for fonts and popular modern 3-D scene formats such as COLLADA and the FBX formats.

Although these formats are popular and have the widest support in tooling options, they are not considered efficient runtime formats. The gameplay library requires that you convert these formats to its documented gameplay bundle format (.gpb) using the gameplay-encoder executable.

## Pre-built gameplay-encoder tool

The gameplay-encoder executable tool comes pre-built for Windows 7 and Mac OS X and can be found in the **<gameplay-root>/bin** folders. The general usage is:

```
>gameplay-encoder <options> files
```

## Building gameplay-encoder

Even though the gameplay-encoder tool comes pre-built, you make want to customize it and built it again yourself. To build the gameplay-encoder project, open the gameplay-encoder project in Visual Studio or XCode and build the executable.

## Building support for the FBX format

Although the FBX format is supported by the gameplay-encoder tools, FBX is not allowed to be re-distributed as part of our framework. However, it is free for you to use. Simply download the FBX SDK and then re-build the code in the gameplay-encoder using the USE_FBX preprocessor directive and ensure that you include the header and library paths in the project to the FBX SDK paths.

## Content pipeline

The content pipeline for fonts and scenes works like this:

1. Take any TrueType fonts or COLLADA/FBX scene files.
2. Run the gameplay-encoder executable passing in the font or scene file path and optional parameters to produce a gameplay binary version for the file (.gpb).
3. Bundle your game and include the gameplay binary file as a binary game asset.
4. Load any binary game assets using the `gameplay::Bundle` class.

## Using binary bundles

Use the `gameplay::Bundle` class from your C++ game source code to load your encoded binary files as bundles. The class offers methods to load both fonts and scenes. Scenes are loaded as a hierarchical structure of nodes, with various entities attached to them. These entities include things like mesh geometry or groups of meshes, and cameras and lights. The `gameplay::Bundle` class also has methods to filter only the parts of a scene that you want to load.

## Release mode assets

When releasing your game title, all of the images should be optimized and converted to the compressed texture format that is supported by OpenGL (ES). Audio should be encoded to save space on storage.

# Game

The `gameplay::Game` class is the base class for all your games created with the gameplay framework. You are required to extend this class using C++ and to override the core game and lifecycle event methods initialize, finalize, update, and render. This is where you'll write your code to load the game assets and apply game logic and rendering code. Under the hood, the game class will receive events and act as an abstraction between the running game and the underlying platform layer that is running the game loop and reacting to operating systems.

There are four methods you must implement to get started in writing your own game:

```
#include "gameplay.h"

using namespace gameplay;

class MyGame : public Game
{
    void initialize();
    void finalize();
    void update(float elapsedTime);
    void render(float elapsedTime);
};
```

The `Game::initialize()` and `Game::finalize()` methods are called when the game starts up and shuts down, respectively. They are the methods to which you'll add code to load your game assets and cleanup when the game has ended. The `Game::update()` and `Game::render()` methods are called once per frame from the game loop implemented in the `gameplay::Platform` for each operating system. This allows you to separate the code between handling updates to your game's state and rendering your game's visuals. You can use a variety of built-in classes to help with the game rendering.

## Accessing the game instance

The `gameplay::Game` class can be accessed from anywhere in your game code. It implements a singleton design pattern. Call the static method `Game::getInstance()` to gain access to the instance of your game from any code.

## Graphics and audio devices

After your game has started, the underlying graphics and audio devices will automatically initialize. This happens prior to the `Game::initialize()` method being called and readies any classes that use OpenGL (ES) 2.0 or Open AL 1.1. The graphics devices of your `Game` will be set up with a default 32-bit color frame buffer, a 24-bit depth buffer, and an 8-bit stencil buffer ready for your use. These are the active graphics hardware buffers, which are rendered into from your rendering code.

For more advanced usage, you can apply alternative frame buffers using the `gameplay::FrameBuffer` class. Immediately after the `Game::render()` method, the frame buffer is swapped/presented to the physical display for the user to see. You can invoke the `Game::clear()` method to clear the buffers through any of the methods. You can also call `Game::renderOnce()` from code, such as from the `Game::initialize()` method, to callback onto a method that will be called only once and then swapped/presented to the display. This is useful for presenting ad-hoc updates to the screen during initialization for rendering, such as loading screens.

## Game sub-system controllers

The `gameplay::Game` class also manages game sub-system controllers, such as audio, animation and physics controllers, and provides access to them directly using getter methods. These classes act as controlling interfaces for managing and playing audio and animations that are active in the game, as well as updates to dynamics in the physics systems. These controllers are hosted by the `gameplay::Game` class and react on lifecycle events being handled in the game.

## Game time and state

Once the instance of a `gameplay::Game` class has started, the game starts a running time. You can call the `Game::getGameTime()` to determine how long a game has been running. You can also call `Game::getAbsoluteTime()` to determine the absolute time that has elapsed since the first `Game::run()` call. This includes any paused time too. You can call the `Game::pause()` method and the game will be put into the `Game::PAUSED` state. If the user on the platform puts the game into the background, the game time is also paused. If the user puts the game back into the foreground, the game will invoke `Game::play()` and the game will resume. At any time in the game you can determine the game state by calling `Game::getState()`. The game state can be UNINITIALIZED, RUNNING or PAUSED.

# Input and sensors

By creating your game and extending `gameplay::Game`, you'll be able to add all the required handlers of input events. Additionally, there are methods on `gameplay::Game` to poll for the current sensor data. This architecture insulates you, as a developer, from the platform-specific details on handling keyboard, touch and mouse events, and from polling the accelerometer state. The following illustrates overridden methods to handle input events:

```
#include "gameplay.h"

using namespace gameplay;

class MyGame : public Game
{
    ...

    void keyEvent(Keyboard::KeyEvent evt, int key);
    void touchEvent(Touch::TouchEvent evt, int x, int y, unsigned int contactIndex);
    bool mouseEvent(Mouse::MouseEvent evt, int x, int y);
    void getAccelerometerValues(float* pitch, float* roll);
};
```

## Handling input events

You have the opportunity, on either desktop platforms or mobile devices, to handle mouse events uniquely from the `Game::touchEvent()` method (this includes support for a Bluetooth enabled mouse). However, this is not required, and the default implementation of the `Game::mouseEvent()` method returns `false`, which means that the user can allow mouse events to be treated automatically as touch events.

You can decide to disable multi-touch support for games when you do not want this functionality. You can call `Game::setMultiTouch()` and pass in `false` to ensure that the platform treats and handles touch events as single touches.

You can also call `Game::displayKeyboard()` to show or hide a virtual keyboard for platforms that support it. You'll want to integrate it into points in the game and user interfaces in the game where text input is required.

You can call `Game::getAccelerometerValues()` and pass in pointers to parameters that will be populated with the current sensor values for the accelerometer.

# Sprites and fonts

Use the `gameplay::SpriteBatch` and `gameplay::Font` classes to integrate simple 2-D sprite and text rendering for both 2-D and 3-D games.

## Binary encoding fonts

The first thing to do is to create or find a TrueType font that you want to use. There are a number of sites on the web that offer .TTF files to purchase, or tools to make them yourself.

Next, you'll want to binary encode your TrueType font to a binary format via gameplay-encoder to produce a binary file. To do this run the following command with your gameplay-encoder executable:

```
> gameplay-encoder -s 28 airstrip.ttf
```

## Drawing text and images

The following code sample illustrates how to render an image and text together:

```
void MyGame::initialize()
{
    // Create your sprite batch and font and associate resources
    _batch = SpriteBatch::create("res/image.png");
    _font = Font::create("res/airstrip28.gpb");
}

void MyGame::render(float elapsedTime)
{
    // Clear the frame buffer
    clear(CLEAR_COLOR_DEPTH, Vector4(0, 0, 0, 1), 1.0f, 0);

    // Draw your sprites (we will only draw one now
    _batch->start();
    _batch->draw(Rectangle(0, 0, WINDOW_WIDTH, WINDOW_HEIGHT),
```

```
                Rectangle(0, 0, WINDOW_WIDTH, WINDOW_HEIGHT), Vector4::one());
    _batch->finish();

    // Draw the text at position 20,20 using red color
    _font->start();
    char text[1024];
    sprintf(text, "FPS:%d", Game::getFrameRate());
    _font->drawText(text, 20, 20, Vector4(1, 0, 0, 1), _font->getSize());
    _font->finish();
}

void MyGame::finalize()
{
    // Use built-in macros to clean up our resources.
    SAFE_DELETE(_batch);
    SAFE_RELEASE(_font);
}
```

## Batch, batch, batch

You'll notice that the `gameplay::SpritchBatch` and `gameplay::Font` code sequences above both have a common flow to them. The developer performs a call to `start()` followed by drawing operations and finishing with a call to `finish()`. This is to support batching or combining drawing operations into a single hardware rendering call.

# Scene and nodes

At the heart of any game is a visual scene. Using the `gameplay::Scene` class, you can create and retain a rich 3-D scene for organizing visual, audio, animation and physics components in your game.

The `gameplay::Scene` class is based on a hierarchical data structure that is often referred to as a scene graph. Using the `gameplay::Scene` and `gameplay::Node` classes, you can build up a game level by attaching various game components to the nodes in the scene. The node will maintain the transformation for any attachments. As a basic example, a scene might have two nodes. The first node could have a `gameplay::Camera` attached to it and the second node could have a `gameplay::Model` attached to it. The `gameplay::Scene` will have the camera set as the active camera. You could then transform either/both of the nodes to change the player's perspective on what they will see in the game.
There are a variety of components you can attach to the `gameplay::Node` class:

| Component | Description |
|---|---|
| `gameplay::Model` | Used to represent the mesh/geometry in the scene. |
| `gameplay::Camera` | Used to represent a view/perspective into the scene. |
| `gameplay::Light` | Used to hold lighting information that can affect how a `Model` is rendered. |
| `gameplay::PhysicsCollisionObject` | Used to define the basic physics dynamics that will be simulated. |
| `gameplay::ParticleEmitter` | Used to represent smoke, steam, fire and other atmospheric effects. |
| `gameplay::AudioSource` | Use to represent a source where audio is being played from. |

A typical flow will have you loading/building a large scene representing all the components needed in the game level. This is done once during `Game::initialize()`. For every call to the `Game::update()` method, the code will update changes to the nodes and attached components based on events such as user input . Then the application will traverse the scene and render the parts in the scene that are visible from scene's active camera.

## Exporting a 3-D scene from Autodesk Maya/Max

If you want to export 3-D scenes, use the native FBX Export (for FBX) or DAE_FBX Export (for COLLADA).

# Exporting a 3-D scene from Blender

Blender supports exporting to the COLLADA and FBX file formats.

- **File** > **Export** > **Autodesk FBX (.fbx)**
- **File** > **Export** > **COLLADA (.dae)**

If you run into problems when using COLLADA files from Blender, try re-importing the COLLADA file back into Blender or Maya software to see if there is a problem with the exported model.

# Binary encoding a scene

Run gameplay-encoder with no arguments to see the usage information and supported arguments.

```
Usage: gameplay-encoder [options] <filepath>
```

**Example**

Convert the COLLADA file duck.dae into gameplay binary file duck.gpb.

```
> gameplay-encoder duck.dae
```

# Encoding an FBX file

To convert an FBX file to a gameplay binary file, you must install the FBX SDK and set the preprocessor directive USE_FBX. See the instructions in the gameplay-encoder README on GitHub.

## Loading a scene

Using the gameplay::Bundle class, you can load either an entire scene or various parts of a scene into any existing scene. The gameplay::Bundle parses the binary file and de-serializes the objects from the file so that you can use them in your game.

Here is an example of loading a simple scene containing a model of a duck, a light, and a camera from a gameplay binary file:

```
void MeshGame::initialize()
{
    // Load the scene from our gameplay binary file
    Bundle* bundle = Bundle::create("res/duck.gpb");
    Scene* scene = bundle->loadScene();
    SAFE_RELEASE(bundle);

    // Get handles to the nodes of interest in the scene
    _modelNode = scene->findNode("duck");
    Node* _lightNode = scene->findNode("directionalLight1");
    Node* _cameraNode = scene->findNode("camera1");

    // More initialization ...
}
```

## Updating a scene

After handling input events or polling the sensors, it's time to update the scene. It is very important to understand the scene representing your game level. We always want to update things that are impacted by the changes to optimize performance. In order to optimize the performance of your game, it is essential that you only update objects that need to be changed. In this example, we'll apply a rotation when the user has touched the screen or mouse button:

```
void MyGame::update(float elapsedTime)
{
    // Rotate the model
    if (!_touched)
        _modelNode->rotateY(elapsedTime * MATH_DEG_TO_RAD(0.05f));
```

```
    }
}
```

Some examples of typical things you will want to update in your scene may include:

- applying forces or impulses onto rigid bodies
- applying transformations
- starting or stopping animations
- showing or hiding components

## Rendering a scene

To render a scene you'll need to gather all the models in the scene that are attached to nodes and then draw them. Calling the `Scene::visit()` method, the scene's hierarchical data structure is traversed and for each node in the scene, the specified method is invoked as a callback.

```
void MyGame::render(float elapsedTime)
{
    // Clear the buffers to black
    clear(CLEAR_COLOR_DEPTH, Vector4::zero(), 1.0f, 0);

    // Visit all the nodes in the scene, drawing the models/mesh.
    _scene->visit(this, &MeshGame::drawScene);
}

bool MyGame::drawScene(Node* node, void* cookie)
{
    // This method is called for each node in the scene.
    Model* model = node->getModel();
    if (model)
        model->draw();
    return true;
}
```

## Culling non-visible models

In some scenes, you may have many models contributing to the game level. However, with a moving camera, only some models will be visible at any particular time. Running the code in the snippet above on much larger scenes would cause many models to be drawn unnecessarily. To avoid this, you can query a `gameplay::Node` class and retrieve a `gameplay::BoundingSphere` using `Node::getBoundingSphere()`. This bound represents an approximation of the representative data contained within a node. It is only intended for visibility testing or first-pass intersection testing. If you have a moving camera with many objects in the scene, ensure that you add code to test visibility from within your visitor callback. This will ensure the node is within the camera's viewing range. To do this, make a simple intersection test between the front of each node and the active camera frustum (by calling `Camera::getFrustum()`) that represents the outer planes of the camera's viewing area. Here is a snippet of code to perform such an intersection test:

```
bool MeshGame::drawScene(Node* node, void* cookie)
{
    // Only draw visible nodes
    if (node->getBoundingSphere()->intersect(_camera->getFrustum())
    {
        Model* model = node->getModel();
        if (model)
            model->draw();
    }
    return true;
}
```

# Model and mesh

The `gameplay::Model` class is the basic component used to draw geometry in your scene. The model contains a few key elements: a `gameplay::Mesh`, an optional `gameplay::MeshSkin` and one or more `gameplay::Material`. These contribute to the information that is needed to perform the rendering of a model.

## Mesh geometry

The `gameplay::Mesh` class consists of a `gameplay::VertexFormat` attribute. This attribute describes the layout for the vertex data as well as the actual vertex data, which is used as input in the rendering of the geometry. In addition, it holds one or more `gameplay::MeshParts`. These parts define the primitive shapes and indices into the vertex data that describe how the vertices are connected.

Game artists use 3-D modeling tools that are capable of organizing and splitting the vertex data into parts/subsets based on the materials that are applied to them. The `gameplay::Mesh` class maintains one vertex buffer to hold all the vertices, and for each `gameplay::MeshPart`, an index buffer is used to draw the primitive shapes.

## MeshSkin and Joints

The `gameplay::Mesh` class supports an optional `gameplay::MeshSkin`. This is used when loading models that represent characters in the game that have a skeleton consisting of `gameplay::Joint` objects (bones). Vertex skinning is the term used to describe the process of applying a weighting or relationship with the Joints and their affected vertices. Using 3-D modeling tools, artists can add this additional weighting information onto the vertices in order to control how much a particular vertex should be impacted. This is based on the transformation of joints that can affect them. You will learn later how to apply special, skinned Materials that support this weighting. The gameplay 3-D framework supports a maximum of four blend weights per vertex. The `gameplay::MeshSkin` class holds and maintains a hierarchy of `gameplay:Joint` objects that can be transformed. A typical operation is to animate the transformation (usually only rotations) of the joints. The data within this class can be bound onto skinned Materials to ensure proper impact of weights onto their influenced vertices.

# Lights

The `gameplay::Light` class can be attached to any `gameplay::Node` in order to add lighting information into a `gameplay::Scene`. This lighting information must be bound to the `gameplay::Material` that is being applied onto the `gameplay::MeshParts`. There are three types of lights in the gameplay 3-D framework - directional, point, and spot lights.

All `gameplay::Light` components can be loaded into a `gameplay::Scene` using the `gameplay::Bundle` class. However, it is your responsibility to bind the relevant lighting information stored in the light into the `gameplay::Material` class.

You can also programmatically create a light using the factory methods on the `gameplay::Light` class. Here is an example of how to create and add a directional light to your scene and bind the lighting information onto a model's material(s):

```
void MyGame::initialize()
{
    ...

    // Create a node and light attaching the light to the node
    Node* lightNode = Node::create("directionalLight1");
    Light* light = Light::createDirectional(Vector3(1, 0, 0));
    lightNode->setLight(light);

    // Bind the relevant lighting information into the materials
    Material* material = _modelNode->getModel()->getMaterial();
    MaterialParameter* parameter = material->getParameter("u_lightDirection");
    parameter->bindValue(lightNode, &Node::getForwardVectorView);
}
```

## Pre-computed lighting maps

Adding lighting information into `gameplay::Material` adds computationally expensive graphics computations. In many games, there are usually multiple static lights and objects in the scene. In this relationship, the additive light colors contributing to the objects can be pre-computed during the design phase. 3-D modeling tools typically support the ability to compute the light's additive color contributions using a process called *baking*. This process allows the artist to direct the contributing light and color information into a separate or combined texture so that this is not required during the rendering.

You can optionally declare and pass in pre-generated light maps using the colored-unlit.frag/textured-unlit.frag shaders and specifying in your materials

```
defines = TEXTURE_LIGHTMAP
```

Then you just assign them using the sampler `m_lightmapTexture` in your material definition to the image that was pre-generated that contains the light+color for your object. It is recommended to use 8-bit alpha textures to reduce the size.

## Directional lights

In most games, you'll want to add a `gameplay::Light` class whose type is `Light::DIRECTIONAL`. This type of light is used as the primary light source, such as a sun or moon. The directional light represents a light source whose color is affected only by the constant direction vector. It is typical to bind this onto the `gameplay::Materials` of objects that are dynamic or moving.

## Point and spot lights

Due to the expensive processing overhead in using point and spot lights, many games are designed to restrict point and spot light use to be static, baked into light and color maps. However, the point and spot light types add exceptional realism to games. Using them in separate or combined rendering passes, you can bind point and spot lights into material to add dynamic point and spot light rendering. All the built-in gameplay .materials files support directional, point and spot lights. Also, with minor modification to the shaders, you can add additional passes to combine two or more lights. It should be noted that there is a significant performance impact in doing this. For these cases, you'll usually want to restrict the influence of lights on a material to no more than the one or two closest lights at a time. This can be achieved by using a simple test in the `Game::update()` method to find the closest light to a `gameplay::Model` and then bind them to the `gameplay::Material` once they are found.

# Materials and shaders

The gameplay 3-D framework uses a modern GPU shader based rendering architecture and uses OpenGL 2.0+ (desktop) or OpenGL ES 2.0 (mobile) along with the OpenGL Shading Language (GLSL). Currently, all the code in graphics-related classes uses the OpenGL hardware device directly.

## Using materials

The `gameplay::Material` class is the high level definition of all the rendering information needed to draw a `gameplay::MeshPart`. When you draw a `gameplay::Model`, the mesh's vertex buffer is applied and for each `gameplay::MeshPart` its index buffer(s) and `gameplay::Materials` are applied just before the primitives are drawn.

## RenderState and Effects

Each `gameplay::Material` consists of a `gameplay::RenderState` and a `gameplay::Effect`. The `gameplay::RenderState` stores the GPU render state blocks that are to be applied, as well as any `gameplay::MaterialParameters` to be applied to the `gameplay::Effect`. While a `gameplay::Material` is typically used once per `gameplay::MeshPart`, the `gameplay::Effect` is created internally based on the unique combination of selected vertex and fragment shader programs. The `gameplay::Effect` represents a common reusable shader program.

## Techniques

Since you can bind only one `gameplay::Material` per `gameplay::MeshPart`, an additional feature is supported that's designed to make it quick and easy to change the way you render the parts at runtime. You can define multiple techniques by giving them different names. Each one can have a completely different rendering technique, and you can even change the technique being applied at runtime by using `Material::setTechnique(const char* name)`. When a material is loaded, all the techniques are loaded ahead too. This is a practical way of handling different light combinations or having lower-quality rendering techniques, such as disabling bump mapping, when the object being rendered is far away from the camera.

## Creating materials

You can create a `gameplay::Material` from the simple `gameplay::Properties` based .material files. Using this simple file format, you can define your material, specifying all the rendering techniques and pass information.

Here is an example of loading a .material file:

```
Material* planeMaterial = planeNode->getModel()->setMaterial("res/floor.material");
```

## Setting vs. binding material parameters

Once you have created a `gameplay::Material` instance, you'll want to get its parameters and then set or bind various values to them. To set a value, get the `gameplay::MaterialParameter` and then call the appropriate `setValue()` method on it. Setting material parameter values is most common in parameters that are based on values that are constants.

Here is an example of setting a value on a parameter:

```
material->getParameter("u_diffuseColor")->setValue(Vector4(0.53544f,
                                                           0.53544f,
                                                           0.53544f, 1.0f));
```

For values that are not constants and are determined from other objects, you'll want to bind a value to it. When binding a value, you are giving the parameter a function pointer that will only be resolved just prior to rendering. In this example, we will bind the forward vector for a node (in view space).

Here is an example of binding a value on a parameter:

```
material->getParameter("u_lightDirection")->bindValue(lightNode,
                                                      &Node::getForwardVectorView);
```

# .material files

As you can see in the following .material file, we have one Material, one Technique and one Pass. The main parts of this material definition are the shaders, uniforms, samplers and renderState. You will see certain upper case values throughout the file. These represent constant enumeration values and can usually be found in the `gameplay::RenderState` or `gameplay::Texture` class definitions:

```
material duck
{
    technique
    {
        pass 0
        {
            // shaders
            vertexShader = res/shaders/textured.vert
            fragmentShader = res/shaders/textured.frag
           defines = SPECULAR

            // uniforms
            u_worldViewProjectionMatrix = WORLD_VIEW_PROJECTION_MATRIX
            u_inverseTransposeWorldViewMatrix = INVERSE_TRANSPOSE_WORLD_VIEW_MATRIX
            u_cameraPosition = CAMERA_WORLD_POSITION

            // samplers
            sampler u_diffuseTexture
            {
                path = res/duck-diffuse.png
                mipmap = true
                wrapS = CLAMP
                wrapT = CLAMP
                minFilter = NEAREST_MIPMAP_LINEAR
                magFilter = LINEAR
```

```
            }
            // render state
            renderState
            {
                cullFace = true
                depthTest = true
            }
        }
    }
}
```

# Built-in shaders

The **<gameplay-root>/gameplay/res/shaders** directory contains a set of the most common shaders used in your games. To reduce shader code duplication the gameplay framework also supports declaring including of shader files within vertex and shader program files.

If there is an error compiling the shaders the expanded shader without the definitions is output with an .err file extension in the same directory where the file was loaded from.

**Example:**

```
#include "lib/lighting.frag"
```

# Shader preprocessor definitions

Using preprocessor definitions, the built-in shaders support various features. Adding certain shader definitions (defines=XXX) will require use specific uniform/samplers 'u_xxxxxxx'. You must set these in your vertex stream in your mesh and/or material parameters.

# Property inheritance

When making materials with multiple techniques or passes, you can put any common things, such as renderState or shaders, above the material or technique definitions. The `gameplay::Property` file format for the .material files supports property inheritance. Therefore, if you put the renderState in the material sections, then all techniques and passes will inherit its definition.

# Particle emitters

The `gameplay::ParticleEmitter` class defines all the information needed to simulate and render a system of particles. The emitter can be defined in various ways to represent smoke, steam, fire and other atmospheric effects, such as rain and lightning. Once created, the emitter can be set on a `gameplay::Node` in order to follow an object, or it can be placed within a scene.

## Particles as sprites

A `gameplay::ParticleEmitter` always has a sprite/texture and a maximum number of particles that can be alive at any given time. After the emitter is created, these cannot be changed. Particles are rendered as camera-facing billboards using the emitter's sprite/texture. The emitter's sprite/texture properties determine whether the texture is treated as a single image, a texture atlas, or an animated sprite.

## Particle properties

A `gameplay::ParticleEmitter` also has a number of properties that determine values assigned to the individual particles it emits. Scalar properties, such as particle begin- and end-size, are assigned within a minimum and a maximum value; vector properties are assigned within the domain or space, and are defined by a base vector and a variance vector.

The variance vector is multiplied by a random scalar between 1 and -1, and the base vector is added to this result. This allows an emitter to be created, which emits particles with properties that are randomized, yet fit within a well-defined range. To make a property deterministic, simply set the minimum value to the same value as the maximum for that property, or set its variance to a zero vector. To learn more about different scalars, vector and rendering properties that can be set on a `gameplay::ParticleEmitter`, look at the C++ API.

## Creating particle emitters

Use the `ParticlEmitter::create()` method to create an emitter from a particle file. The .particle file format and semantics are very similar to the .material file format. This is because it also leverages the `gameplay::Properties` file definition and supports all the properties supported in the C++ API for the `gameplay::ParticleEmitter` class.

## Animated sprites for particles

It is very easy to make the particles animate through a list of images. Just make your images have a tile of sprite images and then modify the sprite's base properties in the emitter to control the animation behavior.

You can then even do things such as animate images of 3-D dice using only 2-D images.

# Physics

The gameplay framework supports 3-D physics using the game service/controller `gameplay::PhysicsController`. The `gameplay::PhysicsController` class maintains a physics world that has gravity, and will simulate the objects you add to it.

The gameplay physics system supports 3-D rigid body dynamics, including collision shapes, constraints, and a physics character class. To simulate objects within the physics world, you need to create a `gameplay::PhysicsCollisionObject` object representing the geometry, or `gameplay::Model`. By attaching a collision object to a `gameplay::Node`, the rigid body will be added to the physics world and the simulation will automatically update the node's transformation.

## PhysicsCollisionObject

`PhysicsCollisionObject` is the base class that provides an interface for receiving collision events.

You can add collision listeners to a `PhysicsCollisionObject` or test if the collision object currently collides with another collision object.

There are 3 types of collision objects:

- PhysicsRigidBody
- PhysicsGhostObject
- PhysicsCharacter

# PhysicsRigidBody

A rigid body is an idealized, infinitely hard, non-deformable solid object. Rigid bodies have mass, shape and other properties that affect forces within the simulation.

A `PhysicsRigidBody` can be set to be a kinematic rigid body. A kinematic rigid body is an object that is not simulated by the physics system, and instead has its transform driven manually.

### Create a PhysicsRigidBody

To create a rigid body, first you need to know what kind of shape you want to simulate. The physics system supports boxes, spheres, meshes, capsules, and terrain height fields. For basic shapes, such as boxes and spheres, you can programmatically create the rigid bodies by calling `Node::setCollisionObject()` and passing in the desired shape type.

```
PhysicsRigidBody::Parameters params;
params.mass = 10.0f;
node->setCollisionObject(PhysicsCollisionObject::RIGID_BODY,
                         PhysicsCollisionShape::box(), &params);
```

All other types of rigid bodies must be created using the `.scene` and `.physics` property definition files. The `.scene` file allows you to bind various attachments or properties to nodes, including a rigid body.

For example, to create a mesh rigid body for the node within the scene with ID equal to tree_1:

**game.scene:**

```
scene
{
    ...
    node tree_1
    {
        ...
        collisionObject = game.physics#tree_mesh
    }
    ...
}
```

**game.physics:**

```
collisionObject tree_mesh
{
    type = RIGID_BODY
    shape = MESH
    mass = 15.0
    ...
}
```

## RigidBody schema

All properties have default values if not defined. See `PhysicsRigidBody::Parameters` for more information.

```
collisionObject <string>
{
    type                = <RIGID_BODY | GHOST_OBJECT | CHARACTER>
    shape               = <BOX | SPHERE | MESH | HEIGHTFIELD | CAPSULE>
    image               = <string> // only for HEIGHTFIELD
    radius              = <float>
    height              = <float>
    extents             = <float, float, float>
    center              = <float, float, float>
    centerAbsolute      = <float, float, float>

    mass                = <float>
    friction            = <float>
    restitution         = <float>
    linearDamping       = <float>
    angularDamping      = <float>
    kinematic           = <bool>
    anisotropicFriction = <float, float, float>
    gravity             = <float, float, float>
}
```

| Shapes | Properties |
|---|---|
| BOX | extents, center, center-absolute |
| SPHERE | radius, center, center-absolute |
| MESH | |
| HEIGHTFIELD | image |
| CAPSULE | radius, height, center, center-absolute |

## PhysicsGhostObject

A ghost object is like a rigid body except that it does not have an effect the simulation. It will not cause forces or react to the other rigid bodies. Ghost objects have a shape but they do not have mass, or any of the properties that affect forces.

Ghost objects are useful for querying the simulation, or detecting collisions without having rigid bodies react to the ghost object. A ghost object could be used to detect if an object entered a volume, such as a soccer ball going into a goal. This use of a ghost object is often called a volumetric trigger. Ghost objects can also detect if they collide with other ghost objects.

Collision objects do not require a model so you could use a ghost object to check if a camera collides with a wall.

### Creating a PhysicsGhostObject

Programmatically:

```
// Create a ghost object with radius 5
node->setCollisionObject(PhysicsCollisionObject::GHOST_OBJECT,
                         PhysicsCollisionShape::sphere(5.0f));
```

In a .physics file:

```
collisionObject powerup
{
    type = GHOST_OBJECT
    shape = SPHERE
    radius = 5.0
}
```

### PhysicsGhostObject schema

Ghost objects only have a shape and support the same shapes as rigid bodies.

```
collisionObject <string>
{
    type                = GHOST_OBJECT
    shape               = <BOX | SPHERE | MESH | HEIGHTFIELD | CAPSULE>
    radius              = <float>
    height              = <float>
    extents             = <float, float, float>
    center              = <float, float, float>
    centerAbsolute      = <float, float, float>
    image               = <string>  // HEIGHTFIELD shapes only.
}
```

## PhysicsCharacter

The `PhysicsCharacter` class can be used to control the movements and collisions of a character in a game. It interacts with the physics system to apply gravity and handle collisions, however dynamics are not applied to the character directly by the physics system. Instead, the character's movement is controlled directly by the `PhysicsCharacter` class. This results in a more responsive and typical game character than would be possible if trying to move a character by applying physical simulation with forces.

### Creating a PhysicsCharacter

To programmatically create a `PhysicsCharacter` with mass 20 and capsule shape:

```
PhysicsRigidBody::Parameters params(20.0f);
node->setCollisionObject(PhysicsCollisionObject::CHARACTER,
                         PhysicsCollisionShape::capsule(1.2f, 5.0f,
                                                        Vector3(0, 2.5, 0), true),
                                                        &params);
PhysicsCharacter* character = static_cast<PhysicsCharacter*>(
                                                   node->getCollisionObject());
```

### PhysicsCharacter schema

Physics characters have a mass and shape. A capsule is a typical shape for a typical biped character.

```
collisionObject <string>
{
    type                = CHARACTER
    shape               = <BOX | SPHERE | MESH | CAPSULE>
    radius              = <float>
    height              = <float>
    extents             = <float, float, float>
    center              = <float, float, float>
    centerAbsolute      = <float, float, float>
    mass                = <float>
}
```

## Creating a PhysicsContraint

The gameplay framework supports various types of constraints between two rigid bodies (or one rigid body and the physics world), including hinge, fixed, generic (six-degree-of-freedom), socket, and spring. Constraints can be created programmatically using one of the create functions on `gameplay::PhysicsController`, or they can be specified within the `physics` section of the `.scene` file. For example, to create a hinge constraint from within a `.scene` file between the rigid body attached to the node with id door and the physics world:

**game.scene:**

```
scene
{
    ...
    physics
    {
        ...
        constraint
         {
            type = HINGE
            rigidBodyA = door
            rotationOffsetA = 0.0, 1.0, 0.0, 90.0
            translationOffsetA = 0.0, 0.0, 2.0
            limits = 0.0, 90.0, 0.5
       }
    }
}
```

**PhysicsConstraint schema**

```
constraint <string>
{
    type               = <FIXED | GENERIC | HINGE |  SOCKET | SPRING>
    rigidBodyA         = <string>
    rigidBodyB         = <string>
    translationOffsetA = <float, float, float>
    translationOffsetB = <float, float, float>
    rotationOffsetA    = <float>
    rotationOffsetB    = <float>
    angularLowerLimit  = <float, float, float>
    angularUpperLimit  = <float, float, float>
    linearLowerLimit   = <float, float, float>
    linearUpperLimit   = <float, float, float>
    limits             = <float, float, float>
    angularDampingX    = <float>
    angularDampingY    = <float>
    angularDampingZ    = <float>
    angularStrengthX   = <float>
    angularStrengthY   = <float>
    angularStrengthZ   = <float>
    linearDampingX     = <float>
    linearDampingY     = <float>
    linearDampingZ     = <float>
    linearStrengthX    = <float>
    linearStrengthY    = <float>
    linearStrengthZ    = <float>
    breakingImpulse    = <float>
}
```

| Constraint Types | Properties |
|---|---|
| FIXED | |
| GENERIC | translationOffsetA, translationOffsetB, rotationOffsetA, rotationOffsetB, angularLowerLimit, angularUpperLimit, linearLowerLimit, linearUpperLimit |
| HINGE | translationOffsetA, translationOffsetB, rotationOffsetA, rotationOffsetB, limits |
| SOCKET | translationOffsetA, translationOffsetB |
| SPRING | translationOffsetA, translationOffsetB, rotationOffsetA, rotationOffsetB, angularLowerLimit, angularUpperLimit, linearLowerLimit, linearUpperLimit, angularDampingX, angularDampingY, angularDampingZ, angularStrengthX, angularStrengthY, angularStrengthZ, linearDampingX, linearDampingY, linearDampingZ, linearStrengthX, linearStrengthY, linearStrengthZ |

# Handling collisions

The gameplay framework allows you to register to be notified whenever a collision occurs between two rigid bodies (and also when two rigid bodies stop colliding). In order to do this, you must define a class that derives from `gameplay::PhysicsRigidBody::Listener` and implements the function `collisionEvent(…)`. Then, you must add an instance of the class as a listener on a given rigid body using the `PhysicsRigidBody::addCollisionListener` function. For example, to print all information for all collisions with the door and for collisions between the character and the wall:

### MyGame.h:

```
class MyGame: public gameplay::PhysicsRigidBody::Listener
{
public:
    ...

    /**
     * Collision event handler.
     */
    void collisionEvent(PhysicsRigidBody::Listener::EventType type,
                        const PhysicsRigidBody::CollisionPair& pair,
    const Vector3& pointA, const Vector3& pointB);
    ...
};
```

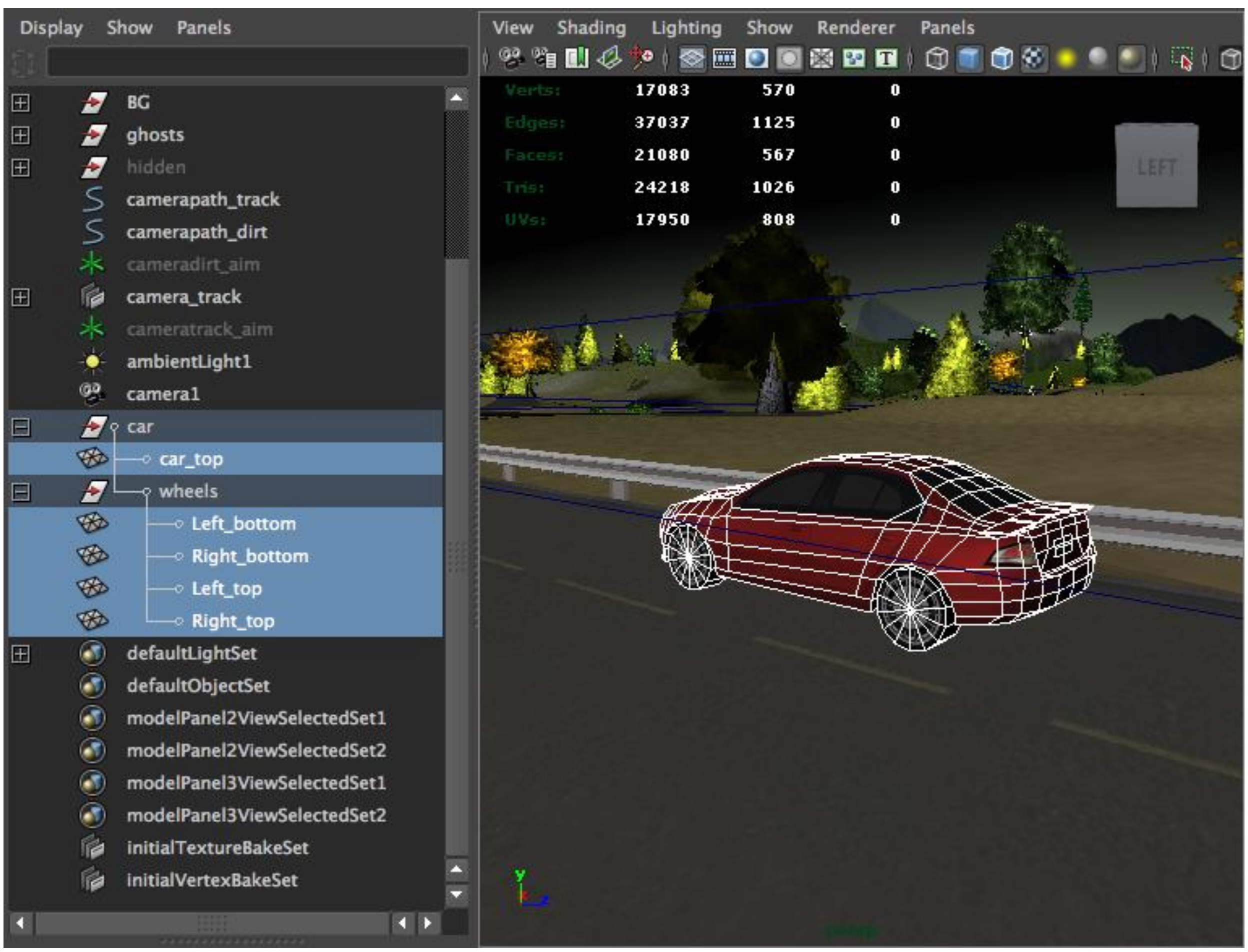
### MyGame.cpp:

```
MyGame* mygame;
Node* door;
Node* character;
Node* wall;

...

door->getRigidBody()->addCollisionListener(mygame);
character->getRigidBody()->addCollisionListener(mygame, wall);

...

void MyGame::collisionEvent(PhysicsRigidBody::Listener::EventType type,
                            const PhysicsRigidBody::CollisionPair& pair,
                            const Vector3& pointA, const Vector3& pointB)
{
    GP_WARN("Collision between rigid bodies %s (at point (%f, %f, %f)) "
            "and %s (at point (%f, %f, %f)).",
            pair._rbA-getNode()-getId(), pointA.x, pointA.y, pointA.z,
            pair._rbB-getNode()-getId(), pointB.x, pointB.y, pointB.z);
}
```

# PhysicsVehicle

The `PhysicsVehicle` and `PhysicsVehicleWheel` classes give you access to vehicle physics for racing games. You designate a `VEHICLE` type collision object for the node in your scene representing the vehicle body or chassis, and

VEHICLE_WHEEL for the nodes representing the wheels. When gameplay loads the scene, it attempts to automatically bind the wheels to the associated vehicle chassis. In the hierarchy of your scene be sure to locate the wheel nodes and the vehicle chassis under a common group node. This is how gameplay determines which vehicle body the wheels belong to – by searching for a common ancestor in the hierarchy. The nodes do not need to be direct descendents of the group node; they just need to appear somewhere below it in the hierarchy. The presence of other mesh nodes under the common node has no effect. All that matters is that the node of collision type VEHICLE shares a common ancestor with the nodes of collision type VEHICLE_WHEEL (details below):




Then in your .scene file, designate collision objects for the car and its wheels, like this:

```
scene main
{
    path = res/common/game.gpb

    activeCamera = camera1

    node carbody
    {
        url = car_top
        material = res/common/game.material#car
        collisionObject = res/common/game.physics#car
    }

    node wheelFrontLeft
    {
        url = Left_top
        material = res/common/game.material#car
        collisionObject = res/common/game.physics#carWheelFrontLeft
    }

    node wheelFrontRight
    {
        url = Right_top
        material = res/common/game.material#car
        collisionObject = res/common/game.physics#carWheelFrontRight
    }

    node wheelBackLeft
    {
        url = Left_bottom
        material = res/common/game.material#car
        collisionObject = res/common/game.physics#carWheelBackLeft
    }

    node wheelBackRight
    {
        url = Right_bottom
        material = res/common/game.material#car
        collisionObject = res/common/game.physics#carWheelBackRight
    }

...

    physics
    {
        gravity = 0.0, -9.8, 0.0
    }
}
```

In the .physics file be sure to specify type `VEHICLE` for the chassis and type

`VEHICLE_WHEEL` for the wheels:

```
collisionObject car
{
    type = VEHICLE

    shape = BOX
    mass = 800.0
    friction = 0.5
    restitution = 0.01
    linearDamping = 0.025
    angularDamping = 0.6

    steeringGain = 0.4
    brakingForce = 350.0
    drivingForce = 2000.0

    steerdownSpeed = 87
    steerdownGain = 0.22
    brakedownStart = 100
    brakedownFull = 170
    drivedownStart = 105
    drivedownFull = 180
    boostSpeed = 74
    boostGain = 2.6
    downforce = 4.5
}

collisionObject carWheel
{
    type = VEHICLE_WHEEL

    shape = MESH
    mass = 1.0
    friction = 0.5
    restitution = 0.01
    linearDamping = 0.025
    angularDamping = 0.16

    wheelDirection = 0, -1, 0
    wheelAxle = -1, 0, 0

    strutRestLength = 0.6
    strutStiffness = 25.0
    strutDampingCompression = 5.1
    strutDampingRelaxation = 2.3
    frictionBreakout = 1000.0
    wheelRadius = 0.5
    rollInfluence = 0.1
    strutConnectionOffset = 0.0, 0.0, 1.4
}

collisionObject carWheelFrontLeft : carWheel
{
```

```
    steerable = true
}

collisionObject carWheelFrontRight : carWheel
{
    steerable = true
}

collisionObject carWheelBackLeft : carWheel
{
    steerable = false
}

collisionObject carWheelBackRight : carWheel
{
    steerable = false
}
```

Practically speaking the only collision shape that makes sense right now for the vehicle chassis is `BOX` because currently there is a known issue with `MESH` collision shapes.

In the `initialize()` method of your Game class, you can set a member variable for accessing the vehicle via `PhysicsVehicle`:

```
    Node* carNode = _scene->findNode("carbody");
    if (carNode && carNode->getCollisionObject()->getType() ==
PhysicsCollisionObject::VEHICLE)
    {
        _carVehicle = static_cast<PhysicsVehicle*>(carNode->getCollisionObject());
    }
```

Then, in the `update()` method of your Game class you need to call `PhysicsVehcicle::update()` with the various control inputs described below:

```
     _carVehicle->update(elapsedTime, steering, braking, driving);
```

The `steering` parameter controls vehicle steering and has an expected range of -1 to +1. The `braking` parameter applies wheel brakes and has an expected range of 0 to 1. The `driving` parameter lumps together engine output and overall drivetrain, with an expected range of 0 to 1. Optional properties in the .physics definition for your vehicle give you greater control of the handling characteristics, and are described below in turn.

### Overall Vehicle Controls

The following properties specify the vehicle's overall response to control inputs:

```
// Vehicle steering, braking, and powertrain
steeringGain   = <float>    // steering at full deflection
brakingForce   = <float>    // braking force at full braking
drivingForce   = <float>    // driving force at full throttle
```

This is an over-simplification of vehicle handling, and therefore gameplay provides further refinement as follows.

### Steering Reduction at High Speed

Turning the steering wheel of a real car by 1 degree has a much different effect at 100 km/h than it does at 10 km/h. (Please do not attempt this). In a real vehicle, the "feel" of a steering wheel tends to stiffen as speed increases. In a racing game, we can approximate this effect by reducing the amount of authority at higher speeds. gameplay provides the following properties to control this effect:

```
// Steering gain reduction with speed (optional)
steerdownSpeed = <float>    // steering gain fades to this point
steerdownGain  = <float>    // gain value at that point (less than 1)
```

The gain at zero speed is always 1. The properties `steerdownSpeed` and `steerdownGain` specify a point of reduced gain, above which the gain remains constant. A `steerdownGain` of 1 effectively disables this feature.

### Brake Reduction at High Speed

Due to imperfections in the simulated physics, full braking at high speeds can cause unexpected behavior. gameplay provides the following properties to reduce braking above a certain threshold speed:

```
// Brake force reduction at high speeds (optional)
brakedownStart = <float>    // braking fades above this speed
brakedownFull  = <float>    // braking is fully faded at this speed
```

Braking remains unaffected up to the speed specified by `brakedownStart`. Above that speed, braking fades and reaches zero at the speed specified by `brakedownFull`. An unreachably-large speed value for `brakedownStart` will effectively disable this feature.

### Vehicle Acceleration, All-out Speed, and Aerodynamic Downforce

Driving force is currently simplified down to a single value that lumps together the engine and drivetrain. In the absence of a proper gearbox simulation gameplay provides the following properties for affecting all-out speed and bottom-end acceleration:

```
// Driving force reduction at high speeds (optional)
drivedownStart = <float>   // driving force fades above this speed
drivedownFull  = <float>   // driving force is fully faded at this speed

// Driving force boost at low speeds (optional)
boostSpeed     = <float>    // Boost fades to 1 at this point
boostGain      = <float>    // Boost at zero speed (greater than 1)
```

The first 2 properties allow you to reduce driving force at high speeds which limits the top speed of the vehicle. Above the speed specified by `drivedownStart` driving force begins to fade, and eventually reaches zero at the speed specified by `drivedownFull`, more or less. An unreachably-large value for `drivedownStart` will effectively disable this feature.

The last 2 properties allow you to increase acceleration at low speeds. `boostGain` specifies the gain at zero speed, so a value greater than 1 will increase vehicle acceleration from a standing start. This supplemental gain then fades to 1 at the speed specified by `boostSpeed`. A `boostGain` of 1 effectively disables this feature.

Racing cars typically make use of airfoils to produce a downward force at high speeds. This improves handling and performance. gameplay provides the following property to simulate this effect:

```
// Aerodynamic downforce effect (optional)
downforce      = <float>    // proportional control of downforce
```

The value of downforce controls the amount of downward force at a given speed. In particular, the value of this property represents the product of a reference area and an aerodynamic coefficient. However what's important is that this property acts as a constant of proportionality in computing the downward force as a function of speed. A value of 0 effectively disables this feature.

### PhysicsVehicleWheel

Tire and suspension characteristics can be specified at each individual wheel as follows:

```
collisionObject <wheelID>
{
    type                     = VEHICLE_WHEEL

    steerable                = <bool>      // indicates whether wheel is steerable
    wheelDirection           = <float, float, float> // direction of strut extension,
in chassis space
    wheelAxle                = <float, float, float> // direction of axle (spin
axis), in chassis space
    strutConnectionOffset    = <float, float, float> // offset from default strut
connection point
    strutRestLength          = <float>     // strut rest length
    strutTravelMax           = <float>     // maximum strut travel
    strutStiffness           = <float>     // strut stiffness, normalized to chassis
mass
    strutDampingCompression  = <float>     // strut damping under compression,
normalized to chassis mass
```

```
    strutDampingRelaxation   = <float>     // strut damping under relaxation,
normalized to chassis mass
    strutForceMax            = <float>     // maximum strut force
    frictionBreakout         = <float>     // breakout friction
    wheelRadius              = <float>     // wheel radius
    rollInfluence            = <float>     // how side friction affects chassis roll,
normalized
}
```

gameplay automatically determines a default location on the chassis for the strut connection point based on the position of the wheel nodes relative to the car body. The `strutConnectionOffset` property allows you to specify an offset from the default. This is useful, for example, if the origin of the car body is not located at the center of the mesh:

```
    strutConnectionOffset = 0.0, 0.0, 1.4
```

# Animation

Animation is a key component to bringing your game to life. Within gameplay, there is support to create both property animations and character animations. The `gameplay::Animation` class provides factory methods for creating animations on properties of classes that extend `gameplay::AnimationTarget`. Character animations from within the scene file are imported and stored on the `gameplay::AnimationTarget` they target. All animations on a `gameplay::AnimationTarget` can be obtained by ID.

## AnimationTargets

`gameplay::Transform`, `gameplay::Node`, and `gameplay::MaterialParameter` are animation targets.

Animations can be created on the scale, rotation and translation properties of the `gameplay::Transform`. Animations can also target any `gameplay::Node`, which extends `gameplay::Transform`.

Also, animations can target instances of `gameplay::MaterialParameter`. Any parameters on a material of type `float`, `integer`, or 2-, 3-, and 4-dimensional vectors can be animated.

## Creating property animations

Animations are created from the `gameplay::AnimationTarget`. `AnimationTarget` provides methods to create simple two key frame animations using `createAnimationFromTo()`, and `createAnimationFromBy()`. Multiple key frame sequences can be created from `createAnimation()`.

Here is an example of how to create a multiple key frame animation on a node's translation properties:

```
unsigned int keyCount = 3;
unsigned long keyTimes[] = {0L, 500L, 1000L};
float keyValues[] =
{
    0.0f, -4.0f, 0.0f,
    0.0f, 0.0f, 0.0f,
    0.0f, 4.0f, 0.0f
};
Animation* sampleAnim = enemyNode->createAnimation("sample",
                                                    Transform::ANIMATE_TRANSLATE,
                                                    keyCount, keyTimes, keyValues,
                                                    Curve::LINEAR);
```

Here is the same animation specified in a `.animation` file that can also be loaded by the `gameplay::AnimationTarget`:

```
animation sample
{
    property = ANIMATE_TRANSLATE
    keyCount = 3
    keyTimes = 0, 500, 1000
    keyValues = 0.0 -4.0 0.0 0.0 0.0 0.0 0.0 4.0 0.0
    curve = LINEAR
}
```

To create the animation from this file you would call the following code:

```
Animation* sampleAnim = enemyNode->createAnimation("sample", "sample.animation");
```

# Curves

There are many different interpolation types defined within the `gameplay::Curve` class that can be used to interpolate through the animation data.

# Character animations

Character animations are complex because they can be composed of multiple animations targeting numerous joints within a character model. For this reason, character animations are usually included within the scene file and are imported when the .gpb file is loaded. To simplify and optimize all animations under single animation. The gameplay-encoder supports grouping all the animation on joints leading up to a common root joint under a single animation. This is an option in the gameplay-encoder using the –groupAnimations or –g option. This groups them under a single animation called 'animations'.

These animations can be obtained by calling AnimationTarget::getAnimation() specifying the animation's ID.

## AnimationClips

A gameplay::AnimationClip is created from the gameplay::Animation class and is a snapshot of the animation that can be played back, manipulated with speed and repeated.

Here is an AnimationClip that has been created from a character animation of an elf:

```
AnimationClip* elfRun = elfAnimation->createClip("elf_run", 200L, 310L);
elfRun->setRepeatCount(AnimationClip::REPEAT_INDEFINITE);
elfRun->setSpeed(2.0f);
```

Animation clips can be specified within an .animation file that can be given to an animation to create clips. The total number of frames that make up the animation must be specified in the file. The begin and end parameters of each clip are specified in frames. An assumption that the animation runs at 60 frames per second has been made. Here is an example of an .animation file for an elf animation:

```
animation elf
{
    frameCount = 350
    clip idle
```

```
    {
        begin =  0
        end = 75
        repeatCount = INDEFINITE
    }


    clip walk
    {
        begin = 75
        end = 200
        repeatCount = INDEFINITE
    }
    clip run
    {
        begin = 200
        end = 310
         repeatCount = INDEFINITE
        speed = 2.0
    }
    clip jump
    {
        begin = 310
        end = 350
        repeatCount = 1
    }
}
```

Animations can be played back by calling `Animation::play()`, passing a clip ID, or by calling `AnimationClip::play()` directly on the clip. Animations can also be paused and stopped in the same fashion.

# Animation blending

The `gameplay::AnimationClip` class has a blend weight property that can be used to blend multiple animations. There is also a method called `AnimationClip::crossFade()` that conveniently provides the ability to fade the currently playing clip out and fade in the specified clip over a given period of time.

# AnimationClip listeners

Animation events can be triggered on a `gameplay::AnimationClip` by registering instances of `gameplay::AnimationClip::Listener` with the clip. The listeners can be registered to be called back at the beginning or end of the clip, or at any specific time throughout the playback of the clip. This can be useful for starting a particle emitter when a character's foot hits the ground in an animation, or to play back a sound of a gun firing during an animation of an enemy shooting.

# Audio

You can integrate 3-D audio into your game using the audio services supported by gameplay. The framework uses a very traditional way of representing audio. The `gameplay::AudioController` manages all of the playing audio sources.

## Creating an AudioSource

An `AudioSource` can be created from audio files or from a .audio property file. Ogg audio files are compressed, so they use less memory than .wav files.

```
AudioSource* wheelsSound = AudioSource::create("res/longboard.wav");
AudioSource* backgroundMusic = AudioSource::create("res/music.ogg");
```

## Playing the AudioSource

The following example illustrates how to play audio:

```
wheelsSound->play();
```

## Updating the AudioListener

By default, the `AudioListener` is bound to the active camera of the scene. You can manually bind the camera to the `gameplay::AudioListener` using `gameplay::AudioListener::setCamera()`.

## Audio Properties

The `gameplay::AudioSource` class has methods for modifying the properties of the `AudioSource`, such as pitch, gain, and velocity.

Audio sources can be loaded from `.audio` property files to make it easier to set these properties.

```
audio fireball
{
    path = res/audio/fireball.wav
    looped = false
    gain = 0.7
    pitch = 0.5
    velocity = 0.5 0.0 1.0
}
```

## Binding an AudioSource to a node

An `AudioSource` can be bound to a `Node` in your scene using `Node::setAudioSource()`. The position of the audio source is automatically updated when the node is transformed.

# User Interface

The gameplay framework provides a set of user interface (UI) controls that can be used to create menus and HUDs. To add UI elements to your game, you'll create a form from a properties file and call update() and draw() on it. Other than adding listeners to buttons and modifying controls programmatically, there's not much code to write in your game. Most of the work of defining a form's look and feel happens in the .form and .theme files, as well as the texture atlas used by the theme.

## Creating a form

To create a form, pass a properties file to `Form::create()` to instantiate a form. The top-most namespace in the file must be named 'form'. The following properties are available for forms:

```
form <formID>
{
    // Form properties.
    theme                      = <Path to .theme file>
    layout                     = <Layout::Type constant>
    style                      = <styleID>
    position                   = <x, y>
    alignment                  = <Control::Alignment constant>
    size                       = <width, height>
    autoWidth                  = <bool>
    autoHeight                 = <bool>
    width                      = <width>
    height                     = <height>

    // All the Controls within this Form.
    container { }
    label { }
    textBox { }
    button { }
    checkBox { }
    radioButton { }
    slider { }
}
```

**Form property information:**

The following is a list of form properties, and their purpose:

**theme**: See "Creating a theme" below.

**layout**: Member of Layout::Type enum.

**style**: A style from the theme.

**position**: The on-screen position, in pixels.

**alignment**: Align the form's position within the bounds of the screen. Note the position property will be ignored if the `alignment` property has been set.

**size**: The size of the form, in pixels.

**autoWidth**: Use of this property will result in a form with a width spanning the entire display. Note the width property will be ignored if `autoWidth` has been set.

**autoHeight**: Use of this property will result in a form with a height spanning the entire display. The height property will be ignored if `autoHeight` has been set.

**width**: Can be used in place of `size`.

**height**: Can be used in place of `size`.

A style determines the look of a control and is defined in the theme file, detailed below. Position and size attributes are determined for controls using the same properties as listed above for forms. Controls can be aligned within their parent container by using the `alignment` property. Setting `autoWidth` or `autoHeight` to true will result in a control the width or height of its parent container. You can add controls to the form by placing namespaces within it. The available controls are:

- Container: A container has all the same available properties as a form, except for 'theme'. You can add more controls within a container to group them together, and/or to apply a different layout type to a group of controls.
- Label: A simple text label. Available properties: 'style', 'position', ‘alignment’, 'size', ‘autoWidth’, ‘autoHeight’, and 'text'.
- TextBox: Editable text label. A TextBox control has the same available properties as label.
- Button: A button. A button control has the same available properties as label.

- CheckBox: A button that toggles between 'checked' and 'unchecked' states when tapped or clicked. A CheckBox has the same available properties as label, plus 'checked' for its starting state.
- RadioButton: RadioButton has the same available properties as CheckBox, with an additional property, 'group'. Only one radio button in a given group can be selected at a time.
- Slider: A marker that can slide along a track between its end-caps. A slider makes use of the following properties:

```
slider <controlID>
{
    style = <styleID>      // A style from the theme.
    position = <x, y>      // Position of the control on-screen, in pixels.
    size = <width, height> // The size of the control, in pixels.
    min = <float>          // The value of the left- / bottom-most point on the slider.
    max = <float>          // The value of the right- / top-most point on the slider.
    value = <float>        // The default position of the marker.
    step = <float>         // If greater than 0, force the marker to snap to discrete
                           // multiples of ‘step’.
    text = <string>        // Text to display above, below or alongside the slider
                           // (depending on the style).
}
```

## Creating a theme

A theme contains the information a form needs to determine the look of its controls. A theme has one property, 'texture', which points to a texture atlas containing the images used by the theme. Cursor images, skins, and lists of images used by controls are defined in their own namespaces. The rest of the theme consists of style namespaces. A style describes the border, margin, and padding of a control, what images, skins, and cursors are associated with a control, and font properties to apply to a control's text.

```
theme <themeID>
{
    texture = <Path to texture>

    cursor <cursorID>
    {
        region = <x, y, width, height>
        color = <#ffffffff>
    }

    imageList <imageID>
    {
        image checked
        {
            region = <x, y, width, height>
        }

        image unchecked
        {
            region = <x, y, width, height>
            color = <#fffffffff>
        }

        color = <#fffffffff>
    }

    skin <skinID>
    {
        border
        {
            top = <int>
            bottom = <int>
            left = <int>
            right = <int>
        }

        region = <x, y, width, height>
```

```
        color = <#ffffffff>
    }

    style <styleID>
    {
        margin
        {
            top = <int>
            bottom = <int>
            left = <int>
            right = <int>
        }

        padding
        {
            top = <int>
            bottom = <int>
            left = <int>
            right = <int>
        }

        stateNormal
        {
            skin = <skinID>
            imageList = <imageID>
            cursor = <cursorID>
            font = <Path to font>
            fontSize = <int>
            textColor = <#ffffffff>
            textAlignment = <Control::Alignmentconstant>
            rightToLeft = <bool>
            opacity = <float>
        }
        stateFocus
        {
            skin = <skinID>
            ...
        }
        stateActive
        {
            skin = <skinID>
            ...
        }
        stateDisabled
        {
            skin = <skinID>
            ...
        }
    }
}
```

**Theme property information:**

The following is a list of theme properties, and their sub-properties if applicable.

**texture**: The path to the texture atlas used by this theme.

**cursor**: Describes a single image, to be used as a cursor.

Sub-properties of cursor:

- region: Region within the texture, in pixels.
- color: Blend color to apply to this cursor.
- imageList: A collection of images used by controls.
  - image: A single image within the list.
    - region: Region within the texture, in pixels.
    - color: Optionally override image-list blend color.
  - color: Default blend color for images that don't specify their own.

**skin**: Defines the border and background of a control.

Sub-properties of skin:

- border : The corners and edges of the given region will be used as border sprites.
  - top : Height of top border, top corners.
  - bottom: Height of bottom border, bottom corners.
  - left: Width of left border, left corners.
  - right: Width of right border, right corners.
- region: Total container region including the entire border. A region within the texture, in pixels.
- color: The blend color to apply to this skin.

**style**: A combination of theme attributes that can be applied to any control.

Sub-properties of style:

- margin: Layouts may make use of a style's margin to put space between adjacent controls.
  - top: Empty space above a control.
  - bottom: Empty space below a control.
  - left: Empty space left of a control.
  - right: Empty space right of a control.
- padding: The space between a control's border and its content.
  - top: Empty space between the top border and content.
  - bottom: Empty space between the top border and content.
  - left: Empty space between the left border and content.
  - right: Empty space between the right border and content.
- stateNormal: Properties used when a control is in the normal state.
  - skin: Skin to use for border and background sprites.
  - imageList: Images to use for this state.
  - cursor: Cursor to use when the mouse is over this control.
  - font: Font to use for rendering text.
  - fontSize: Size of text.
  - textColor: Color of text.
  - textAlignment: Align text within the control's content area.
  - rightToLeft: Whether to draw text from right to left.
  - opacity: Opacity to apply to all text/border/icon colors.
- stateFocus: Properties used when a control is in focus.
  - Same properties as stateNormal. Unspecified properties will inherit from stateNormal.

- stateActive: Properties used when a control is active. This is when a touch/mouse is down within the control. If not specified, the normal overlay will be used.
  - Same properties as stateNormal. Unspecified properties will inherit from stateNormal.
- stateDisabled: Properties used when a control is disabled. If not specified, the normal overlay will be used.
  - Same properties as stateNormal. Unspecified properties will inherit from stateNormal.

The top-level property of a theme is the path to its texture atlas. This is a single image containing all the sprites used by the theme. The skin, cursor, and imageList namespaces within a theme file refer to regions of this image to use to represent their various states.

**Skin:** A rectangular area representing a border and background. A container namespace will specify the rectangular region and blend color as well as the border sizes. From this, the region will be divided into nine areas: four corners, four borders, and the center background area. Note that the top and bottom borders will be stretched horizontally; the left and right borders will stretch vertically; and the center of the container will stretch in both directions. The corners will never be stretched. It's perfectly valid to set any border size to 0.

**Cursor**: A single rectangular area representing a mouse cursor.

**ImageList**: A collection of images used by controls. Images for multiple control types can be combined into one list. Controls use the following images:

- CheckBox: 'checked', 'unchecked'
- RadioButton: 'selected, 'unselected'
- Slider: 'minCap', 'maxCap', 'track', 'marker'
- TextBox: 'textCaret'

Note that you may specify separate image lists for each state in a style.

## Adding a form to your game

Once you have a form, theme, and texture atlas, only a small amount of code is required in order to actually display your UI within your game. There are two options for displaying forms: two-dimensionally, where the form is drawn directly to the display and three-dimensionally, where the form is assigned to a node within the game's scene and displayed on a quad.

The 2-D case is simple. To initialize a form, pass the path to your .form file to `Form::create()` to be returned a pointer to your form. Now, simply call `Form::update()` on the form during your game's `update()` method, and call `Form::draw()` on the form during `render()` . See the section below on event handling to learn how to react to player input from within a form.

The 3-D method of drawing forms is somewhat more advanced. For starters, you'll need a scene with at least one node in it. Call `Node::setForm()` to attach the form to the node. This call will also generate a rectangular model with the dimensions of the form. Scale, rotate, and translate the node as necessary. Now, calling `Form::draw()` on the form will render the contents of the form into a framebuffer and use that framebuffer to texture the form's model.

## Event handling within forms

Controls will trigger events when the user interacts with them. You can handle these events by setting listeners on individual controls.

All controls can trigger the mouse / touch events `PRESS` , `RELEASE` , and `CLICK` . Sliders, check boxes, and radio buttons can also trigger a `VALUE_CHANGED` event so that you can update your game as a slider is moving or when a radio button becomes unselected. Finally, text boxes trigger a `TEXT_CHANGED` event any time a character is entered or deleted (but not when the cursor is moved within the text box). Use `TEXT_CHANGED` along with the `getLastKeyPress()` method on a `TextBox` to do things like accepting a player name when the return key is pressed.

To retrieve a control from your form, call `Form::getControl()` with the ID of the control you're looking for. Cast this to the correct control pointer type and then call `addListener()` on it. This method takes an object that implements `Control::Listener` as well as an int representing the events to listen for. You can bitwise-OR together event types. For example, the following code listens for `PRESS` and `RELEASE` events on a button:

```
Button* myButton = static_cast<Button*>(myForm->getControl("myButton");
myButton->addListener(this, Control::Listener::PRESS | Control::Listener::RELEASE);
```

In this example, the game itself implements `Control::Listener`. This is easy to do as there's only one method a listener needs to implement, which should look something like this:

```
void MyGame::controlEvent(Control* control, EventType evt)
{
    switch(evt)
    {
    case Control::Listener::PRESS:
        if (strcmp("myButton", control->getID()) == 0)
        {
            // Do something.
        }
        break;
    case Control::Listener::RELEASE:
        if (strcmp("myButton", control->getID()) == 0)
        {
            // Do something else.
        }
        break;
    }
}
```

Note that `getControl()` is also a method on Container. If multiple controls share the same ID but are children of separate containers, the parent container can be retrieved first and then `Container::getControl()` called to retrieve the specific control needed.

# Scripting

The gameplay framework has a full set of Lua script bindings allowing users to write the majority of their game completely from scripts. Also included is an open-source tool that can be used to generate bindings for user-defined classes (including classes that depend on features and technology of the gameplay framework itself).

## Writing Lua scripts

To write Lua scripts, you can use any text editor or IDE. If Visual Studio is your editor of choice, it is recommended that you install the Lua Language Support extension, which adds syntax highlighting to the editor (available here: http://vslua.codeplex.com/).

To generate your own bindings, you will need to download and install Doxygen (available here: http://www.doxygen.org).

## Lua Basics

For an introductory look at scripting with Lua, including basic language features, visit http://www.lua.org/pil/. Note that the documentation available at this link is aimed at Lua 5.0 and will contain some outdated APIs. However, the basic usage of the language remains the same.

There are two conventions that gameplay uses within its Lua script bindings. First, in order to create a new object, the user calls the **new** function on the class and passes the correct arguments for the corresponding C++ constructor. e.g.

```
-- Create a new Vector2 object.
local v = Vector2.new(1.0, 3.7)
```

Second, to access or set a public member variable of a class, the user simply calls a Lua function with the same name, passing no arguments to access the variable or passing one argument in order to set the variable. e.g.

```
-- Print out the x member variable.
print(v:x())

-- Set the y member variable to 4.2.
V:y(4.2)
```

## Game – Script Event Callbacks

In order to write a game primarily using Lua scripts, one must register for the main game events (initialize, update, render, and finalize), along with the desired input event handlers. To do this, you must edit the 'scripts' section of the game's game.config file. If the user has a Lua script with functions for the four major events and functions that handle the key and touch input, the 'scripts' section would look something like this:

```
scripts
{
    initialize = res/script.lua#initialize
    update = res/script.lua#update
    render = res/script.lua#render
    finalize = res/script.lua#finalize
    keyEvent = res/script.lua#keyEvent
    touchEvent = res/script.lua#touchEvent
}
```

Then on the C++ side, as usual, you must derive a class from Game and create a static instance on the stack. However, in the case of a script-based game, the .h file can simply contain the class definition with all empty implementations while the .cpp file would contain the static instance. For example,

MyScriptGame.h

```
class MyScriptGame: public Game
{
protected:
```

```
    void initialize() {};
    void finalize() {};
    void update(float elapsedTime) {};
    void render(float elapsedTime) {};

};
```

MyScriptGame.cpp

```
#include "MyScriptGame.h"

// Declare our game instance
MyScriptGame game;
```

The sample does not require any other C++ implementation. For a complete sample game using the techniques described above, see sample05-lua as one-to-one mapping of sample00-mesh with a box instead of a duck. It also has some additional scripting code showcasing AIAgent and AIStates.

# Extending ScriptTarget

To add scriptable events to your own class, you simply derive from the class `gameplay::ScriptTarget` and add the required function calls. First, to define the scriptable events that are supported for the class, we call addScriptEvent with the name of the event and, optionally (depending on if the callback takes arguments or not), the parameter string for a valid script callback function for that event (the parameter string follows the format of the parameter string argument to `ScriptController::executeFunction`). For example, to add a 'notify' event that passes an integer to the callback, we would do the following:

```
addScriptEvent("notify", "i");
```

The supported format identifiers for passed parameters are as follows:

| Format | Parameter Type (result) |
|---|---|

| | |
|---|---|
| c, h, i, l | Signed Integer (int) |
| u | Unsigned Integer (unsigned int) |
| b | Boolean (bool) |
| f, d | Floating Point (double) |
| s | String (char*) |
| p | Pointer (void*) |
| [x] | Enum Value [x] |
| <x> | Object References/Pointers <x> |

This step is usually done either in the constructor of the class or in a class initialization function. Next, the class will want to fire the event so that the script callback functions are actually called. This code is placed wherever it makes sense (depending on what the actual event is) and looks like so:

```
fireScriptEvent<void>("notify", 14);
```

The template argument corresponds to the return type of the callback function, the first parameter is the name of the event to fire, and the remaining arguments are the parameters to the actual callback function: in this case, the integer that is passed to the notify callback. To see a full example of a class that derives from `gameplay::ScriptTarget` within gameplay, take a look at the `gameplay::Control` class.

# Tips using Lua with gameplay

- To get printf-like functionality using gameplay and Lua, use the Lua print() function (note: gameplay overrides the default Lua print() function).
- To do integer like comparisons or casts on a number variable x in Lua, use math.floor(x).
- Make sure all your member function calls use ':' instead of '.'
- Remember to access all gameplay variables, including static and global variables

with '()' on the end of the name.

- Primitive data type arrays and object arrays are both inefficient when created in Lua and passed to C++, so try to minimize this.
- There is no reasonable way to unload a Lua script; thus, the recommended usage pattern is to put each script's variables and functions inside a table (see Lua technical note 7 at [http://www.lua.org/notes/ltn007.html](http://www.lua.org/notes/ltn007.html)). i.e.

```lua
-- If you want to load the module at most once, add a line like this.
if Module then return end
-- Declare the module Module.
Module = {}

-- Declare a variable within the module.
Module.a = 47

-- Declare a function within the module.
function Module.myFunc()
    return Module.a + 17
end

-- Cleanup function; call when done with this module.
function cleanupModule()
    Module = nil
end
```

- Note: you can't pass an enumeration value to a function that doesn't explicitly take an enumeration type (i.e. Control::setTextColor, which takes an unsigned char). In these cases, you need to look up the enumeration values and pass them directly.
- On any function that returns a pointer that is owned by the user calling that function (i.e. a create() function), add @script{create} as the last line of its Doxygen comments.
- On any function, variable, class, struct, enum, etc. that should not be accessible from Lua (except for things that are static to a .cpp file, which are already ignored), add @script{ignore} to its Doxygen comments.
- On any functions, variables, classes, structs, enums, etc. that are local to a .cpp file, declare them as static 1) because it is good practice and 2) so that Lua does not generate bindings for them.

## Generating user defined script bindings

The following instructions detail how to generate Lua script bindings for your own project. Note: this requires doxygen to be installed.

1. Copy the gameplay-luagen.doxyfile file to your project's root directory (and rename it). Then, either manually using a text editor or using the Doxywizard tool, go to the INPUT section and ensure both that the path to gameplay's 'src' folder is valid (relative to where the doxyfile is) and that your own source folder is added.
2. Run doxygen using the above doxyfile from your project's root directory. For example, run `doxygen my-project.doxyfile` from the command line or run Doxygen using the Doxywizard application.
3. Create a 'lua' folder inside your source folder.
4. Run gameplay-luagen using the following command (make sure you have a trailing '/' for the output directory (second) parameter):

   ```
   path-to-gameplay/bin/your-platform/gameplay-luagen.exe ./xml
   path-to-your-source/lua/ <your-project-name-here>
   ```

   Note: the parameter <your-project-name-here> is used as the namespace that the bindings are generated within. This can be anything you want **except** for "gameplay".
5. Ensure that your project has "path-to-gameplay/gameplay/src/lua" in its include path.
6. Add the generated Lua script bindings (.h/.cpp) files from path-to-your-source/lua to your project.
7. Compile and run - now you can use your own classes from Lua scripts.

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