Client Programming Guide

BigWorld Technology 2.0. Released 2010.

Software designed and built in Australia by BigWorld.

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Chapter 1. Overview

This document is a technical design overview for the Client Engine for 3d engine Technology. It is part of a larger set of documentation describing the whole system. It only includes references to the BigWorld Server in order to provide context. Readers interested only in the workings of the BigWorld Client may ignore the server information.

The intended audience is technical-typically MMOG developers and designers.

For API-level information, please refer to the online documentation.

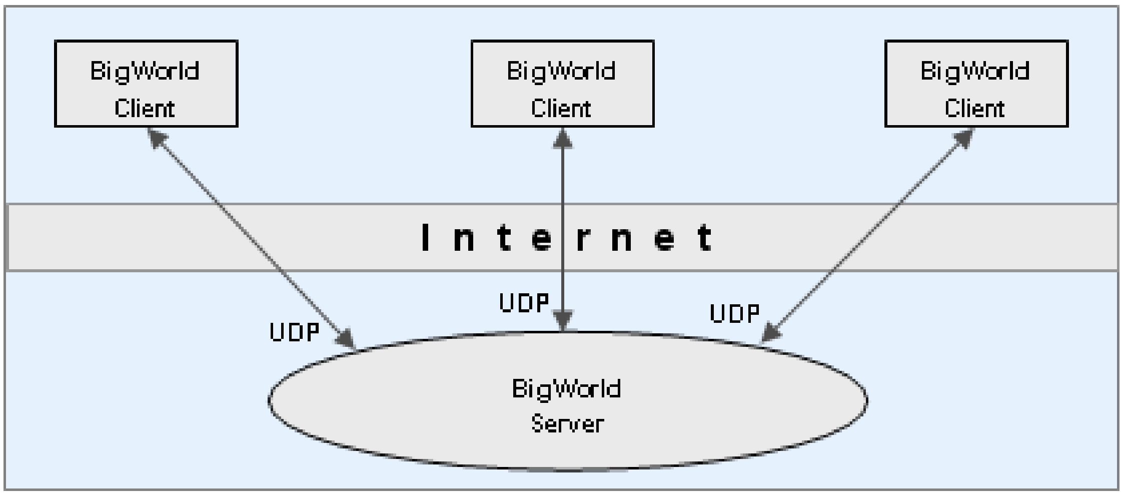
Note

For details on BigWorld terminology, see the document Glossary of Terms.

1.1. Client in context

The BigWorld Client provides the end-user experience of the BigWorld client/server architecture. In a BigWorld client/server implementation, the client connects to the server using UDP/IP over the Internet.

The BigWorld Client presents the user with a realistic and immersive 3D environment. The contents of that environment are a combination of static data stored with the client, and dynamic data sent from the server. The user interacts with the world through an avatar (character) that he or she controls. The movement and actions of that avatar are relayed to the server. The avatars controlled by other connected users are part of the dynamic data sent from the server.



Client perspective of BigWorld system. Note that the BigWorld server is not just one machine, although the client can treat it as such.

Developers may choose to integrate the client with their own server technology, but if they do, they will have to address problems already tackled by the BigWorld architecture, like:

- Uniform collision scene (used on client and server).
- Uniform client/server scripting (used on client and server).
- Tools that produce server and client content.
- Optimised low bandwidth communication protocol.

1.2. Outline

The client initialises itself, connects to the server, and then runs in its main thread a standard game loop (each iteration of which is known as a frame):

- Receive input
- Update world
- Draw world

Each step of the frame is described below:

- **Input**

  Input is received from attached input devices using DirectInput. In a BigWorld client/server implementation, input is also received over the network from the server using WinSock 2.

- **Update**

  The world is updated to account for the time that has passed since the last update.

- **Draw**

  The world is drawn with the 3D engine Moo, which uses Direct3D (version 9c). For details, see *3D Engine (Moo)* on page 113 .

A number of other objects also fall into the world's 'update then draw' system. These include a dozen related to the weather and atmospheric effects (rain, stars, fog, clouds, etc.), various script assistance systems (targeting, combat), pools of water, footprints, and shadows.

There are other threads for background scene loading and other asynchronous tasks.

1.3. Resource search paths

The BigWorld client is a generic executable that is fully configurable via the game specific resources. The location of these resources must be supplied to the client so that it can initialise correctly.

Typically, at least two resource paths need to be specified - your project specific resource path and the BigWorld resource path (which supplies common resources such as standard shaders, fonts, scripts, etc). For example, if your game was located in "my_game", the two resource paths you would define are:

- `my_game/res`
- `bigworld/res`

When the engine tries to access a resource, it will look in each resource tree in the order that they are given to the engine. As an example, if the client scripts request the resource named `sets/models/foo.model` it tries the following locations:

- `my_game/res/sets/models/foo.model`
- `bigworld/res/sets/models/foo.model`

The search will stop at the first valid file found. As such, it is possible to override resources specified in `bigworld/res` by placing it in the same location within `my_game/res`.

There are two ways search paths can be specified:

1.3.1. paths.xml

`paths.xml` is an XML file which the engine will look for on startup and contains a list of resource paths. The client will first try to open `paths.xml` in the current working directory. If it cannot be found in the current directory, then it will try to open `paths.xml` in the same folder as the client executable. The schema of `paths.xml` looks like this:

```
<root>
    <Paths>
        <Path>../../my_game/res</Path>
        <Path>../../bigworld/res</Path>
    </Paths>
</root>
```

Note

Paths are defined relative to the location of `paths.xml`.

1.3.2. Command line switch

By default the client will look for the `paths.xml` illustrated above. However, this can be overridden via the command line using the `--res` switch. Multiple paths are semi-colon separated. For example,

```
"bwclient.exe" --res ../../../my_game/res;../../../bigworld/res
```

Note

These paths must be defined relative to the executable location, *not* the current working directory.

1.4. Configuration files

Configuration files are defined relatively to one of the entries in the resources folders list (or `<res>`). For details on how BigWorld compiles this list, see "Resource search paths" on page 10

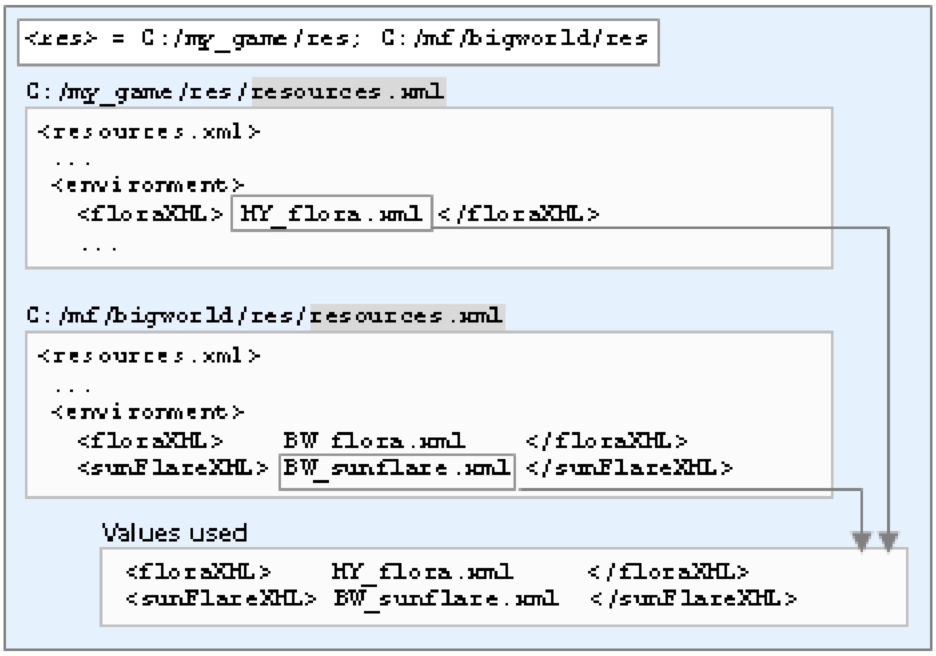
1.4.1. File `resources.xml`

This file defines game-specific resources that are needed by the client engine to run.

The entries in resources.xml are read from the various entries in the resources folders list (or `<res>`), in the order in which they are listed. Only missing entries will have their values read in subsequent folders.

A default file exists under folder bigworld/res, and any of its resources may be overridden by creating your own file `<res>/resources.xml`.

The example below illustrates this mechanism:


<res> = C:/my_game/res; C:/mf/bigworld/res
C:/my_game/res/resources.xml
<resources.xml>
...
<enviroment>
<floraXML> HY_flora.xml </floraXML>
...
C:/mf/bigworld/res/resources.xml
<resources.xml>
...
<enviroment>
<floraXML> BW_flora.xml </floraXML>
<sunFlareXML> BW_sunflare.xml </sunFlareXML>
Values used
<floraXML> HY_flora.xml </floraXML>
<sunFlareXML> BW_sunflare.xml </sunFlareXML>

Precedence of your game's `resources.xml` file over BigWorld's ones

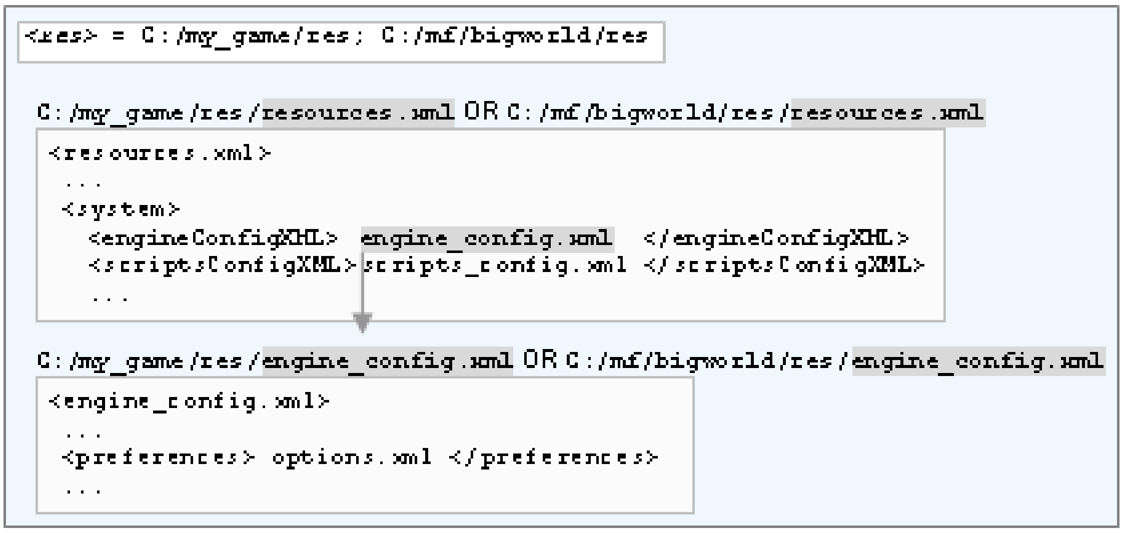
For a complete list of the resources and values used by BigWorld, refer to the `resources.xml` file provided with the distribution.

1.4.2. File <*engine_config*>`.xml`

The XML file <*engine_config*>`.xml` lists several engine configuration options.

The actual name and location of this file is defined by the `resources.xml`'s `<engineConfigXML>` tag. The location of the `resources.xml` file is always defined relative to one of the entries in the resources directories list (or <*res*>), which will be searched in the order in which they are listed.

An example follows below:


<res> = C:/my_game/res; C:/mf/bigworld/res
C:/my_game/res/resources.xml OR C:/mf/bigworld/res/resources.xml
<resources.xml>
...
<system>
<engineConfigXML> engine_config.xml </engineConfigXML>
<scriptsConfigXML> scripts_config.xml </scriptsConfigXML>
...
C:/my_game/res/engine_config.xml OR C:/mf/bigworld/res/engine_config.xml
<engine_config.xml>
...
<preferences> options.xml </preferences>
...

Locating `<engineConfigXML>`'s file

Under the main section of the XML file, a personality tag must be included, naming the personality script to use.

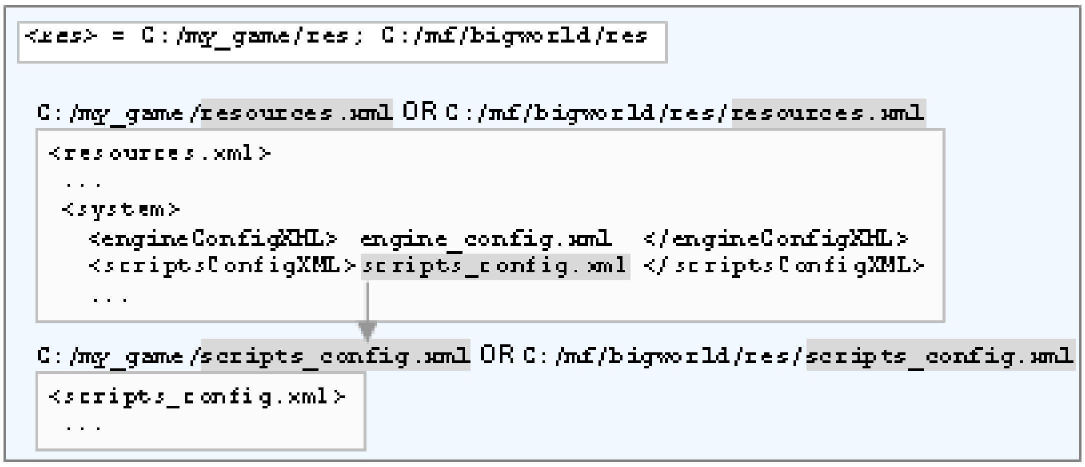
Several other tags are used by BigWorld to customize the way the client runs. For a complete list of the supported tags and a description of their functions, refer to the `engine_config.xml` file provided with the distribution. Additional information can also be found in the Client Python API.

The data contained in this file is passed to the personality script as the second argument to the `init` method (for details, see “`init`” on page 57), in the form of a `DataSection` object.

1.4.3. File <*scripts_config*>.xml

The XML file <*scripts_config*>`.xml` can be used to configure the game scripts. It has no fixed grammar, and its form can be freely defined by the script programmer.

The actual name and location of this file is defined by the `resources.xml`'s `scriptsConfigXML` tag — its location is always defined relative to one of the entries in the resources folders list (or <*res*>), which will be searched in the order in which they are listed.



```
<res> = C:/my_game/res; C:/mf/bigworld/res

C:/my_game/resources.xml OR C:/mf/bigworld/res/resources.xml
<resources.xml>
 ...
 <system>
   <engineConfigXML> engine_config.xml  </engineConfigXML>
   <scriptsConfigXML>scripts_config.xml </scriptsConfigXML>
   ...
C:/my_game/scripts_config.xml OR C:/mf/bigworld/res/scripts_config.xml
<scripts_config.xml>
 ...
```

Locating `scriptsConfigXML`'s file

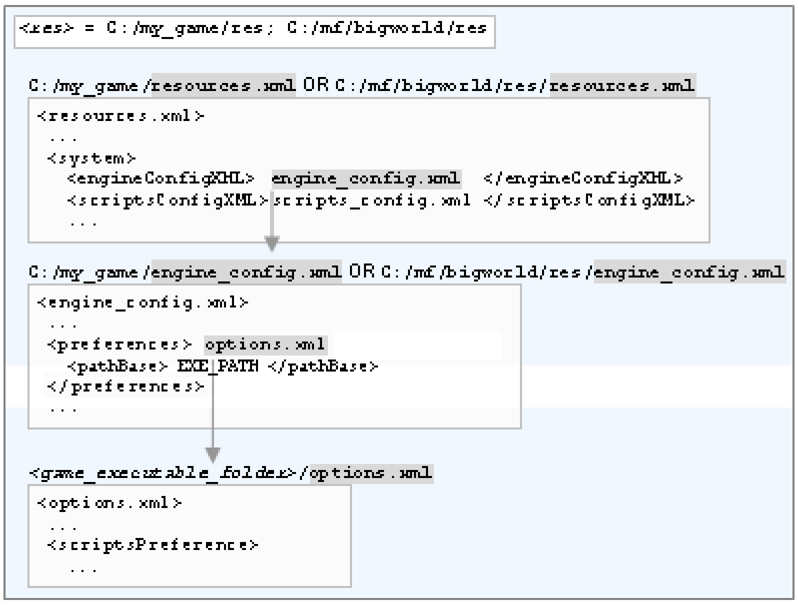
The data contained in this file is passed to the personality script as the first argument to the `init` method (for details, see “`init`” on page 57), in the form of a `DataSection` object.

1.4.4. File <*preferences*>.xml

The XML file <*preferences*>`.xml` is used to save user preferences for video and graphics settings, with a pre-defined grammar.

The file also embeds a data section (called `scriptsPreference`) that can be used by scripts to persist game preferences — there is no fixed grammar for this section.

The actual name and location of this file is defined in file specified by `resources.xml`'s `engineConfigXML` tag, in the `preferences` tag.



```
<res> = C:/my_game/res; C:/mf/bigworld/res

C:/my_game/resources.xml OR C:/mf/bigworld/res/resources.xml
<resources.xml>
 ...
 <system>
   <engineConfigXML> engine_config.xml  </engineConfigXML>
   <scriptsConfigXML> scripts_config.xml </scriptsConfigXML>
   ...

C:/my_game/engine_config.xml OR C:/mf/bigworld/res/engine_config.xml
<engine_config.xml>
 ...
 <preferences> options.xml
   <pathBase> EXE_PATH </pathBase>
 </preferences>
 ...

<game_executable_folder>/options.xml
<options.xml>
 ...
 <scriptsPreference>
   ...
```

Locating `engineConfigXML`'s preferences' file

By default the preferences XML file is relative to the client executable location, but this can be changed to a number of other base paths by specifying a `pathBase` subtag (e.g. it can be defined to be relative to the user's My Documents directory). The base path can be defined as an optional sub-tag of the preferences tag. The available path bases for <preferences>.xml are:

- `EXE_PATH` — The preferences XML file will be stored relative to the location of the client executable. This is the default location if none is supplied.
- `CWD` — The preferences XML file will be stored relative to the current working directory. Note that if the working directory changes during runtime, it will save in the new working directory.
- `APP_DATA` — The preferences XML file will be stored relative to the current user's AppData directory.
- `MY_DOCS` — The preferences XML file will be stored relative to the current user's My Documents directory.
- `RES_TREE` — The preferences XML file will be stored relative to the first resource path found in `paths.xml`.

The data contained in the `scriptsPreference` of this file is passed to the personality script as the third argument to the `init` method (for details, see "`init`" on page 57), in the form of a `DataSection` object.

The current user preferences can be saved back into the file (including changes to the `DataSection` that represents the script preferences) by calling `BigWorld.savePreferences`. For details, see the Client Python API .

1.5. Coordinate System

BigWorld uses a left-handed coordinate system. The x-axis points *"left"*, the y-axis points *"up"* and the z-axis points *"forward"*.

yaw is rotation around the y-axis. Positive is to the right, negative is to the left.

pitch is rotation around the x-axis. Positive is nose pointing down, negative is nose pointing up.

roll is rotation around the z-axis. Positive is to the left, negative is to the right.

Chapter 2. User Input

The BigWorld client uses a combination of Windows messages and the Windows raw input API for keyboard and mouse input. It reads key-up, key-down, and character press events from the keyboard as well as high resolution movement events from the mouse. It uses the DirectInput API to read button and axis movement events from joysticks.

2.1. Key events

Key events, encapsulated by the KeyEvent object (`BigWorld.KeyEvent` in Python), are generated by devices that have keys or buttons. This includes the keyboard, mouse buttons, and joystick buttons.

The two basic types of key events are key-down and key-up.

2.1.1. Character events

If a KeyEvent is generated by the keyboard, it may have a character attached to it. The character generated by a particular key is determined by the currently set locale and input language in the operating system, and is represented by the `KeyEvent.character` member (a Unicode string).

Dead character keys are supported (e.g. in Spanish, a user can type the letter é by first pressing the apostrophe key followed by the e key). In this case the first key press will not have a character associated with it, and the second key press will have the final character.

The BigWorld client supports advanced Input Method Editors (IME). See *Input Method Editors (IME)* on page 103 for details on using an IME in your game.

2.1.2. Auto-repeat

The keyboard will generate auto-repeat events when keys are held down, based on the user's operating system settings (e.g. repeat delay). The mouse and joystick do not generate auto-repeat events.

Auto-repeat events are sent as additional key-down events, however scripts that do not want to handle repeat events can call the `KeyEvent.isRepeatedEvent` method to determine whther or not it is an auto-repeat event.

2.1.3. Sequence of events

When the user presses a button (keyboard, mouse or joystick), the sequence of events are:

- The first key-down event.
- If the key is held down, multiple key-down events are raised due to auto-repeat (keyboard only).
- A key-up event is triggered when the user releases the button.

The output from the user input module is processed by a number of other modules, which take it in turn to examine events and either consume or ignore them. If an event is not consumed by any module then it is discarded. The order of modules that get a turn at the events is as follows:

- **Debug** — Special keys, consoles, etc.
- **Personality script** — Global keys.
- **Application** — Hard-coded keys such as `QUIT`.
- **Player script** — The rest, which is the major part of the processing.

Note

Note that the GUI system does not automatically receive input, instead it is up to the script write to choose when. This could be either in the personality script, or in the player script. The most obvious place is in the personality script callbacks, for example in the personality script's handleKeyEvent, you should call `GUI.handleKeyEvent()` and check the return value.

Similarly, the active camera also does not automatically receive input events. It is up to the Python scripts to decide when and where the camera receives user input.

2.1.4. Sinking events

The BigWorld client performs event matching to ensure consistent module behaviour. If a key-down event is consumed by a module, that module's identifier is recorded as the sink of the event's key number. When the corresponding auto-repeat and key-up event arrives, it is delivered directly to that module. For example, if a chat console is brought up (and inserted into the list) while the player is running, and the user subsequently releases the run key, then the player script will still get the key-up event for that key, and be able to stop the run action.

In some cases it may be desired to temporarily block certain key events from being passed into the scripts. For example, the GUI scripts may handle a key down event by removing the current GUI screen and replacing it with a new GUI screen. By default, since the new GUI screen has become the active screen by the time `handleKeyEvent` returns, any associated auto-repeat and key-up events will be posted to the new GUI screen creating possibly unwanted behaviour.

The `BigWorld.sinkKeyEvents` function can be used to stop all key events for the given key-code from reaching the scripts until (and including) the next key-up. See the Python API guide for details.

2.1.5. Mouse cursor position

It is often a requirement to know where the mouse was when a key event occured (i.e. rather than where the mouse is at the time of handling the event), especially when processing mouse button events. Therefore, the mouse cursor position is available via the `KeyEvent.cursorPosition` property, and should be used instead of `GUI.mcursor().position` where ever possible.

2.2. Mouse

2.2.1. Movement

High resolution mouse movement events are sent to the scripts as a `MouseEvent`. This object exposes three direction deltas.

- The `dx` and `dy` members are signed integers indicating movement of the mouse in the X and Y directions.
- The `dz` member represents movement of the mouse wheel.

Note

If multiple mouse deltas arrive from the driver within a single frame, they are accumulated into a single `MouseEvent`.

Similar to the `KeyEvent` object, the mouse cursor position for when the event occured is available as a member of the `MouseEvent` object.

2.2.2. Buttons

Mouse buttons are sent as a `KeyEvent`, however they do not generate auto-repeat events. See “Key events” on page 15 for details.

2.3. Joystick

The BigWorld client will automatically detect the first joystick device attached to the system, and is been designed to be used with dual-stick style joypads.

2.3.1. Axis events

When axis events occur, they will be sent to the scripts as an `AxisEvent` object via the `handleAxisEvent` personality script function.

2.3.2. Buttons

Joystick buttons are sent as a `KeyEvent`, however they do not generate auto-repeat events. See “Key events” on page 15 for details.

2.3.3. Controlling player direction

The C++ engine will automatically pass axis events to the active cursor, so the direction cursor can be joystick controlled by setting it as the active cursor using `BigWorld.setCursor`. The direction cursor will process any events generated by the right axis.

2.3.4. Avatar movement

The C++ engine will also give the physics subsystem a chance to handle axis events. The physics treats axis input as a special case and will scale movement speed by how far the user as pushed the joystick forward.

In order to enable joystick support on movement physics, set the `Physics.joystickEnabled` property to True and be sure to set `joystickFwdSpeed` and `joystickBackSpeed` properties to values appropriate for your game.

Chapter 3. Cameras

The placement of the camera update within the general update process is a delicate matter, because the camera depends on some components having been updated before it, whilst other components depend on the camera being updated before them.

Conceptually, there are four types of camera: fixed camera, FlexiCam, cursor camera, and free camera. The first three are client-controlled views, ranging from minimum user interaction to maximum user interaction. The last camera is completely user-controlled, but is not part of actual game play.

There are however just three camera classes: `FlexiCam`, `CursorCamera`, and `FreeCamera`. The fixed camera is implemented with a `FlexiCam` object. They all derive from a common `BaseCamera` class.

There is only ever one active camera at a time. The personality script usually handles camera management, since the camera is a global, but any script can also manipulate the camera, and the player script often does (although usually indirectly, through the personality script)

The base class and all the derived classes are fully accessible to Python. Any camera can be created and set to whatever position a script desires, including to the position of another camera. This is particularly useful when switching camera types to remove any unwanted 'jump-cuts'.

3.1. The Cursor Camera

The cursor camera is a camera that follows the character in the game world. It always positions itself on a sphere centred on the character's head. It works primarily with the direction cursor so as to face the camera in the direction of the character's head. You may use any MatrixProvider in place of the direction cursor, and you may use any MatrixProvider in place of the player's head.

The direction cursor is an input handler that translates device input from the user into the manipulation of an imaginary cursor that travels on an invisible sphere. This cursor is described by its pitch and yaw. It produces a pointing vector extending from the head position of the player's avatar in world space, in the direction of the cursor's pitch and yaw. The direction cursor is a useful tool to allow a targeting method across different devices. Rather than have each device affect the camera and character mesh, each device talks to the direction cursor, affecting its look-at vector in the world. The cursor camera, target tracker, and action matcher then read the direction cursor for information on what needs to be done.

The cursor camera takes the position of the direction cursor on the sphere, extends the line back towards the character's head, and follows that line until it intersects with the sphere on the other side. This intersection point is the cursor camera's position. The direction of the camera is always that of the direction cursor.

The cursor camera is an instance of the abstract concept InputCursor. There can be only one active InputCursor at any time, and BigWorld automatically forwards keyboard, joystick, and mouse events to it. Upon startup, the cursor camera is the active InputCursor by default. You can change the active InputCursor at any time, using the method BigWorld.setCursor (for example to change the InputCursor to be a mouse pointer instead).

3.2. The Free Camera

The Free Camera is a free roaming camera that is neither tied to a fixed point in space nor following the player's avatar. It is controlled by the mouse (for direction) and keyboard (for movement), and allows the user to fly about the world. The free camera has inertia in order to provide smooth, gradual transitions in movement. It is not a gameplay camera, but is useful for debugging, development, and demonstration of the game.

3.3. The FlexiCam

The FlexiCam is a flexible camera that follows the character in the game world. It always positions itself at a specified point, relative to the character orientation, and always looks at a specified orientation, relative to the character's feet direction.

It is called FlexiCam because it has a certain amount of elasticity to its movement, allowing the sensation of speed to be visualised. This makes it especially useful for chasing vehicles.

Chapter 4. Terrain

The terrain system employed by the BigWorld client integrates neatly with the chunking system. It allows a wide variety of terrains to be created in an artistic manner and managed efficiently. There are two different terrain renderers available that target different machine specifications. They are called Advanced Terrain and Simple Terrain.

4.1. Advanced Terrain

4.1.1. Overview

The advanced terrain engine uses a height map split up into blocks of 100 by 100 metres. Each block consists of height and texture information, normals, a hole map and LOD information.

4.1.2. Key Features

- Configurable height map resolution
- Unlimited number of texture levels with configurable blend resolution and projection angles
- Configurable normal map resolution
- Configurable hole map resolution
- Per pixel lighting
- LOD System
  - Geo mip-mapping with geo-morphing
  - Normal map LOD
  - Texture LOD
  - Height map LOD

4.1.3. Texturing

Texturing is done by blending multiple textures layers together, each texture layer has its own projection angle and blend values for blending with other texture layers. The resolution of the blend values is configurable per space and the layers themselves are stored per chunk. The textures are assumed to be *rgba* with the alpha channel used for the specular value.

4.1.4. Lighting

The lighting of the advanced terrain is performed per pixel. A normal map is stored per block, which is used in the lighting calculations, this is combined with the blended texture to output the final colour. The terrain allows up to 8 diffuse and 6 specular lights per block. For details of how the specular lighting is calculated see “Terrain specular lighting” on page 30

4.1.5. Shadows

The terrain uses a *horizon shadow map* for shadowing, this map stores two angles (east-west) between which there is an unobstructed view of the sky from the terrain. In the terrain shader, these angles are checked against the sun angle and the sun light is only applied if the sun angle falls between the horizon angles.

4.1.6. LOD

The purpose of the LOD system is to reduce the amount of cpu and gpu time spent rendering terrain and to reduce the memory footprint of the terrain. The terrain LOD system achieves this by reducing geometric and texture detail in the distance and loading/unloading high resolution resources as they are needed. The LODing is broken up by resource so that texture and geometric detail can be streamed separately. The LOD distances are configurable in the space.settings file, please see "`terrain` section in `space.settings`" on page 27 for more information.

4.1.6.1. Geometry

Geometry LOD is achieved by using `geo-mipmaps` and `geo-morphing`. `Geo-mipmaps` are generated from the high resolution normal map for the terrain block. Depending on the x/z distance from the camera a lower resolution version of the terrain block is displayed. To avoid popping when changing between the different resolutions of the height map, geo-morphing is used, this allows the engine to smoothly interpolate between two height map levels. Degenerate triangles are inserted between blocks of differing sizes to avoid sparkles.

4.1.6.2. Collision Geometry

Collision geometry is streamed in using two distinct resolutions. The low resolution collisions are always available, whereas the higher resolution collisions are streamed in depending on their x-z distance from the camera.

4.1.6.3. Texture

Texture LOD is performed by substituting the multi-layer blending with a single top-down image of the terrain block. The LOD image is smoothly blended in based on the x-z distance from the camera. The top-down image is generated in the World Editor.

4.1.6.4. Normal maps

Normal map LOD is performed by using low-resolution and high resolution maps. The low resolution normal map is always available and the high resolution map is streamed in and blended based on the x-z distance from the camera. The normal maps are generated in the World Editor. The size of the LOD normal map is a 16th of the resolution of the normal map or 32x32 whichever value is larger.

4.1.7. Memory footprint

Since the advanced terrain allows for a number of configuration options the memory footprint of the terrain depends on the options selected.

In the Fantasydemo example provided, the terrain overhead is as follows (this information was captured using the resource counters in the Fantasydemo client, the graphics settings were set to high and the far plane was set to 1500 metres):

(*this includes the textures used by the texture layers, which may also be used by other assets*)

Component	Size
Collision data	42,453,517
Vertex buffers	6,169,008
Index buffers	536,352
Texture layers	57,541,905
Shadow maps	26,361,856
LOD textures	35,148,605
Hole maps	4,096
Normal maps	6,572,032
Total	**174,787,371**

Terrain memory usage

4.1.8. terrain2 resources

A terrain2 section is contained in a chunk's .cdata file. It contains all the resources for the terrain in a chunk. The different types of terrain data are described in BNF format in the following chapter.

4.1.8.1. heights sections

The heights sections stores the height map for the terrain block. Multiple heights sections are stored in the block, one for each LOD level, each heights section stores data at half the resolution of the previous one. The heights sections are named as " heights? " where ? is replaced by a number. The highest res height map is stored in a section named heights the second highest in a section called heights1 all the way down to a map that stores 2x2 heights. This way if the height map resolution is 128x128, 7 height maps are stored in the file (heights, heights1, ... heights6)

```
<heightMap> ::= <header><heightData>
<header> ::=
 <magic><width><height><compression><version><minHeight><maxHeight><padding>
```

- **<magic>**

  uint32 0x00706d68 (string "hmp\0")

- **<width>**

  uint32 containing the width of the data

- **<height>**

  uint32 containing the height of the data

- **<compression>**

  (unused) uint32 containing the compression type

- **<version>**

  uint32 containing the version of the data, currently 4

- **<minHeight>**

  float containing the minimum height of this block

- **<maxHeight>**

  float containing the maximum height of this block

- **<padding>**

  4 bytes of padding to make the header 16-byte aligned

- **<heightData>**

  PNG compressed block of int32 storing the height in millimetres, dimensions = width * height from the header

4.1.8.2. layer sections

The layer sections store the texture layers for the terrain block. Multiple layer sections are stored in the terrain block. Each section describes one texture layer. The layer sections are named " layer ? " where ?

is replaced by a number greater than 1. I.e if the block has 3 layers, three layer sections will be stored ("layer 1", "layer 2", "layer 3")

```
<textureLayer> ::= <header><textureName><blendData>
<header> ::=
 <magic><width><height><bpp><uProjection><vProjection><version><padding>
<textureName> ::= <length><string>
```

- **`<magic>`**

  uint32 0x00646c62 (string bld/0")

- **`<width>`**

  uint32 containing the width of the data

- **`<height>`**

  uint32 containing the height of the data

- **`<bpp>`**

  (unused) uint32 containing the size of the entries in the layer data

- **`<uProjection>`**

  Vector4 containing the projection of the u coordinate of the texture layer

- **`<vProjection>`**

  Vector4 containing the projection of the v coordinate of the texture layer

- **`<version>`**

  uint32 containing the version of the data, currently 2

- **`<padding>`**

  12 bytes of padding to make the header 16-byte aligned

- **`<length>`**

  the length of the texturename string

- **`<string>`**

  the name of the texture used by this layer

- **`<blendData>`**

  png compressed block of uint8 defining the strength of this texture layer at each x/z position

4.1.8.3. `normals` & `lodNormals` sections

The `normals` section stores the high resolution normal map for the terrain block. The `lodNormals` section stores the LOD normals for the height block, the LOD normals are generally 1/16th of the size of the normals.

```
<normals> ::= <header><data>
<header> ::= <magic><version><padding>
```

- **`<magic>`**

  uint32 0x006d726e (string "nrm/0")

- **`<version>`**

  uint32 containing the version of the data, currently 1

- **`<padding>`**

  8 bytes of padding to make the header 16-byte aligned

- **`<data>`**

  png compressed block storing 2 signed bytes per entry for the x and z components of the normal the y component is calculate in the shader

4.1.8.4. `holes` section

The `holes` section stores the holemap for the terrain block, this section is only stored when a terrain block has holes in it.

```
<holes> ::= <header><data>
<header> ::= <magic><width><height><version>
```

- **`<magic>`**

  uint32 0x006c6f68 (string "hol/0")

- **`<width>`**

  uint32 containing the width of the data

- **`<height>`**

  uint32 containing the height of the data

- **`<version>`**

  uint32 containing the version of the data, currently 1

- **`<data>`**

  The hole data stored in a bit field of width * height, each row in the data is rounded up to 1 byte. If a bit is set to 1 it denotes a hole in the map.

4.1.8.5. `horizonShadows` section

The `horizonShadows` section stores the horizon shadows for the terrain block.

```
<shadows> ::= <header><data>
<header> ::= <magic><width><height><bpp><version><padding>
```

- **`<magic>`**

  uint32 0x00646873 (string "shd/0")

- **`<width>`**

uint32 containing the width of the data

- **`<height>`**

  uint32 containing the height of the data

- **`<bpp>`**

  (unused)uint32 containing the bits per entry in the data

- **`<version>`**

  uint32 containing the version of the data, currently 1

- **`<padding>`**

  12 bytes of padding to make the header 16-byte aligned

- **`<data>`**

  The shadow data, (uint16,uint16) * width * height, the horizon shadow data stores two angles between which there is no occlusion from any terrain or objects.

4.1.8.6. `lodTexture.dds` section

The `lodTexture.dds` section stores the LOD texture for the terrain block. The LOD texture is a low resolution snapshot of all the texture layers blended together. The texture is stored in the DXT5 format. For more information about the dds texture format please refer to the DirectX documentation.

4.1.8.7. `dominantTextures` section

The `dominantTextures` section stores the dominant texture map. The dominant texture map stores the texture with the highest blend for each x/z location in the terrain block.

```
<dominant> ::=<header><texNames><data>
<header> ::=
 <magic><version><numTextures><texNameSize><width><height><padding>
```

- **`<magic>`**

  uint32 0x0074616d (string "mat/0")

- **`<version>`**

  uint32 containing the version of the data, currently 1

- **`<numTextures>`**

  uint32 containing the number of textures referenced by the dominant texture map

- **`<texNameSize>`**

  uint32 containing the size of the texture entries

- **`<width>`**

  uint32 containing the width of the data

- **`<height>`**

uint32 containing the height of the data

- **`<padding>`**

  8 bytes of padding to make the header 16-byte aligned

- **`<texNames>`**

  `numTextures` entries of `texNameSize` size containing the names of the dominant textures referred to in this map. Texture names shorter than `texNameSize` are padded with `0`

- **`<data>`**

  stored as a compressed bin section. byte array of width * height, each entry is an index into the texture names which indexes the dominant texture at the x/z location of the entry

4.1.9. `terrain` section in `space.settings`

The terrain section in the `space.settings` file contains the configuration options for the terrain. The values in the `lodInfo` and `server` sections can be modified, but the root level values should only be modified by the World Editor.

```
<version> 200 (int) </version>
<heightMapSize> uint </heightMapSize>
<normalMapSize> uint </normalMapSize>
<holeMapSize> uint </holeMapSize>
<shadowMapSize> uint </shadowMapSize>
<blendMapSize> uint </blendMapSize>
<lodInfo>
  <startBias> float </startBias>
  <endBias> float </endBias>
  <lodTextureStart> float </lodTextureStart>
  <lodTextureDistance> float </lodTextureDistance>
  <blendPreloadDistance> float </blendPreloadDistance>
  <lodNormalStart> float </lodNormalStart>
  <lodNormalDistance> float </lodNormalDistance>
  <normalPreloadDistance> float </normalPreloadDistance>
  <defaultHeightMapLod> uint </defaultHeightMapLod>
  <detailHeightMapDistance> float </detailHeightMapDistance>
  <lodDistances>
    +<distance?> float </distance?>
  </lodDistances>
  <server>
    <heightMapLod> uint </heightMapLod>
  </server>
</lodInfo>
```

- **`<version>`**

  The version of the terrain, this value is `200` for advanced terrain

- **`<heightMapSize>`**

  The size of the height map per terrain block, this value is a power of 2 between 4 and 256

- **`<normalMapSize>`**

  The size of the normal map per terrain block, this value is a power of 2 between 32 and 256

- **`<holeMapSize>`**

The size of the hole map per terrain block, this can be any value up to 256

- **`<shadowMapSize>`**

  The size of the shadow map per terrain block, this value is a power of 2 between 32 and 256

- **`<blendMapSize>`**

  The size of the blend maps per terrain block, this value is a power of 2 between 32 and 256

- **`<lodInfo>`**

  This section contains the configurations for the terrain LOD system

- **`<startBias>`**

  This value is the bias value for the start of geo-morphing, this value defines where a LOD level starts fading out to the next one. This value is a factor of the difference between two lodDistances.

- **`<endBias>`**

  This value is the bias value for the end of geo-morphing, this value defines where a LOD level has fully faded out to the next one. This value is a factor of the difference between two lodDistances.

- **`<lodTextureStart>`**

  This is the start distance for blending in the LOD texture, up until this distance, the blended layers are used for rendering the terrain.

- **`<lodTextureDistance>`**

  This is the distance the lodtexture is blended in over, this value relative to `lodTextureStart.`

- **`<blendPreloadDistance>`**

  This is the distance at which the blends are preloaded, this value is relative to lodTextureDistance and lodTextureStart

- **`<lodNormalStart>`**

  This is the start distance for blending in the LOD normals

- **`<lodNormalDistance>`**

  This is the distance the full normal map is blended in over, this value relative to `lodNormalStart.`

- **`<normalPreloadDistance>`**

  This is the distance at which the full normal maps are preloaded. This value is relative to `lodNormalStart` and `lodNormalDistance`

- **`<defaultHeightMapLod>`**

  This is the default LOD level of height map to load, 0 = the full height map, 1 = half resolution, 2 = quarter resolution etc.

- **`<detailHeightMapDistance>`**

  This is the distance at which the full height map is loaded

- **`<lodDistances>`**

This section contains the geometry LOD distances.

- **`<distance>`**

  The `distance` sections define the distances at which each geometry LOD level is blended out. `distance0 is for the first LOD level, distance1 for the second LOD level etc. The distance between LOD levels must be at least half the diagonal distance of a terrain block (~71), this is because we only support a difference of 1 LOD level between neighbouring blocks.`

- **`<server>`**

  This section contains the information used by the server

- **`<heightMapLod>`**

  This defines which LOD level to load on the server, this value is used to speed up loading on the server.

4.2. Simple Terrain

4.2.1. Key features

- Works with the chunking system.
- Individual grid squares addressable from disk and memory.
- Based on a 4x4 metre grid (tiles), which matches portal dimensions.
- Low memory footprint.
- Low disk footprint.
- Fast rendering.
- Automatic blending.
- Easy tool integration.
- Layered terrain with tiled textures for easy strip creation.
- Uses texture projection to apply texture coordinates to save vertex memory.

4.2.2. Overview

The terrain is a huge height map defined by a regular grid of height poles, every 4x4 metres. Terrain is organised into terrain blocks of 100x100 metres. Each of these blocks can have up to four textures, which are blended on a per-vertex (*i.e.*, per-pole) basis. The terrain also is self-shadowing, and allows holes to be cut out of it, for things like cave openings. The terrain also contains detail information, so that the detail objects can be matched to the terrain type.

4.2.3. Chunking

The terrain integrates properly with the chunking: each terrain block is 100x100 metres, which is the size of the outside chunks. The terrain blocks are stored in separate files, so that they can be opened as needed.

4.2.4. Disk footprint

Each terrain block covers one chunk, each with dimension of 100x100 metres. It contains 28x28 height, blend, shadow, and detail values (there are two extra rows and one column to allow for boundary interpolation). Each terrain block also stores 25x25 hole values, one for each 4x4m tile.

The table below display the terrain cost per chunk.

Component	Size calculation	Size
Headers	256 (header) + 128 x 4 (texture names)	768
Height	28 x 28 x sizeof(float)	3,136
Blend	28 x 28 x sizeof(dword)	3,136
Shadow	28 x 28 x sizeof(word)	1,568
Detail	28 x 28 x sizeof(byte)	784
Hole	25 x 25 x sizeof(bool)	625
Total		10,017

Terrain cost per chunk

For example, for a 15x15 km world the total disk size of the terrain would be: 10,017 x 150 x 150 ~ 215MB.

4.2.5. Memory footprint

With a field of view of 500m, and each terrain block covering 100x100 metres, a typical scene would require roughly 160 terrain blocks in memory at any one time.

The memory usage of this much terrain is about 2MB, plus data management overheads.

4.2.6. Texture spacing

The `TerrainTextureSpacing` tag included in the `environment` section of file `<res>/resources.xml` (for details on the precedence of entries in the various copies of file resources.xml, see "File `resources.xml`" on page 11) determines the size (in metres) to which texture map will be stretched/shrunk when applied to the terrain.

This value determines both the length and height of the texture tile.

4.3. Terrain specular lighting

The equation for the specular lighting is:

SpeClr = TerSpeAmt * ((SpeDfsAmt * TerDfsClr) + SunClr) * SpeRfl

The list below describes each variable:

- **`SpeClr` (Specular colour)**

  Final colour reflected.

- **`TerSpeAmt` (Specular amount)**

  Value is given by the weighted blend of the alpha channel of the 4 terrain textures.

- **`SpeDfsAmt` (Specular diffuse amount)**

  Initial value is stored in the variable `specularDiffuseAmount` in the effect file `bigworld/res/shaders/terrain/terrain.fx`.

  Its value can be tweaked during runtime via the watcher `render/terrain/specularDiffuseAmount`.

  Once the desired result is achieved, the new value can be stored in the effect file.

- **`TerDfsClr` (Terrain diffuse colour)**

  Value is given by the weighted blend of the RGB channels of the 4 terrain textures.

- **`SunClr` (Sunlight colour)**

  Colour impinged by sunlight.

- **`SpeFlr` (Specular reflection)**

  Specular reflection value at the given pixel, adjusted by the Specular power coefficient

As a result of the formula, a small amount of the **Terrain diffuse colour** (`TerDfsClr`) is added to the **Sunlight colour** (`SunClr`) to give the **Specular colour** (`SpeClr`).

The initial value of the power of specular lighting is stored in the variable `specularPower` in the effect file `bigworld/res/shaders/terrain/terrain.fx`. Its value can be tweaked during runtime via the watcher `render/terrain/specularPower`. Once the desired result is achieved, the new value can be stored in the effect file.

Note that the **Specular power** can only be adjusted for shader hardware version 2.0 and later. Earlier versions of shader hardware are limited to a **Specular power** value of 4 (which is the default for shader hardware version 2.0 and later).

Note

The final amount of specular lighting applied to the terrain is affected by the variable `specMultiplier` in file `bigworld/res/shaders/terrain/terrain.fx`.

Set it to anything other than 1 to rescale the specular lighting, or 0 to completely disable it.

Note

Terrain specular lighting can be turned off via `TERRAIN_SPECULAR` graphics settings.

For details, see “Graphics settings” on page 132 .

Chapter 5. Cloud shadows

All objects in the BigWorld client engine that are drawn outside are affected by cloud shadows. This effect is applied per-pixel, and is performed using a light map-stored as a texture feed in the engine that is projected onto the world.

This light map is exposed to the effects system via macros defined in the file `bigworld/res/shaders/std_effects/stdinclude.fxh`.

By default, the texture feed is named `skyLightMap`, and therefore is accessible to Python via the command:

```
BigWorld.getTextureFeed( "skyLightMap" )
```

Information for the sky light map is found in the sky XML file, which is defined in the file `<res>/spaces/<space>/space.settings` (for details on this file's grammar, see the document File Grammar Guide's section *`space.settings`*) for the given space. The parameters are the same as in any BigWorld light map.

5.1. Requirements

Cloud shadowing requires one extra texture layer per material. While the fixed-function pipeline supports this for most materials, cloud shadowing on bump-mapped and specular objects requires more than four sets of texture coordinates, meaning that for bump-mapped objects it will only work on Pixel Shader 2 and above.

5.2. Implementation

The sky light map is calculated by the code in C++ file `src/lib/romp/sky_light_map.cpp`, and is updated by the sky module during draw.

It is exposed to the effect engine via automatic effect constants. The light map is updated only when a new cloud is created, or the current set of clouds has moved more than 25% downwind.

Between updates, the projection texture coordinates are slid by the wind speed so that the cloud shadows appear to move with the clouds. All effect files incorporate the cloud shadowing effect, including the terrain and flora.

5.3. Effect File Implementation

There are two effect constants exposed to effect files to aid with sky light mapping:

- **`SkyLightMapTransform`**

  Sets the "World to SkyLightMap" texture projection.Use this constant to convert x,z world vertex positions to u,v texture coordinates.

- **`SkyLightMap`**

  Exposes the sky light map texture to effect files.

There are several macros in file `bigworld/res/shaders/std_effects/stdinclude.fxh` that assist with integrating cloud shadowing into your effect files.

These macros are described in the list below:

- **`BW_SKY_LIGHT_MAP_OBJECT_SPACE`, `BW_SKY_LIGHT_MAP_WORLD_SPACE`**

  These macros declare the variables and constants required for the texture projection, including:

- World space camera position.
- Sky light map transform.
- The sky light map itself.

When using an effect file that performs lighting in object space (for example, if you are also using the macro `DIFFUSE_LIGHTING_OBJECT_SPACE`), use the variation `BW_SKY_LIGHT_MAP_OBJECT_SPACE`, and that will have the world matrix declared.

- **`BW_SKY_LIGHT_MAP_SAMPLER`**

  This macro declares a sampler object that is used when implementing cloud shadows in a pixel shader.

- **`BW_SKY_MAP_COORDS_OBJECT_SPACE`, `BW_SKY_MAP_COORDS_WORLD_SPACE`**

  These macros perform the texture projection on the given vertex position, and set the texture coordinates into the given register.

  Be sure to pass the positions in the appropriate reference frame, depending on which set of macros you are using.

- **`BW_TEXTURESTAGE_CLOUDMAP`**

  This macro defines a texture stage that multiplies the previous stage's result by the appropriate cloud shadowing value.

  It should be used after any diffuse lighting calculation, and before any reflection or specular lighting.

- **`SAMPLE_SKY_MAP`**

  This macro samples the sky light map in a pixel shader, and returns a 1D-float value representing the amount by which you should multiply your diffuse lighting value.

5.4. Tweaking

After the light map is calculated based on the current clouds, it is clamped to a maximum value. This means that the cloud map can never get too dark, or have too great an effect on the world.

For example, even if the sun is completely obscured by clouds during the day, there will still be enough ambient lighting and illumination from the cloud layer itself such that sunlight still takes effect.

The BigWorld watcher `Client Settings/Clouds/max sky light map darkness` sets the maximum value that the sky light map can have. A value of 1 means that the sky light map is able to completely obscure the sun (full shadowing). The default value of 0.65 represents the BigWorld artists' best guess at the optimal value for cloud shadowing. A value of 0 would mean there is never any effect of cloud shadows on the world.

This value is also read from the file sky.xml in the light map settings. It is represented by the maxDarkness tag. For details on the sky light map settings file, see “Sky light map” on page 114 .

Chapter 6. Chunks

The scene graph drawn by the BigWorld client is built from small convex chunks of space. This has many benefits including easy streaming, reduced loading times, concurrent world editing, and facilitation of server scene updates and physics checking.

The concepts and implementation of the chunking system are described in the following sections.

6.1. Definitions

The following terms are related to the BigWorld chunking system:

A space is a continuous three-dimensional Cartesian medium. Each space is divided piecewise into chunks, which occupy the entire space but do not overlap. Every point in the space is in exactly one chunk. A space is split into columns of 100x100 metres in the horizontal dimensions, and total vertical range. Examples of separate spaces include planets, parallel spaces, space stations, and 'detached' apartment/dungeon levels.

A chunk is a convex three-dimensional volume. It contains a description of the scene objects that reside inside it. Scene objects include models, lights, entities, terrain blocks, etc, known as chunk items. It also defines the set of planes that form its boundary.

Note

The *outside* chunk of a column is exempt from this — it needs only define the four planes to adjacent column. The boundary planes of other chunks overlapping that grid square are used to build a complete picture of the division of space inside it.

Some planes have portals defined on them, indicating that a neighbouring chunk is visible through them.

A portal is a polygon plus a reference to the chunk that is visible through that polygon. It includes a flag to indicate whether it permits objects to pass through it. Some portals may be named so that scripts can address them, and change their permissivity.

6.2. Implementation files

The following files are used by the chunking system:

- **One `space.settings` file for each space in the universe (XML format)**

  For details on this file's grammar, see the document File Grammar Guide's section *`space.settings`*.

  - **`<res>/spaces/<space>/space.settings`**
    - Environment settings
    - Bounding rectangle of grid squares

- **Multiple `.chunk` files for each space (XML format)**

  For details on this file's grammar, see the document File Grammar Guide's section *`.chunk`*.

  - **`<res>/spaces/<space>/XXXXZZZZo.chunk` (o = outside)**
  - **`<res>/spaces/<space>/CCCCCCCCi.chunk` (i = inside)**
    - List of scene objects
    - Texture sets used

    - Boundary planes and portals (including references to visible chunks)
    - Collision scene

- **Multiple `.cdata` files for each space (binary format)**
  - **`<res>/spaces/<space>/XXXXZZZZ.cdata`**
    - Terrain data such as:
      - Height map data
      - Overlay data
      - Textures used

    — or —

    - Multiple instances of lighting data for each object in the chunk:
      - Static lighting data
      - A colour value for each vertex in the model

6.3. Details and notes

6.3.1. Includes

Includes are transparent after being loaded (to client, server, and scripts). Label clashes are handled by appending '_*n*' to labels, where *N* is the number of objects with that label already.

Includes are expanded inline where they are encountered, and do not need to have a bounding box for the purposes of the client or server.

The WorldEditor does not generate includes.

6.3.2. Models

Material overrides and animation declarations remain the domain of model files. For more details, see *Models* on page 63 .

6.3.3. Entities

Only entities that are implicitly instantiated need to have their ID field filled in. If it is zero or is missing, then the entity is assigned a unique ID from either the client's pool (if it is a client-instantiated entity) or the creating cell's pool (if it is a server-instantiated entity).

If an entity needs a label, it must include the label as a property in its formal type definition.

6.3.4. Boundaries and portals

The special chunk identifier heaven may be used if only the sky (gradient, clouds, sun, moon, stars, etc...) is to be drawn there. Similarly with earth, if the terrain ought to be drawn. Therefore, outside chunks will have six sides, with the heaven chunk on the top and the earth chunk on the bottom.

The absence of a chunk reference in a portal means it is unconnected and that nothing will be drawn there.

If a chunk is included inside another, then its boundary planes are ignored — only things like its includes, models, lights, and sounds are used.

An internal portal means that the specified boundary is not an actual boundary, but instead that the space occupied by the chunk it connects to (and all chunks that that chunk connects to) should be logically subtracted from the space owned by this chunk, as defined by its non-internal boundaries. This was originally intended only for 'outside' chunks to connect to 'inside' chunks, but it may be readily adapted for 'interior portals', the complement to 'boundary portals'.

In a portal definition, the vAxis for the 2D polygon points is found by the cross product of the normal with uAxis.

In boundary definitions, the normals should point inward.

6.3.5. Transforms

Everything in the chunk except the bounding box is interpreted in the local space of the chunk (as specified in the top-level transform section).

6.3.6. Other items

The following items can also exist in chunks:

- Spot Light
- Ambient Light
- Directional Light
- Water (body of water)
- Flare (lens flare)
- Particle System

6.4. Loading and ejecting

At every frame, the Chunk Manager performs a simple graph traversal of all the chunks it has loaded, looking for new chunks to load. It follows the portals between chunks, keeping track of how far it has 'travelled' in its scan. Its scan is limited to the maximum visible distance, *i.e.*, a little further than the far plane distance.

The closest unloaded chunk it finds on this traversal is the chunk that is loaded next. Loading is done in a separate thread, so it does not interfere with the running of the game. Similarly, any chunks that are beyond the reach of the scan are candidates for ejecting (unloading).

6.5. Focus grid

The focus grid is a set of columns surrounding the camera position. Each column is 100x100metres and is aligned to the terrain squares and outside chunks. The focus grid is sized to just exceed the far plane.

For a far plane of 500m, for example, the focus grid goes 700m in each direction, making for 14 x 14 = 196 columns total.

The set of columns in the focus grid is dependent on the camera position. As the camera moves, the focus grid disposes columns that are no longer under the grid and 'focuses' on ones that have just come close enough.

Each column contains a hull tree and a quad tree.

6.5.1. Hull tree

A hull tree is a kind of binary-space partitioning tree for convex hulls. It can handle hulls that overlap. It can do point tests and proper line traversals.

The hull tree is formed from the boundaries of all the chunks that overlap the column. From this tree, the chunk that any given point lies in can be quickly determined. (*e.g.*, the location of the camera)

6.5.2. Quad tree

The quad tree is made up of the bounding boxes (or, potentially, any other bounding convex hull) of all the obstacles that overlap the column. This tree is used for collision scene tests. Chunk items are responsible for adding and implementing obstacles. Currently only model and terrain chunk items add any obstacles.

If a chunk or obstacle is in more than one column, it is added to the trees of both columns.

6.6. Collisions

Using its focus grid of obstacle quad trees, the chunk space class can sweep any 3D shape through its space, and report all the triangle collisions to a callback object. The currently supported 3D shapes are points and triangles, but any other could be added with very little difficulty.

The bottommost level of collision checking is handled by a generic obstacle interface, so any conceivable obstacle could be added to this collision scene, as long as it can quickly determine when another shape collides with it (in its own local coordinates).

For more details, see file `bigworld/src/client/physics.cpp`.

6.7. Sway items

A sway item is a chunk item that is swayed by the passage of other chunk items. Whenever a dynamic chunk item moves, any sway items in that chunk get the sway method called on them, specifying source and destiny of movement.

Currently the only user of this is `ChunkWater`. It uses movements that pass through its surface to make ripples in the water. This is why the ripples work for any kind of dynamic item — from dynamic obstacles/moving platforms to player models to small bullets.

- **In `mf/src/lib/chunk/chunk_water.cpp`:**

```
/**
 * Constructor
 */
ChunkWater::ChunkWater() :
  ChunkItem( 5 ), 1
  pWater_( NULL )
{
}
...
/**
 *   Apply a disturbance to this body of water
 */
void ChunkWater::sway( const Vector3 & src, const Vector3 & dst )
{
  if (pWater_ != NULL)
  {
    pWater_->addMovement( src, dst );
  }
}
```

1 Calls `ChunkItem` constructor with `wantFlags` =5:

- **1** — `wantsDraw`

  - **4** — wantsSway

- In **mf/src/lib/chunk/chunk_item.hpp**:

```
...
class ChunkItem : public SpecialChunkItem
{
public:
  ChunkItem( int wantFlags = 0 ) : SpecialChunkItem( wantFlags ) { }
};
...
typedef ClientChunkItem SpecialChunkItem;
...
class ClientChunkItem : public ChunkItemBase
{
public:
  ClientChunkItem( int wantFlags = 0 ) : ChunkItemBase( wantFlags ) { }
};
...
ChunkItemBase( int wantFlags = 0 );

bool wantsDraw() const { return !!(wantFlags_ & 1); }
bool wantsTick() const { return !!(wantFlags_ & 2); }
bool wantsSway() const { return !!(wantFlags_ & 4); }
bool wantsNest() const { return !!(wantFlags_ & 8); }
```

Chapter 7. Entities

Entities are a key BigWorld concept, and involve a large system in their own right. They are the link between the client and the server and are the feature most particular to BigWorld Technology, in comparison to other 3D game systems.

This section deals only with the management aspects of entities on the client.

For details on the environment in which entity scripts are placed, and the system that supports them, see *Scripting* on page 47. For details on the definition of an entity, which is shared between the server and the client, see the document Server Programming Guide's section *Physical Entity Structure for Scripting* → “The Entity Definition File”.

Depending on the entity type, it can exist in different parts of BigWorld, as listed below:

- **Client-only**

  For example, a security camera prop, or an information icon. Client-only entities are created by setting WorldEditor's **Properties**' panel **Client-Only** attribute to **true**. (for details on this panel, see the document Content Tools Reference Guide 's section *WorldEditor* → “Panel summary” → “Properties panel”). Client-only entities should not have cell or base scripts.

- **Client and server**

  The entity will exist in both parts at the same position. For example, the player Avatar, NPCs, a vending machine.

- **Server-only**

  The entity will be instantiated on the server only. For example, a NPC spawn point or teleportation destination point. Server-only entities do not have any scripts on the client side.

7.1. Entity Manager

The Entity Manager stores two lists of entities:

- **Active List** — Contains the entities that are currently in the world, as relayed by the server or indicated by the chunk files.
- **Cached List** — Contains the entities that have recently been in the world, but are now just outside the client's 500m radius area of interest (AoI).

Entities are cached so that if they come back into the client's AoI shortly after they have left it, the server does not have to resend all the data associated with that entity; only the fields that have changed.

Since messages may be received from the server out of order, the Entity Manager is not sensitive to their order. For example, if an entity enters the player's AoI then quickly leaves it, the BigWorld client behaves correctly even if it receives the entity's 'leave AoI' message before its 'enter AoI' message.

The Entity Manager can always determine the relative time that it should have received a message from the sequence number of the packet, since packets are sent at regular intervals.

7.2. Entity scripts

Entity scripts on the client are Python classes that derive from the `BigWorld.Entity` class. This base class exposes a number of methods and attributes which allow the script to control the behaviour of the entity (e.g. position, orientation, and the entity model are all exposed via the `BigWorld.Entity` interface).

In addition exposing to methods and attributes, the client engine will notify the entity scripts when certain events occur via named event handlers.

See *Scripting* on page 47 and the Client Python API reference guide for details on what methods, attributes, and event handlers are available.

7.3. Entity resources

Generally, each entity type require some resources in order to operate, for example models, textures, shaders, sounds, or particle systems. The BigWorld client provides a couple of ways to make sure these resources are available when the entity enters the world, avoiding stalling the main thread.

7.3.1. Preloads

When the client starts up, it will query each entity Python module for a function named `preload`. Resource names returned by this function will be loaded on client startup and kept in memory for the entire life-time of the client (i.e. it will be instantly available for use at any time). This is useful for commonly used assets to avoid potentially loading and re-loading at a later time. The tradeoff, however, is that the client will take longer to start and will use more memory (if the resource isn't actually being used at some point).

To use the preloads mechanism, create a global function called `preload` in the relevant entity module. It must take a single parameter which is a Python list containing resource to preload. Modify this list in place (e.g. using list.append or list concatenation), inserting the string names of each resource to be preloaded by the client.

For example,

```
# Door.py
import BigWorld

class Door( BigWorld.Entity ):
    def __init__( self ):
        ...

def preload( list ):
    list.append( "doors/models/generic_door.model" )
    list.append( "doors/maps/door_highlight.tga" )
    ...
```

The type of resources which can be preloaded are,

- Fonts
- Textures
- Shaders
- Models

7.3.2. Prerequisites

When an entity is about to appear in the world on the client, the engine will execute a callback on the entity script called `prerequisites`. This allows entity scripts to return a list of resources that must be loaded before the entity may enter the world. These resources are loaded by the loading thread, so as to not interrupt the rendering pipeline.

It is recommended practice for an entity to expose its required resources as pre-requisites, and load them in the method `onEnterWorld`. Unlike using preloads, prerequisites do not leak a reference, so when the entity leaves the world, it will free its resources.

The Entity Manager calls `Entity::checkPrerequisites` before allowing an entity to enter the world. This method checks whether the pre-requisites for this entity entering the world are satisfied. If they are not, then it starts the process of satisfying them (if not yet started).

Note that when the `prerequisites` method is called on the entity, its script has already been initialised and its properties have been set up. The entity thus may specialise its pre-requisites list based on the specific instance of that entity. For example:

```
def Door( BigWorld.Entity ):
    ...
    def prerequisites( self ):
        return [ DoorResources[ self.modelType ].modelName ]
    ...
```

Chapter 8. User Data Objects

User data objects are a way of embedding user defined data in Chunk files. Each user data object type is implemented as a collection of Python scripts, and an XML-based definition file that ties the scripts together. These scripts are located in the resource tree under the folder `scripts`.

User data objects differ from entities in that they are immutable (i.e. their properties don't change), and that they are not propagated to other cells or clients. This makes them a lot lighter than entities.

A key feature of user data objects is their linkability. Entities are able to link to user data objects, and user data objects are able to link to other user data objects. This is achieved by including a `UDO_REF` property in the definition file for the user data object or entity that wishes to link to another user data object.

For more information about linking, please refer to Server Programming Guide's section “User Data Object Linking With `UDO_REF` Properties”.

For details on the definition of a user data object, which is shared between the server and the client, see the document Server Programming Guide's section *Physical User Data Object Structure for Scripting* → “The User Data Object Definition File”.

8.1. .1. User Data Objects are Python script objects

Each user data object is a Python script object (`PyObject`). Depending on the user data object type, it can exist in different parts of BigWorld, as listed below:

- **Client only**

  Client only user data objects are created by using the `CLIENT` domain in the `Domain` tag inside its definition file. Client-only user data objects should not have cell or base scripts

  For an example of a client-only user data object, please refer to the `CameraNode` user data object, implemented in the `<res>/scripts/client/CameraNode.py` and the `<res>/scripts/user_data_object_defs/CameraNode.def` files.

- **Server only**

  Server only user data objects are instantiated on the server only, and will be instantiated in the cell if its `Domain` tag is `CELL`, or in the base if the `Domain` tag is set to `BASE`.

  For an example of a server user data object, please refer to the `PatrolNode` user data object, implemented in the `<res>/scripts/cell/PatrolNode.py` and the `<res>/scripts/user_data_object_defs/PatrolNode.def` files.

8.2. .2. Accessing from the Client

The client can access all client-only user data objects using the command:

```
>>> BigWorld.userDataObjects
<WeakValueDictionary at 3075900908>
```

This will return a Python dictionary, using the user data object’s unique identifier as the key, and its `PyObject` representation as its value. The attributes and script methods of the user data object can be accessed using the standard dot syntax:

```
>>> patrolNode.patrolLinks
```

```
[UserDataObject at 2358353012, UserDataObject at 2358383771]
```

Chapter 9. Scripting

The facilities provided to scripts are of extreme importance, as they determine the generality and extensibility of the client. To a script programmer this environment is the client; just as to an ordinary user, the windowing system is the computer.

The scripting environment offers a great temptation to try to write the whole of a program in it. This can quickly make for slow and incomprehensible programs (especially if the same programming discipline is not applied to the scripting language as is to C++). Therefore, we recommend that a functionality should only be written in script when it does not need to be called at every frame. Furthermore, where it is global, it should be implemented in the personality script. So, for example, a global chat console would be implemented in the personality script, whilst a targeting system, which needs to check the collision scene at every frame, is best implemented in C++.

Importantly, the extensive integration of Python throughout BigWorld Technology allows for both rapid development of game code, and enormous flexibility.

Note

Garbage collection is disabled in BigWorld's Python integration, because garbage collection is an expensive operation that can occur at any time, blocking the main thread and causing frame rate spikes for example.

9.1. Functional components

This section describes the contents and services of the (general) C++ entity, from the point of view of a script that uses these facilities. The functional components of an entity, described in the following sections are:

- Entity Skeleton
- Python Script Object
- Model Management
- Filters
- Action Queue
- Action Matcher
- Trackers (IK)
- Timers and Traps

9.1.1. Entity skeleton

The Entity class (entity.cpp) is the C++ container that brings together whatever components are in use for a particular entity. It is derived from Python object and intercepts certain accesses, and passes those it does not understand on to the user script. This allows scripts to call C++ functions on themselves (and other entities) transparently, using the 'self' reference. The same technique of integration has been used in the cell and base components of the server.

This class handles any housekeeping or glue required by the component classes — it is the public face of an entity as far as other C++ modules are concerned.

The data members of this class include id, type, and position.

9.1.2. Python script object

This is the instance of the user-supplied script class. The type of the entity selects the class. It stores type-specific data defined in the XML description of the entity type, as well as any other internally used data that the script wishes to store.

When field data is sent from the server, this class has its fields automatically updated (and it is notified of the change). When messages are received from the server (or another script on the client), the message handlers are called automatically. The entity class performs this automation — it appears to be automatic from the script's point of view.

9.1.3. Model management

A model is BigWorld's term for a mesh, plus the animations and actions used on it.

The model management component allows an entity to manage the models that are drawn and animated at its position. Models can be attached to each other at well-defined attachment points (hard points), or they can exist independently. A model is not automatically added to the scene when it is loaded — it must be explicitly put in it.

An entity may use any number of independent (disconnected) models, but most will use zero or one. Those that use more require special filters to behave sensibly. For details, see “Filters” on page 48 .

The best way to understand models is t`o be acquainted to their Python interface, which is described in the Client Python API's entry **Main → Client → BigWorld → Classes → `PyModel`**. For more details, see *Models* on page 63 .

9.1.4. Filters

Filters take time-stamped position updates and interpolate them to produce the position for an entity at an arbitrary time.

BigWorld provides only the Filter base class. The game developer would derive game-specific filters from this. Each entity can then select one type of filter for itself from the variations available. It can dynamically change its filter if it so desires.

Whenever a movement update comes from the server, it is handed over to the selected filter, along with the time that the (existing) game time reconstruction logic calculated for that event.

The filter can also be provided with gaps in time and transform, *i.e.*, 'at game-time x there was a forward movement of y metres and a rotation of z radians lasting t seconds'. The filter (if it is smart enough) can then incorporate this into its interpolation.

The filter can also execute script callbacks at a given time in the stream.

Filters are fully accessible from Python.

9.1.5. Action Queue

The action queue is the structure within the BigWorld Technology framework that controls the queue of actions in effect on a model (actions are wrapped by ActionQueuer objects that are contained by the action queue).

The ActionQueue deals with the combining of layers and also applying the appropriate blend in and blend out times.

The ActionQueue also deals with any scripted callback functions that are linked to the playing of an action, like for example calling sound-playing callbacks at particular frames in an action.

An action is described in XML as illustrated the example `.model` file below (model files are located in any of the various sub-folders under the resource tree `<res>` , such as for example, `<res>/environments`, `<res>/flora`, `<res>/sets/vehicles`, etc...):

```
<action>
   <name>          ACTION_NAME     </name>
  ?<animation>     ANIMATION_NAME  </animation>
  ?<blendInTime>   float           </blendInTime>
  ?<blendOutTime>  float           </blendOutTime>
  ?<filler>        [true|false]    </filler>
  ?<track>         int             </track>
  ?<isMovement>    [true|false]    </isMovement>
  ?<isCoordinated> [true|false]    </isCoordinated>
  ?<isImpacting>   [true|false]    </isImpacting>
  ?<match>
    ?<trigger>
      ?<minEntitySpeed> float  </minEntitySpeed>
      ?<maxEntitySpeed> float  </maxEntitySpeed>
      ?<minEntityAux1>  float  </minEntityAux1>
      ?<maxEntityAux1>  float  </maxEntityAux1>
      ?<minModelYaw>    float  </minModelYaw>
      ?<maxModelYaw>    float  </maxModelYaw>Coor
      ?<capsOn>  capabilities  </capsOn>
      ?<capsOff> capabilities  </capsOff>
     </trigger>
    ?<cancel>
      ?<minEntitySpeed> float  </minEntitySpeed>
      ?<maxEntitySpeed> float  </maxEntitySpeed>
      ?<minEntityAux1>  float  </minEntityAux1>
      ?<maxEntityAux1>  float  </maxEntityAux1>
      ?<minModelYaw>    float  </minModelYaw>
      ?<maxModelYaw>    float  </maxModelYaw>Coor
      ?<capsOn>  capabilities  </capsOn>
      ?<capsOff> capabilities  </capsOff>
     </cancel>
    ?<scalePlaybackSpeed>  [true|false] </scalePlaybackSpeed>
    ?<feetFollowDirection> [true|false] </feetFollowDirection>
    ?<oneShot>             [true|false] </oneShot>En
    ?<promoteMotion>       [true|false] </promoteMotion>
   </match>
</action>
```

Example `.model` file describing action

The list below describes some of the tags in the XML file:

- **`name`**

  Name of that action as used by a script.

  These are available as named 'constants' off the model object returned by the Model Manager.

- **`animation`**

  The base animation whence the frame data is sourced.

- **`blendInTime`**

Time in seconds the action takes to completely blend in.

- **`blendOutTime`**

  Time in seconds the action takes to completely blend out.

- **`filler`**

  Specifies if the action is just padding and can be interrupted if anything else comes on the queue.

- **`track`**

  Track number in which the action should be played.

  If the action has a track, then the animation is blended on top of whatever other animations exist — *i.e.*, it bypasses the queue.

- **`isMovement`**

  Specifies that the action uses a simple movement animation such as walk, run, side-step, etc. The translation must be linear, and is subtracted from the action when played (so a run animation which moves from the origin will now appear to run on the spot). This setting requires the PromoteMotion flag to be set, and doing so means this translation then moves the model accordingly. If the model is owned by a client-controlled Entity, then the server-side entity's position will be updated accordingly. This setting allows the use of scalePlaybackSpeed. This setting cannot be used with isCoordinated and isImpacting.

- **`isCoordinated`**

  Specifies that the action's animation starts from an offset position. Used for actions that require coordination with a non-player character (NPC), which needs to be positioned relative to the player's character for the purpose of matching contact points (e.g. shaking hands). This setting cannot be used with isMovement and isImpacting.

- **`isImpacting`**

  Specifies that the action is a complex (non-linear) movement animation. If the entity is client-controlled, then its position on the server will also be updated. Examples of animations used with isImpacting are jumping, combat and knockdowns, interacting with entities, etc. This setting requires PromoteMotion and cannot be used with isMovement and isCoordinated.

- **`match`**

  If this section is present, it means the Action Matcher can automatically select the action (see below).

- **`trigger` (section `match`)**

  This section defines criteria used to determine when to start an action.

- **`minEntitySpeed` (section `trigger`)**

  Determines the minimum velocity of the entity for the action to start.

- **`maxEntitySpeed` (section `trigger`)**

  Determines the maximum velocity of the entity for the action to start.

- **`minEntityAux1` (section `trigger`)**

  Determines the minimum pitch of the entity for the action to start.

- **`maxEntityAux1` (section `trigger`)**

  Determines the maximum pitch of the entity for the action to start.

- **`minModelYaw` (section `trigger`)**

  Determines the minimum yaw of the model for the action to start.

- **`maxEntityYaw` (section `trigger`)**

  Determines the maximum yaw of the model for the action to start.

- **`capsOn` (section `trigger`)**

  Determines which special case character states need to be on for the action to start.

- **`capsOff` (section `trigger`)**

  Determines which special case character states need to be off for the action to start.

- **`cancel` (section `match`)**

  This section defines the criteria used to determine when to stop an action.

- **`minEntitySpeed` (section `cancel`)**

  Determines the minimum velocity of the entity for the action to stop.

- **`maxEntitySpeed` (section `cancel`)**

  Determines the maximum velocity of the entity for the action to stop.

- **`minEntityAux1` (section `cancel`)**

  Determines the minimum pitch of the entity for the action to stop.

- **`maxEntityAux1` (section `cancel`)**

  Determines the maximum pitch of the entity for the action to stop.

- **`minModelYaw` (section `cancel`)**

  Determines the minimum yaw of the model for the action to stop.

- **`maxEntityYaw` (section `cancel`)**

  Determines the maximum yaw of the model for the action to stop.

- **`capsOn` (section `cancel`)**

  Determines which special case character states need to be on for the action to stop.

- **`capsOff` (section `cancel`)**

  Determines which special case character states need to be off for the action to stop.

- **`scalePlaybackSpeed` (section `match`)**

  Specifies that the animation playback speed should be scaled as a function of the entity's speed. This setting requires isMovement.

- **`feetFollowDirection` (section `match`)**

  Specifies that the model should turn to track the Entity. In practice this means while this action is matched, the model rotates on the spot instead of playing a turning action.

- **`oneShot` (section `match`)**

  Specifies that the action will only be selected for playing once in a row by the action matcher. Note the distinction between this and filler, where filler is not related to the action matcher.

- **`promoteMotion` (section `match`)**

  Specifies that the motion of the root node within the animation should affect the model's position (and the owner entity's position, if the entity is client-controlled). This setting must be enabled for isImpacting or isMovement actions to work correctly. This setting cannot be used with filler.

The Python interface to a model's action queue allows actions to be played directly on that model, or a set of actions to be queued and played in sequence. Callback functions can be defined and played when actions are finished.

In Python, a model can be easily created and an action played on it, as illustrated in the example below:

```
class Jogger( BigWorld.Entity ):
  ....
def __init__( self ):
  self.model = BigWorld.Model( "jogger.model" )

def warmUp( self ):
  self.model.action( "StretchLegs" )()
...
```

Model creation in Python

9.1.5.1. Debugging animations

If a model is not being animated as it is supposed to, it is useful to display the Action Queue graph in the Python console.

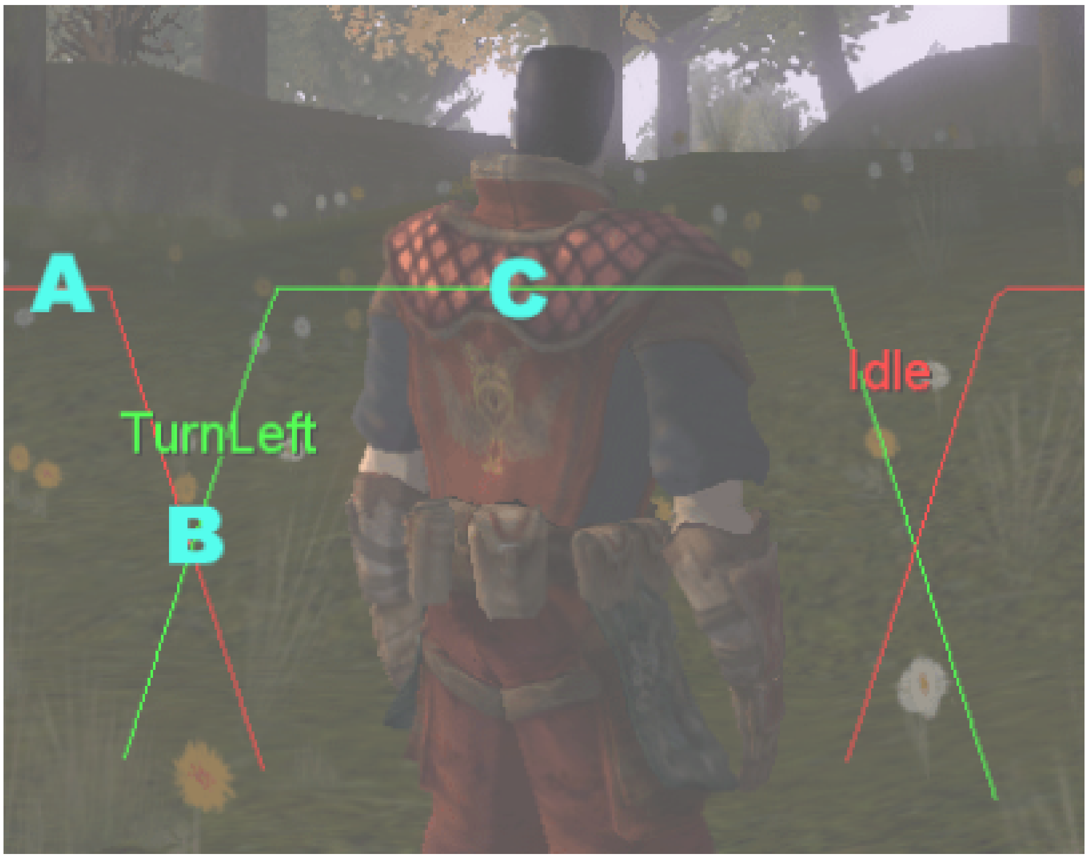
This is can be done by calling `BigWorld.debugAQ()` method, which can receive two kinds of arguments:

- **`PyModel`**

  Displays the graph for the specified model, with the blend weight of each action. Each action is represented in a different, arbitrarily chosen, colour.

- **None**

  Switches off the graph display.



Python console displaying Action Queue's debugging graph

The graph in the picture above displays the execution on the TurnLeft animation (in green) and the Idle one (in red). We can determine the animations that were being played in each labelled point in the graph:

- **A** — 100% of the `Idle` animation is being played.
- **Between A and B** — `Idle` animation is being blended in with `TurnLeft` animation.
- **B** — 50% of the `Idle` animation is being played, and 50% of the `TurnLeft` animation is being played.
- **C** — 100% of the `TurnLeft` animation is being played.

For more details, see the Client Python API.

Note

ModelEditor offers the same functionality for the model. For details, see the document Content Tools Reference Guide's section *ModelEditor* → “Panel summary” → “Actions panel”.

9.1.6. Action Matcher

Given a model, an action queue, and a set of actions, all behaviour of a game object/character can be specified by event-driven calls on the Action Queuer. This ends up with a heavy overhead, as many changes in object state need to directly call the object and solve which animation should be played.

The solution to this problem is to internalise most of the behaviour of a character in a system called the Action Matcher, which automatically updates an object's motion based on the object's state. It is a simple pattern matcher, picking an animation based on model's attributes such as speed, direction, etc.

State parameters such as speed, rotation, or power are exposed to the Action Matcher, which then selects the action that best maps to these parameters. This frees the game from having to handle many aspects of animation, allowing it to only have to update state parameters, such as position.

When there are no (unblended) actions in the Action Queue for a model (within the player's AoI), the Action Matcher takes over and plays an 'idle' action. It triggers these 'idle' animations to give the game world more life, since real living things are not still. It can also be used to automate menial animation tasks.

This class looks at all the actions that have a match section (see XML example in section “Action Queue” on page 48 , whose constraints are satisfied for the Action Matcher object controlling the model.

Scriptable constraints are tested against the capabilities bit fields `capsOn` and `capsOff`. The Action Matcher for a model has a set of capability bits, which value is controlled by script. An action will only be matched if all the capsOn bits are on and all the capsOff bits are off in the Action Matcher's set.

It then looks at the change in pose (position and orientation — as set by the filter) and selects the first action that matches this change for the time over which the change occurred. The trigger constraints are used to test most actions. The cancel constraints are used if the action that matched last frame is encountered. This feature is intended primarily to reduce action hysteresis.

The update function of an action-matched object takes the previous updated position of the object, chooses the best matched action from its matched action list, then plays the animation back at the correct speed to smoothly link action with speed. As a game character starts moving faster, the Action Matcher may choose a faster running cycle to play back and increase its playback speed to precisely match speed so no foot sliding is seen.

This method allows an AI system to define behaviour with respect to a few variables such as orientation, speed, and aiming direction, and the Action Matcher will convert these updated parameters into a smoothly moving character.

In a client/server architecture where position and orientation are updated over a network, the Action Matcher (combined with a filter) can automatically compensate for position jumps caused by network lag by having characters realistically run faster to the latest updated position.

When an action is loaded, its data is augmented with the effect on pose that performing the action would have on the root node. This information is used for the matching described above.

Now that an action has been selected, it is passed to the Action Queue. If the action supplied is the same as the previous action, it continues to be played in the normal fashion (*i.e.*, `frame += fps*deltaTime`). Otherwise, it is blended in over a few frames while the other is blended out.

9.1.6.1. Using the Action Matcher

Each action designed to be matched must define a <match> section. These are added via ModelEditor using the Actions window. The matching parameters are divided in two:

- **Trigger parameters** — Define when an action can be started, and
- **Cancel section** — Defines when an action should be stopped.

The minEntitySpeed and minEntitySpeed tags in each section define the velocities in which actions can and cannot be triggered or cancelled.

The auxiliary parameters can be used to define a pitch range that is used to match action. The minModelYaw and maxModelYaw tags define a yaw range. The main matching parameters define speed and orientation ranges that the action applies to, and also a user-defined set of matching flags that are used with special case character states. These flags can be used to set whether a game character is not using the basic action set, such as being injured or being angry.

The BigWorld engine uses the matchCaps parameter to store the bitwise flag set of an action. At any given time, the model itself will have an on/off flag set representing the state of these states, and this is tested against each action's matchCaps per frame.

A set of user-defined action states should be defined (created as a text file or as comment section in model file). A simple example is given in the list below:

- **Capability flag: 1** — State: Angry
- **Capability flag: 2** — State: Happy
- **Capability flag: 3** — State: Sad

A set of angry animation can now be accessed using the action matcher by just adding the angry flag to the current matchCaps.

In Python code, a simple example of a character that should now move and behave in an angry manner is shown below:

```
class AngryMan( BigWorld.Entity ):
  ....
def onEnterWorld( self, prereqs ):
  self.am = BigWorld.ActionMatcher( self )

def enterAngryMode( self ):
  self.am.matchCaps = self.am.matchCaps + [1]
...
```

Python implementation of character in angry mode

By using the Action Matcher this way, a character's natural motion can be fleshed out without having to explicitly call any function to play animations. Specific event-based actions should still be called directly via the Action Queue structure, but the background behaviour of the character can be completely defined using the ModelEditor tool and setting matching flags appropriately in the code base.

9.1.7. Trackers

A tracker applies inverse kinematics to nodes in the entity's model so that they appear to point to a position defined by a given 'target' entity. An entity may have any number of trackers.

To add a tracker to an entity, use a script call like this:

```
tracker = BigWorld.Tracker()
tracker.dirProvider = DiffDirProvider(
  self.focalMatrix, target.focalMatrix )
tracker.nodeInfo = BigWorld.TrackerNodeInfo(
  model,
  primaryNode,
  secondaryNodeList,
  pointingNodeName,
  minPitch, maxPitch,
  minYaw, maxYaw,
  angularVelocity )
self.model.tracker = tracker
```

Adding tracker in Python

The parameters for the `BigWorld.TrackerNodeInfo` method are described below:

- **`model`**

  PyModel that owns the nodes that the tracker will affect.

- **`primaryNode`**

  Primary node reference.

  Node references are built up from the entity's independent model (the first one if there are multiple) following a path of attachment points and ending in a node name. This allows trackers to transparently work through attached models (*i.e.*, they are treated as if they are welded onto the model's skeleton).

  This is more important for Supermodels (for more details, see “SuperModel” on page 66), where characters are built out of multiple model parts.

- **`secondaryNodeList`**

  List of secondary nodes, containing tuples of the form (node, weight).

  These have the same transform performed on them as on the primary node, in proportion with the weight amount. Actually, all the weights (including the primary node, with a weight of 1.0) are summed, and each node gets their weight proportion of this total applied to them.

- **`pointingNodeName`**

  Name of the node providing the frame of reference used for tracker manipulations.

  If the node specified is not present, then the model's scene root is used.

- **`minPitch`**, **`maxPitch`**, **`minYaw`**, **`maxYaw`**

  Limits on the turn that the tracker is permitted to apply, in degrees.

- **`angularVelocity`**

  Speed at which a tracker will turn the PyModelNode instances that it influences, in degrees per second.

9.1.8. Timers and Traps

These are generic helper services provided to entity scripts.

A script can set timers to have itself called-back at a certain time, as illustrated in the example below:

```
BigWorld.callback( afterTime, fn )
```

Traps use a slightly different interface:

```
trapRef = self.addTrap( radius, function )
```

A trap goes off if any entity wanders within the given radius of the entity it is created on, and can be cancelled with the self.delTrap method.

There are two other types of trap, optimised for their specific need, as discussed in the following sections.

9.1.8.1. Pot

A Pot is a 'player-only-trap', and is triggered only by the player entity. Due to this, it is a lot cheaper to use than a general trap.

A Pot is added given a matrix provider, a radius, and a script callback for triggering.

```
potHandle = BigWorld.addPot( trapMatrix, radius, callback )
```

9.1.8.2. Mat

A Mat is a 'matrix trap', and is triggered when an area is triggered by another. This makes sense only because matrix providers are dynamic. The areas are defined as:

- Source-matrix translation and a bounding area given by the scale of the x-, y- and z-axes in that matrix.
- Destination-matrix translation of destination matrix (treated as a point).

A Mat is defined in Python as listed below:

```
matHandle = BigWorld.addMat( sourceMatrix, callback, destMatrix )
```

9.2. Personality script

The personality script is a Python script used to handle several callbacks from the BigWorld engine for initialisation, cleanup, input handling, and environment changes. It can also implement client functionality that does not belong to any particular entity in the game, such as the game start screen.

Its name is defined in the file specified by the `resources.xml`'s `engineConfigXML` tag, in the `personality` tag — for more details, see “File <*engine_config*>`.xml`” on page 12 .

The personality script generally declares a class to contain all data to be shared by functions in the script, and declares a global variable using the constructor of that class. For example, a personality script may include the following code:

```
class SharedData:
  def __init__( self ):
    self.settings = ""

# initialise the shared data object for this personality script
sd = SharedData()

# This callback is called by BigWorld when initialising
def init( configSect ):
  # save the configSect object for later use
  sd.configSect = configSect
```

Example of personality script

The sections below describe the available personality callbacks.

9.2.1. `init`

The callback has the following syntax:

```
init(scriptsConfig, engineConfig, preferences, loadingScreenGUI = None)
```

The script is called once, when the engine initialises, and receives the arguments below:

- **`scriptsConfig`**

`PyDataSection` object containing data from XML file defined in `resources.xml`'s `scriptsConfigXML` tag (for details, see “File <*scripts_config*>.xml” on page 13).

- **`engineConfig`**

  `PyDataSection` object containing data from XML file defined in `resources.xml`'s `engineConfigXML` tag (for details, see “File <*scripts_config*>.xml” on page 13).

- **`preferences`**

  `PyDataSection` object containing data from the `scriptsPreference` section of the file specified in the `preferences` tag of the file specified in `resources.xml`'s `engineConfigXML` tag (for details, see “File <*preferences*>.xml” on page 13).

- **`loadingScreenGUI`**

  Optional argument representing the loading screen GUI, if one was defined in `resources.xml` (for details, see “File <*preferences*>.xml” on page 13).

The available read functions are listed below:

- **`readBool`**
- **`readFloat`**
- **`readFloats`**
- **`readInt`**
- **`readInts`**
- **`readMatrix34`**
- **`readString`**
- **`readStrings`**
- **`readVector2`**
- **`readVector2s`**
- **`readVector3`**
- **`readVector3s`**
- **`readVector4`**
- **`readVector4s`**
- **`readWideString`**
- **`readWideStrings`**

To read data from PyDataSection, call the read function that relates to the data type, passing in the section name as the first argument, and the default value as the second argument. The plural read functions (ending in 's') read the contents of all matching subsections of the specified section, and return the results as tuple of values. You can refer to sub-sections by using the forward slash.

For example:

```
username = userPreferences.readString("login/username", "guest")
```

You can also reference to subsections of a PyDataSection by calling the section name prefixed with an underscore.

For example:

```
username = userPreferences._login._username.asString
```

9.2.2. `fini`

The callback has the following syntax:

```
fini()
```

This is script is called when the client engine shuts down. It is used to do any cleanup required before the client exits. This is a good place to perform a logout procedure on the player to logout gracefully.

For example:

```
# note: you must set up a logOff method as a base method in the
# def file of the class that the player is using.
def fini():
  try:
    BigWorld.player().base.logOff()
  except:
    pass
```

Example of `fini()` implementation

9.2.3. `handleKeyEvent`

The callback has the following syntax:

```
handleKeyEvent( event )
```

The event argument is a PyKeyEvent which contains information about the key event. See the Python Client API document for details.

Generally, several systems can process keyboard input, so the arguments are passed to a `handleKeyEvent` method on each system in turn, until one returns a Boolean value of True, indicating that it has processed the key event.

For example:

```
def handleKeyEvent( event ):
  global rds

  # give the chat console a go first
  if rds.chat.editing:
    if rds.chat.handleKeyEvent( event ):
      return True
  # try the gui
  if GUI.handleKeyEvent( event ):
    return 1
  # now do our custom keys
  if not event.isKeyDown(): return False # we are not interested in key
releases
  if event.key == KEY_RETURN and event.modifiers == 0:
    rds.chat.edit( True )  # bring up the chat console
    return True

  # return False because the key event has not been handled
  return False
```

Example of `handleKeyEvent()` implementation

Note that the engine also calls the `handleKeyEvent` method on the entity that the player is controlling. All keys related to player control are handled there.

9.2.4. `handleMouseEvent`

The callback has the following syntax:

```
handleMouseEvent( event )
```

This script is called whenever the mouse moves, and is given an instance of PyMouseEvent. It operates similarly to handleKeyEvent.

For example:

```
def handleMouseEvent( event ):

  # try the gui
  if GUI.handleMouseEvent( event ):
    return True

  # return False because the mouse event has not been handled
  return False
```

Example of `handleMouseEvent()` implementation

9.2.5. `handleAxisEvent`

The callback has the following syntax:

```
handleAxisEvent( event )
```

This script is called whenever a joystick axis event occurs, and is given an instance of PyAxisEvent.

For example:

```
def handleAxisEvent( event ):

  # try the GUI
  if GUI.handleAxisEvent( event ):
    return True
  # return False because the axis event has not been handled
  return False
```

Example of `handleAxisEvent()` implementation

9.2.6. `handleIMEEvent`

The callback has the following syntax:

```
handleIMEEvent( event )
```

This is called when an Input Method Editor (IME) related event occurs and is used to update the GUI respectively, and is given a `PyIMEEvent` object as it's first parameter. See *Input Method Editors (IME)* on page 103 for details on IME support.

9.2.7. `handleLangChangeEvent`

The callback has the following syntax:

```
handleLangChangeEvent()
```

This event occurs whenever the current input language has been changed by the user. It is useful for tasks such as updating language indicators on GUI edit fields.

9.2.8. `onChangeEnvironments`

The callback has the following syntax:

```
onChangeEnvironments( inside )
```

This script is a callback acknowledging the environment type the player is currently in.

Currently there are only inside and outside environment types. The argument is a Boolean value indicating whether the player is inside or not. This may be useful for modifying the behaviour of the camera in third person mode.

For example:

```
def onChangeEnvironments( inside ):
  global sd
  sd.inside = inside
  sd.updatePivotDist()
```

9.2.9. `onGeometryMapped`

The callback has the following syntax:

```
onGeometryMapped(spaceID, spacePath)
```

This callback method tells the player entity about changes to the geometry in a space. It is called when geometry is mapped into any of the currently existing spaces on the client. The space ID and the name of the space geometry are passed as parameters.

The first parameter is the ID of the space the geometry is being mapped in to. The second parameter is the name describing the space's geometry.

9.2.10. `onRecreateDevice`

The callback has the following syntax:

```
onRecreateDevice ()
```

This script is a callback alerting the scripts that the Direct3D device has been recreated. This often occurs when the screen resolution is changed.

This callback was introduced primarily so that scripts can re-layout their GUI component scripts, but it is also useful for recreating any static `PyModelRenderer` textures (since these do not automatically update, unless they are dynamic).

For example:

```
def onRecreateDevice():
  (width,height) = GUI.screenResolution()
  myGuiController.doLayout( width, height )
  myRenderers.recreateTextures()
```

9.2.11. `onTimeOfDayLocalChange`

The callback has the following syntax:

```
onTimeOfDayLocalChange( gameTime, secondsPerGameHour )
```

This script is a callback to allow scripts to be notified of changes in the game time.

It is passed two floats as arguments: the first one is the game time in seconds, and the second is the number of real-time seconds per game hour.

9.2.12. `start`

The callback has the following syntax:

```
start()
```

This script is called after the engine has initialised, and used to start the game. It may be used to bring up a start menu, or login screen.

Chapter 10. Models

For the purposes of the BigWorld client, a model is a self-contained unit of geometry that can draw itself into a 3D scene at the location of a world-space transform matrix. Moreover, all models may have animations that alter their appearance over time — some models explicitly support animations of their nodes (which are skinned), whereas the others are animated by displaying alternate geometries.

Moo, the BigWorld 3D engine, currently exports three kinds of objects that may be used as models:

- Meshes with skeletons.
- Meshes without skeletons.
- Billboards (a special form of simple geometry).

However, the model concept in the BigWorld client encapsulates anything that fits into the definition above, and the implementation is easily extended to incorporate new kinds of objects.

Moo names its meshes *visuals* (visuals actually include a good deal more than a simple polygon mesh. They can have groups of meshes, bones, envelopes, materials, and a hierarchical skeleton too) and `.visual` files can be readily created from a 3ds Max model using a BigWorld exporter. Node-based animations can also be created with the exporter. A .model file can then be created with the tool ModelEditor, so that the visual and its animations are tied together. Model files that are billboards or static meshes (and their animations) can also be created with ModelEditor.

A model file can also specify a simpler parent file to be used when drawn in the distance. Chains of parent model files thus formed are known as level-of-detail (LOD) chains.

10.1. Performance

In order to improve rendering performance, a model can be flagged in ModelEditor to be batch rendered, which results in the creation of the `batched` tag in the generated model file (for details, see the document Content Tools Reference Guide's section *ModelEditor* → “Panel summary” → “Object Properties panel”).

The batch rendering works by caching per-instance data (essentially lighting conditions and transforms) at traverse time, and once the scene has been traversed, rendering all instances at the same time, only updating the data necessary for each render. This saves the engine from setting vertices, indices, and textures multiple times for batched models. It does use a bit more memory, but gives a considerable performance boost.

It is advisable to use the batch flag on models with many instances of it in the scene. In FantasyDemo, the batch flag is used on trees, guards, striffs, chickens, and the guard's guns. Please note that the flag does not affect models that use tints.

10.2. Hard Points

Hard points, or attachment points, can be conceived as logical patches of Velcro that allow us to stick a gun in a hand, sling a backpack over a shoulder, or place a security camera on a turret. The artists must embed hard points in their .visual files using dummy nodes.

Hard points use well-defined names, preceded by 'HP_' prefix, so that entities can scan for hard point nodes. The significant information is:

- Name.
- Position.
- Orientation.

This information allows the developer to attach any object to any other, within the constraints of game logic.

Examples of hard points include:

- `HP_LeftHand`
- `HP_RightHand`
- `HP_Shoulder`
- `HP_Belt1`

10.2.1. Naming scheme

In order to avoid the need for an intermediate step, there needs to be an explicit pairing between character hard points and item hard points. Every item needs a hard point for every specific way that it can be held.

As an example, listed below are the hard points for a human character and a gun.

- **In `human.model`:**
  - `HP_Left_Hand`
  - `HP_Right_Hand`
  - `HP_Belt_1`
  - `HP_Belt_2`
  - `HP_Belt_3`
  - `HP_Belt_4`
  - `HP_Shoulder`
  - `HP_Blade_Lower`
  - `HP_Blade_Upper`
- **In `gun.model`:**
  - `HP_Left_Hand`
  - `HP_Right_Hand`
  - `HP_Belt_2`
  - `HP_Shoulder`

10.2.2. How it works

The (client-side) Entity class provides a list of hard points, but only if asked by the specializing class. For example, when a model is loaded, it will find all nodes prefixed with (for instance) 'HP_'. These are then stored in a hardPoint list that is owned by the model.

When an item is equipped, the entity/game arbiter will be asked to match up the item with the correct hard point. For example, if the 'next weapon' button is pressed, the next weapon in the inventory can be attached to the right hand hard point.

10.2.3. Syntax

The syntax for using hard points from Python is elegant and powerful. To attach model gun to model avatar on hard point hand, use the following syntax:

```
avatar.hand = gun
```

A model is checked when it is attached to ensure that it is not attached elsewhere. To retrieve the model attached to avatar's hand, simply use:

```
model = avatar.hand
```

If no model is attached, then None is returned.

The model is attached by reference, not by copy, so anything that can be done to the original model reference can be done to the reference retrieved from a hard point.

For example, gun.Shoot() and avatar.hand.Shoot() have the same effect.

10.2.4. Data

A model definition is an XML file specifying:

- A base model definition reference (optional).
- The visual defining the mesh.
- The animations the mesh can use.
- The actions that the model can perform (for more details, see “Action Queue” on page 48).

The ModelEditor tool is used to create a .model file that links an object's geometry to its animations and defines the sets of animations/actions that are possible to play on this object.

As with all resource files in the BigWorld framework, .model files are in XML format. They are hierarchical and inherit data from their parent(s), in this way basic animations that apply to a large set of characters can be isolated from more character-specific animations without having to be duplicated.

The example below defines a very simple model:

```
<jogger.model>

  <nodefullVisual>  jogger  </nodefullVisual>
  <parent>          biped   </parent>

  <animation>
    <name>      jog         </name>
    <frameRate> 30.0        </frameRate>
    <nodes>     jogAnim     </nodes>
    <alpha>
      <Torso>   0.0  </Torso>
      <Pelvis>  1.0  </Pelvis>
    </alpha>
  </animation>

  <action>
    <name>          BIPED_JOG  </name>
    <animation>     jog        </animation>
    <blendInTime>   0.300000   </blendInTime>
    <blendOutTime>  0.300000   </blendOutTime>
    <filler>        false      </filler>
    <blended>       false      </blended>
    <isMovement>    true       </isMovement>
    <isCoordinated> false      </isCoordinated>
    <isImpacting>   true       </isImpacting>
    <match>
      <trigger>
        <minEntitySpeed> 1.0  </minEntitySpeed>
        <maxEntitySpeed> 3.0  </maxEntitySpeed>
        <capsOn>         16   </capsOn>
      </trigger>
    </match>
  </action>
<jogger.model>
```

Example of `.model` file

This file describes a character (`jogger`) which has a geometry defined by the visual file jogger and has a standard set of biped actions via the `<parent>` tag, which may include walk, run, and jump animations, but also specifies a jog animation.

The animation section includes:

- Name of the animation.
- Frame rate at which the animation should normally be played at.
- Tag `<nodes>`, which refers to the name of the animation file that contains the raw keyframe data.

The `<action>` section describes the action name that is used to play this action from the Python code.

10.3. SuperModel

A SuperModel is a collection of models that need to function as one. The SuperModel class is a utility class that forms a flexible basis for modules that want to use models. It is used for the static models specified in chunks, and the dynamic models that entities can manipulate.

The SuperModel provides an efficient representation (both in memory and in CPU) of a conceptual model. The supermodel is made up of selectable parts, and these parts have an inheritance tree for specifying animations, actions, material overrides, and most importantly, lower level of detail (LOD) parts that may be substituted at appropriate distances.

The supermodel brings all these parts and their adornments together into one conceptual model that automatically takes care of the complexity that arises from the multi-part and LODing features.

An example of the most basic SuperModel is a single mesh, which has been exported from 3ds Max using the BigWorld exporter; into the format understood by the 3D engine Moo.

SuperModels do not live in the scene graph or in chunks, and provide no interfaces to the scripting system. These matters are left up to higher-level classes, which are encouraged to use SuperModel for all their model needs.

10.3.1. Design

There are model files, with the .model extension, but there are no explicit SuperModel files.

There is the SuperModel class, which holds together and controls the animation and rendering of a number of models. A SuperModel is created based on information in chunk and model files (these are instance-like classes — there is nothing analogous to PyModelInfo.).

Using LOD ratios, the SuperModel class can manage the transition between, say, an avatar being rendered at a high LOD using three separate models, to it being rendered at a low LOD using just one.

Animations are accumulated on the same inheritance hierarchy, and the animation most appropriate to the current LOD level is used. All the animations for all the LOD levels are interpreted and selected from a flat namespace. Attempting to play an animation that does not exist (or does not exist at the current LOD level) selects an infinite length animation of the model's initial pose. Care must be taken to ensure that multi-model SuperModels do not waste time animating unnecessarily (*e.g.*, when all the small parts have an animation overriding the whole part's animation, it would be a waste of time to apply the whole part's animation).

The mesh files themselves specify how a part is connected to others for multi-part supermodels.

10.3.2. SuperModel classes

The SuperModel class implements the basic functionality of the BigWorld model definition, using the objects provided by Moo. It combines a number of the .model files created by ModelEditor (but usually just one) into one conceptual model, managing any animations and level-of-detail chains. The SuperModel class is detailed in “SuperModel” on page 66 .

Two classes currently use SuperModels in the BigWorld client, for two different needs:

- ChunkModel
- PyModel

Both are described in the following subsections.

10.3.2.1. ChunkModel

A ChunkModel is a model that inhabits the static scene base (*e.g.*, rocks, trees). Together with the terrain, it populates the client world and forms the majority of interesting scenery.

All ChunkModels are added to the collision scene for their chunk, unless flagged otherwise. They may optionally play one animation, at a specified speed multiplier — otherwise they are static.

They depend heavily upon the services of their SuperModel, supplying only the interface required to live in a chunk, and the simple instructions to play back their single animation.

10.3.2.2. PyModel

This class implements the model as it appears to the scripting environment.

It allows scripts to perform the following operations:

- Fetch bound actions sourced from the model's definition.
- Reference hard points (for details, see “Hard Points” on page 63).
- Specify position, rotation, and scaling.
- Add motors to move itself around in the scene (such as an Action Matcher).
- Add trackers for inverse kinematics.
- Add particle systems tied to any node.
- Control the generation of footsteps and dust particles.
- Control visibility and shadows.

Chapter 11. Animation System

The animation system in the BigWorld engine combines many sophisticated techniques that are accessed via an easy-to-use interface. This system allows game developers to quickly create lifelike characters and environments. The problem this system solves is taking the raw content that is created by artists and integrating it into a believable dynamic game world.

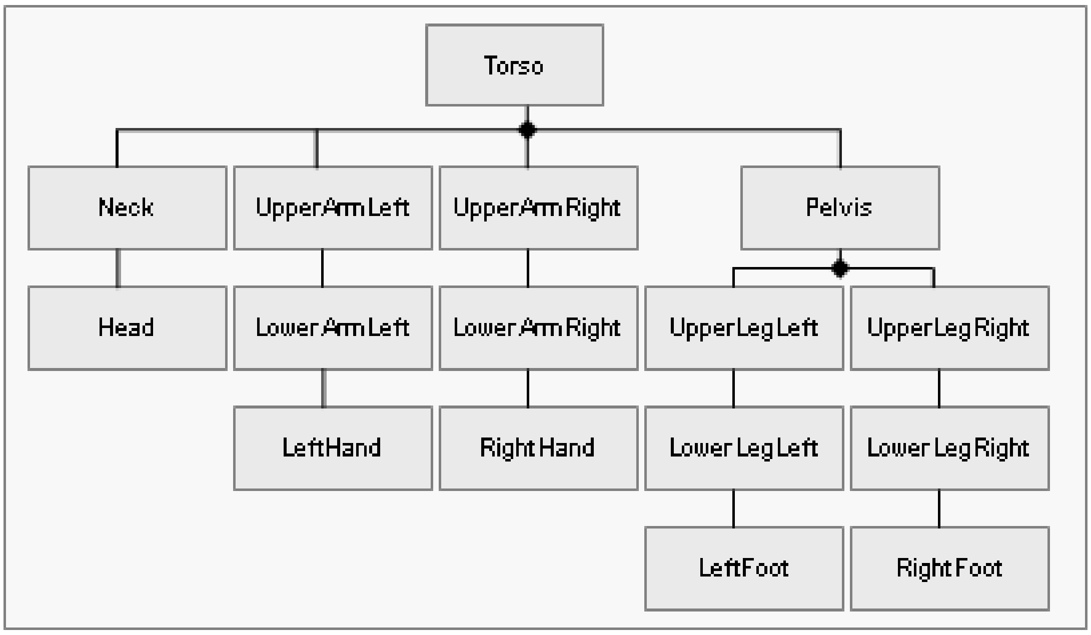
Artists working on design tools such as 3ds Max or Maya can create models and animations, then use the BigWorld Exporter plug-in to export them into data files of a format understandable by the graphics engine.

The ModelEditor tool can be used to view these models and play back animations. It is then used to create a list of actions from these animations that are the Python-accessible interfaces within the game engine.

11.1. Basic keyframed animations

The motions of an object over time can be stored as an array of keyframes that describe the position, rotation, and scale of an object (or part of one) at different points in time. These keyframes are then used as reference values and intermediate positions and rotations are calculated by interpolating between keyframe data.

More realistic intricate objects are described as nodal trees representing a bone hierarchy. An example is a simple biped character that would have a typical hierarchy shown below:



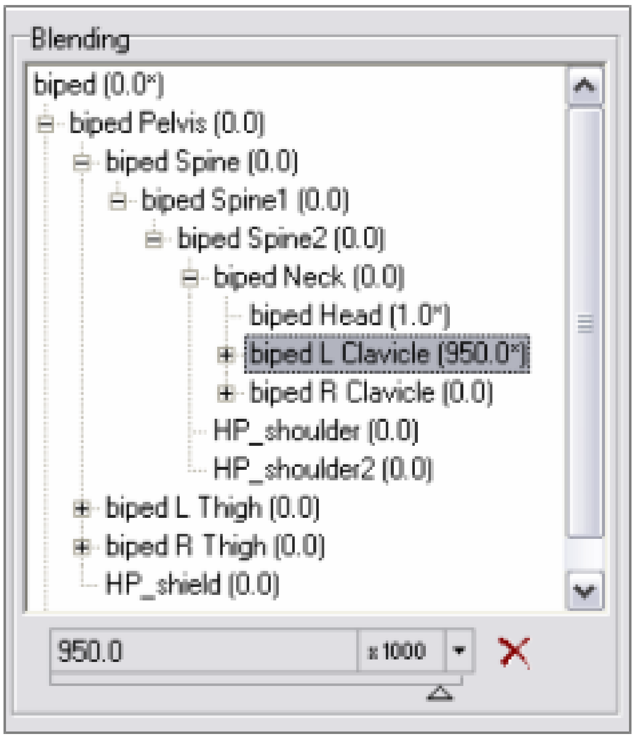
Typical biped hierarchy

Each node represents the spatial state of a part of an object. These can map to rendered geometry either directly for rigid objects such as a hydraulic machine or as bone transforms that are used to update a skinned mesh (each geometry vertex having a set of weights that define how each bone influences its movement).

11.2. Animation layering and blending

A simple animation such as a man waving may consists of keyframe arrays from a subset of the whole bone tree, *e.g.*, only for `Torso`, `UpperArmRight` and `LowerArmRight`.

A different animation of the man walking may include only the `Torso` and `Pelvis` sub-tree. These two animations can be seen as different layers of the total movement. Within the BigWorld framework, this layering is achieved via setting nodal alpha values with the ModelEditor tool, as illustrated below:


Blending

biped (0.0*)
biped Pelvis (0.0)
biped Spine (0.0)
biped Spine1 (0.0)
biped Spine2 (0.0)
biped Neck (0.0)
biped Head (1.0*)
biped L Clavicle (950.0*)
biped R Clavicle (0.0)
HP_shoulder (0.0)
HP_shoulder2 (0.0)
biped L Thigh (0.0)
biped R Thigh (0.0)
HP_shield (0.0)

950.0 x 1000

ModelEditor 'Blending' fields

Within the engine, different layers can be seen to be played on different animation tracks, which control the stopping and starting of animations for particular parts of the body (the usual separation into upper and lower body allows motion and action to be dealt with smoothly yet independently within a game).

It is possible to play an arbitrary number of animations at once and have the resulting motion be a blended interpolation of all the animations. This is essentially the same procedure as keyframed interpolation, as we are interpolating position, rotation, and scale data. When the different animation layers need to be combined into a single motion, the nodes that overlap in the different tracks need to be blended together.

Transitions between animations could be achieved by creating all possible animation transitions and allowing all animations to complete their cycle before starting a new animation.

A much more adaptable and robust method is to blend out ending animations and blend in starting animations over a period of time. As long as the animation list is large enough to account for possible jarring transitions. For example, instead of having only stand and run animations, include also walk and jog ones, then this system combined with good animations creates smooth lifelike behaviour in game characters.

11.3. Animation data files

The BigWorld exporter outputs the following data files (all file types exported to the resource tree `<res>`):

- **`.visual` files**

  Define an object's bone structure and material data.

- **`.primitive` files**

  Define the vertex data such as offset and weighting values for a skinned object, and contain BSP data where appropriate.

- **`.animation` files**

  Define the keyframe data of an animation.

11.4. Animation data streaming

Animation data is stored as a series of blocks that are asynchronously streamed into memory on demand.

The sum of all these blocks is referred to as the streamed block cache, which size is constrained to prevent excessive memory usage. To specify the size of the cache, set the `animation/streamChacheSizeKB` tag in `<engine_config>.xml` (for details, see "File `<engine_config>.xml`" on page 12)

The watchers `Memory/StreamedBlocks_CacheSize` and `Memory/StreamedBlocks_CacheMaxSize` display the current size and the limit of the cache in bytes, respectively.

11.5. Actions

An action is a wrapper object that links an animation to in-game behaviour and events. Action objects differ from animation ones in the information they hold, as described below:

- **Animation object**
  - Raw keyframe data.
  - Information on frame rate.
  - Functionality on how to play itself on a model.
- **Action object**
  - Blending time information.
  - Information on whether action is loop.
  - Information on whether an animation is movement.
  - Animation-matching data specifying particular object state values for when a particular action should be played.

The raw data describing an action is defined in a `.model` file in XML format (located in any of the various sub-folders under the resource tree `<res>`, such as for example, `<res>/environments`, `<res>/flora`, `<res>/sets/vehicles`, etc...).. This data is produced from the ModelEditor tool.

For details, see "Action Matcher" on page 53 .

Chapter 12. Server Communications

The communication with the server uses a low-level UDP-based protocol named Mercury. Mercury is described in detail in the document Server Overview's section “Inter-Process Communication (Mercury)”.

Server communication is accessible from both C++ and Python scripts.

Note

This section is only applicable for a full client/server BigWorld implementation.

12.1. Login

To log in, the client sends a UDP packet using Mercury to the login server, on a well-known port. The packet contains all the account and character information required to authenticate the client and select a character.

If login is successful, the login server adds an entity for the character to the BigWorld server system, and refers the client to a proxy server, which handles all in-game communication. Both sides then begin sending data to each other. For more details on the login process, see the document Server Overview's section *Design Introduction* → “Use Cases” → “Logging In”.

12.2. Online

A Mercury channel is created between the proxy and the client. Only selected data that is classified as reliable is resent in the event of a dropped packet. Due to the average packet rate, and the expected network latency, a packet is classified as dropped if a packet with a higher sequence number is received before it is.

Since the client is operating in high-latency conditions, the server does not wait for dropped packets to be resent before delivering other pending information to the client. The client must therefore cope with receiving out-of-order messages of all kinds.

Messages are sent to the server through a `ServerConnection` class. The position of the player is sent to the server 10 times a second. Messages are received from the server by this class during the input loop, and dispatched to their handlers in the Entity Manager.

- **The types of messages that the server can send to the client are as follows:**

  - **`enterEntity`**

    Informs the client that the entity with the given ID has entered its AoI.

  - **`leaveEntity`**

    Informs the client that the entity with the given ID has left its AoI.

  - **`createEntity`**

    In response to a query from the client, provides the type and other immediate data of the entity.

  - **`avatarUpdate`**

    Updates the position of an entity that has a volatile position.

    These messages are sent unreliably (*i.e.*, they are not resent if the packet is lost).

  - **`entityMessage`**

Sends a script message to, or updates a property of the client representation of an entity.

- **The types of messages that the client can send to the server are as follows:**
  - **`avatarUpdate`**

    Informs the position of the client's player entity to the server.
  - **`requestEntityUpdate`**

    Requests information about the entity with the given ID that has just entered the client's AoI.

    This works by effectively setting the entity's last update time (to the requesting client) to the time contained in this message.

    Properties that have been changed since that time are resent.
  - **`entityMessage`**

    Sends a script message to the server side of an entity (either on the base or on the cell).

12.3. Firewalls

The bane of mass-market online gaming is the firewall, especially the corporate ones. Our protocols have been designed to work smoothly through all but the most paranoid of firewalls.

From the firewall's point of view, it should appear that the client has initiated both the login and the proxy packet streams — since the login reply packet contains the address of the proxy server to send to, the client can immediately begin sending data, which makes it appear to the server it has initiated this stream too, *i.e.*, it 'punched a hole in the firewall'.

The BigWorld server correctly handles the case where it sends data to the client (which may be lost if the client is behind a firewall) before the client has sent any data to it — the lost data is resent.

All that the firewall needs to support for these protocols to work is the storing of a UDP reply mapping entry when it forwards an outgoing packet, so that a when a reply packet arrives with exactly reversed addresses (the source and destination IP and port are swapped from the request packet), it is forwarded back to the requesting client. This is the same requirement as that of the ubiquitous Internet Domain Name Service (DNS), which practically all firewalls support.

The BigWorld server does not require the client to make requests from any particular port, so it is not confused if a firewall masquerades the port as well as the IP.

Chapter 13. Particles

A particle is a textured rectangle or a small mesh that can be drawn quickly and simply, usually with an additive blend mode. They are mostly used to create interesting graphical effects.

Particles are managed within particle system objects, which keep track of a number of particles with similar properties, and an identical function pipeline to describe the transition of its particles' properties.

13.1. Particle Systems

The particle system is implemented in C++ and is accessible from both the scripting environment and C++. The Python module for particle systems is named Pixie.

Each particle system is presently responsible for a set of particles of the same texture. While a particle system can change its particle texture colour dynamically, effects that require different simultaneous textures require separate particle systems.

A particle system is a conglomerate of the following:

- Particles. This is a container that has specific allocation requirements determined by the renderer type. Currently there are contiguous particles, which have optimal insert/erase characteristics; and FixedIndex particles, these behave like a circular buffer and ensure that particle indices remain constant over their lifetime. FixedIndexParticles are a requirement for trail rendering and mesh particle rendering.
- Particle Actions, which are responsible for the movement of particles (these actions do all the work of moving, creating and destroying each particle).
- Particle Renderer, which is in charge of drawing the particles.

The Particle System itself provides a common access point for all three objects.

The Particle Renderer is for the most part hidden within the particle system. Likewise, the particles themselves are inaccessible to the outside. Most game code associated with the Particle System involves the creation of special Particle Actions.

Particle Actions work only during the update phase of the client. They are called in turn during the tick method for a particle system, and the combined actions of each produce the overall particle effect of the system.

For each particle system class, there is a corresponding python wrapper class. For example, `MetaParticleSystem` is wrapped by `PyMetaParticleSystem`. These python wrappers hold no state, they only hold a smart pointer reference to the underlying C++ object. The reason for this separation between the C++ object and their python equivalent is to allow the full construction of particle systems in the background thread (Python objects may only be constructed in the main thread.)

There is one more particle system class, which is the ChunkParticles class. This is entirely C++ and implements a ChunkItem for particle systems, it allows particle systems to be placed in the world via the WorldEditor tool. Note that such particle systems should be automatically time triggered, as there is no way to access them at run-time in python and turn them on or off.

At present, the procedure for using a particle system involves the following steps:

- Particle System is created using Particle Editor.
- Particle Editor is used to create the different types of Particle Actions that control the particles.
- Any texture and material effects are set.
- Particle System is added to a model, in order to be displayed and updated.

Particle Systems can easily be created in the BigWorld ParticleEditor and saved as XML files — typically under folder the resource tree `<res>`. In the client, they can either be placed directly into the scene using the World Editor, or invoked from Python as such:

```
import Pixie
ps = Pixie.create( "my_particle_system.xml" )
BigWorld.player().model.node( "biped head" ).attach( ps )
```

Note that particle systems can take a reasonably long time to construct - for a moderately complex system it might take 5ms to parse the xml file, create all the subsystems and hook them all up together. For this reason, it is highly recommended that the script-writer load Particle Systems asynchronously, using either the Pixie.createBG method, the BigWorld.loadResourceListBG method, or using Entity prerequisites. For example:

```
Example 1:

import Pixie
ps = Pixie.createBG( "my_particle_system.xml", self.onLoadPS )

def onLoadPS( self, ps ):
  BigWorld.player().model.node( "biped head" ).attach( ps )


Example 2:

import BigWorld
BigWorld.loadResourceListBG( ("particles/one.xml", "particles/two.xml"),
 self.onLoadResources )

def onLoadResources( self, resources ):
  self.model.root.attach( resources["particles/one.xml"] )
  self.model.root.attach( resources["particles/two.xml"] )
```

13.2. Particle Actions

There are four main categories of Particle Actions:

- **Source**

  Creates particles

- **Movement**

  Changes the velocity or position of the particles based on a set of rules. One movement action is special as it applies the effect of velocity onto the position of each particle.

- **Sink**

  Removes particles from the list of active particles according to a set of rules.

- **Alteration**

  Changes the appearance of the particles.

13.2.1. Source actions

Source actions can create particles over regular periods of time, on demand, or even be sensitive to the movement of the model to which it is attached. The size, colour, velocity, position, and even age of the particles can be specified upon creation. The key behind vector descriptions of particles is the Vector Generation subsystem.

Each source action requires three vector generators. A vector generator is a class of objects that randomly create vectors within a given space; the space is usually defined by the type of generator and the parameters given to it. For example, a sphere generator may accept a point in 3D space and a radius value, while a line generator may accept two points in 3D space.

The three generators are used to find the initial position, velocity, and colour of the particle when created. When calculating position and velocity, the local space of the model is taken into account, but only for the creation of the particle. What this means is that a cube described by two points, (-0.5, -0.5, -0.5) to (0.5, 0.5, 0.5) is roughly the bounding box of the particle in position.

13.2.2. Movement actions

Movement actions act on every particle in the system. There is a variety of movements that can be applied to a particle. Examples would be force, stream, barrier, and jitter.

Basic movement of particles due to velocity is calculated automatically within the particle system, taking wind also into account.

Particles can also undergo full scene collision — *e.g.*, spent bullets tumbling down steps.

13.2.3. Sink actions

Sink actions remove particles from the system, whether it is due to age or for moving beyond a specified boundary. Examples of sink actions are *sink*, *barrier,* and *splat*.

It is important to note that without sink actions, particles once created will never leave the system, eventually forcing it to hit its particle limit.

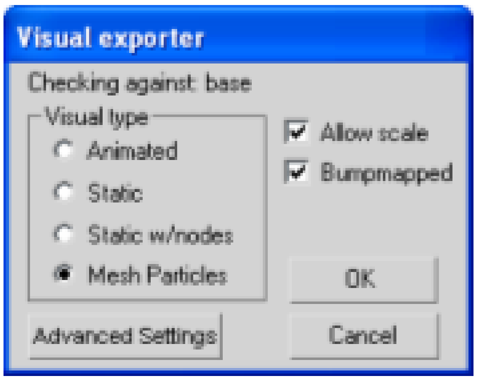
13.2.4. Alteration actions

Alteration actions affect the appearance of the particles. They can modify the shading, alpha level, and size of the particle over time. They are typically used in smoke effects, gentle fading in and out, and glowing effects. Particle textures can be animated if the texture specified is an animated texture.

13.3. Particle types

The particle system renderer is separate from the main particle system calculations, and allows not just texture-based particles, but also sprite-based and mesh-based particles. Multiple particle systems can share the same renderer.

The mesh particle renderer can use any visual, but for optimum performance, meshes specific for use in particle systems should be exported from 3ds Max or Maya in groups of 15, having the Mesh Particles option button selected in its respective exporter dialog. For more details, see the document Content Tools Reference Guide's chapter *3ds Max and Maya Exporters* .

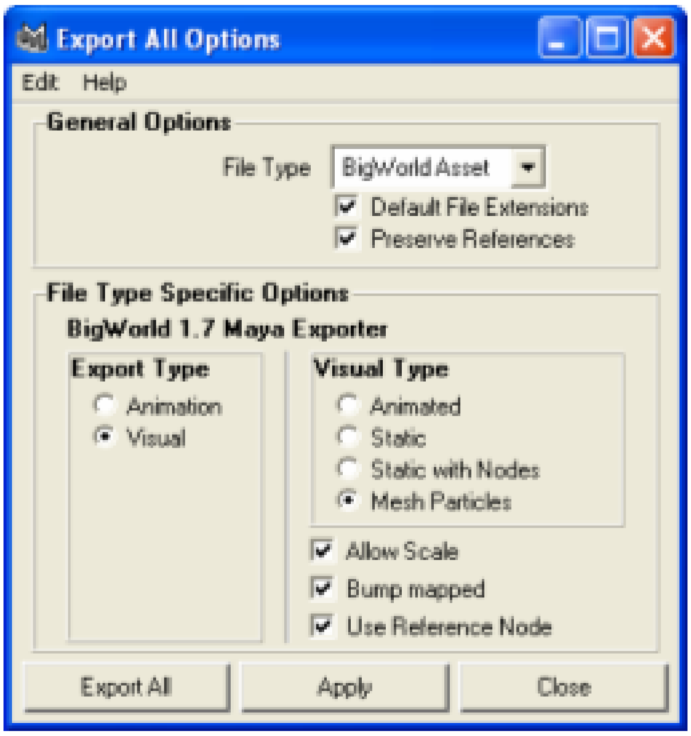


Visual exporter

Checking against: base

Visual type: Animated / Static / Static w/nodes / [✓ Mesh Particles]

☑ Allow scale
☑ Bumpmapped



Export All Options

General Options

File Type: BigWorld Asset
☑ Default File Extensions
☑ Preserve References

File Type Specific Options

BigWorld 1.7 Maya Exporter

Export Type: Animation / [✓ Visual]

Visual Type: Animated / Static / Static with Nodes / [✓ Mesh Particles]

☑ Allow Scale
☑ Bump mapped
☑ Use Reference Node

3ds Max Visual Exporter dialog and Maya Visual Exporter dialog

13.4. Attaching particle systems to bones

Note

For details on any class mentioned in this section, see the Client Python API's entry **Class List**.

To have a particle system follow a bone and orient to an external target, you should attach it to a node, and then point that node using a tracker.

The tracker class provided by the BigWorld module (BigWorld.Tracker) can be set up using a variety of DirectionProviders to point a node in the appropriate direction:

- **`EntityDirProvider`**

  Points a node in the direction that an entity is facing.

- **`DiffDirProvider`**

  Points a node towards the position given by a MatrixProvider (*e.g.*, to point at the head node of another entity, or to point in a constant world direction).

- **`ScanDirProvider`**

  Makes a node swing back and forth around its Y-axis (*e.g.*, to simulate a security camera).

Depending on your particular game, you might not be able to use a tracker to point a node on the source model. For example, the node may be part of a character's skeleton and have some mesh rigged to it, so you may not want to actually point to this bone (only the particle system attached to it). If this is the case, then you will need to create a new node on which to mount your particle system — ask your artists to build dummy nodes into their models on which to mount FX.

To have a particle system exist at a position that is not provided by a bone, you should attach it to a separate model, and display the separate model using `Entity.addModel`. Using `Entity.addModel` instead of `Entity.model.node(xxx).attach` means that the model exists at location independent from the entity — in fact, it means that nobody will be setting the position/direction of the model, and it is entirely up to the script.

Once you have an independent model, you can set its position and orientation to any `MatrixProvider`, by using the `Servo Motor`. As explained in the Client Python API, the `Servo` class is a `Motor` that sets the transform of a model to the given `MatrixProvider` — as the `MatrixProvider` is updated, the model moves. The signal attribute is the `MatrixProvider` that sets the model's transform.

This way, you can use the `Servo` `Motor` to move the model to a position provided by any dynamic matrix. If the independent model has a node to point to, then you can set its orientation by using a `Tracker`, as explained above. This allows you to detach the position of a particle system from a bone, but still set the orientation of the particle system to the orientation of the bone, or towards an external target.

Finally, if you want a particle system to exist at a fixed point/orientation, then use the `ParticleSystem`'s `explicitPosition` and `explicitDirection` attributes. These set the position/orientation of a particle system once, and cannot be set to dynamic matrices. Note that if you use either attribute, you will need to use both (setting either attribute tells the particle system that it is using an 'explicit transform' derived from both attributes).

Note

Be careful when attaching particle systems to bones! To attach a particle system to a bone, a PyModelNode must be retrieved. If there are no existing PyModelNodes referencing the bone you want to use, then its transform is undefined until the next draw call. Since python scripts are updated *before* the draw call, there is no way of knowing where a node is at the time of first retrieval. Therefore in this case, you should only attach a particle system to a PyModelNode when you know it has been updated. Your possible options are :

- Retrieve and keep a reference to the bone when you create your model. This will ensure at a later date when a particle system is attached to that bone, that the bone's position is well-known.
- Retrieve a reference to the bone you require, and callback yourself the next frame to attach the particle system to it. For example :

  BigWorld.callback(0.0, partial(self.model.node("HP particles").attach, self.particles))

Chapter 14. Detail Objects

A detail object is a small mesh drawn in large numbers onto the terrain around the camera position. They are separated from ordinary models for efficiency. The selection and placement of these objects is largely automatic — it is based on the texture used by the underlying terrain.

Examples of detail objects are: grasses, ferns, bulrushes, pebbles, and rocks. The user does not interact with detail objects (for example, no collision detection is performed).

14.1. Flora

BigWorld by default has about 60,000 triangles of flora active at any time, of which about 15,000 will be drawn at any one time. You may change the size of the vertex buffer used by changing the value of the `vb_size` tag in your flora configuration file (which is specified by the `environment/floraXML` tag in your configuration file `<res>/resources.xml` — for details, see "File `resources.xml`" on page 11 .).

14.1.1. Placement

Because of the multitude of objects involved, it is impractical to place detail objects by hand. Instead, BigWorld has Ecotypes.

Ecotypes define objects that are automatically placed within the world, guided by terrain texture. They are defined in XML, and have the following properties:

- One or more units (Moo visuals).
- One or more textures, which are used to match the terrain to an ecotype.
- Sound tag, for character footsteps.

For example, a grass ecotype could contain two separate meshes: one for low-height grass, and another for mid-height grass.

The set of ecotypes currently active is managed by the Flora class, which also manages the individual active detail objects, allocating and de-allocating them as required.

Each terrain block can have four textures, and each of these textures can have one associated ecotype. This allows for four different ecotypes per terrain block. Hence, within the detail sphere (50-metre radius from the camera) up to 16 different ecotypes may be visible.

Detail objects are not placed precisely within the terrain blocks — this would create square regions of detail objects. Detail objects 'jitter' their position before querying the terrain for its detail mapping. This effectively antialiases the quantized detail map.

Flora is calculated and stored in terrain files by the World Editor. For more details, see the document Content Creation Manual (accessible in WorldEditor, ModelEditor, and ParticleEditor via the **Help → Content Creation** menu item, or by pressing `F1`).

14.1.1.1. Visual consistency

The detail objects are mapped directly from terrain textures. Visually this is correct, since in real life the colour on the terrain is actually made from the colour of millions of detail objects (blades of grass, etc...). Thus, a green 'grassy' terrain texture can be made to map perfectly to a grass ecotype.

In BigWorld, whenever a texture is used, its accompanying detail objects are displayed.

14.1.2. Implementation

Drawing detail objects is an extremely performance-critical area, as all routines are run thousands of times per frame.

Vertex buffers are the perfect solution. The detail objects are kept transformed in a large vertex buffer. Thus, 1,000 pieces of grass at 6 vertices each means a world-space vertex buffer of 6,000 vertices. This allows all grass to be drawn using one call to the video card, using one transform matrix. 3D accelerators are extremely fast performing this kind of batched rendering.

As the player moves around the world, he sees the detail objects in the immediate vicinity (50m). In reality, this means that the active set of detail objects must change according to the camera position. Detail objects that are just coming into view are faded in, using alpha blending.

The flora configuration XML file `<flora>.xml` (for details on this file's grammar, see the document File Grammar Guide's section “`<flora>.xml`”) can define the size of the vertex buffer either statically or as a set of options selectable by the user via the `FLORA_DENSITY` graphics setting. For details, see “`FLORA_DENSITY`” on page 136 .

14.1.3. Frame coherency

In a multi-thousand object system, frame coherency must be utilised aggressively. The obvious choice for frame coherency is the vertex transforms. Each detail object is kept transformed in a vertex buffer in world space, until its terrain tile (or 'flora block') leaves the detail radius, at which point another terrain tile will have moved into the detail radius. Then the new tile's detail objects will be transformed and placed in the freed up vertex buffer memory.

On average, detail objects have shown around 97% coherency between frames, making for a huge saving in transformation cost.

14.1.4. Animation

In order to create an immersive, living, breathing world, most things must animate.

Animating detail objects add greatly to the illusion of the world. The BigWorld client uses 3D Perlin noise based on (wx, wz, time) to create believable procedural animation to the detail objects. Perlin noise was chosen because it is a cheap way to create space-time coherent noise. The implementation performs the animation efficiently in the vertex shader.

14.1.5. Lighting

When using simplified meshes (which is crucial in a multi-thousand object ornamentation system), lighting becomes challenging. Consider a criss-cross grass object rising vertically out of the terrain. If lit using standard procedures, the criss-cross objects would flare up in the evening sun.

In the BigWorld client, lighting for detail objects is performed using the light map calculated from the actual terrain. Thus, it picks up terrain shadows as well. This is a mostly correct solution, because the mesh-based terrain itself is really a simplified version of the millions of detail objects in existence.

14.1.6. File format

The XML flora file defines among other things, the light map to be used, plus the ecotypes and noise generation functions. For details on this file's grammar, see the document File Grammar Guide's section “`<flora>.xml`”.

Chapter 15. Water

Bodies of water can be placed in the world via WorldEditor, using the provided helper file `bigworld/res/helpers/misc/water.xml` — for details, see the document Content Creation Manual's lesson **Add Water to the World**.

As all water objects are VLO's, every instance will create two new files in the chunk folder (named with a unique ID for each instance):

- **`.vlo` file**

  Contains the XML chunk item section for the water object.

- **`.odata` file**

  Contains binary information related to the VLO (in this case, the water's per-vertex transparency/edging data).

15.1. Code overview

The water implementation is contained in the `bigworld/src/lib/romp` library, more specifically in the following files:

- **`chunk_water.cpp`, `chunk_water.hpp`**

  Water's link to the BigWorld chunking system.

  See also: `bigworld/src/lib/chunk/chunk_vlo.cpp`, and `bigworld/src/lib/chunk/chunk_vlo.hpp`.

- **`editor_chunk_water.cpp`, `editor_chunk_water.hpp`**

  Editor-related features, like saving, moving, and editing.

  See also: `bigworld/src/lib/chunk/editor_chunk_vlo.cpp` and `bigworld/src/lib/chunk/editor_chunk_vlo.hpp`.

- **`water.cpp`, `water.hpp`, `water.ipp`**

  The main files. Contains the surface drawing/setup.

- **`water_scene_renderer.cpp`, `water_scene_renderer.hpp`**

  Implementation of the water scene (reflection/refraction) generation.

- **`water_simulation.cpp`, `water_simulation.hpp`**

  Implementation of the simulation of water surface.

The water features also uses the shaders below (located in res/shaders/water):

- **`water.fx`**

  Main surface shader for the water.

- **`simulation.fx`**

  Shader for simulation of GPU water interaction.

Each `ChunkWater` in the world creates its own `Water` object. A `ChunkWater` is created by the first reference `ChunkVLO` encountered. The water is a very large object (VLO), which means that it can span/belong to more than one chunk. This is implemented by placing a VLO reference object (`ChunkVLO`) into every chunk that the water overlaps. Each reference is treated like the actual large object, passing and retrieving data from/to it.

Each water object adds itself to the draw list at each frame, with `Waters::addToDrawList`. The engine then draws the list of water surfaces with a call to `Waters::drawWaters`.

15.2. Scene generation

A reflection scene are rendered based on the current water quality level (for details, see "Setting the quality" on page 84). The reflection scene is a render target that is updated in the main game loop, during the call to `TextureRenderer::updateDynamics`.

Multiple water surfaces can share a reflection render target (`WaterScene` class) if they are both in the same position on the y-axis. The water scene generation assumes a flat plane for the water to reflect/clip around the defined y-axis position.

The refraction scene uses the Distortion channel texture which contains a copy of the main render target.

15.3. Render settings

The terrain will always be drawn, but everything else is linked to the current quality setting defined by the following variables:

- **`WaterSceneRenderer::s_drawDynamics_`**

  Determines if dynamic objects are drawn into the water scene.

- **`WaterSceneRenderer::s_drawPlayer_`**

  Determines if the player model is drawn into the water scene.

- **`WaterSceneRenderer::s_drawTrees_`**

  Determines if trees are drawn into the water scene.

- **`WaterSceneRenderer::s_maxReflectionDistance_`**

  Maximum distance that a dynamic object can be away from the water. Default value is 25.

- **`WaterSceneRenderer::s_maxReflections_`**

  Maximum number of dynamic objects to draw. Default value is 10.

- **`WaterSceneRenderer::s_useClipPlane_`**

  Toggles the use of the hardware clipping planes

15.3.1. Setting the quality

The Water::init method is used to initialise the graphics settings options menu link and the FX files, and is only called once. It will make available the following menu items:

- **Water Quality → High** — Invoked method: `Waters::setQualityOption`

  All world items are drawn in the water scenes. Highest detail shader is also used.

- **Water Quality → Mid** — Invoked method: `Waters::setQualityOption`

Except for dynamic objects, all world items are drawn in the water scenes.

- **Water Quality → Low** — Invoked method: `Waters::setQualityOption`

  Player, trees and sky are drawn in the Reflection. Reflection texture size is reduced.

- **Water Quality → Lowest** — Invoked method: `Waters::setQualityOption`

  Dynamic objects, player drawing, terrain and trees are disabled. Only the sky will be drawn into the reflection.

- **Water Simulation Quality → High** — Invoked method: `Waters::setSimulationOption`

  Perturbations can propagate between cells[A].

- **Water Simulation Quality → Low** — Invoked method: `Waters::setSimulationOption`

  Simulation is restricted to the individual cells[A].

- **Water Simulation Quality → Off** — Invoked method: `Waters::setSimulationOption`

  Simulation is disabled

A — Cells are sub-divisions of the water surface (for details, see “Simulation” on page 85).

15.4. Simulation

The water surface is divided up into cells with size defined by the water surface (defaulting to be 100.0 units). Each cell defines an area of water simulation that can be active.

There is a common pool of simulation textures (of size `MAX_SIM_TEXTURE_BLOCKS`) maintained by the SimulationManager class.

A cell is activated when a movement enters its defined area, and is deactivated after a period of inactivity (defined by `SimulationManager::maxIdleTime_`, with a default value of 5.0 seconds).

When the high detail simulation options are selected, water movements will propagate to (and activate) neighbouring cells.

The maximum number of active movements is defined by `MAX_SIM_MOVEMENTS`. Water movements are passed into the simulation manager through the Sway system — for details, see the Client C API's entry **Class List → `ChunkWater`, Public Member Fuction `sway`**.

15.5. Rain

Water is automatically affected by rain — there is another simulation texture block reserved in the SimulationManager, and that is used for the rain.

15.6. Water depth

The water depth is determined by the lowest terrain point underneath the water. The bounding box generated from this value could also be used to define a water volume for gameplay purposes. This can be found by searching for the `bbDeep_ references` in `bigworld/src/lib/romp/water.cpp`.

This depth information is also used to colour the water's refraction based on the actual per-pixel depth of the water surface. This uses an MRT (multiple render target) depth texture generated in the main scene render. A foaming edge effect is also added using this information.

15.7. Watchers

To configure the behaviour of the water system, the watchers below are used (all watchers are prefixed by **`Client Settings/Water/`**):

- **`character impact`**

  Strength at which a movement will hit the water surface simulation.

- **`draw`**

  Defines whether water surfaces are drawn.

- **`Draw Dynamics`**

  Linked to `WaterSceneRenderer::s_drawDynamics_`.[A]

- **`Draw Player`**

  Linked to `WaterSceneRenderer::s_drawPlayer_`.[A]

- **`Draw Trees`**

  Linked to `WaterSceneRenderer::s_drawTrees_`.[A]

- **`Max Reflection Distance`**

  Linked to `WaterSceneRenderer::s_maxReflectionDistance_`.[A]

- **`Max Reflections`**

  Linked to `WaterSceneRenderer::s_maxReflections_`.[A]

- **`Scene/Use Clip Plane`**

  Linked to `WaterSceneRenderer::s_useClipPlane_`.[A]

- **`water speed square`**

  Speed in which a wave will travel in the water simulation.

- **`wireframe`**

  Toggles wireframe mode for water surface.

A — For details, see "Render settings" on page 84 .

Chapter 16. Graphical User Interface (GUI)

The BigWorld GUI can be broken into standalone (menu and options interfaces) and in-game overlays.

The in-game overlays require 3D integration, and thus have a separate design. The unique features of the in-game interface are support for:

- Linking to in-game objects (specifically models' bounding boxes),
- Alpha blending, or superimposing over the scene,
- Special effects like scaling, rotation, colour change, fading in/out, and motion blur.

The most important feature of the in-game interface is the ability to fade away when not in use. This allows the game designer to create a more immersive game world experience. Whilst a GUI is required to relate important information to the player, it should only do so when that information is required. At other times, the player should not be distracted by overlays, but immersed fully in the 3D world.

Some examples of in-game interfaces would be:

- Targeting
- Current item display
- Player health and damage
- Chat window

16.1. C++ GUI support

There are two C++ base classes for GUI support:

- SimpleGUIComponent
- GUIShader

There is also one management class:

- SimpleGUI

16.1.1. SimpleGUIComponent

The SimpleGUIComponent class is simply a textured rectangle. The derived class TextGUIComponent draws text, and the also derived class FrameGUIComponent draws a resizable frame using three bitmaps (corner, edge, background).

SimpleGUIComponent has many properties, mostly accessed from Python and XML files. For more details, see "Python GUI support" on page 88 .

Components are hierarchical only in that parents draw their children; children do not inherit their parents' transform. WindowGUIComponent is an exception to this rule — children are automatically clipped and translated by their parent. Note that this is a feature of WindowGUIComponent, not the GUI system in general.

16.1.2. GUIShader

The GUIShader class alters the way that components are drawn, in an analogous form to vertex shaders (in fact, 99% of GUI shaders operate only on temporary variables instead of vertices, hardware TnL support).

- ClipGUIShader clips GUIComponents to a proportion of its original length, which is useful for making health bars.
- ColourGUIShader colours a component.
- AlphaGUIShader fades a component.
- MatrixGUIShader transforms a component.

Shaders are applied to all children — so use a MatrixGUIShader to implement windowing, and an AlphaGUIShader to fade in/out a whole tree of components.

16.1.3. SimpleGUI

This is the GUI root, and it is ticked and drawn at every frame.

Use SimpleGUI::addSimpleComponent() and SimpleGUI::removeSimpleComponent() to build your tree of GUI components. Note that you would normally never call these methods from C++, as they are mostly called by scripts.

16.2. Python GUI support

You probably will create GUIs using Python and XML most of the time. There is no BigWorld GUI editor, thus all GUI is currently created using the Python console in game.

The code below shows an example:

```
import GUI

#create a simple GUI component
s=GUI.Simple( "maps/guis/stats_bar.dds" )

#width/height initially in pixels. can use widthRelative/heightRelative
#to designate the component uses clip coordinates ( -1 .. +1 ) instead.
s.width = 64
s.height = 16

#colour attribute is ( r,g,b,a )
s.colour = ( 255, 128, 0, 255 )

#the materialFX is simply the blend mode. can be "BLEND","SOLID","ADD"...
s.materialFX = "BLEND"

#the position is always in clip coordinates ( -1 .. +1 )
s.position = ( 0, 0.85, 0.5 )

#the anchors determine what the position means with respect to the width
#and height. in this example, the position of (0,0.85,0.5) and anchors
#"TOP,CENTER" means that the top centre of the component will rest at
#the given position.
#The component will hang down from y=0.85, and will be centred on x=0.0
s.verticalAnchor = "TOP"
s.horizontalAnchor = "CENTER"

#create a clipper for the health amount. clip shaders are used to
#implement stats bars. the constructor parameter "RIGHT" means the
#shader will clip the component from the right hand side.
c=GUI.ClipShader( "RIGHT" )

#all shaders animate their values. the speed indicates how long the
```

```
#internal parameter will change from the old value to the new. This speed
#indicates the health bar will always take 1/2 a second to change.
c.speed = 0.5

#the value is what the game normally changes if player's health changes.
c.value = 1.0

#this line adds the shader. Note that you can call your shader any name
#you like. Internally, the simple GUI component sees you are trying to
#add a GuiShader to it, under the name of clipper.
#Internally it will call SimpleGUIComponent::addShader()
s.clipper = c

#create a colourer for the health amount
c=GUI.ColourShader()

#the start,middle and end simply represent colours to blend to when the
# value parameter is 1.0, 0.5 and 0.0 respectively.
c.start=(255,0,0,192)
c.middle=(255,255,0,192)
c.end=(0,255,0,192)
c.speed=0.5
c.value=1.0
s.colourer=c

#and make the health bar be drawn
GUI.addRoot( s )
```

Example of GUI creation

You can then customize the new health bar simply by setting the appropriate values in the shaders:

```
# player's health went down to 80%
s.clipper.value = s.colourer.value = 0.8
```

Finally, you can associate a script with the GUI component, in order to handle input and I/O events, and to build high-level functionality onto it. Associate a script object with the component using the script attribute:

```
s.script = PyGUI.Button( s )
```

For more details about GUI scripts, see "XML and Python" on page 90, and "Input events" on page 90 . For more details on attributes, see the Client Python APIs entry **Main Page → Client → GUI → Classes → `SimpleGUIComponent`**.

16.3. XML

GUI can also be represented as XML files. They can be saved in the folder `<res>/guis` once constructed, for example, using the method described above.

The advantage of the Python interface is that once you have created the GUI, simply call:

```
s.save( "guis/health_bar.gui" )
```

An XML file will be created encapsulating the GUI component, its shaders, and all of its children. Once you have done this, write:

```
GUI.delRoot( s )
s = None
s = GUI.load( "guis/health_bar.gui" )
GUI.addRoot( s )
```

After that, you will have exactly the same component, with all its shaders and children set up.

Advanced users will find creating XML by hand the quickest way to create your GUI. Alternatively, a GUI editor can be entirely created in Python.

16.4. XML and Python

When you have a GUI component with a script saved in XML, your Python script must implement the following methods (at the very least to stub them out):

- `def onLoad( self, section )`
- `def onBound( self )`
- `def onSave( self, section )`

16.4.1. `onLoad(self,section)`

The `onLoad` method is called just after the C++ load method has been called, the standard member variables have been setup, and the associated script has already been constructed.

The data section that the GUI component is being loaded from is passed into the method. This allows the definition of custom attributes, especially for loading custom data into the script object.

Note that the method is called before any children components or shaders have been loaded.

16.4.2. `onBound(self)`

The `onBound` method is called after the load is complete.

The main difference between this method and `onLoad` is that by the time `onBound` is called, the whole GUI component tree has been created. Thus in the `onBound` method you can write custom script handling to manipulate child components. For example, you could invoke your own custom Layout Manager in this method.

16.4.3. `onSave(self,section)`

The `onSave` method is called just after the C++ save method has saved all standard GUI component members, but before the shaders and children are saved.

16.5. Input events

`SimpleGUI` offers support for keyboard, joystick, and mouse input. To capture events, a component needs to have its property focus set to true, and an associated Python script attached.

When loading a component from a GUI file, the attribute of a `SimpleGUIComponent` is automatically set if the XML declares a script field. The value of the field is used to instantiate the script object (it must be a callable receiving one parameter — the `SimpleGUIComponent` being created — , and returning a Python object). The Python object returned will be the one assigned as the script object for the newly created component.

The script attribute can also be set manually for an existing component, like in the example below:

```
# instantiate a new PyGUI Button class, and make it the component's
# script attribute. note most scripts are passed the GUI component
# in their constructor so they can perform operations on them.
s.script = PyGUI.Button( s )
```

There are separate focus properties for each category of input events, as described below:

- **`focus`**

  Associated with: Keyboard events (including character events), joystick (axis) events, and global mouse button events.

- **`mouseButtonFocus`**

  Associated with: Mouse button events that occur while the mouse position is contained within the region of the component.

- **`crossFocus`**

  Associated with: Mouse *enter* events, and mouse *leave* events.

- **`moveFocus`**

  Associated with: Mouse *move* events.

- **`dragFocus`**

  Associated with: Drag events.

- **`dropFocus`**

  Associated with: Drop events.

To make a component start receiving input events, you must set the appropriate property to True, and to have it no longer receiving events set it to False, as illustrated below:

```
# start receiving key/axis events
c.focus = True

# stop receiving mouse enter/leave events
c.crossFocus = False
```

When a component has a script and it has focus enabled, the script will start capturing input events.

The script must define the appropriate methods to handle the events. The example below illustrated a script defining the methods to handle keyboard and joystick (axis) events:

```
class Button:
   def handleKeyEvent( self, event ):
      # do whatever, and return 1 if
      # this key event was consumed

   def handleAxisEvent( self, event ):
      # do whatever, and return 1
      # if this axis event was consumed
```

The following sub-sections describe the events supported by `SimpleGUI`. For more details, see the Client Python API's entry **Main Page → Client → GUI → Classes → `SimpleGUIComponent`**.

16.5.1. Keyboard Events

Keyboard events are related to input from keyboard, mouse, and joystick buttons. They are reported to script objects through the `handleKeyEvent` method:

```
def handleKeyEvent( self, event )
```

The parameters are described below:

- **`event`**

  `PyKeyEvent` containing information about this event.

A return value of `True` means that the event has been consumed, thus effectively preventing it from being propagated to other components or game scripts. A return value of `False` allows further propagation.

To receive key events, a component must have the property `focus` set to True.

Note that mouse button events reported through the method `handleKeyEvent` differ from those reported through `handleMouseButtonEvent` in that the mouse cursor does not have to be inside the area defined by a component for that component to capture the event. The only requirements for the capture are to have the property `focus` set to True, and not having another component consuming the event earlier in the focus list.

Character events are attached to key events. Check the `PyKeyEvent.character` parameter, which will be a string containing the fully translated character. It will otherwise it will be None. Keep in mind that due to more complex input methods (e.g. dead-keys) the length of the character string can be greater than 1.

16.5.2. Axis Events

Axis events are related to joystick axis input. They are reported to script objects through the `handleAxisEvent` method:

```
def handleAxisEvent( self, axis, value, dTime )
```

The parameters are described below:

- **`event`**

  `PyAxisEvent` containing information about this event.

A return value of `True` means that the event has been consumed, effectively preventing it to be propagated to other components or game scripts. A return value of `False` allows further propagation.

To receive axis events, a component must have the property `focus` set to `True`.

16.5.3. Mouse Events

Mouse events can be grouped into three categories:

- Button events
- Cross events
- Move events.

Mouse events are propagated from the top-most component under the mouse cursor down to the bottom component until it is handled by a component (by returning True in one of its event handling methods).

The following sub-sections describe how to handle input from each category of mouse event.

Note that mouse events are only generated when the object MouseCursor is active. For more details, see "Mouse cursor" on page 98 .

16.5.3.1. Button events

Button events are related to mouse buttons input. They are reported to the script objects through the methods handleMouseButtonEvent and handleMouseClickEvent methods.

16.5.3.1.1. `handleMouseButtonEvent`

This method is called by SimpleGUI on the top most component under the mouse that has `mouseButtonFocus` set to True:

```
def handleMouseButtonEvent( self, comp, event )
```

The parameters are described below:

- **`comp`**

  Component over which the button was pressed or released.

- **`event`**

  PyKeyEvent containing information about this event.

A return value of True means that the event has been consumed, effectively preventing it to be propagated to other components or game scripts. A return value of False allows further propagation.

To receive mouse button events, a component must have the property mouseButtonFocus set to True.

16.5.3.1.2. `handleMouseClickEvent`

This method is called by SimpleGUI when the left mouse button was pressed and released over the component.

```
def handleMouseClickEvent( self, comp, pos )
```

The parameters are described below:

- **`comp`**

  Component over which the button was pressed.

- **`pos`**

  Position of the mouse on the instant of the mouse button click.

  Value is a 2-tuple of floats in clip-space, ranging from -1.0 (leftmost in x-axis, top in y-axis) to 1.0 (rightmost in x-axis, bottom in y-axis).

A return value of True means that the event has been consumed, effectively preventing it to be propagated to other components or game scripts. A return value of False allows further propagation.

To receive mouse click events, a component must have the property focus set to True.

16.5.3.2. Cross events

Cross events are related to the mouse pointer entering or leaving the region defined by the component in the screen. They are reported to the script objects through the methods handleMouseEnterEvent and handleMouseLeaveEvent.

The signature for handleMouseEnterEvent is described below:

```
def handleMouseEnterEvent( self, comp, pos )
```

The signature for handleMouseLeaveEvent is described below:

```
def handleMouseLeaveEvent( self, comp, pos )
```

The parameters for both methods are described below:

- **`comp`**

  Component that the mouse entered or left.

- **`pos`**

  First position of the mouse when entering or leaving the component.

  Value is a 2-tuple of floats in clip-space, ranging from -1.0 (leftmost in x-axis, top in y-axis) to 1.0 (rightmost in x-axis, bottom in y-axis).

A return value of True means that the event has been consumed, effectively preventing it to be propagated to other components or game scripts. A return value of False allows further propagation.

To receive mouse enter and leave events, a component must have the properties focus and crossFocus set to True.

16.5.3.3. Move events

Move events are related to the mouse pointer hovering over the region defined by the component in the screen. They are reported to the script objects through the handleMouseEvent method:

```
def handleMouseEvent( self, comp, event )
```

The parameters are described below:

- **`comp`**

  Component over which the mouse cursor hovered.

- **`event`**

  `PyMouseEvent` containing information about this event.

A return value of True means that the event has been consumed, effectively preventing it to be propagated to other components or game scripts. A return value of False allows further propagation.

To receive mouse move events, a component must have the property focus and moveFocus set to True.

16.5.4. Drag-and-drop events

SimpleGUI offers support for drag-and-drop functionality. Drag-and-drop events can be grouped into two categories:

- Drag events
- Drop events

The following sub-sections describe how to handle input from each category of drag-and-drop event.

Note that drag-and-drop events are only generated when the MouseCursor is active. For more details, see "Mouse cursor" on page 98 .

16.5.4.1. Drag events

Drag events are related to a component being dragged by the user. They are always generated on the component being dragged and reported through the methods handleDragStartEvent and handleDragStopEvent.

16.5.4.1.1. `handleDragStartEvent`

This method is called when the user is trying to drag the component:

```
def handleDragStartEvent( self, comp, pos )
```

The parameters are described below:

- **`comp`**

  Component that the user is trying to drag.

- **`pos`**

  Position of the mouse on the instant of the event.

  Value is a 2-tuple of floats in clip-space, ranging from -1.0 (leftmost in x-axis, top in y-axis) to 1.0 (rightmost in x-axis, bottom in y-axis).

A return value of True signals to the GUI manager that this component is willing to be dragged, and consumes the event. A return value of False prevents the component from being dragged, and allows further propagation of the event.

To receive this event, a component must have the property dragFocus set to True.

16.5.4.1.2. `handleDragStopEvent`

This method is called when the user released the mouse left button, and therefore wants to drop the component:

```
def handleDragStopEvent( self, comp, pos )
```

The parameters are described below:

- **`comp`**

  Component being dragged.

- **`pos`**

  Position of the mouse on the instant of the event.

  Value is a 2-tuple of floats in clip-space, ranging from -1.0 (leftmost in x-axis, top in y-axis) to 1.0 (rightmost in x-axis, bottom in y-axis).

The return value from this method is always ignored, and the originating mouse button event is allowed to propagate further.

To receive this event, a component must have the property dragFocus set to True.

16.5.4.2. Drop events

Drop events are related to a component being dropped over another one. They are always generated on the recipient component and reported through the handleDragEnterEvent, handleDragEnterEvent and handleDropEvent methods.

16.5.4.2.1. `handleDragEnterEvent`

This method is called when the user just dragged another component over this one, but has not dropped it yet:

```
def handleDragEnterEvent( self, comp, pos, dropped )
```

The parameters are described below:

- **`comp`**

  Component about to receive the drop.

- **`pos`**

  Position of the mouse on the instant of the event.

  Value is a 2-tuple of floats in clip-space, ranging from -1.0 (leftmost in x-axis, top in y-axis) to 1.0 (rightmost in x-axis, bottom in y-axis).

- **`dragged`**

  Component being dragged.

The return value from this method is used to determine if the recipient component is willing to accept the drop. This event is always considered consumed when first triggered, and the originating mouse move event is propagated no further.

To receive this event, a component must have the property dropFocus set to True. Arguments

16.5.4.2.2. `handleDragLeaveEvent`

This method is called when the dragged component is no longer over this one:

```
def handleDragLeaveEvent( self, comp, pos )
```

The parameters are described below:

- **`comp`**

  Component that was about to receive the drop.

- **`pos`**

  Position of the mouse on the instant of the event.

  Value is a 2-tuple of floats in clip-space, ranging from -1.0 (leftmost in x-axis, top in y-axis) to 1.0 (rightmost in x-axis, bottom in y-axis).

A return value of True means that the event has been consumed, effectively preventing the originating mouse event to be propagated to other components or game scripts. A return value of False allows further propagation.

To receive this event, a component must have the property dropFocus set to True.

16.5.4.2.3. `handleDropEvent`

This method is called when the user has dropped a component over this one:

```
def handleDropEvent( self, comp, pos, dropped )
```

The parameters are described below:

- **`comp`**

  Component receiving the drop.

- **`pos`**

  Position of the mouse on the instant of the event.

  Value is a 2-tuple of floats in clip-space, ranging from -1.0 (leftmost in x-axis, top in y-axis) to 1.0 (rightmost in x-axis, bottom in y-axis).

- **`dropped`**

  Component receiving the drop.

The return value from this method is always ignored, and the originating mouse button event is allowed to propagate further.

To receive this event, a component must have the property dropFocus set to True.

16.5.5. Component PyGUI

You might find it useful to build your own Python module with custom GUI components. To do that, the best starting point is the module PyGUI.

PyGUI is the informal Python module for basic GUI elements, created for the Citizen Zero project, and defined in `fantasydemo/res/scripts/client/Helpers/PyGUI`.

Starting from the basic functionality offered by SimpleGUI native components, you can code your own GUI toolkit in Python. Below are some examples of widgets you can create:

- Page control
- Drop-down List
- Edit field
- Multi-line text field

- Check box

16.6. Mouse cursor

It is possible to control the behaviour and appearance of the mouse cursor from the game scripts. Mouse cursor-related functions and properties can be accessed though the MouseCursor object.

The MouseCursor object is a singleton, and can be obtained using the method `GUI.mcursor.`

The properties published by it are described below:

- **`position`** — Read/write

  Mouse cursor position

- **`shape`** — Read/write

  Mouse cursor shape

- **`visible`** — Read/write

  Mouse cursor visibility status

- **`active`** — Read-only

  Mouse activity status

- **`clipped`** — Read/write

  When set to true, the mouse cursor will be clipped to the region of the client window.

The MouseCursor is an instance of the abstract concept InputCursor. There can only be one active InputCursor at any given time.

To activate the MouseCursor, use the method BigWorld.setCursor. To deactivate it, activate another input cursor, or pass None to BigWorld.setCursor.

Mouse and drag-and-drop events are only propagated to GUI components while the MouseCursor is active.

The code below illustrates how to use the MouseCursor:

```
# access and modify the mouse cursor
import GUI
import BigWorld

mc = GUI.mcursor()
mc.shape = "arrow"
mc.visible = True
if not mc.active:
   lastPosition = mc.position
   mc.position = ( 0.0, 0.0 )
   BigWorld.setCursor( mc )
   # mc.active is now True
```

Example of how to use `MouseCursor` object

Chapter 17. Fonts

BigWorld has an in-built font generation and glyph caching system. It supports large international character sets. Internally, BigWorld uses GDI+ and requires an installed true-type font file to draw the glyphs into a glyph-cache render target. As an alternative, you can ship your game with pre-cached font maps, however this method does not support dynamic glyph usage, and as such is not appropriate for large character sets.

17.1. Creating and Using Fonts

To use fonts, you must first create a font definition file that describes the font style, point size, and desired effects. Once a font is defined, you can use the font to display text on-screen. The main way to display text on-screen is via a Python GUI.Text component.

17.1.1. Creating a Font Definition File

Font Definition Files are an XML file describing the font itself, the size of the glyph cache and the details of any preloaded glyphs :

```
<example_font.font>
    <creation>
        <sourceFont> Arial </sourceFont>
        <sourceFontSize> 16 </sourceFontSize>
        <effectsMargin>   1 </effectsMargin>
        <textureMargin>   1 </textureMargin>
        <dropShadow>   true </dropShadow>
        <shadowAlpha>   192 </shadowAlpha>
        <bold>         true </bold>
    </creation>
</example_font.font>
```

Since fonts are generated on-the-fly and their glyphs cached at runtime, this is all you need to do to begin using a new font. If the specified source font name does not exist on the system, then Windows will automatically choose the nearest matching typeface. To avoid any potential problems, please make sure you license and install your desired true-type fonts on the end-users' system (e.g. as part of the installer scripts). If you do decide to choose only Windows fonts (and assume they exist on the end-users' machines) then be aware that there are large differences in the standard fonts used by Windows, depending on the region. For example, if Windows has been installed with the Asian font pack, it will have a significantly different standard font sets by default (even for English language fonts).

See `.font` for a detailed description of the .font definition format.

17.1.1.1. Secondary Font Families

In order to allow mixing different character sets within the same string of text while maintaining control over how each character set is rendered, secondary font families can be defined. For example, Arial may be desired for latin-1 (e.g. English) characters, however Arial is not designed to render east-Asian character sets (e.g. Chinese). This would mean artifacts are produced when rendering east-Asian characters.

Secondary fonts are defined using one or more `secondary` tags within the `creation` section. A secondary font consists of a font name and a Unicode range used to selected which secondary font to use.

For example, to use Arial and Chinese you could add a `secondary` font using SimSun:

```
<example_font.font>
    <creation>
```

```
        <sourceFont> Arial </sourceFont>
        ...
        <secondary>
            <sourceFont>      SimSun         </sourceFont>
            <unicodeRange>    U+2F00-U+9FFF   </unicodeRange>
        </secondary>
    </creation>
</example_font.font>
```

17.1.2. Preloading Glyphs

For languages that have a limited number of glyphs, for example English, you may want to preload all the glyphs into the cache so the client doesn't have to do anything more at runtime. Additionally, for larger Asian languages, you may still want to preload the cache with some often-used glyphs and from then on let the cache deal with whichever less-frequently used glyphs are required at runtime. The glyph caching system will still be in effect, but the cache will contain these glyphs to begin with. Additionally, the preloaded glyphs will never leave the cache during the duration of client execution, even if they are not used.

To preload glyphs or a range of glyphs, add any combination of the following tags into your font definition file.

```
<startChar>    32    </startChar>
<endChar>     192    </endChar>

or

<unicodeChar>  U+3000  <unicodeChar>

and/or

<unicodeRange>  U+AC00-U+D7A3   </unicodeRange>
```

17.1.3. Specifying the widest character

Font glyphs are cached into a texture and are positioned on a regular grid (i.e. each grid element is the same width and height). In order to determine the size of each grid element up front, the glyph cache must know the dimensions of the widest character. By default the letter 'W' is used to calculate this size but this may be inappropriate for some character sets (including Chinese). If the widest character is too narrow, then visual artifacts will occur (characters will be clipped and neighbouring characters may 'leak' into each other). If it is too wide, then texture space will be wasted.

The widest character can be set using the <widestChar> tag in the font definition file. For example:

```
<example_font.font>
    <creation>
        ...
        <widestChar>  U+FF1F  </widestChar>
        ...
    </creation>
</example_font.font>
```

17.1.4. Displaying Text

Text GUI Components are the main way that fonts are used to display text on-screen. For full details on Text GUI Components and their python GUI.Text counterpart, please refer to the Python Client API guide, under the section GUI.Text. The GUI.Text class supports the "font" attribute, this specifies the name of the font definition file, relative from the font root (see File Grammar Guide / resources.xml to see how to choose or change the font root folder.)

Here is an example of how to use the above example font file, which for now we will assume was saved to $FONT_ROOT/example_font.font.

```
import GUI
t = GUI.Text( "Some Text" )
t.font = "example_font.font"
GUI.addRoot(t)
```

17.2. Artist modified Fonts

Built-in or licensed true-type fonts may not necessarily have to desired look for your game. For example you may want to use fonts that have a glow effect, or an internal gradient fill. In these situations, you have the choice to output a fixed snapshot of a glyph cache as a .dds file. This file can then be processed by an artist to generate whatever font effects they like. Note that this procedure will only work with a fixed set of glyphs, as the client will not internally posess the ability to recreate the steps the artist took to modify the font.

17.2.1. Generating a Snapshot of a Font's Glyph Cache

The python API contains a function, BigWorld.saveFontCacheMap, that outputs the contents of the font's glyph cache to a DDS file, and the details of the font metrics to the .font file. Once this snapshot is taken, the .font file contains a <generated> section, and the font will no longer use the glyph cache, or be able to generate any new glyphs at runtime. To revert this change, simply remove the <generated> section from the .font file, and delete the .dds file. The texture will be named $FONT_ROOT/$FONTNAME_font.dds

```
import BigWorld
BigWorld.saveFontCacheMap( "super_turbo.font" )
#this generates super_turbo.font.dds, super_turbo.font.generated, and
 super_turbo.font.grid.dds
```

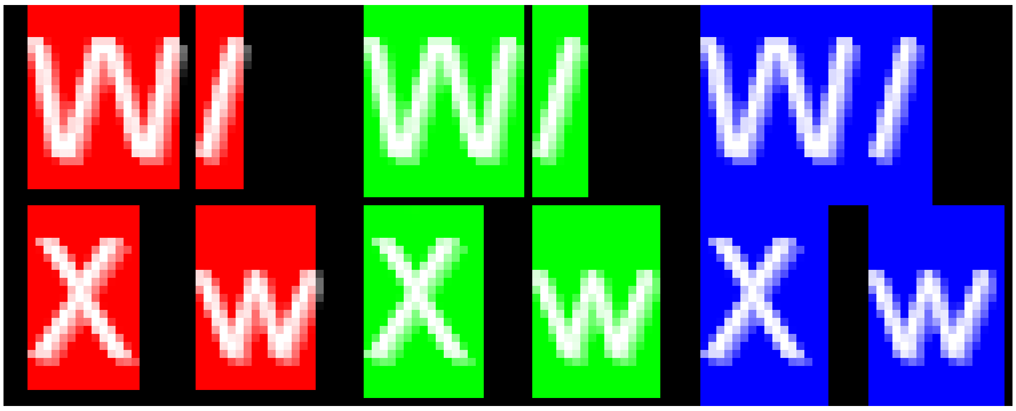
17.2.2. Modifying the Font Texture

Once a snapshot has been created, the generated font .dds file can be loaded into Photoshop (you may need to download and install a .dds file plugin, depending on the version of Photoshop you are using). The glyphs can then be modified freely, however care must be taken not to go outside of the designated bounds for each character. The grid reference bitmap describes the go and no-go areas, and its alpha-channel has a copy of the glyphs to provide shape information and to simply demonstrate which character goes where.

Once you have modified a font texture, simply save over the *.font.dds file, and make sure both it and the *.font.generated file is committed as part of your asset repository. The presence of these files on disk instructs the font system to use the generated map from now on, and never attempt to expand the glyph cache. If glyphs are encountered that do not exist as part of the generated glyph cache, a warning will be output to the debug window and a filler character will be used.

17.2.3. Explaining the Font Grid .dds File

Below is a portion of a font.grid.dds file, duplicated 3 times in photoshop with various colour channels extracted. You can see the three colour channels, with the alpha channel overlayed in white.



Example extracted from a .font.grid.dds file

On the left, **the red channel describes the raw glyph rectangle as given by GDI+**. As you can see in the example, the W and / glyphs go outside of this region. This is because this particular font already has a drop-shadow applied. The drop shadow, as provided in-engine, is a copy of the glyph, with a single pixel offset. This is demonstrated by the green region below.

The green region describes the glyph region plus the effect margin, and is the rectangle that will be drawn by the engine. Any pixels outside of the green area will be clipped when drawing text to the screen. Note too that when glyphs are drawn together, creating a string or a sentence, the red regions (raw size) determine the spacing between characters, and any effects margin is overlapped by the next glyph, this ensures that adding effects like drop shadows do not increase the width of your strings.

The blue region describes the glyph region plus effect margin plus texture margin. The texture margin is used to pad the glyphs apart in the texture map, to avoid any filtering artifacts. The texture margin should never be drawn, and is pretty much wasted space. If you are sure that your font will only be drawn at a 1:1 ratio between pixels and texels (for example the text will never be shrunk, or drawn in 3D where it can be rotated and mip-maps come into play), then you can safely do away with any texture margin.

Chapter 18. Input Method Editors (IME)

An Input Method Editor (IME) is an advanced user interface which is used to enter input text for East Asian such as Chinese where the character set is much larger than can be practically mapped directly to keyboard buttons. This is a mechanism provided by Windows and is determined by the currently installed keyboard layout.

Unfortunately the default IME interfaces used by Windows overlay additional child pop-up windows which do not work well within the context of a game. These pop-ups will conflict with the Direct3D device (especially in full-screen mode), are not skinnable, and, since Windows has no knowledge about your in-game user interface, it will not be positioned to line up with your in-game edit controls. Thus in order to integrate nicely with a game and deliver a smooth experience for the user, the IME interface should be rendered using the in-game GUI system.

The BigWorld engine provides an API which allows the Python scripts to respond to IME events generated by the operating system and populate an in-game IME based on the current state of the system input driver.

The currently supported IME types are:

- Chinese Simplified (PRC)
  - Microsoft Pinyin
  - QuanPin
  - Sogou Pinyin
  - Sogou Wubi
  - Google Pinyin
- Chinese Traditional (Taiwan)
  - Microsoft New Phonetic IME
- Japanese
  - Microsoft IME
- Korean
  - Microsoft IME

This chapter describes how to setup Python scripts to respond to IME events and display an interface accordingly.

In addition to this document, there is an example implementation located at `fantasydemo/res/scripts/client/Helpers/PyGUI/IME.py`. This script is used by the `PyGUI.EditField` class.

Please note that the BigWorld IME system will be disabled if the Scaleform IME library is enabled.

18.1. Components of an IME interface

There are three main components that make up an Input Method Editor:

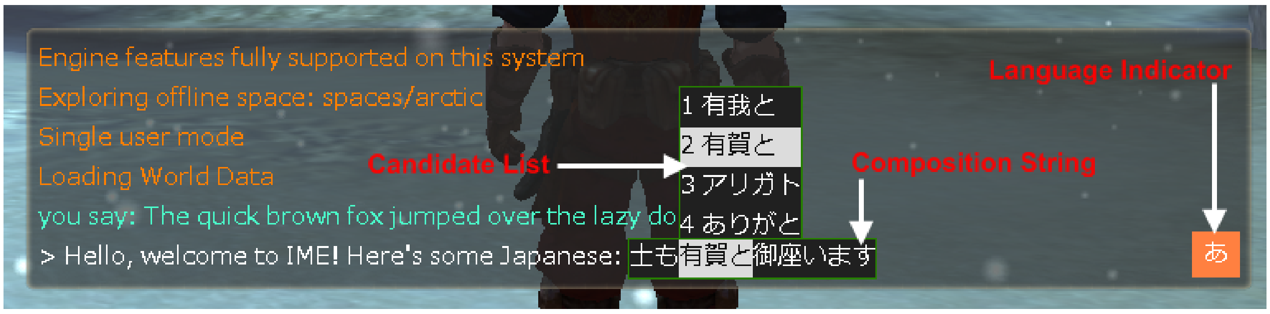
- Composition string. This contains the characters that the user has composed with the IME and is the string that will be sent to the application once it has been finalised by the user. The composition string is usually drawn on top of the edit control at the current location of the input cursor.

- Reading window. Typically used only by Chinese IME's, this contains the most recent keystrokes which have not yet been translated to the target language.
- Candidate list. This is a list of candidate characters based on the current contents of the composition string. The user can use the arrow keys to cycle through the available options and can use page-up and page-down if there are multiple pages of options. The desired candidate is selected by pressing the number key corresponding to the candidate list item, or by pressing enter on the highlighted item.

A particular IME may use all or only some of these components. The `PyIME` object is used by the Python scripts to determine when a particular component needs to be drawn (e.g. the `BigWorld.ime.readingVisible` flag can be used to determine whether or not the reading window should be drawn at any particular time).

While not strictly part of the IME itself, including a language indicator on your edit control is useful as a visual aid to keep track of which language is currently active. By changing its colour, you can also indicate the current state of the IME (e.g. whether or not the IME is currently in alpha-numeric mode).

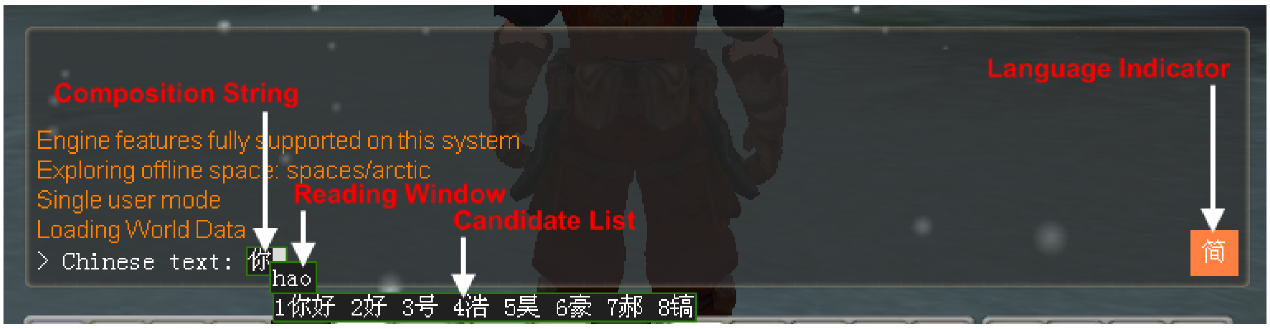
18.1.1. Examples



```
Engine features fully supported on this system
Exploring offline space: spaces/arctic
Single user mode
Loading World Data
you say: The quick brown fox jumped over the lazy do
> Hello, welcome to IME! Here's some Japanese: 土も有賀と御座います
```

```
1 有我と
2 有賀と
3 アリガト
4 ありがと
```

Japanese IME



```
Engine features fully supported on this system
Exploring offline space: spaces/arctic
Single user mode
Loading World Data
> Chinese text: 你
hao
1你好 2好 3号 4浩 5昊 6豪 7郝 8镐
```

Chinese IME

18.1.2. Recommended Reading

[Installing and Using Input Method Editors, MSDN - http://msdn.microsoft.com/en-us/library/bb174599%28VS.85%29.aspx]

[Using an Input Method Editor in a Game, MSDN - http://msdn.microsoft.com/en-us/library/bb206300%28VS.85%29.aspx]

18.2. IME Python API

The BigWorld IME Python API is accessed via the `BigWorld.ime` object. This is a singleton instance of the `PyIME` class.

See the Python client API documentation for details on all methods and properties mentioned here.

18.2.1. Enabling IME

Disabled by default, IME can be enabled and disabled from the Python script. Typically, an application would enable IME when a text-input interface comes into focus (e.g. an edit box), and disable it again once it has lost focus. The `enabled` property on the `PyIME` object controls the current state:

```
BigWorld.ime.enabled = enableBoolean
```

The internal state will be reset when IME is disabled.

18.2.2. Receiving IME events

Once the IME system is enabled, the engine will start posting events to the personality script.

18.2.2.1. BWPersonality.handleInputLangChangeEvent

The `BWPersonality.handleInputLangChangeEvent` will be called whenever the user has switched the current input language. The function does not take any parameters, so the handler should check the `BigWorld.ime.language` property and the `BigWorld.localeInfo` function to check the new language and update accordingly.

Typically, an application would update language indicators and/or fonts based on the new language.

18.2.2.2. BWPersonality.handleIMEEvent

The `BWPersonality.handleIMEEvent` gets called whenever the user performs some action (usually a keystroke) that causes the internal IME state to be changed. The only parameter to the `handleIMEEvent` is a `PyIMEEvent` object. The event object itself does not have any data, rather it has a set of flags which indicate which `BigWorld.ime` properties have been updated. The `handleIMEEvent` function will be called when the following events occur:

- The current IME state has been changed (e.g. switching between alpha-numeric mode and Hiragana mode whilst in the Japanese language).
- The composition string has been modified.
- The cursor position within the composition string has been modified.
- The reading window string has changed.
- The reading window visibility has changed.
- The candidate list visibility has changed.
- The candidate list items have changed.
- The user has changed the highlighted item within the candidate list.

18.2.2.3. Finalising characters

When the user has finished entering their desired text into the method editor they will press enter to commit the string. When this occurs, `BWPersonality.handleKeyEvent` will be called for each unicode character in the finalised string, and will be posted with the key code `Keys.KEY_IME_CHAR`.

18.2.3. Displaying the IME

The task of actually displaying the IME interface based on the current underlying state is a task for the Python script programmer. The complexity of the IME presentation scripts will be determined by how many languages need to be supported, as each language has their own standard way of presenting the IME.

Note that due to the number of different IME's available for a single language, and due to differences between Windows XP and Windows Vista, it is recommended to test across these different configurations as much as possible.

Generally, when constructing an IME interface, the scripts will do the following:

- Build a composition string window based on the contents of `BigWorld.ime.composition`. Each character in the composition string will have a different attribute associated with it which determine its state (e.g. whether or not it is highlighted). This is determined by the `BigWorld.ime.compositionAttr` property (an array of the same length as the composition string).

  A cursor should be drawn within the composition string based on the `BigWorld.ime.compositionCursorPosition` attribute.

- If `BigWorld.ime.readingVisible` is True, build a reading window based on the contents of `BigWorld.ime.reading`.

  The orientation of the reading window is determined by the `BigWorld.ime.readingVertical` property.

- If `BigWorld.ime.candidatesVisible` is True, build a candidate window based on the contents of `BigWorld.ime.candidates`. This is an array of candidate strings for the current page (each page has a maximum of 9 entries). The highlighted item of the composition is determined by the `BigWorld.ime.selectedCandidate` property.

  The candidate window should be placed so it appears just under the location of the composition window cursor.

  The orientation of the candidate window is determined by the `BigWorld.ime.candidatesVertical` property.

18.2.3.1. Japanese

- Rather than placing the candidate window at the location of the composition string cursor, the candidate window should be placed below the first target converted character (determined via the `compositionAttr` property).

18.2.3.2. Korean

Korean IME's require a bit more specialisation than Chinese and Japanese. The main considerations for creating a Korean IME are:

- The composition string is edited in-line. In other words, the composition character is directly inserted into the edit box immediately so that the character to the right of the cursor is moved across. The underlying Korean IME implements this by injecting keystrokes such as `LEFTARROW`, `RIGHTARROW` and `BACKSPACE` into the input stream to automatically insert and remove a character into your edit box.

- The composition string background blinks, itself acting as the cursor. As such, `BigWorld.ime.compositionCursorPosition` can be ignored.

Chapter 19. BigWorld Web Integration

The BigWorld Technology engine now includes the open source Mozilla project allowing for displaying and interacting with web pages as part of the client.

19.1. Architecture

The BigWorld Technology Client includes the following components as part of the web browser integration:

- The bigworld/src/lib/web_render directory contains the BigWorld web integration code. The WebPageProvider class is the main interface for the web integration. The MozillaWebPageInterface class contains the main interface implementation for the Mozilla integration.
- The Mozilla project, see http://www.mozilla.org/ is the web layout engine used by the BigWorld Technology Client. This project is shipped as compiled dlls as part of the BigWorld engine. These dlls are available in the fantasydemo/game/mozilla directory. Different dlls are compiled for Visual Studio 2005 and Visual Studio 2008. These dlls are based on the Mozilla 1.8 release. If required, customers can also replace these dlls by recompiling Mozilla using the instructions available at http://ubrowser.com/. When recompiling Mozilla, additional fixes to the Mozilla source code might be required (see the content of bigworld/bin/client/mozilla/patch/mozilla_diff.txt for more details. Any modification to the Mozilla source code will require redistribution of the modification (as required by the Mozilla license).
- The LLMozlib library, see http://ubrowser.com/ is an open source wrapper for the Mozilla project and is shipped as part of the BigWorld source code. The LLMozlib source code is available in bigworld/src/lib/third_party/llmozlib2 and is compiled as part of the BigWorld client solution file. Any modification to the LLMozlib source code will require redistribution of the modification (as required by the LLMozlib license).

How the code works:

- A secondary thread is used to deal with all web related requests. This prevents performance spikes when responding to long web related requests.
- The MozillaWebPageManager manages calls to Mozilla and callbacks by using a separate command thread with two FIFO buffers.
- Users (i.e. Python/C++ classes) use MozillaWebPageInterface to interact with the MozillaWebPageManager, and they send commands to the manager which are sent over via the FIFO buffer to be dealt with by the secondary thread. This thread dispatches the commands to the MozillaWebPage instance which correlates with the MozillaWebPageInterface.
- Callbacks are dispatched using a second FIFO buffer which is flushed by the main thread during the tick method.
- Please note that all interaction with Mozilla must be done in the second thread (as Mozilla itself is not thread safe).

19.2. Using the Web Integration

The BigWorld web integration can be used in multiple scenarios. Multiple usage examples are available as part of FantasyDemo and will be explained below.

19.2.1. In Game Web GUI Component

An in game web GUI component is a GUI component capable of displaying 2D web content and sending mouse and keyboard events to that web content. There is some experimental (not supported) code also allows building a game integrated with ActionScript and JavaScript components (see below).

19.2.1.1. Creating an Interactive 2D Web GUI Component

Displaying an interactive 2D web GUI Component which can be used to browse the web can be done by creating a GUI component containing a child SimpleGuiComponent using the fantasydemo/res/scripts/client/Helpers/PyGUI/InternalBrowser.py script. For an example of a 2D web GUI component please review the fantasydemo/res/gui/web.gui. Following are the main considerations for creating an interactive 2D web GUI component.

- The web.gui contains multiple child GUI components. The main GUI component used to display the web content is the InternalBrowser component. Other child components are mainly used to display navigation buttons, a window label and the window texture.
- The InternalBrowser.py sets the SimpleGuiComponent texture to use the TextureProvider returned by the WebPageProvider in order to display the web page as part of the SimpleGuiComponent.
- The InternalBrowser.py implementation currently supports two types of keyboard input methods. Keyboard input is automatically captured by Mozilla when mozillaHandlesKeyboard is set to True, otherwise key events are sent to Mozilla by the InternalBrowser script, allowing for in game IME implementation.

19.2.1.2. Creating a Game Integrated 2D Web GUI Component

A game integrated 2D web GUI component is a web GUI component which can interact with the game logic. This allows building game GUI using fast development tools like HTML or Flash, and having them call Python methods using a JavaScript to Python or ActionScript to Python bridges. Please note that this BigWorld feature is not supported and we recommend using the ScaleForm solution for customers interested in such a solution. Implementing a Game Integrated 2D Web GUI Component is done similarly to the above Interactive Component but with several additional steps. The fantasydemo/res/gui/html_chat_window.gui contains an example html GUI component using the JavaScript to Python bridge.

19.2.2. In Game Web Screen

An in game web screen is a 3D in game entity with similar capabilities and use cases as the previously explained Web GUI Component. The main difference between the Web GUI component and the in game web screen is that the Web Screen is part of the 3D game scene and not a 2D GUI component. This Web Screen is located in a specific world location and isn't available for gamers as part of their HUD.

19.2.2.1. Creating an In Game Web Screen

The WebScreen entity available as an example in fantasydemo/res/scripts/client/WebScreen.py implements an in game web screen. Following are the main considerations for creating an In Game Web Screen:

- The WebScreen entity uses a model with multiple tints, the current tint is fed by a TextureFeed created by the WebScreen entity. The parameters usedTint and textureFeedName control the entity model used tint and the TextureFeed name used by this entity. These should usually contain the same string based on the tints available for that model. These options are exposed as part of WorldEditor.
- The model used by the WebScreen entity should also have three hard points called HP_top_left, HP_top_right, HP_bottom_left. These hard points are used by the _intersectMouseCoordinates method to find an intersection between a world ray and the entity model. This allows sending mouse events with a 2D position to the actual web page.
- The webPage member of this entity contains a WebPageProvider and is used to render a web page and to send mouse and keyboard events to the web page.

19.2.3. Texture Mapping of Web Pages into a world object

The TextureProvider returned by the WebPageProvider can be used to build a TextureFeed (similar to the one used for the WebScreen entity above). A VideoScreen Entity allows simple usage of the TextureFeed to map the texture into 3D world objects with the correct material settings (same as the tints used above). The exhibition room in the Urban space contains a teapot example of mapping a web texture into a world object using a VideoScreen entity.

Chapter 20. Sounds

BigWorld provides sound support via the third-party FMOD sound library (www.fmod.org). See the document "Third-Party Integrations" for more information.

Chapter 21. 3D Engine (Moo)

Moo is a 3D engine using DirectX 9 that provides resource-, object- and device- based services up to, but not including the scene database.

Resource-based services include the generation and management of vertex buffers, index buffers, vertex shaders, pixel shaders, and effects. Textures are compressed and stored automatically. All resources that are not managed by Direct3D are managed by Moo, allowing for large amounts of data moving in and out of use.

Object-based services include a full animation system, skinned bipeds, compound skeletal geometrics, and specialised terrain rendering. Moo exposes the concept of a visual, an important mid-level geometric construct that sits beneath the scene database and greatly simplifies the scene database code.

Device-based services include level-of-detail control over rendering states, encapsulated in materials and shaders. The 3D window is encapsulated as a RenderContext, and provides frames-of-reference in which to render geometrics and store lighting states.

Finally, Moo provides the essential alpha-blended sorted triangle pipeline, a service that unfortunately is still not provided by Direct3D or directly in (most) hardware.

It is important to note that where possible, Moo uses underlying Direct3DX structures such as D3DXMatrix, D3DXVector, and D3DXQuaternion. The DirectX team continually improves the implementation of these mathematical classes, and their functionality often takes advantage of processor specific instructions, such as MMX, SIMD and 3DNow!. It is prudent to leverage the efforts of these engineers.

21.1. Features

Some of the advanced features of Moo are listed below:

- D3DXEffects vertex and pixel shader support
- Cubic environment maps
- Render targets
- Lighting
- Normal mapping/bump mapping
- Terrain
- Animation
- Vertex morphing

The following sections describe these features.

21.1.1. D3DXEffects vertex and pixel shader support

Effect files are used extensively in Moo. Most of the rendering pipeline is based around the class EffectMaterial, which implements a way of managing the global values used by the effects, and also the per-instance data for the effects, such as textures, self-illumination values, and specular reflection constants.

The effect files also make it easier to manage pixel and vertex shaders, as they are created together in one file. Using the D3DXEffect format removes much of the complexities of adding new shader effects to the engine and allows rapid prototyping of new visual effects.

21.1.2. Cubic environment maps

Cubic environment maps can be used for some reflections and for normalisation cube maps (used for normal mapping).

21.1.3. Render targets

Render targets are used to create billboard textures. They can also be used in conjunction with the GUI components to display 3D objects in the 2D GUI (for example, for item selection previews).

21.1.4. Lighting

The lighting component of Moo supports three different kinds of lights:

- Directional lights.
- Point lights.
- Spot lights.

Any object can be lit by two directional lights, four point lights and two spot lights. These lights are picked according to an attenuation metric, so that generally the closest lights will be chosen. It is also important to note that the fewer lights used, the faster the execution of the lighting vertex shader will be.

21.1.4.1. Light maps

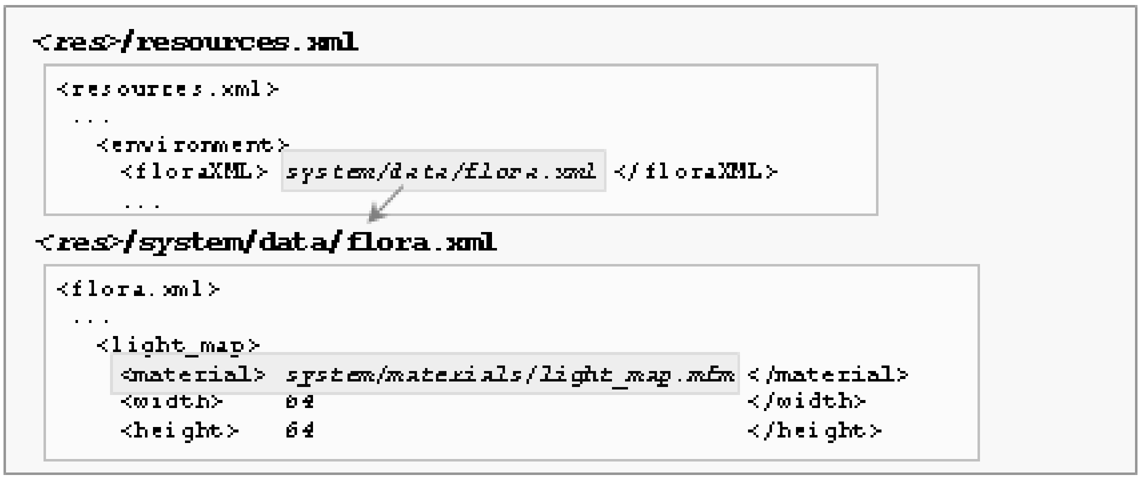
The class `bigworld/src/lib/romp/light_map.cpp` is generalised to support both the flora and sky light maps. Light maps are configurable in XML files.

21.1.4.1.1. Flora light map

The flora light map details are specified in `flora.xml` (for details on this file's grammar, see the document File Grammar Guide's section "*`<flora>`*`.xml`") and its location is specified in the file `resources.xml` (for details on this file, see "File `resources.xml`" on page 11).

The `material` tag for flora light map should be `system/materials/light_map.mfm` (for details on this file's grammar, see the document File Grammar Guide's section *`.mfm`*).

The default width/height for the flora light map is 64x64. This is small, but still enough resolution for the projection onto the flora, because its visible area is 100x100 metres.



<res>/resources.xml

```
<resources.xml>
 ...
   <environment>
     <floraXML> system/data/flora.xml </floraXML>
     ...
```

<res>/system/data/flora.xml

```
<flora.xml>
 ...
   <light_map>
     <material> system/materials/light_map.mfm </material>
     <width>    64                              </width>
     <height>   64                              </height>
```

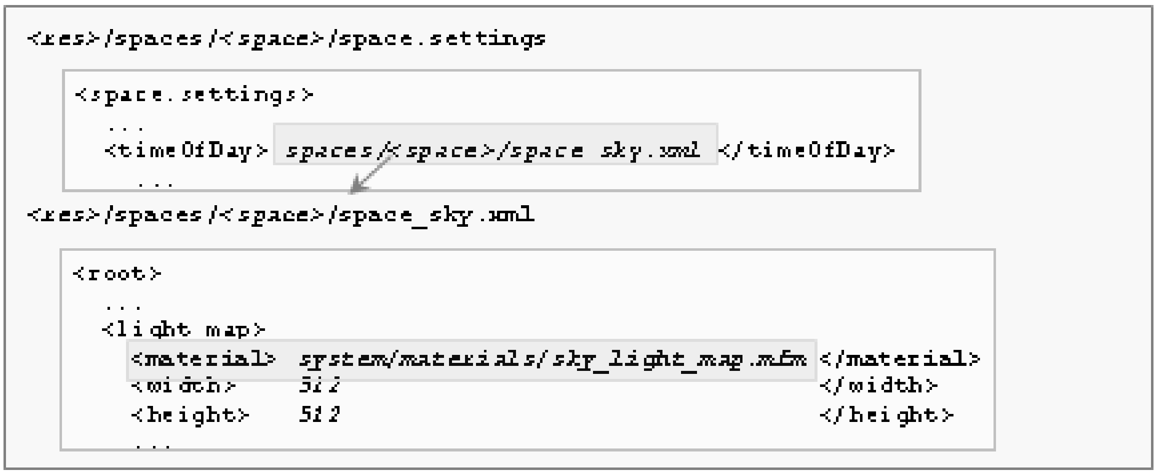
Definition of flora light map

21.1.4.1.2. Sky light map

The sky light map details are specified in the space's `sky.xml` file, and its location is specified in the space's `space.settings` file (for details on this file's grammar, see the document File Grammar Guide's section *`space.settings`*.).

The material tag for sky light map should be `system/materials/sky_light_map.mfm` (for details on this file's grammar, see the document File Grammar Guide's section *`.mfm`*).

The default width/height for the sky light map is 512x512. This is quite large because the light map is projected across the whole visible world (usually around 1x1 km).



```
<res>/spaces/<space>/space.settings

  <space.settings>
    ...
    <timeOfDay> spaces/<space>/space_sky.xml </timeOfDay>
      ...
<res>/spaces/<space>/space_sky.xml

  <root>
    ...
    <light_map>
      <material>  system/materials/sky_light_map.mfm </material>
      <width>     512                                </width>
      <height>    512                                </height>
      ...
```

Definition of sky light map

Note

The sky light map can be disabled via the `SKY_LIGHT_MAP` graphic setting (for details, see “Customising options” on page 135).

21.1.5. Normal mapping/bump mapping

Normal mapping is used to add surface detail to objects by using per-texel normals baked into a texture. Moo currently supports normal maps for specular and diffuse lighting on dynamically lit objects, and specular lighting on statically lit objects. The current version of the Exporter supports tangent space normal mapping only.

21.1.6. Terrain

Moo takes advantage of the multi-texture, vertex, and pixel shading capabilities of the supported graphics cards. Since it uses a blended 4-layered texturing system for the terrain, Moo utilises the hardware's four texture stages optimally so that that most of the terrain can be rendered in just one pass. The terrain also supports self-shadowing from a directional light source.

21.1.7. Animation

Moo supports node-based and vertex-based (morph) animation. Moo can also blend animations together to provide smooth transitions between them.

21.1.8. Vertex morphing

Moo's vertex morphing is suitable for small changes in surfaces, such as facial animation. Morph targets are exported from the content creation package, and controlled through the normal animation system.

Please note that as morph targets are applied in software, extensive use will affect rendering performance.

21.2. Supported video cards

The currently supported graphics cards are as follows:

- **NVIDIA**

  GeForce4 series, GeForce FX series, GeForce 6x00 series, GeForce 7x00 series cards and above.

- **ATI**

  Radeon 9000 series, and Radeon x000 series of cards.

Any graphics chip that supports at least Hardware Transform and Lighting and two texture stages should work, some with a limited subset of features enabled. These include (but are not limited to):

- **NVIDIA**

  GeForce3 series and GeForce GO 4 series cards.

- **ATI**

  Radeon 7000 series, Radeon 8000 series, Mobility 8000 and Mobility 9000 series.

21.3. Hardware requirements for special effects

The table below lists the special effects available in Moo, and their hardware requirements:

Special effect	Vertex shader version	Pixel shader version	Texture stages required
Bloom	1.1	1.1	4
Cloud shadows	1.1	-	3
Flora	1.1	-	1
Heat Shimmer	1.1	-	1
Normal mapping	1.1	1.1	4
PyModel Shimmer	1.1	-	1
PyModel stipple	1.1	1.1	4
Entity shadows	2.0	2.0	1
Simulated sub-surface scattering	3.0	3.0	4
Sky Gradient dome	1.1	-	3
Terrain shadows	1.1	1.1	4
Terrain Specular	1.1	1.1	4

Hardware requirements for special effects

21.4. Visual

The `Visual` class implements the basic renderable objects drawn by the 3D engine. A visual contains a node hierarchy, vertices, indices, and materials used for rendering objects, and it also contains a BSP tree used for collision detection.

The node hierarchy gives the renderable object a frame of reference when rendering objects. Visual uses the `EffectMaterial`, `Primitives`, and `Vertices` classes to render its geometry.

21.5. EffectMaterial

The material system in the BigWorld 3D engine uses `D3DXEffects` files extensively.

The material system is implemented through the class `EffectMaterial`, which contains one or more D3DX effects, their overridden values, and information about the collision properties and surface type of the material.

The idea behind the material system is to give as much control as possible to the artists, to allow them to experiment with new rendering techniques without involving programmers.

21.5.1. Format

The format of the `EffectMaterial` on disk is very simple, having only a handful of sections, and with most of the work done through the .fx file.

21.5.2. Automatic variables/Globals

Automatic variables are used for any variable that is controlled by the engine, such as transforms, lights, camera positions, etc... Automatic variables are exposed to Effect files using variable semantics.

In an Effect file, the automatic variables are defined like below:

```
<type> <variableName> : <semantic>;
```

where:

- ***`<type>`***

  The variable type (float, bool, texture, etc.).

- ***`<variableName>`***

  Name used for the variable in the effect file.

- ***`<semantic>`***

  Name exposed to the engine.

The automatic variables are connected to the effect through the class EffectConstantValue. New automatic variables can be added by overriding the EffectConstantValue interface, implementing the operation (), and adding an instance of the new class using EffectConstantValue::set or using a handle returned from EffectConstantValue::get.

The automatic variables set up by Moo::EffectVisualContext are listed below:

- **`Ambient` (`float4`)**

  Current ambient colour.

- **`CameraPos` (`float3`)**

  Current camera position in world space.

- **`CameraPosObjectSpace` (`float3`)**

  Current camera position in object space.

- **DepthTex (`texture`)**

  The depth of the scene, stored encoded in a 32-bit RGBA texture. This is only available when the Advanced Post Processing graphics setting is switched on.

- **`DirectionalLightCount` (`int`)**

Number of directional lights.

- **`DirectionalLights` (`DirectionalLights[2]`)**

  Current diffuse directional lights in world space.

- **`DirectionalLightsObjectSpace` (`DirectionalLights[2]`)**

  Current diffuse directional lights in object space.

- **EnvironmentCubeMap (`texture`)**

  Cube map containing a low-resolution dynamic cube map of the environment (sun, moon, sky gradient dome, sky boxes).

- **EnvironmentTransform(`float4x4`)**

  Matrix used to transform environmental and skybox objects to the screen. Comes pre-multiplied with the projection matrix.

- **EnvironmentShadowTransform(`float4x4`)**

  Matrix used to transform environmental and skybox objects to the sky light map.

- **FarPlane (`float`)**

  Current far plane in metres.

- **`FloraAnimationGrid` (`float4[64]`)**

  8x8 array of Perlin noise values used to animate the flora vertex buffer.

- **`FloraTexture` (`texture`)**

  The composite Flora texture map used by the FloraRenderer.

- **`FogColour` (`float4`)**

  Fog colour.

- **`FogEnd` (`float`)**

  End of linear fog.

- **`FogGradientTexture` (`texture`)**

  The fog texture used by the terrain renderer.

- **`FogStart` (`float`)**

  Start of linear fog.

- **`FogTextureTransform` (`matrix`)**

  Projects the fog texture onto the terrain.

- **`GUIColour` (`float4`)**

  Colour for use by the GUI.

- **`LastViewProjection` (`float4x4`)**

The last frame's view*projection matrix.

- **`InvView` (`float4x4`)**

  Current inverse view matrix.

- **`InvViewProjection` (`float4x4`)**

  Current inverse view*projection matrix.

- **`MipFilter` (`int`)**

  Configurable MIPFILTER.

- **`MinMagFilter` (`int`)**

  Configurable MIN/ MAGFILTER.

- **`MaxAnisotropy` (`int`)**

  Configurable MAXANISOTROPY.

- **NearPlane (`float`)**

  Current near plane in metres.

- **`NormalisationMap` (`texture`)**

  Normalisation cubemap.

- **ObjectID (`float`)**

  Set to 1 when rendering a PyModel, aka a dynamic/entity model. Set to 0 for all other models. In future, this may expand to designate further groups of objects.

- **`PenumbraSize` (`float`)**

  Used by the terrain renderer for self-shadowing.

- **`PointLightCount` (`int`)**

  Number of point lights.

- **`PointLights` (`PointLights[4]`)**

  Current diffuse point lights in world space.

- **`PointLightsObjectSpace` (`PointLights[4]`)**

  Current diffuse point lights in object space.

- **Screen (`float4`)**

  Holds the screen dimension thus : (width, height, half width, half height)

- **SkyBoxController (`float4`)**

  Holds the current value of the Vector4 that was registered with the sky box currently being rendered. How this variable is interpreted is up to the individual sky box, although the fourth component is generally treated as an alpha value.

- **`SpecularDirectionalLightCount` (`int`)**

Number of specular directional lights.

- **`SpecularDirectionalLights`** **(`DirectionalLights[2]`)**

  Current specular directional lights in world space.

- **`SpecularDirectionalLightsObjectSpace`** **(`DirectionalLights[2]`)**

  Current specular directional lights in object space.

- **`SpecularPointLightCount`** **(`int`)**

  Number of specular point lights.

- **`SpecularPointLights`** **(`PointLights[2]`)**

  Current specular point lights in world space.

- **`SpecularPointLightsObjectSpace`** **(`PointLights[2]`)**

  Current specular point lights in object space.

- **`SpotLightCount`** **(`int`)**

  Number of spot lights.

- **`SpotLights`** **(`SpotLights[2]`)**

  Current diffuse spot lights in world space.

- **`SpotLightsObjectSpace`** **(`SpotLights[2]`)**

  Current diffuse spot lights in object space.

- **`StaticLighting`** **(`bool`)**

  Whether static lighting is applied or not.

- **`StippleMap`** **(`texture`)**

  Map to be used for the stipple effect.

- **`SunAngle`** **(`float`)**

  Used by the terrain renderer for self-shadowing.

- **`TerrainTextureTransform`** **(`float4[2]`)**

  Projects textures onto the terrain.

- **`Time`** **(`float`)**

  Time in seconds since the game started.

- **`View`** **(`float4x4`)**

  Current view matrix.

- **`ViewProjection`** **(`float4x4`)**

  Current view*projection matrix.

- **`WindAnimation`** **(`float4`)**

Two Vector2's. in (x,y) is a value that can be used for wind-affected texture scrolling. It keeps the incremental value of a single uv coordinate blown around by the wind. in (x,z) is the current wind average speed.

- **`World`** **(`float4x4`)**

  Current world matrix.

- **`WorldPalette`** **(`float4[17*3]`)**

  Matrix palette, made up of the current renderset matrices stored as transposed 4x3 matrices.

- **`WorldView`** **(`float4x4`)**

  Current world*view matrix.

- **`WorldViewProjection`** **(`float4x4`)**

  Current world*view*projection matrix.

21.5.3. Artist-editable/tweakable variables

Artist-editable variables are variables that are designed to be overridden on a per-material basis. These variables can be edited in WorldEditor and ModelEditor, allowing you to change the look of a model in real time, while visualising it.

The artist-editable variables can be exposed to the engine by setting the attribute `artistEditable` or `worldBuilderEditable` to `true`.

Setting `artistEditable` to `true` exposes the variable to ModelEditor's **Materials Settings** panel (for details, see the document Content Tools Reference Guide's section *ModelEditor* → "Panel summary" → "Materials Settings panel"), while setting `worldBuilderEditable` to `true` exposes it to both ModelEditor and, if the `objects/materialOverrideMode` tag is set to `1` in `bigworld/tools/worldeditor/options.xml` (for details on this file's grammar, see the document File Grammar Guide's section *`options.xml`* → "WorldEditor") file, to WorldEditor's **Properties** panel (for details, see the document Content Tools Reference Guide's section *WorldEditor* → "Panel summary" → "Properties panel").

The notation for these variables in a FX file is described below:

```
<type> <variableName>
<
  bool [artistEditable|worldBuilderEditable] = true;
  ... 1
> = <defaultValue>;
```

1 Other attribute definitions.

where:

- **`<type>`** — Type of the object.
- **`<variableName>`** — Variable name in the effect file.
- **`<defaultValue>`** — Default value of the variable.

Currently, the supported types of artist-editable variables are:

- **`bool`**
- **`float`**

- `float4`
- `float4x4`
- `int`
- `texture`

The conditions to have the variable exposed in either tool are described below:

- **If `artistEditable` is set to `true` in the FX file**

  Exposed in ModelEditor?: Yes

  Exposed in WorldEditor?: No

- **If `worldBuilderEditable` is set to `true` in the FX file**
  - **If `materialOverrideMode` is set to `1` in `bigworld/tools/ worldeditor/options.xml`**

    Exposed in ModelEditor?: No

    Exposed in WorldEditor?: No

  - **If `materialOverrideMode` is set to `0` in `bigworld/tools/ worldeditor/options.xml`**

    Exposed in ModelEditor?: No

    Exposed in WorldEditor?: Yes

21.5.4. Multiple-layered effects per material

The `Moo::EffectMaterial` class supports having multiple-layered D3DXEffects per material.

This is useful for materials that need to use a standard set of vertex shaders, but only have slight changes to the pixel shader component of the effect. These materials would generally only be created by the asset converter, as ModelEditor does not support adding more than one effect per material.

21.5.5. Recording material states

Material states can be recorded by class `Moo::EffectMaterial` by calling the method `recordPass()` between a `begin()` and `end()` pair on the material.

This method returns a `Moo::StateRecorder` that is used to store the current render states for delayed rendering.

This object only stays valid until the end of the current render loop, and will not be usable after this point.

21.5.6. Using BigWorld `.fx` files with 3ds Max

BigWorld `.fx` files and 3ds Max .fx files unfortunately are not 100% compatible. It is however possible to create a `.fx` file that can be used in both applications.

To expose editable parameters, BigWorld shaders use the annotation below:

```
bool artistEditable = true;
```

whereas 3ds Max requires the annotation string below:

```
UIName="name"
```

The sample effect file `bigworld/res/shaders/std_effects/normalmap.fx` exposes its parameters properly to BigWorld and 3ds Max. The exporter also exports the values entered in the 3ds Max shader material panel.

The file `normalmap.fx` also uses a separate technique, called `max_preview`, plus additional vertex and pixel shaders.

This is due to two reasons:

- There is no uniform way to apply the lighting in both the BigWorld engine and 3ds Max.
- 3ds Max uses a right-handed coordinate system, while BigWorld uses a left-handed one.

In itself this is not a big problem, but it means that additional shader work is required if you want to preview your shaders in 3ds Max.

If you have not applied Service Pack 1for 3ds Max 7, an issue exists in that its **Material Panel** is very poor at dealing with `#include` directives in the effect files. What happens is that if you save a material with the effect `normalmap` applied, then not always it will be properly loaded up again in 3ds Max, which can cause additional confusion for the artists. This problem has been fixed in Service Pack 1, so it is important to apply it if you want to use `.fx` files in 3ds Max.

It is important to be mindful of these issues before you decide to make your `.fx` files compatible with 3ds Max.

21.6. Visual channels

The visual channels implement the delayed rendering pipeline in Moo.

There are presently five standard channels implemented:

- Sorted channel
- Internal sorted channel
- Shimmer channel
- Sorted shimmer channel
- Distortion channel

An application can create as many channels as it wants by overriding the `Moo::VisualChannel` interface and implementing `VisualChannel::addItem`.

The following sub-sections describe these channels.

21.6.1. Sorted channel

The sorted channel is used for objects that need to be rendered in a back-to-front order.

When a primitive group from a visual is added to this channel, its triangles are not sorted internally.

This channel is mostly useful for additive objects, *i.e.*, objects with a destination blend of one.

21.6.2. Internal sorted channel

The internal sorted channel is used for objects that need to be rendered in a back-to-front order, and also have its triangles rendered in a back-to-front order.

Objects that are added to this channel will also be sorted against objects in the sorted channel.

This channel is useful for alpha-blended objects, and any transparent object that does not have a destination blend of one.

21.6.3. Shimmer channel

The shimmer channel is used for objects that need a heat shimmer.

Any object that is added to this channel should only write to the alpha channel of the frame buffer.

21.6.4. Sorted shimmer channel

The *sorted shimmer channel* is used for objects that need a heat shimmer, and also need to draw colour information.

Any object added to this channel should write to both the alpha channel (for shimmer amount) and colour channel of the frame buffer.

21.6.5. Distortion channel

The *distortion channel* is used for objects that want direct access to the final scene as a texture. This can be used to achieve effects like refraction (for example, the water).

21.7. Textures

21.7.1. Texture detail levels/compression

Textures are loaded and compressed automatically based on their filenames, which control the size, format conversions, and compression levels.

For details on this file's grammar, see the document File Grammar Guide's section *`.texformat`*.

The system is implemented through the class `Moo::TextureDetailLevel`. The Texture Manager stores a list of texture detail levels and uses them to resize and compress textures based on their filenames. The legacy `.texformat` system is still supported.

The properties for the `TextureDetailLevel` are divided into two sets:

- Filename matching criterion.
- Conversion rule.

The filename matching criterion set of properties defines the criteria used to check if the current TextureDetailLevel applies to the texture being checked. They are described below:

- **`contains_`**

  Matched strings for a string contained in the texture filename.

- **`postFixes_`**

  Matched strings for the postfixes of the texture filename.

- **`preFixes_`**

  Matched strings for the prefixes of the texture filename.

Only one string from each list of strings has to match the texture name for the `TextureDetailLevel` to consider it a match. If there are no strings in one of the lists, that will be considered a match as well.

The conversion rule set of properties defines how matching textures will be converted. They are described below:

- **`compressedFormat_`**

  Format to which convert the texture (when texture compression is enabled).[AB]

- **`format_`**

  The format to convert the texture to.

- **`lodMode_`**

  Defines how texture responds to the texture quality settings.

  Texture quality is set via `TEXTURE_QUALITY` graphics setting.[AB]

- **`maxDim_`**

  The maximum width/height dimension of the texture.

- **`minDim_`**

  The minimum width/height dimension of the texture.

- **`noResize_`**

  Determines that the texture will not be scaled to be a power of two, and will not have mipmapping, compression or a .dds version.

- **`reduceDim_`**

  The number of times to halve the dimensions of the texture when compression is disabled.[A]

A *— Texture compression can be toggled via TEXTURE_COMPRESSION graphics setting.*[B]

B *— For details, see "Graphics settings" on page 132 .*

The texture detail level can be read from a datasection, as displayed in the example below:

```
<prefix>     objects/ </prefix>
<postfix>    tga      </postfix>
<postfix>    bmp      </postfix>
<contains>   norms    </contains>
<contains>   normals  </contains>
<maxDim>     512      </maxDim>
<minDim>     128      </minDim>
<reduceDim>  1        </reduceDim>
<format>     A8R8G8B8 </format>
```

Example texture detail level format

The example above results in any texture loaded from a sub-tree of folder objects/ with the extension `.tga` or `.bmp` and that contains the string norms or normals to have its dimensions reduced by half once, as long as the smallest dimension does not fall below 128. If the format is different, it will be changed to a 32-bit colour with alpha.

The default detail levels are:

- Any file with a filename ending in `norms.tga` or `norms.bmp` will be converted to an A8R8G8B8 texture (so as to not compress BigWorld's normal maps).
- Any other `.tga` file is converted to the DXT3 format.
- Any other `.bmp` file is converted to the DXT1 format.

By default textures are only scaled down if their dimensions are bigger than 2048.

21.7.2. Animated textures

Moo supports simple animated textures by texture swapping.

When Texture Manager loads a texture, it will look for a file with the same name as the one being loaded, but with a `.texanim` extension. If such file is found, then it will be loaded as an animated texture.

The `.texanim` file is a simple XML file that references a number of textures, contains an animation string and a frames-per-second value.

The format of a `.texanim` file is described below:

```
 <frames>  string           </frames>
 <fps>     .f               </fps>
+<texture> TEXTURE_RESOURCE </texture>
```

File `.texanim` format

An example of a `.texanim` file is displayed below:

```
<frames>  abcdefgh               </frames>
<fps>     10.0                   </fps>
<texture> maps/fx/fx_dirt01.tga </texture>
<texture> maps/fx/fx_dirt02.tga </texture>
<texture> maps/fx/fx_dirt03.tga </texture>
<texture> maps/fx/fx_dirt04.tga </texture>
<texture> maps/fx/fx_dirt05.tga </texture>
<texture> maps/fx/fx_dirt06.tga </texture>
<texture> maps/fx/fx_dirt07.tga </texture>
<texture> maps/fx/fx_dirt08.tga </texture>
```

Example file `.texanim` format

In this case, the animating texture will play the `fx_dirt` textures back in order at a rate of ten frames per second.

You can change the order in which the frames are played back by changing the `frames` tag . The a in the tag's value refers to the first texture stored in the XML file, b refers to the second texture stored, and so on.

21.7.3. Applying a code-generated texture to a character

To apply a code-generated texture to a model, follow the steps below:

1. Create an automatic `.fx` variable (*e.g.*, `customTexture`).
2. Update the character's shaders so that they render using the new `.fx` variable, instead of the `diffuseMap` property.
3. You will need a single `TextureSetter`, which is a `Moo::EffectConstantValue`. This provides the "current custom texture" to `.fx` files.
4. Write a `PyFashion` that sets up the "current custom texture" when drawing an instance of a `PyModel`.
5. Create a `Moo::BaseTexture` that wraps the custom texture creation process.

21.7.3.1. Loading textures from disk

When loading texture from disk, it is recommended to have the loading thread running in the background, so that it does not interrupt the rendering thread.

The example below illustrates a texture loader using the `BackgroundTask` and `BGTaskManager` classes. Note that the code provides two features — threaded texture loading, and providing the texture to the `.fx` file system.

```
#include "pch.hpp"
#include "cstdmf/bgtask_manager.hpp"
#include "cstdmf/concurrency.hpp"

DECLARE_DEBUG_COMPONENT2( "romp", 0 );

// ---------------------------------------------------------------------------
// Section: Texture Setter
// --------------------------------------------------------------------------
/**
 *  This class sets textures on the device.  It is also multi-threaded.
 *  When it is told to use a new texture, it uses the background loading
 thread
 *  to do so.  While it is doing this, the textureName refers to the new
 *  texture, but isLoading() will return true.  And in this state, it will be
 *  sneakily using the pre-existing texture until the new one is ready.
 */
class ThreadedTextureSetter : public Moo::EffectConstantValue
{
public:
  ThreadedTextureSetter():
    pTexture_( NULL ),
    bgLoader_( NULL ),
    textureName_( "" )
  {
  }
  /**
   *  This method is called by the effect system when a material needs
   *  to draw using a texture with the given automatic semantic.
   */
  bool operator()(ID3DXEffect* pEffect, D3DXHANDLE constantHandle)
  {
    SimpleMutexHolder holder( mutex_ );

    if (pTexture_ && pTexture_->pTexture())
      pEffect->SetTexture(constantHandle, pTexture_->pTexture());
    else
      pEffect->SetTexture(constantHandle, NULL);

    return true;
  }

  /**
   *  This method sets our texture.  If the texture is different then
   *  the existing one, we schedule the new one for loading, and set
   *  the textureName and the isLoading() flag.  In an unspecified amount
   *  of time, the new texture will be loaded and used.
   */
  void texture( const std::string& texName )
  {
    if (textureName_ == texName)
      return;

    if (this->isLoading())
      return;

    textureName_ = texName;
    bgLoader_ = new BackgroundTask(
            &ThreadedTextureSetter::loadTexture, this,
            &ThreadedTextureSetter::onLoadComplete, this );

#ifndef EDITOR_ENABLED
    BgTaskManager::instance()->addTask( *bgLoader_ );
#else
    ThreadedTextureSetter::loadTexture( this );
    ThreadedTextureSetter::onLoadComplete( this );
#endif
  }

  /**
   *  This class-static method is called by the background loading thread
   *  and allows us to load the texture resource in a blocking manner.
   */
  static void loadTexture( void* s )
  {
    ThreadedTextureSetter* setter = static_cast<ThreadedTextureSetter*>(s);
    Moo::BaseTexturePtr pTex =
      Moo::TextureManager::instance()->get( setter->textureName() );
    setter->pTexture(pTex);
  }

  /**
   *  This class-static method is called when the background loading thread
   *  has finished.
   */
  static void onLoadComplete( void* s )
  {
    ThreadedTextureSetter* setter = static_cast<ThreadedTextureSetter*>(s);
    setter->onBgLoadComplete();
  }

  /**
   *  This method returns the name of the texture we are currently
   *  drawing with.  If isLoading() is true, then the textureName
   *  refers to the texture we would like to draw with (however we
   *  will be actually drawing with the previous texture ptr).
   */
  const std::string& textureName() const
  {
    return textureName_;
  }

  /**
   *  This method returns true if we are currently waiting for the
   *  background loading thread to load our texture.
   */
  bool isLoading()
  {
    SimpleMutexHolder holder( mutex_ );
    return (bgLoader_ != NULL);
  }

private:
  //only called by the background loading thread
  void pTexture( Moo::BaseTexturePtr pTex )
  {
    SimpleMutexHolder holder( mutex_ );
    pTexture_ = pTex;
  }
  //only called by the background loading thread
  void onBgLoadComplete()
  {
    SimpleMutexHolder holder( mutex_ );
    delete bgLoader_;
    bgLoader_ = NULL;
  }

  Moo::BaseTexturePtr pTexture_;
  std::string textureName_;  //store a copy for use while loading.
  BackgroundTask* bgLoader_;
  SimpleMutex    mutex_;
};
```

Example of texture loader

21.7.3.2. Manipulate individual pixels within a texture

To manipulate pixel within a code-generated texture, there are at least two available options:

1. **Create the texture in the managed pool**

   This way there will be a system memory copy and a video memory copy. You can then lock the texture and manipulate it as needed — DirectX will update the changes to video memory.

   The only drawback to this option is that on some hardware configurations, the system memory texture may be stored swizzled, meaning that the lock operation would have to unswizzle it before you can make changes — a potentially costly lock operation.

   Note that to use the texture, you will need to have mipmaps available, so when performing the lock you will have to either:

   - Update each surface of the texture individually.

   — or —

   - Use stretch rect to supply the mipmap chain from the top surface.

2. **Create the texture in video memory as a render target**

   You will have to use shaders to write your changes to the texture.

   The drawback to this method is that if the device is reset, then your changes will be lost. If that happens, you will have to handle the CreateUnmanagedObjects callback (from the DeviceCallback interface) and recreate the custom texture.

   Unfortunately, you cannot just copy the data to system memory, because a CTRL+ALT+DEL will lose the device without giving you a chance to save the video memory data first.

   Note again that to use the texture, you will need to have mipmaps available. So perhaps in this instance you can create a separate mipmap texture in video memory, and use stretch rect to supply the mipmap chain from the source render target. The source render target might be a 'scratch pad' used in building all the custom character textures.

21.7.3.3. Using a shader to build a custom texture

The closest example on how to achieve this is provided by the flora light map, which uses a variation of the terrain shaders to render the lighting information to a render target. For details, see bigworld/src/lib/romp/flora_light_map.cpp.

Note that to use shaders you will need a video memory/render target surface as described in the section above.

21.7.3.4. Dealing with the texture cache

The custom texture is needed to implement the Moo::BaseTexture interface, so that it can add itself to the Texture Manager. However, depending on the following step (applying custom textures to models), you may not even need to use the TextureManager, as it simply provides a 'retrieve texture by name' access to textures.

If you are creating several custom textures for characters, then you may have an internal (hidden) naming scheme, which would result in a minimal benefit for using the texture cache. It may be good enough simply to use smart pointers to handle caching.

21.7.3.5. Assigning custom textures to a model

Assuming that you have one model that you want display many times, each with a unique custom texture, then you will have to implement a class deriving from the `PyFashion` class.

Such classes are created from Python, assigned to a `PyModel` instance, and given an opportunity to alter how a shared model renders (*i.e.*, to set the custom texture on the model). The `PyFashion` class will become the main interface to your scripts, so in Python you can construct the `PyFashion` instance with the names of the texture you want to combine, and then assign it to a player's model by simply setting the fashion as any named attribute on its `PyModel` (`PyModel::pySetAttribute` automatically detects when a fashion is set on itself, and incorporates it into its rendering chain).

To actually set the custom texture on the model, we recommend creating a class deriving from `Moo::EffectConstantValue`, and that provides the custom texture to `.fx` files by name. In the `.fx` files, use the automatic variable semantic (*e.g.*, `Texture diffuseMap :customCharacterTexture`), instead of the existing `artistEditable` property.

For an example code on creating a texture setter, see “Loading textures from disk” on page 126 .

21.8. Vertex declaration

Vertex declarations are used by Direct3D to map vertex stream data to vertex shaders.

Moo uses the `VertexDeclaration` class to ease the handling of vertex declarations used by Direct3D. Vertex declarations are stored on disk in XML format and loaded as needed. The vertex declarations stored on disk can be retrieved by calling method `VertexDeclaration::get()`.

By default, the vertex declarations are stored under folder bigworld/res/shaders/ formats.

Two declarations can be combined with `VertexDeclaration::combine()` as long as the elements of both declarations are mutually exclusive.

21.8.1. File format

The format of the vertex declaration file is described below:

```
<root>

  +<USAGE> (usage index, optional defaults to 0)

    ?<stream> (strm #, opt, dflt is strm used by the prev elmnt)     </stream>
    ?<offset> (ofst into strm, opt, dflt is nxt ofst aft prev elmnt) </offset>
    ?<type>    (data type, opt, defaults to FLOAT3)                   </type>

   </USAGE>
```

```
</root>
```

Vertex declaration file format

The `USAGE` tag maps to the enumerated type `D3DDECLUSAGE`, and its possible values are listed below:

- **`POSITION`**
- **`BLENDWEIGHT`**
- **`BLENDINDICES`**
- **`NORMAL`**
- **`PSIZE`**
- **`TEXCOORD`**
- **`TANGENT`**
- **`BINORMAL`**
- **`TESSFACTOR`**
- **`POSITIONT`**
- **`COLOR`**
- **`FOG`**
- **`DEPTH`**
- **`SAMPLE`**

The data types entered in the `type` tag map to enumerated type `D3DDECLTYPE`, and its possible values are listed below:

- **`D3DCOLOR`**
- **`DEC3N`**
- **`FLOAT1`**
- **`FLOAT16_2`**
- **`FLOAT16_4`**
- **`FLOAT2`**
- **`FLOAT3`**
- **`FLOAT4`**
- **`SHORT2`**
- **`SHORT2N`**
- **`SHORT4`**

- **`SHORT4N`**
- **`UBYTE4`**
- **`UBYTE4N`**
- **`UDEC3`**
- **`USHORT2N`**
- **`USHORT4N`**

As an example, the `xyznuv_d` vertex format is defined like this:

```
<xyznuv_d.xml>

  <POSITION/>
  <NORMAL/>
  <TEXCOORD>
    <type>  FLOAT2  </type>
  </TEXCOORD>
  <COLOR>
    <stream> 1         </stream>
    <offset> 0         </offset>
    <type>   D3DCOLOR  </type>
  </COLOR>

</xyznuv_d.xml>
```

Vertex declaration file `xyznuv_d.xml`

21.9. Graphics settings

To allow the game client to run as smoothly as possible in the widest range of systems, BigWorld's 3D engine exposes several parameters. These can be tweaked by the player to achieve the optimal balance between visual quality and game responsiveness for his particular hardware configuration.

These parameters are known as graphics settings, and are listed below:

- **`FAR_PLANE`**[A]

  Available options: `FAR`, `MEDIUM`, `NEAR` "Customising options" on page 135

  Modifies the viewing distance. The viewing distance is defined per space and this graphics option modifies the viewing distance by a factor. The factors and options are configurable in the file `bigworld/res/system/data/graphics_settings.xml`

- **`FLORA_DENSITY`**[A]

  Available options: `HIGH`, `MEDIUM`, `LOW`, `OFF` "Customising options" on page 135

  Sets the density of the flora detail objects by a factor. The factors and options are configurable in the file `bigworld/res/system/data/graphics_settings.xml`.

- **`FOOT_PRINTS`**

  Available options: `ON`, `OFF`

  Toggles footprints on and off.

- **`OBJECT_LOD`**^{A}

  Available options: `HIGH`, `MEDIUM`, `LOW` "Customising options" on page 135

  Modifies the relative distance from the camera for LOD transitions by a factor.

- **`SHADER_VERSION_CAP`**

  Available options: `SHADER_MODEL_3`, `SHADER_MODEL_2`, `SHADER_MODEL_1`, `SHADER_MODEL_0`

  Sets the maximum shader model version available to the engine.

  SHADER_MODEL_0 is disabled if client is running with a graphics card supports Shader Model 1 only. SHADER_MODEL_0 need vertex shader 2.0 capability, no matter it is software or hardware vertex processing. SM1 graphics card such as nVidia TI4400 enables hardware vertex processing but only support vertex shader 1.1, so SHADER_MODEL_0 option can't be applied.

- **`SHADOWS_COUNT`**^{A}

  Available options: From 1 to `maxCount` (defined in `shadows.xml` — for details on this file's grammar, see the document File Grammar Guide's section *`shadows.xml`*)

  Sets the number of simultaneously visible dynamic entity shadows.

- **`SHADOWS_QUALITY`**

  Available options: `HIGH`, `MEDIUM`,`LOW`, `OFF`

  Sets entity shadow quality. `HIGH` uses a 12-tap filter for shadows, `MEDIUM` uses a 4-tap filter for shadows, `LOW` uses a 1-tap filter for shadows and `OFF` turns shadows off

- **`SKY_LIGHT_MAP`**^{B}

  Available options: `ON`, `OFF`

  Toggles the cloud shadows on and off.

- **`TERRAIN_SPECULAR`**^{B}

  Available options: `ON`, `OFF`

  Toggles terrain specular lighting on and off.

- **`TERRAIN_LOD`**

  Available options: `FAR`, `MEDIUM`,`NEAR`

  Modifies the terrain geo-morphing distances by a factor. The factors and options are configurable in the file `bigworld/res/system/data/terrain2.xml`

- **`TERRAIN_MESH_RESOLUTION`**

  Available options: `HIGH`, `MEDIUM`,`LOW`

  Selects the terrain resolution to use. HIGH uses the highest available resolution, MEDIUM uses half the available resolution, LOW uses a quarter of the available resolution

- **`TEXTURE_COMPRESSION`**^{AC}

  Available options: `ON`, `OFF` "Customising options" on page 135

Toggles texture compression on and off

- **TEXTURE_FILTERING**

  Available options: ANISOTROPIC_16X, ANISOTROPIC_8X, ANISOTROPIC_4X, ANISOTROPIC_2X, TRILINEAR, BILINEAR, LINEAR, POINT

  Selects texture filtering. Shaders can be modified to take advantage of this setting by using the automatic variables MinMagFilter, MipFilter, and MaxAnisotropy to set the MINFILTER , MAGFILTER, MIPFILTER and MAXANISOTROPY sampler states. For details, see bigworld/res/shaders/speedtree/speedtree.fx.

- **TEXTURE_QUALITY**^{AC} **"Customising options" on page 135**

  Available options: HIGH, MEDIUM, LOW

  Sets texture quality level.

- **SPEEDTREE_QUALITY**

  Available options: VERYHIGH, HIGH, MEDIUM, LOW, LOWEST

  Sets the quality of the speedtree rendering. VERYHIGH Enables per-pixel lighting (normal mapped) on all tree parts, HIGH Enables per-pixel lighting (normal mapped) on only the tree branches, MEDIUM Trees use simple lighting, LOW Trees use simple animation and lighting, using the fixed function pipeline.

- **WATER_QUALITY**

  Available options: HIGH, MEDIUM, LOW, LOWEST

  Sets the quality of water reflection rendering. HIGH Enables drawing of all object types, MEDIUM Disables drawing of dynamic objects, LOW Disables drawing of dynamic objects and halves the resolution of the render target. LOWEST only renders specular reflections.

- **WATER_SIMULATION**

  Available options: HIGH, LOW, OFF

  Sets the quality of the water simulation. HIGH Enables inter-cell water simulation, MEDIUM enables water simulation on a cell by cell basis, OFF turns water simulation off.

- **POST_PROCESSING**

  Available options: HIGH, MEDIUM, LOW, OFF

  Sets the default post-processing chain. These are selected from the chains folder, for example : bigworld/res/system/post_processing/chains/high_graphics_setting.xml. If you want to edit the default post-processing then edit the three chain files there.

- **MRT_DEPTH**

  Available options: ON, OFF

  Enables creation of the depth texture (exposed to .fx files via the DepthTex semantic.) This enables a variety of advanced post-processing effects such as depth-of-field and depth-fades, as well as the depth-based colouring of the water.

A *— Adjustable via configuration files. For details, see "Customising options" on page 135 .*

B *— Requires restart of the client. For details, see "Settings that require restarting the client" on page 140 .*

C — Delayed setting. For details, see “Delayed settings” on page 139 .

21.9.1. Customising options

Although most of these settings have their options determined in the engine, some settings can have their options customized via configuration files.

These settings and their customisation are discussed in the following topics.

21.9.1.1. TEXTURE_QUALITY and TEXTURE_COMPRESSION

Both `TEXTURE_QUALITY` and `TEXURE_COMPRESSION` settings are customized by the way of the texture format (`.texformat`) and detail levels (`texture_detail_level.xml`) files (for details on this file's grammar, see the document File Grammar Guide's section *`.texformat`*).

Lowering the texture quality and using compressed formats helps improving engine performance, by reducing the amount of texture memory required to store them. This means that less data needs to be sent to the graphics card at each frame, ultimately improving frame rate.

`TEXURE_QUALITY` adjusts the resolution of a texture by preventing its topmost mipmap levels from being loaded. This means that, at the highest level of quality, the texture will be at the same resolution as the original texture map. At medium level, it will be at half its original size, and at a quarter of it at the lowest level of quality.

How many mipmap levels are skipped in each quality level for each texture can be controlled by the `lodMode` tag in the texture's `detailLevel` section.

The table below lists the values `lodMode` can assume, next to the number of mipmaps skipped for each of the texture quality setting levels:

`lodMoc`		**# of skipped mipmaps**		
Value	Descriptic	High quality	Medium quality	Low quality
1	Normal	0	1	2
2	Low bias	0	1	1
3	High bias	0	0	1

Number of skipped mipmaps per quality setting level/ LOD level

`TEXTURE_COMPRESSION` affects the format in which texture maps are stored in memory. When texture compression is disabled, all textures are stored using the format defined by the format tag in the texture's `detailLevel` section. When texture compression is enabled, the format defined by the `formatCompressed` is used. If `formatCompressed` is not defined for a texture, then format is used, whatever the compression setting is.

Note that there is no restriction to what texture format is used for format or `formatCompressed`, but for the texture compression setting to yield any significant performance results, `formatCompressed` should define a texture format that uses less texture memory than its non-compressed format counterpart.

For details on how to setup a texture's level of detail, see “Texture detail levels/compression” on page 124 . For details on the configuration file's grammar, see the document File Grammar Guide's section *`.texformat`*.

21.9.1.2. SHADOWS_COUNT

SHADOWS_COUNT defines the maximum number of simultaneous dynamic entity shadow casters in a scene.

Shadows are rendered using shadow buffers, thus consuming texture memory. Filling the buffers up at every frame requires rendering the scene again for each shadow caster. Reducing the number of simultaneous dynamic shadow casters reduces the memory requirements and the amount of processing used to update the buffers at every frame.

Value ranges from 1 to value specified in maxCount shadows.xml file, in power of two steps (defined in shadows.xml — for details on this file's grammar, see the document File Grammar Guide's section *shadows.xml*).

21.9.1.3. FLORA_DENSITY

FLORA_DENSITY defines the size of the vertex buffer used to render the flora detail objects.

Since the flora drawing distance to the camera is fixed, defining the size of the vertex buffer also determines the flora density. Because it uses alpha blending, drawing the flora can negatively influence the frame rendering time, especially on hardware with limited fill rate performance. Reducing the amount of flora rendered at any one time may help improving the frame rate.

Flora density options are defined in <graphics_settings>.xml (for details on this file's grammar, see the document File Grammar Guide's section “*<graphics_settings>.xml*”) as a multiplier of the vertex buffer, which actual size is defined per space in <flora>.xml (for details on this file's grammar, see the document File Grammar Guide's section “*<flora>.xml*”).

```
<graphics_settings.xml>

  <flora>
    <option>
      <label>  HIGH </label>
      <value>  1.0  </value>
    </option>

    <option>
      <label>  LOW  </label>
      <value>  0.5  </value>
    </option>

    <option>
      <label>  OFF  </label>
      <value>  0    </value>
    </option>
  </flora>

</graphics_settings.xml>
```

Example <graphics_settings>.xml — Configuring flora density

21.9.1.4. FAR_PLANE

FAR_PLANE defines the maximum viewing distance when rendering the 3D world.

Decreasing the viewing distance reduces the amount of geometry sent to the rendering pipeline, resulting in higher frame rates.

Because the far plane distance can be defined on a per-space basis (in space.settings file — for details on this file's grammar, see the document File Grammar Guide's section *space.settings*), FAR_PLANE is actually multiplied by the space's specific far plane value before it is applied to the camera.

Specified in *<graphics_settings>*.xml (for details on this file's grammar, see the document File Grammar Guide's section "*<graphics_settings>*.xml"), the far plane can be configured as in the example below:

```
<graphics_settings.xml>

  <farPlane>

    <option>
      <value>  1.0     </value>
      <label>  FAR     </label>
    </option>

    <option>
      <value>  0.75    </value>
      <label>  MEDIUM  </label>
    </option>

    <option>
      <value>  0.5     </value>
      <label>  NEAR    </label>
    </option>

  </farPlane>

</graphics_settings.xml>
```

Example *<graphics_settings>*.xml — Configuring far plane

21.9.1.5. OBJECT_LOD

`OBJECT_LOD` defines the relative distance to the camera before LOD transitions occur.

For standard BigWorld models, LOD distances are defined using the ModelEditor. ParticleEditor is used to set the LOD distance for particle systems (the maximum distance to which the system is still visible). LOD levels and transition distances for SpeedTrees are defined inside SpeedTreeCAD (although they can be overridden by the SpeedTree's XML configuration file, which is specified in `resources.xml` file's `speedTreeXML` tag. For details on this file, see "File `resources.xml`" on page 11).

The `OBJECT_LOD` setting specify multipliers that will modify those distances during runtime, allowing the user to trade some visual quality for better performance.

The LOD multipliers are defined in *<graphics_settings>*.xml (for details on this file's grammar, see the document File Grammar Guide's section "*<graphics_settings>*.xml"):

```
<graphics_settings.xml>

  <objectLOD>

    <option>
      <value>  1.0     </value>
      <label>  HIGH   </label>
    </option>

    <option>
      <value>  0.66    </value>
      <label>  MEDIUM  </label>
    </option>
    <option>
      <value>  0.33    </value>
      <label>  LOW     </label>
    </option>

  </objectLOD>

</graphics_settings.xml>
```

Example <*graphics_settings*>.xml — Configuring object LOD

21.9.2. Using settings

Upon startup, the client automatically tries to load the graphics settings from disk. All graphics settings are stored in the `graphicsPreferences` section of the file specified in preferences tag of the file specified in `resources.xml`'s `engineConfigXML` tag (for details, see "File <*preferences*>.xml" on page 13). The first time the application is run, and when the graphics card or its driver has changed, the graphics settings will try to auto-detect the most appropriate settings for the device.

Saving, on the other hand, is not performed automatically; it must be controlled from the scripts, using the `BigWorld.savePreferences` method — it will save both the graphics settings and the video and script preferences.

The game scripts can use the functions `BigWorld.graphicsSettings` and `BigWorld.setGraphicsSettings` to query and change the current state of the settings (usually trough a graphical user interface).

21.9.2.1. Auto-detecting settings

Auto-detecting of settings is supported through an xml configuration file specified by the tag `graphicsSettingsPresets` in `resources.xml`. This file defines matching criteria to attempt to match a group of settings to a specific device (graphics card). There are three different ways of matching a group of settings to a device. All matching is done against the `D3DADAPTER_IDENTIFIER9` structure. The auto-detection itself is performed in the method `Moo::GraphicsSetting::init`

- **`GUID`**

  Matches a specific device type and driver version to a settings group, this is useful when there are known issues with a certain driver/device pair and you can adjust your graphics settings accordingly

- **`VendorID/DeviceID pair`**

  Matches a specific device type to the settings this is useful when you know the vendor and device id's for a specific device

- **`Device description string`**

  Matches the strings to the device description, all the strings need to match for the setting to be selected

```
<graphicsPreferences> HIGH <=== Name of the preset, if no name is present, the
 preset will not appear in the list of settings,
                               but it will still be used when auto-detecting
 settings for the graphics card

  <entry> <=== a graphics setting to change
    <label> CLASSIC_TERRAIN_QUALITY </label> <=== the name of the graphics
 setting
    <activeOption> 0 </activeOption> <===the selected option
  </entry>

  <GUIDMatch>  01234567.89abcdef.01234567.89abcdef </GUIDMatch>
    <===  Combined GUID of device and driver version, this is the value from
 DeviceIdentifier in the
          D3DADAPTER_IDENTIFIER9 structure saved out using the BigWorld
 UniqueID class.
          If this value matches, the setting will be used.

  <VendorDeviceIDMatch>
    <VendorID> 4318 </VendorID> <=== the VendorId from D3DADAPTER_IDENTIFIER9
    <DeviceID> 1554 </DeviceID> <=== the DeviceId from D3DADAPTER_IDENTIFIER9
  </VendorDeviceIDMatch> <=== If these two values match the current device,
 the setting will be selected
                             unless there is a GUIDMatch with the current
 device

  <DeviceDescriptionMatch>
    <string> nvidia </string> <=== Any number of strings that will be matched
 against the
    <string> 6800 </string> <=== Description property from
 D3DADAPTER_IDENTIFIER9
  </DeviceDescriptionMatch>  <=== If these values match the current device,
 the setting will be selected
                                 unless there is a GUIDMatch or
 VendorDeviceIDMatch with the
                                 current device

  <defaultSetting> true </defaultSetting> <=== this value is true for the
 value to be used as the default setting,
                                              the default setting is used
 when no other settings match.
</graphicsPreferences>
```

Example <*graphics_settings_presets*>.xml — Setting up device matches

21.9.2.2. `GraphicsPresets` class

A simple python graphics presets class is also supplied. This class helps with grouping several graphics settings together so that you can have pre-defined settings for multiple graphics options for a specific level of hardware or performance. The `GraphicsPresets` class can be found in the folder `bigworld/res/scripts/GraphicsPresets.py`.

21.9.2.3. Delayed settings

Most settings take effect immediately after calling `BigWorld.setGraphicsSettings`, but some are just flagged as delayed. That means that after being set they are added to a list of pending settings, and that they will only come into effect when that list gets committed.

This was designed to give the interface programmer a chance to warn the user that processing the new settings may take a while to complete before the client application blocks for a few seconds (currently, there is no support for displaying a progress bar while the settings are being processed).

The following functions allow the scripts to manage the pending settings list:

- **`BigWorld.hasPendingGraphicsSettings`**
- **`BigWorld.commitPendingGraphicsSettings`**
- **`BigWorld.rollBackPendingGraphicsSettings`**

21.9.2.4. Settings that require restarting the client

Some settings are not applied until the client application is restarted. The function `BigWorld.graphicsSettingsNeedRestart` returns true whenever the client requires a restart for a recently changed setting to take effect.

21.10. Taking Screenshots

The BigWorld client is able to take screenshots and save them to a number of different formats. It does this by retrieving the current content of the back buffer at the time the screenshot operation is called. To take an in-game screenshot, press the `PrtScn button`, or use the `BigWorld.screenShot(`*`extension`*`, `*`name`*`)` Python API function.

The default image type, filename prefix, and output location are all configured within the `engine_config.xml` (see "File `<`*`engine_config`*`>.xml`" on page 12). The schema for the `<screenShot>` tag is:

```
<engine_config.xml>
  ...
    <screenShot>
        <path> relativePath
            <pathBase>  basePathName </pathBase>
        </path>
        <name> prefixName </name>
        <extension> extension </extension>
    </screenShot>
  ...
</engine_config.xml>
```

- **`relativePath`** — This is the output path relative to basePath (outlined below). For example, if relativePath is `MY_DOCS`, you may want to set this to something like `"My Company/Game Name/Screenshots"`. Leave blank or specify `"./"` to place directly in `basePathName` (which is the default behaviour).
- **`basePathName`** — This configures the base output location for the screenshots. This can be one of the following values:
  - `EXE_PATH` — Screenshots relative to the location of the client executable. This is the default location if none is supplied.
  - `CWD` — Screenshots will be stored relative to the current working directory. Note that if the working directory changes during runtime, it will save in the new working directory.
  - `APP_DATA` — Screenshots will be stored relative to the current user's AppData directory.
  - `MY_DOCS` — Screenshots will be stored relative to the current user's My Documents directory.
  - `RES_TREE` — Screenshots will be stored relative to the first resource path found in `paths.xml`.

  The default value is `EXE_PATH`.
- **`prefixName`** — Specifies the prefix to use when generating a numbered screenshot. The default value is "shot".
- **`extension`** — Specifies the file format to use when saving the screenshot. This can be one of "bmp", "jpg", "tga", "png" or "dds". The default value is "bmp".

The full path of the generated screenshot will therefore be `basePathName/relativePath/prefixName_<`*`sequence`*`>.extension`, where `<`*`sequence`*`>` is a four-digit non-negative integer, padded with leading zeros (*e.g.*, `shot_0012.bmp`). The screen capture mechanism will not overwrite pre-existing files.

21.10.1. High Resolution Screenshots

Normally the back buffer is the same size as the window or the screen resolution when in full-screen mode. However, when running in windowed mode it is possible to have a back buffer that is larger than the window itself, thus increasing the size of the screenshot.

21.10.1.1. The backBufferWidthOverride watcher

The size of the back buffer can be changed (via Debug (Watchers) Console) by the `backBufferWidthOverride` watcher.

The values specified to the watcher, and their effect on the back buffer are described below:

- **Watcher's value: 0 (default)**

  Resulting dimensions of the back buffer: Same as those of the window (when in windowed mode) or screen (when in full-screen mode).

- **Watcher's value: Between 1 and the maximum surface width (4096 high-end cards)**

  Resulting dimensions of the back buffer: Width of the back buffer will be as specified. Height of the back buffer will be the specified width divided by the aspect ratio of the window.

- **Watcher's value: Greater than supported by hardware**

  Resulting dimensions of the back buffer: Maximum value supported by the hardware (typically 2048 or 4096). Specified value will be ignored.

21.10.1.2. How to take a high resolution screenshot

To take a high-resolution screenshot

1. Open `engine_config.xml` (for details on this file, see “File `<engine_config>.xml`” on page 12) and check the settings in <supershot> tag. If you have a video card with a large amount of memory you may be able to change hRes to 4096.

2. Load the space/level and navigate to the place of which you want the screenshot.

3. Press ctrl+PrtScn to enable high resolution screenshot settings.

4. Press PrtScn to take a screenshot.

5. Press ctrl+PrtScn to restore regular render settings.

21.10.1.3. Troubleshooting

The list below describes some errors that you might come across when taking high-resolution screenshots and how to solve them:

- **Back buffer's size did not change to the value that I specified.**

  When setting `backBufferWidthOverride`, client checks if specified size is larger than the hardware can support. If that is the case, then hardware will ignore the specified size and use its maximum (typically 2048 or 4096).

  — or —

When very large numbers are specified in the **Debug (Watchers) Console**, parsing may wrap the value. If this is the case of the value specified for backBufferWidthOverride, then it will be set to 0.

- **There is a glow covering the screen.**

  Sometimes, limited video memory resources will stop the renderer from allocating some of the buffers that it uses, or from drawing full-screen post-processing.

  This is particularly common when changing to a lower resolution after using a very large one.

  To solve this, you can either:

  - Set buffer to a smaller width (an application restart may also be necessary).
  - Turn off post-processing through the graphics settings
    - Press `DEBUG`+P to open the **Python Console**.
    - Type BigWorld.setGraphicsSetting("POST_PROCESSING", 3)

- **Changing back buffer's size had no effect when working in full-screen mode.**

  When in full-screen mode, the back buffer must always have the same dimensions as the screen resolution — this is a hardware/API limitation.

  Hence, `backBufferWidthOverride` will always be disabled (value equals 0) when running in full-screen mode.

21.10.1.4. Hardware recommendations

To produce high-resolution screenshots, a very capable video card is necessary — the two key requirements are:

- Maximum texture resolution
- Available video memory

DirectX 9 requires 2048 resolution as a minimum, but 4096 is available on nVidia GeForce3+ (7800+ recommended) and ATI 1X800+ series cards. It is recommended that you have a minimum of 256MB video memory when taking screenshots at resolutions in the order of 4096x3072.

21.11. Dynamic Entity Shadows

The client supports two different ways to allow entity models to cast shadows into the scene. The method you choose to use will depend on the target hardware as they differ greatly in cost.

21.11.1. Splodges

This system works by drawing a special "splodge" texture onto the geometry below the feet of the entity model, projected in the direction of the sun (they are only visible while in outside chunks). This is a good low-end solution as they are inexpensive to draw, however they will only provide a crude approximation of a shadow.

Splodges can be added to an entity model by using the PySplodge API. The PySplodge class is a type of attachment, and are attached to the feet of the entity model (one per foot). For example:

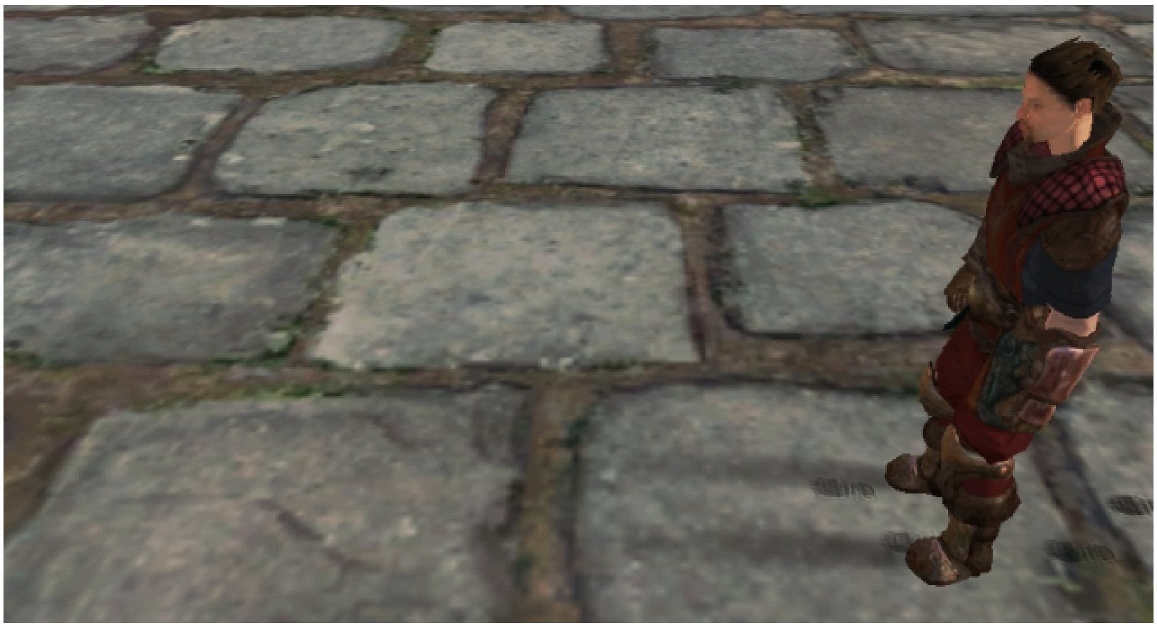
```
>>> lsplodge = BigWorld.Splodge()
>>> rsplodge = BigWorld.Splodge()
>>> model.node( "biped L Toe0" ).attach( lsplodge )
>>> model.node( "biped R Toe0" ).attach( rsplodge )
```

While all splodges use the same material to draw (this can be configured by modifying the environment/splodgeMaterial section in resources.xml), each PySplodge intstance can modify the following parameters:

- The maximum LOD distance from the camera, after which they are culled. Defaults to 50 metres.
- The size of the individual splodge.

Note

Since the collision scene is used to determine where to draw a splodge, only solid objects will receive splodge shadows.


An example of splodge shadows

21.11.2. Shadow maps

Entity models can be configured so that they cast a shadow into the scene based on the direction of the sun light, utilising a dynamic shadow map. Each frame the engine will select a set of shadow casting entities closest to the camera, the number of which is configured via the `SHADOWS_COUNT` graphics setting. For each shadow caster it will render the caster into a texture from the direction of the light and then project this texture into the scene by re-rendering each object that intersects the shadow (using the shadow map as input).

In order to cast shadows, an entity must be explicitly added to the entity shadow manager. Two Python API's are provided:

- `BigWorld.addShadowEntity` - this is usually called from the `onEnterWorld` entity callback.
- `BigWorld.delShadowEntity` - this is usually called from the `onLeaveWorld` entity callback.

Global shadow settings (e.g. shadow map resolution, intensity, and shaders) are configured in the shadows XML file (defined in `shadows.xml` — for details on this file's grammar, see the document File Grammar Guide's section *`shadows.xml`*).

User controllable graphics settings are `SHADOWS_COUNT` and `SHADOWS_QUALITY`. See “Graphics settings” on page 132 for details.

Note

Shadows will be cast onto terrain, solid models, and flora. Sorted triangles (i.e. transluscent objects) will not cast or receive shadows.

Note

Keep in mind that the expense of using entity shadows will increase as the number of rendered shadowed entities increases, so it is recommended to keep the `SHADOWS_COUNT` setting as low as possible to maintain performance. As such this is not designed to be a general purpose full-scene shadowing system.

An example of dynamic entity shadows

Chapter 22. Post Processing

Post-processing effects are used extensively in all modern games, and have many applications - from HDR tone-mapping and colour-correction to cartoon effects, the possibilities are almost limitless.

BigWorld Technology has support for complete user customisation of the post-processing chain, for artists via a built-in editing tool, and for programmers by offering full control over every parameter in python and drop-in shaders in the way of DirectX/HLSL effect files.

However before you jump into creating your own new swanky effect, it pays to think about it. Effects should play nicely together, they should reuse render targets where possible, and you need to monitor performance.

22.1. Pipeline Overview

After the opaque scene, translucencies and lens effects, and before the GUI is drawn, the **PostProcessing::Manager** draws its current chain. A **Chain** contains a list of effects that draw in order. Internally each **Effect** contains a list of Phases that draw in order. A **Phase** usually draws a full-screen quad to the screen using an effect file, although other transfer meshes are available.

There are three parts to the implementation of post-processing. The core is written in C++, in the *bigworld/src/lib/post_processing* library. All of the features there are exposed to python via the **_PostProcessing** module.

In Python, the **PostProcessing** module exists in *bigworld/res/scripts/client/PostProcessing* and imports all of the methods from **_PostProcessing**. This allows you to override, or wrap, any of the C++ methods. Therefore all python calls should be to the **PostProcessing**, not **_PostProcessing**.

By default, the **PostProcessing** module registers 3 graphics settings. If the user selects high/medium/low, an appropriate post-processing chain is loaded. These are found in *bigworld/res/system/post_processing/chains/* and are "High Graphics Setting.ppchain", "Medium Graphics Setting.ppchain" and "Low Graphics Setting.ppchain". Therefore it is easy for developers to redefine the default post-processing chains by creating new chains in WorldEditor and saving over the top of these files.

In general it is expected that a game will use a combination of the default post-processing chain files, dynamically mixed in with gameplay related effects. In order to achieve this, follow the examples in the **PostProcessing** module. Additionally, take a look at the Python API for **PyMaterial**, as it will demonstrate how you can smoothly fade in/out your dynamic post-processing effects.

Finally in WorldEditor, the Post-Processing tab is a full-featured editor and preview tool for chains. It loads and saves .ppchain files. Please see the Content Creation Manual and the Content Tools Reference Guide for further information.

22.2. Creating a Custom Post-Processing Effect

While BigWorld comes with a basic set of post-processing shaders, phases and effects, more likely than not you will find yourself needing to implement an effect that is unique to your game.

For this example, we will be creating a post-process that will invert all the colours on the screen.

We will author a post-processing effect that can be added as part of the client's overall post-processing chain, and we will write a custom shader that performs the actual colour inversion.

22.2.1. Creating the Custom Pixel Shader

So how are we going to get the GPU to invert all the colours on the screen?

Because the BigWorld client supports drop-in DirectX Effect files (.fx), this step is relatively easy. All we need to do is author a .fx file that takes an input texture, inverts the colour, and outputs that value.

```
float4 ps_invert(PS_INPUT input) : COLOR0
{
    float4 map = tex2D(inputTextureSampler, input.tc);
    float4 invMap = float4(1,1,1,1) - map;
    return invMap;
}
```

OK, so that was the easy bit. This pixel shader assumes a couple of things, namely that the vertex shader is passing through a set of texture coordinates, that there is a sampler reading the correct texture map, and that there is a PS_INPUT structure defined.

Luckily all of this has been taken care of, via the effect include file post_processing.fxh (bigworld/res/shaders/post_processing/post_processing.fxh)

The complete effect utilising this pixel shader is quite straightforward, and looks something like this:

```
#include "post_processing.fxh"

DECLARE_EDITABLE_TEXTURE(inputTexture, inputSampler)

float4 ps_invert(PS_INPUT input) : COLOR0
{
    float4 map = tex2D(inputSampler, input.tc);
    float4 invMap = float4(1,1,1,1) - map;
    return invMap;
}

vs2 = compile vs_2_0 vs_main()
ps2 = compile ps_2_0 ps_invert()

STANDARD_TECHNIQUE(vs2, ps2)
```

22.2.2. Previewing the Results

As the post-processing chain contains many phases, which often write to intermediate, invisible render targets, it is often desirable to see the intermediate results of a post-processing effect or chain. There are two methods available for this purpose, **PostProcessing.debug()** and WorldEditor's preview feature.

In the client, you can register a render target of arbitrary size with the **_PostProcessing** module, and have it record all intermediate steps. This render target can then be viewed by displaying it in the GUI. A helper class, **ChainView**, is available in the **PostProcessing** module, this will display the entire chain on-screen in real-time.

In WorldEditor, there is a preview button in the post-processing editor, this displays the intermediate results inside each of the phase nodes in the editing graph.

22.2.3. Writing a Custom Pixel Shader for Previewing the Results

Sometimes, this simple preview is not going to be suitable. By default, the preview directly displays the output of each phase's pixel shader. However, often the output of an intermediate step is written to a floating-point render target that does not directly map to the visible colour range, other times there is information encoded in specific ways that are not directly viewable.

Take for example a depth-of-field lens simulation. One possible implementation might decode the depth buffer, and categorise the scene into 7 separate areas, 3 levels of blur in front of the focal range, in-focus and 3 levels after. This information may be written into a single-component floating point render target and contain a value between -3 and +3.

When the output of a pixel shader is not directly viewable, you can author another pixel shader that is used for the preview function. To do this, you need to add a new technique to your effect. This technique must be called "**Preview**", and if available, will be used in lieu of the main technique when previewing the post-processing chain. This technique should output the data such that it will be viewable and make sense on an ordinary R8G8B8A8 render target and when viewed on-screen.

In the above example, you could write a preview technique that displays 3 shades of red for blurred areas in front of the focal range, full-green for all areas in focus, and 3 shades of blue for all areas being blurred behind the focal range.

22.2.4. Authoring a Post-Processing Effect in Python

So now how do we get our new effect to manipulate the screen at post-processing time? We have to author a **PostProcessing::Effect**. Most often, this will be done via the post-processing editor in WorldEditor. WorldEditor saves out .ppchain files, these contain chains of effects and phases, and can simply be loaded up and set as the current post-processing chain. However, it's also useful to know how to use the Python API, as you do have access to the entire chain, and often you will want to tie in post-processing effects directly to game logic. It also helps to understand what is happening 'under-the-hood' when authoring chains in the editor.

For this example effect, we must write every pixel in the backbuffer with the inverse of whatever colour is in the backbuffer.

PC hardware cannot read from the same texture that is being written to, so we will need first to grab a copy of the back buffer, and store it in another texture.

This snippet of python code creates a **CopyBackBuffer** phase, creates a render target that is the size of the back buffer, and hooks the two up.

```
import PostProcessing

phase1 = PostProcessing.CopyBackBuffer()
bbcRT = BigWorld.RenderTarget("backBufferCopy", 0, 0)
phase1.renderTarget = bbcRT
```

In WorldEditor, we can simply drop a "BackBufferCopy" phase into our effect and be done with it.

Note in this case, we are creating a new render target, however generally you want to share render targets between effects and phases, especially full-screen ones like the one above. So instead of creating a render target, we could instead use the **RenderTargets** module like this:

```
bbcRT = PostProcessing.RenderTargets.rt("backBufferCopy")
```

Now we have a copy of the back buffer that we can read in as a texture, now is time to do our colour inversion pass

```
phase2 = PostProcessing.Phase()
phase2.material =
 BigWorld.Material("shaders/post_processing/colour_invert.fx")
phase2.material.inputTexture = phase1.renderTarget.texture
phase2.renderTarget = None
phase2.filterQuad = PostProcessing.TransferQuad()
```

This code sample creates a new phase, this time a generic **PyPhase** object. A **PyPhase** object has a **PyMaterial** and a **FilterQuad**. It uses these to write to a **RenderTarget**.

We have created a new **PyMaterial**, from "colour_invert.fx", the shader we authored earlier.

The effect file uses a texture variable named "inputTexture". Since we marked this variable in the effect as 'editable', it shows up in the python dictionary for the material. Thus we can set it directly to the texture held by the back buffer copy render target.

We have set this phase's *renderTarget* attribute to None. Specifically this means "don't set a render target", in practice this means we want to write directly to the main scene's back buffer, instead of an off-screen render target.

Note that whenever we write to the back buffer, we change its contents, and the next post-processing effect or phase must use a new copy that contains these changes. The **BackBufferCopy** phase internally detects whether or not the back buffer has been modified since the last copy was taken. Therefore it is ok to use **BackBufferCopy** phases all the time, and there will be no performance penalty if that phase is in fact not needed at that time.

Finally the phase uses a **FilterQuad** to draw with; these usually draw with n sets of filter taps, in this case we just want to read a single pixel from the source texture, for each pixel in the output render target. So we have created a **PyTransferQuad**, which has only a single sample point, and with no offsets. If we wanted to do some texture filtering, we could have used a **PyFilterQuad** instead, and specified n sample points - with each sample point representing (u-offset in texels, v-offset in texels, weight, unused).

```
colourInvert = PostProcessing.Effect()
colourInvert.phases = [phase1, phase2]
colourInvert.name = "Invert Colours"
PostProcessing.chain([colourInvert])
```

This final code example wraps up our two phases into a single **Effect**, and registers the Effect as the post-processing chain. From here on in, the colours on the screen will be inverted.

22.3. Render Targets

One of the main sets of resources used by post-processing chains are render targets. These tend to be multiples of the back buffer size, and have different surface formats and uses. The BigWorld client exposes the **PyRenderTarget** class which can be used to create custom render targets on demand. Please see the *Python Client API* for detailed instructions on how to use **PyRenderTarget**.

Note that it is ok to create as many render targets as you like, as the actual surface memory is only allocated when the render target is first used for drawing into (via *RenderTarget.push*). Therefore you can define render targets that are not actually used, with negligible overhead. However for the render targets in use, the video memory can quickly add up, so it pays to take care when designing your post processing chains. The total memory used by any particular chain can be viewed in the WorldEditor, or by calling the function *PostProcessing.RenderTargets.reportMemoryUsage()*.

In Python, the **PostProcessing** module has its own **RenderTargets** module, in *bigworld/res/scripts/client/PostProcessing/RenderTargets*. If you want to add more render targets for use by your post-processing chains, then add them to the render target list here. Doing this is necessary because this is where WorldEditor gets its list of available post-processing render targets.

22.4. Performance

There are two main performance metrics to be aware of when authoring post-processing chains. These are: memory use (mainly by the render targets); and the time spent in the GPU. Render targets and their associated memory use are described in the previous chapter. As always, PostProcessing resources created dynamically should be loaded in the background thread, to avoid stalling the rendering thread.

22.4.1. Measuring the Time Spent on the GPU

Post-processing chains tend to have a low CPU cost - involving simple iteration through effects and phases and simple geometry setup - but a high GPU cost, with complex pixel shaders that perform full-screen passes and many texture fetches per pixel. Therefore the main cost is normally GPU bandwidth: fill-rate, and texture-fetch.

The BigWorld client has a python API function, *PostProcessing.profile(nIterations)*, which measures the time taken by the GPU. The parameter *nIterations* should usually be around 10 or so to make sure an accurate value is measured. Since the main cost is fill-rate and texture-fetch, this value depends on the resolution of the screen, so it is necessary to profile on different GPUs and at different resolutions. Note that WorldEditor also comes with a toolbar button on the Post-Processing panel that also profiles the chain.

22.4.2. Background Loading

There is no direct support for background creation of **.ppchain** files, since the library uses many **PyObject** pointers which can only be created in the main thread. Instead, support for background loading of .ppchain files can be achieved via the *PostProcessing.prerequisites()* method. This extracts the appropriate resources (mainly EffectMaterials) from the XML file and returns a list of the required resources which can then be passed directly to *BigWorld.loadResourceListBG()*.

For example:

```
filename = "system/post_processing/chains/underwater.ppchain"
BigWorld.loadResourceListBG(PostProcessing.prerequisites(filename), onLoadBG)
```

PostProcessing chains loaded via the SFX system are automatically loaded in the background.

Because gathering the PostProcessing prerequisites relies on the .ppchain file data section already being loaded, it is recommended that you **preload** all your .ppchain XML files.

Chapter 23. Job System

23.1. Overview

The job system allows additional cores in multicore systems to execute code and calculate data for rendering just in time. It also moves the issue of D3D commands onto its own core, with the main thread simply recording them for execution in the next frame.

The rendering of a frame is divided into blocks. Blocks are rendered in order. Each block begins only after the previous block has finished.

Each block consists of any D3D rendering commands and associated vertex and index buffers, textures, shader constants or any other data. The block can be produced as a combination of conventional D3D rendering from the main thread and output from jobs running in parallel on cores allocated to run jobs.

Any number of jobs can produce the input for a block. Since only one block is rendering at a time and jobs execute in parallel you should use at least as many jobs as there are cores, otherwise there will be idle cores. Jobs within a block can finish in any order, but the block will not be rendered until all jobs are complete. While the jobs are executing D3D executes the previous block. Thus the job cores and the D3D core are constantly working while at the same time the main thread is preparing another frame of blocks and their corresponding jobs.

23.2. Under the Hood

All rendering commands and jobs are stored in a command buffer. This is accomplished by wrapping D3D. All D3D function calls go to the wrapper which records them to be executed on the next frame while at the same time the commands from the previous frame are executed in another thread on the D3D core.

When flushed the D3D core first stalls for the results of the first block's jobs. Meanwhile each core in the job cluster starts grabbing jobs from the block. There is no central dispatch mechanism. The cores grab jobs and atomically decrement a counter for that block when they finish writing their results. Note that jobs are grabbed in order but they are not necessarily finished in order. For example, if the first job takes a long time the second might finish first and that core can begin on another job. This means that the output is not guaranteed to be contiguous until after the last job finishes and decrements the counter to zero.

Only then can the D3D core begin to process the results of the first block, while the cluster begins to operate on the second block, outputting the results into another buffer.

If the D3D core finishes first it retires the buffer and stalls until its next buffer is ready. If the cluster finishes first it stalls until the D3D core retires the buffer it is consuming so it can receive output from the cluster.

23.3. Wrapper API

In addition to wrapping D3D the wrapper has a small API to control its behaviour.

`DX::newBlock()`: Starts a new block. All rendering from the previous block will finish before this one will begin and all job output that was used to render the previous block will no longer be accessible. What this means is that all jobs producing output for this block must be allocated before the next call to `DX::newBlock()`.

`DX::setWrapperFlags()` and `DX::getWrapperFlags()`: These functions get and set flags that control the behaviour of the wrapper.

`IMMEDIATE_LOCK`: Flush the command buffer and then execute the lock in the main thread. This is required if you are not going to fill in the entire locked region. It is an extremely expensive way to lock and should be avoided where possible.

`DEFERRED_LOCK`: This flag is used to lock a buffer that will be filled in with a job. The pointer that a lock returns can only be used to store into a job and then accessed when the job executes. The actual lock occurs in the next frame when the job executes.

23.4. Job System API

The Job System API is accessed through the JobSystem singleton. It is obtained with `JobSystem::instance()`.

`allocJob()`: This method places a job into the list of jobs for the current block and returns a user implemented class derived from Job. This has a virtual function called `execute()` which actually performs the job. The derived class stores anything necessary for the execution of the job. Note that the jobs within a block will not execute in order.

`allocOutput()`: The job will need to produce output and this is allocated up front with `allocOutput()`. It is called from the main thread and its result is placed into the Job object. The memory for the output is not actually allocated at this time, but it will be made ready at the time that the job is executed next frame.

Within a block you can have any mix of job and output allocations. For example, you may allocate one output and divide it between many jobs or vice versa or any combination you like. The only rule is that the output and the jobs must all come from the same block.

23.5. An Example

Let us imagine that we are updating and rendering a simple particle system. This will be done in one block. The particle system consists of 4096 points, each of which will be updated and generate one vertex into a vertex buffer for rendering.

Our block will consist of setting a vertex bufferer and calling DrawPrimitive on it. The vertex buffer will be filled using jobs. The vertex buffer will be divided into 8 parts of 512 vertices each. Each part will be filled in with one job.

Main thread:

- New Block
- Lock vertex buffer of 4096 points using the `DEFERRED_LOCK` flag
- Set 8 jobs, each filling in 512 points
- Set rendering states
- DrawPrimitive
- Reset wrapper flags

All of the above steps are not immediately executed but rather recorded for execution on the next frame.

Jobs and D3D core:

During the next frame the default block renders until the new block for the particles is reached. At the same time the 8 jobs to fill the vertex buffers are executed. When the new block is reached and the jobs are completed the particles are rendered. At the same time the jobs for the next block are executed.

23.6. Implementing it

Now that we understand how this example works we can go through the steps of implementing it.

First we need to implement our job object.

```
class PointSpriteParticleJob : public Job
{
public:
    void set( Particle* particles, Moo::VertexXYZDP* pVertex, uint nPoints );
    virtual void execute();

private:
    Particle* particles_;
    Moo::VertexXYZDP* pVertex_;
    uint nPoints_;
};
```

The job object inherits the virtual `execute()` method which gets called in the next frame just before the output of the job will be needed for consumption by the D3D core.

We also implement a `set()` method which gets called from the main thread and stores all the information that will be needed in `execute()`.

The `execute()` method will do two things. It will update the positions of the particles and output the new positions into a vertex buffer. Each given job object will do this for only a part of the particle system and vertex buffer so that the entire task can be divided into several jobs and execute in parallel on several cores.

Now we are ready to use the job class in our rendering code.

We begin this with a new block.

```
DX::newBlock();
```

Now we are ready to queue our rendering commands.

First we need to lock a deferred vertex buffer, and to do this we need to set the appropriate wrapper flag before locking.

Normally when locking you get a pointer that you can use immediately to write vertex data. However our vertex data will be calculated in the next frame by jobs, so the lock actually has to occur at that time. Therefore we use a deferred lock which returns a pointer now but does not perform the lock until required.

```
uint32 oldFlags = DX::getWrapperFlags();
DX::setWrapperFlags( DX::WRAPPER_FLAG_DEFERRED_LOCK );

Moo::DynamicVertexBufferBase2<Moo::VertexXYZDP>& vb =
 Moo::DynamicVertexBufferBase2<Moo::VertexXYZDP>::instance();
Moo::VertexXYZDP* pVertex = vb.lock2( 4096 );
```

Now we are ready to allocate and set up our jobs. The pointer from the lock is used to set up the jobs.

```
for ( uint i = 0; i < 8; i++ )
{
    job = jobSystem.allocJob<UpdateParticlesJob>();
    job.set( particles + i*512, vertices + i*512, 512 );
}
```

Finally we can unlock the buffer, reset the wrapper flags and render.

At this point we can render as if the jobs that we have allocated and set are complete, since the following rendering commands will not be executed until that time.

```
vb.unlock();
uint32 lockIndex = vb.lockIndex();

DX::setWrapperFlags( oldFlags );

vb.set( 0 );
Moo::rc().drawPrimitive( D3DPT_POINTLIST, lockIndex, nPoints );
```

Chapter 24. Debugging

This section describes some of the debugging features of the BigWorld client.

Debugging is an important part of any development process, and the client has many features that facilitate finding bugs early, in-game debugging, remote debugging, and the immediate application of changes without restarting.

Many debugging features are accessed via a specially defined debug key. By default, the debug maps to the grave (tilde) key on the keyboard, however this can be re-configured by editing the engine configuration XML file.

24.1. Build configuration — conditional feature inclusion

BigWorld provides a number of features that aid in runtime debugging, such as the debug menu and the telnet Python service.

To remove these features from a final release build of the client, a number of compile guards exist. These are collectively controlled by the following define located in src/lib/ cstdmf/config.hpp.

```
#define CONSUMER_CLIENT_BUILD 0
```

If `CONSUMER_CLIENT_BUILD` is 0, then the development features will be compiled.

Individual features are encapsulated in their own individual compile guards, which can collectively be switched using the above define. Individual features may also be enabled, by setting the corresponding force enable define to a non-zero value.

This is illustrated in the example below:

```
#define CONSUMER_CLIENT_BUILD    0

#define FORCE_ENABLE_DEBUG_KEY_HANDLER    0
#define ENABLE_DEBUG_KEY_HANDLER  (!CONSUMER_CLIENT_BUILD \
                                   || FORCE_ENABLE_DEBUG_KEY_HANDLER)
```

24.2. Watchers

A watcher is an object that wraps a variable or function result in a program, and turns it into a string.

Watchers can be read-write or read-only, and can be viewed in various ways. Their hierarchy is usually organised by functionality. There are also watchers that can dynamically match changing data, such as the contents of a sequence or map.

24.2.1. Watcher types

The simplest watcher type is the DirectoryWatcher, which allows the creation of a directory of other watchers (including DirectoryWatchers). This is one way in which the hierarchy can be built up. For example, a float value for the amount of rain drawn by the rain system in the BigWorld client is specified at 'Client Settings/ Rain/ amount'. This uses three DirectoryWatchers: the root directory, the Client Settings directory, and the Rain directory.

There are also templatised watchers for any data type that can be streamed onto a std::stream object. These come in two flavours, as DataWatchers of variables, and as MemberWatchers of the result (or sole argument) of member functions of a class.

The DataWatchers and MemberWatchers can also take a 'base object' argument, which the data they point to is considered a member of. This is very useful when combined with more complicated types of watchers, such as the SequenceWatcher.

The SequenceWatcher and MapWatcher appear to be the same as a DirectoryWatcher, but they watch any class that supports the STL sequence or mapping methods. They have just one client watcher, but they present as many children as there are elements of their wrapped container. The child watcher is called with its 'base object' set to the element of the container. To handle pointers in these containers, there is also the BaseDereferenceWatcher, which presents no extra hierarchy level, but rather dereferences its base object and calls a sole child watcher with that value. The children can be named either by a static list, or by making a request for a certain value in the child watcher (such as name).

24.2.2. Using watchers

From the types above, it can be seen that a watcher hierarchy can be set up to both expose simple settings and to track complex structures.

The simplest way to make a watcher is to use the MF_WATCH macro. This macro takes the path name for the watcher, and a variable or member function to get/set its value. It expands to code that adds the appropriate watcher.

To change the parsing or display of a value (as a string), it is not necessary to write a new watcher. Instead, you can use member functions that get and set the value as a string. This is how the 'Client Settings/Time of day' value works — there are simple accessors for timeOfDayAsString, which format the time of day as 'hours:minutes' and parse it back from the same format. Setting a watcher can also be used to trigger a command — for example, the server is also notified whenever the time of day is set (for debugging purposes only).

To track complex structures, the appropriate watcher must be created directly, and inserted into the watcher hierarchy. Classes that participate in such an arrangement often implement a getWatcher() static method that returns a watcher object that works when the 'base object' is set to an instance of their class. The same watcher can be shared by all instances of the class, and is usually of type DirectoryWatcher of DataWatchers and MemberWatchers.

This is done on the client with the map of entities maintained by the Entity Manager. The entities are named by their ID.

Most of the C++ state of the client is also available through explicitly added watchers, as they were needed for some stage of the debugging already.

24.2.3. Watcher Console

The watcher console provides access to the watcher system from within the game. It can be brought up at any time, and overlays the game screen with a listing of the current watcher directory.

Directory-like entries can be followed down, and the value of any writable watcher can be set by selecting it, pressing `Enter`, then typing in a new value.

There are also keys for adjusting numerical values by 1, 10, 100, or 1000.

24.2.4. Remote watcher access

The watcher system is exported from the client using a very simple UDP-based watcher message protocol. The server uses this protocol extensively for its own debugging needs.

This is not related to Mercury, although it can be (and currently is) linked to its input loop. When the client starts up, it broadcasts a watcher nub notification packet, advertising the port its watcher nub is listening for requests on (it sends a similar message when it shuts down cleanly).

To access the watcher values, a number of tools may be used, but by far the most useful is a UNIX daemon called 'watcher'. This daemon listens for any broadcast watcher packets and adds or removes them from an internal list.

The other side of the daemon presents an HTTP interface to all the watcher nubs it knows. It inserts the name of the watcher nub (contained in the registration message, *e.g.*, 'client of John', 'cell14', etc...) as the top level of a watcher super-hierarchy. It presents the individual watcher trees as branches of this top directory. The path in the request URL is translated into the watcher value request path. This interface can get and set values.

So by connecting to this daemon with any web browser, all the running clients on the local network can be seen, and then investigated or manipulated, right down to changing the value of a Python variable in an entity. Python variables can be set to arbitrary Python, which is executed on the client to find its value. The client can also send its watcher nub notification to another external address if so desired, so even remote clients can be accessed in this way.

24.3. Memory tracking

The memory tracking system can be used to determine the amount of memory allocated to a class or module. The ResourceCounters class is the primary class used to perform the tracking.

24.3.1. ResourceCounters overview

This is a simple class that tracks the memory usage of a component based on a description string (the component allocating/deallocating the memory) and a memory pool enumeration (the memory pool to be used, *i.e.*, system memory, managed video memory, or default video memory).

The two main worker methods of this class are add and subtract, which respectively track memory allocations and deallocations using the description-pool.

The `ResourceCounters` class maintains a map of the components it is tracking. Rather than calling the methods of ResourceCounters directly, two macros are exposed. These macros are defined away to nothing when memory tracking is disabled:

```
#define RESOURCE_COUNTER_ADD(DESCRIPTION_POOL, AMOUNT) /
  ResourceCounters::instance().add(DESCRIPTION_POOL, (size_t)(AMOUNT));
#define RESOURCE_COUNTER_SUB(DESCRIPTION_POOL, AMOUNT) /
  ResourceCounters::instance().subtract(DESCRIPTION_POOL, (size_t)(AMOUNT));
```

ResourceCounters also exposes `toString`-style methods that are used by the realtime resource-monitoring console to display the current memory usage statistics.

24.3.2. Memory allocation taxonomy

With respect to the memory tracking system, there are two basic types of memory allocation:

- **DirectX memory allocation**

  All DirectX resources are COM objects. COM objects use reference counting to manage their sharing among multiple objects. The Moo library provides the wrapper class ComObjectWrap for dealing with these objects.

  Inside BigWorld, there are two reference types used to refer to DirectX objects: plain points (*e.g.*, DX::Texture*) and ComObjectWrap pointers. For DirectX objects, the memory tracking is performed purely through the ComObjectWrap class. Therefore, any DirectX resource that needs its memory tracked must be refactored to use ComObjectWrap references if it does not do so already. For details on how the DirectX textures were instrumented, see "DirectX textures" on page 158 .

- **Standard memory allocation**

All other objects in BigWorld use standard stack or heap memory. Unlike the memory tracking for DirectX resources, there is no unified way of instrumenting a particular class or set of classes. For details on the main issues encountered when instrumenting arbitrary classes, see “Binary blocks” on page 160, “Terrain height maps” on page 161 , and “Terrain texture layers” on page 164 .

24.3.3. Case studies

This section documents the instrumenting of four classes/types that make up the BigWorld system:

- DirectX textures
- Binary blocks
- Terrain height maps
- Terrain texture layers.

Each of these classes/types presents its own set of challenges. These examples highlight the main issues that come up during instrumentation.

24.3.3.1. DirectX textures

Even with the memory-tracking functionality added to the `ComObjectWrap` class, COM objects are not memory-tracked by default, because the accounting for memory must occur after the resource has been created. Since there is no way of knowing when this happens automatically, memory tracking cannot be activated automatically for all COM objects.

In order to activate the memory tracking for a particular DirectX resource, the programmer must make a call to `ComObjectWrap::addAlloc(<`*`string description`*`>)` after creating the DirectX resource to activate the memory tracking for this resource. Note that `ComObjectWrap` objects automatically handle the deallocation of memory from the memory tracking system on destruction of the last resource reference. Therefore there is no need for the programmer to explicitly make the deallocation.

Below are excerpts of the `lock_map.*pp` files that support DirectX texture instrumenting.

- **`src/tools/worldeditor/project/lock_map.hpp`**

```
Class LockMap
{
public:
  ...
  ComObjectWrap<DX::Texture> lockTexture() { return lockTexture_; }
  ...
private:
  ...
  ComObjectWrap<DX::Texture> lockTexture_;
  ...
};
```

- **`src/tools/worldeditor/project/lock_map.cpp`**

```
LockMap::LockMap() :
  gridWidth_(0),
  gridHeight_(0),
  colourLocked_(Colour::getUint32(COLOUR_LOCKED)),
  colourLockedEdge_(Colour::getUint32(COLOUR_LOCKED_EDGE)),
  colourLockedByOther_(Colour::getUint32(COLOUR_LOCKED_BY_OTHER)),
  colourUnlocked_(Colour::getUint32(COLOUR_UNLOCKED))
```

```
{
}
...

void LockMap::setTexture(uint8 textureStage)
{
  Moo::rc().setTexture(textureStage, lockTexture_.pComObject());
}
...

void LockMap::updateLockData(  uint32 width, uint32 height, uint8* lockData)
{
  bool recreate = !lockTexture_.pComObject(); 1
  ...
}

void LockMap::releaseLockTexture()
{
  lockTexture_ = NULL; 2
}
...

void LockMap::createLockTexture()
{
  ...
  HRESULT hr = Moo::rc().device()->CreateTexture(
    gridWidth_, gridHeight_, 1, 0, D3DFMT_A8R8G8B8,
    D3DPOOL_MANAGED, &lockTexture_, 0 );
  lockTexture_.addAlloc("texture/lock terrain");
  ...
}
```

1 Several functions require a reference to a DirectX texture resource, such as `setTexture`. A call to `ComObjectWrap:: pComObject()` returns such a pointer.

2 When releasing resources, the release call is handled automatically. It must not be called explicitly on release — `ComObjectWrap` should simply be set to `NULL`.

It is important that when `ComObjectWrap` objects are being used to access a DirectX resource that they be used everywhere to access that resource. `ComObjectWrap` objects automatically increment and decrement the internal reference count of the COM objects they reference when passing COM objects between themselves. Passing a COM object reference from a `ComObjectWrap` object to a regular pointer circumvents the automated memory deallocation and reference decrementing functionality.

The only situation when a DirectX resource should be exposed as a plain pointer is when passing the object to DirectX functions directly (see the above example in `src/tools/bigbang/project/lock_map.cpp`'s function `setTexture`, when `Moo::rc().setTexture` is called).

In `src/tools/worldeditor/project/lock_map.cpp`'s function `createLockTexture`, directly after the call to `Moo::rc().device()->CreateTexture`, a call to `lockTexture_.addAlloc("texture/lock terrain")` is made. This call accounts for the allocation of memory during the `Moo::rc().device()->CreateTexture` call for the `lockTexture_` object. The" texture/lock terrain" memory resource pool will be incremented by the amount of memory used by `lockTexture_`. But how to is the amount of memory used by `lockTexture_` determined?

`ComObjectWrap` is a templated class. A different class implementation is created at compile time for each COM object that makes use of this class. In the case of `DX::Texture`, a `ComObjectWrap<Dx::Texture>` class is created. During the call `ComObjectWrap::addAlloc(<`*`string description`*`>)`, calls to the functions `ComObjectWrap::pool` and `ComObjectWrap::size` are made. Each COM object can implement its own version of these methods using template specialisation. The `ComObjectWrap<Dx::Texture>` versions are:

```
template<> uint ComObjectWrap<DX::Texture>::pool() const
{
  // Get a surface to determine pool
  D3DSURFACE_DESC surfaceDesc;
  pComObject_->GetLevelDesc(0, &surfaceDesc);

  return (uint)surfaceDesc.Pool;
}

template<> uint ComObjectWrap<DX::Texture>::size() const
{
  // Determine the mip-map texture size scaling factor
  double mipmapScaler = 0.0;
  for (DWORD i = 0; i < pComObject_->GetLevelCount(); i++)
  mipmapScaler += 1 / pow(4.0, (double)i);

  // Get a surface to determine the width, height, and format
  D3DSURFACE_DESC surfaceDesc;
  pComObject_->GetLevelDesc(0, &surfaceDesc);

  // Get the surface size
  uint32 surfaceSize = DX::surfaceSize(surfaceDesc);

  // Track memory usage
  return (uint)(surfaceSize * mipmapScaler);
}
```

Excerpt — `src/lib/moo/com_object_wrap.ipp`

The `ComObjectWrap<DX::Texture>::pool` function determines what memory pool the texture resides in by examining the surface description of the surface at mipmap level 0. The `ComObjectWrap<DX::Texture>::size` function determines the size of the memory allocation by computing the mipmap scaling factor due to the mipmap levels, determining the memory footprint of the zero level mipmap level for the given texture format, and then multiplying the two.

Every DirectX resource that is to be memory-tracked will need to implement its own versions of these functions.

24.3.3.2. Binary blocks

Memory tracking for `BinaryBlock` involves calls to the `RESOURCE_COUNTER_ADD` and `RESOURCE_COUNTER_SUB` macros in the constructor and destructor respectively. In the constructor, if the `BinaryBlock` is the owner of the data, the memory tracking call is:

```
RESOURCE_COUNTER_ADD( ResourceCounters::DescriptionPool(  "binary block",
                     (uint)ResourceCounters::SYSTEM),
                     (uint)(len_ + sizeof(*this)))
```

Otherwise, if another `BinaryBlock` owns the data, the call is:

```
RESOURCE_COUNTER_ADD( ResourceCounters::DescriptionPool(  "binary block",
                      (uint)ResourceCounters::SYSTEM),
                      (uint)sizeof(*this))
```

Note that in the first version, the size of the binary data allocation is accounted for, as well as the size of the `BinaryBlock` object, while in the second version only the size of the `BinaryBlock` object is accounted for. Similarly in the destructor, if the `BinaryBlock` owns the data, the memory tracking call is:

```
RESOURCE_COUNTER_SUB( ResourceCounters::DescriptionPool(  "binary block",
                      (uint)ResourceCounters::SYSTEM),
                      (uint)(len_ + sizeof(*this)))
```

Otherwise, the call is:

```
RESOURCE_COUNTER_SUB( ResourceCounters::DescriptionPool(  "binary block",
                      (uint)ResourceCounters::SYSTEM),
                      (uint)sizeof(*this))
```

As it stands, the memory usage for all `BinaryBlock` objects is placed in a single resource pool called "binary block". This is still a very high level of granularity — it is likely that `BinaryBlock` objects are used by many different objects to varying degrees. It would be useful to known their distribution throughout the system. For details on how this is done, see "Terrain texture layers" on page 164 .

24.3.3.3. Terrain height maps

Like most classes, `TerrainHeightMap2` has primitive types, pointers, and objects as member variables.

```
TerrainHeightMap2::TerrainHeightMap2(CommonTerrainBlock2 &terrainBlock2):
...
{
  ...
  RESOURCE_COUNTER_ADD( ResourceCounters::DescriptionPool(  "height map",
                        (uint)ResourceCounters::SYSTEM),
                        (uint)(sizeof(*this)))
}
TerrainHeightMap2::~TerrainHeightMap2()
{
  RESOURCE_COUNTER_SUB( ResourceCounters::DescriptionPool(  "height map",
                        (uint)ResourceCounters::SYSTEM),
                        (uint)(sizeof(*this)))
}
```

Excerpt — `src/lib/moo/terrain_height_map2.cpp`

The calls to `RESOURCE_COUNTER_ADD` and `RESOURCE_COUNTER_SUB` account for the static memory used by the member variables, but do not account for the dynamically allocated memory used by our member pointers, the member pointers of our member objects, member pointers of member objects of our member objects, and so on.

Therefore, it is necessary to examine both the member pointers and the member objects to account for their dynamic memory usage, if any. With respect to the TerrainHeightMap2 class, there are three members of interest:

- `CommonTerrainBlock2* terrainBlock2_`
- `TerrainQuadTreeCell quadTree_`
- `Image<float> heights_`

24.3.3.3.1. `CommonTerrainBlock2* terrainBlock2_`

On construction of a `TerrainHeightMap2` object, a reference to the parent `CommonTerrainBlock2` objects is passed in. As such, the `TerrainHeightMap2` is not responsible for the memory usage of this class (in fact, the opposite is true — if memory tracking is added to `CommonTerrainBlock2`, then it is likely that the memory allocated by `TerrainHeightMap2` should be allocated into the `CommonTerrainBlock2` resource counter). Simply accounting for the `terrainBlock2_` pointer in the constructor's call to `RESOURCE_COUNTER_ADD` is sufficient.

24.3.3.3.2. TerrainQuadTreeCell quadTree_

The `TerrainQuadTreeCell` class must be inspected to check whether it or any of its members result in any dynamic memory allocations. The inspection is recursive until all members and their allocations are accounted for. For the `TerrainQuadTreeCell` class we have the following expansion:

```
TerrainQuadTreeCell

    std::string allocator_;                          // Need to account for this
    std::vector<TerrainQuadTreeCell> children_;  // Need to account for this
    BoundingBox boundingBox_;                        // Need to expand

      static BoundingBox s_insideOut_;              // For simplicity we do not
                                                    // account for static members
      Outcode oc_;                                  // Is of primitive type uint32
      Outcode combinedOc_;                          // Is of primitive type uint32
      Vector3 min_;                                 // Only contains primitives
      Vector3 max_;                                 // Only contains primitives
```

For `TerrainQuadTreeCell`, the dynamic memory used by member variables `TerrainQuadTreeCell::allocator_` and `TerrainQuadTreeCell::children_` must be accounted for.

- **`TerrainQuadTreeCell::allocator_`**

  `allocator_` is a `std::string` that records the resource pool being used. Since we want `TerrainHeightMap2`'s `TerrainQuadTreeCell` instances to use `TerrainHeightMap2`'s resource pool, we need a way to configure `TerrainQuadTreeCell`s resource pool. This is done by passing the resource pool string to the `TerrainQuadTreeCell` constructor.

  ```
  TerrainQuadTreeCell::TerrainQuadTreeCell(const std::string& allocator);
  ```

  Excerpt — `src/lib/moo/terrain_quad_tree_cell.cpp`

  `allocator_` is then set to the resource pool passed as parameter, so that the correct resource pool will be used. It is a simple matter to account for `allocator_`'s additional memory usage in the constructor's memory-tracking call to `RESOURCE_COUNTER_ADD`:

  ```
  TerrainQuadTreeCell::TerrainQuadTreeCell(const std::string& allocator);
  {
    ...
    RESOURCE_COUNTER_ADD( ResourceCounters::DescriptionPool(  allocator_,
                          (uint)ResourceCounters::SYSTEM),
                          (uint)( sizeof(*this) +
                          allocator_.capacity() ))
    ...
  }
  ```

  A similar call is made in the destructor.

- **`TerrainQuadTreeCell::children_`**

children_ is a std::vector containing zero or four TerrainQuadTreeCell objects. Vectors use dynamic memory allocation, but since the objects are of type TerrainQuadTreeCell, that means we are already accounting for the memory of each allocation. The only catch with having a vector of TerrainQuadTreeCell objects is that the call to children_.resize(4) in TerrainQuadTreeCell::init would create four TerrainQuadTreeCell objects using the default constructor. These objects must use the same resource pool as their parent TerrainQuadTreeCell object. This is achieved by passing a prototype instance to the resize method with the appropriate resource pool:

```
void TerrainQuadTreeCell::init(...)
{
  ...
  TerrainQuadTreeCell childPrototype(allocator_);
  children_.resize(4, childPrototype);
  ...
```

Excerpt — src/lib/moo/terrain_quad_tree_cell.cpp

At this point all memory has been accounted for in class TerrainHeightMap2.

24.3.3.3.3. Image<float> heights_

The Image<float> class must be inspected to see if it or any of its members result in any dynamic memory allocations. Like the inspection performed on TerrainQuadTreeCell, the inspection is recursive until all members and there allocations are accounted for. The member variables of the Image<PixelType> class are:

```
Image<PixelType>

  std::string allocator_;           // Need to account for this
  PixelType* pixels_;               // Need to account for this
  PixelType** lines_;               // Need to account for this
  uint32 width_;                    // Primitive
  uint32 height_;                   // Primitive
  bool owns_;                       // Primitive
  size_t stride_;                   // Primitive
```

For Image<float>, the dynamic memory used by the member variables Image<float>::allocator_, Image<float>::pixels_, and Image<float>::lines_ must be accounted for.

- **Image<float>::allocator_**

  Just like TerrainQuadTreeCell::allocator_ (for details, see "TerrainQuadTreeCell quadTree_" on page 162), Image<float>::allocator_ stores the resource pool for this object. Its memory is accounted for in the constructor's memory tracking call to RESOURCE_COUNTER_ADD:

```
RESOURCE_COUNTER_ADD(  ResourceCounters::DescriptionPool(  allocator_,
                       (uint)ResourceCounters::SYSTEM),
                       (uint)( sizeof(*this) + allocator_.capacity() ))
```

  A similar call is made in the destructor.

- **Image<float>::pixels_**

  The dynamic memory allocations assigned to Image<float>::pixels_ can be determined simply by searching through the Image class. Every direct or indirect memory allocation and deallocation must be accounted for. The following is an example of an indirect dynamic memory allocation to the `Image<float>::pixels_` member variable.

```
template<typename PixelType>
bool Image<PixelType>::createBuffer(uint32 w, uint32 h, PixelType* & buffer,
                          bool& owns, size_t& stride, bool& flipped)
{
  ...
  // Track memory usage
  RESOURCE_COUNTER_ADD(
    ResourceCounters::DescriptionPool(  allocator_,
                              (uint)ResourceCounters::SYSTEM),
                              (uint)(sizeof(PixelType) * w * h))
  buffer = new PixelType[w*h];
  ...
}

template<typename PixelType>
void Image<PixelType>::init(  uint32 w, uint32 h, PixelType *pixels,
                      bool owns, size_t stride, bool flipped)
{
  ...
  pixels_ = pixels;
  width_  = w;
  height_ = h;
  owns_   = owns;
  stride_ = (stride == 0) ? w*sizeof(PixelType) : stride;
  createLines(width_, height_, pixels_, stride_, flipped);
}

template<typename PixelType>
inline void Image<PixelType>::resize(uint32 w, uint32 h)
{
  ...
  PixelType *newBuf = NULL;  // Creates a PixelType pointer
  bool owns, flipped;
  size_t stride;

  // newBuf points to newly created pixel buffer
  createBuffer(w, h, newBuf, owns, stride, flipped);

  // pixels_ now points to newly created pixel buffer
  init(w, h, newBuf, owns, stride, flipped);
}
```

- **`Image<float>::lines_`**

  Use the same technique described above for `Image<float>::lines_`.

24.3.3.4. Terrain texture layers

The final instrumenting case study is for class `TerrainTextureLayer2`. The techniques described in the earlier case studies can be used to account for all but three of `TerrainTextureLayer2`'s member variables:

```
CommonTerrainBlock2* terrainBlock_;      // Same as CommonTerrainBlock2*
 terrainBlk2
std::string textureName_;                // Need to account for this
TerrainTextureLayer2::ImageType blends_; // Same as Image<float> heights_
uint32 width_;                           // Primitive
uint32 height_;                          // Primitive
```

```
Vector4 uProjection_;                    // Primitive
Vector4 vProjection_;                    // Primitive
size_t lockCount_;                       // Primitive
BaseTexturePtr pTexture_;                // Need to account for this
State state_;                            // Primitive
BinaryPtr compressedBlend_;              // Need to account for this
```

TerrainTextureLayer2's member variables

- **std::string::textureName_**

  textureName_ can be accounted for in a similar manner to TerrainQuadTreeCell::allocator_ (for details, see "TerrainQuadTreeCell quadTree_" on page 162) and Image<float>::allocator_ (for details, see "Image<float> heights_" on page 163), except that the allocation occurs in several places in terrain_texture_layer2.cpp. Each can be handled similarly by subtracting from the resource pool before an assignment and adding to the resource pool after an assignment, as illustrated below:

```
RESOURCE_COUNTER_SUB(  ResourceCounters::DescriptionPool(  "texture layer",
                       (uint)ResourceCounters::SYSTEM),
                       (uint)textureName_.capacity())

textureName_ = filename;

RESOURCE_COUNTER_ADD(  ResourceCounters::DescriptionPool(  "texture layer",
                       (uint)ResourceCounters::SYSTEM),
                       (uint)textureName_.capacity())
```

  Excerpt — src/lib/moo/terrain_texture_layer2.cpp

- BaseTexturePtr::pTexture_

  BaseTexturePtr is a smart pointer to the abstract class BaseTexture. The first case study above already accounted for all texture usage in the system, therefore we need a way to override the call to ComObjectWrap::addAlloc(std::string description) so that for this particular texture the "terrain texture layer/texture" memory resource pool is used.

  First, a search is performed to find where pTexture_ is being assigned:

```
pTexture_ = TextureManager::instance()->get( textureName_ );
```

  The desired memory pool needs to be added to this parameter list to override the default pool used for TextureManager's created textures. The call now looks like this with all the default values for the parameters filled in:

```
pTexture_ = TextureManager::instance()->get(
      textureName_, true, true, true, "terrain texture layer/texture" );
```

  The last parameter must have a default value assigned so that the interface for the method is not broken. The allocator pool must be passed through to the construction of the AnimatingTexture and ManagedTexture classes. This requires the addition of the allocator pool description string to the constructors of these classes (and any other classes that inherit from BaseTexture that need more accurate memory tracking). The constructor of the BaseTexture class is also changed to accept this allocator string in its constructor and store it in a member variable. This member variable can then be used by all classes that inherit from BaseTexture to account for the memory allocated in the call to CreateTexture.

- **`BinaryPtr::compressedBlend_`**

  As mentioned above, the `BinaryBlock` class accounts for all its memory usage. Therefore, if we wish to account for the `compressedBlend_` dynamic allocation in the `TerrainTextureLayer2` memory pool we must override the memory tracking in `BinaryBlock`. This can be achieved similarly to how the resource pool was overridden when creating a texture. The desired pool must be passed through to the `BinaryBlock` constructor. This required adding the default valued allocator string to the end of the following methods:

```
inline BinaryPtr Moo::compressImage( Image<PIXELTYPE> const &image,
                                     std::string allocator)
{
   ...
   return compressPNG(pngData, allocator);
}
...
```

  `src/lib/moo/png.hpp`

```
BinaryPtr Moo::compressPNG( PNGImageData const &data,
                            std::string allocator)
{
   ...
   BinaryPtr result = concatenate(outputBuffers, allocator);
   ...
}
...
BinaryPtr concatenate ( std::vector<BinaryPtr> const &buffers,
                        std::string            const &allocator)
{
   ...
   BinaryPtr result = new BinaryBlock(data, totalSize, allocator() );
   ...
}
```

  `src/lib/moo/png.cpp`

```
BinaryBlock::BinaryBlock( const void * data, int len,
                          const char *allocator, BinaryPtr pOwner )
{
   ...
   RESOURCE_COUNTER_ADD( ResourceCounters::DescriptionPool(allocator_,
                         (uint)ResourceCounters::SYSTEM),
                         (uint)sizeof(*this))
}
```

  `src/lib/resmgr/binary_block.cpp`

24.3.4. Displaying the memory tracking console

The memory tracking console can be displayed in the client, WorldEditor, ModelEditor and ParticleEditor. To display the console in the client, press `Ctrl+DEBUG+F5`, and to display it in the tools, press `Shift+Ctrl+F5`.

The user can cycle through the realtime memory usage information by pressing `Space`. There are three levels of granularity:

- **All memory** — one pool.

- **System memory, video memory, and miscellaneous memory** — three pools.
- **System memory, managed memory, default memory, and miscellaneous memory** — four pools

Note that video memory is a combination of managed and default memories. Also, miscellaneous memory is a catchall for any memory that does not fall into the system, managed, or default pools (*e.g.*, DirectX Scratch memory).

24.4. Scripts

The implementation of a game using the BigWorld client can potentially involve many scripts. These scripts will interact and have real-time requirements and dependencies, since they are part of a network game — in some cases, the game cannot be simply stopped and stepped through without affecting the behaviour of the client being debugged.

Scripting must therefore be approached in the same way as any other coding, and not as a poor alternative to C++ coding. Scripts must be designed properly, and consideration must be given to the appropriate use of class hierarchies and other language concepts.

24.4.1. Python Console

The Python console can be brought up at any time during the game.

This is a console that looks and acts exactly like a Python interpreter, so arbitrary Python can be entered into it. All C++ modules can be accessed, so the environment is the same as that in which the scripts are executed.

Python errors and exceptions that are not caught by the script itself (before they reach the C++ call-in point) are output to the console, and therefore are errors from commands entered into the Python console itself. The console is the first place to access when an error occurs in a game.

The Python console supports multi-line commands the same way that the standard Python interpreter does, and it also supports macros like a UNIX shell. Macro invocations begin with a dollar sign ($), and their expansions are contained in a dictionary in the personality file (see the fantasydemo personality script for an example). It implements the BWPersonality.expandMacros() callback function.

The list below describes the line editing shortcuts supported by the Python console:

- **`Backspace`**

  Deletes the character to the left on insertion point. Same as `Ctrl+H`.

- **`Delete`**

  Deletes the character to the right of insertion point. Same as `Ctrl+D`.

- **`End`**

  Moves insertion point to the end of line. Same as `Ctrl+E`.

- **`Home`**

  Moves insertion point to the beginning of line. Same as `Ctrl+A`.

- **`Ctrl+Backspace`**

  Cuts to clipboard all text between insertion point and beginning of word. Same as `Ctrl+W`.

- **`Ctrl+Delete`**

Cuts to clipboard all text between insertion point and end of word. Same as `Ctrl+R`.

- **`Ctrl+Insert`**

  Pastes the content of clipboard after insertion point. Same as `Ctrl+Y`.

- **`Ctrl+Left arrow`**

  Moves insertion point to the beginning of word.

- **`Ctrl+Right arrow`**

  Moves insertion point to the end of word.

- **`Ctrl+A`**

  Moves insertion point to the beginning of line. Same as `Home`.

- **`Ctrl+D`**

  Deletes the character to the right of insertion point. Same as `Delete`.

- **`Ctrl+E`**

  Moves insertion point to the end of line. Same as `End`.

- **`Ctrl+H`**

  Deletes the character to the left of insertion point. Same as `Backspace`.

- **`Ctrl+K`**

  Cuts to clipboard all text between insertion point and end of line.

- **`Ctrl+R`**

  Cuts to clipboard all text between insertion point and end of word. Same as `Ctrl+Delete`.

- **`Ctrl+U`**

  Cuts to clipboard all text between insertion point and beginning of line.

- **`Ctrl+W`**

  Cuts to clipboard all text between insertion point and beginning of word. Same as `Ctrl+Backspace`.

- **`Ctrl+Y`**

  Pastes the content of clipboard after insertion point. Same as `Ctrl+Insert`.

The console also offers the functionality of auto code completion. By pressing `Tab`, it automatically completes the current word by trying to match it against the attributes defined for the referenced context. If a unique match is found, then it is added after the insertion point. If more than one match exists, then pressing `Tab` cycles through all of them.

24.4.2. Remote Python Console

The services provided by the Python console are also available remotely over the network.

The client accepts connections using the telnet protocol on TCP port 50001. A number of telnet options are supported, such as the emulation of line editing.

24.4.3. Script reloading

All scripts can be reloaded by pressing `Caps Lock+F11`.

Existing entity class instances are updated so that they are instances of the new classes, without losing their dictionary. Entity script classes can provide a reload method to refetch stored function references that have changed after reloading. For example, the reload function in the player script recalculates its key bindings, which would otherwise continue to reference functions in the old version of the class.

When the server sends an update to a script, only that script is reloaded and only its instances are updated.

24.4.4. Common errors

Some common scripting errors are listed below:

- **Could not find class <*entity*>**

  There is a Python error in the file `<res>/scripts/client/<entity>.py`. Check the file `python.log` in the current working folder.

- **`App::init: BigWorldClientScript::init()` failed**

  There is a mismatch between Python script and `<res>/scripts/entity_defs/<entity>.def`.

- **`EntityType::init: EntityDescriptionMap::parse` failed**

  An undefined data type was used in file `<res>/scripts/entity_defs/<entity>.def` file, or in `<res>/scripts/entity_defs/alias.xml`.

For details on entity definition and Python script files, see the document Server Programming Guide's sections *Physical Entity Structure for Scripting* → “The Entity Definition File” and *Physical Entity Structure for Scripting* → “The Script Files”, respectively.

24.5. Script interactive debugging

You can run BigWorld Client as a Python extension module, instead of as an executable. This will allow you to use third party interactive debuggers (such as Wing IDE and Komodo), or Python's built-in debug module (pdb) to debug your game's scripts.

To run the client as Python extension module, follow these steps below:

1. Create the Python extension module by build the client using the `PyModule_Hybrid` configuration.

   This configuration requires the environment variable `PYTHONHOME` to be set to the top-level folder of a standard Python installation (*e.g.*, `C:\Python25`).

   Because the client will link against the stock standard dynamic Python libraries, you must disable the dependency of your startup project (*e.g.*, `fantasydemo`) to the `pythoncore` project. To do so, follow the steps below:

   - On the **Solution Explorer** pane, right-click your startup project.
   - In the context menu, select the **Project Dependencies** menu item
   - In the **Project Dependencies** dialog box, check **`pythoncore`** on the **Depends On** list.
   - Click OK.

Note

Instead of a `winMAIN` entry point, when build as an extension module, the client will require a Python module initialisation entry point.

For a sample implementation, see `<mfroot>/fantasydemo/src/client/winmain.cpp`, or just copy the code inside the `BWCLIENT_AS_PYTHON_MODULE` `#if/#endif` block into your `winmain.cpp` file).

2. Run the client using the following start-up script:

```
# add client script directories
# to Python's script search path
import sys
sys.path[1:1] = [
  r'd:\mf\fantasydemo\res\scripts\client',
  r'd:\mf\fantasydemo\res\scripts\common']

# run the client. Replace fantasydemo with
# the name of your extension module (.pyd)
import fantasydemo
fantasydemo.run(' '.join(sys.argv))
```

Using the script above, you can start the client from the command prompt (for example, with the command `python.exe fantasydemo.py`.) or from Visual Studio. Now, from anywhere in the scripts or from the Python console, you can invoke the standard Python debugger:

```
import pdb
pdb.set_trace()
```

For more information on how to use the pdb module, please refer to the Python Manuals.

You can also use the start-up script to run the client using a third party interactive Python debugger/IDE. This should allow you to set breakpoints and inspect variables. For more information on how to use an interactive debugger, please refer to your package manuals.

Note

The client will be disconnected from the server if the execution of the main thread is interrupted by more than a few seconds, as it usually happens when Python scripts are debugged interactively.

Note

When running the client as an extension module, it is possible to quit the Python interpreter before exiting the client (by, for example, invoking exit() from pdb prompt).

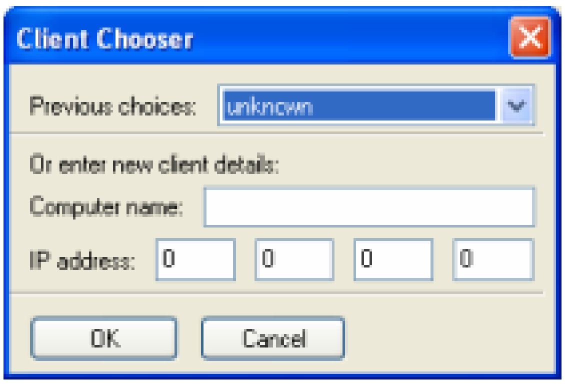
Because the client will still try to execute Python commands during its shutdown process, this will cause the client to crash.

24.6. Client Access Tool (CAT)

CAT provides a graphical interface to change watcher values and run Python console commands on a remote or local client. It does so via the Remote Python Console service provided by the client. For more details, see "Remote Python Console" on page 168 .

24.6.1. Connecting to the client

In order to connect to the client, you have to provide the computer name and/or the IP address where it is running.



Previous choices: unknown

IP address: 0 0 0 0

Client Chooser dialog

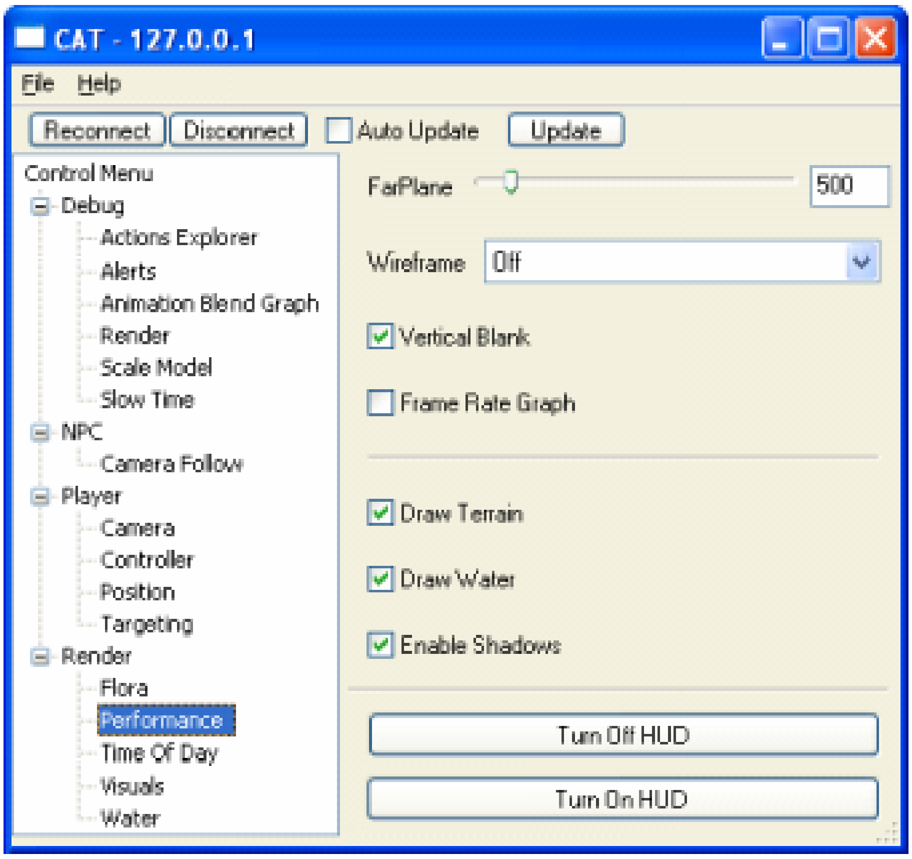
If you provide both the computer name and the IP address, CAT first tries to connect using the computer name, and if that fails, then it uses the IP address. Specify localhost as the computer name or 127.0.0.1 in the IP address to connect to the local client.

CAT automatically reconnects to the last client when it is started.

24.6.2. CAT Scripts

CAT searches for scripts in folder `<res>/../tools/cat/scripts`, where `<res>` is one of the entries in the resources folders list (for details on how BigWorld compiles this list, see the document Content Tools Reference Guide's chapter *Starting the Tools*).

For example, if one of the entries in `<res>` is `C:/mf/fantasydemo/res`, then CAT will look for scripts under the folder `C:/mf/fantasydemo/tools/cat/scripts`. It will then present a tree view of the scripts, as illustrated in the picture below:



Tree view of scripts

CAT scripts are specialised Python scripts. In the image above, the CAT script `<res>/../tools/cat/scripts/Render/Performance.py` is selected. It defines the GUI controls to the right of the tree. When you select a different CAT script from the tree, different controls will be presented to the right of the tree.

CAT scripts allow the viewing and manipulation of client watcher values as well as the execution of commands in the client's Python console. See the examples provided in folder `fantasydemo/tools/cat/scripts` for information on how to create your own scripts.

The list below describes the toolbar buttons and its functions:

- **Reconnect**

  Reconnects to the client, *e.g.*, after you restart the client.

- **Disconnect**

  Disconnects from the client.

- **Auto update**

  Refreshes the data on the current tab once every 2 seconds.

- **Update**

  Refreshes the data on the current tab *e.g.*, if watcher values are changed from the within client.

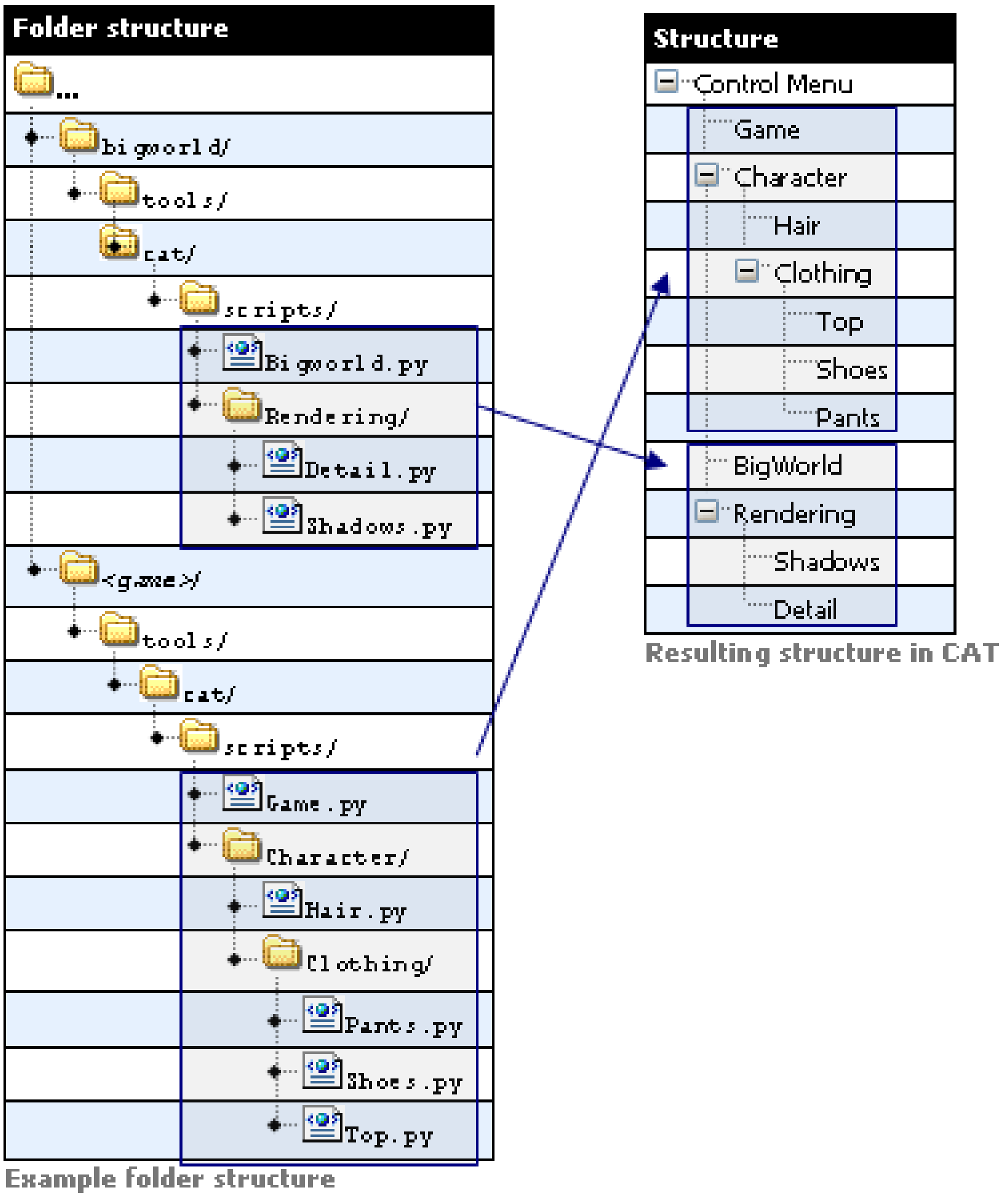
24.6.3. Creating scripts for CAT

CAT looks for scripts in folder `<res>/../tools/cat/scripts`, thus enabling two separate sets of CAT scripts to exist:

- BigWorld system scripts
- Scripts defined by you that are specific for your game.

CAT scans this directory hierarchically, and generates a folder tree akin to Windows Explorer's one, using the folder names as branches and script files as leaves.

The picture below illustrates how a folder structure will be displayed in CAT:



Example folder structure vs. Resulting structure in CAT

The basic structure of the CAT script files is illustrated below:

```
from controls import *
envSetup = \
"""
…
"""
```

```
args = \
(
  ...
)

commands = \
(
  ...
)
```

Skeleton of CAT script files

CAT script files are divided in three blocks, which are described below:

- **`envSetup`**

  Block where variables local to this CAT script are created and initialised.

- **`args`**

  Represent various controls for variables, which can be edited. They can either represent variables local to the CAT page, or watchers that mirror values on the client.

- **`commands`**

  Executable commands that appear on the CAT page as buttons.

The following sections discuss the blocks args and commands.

24.6.3.1. Block args

There are several widget elements available in the args block of the CAT pages.

In order to add multiple elements, they should be placed in a list with comma delimiters. Any underscores in names are ignored and replaced by spaces.

24.6.3.1.1. Basic Elements

The basic elements of args control the layout of CAT pages.

- **`Divider()`**

  This element causes CAT to display a horizontal divider between elements, allowing pages to be visually divided.

- **`FixedText( "`*`<text>`*`" )`**

  This element displays any static text segments such as headings. Multiple lines of text can be specified by using the newline character "`\n`".

24.6.3.1.2. Variables

It is possible to set up variables that are local to a specific CAT page.

These can also have an associated Python variable tied to them, to allow for updates from the client application.

Below is a list of commands to create variables in CAT:

- **`StaticText ( "<name>" [, default = "<value>"] [, updateCommand = "<python_update _source>" ] )`**

  This widget creates a non-editable field with the specified name and default value (if default is present).

  If updateCommand is specified, then <*python_update_source*> will be used as the Python value from the client that will be displayed.

  For example:

```
StaticText( "Position",
updateCommand = """
  location = $B.findChunkFromPoint( $p.position ).split( '@' )
  print "(%.1f,%.1f,%.1f) @ %s @ %s" %
    ( $p.position.x, $p.position.y, $p.position.z,
      location[0], location[1] )
  """ )
```

  Creation of field

- **`CheckBox( "<name>" [, updateCommand = "<python_update_source>" [, setCommand = "<python_set_source>" ] ] )`**

  This widget creates a check box called with the specified name.

  If updateCommand is specified, then until the check box is edited, it will use <python_update_source> as the Python code to get the value that will be displayed.

  If setCommand is specified, then when the field is edited, <python_set_source> will be executed.

  For example:

```
CheckBox( "Use Dash",
          updateCommand = "$p.isDashing",
          setCommand = "$p.switchToDash(Use_Dash)" )
```

  Creation of check box

- **`Int ( "<name>" [, default = <value> ] [, updateCommand = "<python_update_source>" [, setCommand = "<python_set_source>" [, minMax = (<min>,<max>) ] ] ] )`**

  This widget creates an integer field with the specified name and default value (if default is present).

  If setCommand is specified, then when the field is edited, <python_set_source> will be executed.

  If updateCommand is specified, then <python_update_source> will be used as the Python value from the client that will be displayed.

  If minMax is specified, then the field will have the specified (inclusive) value range.

  For example:

```
Int( "Health",
     default = 100,
     updateCommand = "$p.healthPercent",
     setCommand = "$p.healthPercent = Health; $p.set_healthPercent()",
      minMax = ( 0, 100 ) )
```

Creation of integer field

- **`Float ( ( "<name>" [, default = <value> ] [, updateCommand = "<python_update_source>" [, setCommand = "<python_set_source>" [, minMax = (<min>,<max>) ] ] ] )`**

  This widget creates a float field with the specified name and default value (if default is present).

  If updateCommand is specified, then <python_update_source> will be used as the Python value from the client that will be displayed.

  If setCommand is specified, then when the field is edited, <python_set_source> will be executed.

  If minMax is specified, then the field will have the specified (inclusive) value range.

  For example:

```
Float( "Speed Multiplier",
       default = 1.0,
       updateCommand = "$p.speedMultiplier",
       setCommand = "$p.speedMultiplier = Speed_Multiplier",
       minMax = ( 1.0, 10.0 ) )
```

Creation of float field

- **`FloatSlider ( ( "<name>" [, updateCommand = "<python_update_source>" [, setCommand = "<python_set_source>" [, minMax = (<min>,<max>) ] ] ] )`**

  This widget creates a float slider with the specified name and default value (if default is present).

  If updateCommand is specified, then <python_update_source> will be used as the Python value from the client that will be displayed.

  If setCommand is specified, then when the field is edited, <python_set_source> will be executed.

  If minMax is specified, then the field will have the specified (inclusive) value range.

  For example:

```
FloatSlider( "Camera_Distance",
updateCommand = "BigWorld.camera().pivotMaxDist",
setCommand = "BigWorld.camera().pivotMaxDist=Camera_Distance",
minMax = (0.01, 200.0) )
```

Creation of float slider

- **`List ( "<name>", ("<option1>", "<option2>", ...), [, default = "<option9>" [, updateCommand = "<python_update_source>" ] ] )`**

  This widget creates a drop-down menu with the specified name, containing the entries specified in the list passed as the second argument.

  If default is specified, then the value entered must be present in the list passed as the second argument.

In a similar fashion to the Int and Float widgets, the drop-down menu can be given an associated Python variable.

- **`Enum ( "<name>", ( ("<option_1>",<value1>), ("<option_2>",<value2>), ...), [, updateCommand = "<python_update_source>" [, setCommand = "<python_set_source>" ] ] )`**

  This widget creates a drop-down menu with the specified name, containing the entries specified in the list of 2-tuple passed as the second argument.

  Each entry will be associated with the value specified on the second element of its tuple.

  If updateCommand is specified, then <python_update_source> will be used as the Python value from the client that will be displayed.

  If setCommand is specified, then when the field is edited, <python_set_source> will be executed.

  For example:

```
Enum( "Mode",
( ("Walk",0), ("Run",1), ("Dash",2) ),
updateCommand = "2*$p.isDashing + $p.isRunning",
setCommand = """
 if Mode==0: $p.switchToRun(1); $p.switchToDash(0)
 if Mode==1: $p.switchToRun(0); $p.switchToDash(0)
 if Mode==2: $p.switchToRun(1); $p.switchToDash(1)
 """ )
```

  Creation of drop-down menu with associated numeric values

- **`Bool ( "<name>", [, updateCommand = "<python_update_source>" [, setCommand = "<python_set_source>" ] ] )`**

  This widget creates a drop-down menu with the specified name, with just one entry having two possible values: true or false.

  If updateCommand is specified, then <python_update_source> will be used as the Python value from the client that will be displayed.

  If setCommand is specified, then when the field is edited, <python_set_source> will be executed.

  For example:

```
Bool( "Walking", updateCommand = "1-$p. isRunning ", setCommand = "$p.
 switchToRun (Walking)" )
```

  Creation of drop-down menu with true/false entry

24.6.3.1.3. Watchers

Watchers allow you to view the value of specific variables in a live system.

These values can be accessed from the Debug (Watchers) Console in the FantasyDemo (accessed by pressing `DEBUG+ F7`). However, CAT gives you a much simpler way to manipulate them.

Whenever adding a CAT control, it is essential to ensure that there is a matching `MF_WATCHER` that corresponds to the value in question. The best way to check that is by looking for the value in the watcher console within the game.

The value is retrieved from and saved to the value that matches the *value path* `MF_WATCHER`.

Below is a list of commands that allow you to manipulate watchers:

- **`WatcherCheckBox( "<name>", "<value_path>" )`**

  Shows a check box with the specified name.

- **`WatcherFloat( "<name>", "<value_path>" [, minMax = (<min>,<max>)] )`**

  Shows a float field with the specified name. If minMax is specified, then the field will have the specified (inclusive) value range.

- **`WatcherFloatEnum ( "<name>", "<value_path>", ( ( "<option1>", <value1> ), ( "<option2>", <value2> ) ) )`**

  Shows a dropdown menu with the specified name, containing the entries specified in the list of 2-tuple passed as the third argument.

  Each entry will be associated with the value specified on the second element of its tuple.

- **`WatcherFloatSlider( "<name>", "<value_path>", minMax = (<min>,<max>) )`**

  Shows a float slider with the specified name, and with the specified (inclusive) value range.

- **`WatcherInt( "<name>", "<value_path>" [, minMax = (<min>,<max>)] )`**

  Shows an integer field with the specified name. If `minMax` is specified, then the field will have the specified (inclusive) value range.

- **`WatcherIntSlider( "<name>", "<value_path>", minMax = (<min>,<max>) )`**

  Shows a slider with the specified name, and with the specified (inclusive) value range.

- **`WatcherText( "<name>", "<value_path>" )`**

  Creates a field with the specified name.

24.6.3.2. Block commands

These are commands that appear as buttons in CAT, shown below the elements specified in the block args.

They execute a given Python script. Each command to be added takes the following format:

```
( "<description>", "<script>" ),
```

where <*`description`*> is the button's caption, and <*`script`*> is the Python script to be executed.

For example:

```
from controls import *

...

commands = \
(
    ( "Hide_GUI", "BigWorld.hideGui()" ),
    ( "Show_ GUI ", "BigWorld.showGui()" )
)Example implementation of block commands
```

Example implementation of block commands

24.7. Timing

The BigWorld libraries provide a number of timing tools for analysing game performance. One of the most important of these is the DogWatch timer class.

When a DogWatch is created, it is registered in a global list. Whenever that timer is started, it is automatically entered into a timing statistics hierarchy, based on what other timers are running when it is started. The same timer can have multiple instances in the hierarchy if it is run more than once in different contexts.

The root timer is called Frame, and is always running for the entire frame time at every frame. All other timer instances are children of this timer's instance. Care is taken at the frame boundary to ensure that no time goes unaccounted for. Timers can even be running across the frame boundary. If this is the case, then they are momentarily stopped, and then restarted in the next frame's time slice.

A view of the DogWatch timer hierarchy is displayed in a debug console, which shows the average of the DogWatch times over the last second. The user can navigate and drill down in the hierarchy, which is displayed using indentation on a single console page. Any of the timer instances can also be graphed, and there can be as many graphs displayed simultaneously as desired. By default, the client keeps 120 frames of DogWatch timer history.

Chapter 25. Releasing The Game

This chapter lists the steps necessary to prepare the game for its release.

The following sections detail each of these steps.

25.1. Configure the engine for limited user accounts

In order to allow the client to run on a system with limited privileges, the engine should not try to write to the installation directory (which, depending on how the game is installed, is usually a privileged location). Certain files that need to be written must be configured to be written to the user's directory.

- The *prefrences.xml* file contains end-user specific settings such as graphics settings and is written whenever the client closes or when `BigWorld.savePreferences()` is called. To configure where this file is saved, edit the `preferences/pathBase` configuration key in engine_config.xml.

  For example, you may want to configure preferences.xml to be written to `MY_DOCS/GameTitle/preferences.xml`.

  See “File `<preferences>.xml`” on page 13 for details on how to configure this setting.

- *Screenshots* can be taken either by pressing PrtScn or by calling `BigWorld.screenShot()`. To configure where screenshots are saved, edit the `preferences/screenShot/path/pathBase` configuration key in engine_config.xml.

  For example, you may want screen shots to be written to `MY_DOCS/GameTitle/Screenshots`.

  See “Taking Screenshots” on page 140 for details on how to configure this setting.

25.2. Prepare the assets

Since "just-in-time" resource processing is not enabled in the Consumer Release client (e.g. converting textures to DDS format on the fly), all resources must be pre-prepared for release. A command line tool, called `res_packer`, is provided which will process a given list of assets. A higher level wrapper for `res_packer` is `bin_convert` (implemented in Python), which will batch process an entire resource tree.

This section provides an overview of how to use both `res_packer` and `bin_convert`.

25.2.1. bin_convert

`bin_convert` is a command-line tool implemented in Python that prepares assets in batch, which makes use of the `res_packer` binary. Its usage is described below:

```
bin_convert [--res|-r search_paths] [source_path [dest_path [base_path]]]
```

The options for invoking `bin_convert.py` are described below:

- **`search_paths`**

  Search paths of the original source assets, as specified in `<res>` (the resources folders list) — for details on how BigWorld compiles this list, see the document Content Tools Reference Guide's chapter *Starting the Tools*.

  This value overrides the local `paths.xml`, if there is one.

- **`source_path`**

Path of the original source assets.

- **`dest_path`**

  Path of the final game, *i.e.*, the destination of processed assets.

- **`base_path`**

  The resource root for `dest_path`, only needs to be specified if not converting the entire resource folder.

This tool can be customised in different ways, so it can skip certain files, skip entire folder, have special handlers for asset types (overriding `res_packer`).

For more information on customising `bin_convert.py`, please refer to its source code.

If the desired processing cannot be achieved in Python, then you can modify the source of `res_packer` using any of the included packer classes as example.

The list below shows some example of usage of `bin_convert.py`:

- **`python bin_convert.py /mf/fantasydemo/res /mf/fantasydemo/packed`**

  Converts all FantasyDemo assets in res to packed folder.

- **`python bin_convert.py --res /mf/fantasydemo/res;/mf/bigworld/res /mf/fantasydemo/res /mf/fantasydemo/packed`**

  Converts all FantasyDemo assets in res to packed folder, specifying the search paths in the command line.

- **`python bin_convert.py /mf/fantasydemo/res/characters /mf/fantasydemo/packed/characters /mf/fantasydemo/packed`**

  Converts all FantasyDemo assets in the `res/characters` folder to the `packed/characters` folder.

  Note that `base_path` (in this case `c:/mf/ fantasydemo/packed`) must be specified to ensure that `res_packer` works properly.

25.2.2. `res_packer`

`res_packer` is a command-line tool that is capable of processing assets depending on their type, pre-processing assets to make them load faster and stripping information that is not needed when running the game. Usually, it is called from `bin_convert` and is not used directly by the developer. Its usage is as follows:

Batch list mode:

```
res_packer [--res|-r search_paths] -list|-l asset_list_file -in|-i src_path
 -out|-o dest_path [-err|-e error_log_file]
```

Compatible mode:

```
res_packer [--res|-r search_paths] source_file [dest_file [base_path] ]
```

The options for invoking `res_packer` are described below:

Batch list mode:

- **`search_paths`**

  Search paths of the original source assets, as specified in `<res>` (the resources folders list) — for details on how BigWorld compiles this list, see the document Content Tools Reference Guide's chapter *Starting the Tools*.

  This value overrides local `paths.xml`, if there is one.

  Note

  For some asset types, search paths have to be specified, either in the command line, in the game's `paths.xml`, or in the `BW_RES_PATH` environment variable.

  These paths should be the source search paths used by the game, so that `res_packer` can find other source files that might be needed in the processing.

  For instance, to process a model file, other assets such as the visual, textures, and animations must be also read.

- **`asset_list_file`**

  A text file that contains a list of all the assets to process. This expected the dissolved paths with one per line.

- **`src_path`**

  The root path of the input files.

- **`dest_path`**

  The root path of the output files.

- **`error_log_file`**

  An optional error output log. Any files that fail to process will be added to this log.

Compatible mode:

- **`source_file`**

  Source file (with path) to process.

- **`dest_file`**

  Destination file (with path) of the processed assets.

  In some cases, `source_file` might not be copied at all (`.bmp` files are not copied), or the processed file could be of a different type than the original source file (`.bmp` files are converted to `.dds` files).

  If this argument is missing, then `source_file` will not be processed, and a message will be sent to the standard output (useful for examining XML files, for instance).

- **`base_path`**

  Base path of the final game — usually corresponds to `dest_file`'s path.

  This argument is used when packing file types that require special processing, such as images, models, and chunk files.

  If this argument is missing, then the `dest_file`'s path is used.

To modify `res_packer`'s default behaviour for an asset type, or to add new asset types for processing, modify the source code using any of the included packer classes as example.

Note

When processing `Python` files, `res_packer` does not compile the `.py` files into `.pyc` when called directly without `bin_convert`. Compiling of `.py` files is done directly inside `bin_convert`. Furthermore, if old `.pyc` files exist in the source folder, `res_packer` copies them to the destination folder without recompiling when run directly without `bin_convert`.

25.2.3. Processing done in `bin_convert` and `res_packer`

The default processing done by these tools is as follows:

- **`bin_convert`**
  - Skips the `scripts/editor`, `scripts/cell` and `scripts/base` folders.
  - Skips the `animations`, `.bwthumbs` and `CVS` folders.
  - Skips the thumbnail files (*i.e.*, files with `.thumbnail.*` extension).
  - For `.py` files

    Generates `.pyc` compiled Python files and skips the source `.py`, using a custom handler.
- **`res_packer`:**
  - **For `.bmp`, `.tga`, `.jpg`, `.png`, `.texformat` and `.dds` files:**

    Generates DDS for source image files that do not have one, and copies DDS files that do not have a corresponding source image file. The `.texformat` files are skipped after processing.
  - **For `.model` and `.anca` files:**

    Loads models to generate `.anca` files. The .animation files are skipped after processing, and the `.model` files are packed.
  - **For `.cdata` files:**

    Strips thumbnail.dds and navgen sections.
  - **For `.chunk` files:**

    Strips entities that are not client-only, then packs the file.
  - **For `.fx`, `.fxh` and `.fxo` files:**

    By default it ignores `.fx` and `.fxh` files, and only copies `.fxo` files, but it can also be configured to copy the source `.fx` and `.fxh` (requires recompiling, see `src/tools/res_packer/config.hpp`) .

    Note

    res_packer itself does not rebuild shaders, it only copies any existing binaries. Use the utility script located in `bigworld/tools/misc/rebuild_shaders/RebuildShaders.py` to pre-build all shader combinations before running res_packer.

- **For all other file types:**

  Text XML files — *i.e.*, files beginning with the < (left angle bracket) character, regardless of extension — will be packed, while others will just be copied.

25.2.4. Files and folders that do not need to be shipped to the end user

Both bin_convert and res_packer try their best to slim down the game's assets that will be shipped to the end user, but because each game has different architecture and requirements, some final tuning might be needed for your game. Following is a list of files and folders to help identify what should not be shipped to the end user:

- Files `*.bmp`, `*.tga`, `*.jpg`, `*.png`, `*.texformat`: The final `dds` files are generated and packed by `res_packer`, so the source images are not needed.
- Files *`.thumbnail.*:` These files are not packed, as these are generated and used in the tools' Asset Browser only.
- Files `*.animation:` Packed `.anca` files are generated from the source `.animation` files by `res_packer`.
- Files *.py: Compiled `.pyc` files are generated by `bin_convert`, so Python source is not needed.
- Folders to skip: `animations, .bwthumbs, scripts/editor, scripts/cell, scripts/base, scripts/db, scripts/bot, bigworld/res/server, bigworld/res/helpers.`

25.2.5. Font Licensing issues with `bin_convert` and `res_packer`

By default, `res_packer` will pack any font `DDS` files into your game's destination folder, and font authors usually require buying a license in order to allow their font(s) to be used. Please make sure you own license(s) to the font(s) you use in your game.

25.3. Zip assets and specify paths

To pack assets to zip files, simply create one or more zip files containing the game's assets. To create a set of Zip files that can be used by the BigWorld client application:

1. **Zip files bigger than 2GB are not supported. More than one Zip file might be required.**

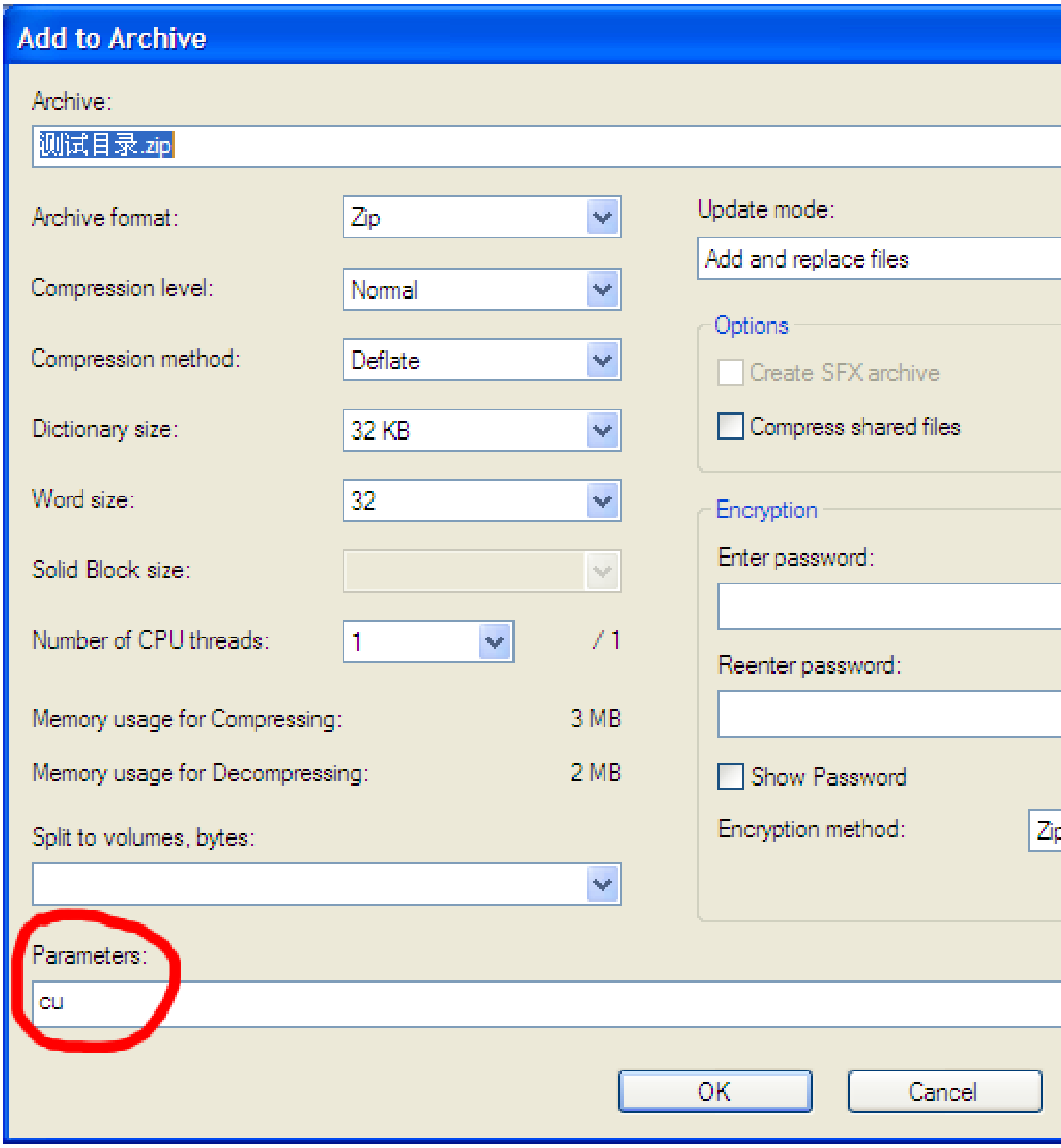
   The maximum Zip file size supported is 2GB.

2. **Before creating the Zip files, the assets should be prepared via bin_convert.py.**

   This tool is located under `bigworld/tools/misc/res_packer` folder.

3. **Zip file access is done through zlib, and the supported Zip compression methods are DEFLATE and STORE. Non-ASCII file names should be encoded as UTF-8.**

   Zip files created with WinRAR, WinZip and 7-Zip have been successfully tested. If Non-ASCII file names are included, make sure they are encoded as UTF-8, ie. in the case of 7-Zip, choose "Add to archive..", set "cu" as the parameters which will force the file names to be encoded as UTF-8.



Archive: 测试目录.zip

Archive format: Zip

Compression level: Normal

Compression method: Deflate

Dictionary size: 32 KB

Word size: 32

Solid Block size:

Number of CPU threads: 1 / 1

Memory usage for Compressing: 3 MB

Memory usage for Decompressing: 2 MB

Split to volumes, bytes:

Parameters: cu

Update mode: Add and replace files

Create SFX archive

Compress shared files

Enter password:

Reenter password:

Show Password

Encryption method: Zip

7-Zip Add to Archive dialog

4. **Create Zip files for the base BigWorld resources.**

   Navigate to the folder containing BigWorld's packed assets, and create the Zip files for its files and sub-folders.

5. **Create Zip files for the actual game assets.**

   Navigate to the game assets folder, and create the Zip files for its files and sub-folders.

6. **Specify Zip files as paths in the paths.xml file, in order of precedence.**

   The paths.xml file's Path tag can be set either to a path, or to a Zip file. Usually, game asset folders/zip files are listed before BigWorld resources folders/zip files. All paths must be specified relative to the client executable.

   Assuming the following:

   - Common BigWorld resources compressed to `bwres001.zip`.
   - Final game assets compressed to `res001.zip` and `res002.zip`.
   - The resource packages are located next to client executable.

   Your `paths.xml` file should look similar to this:

```
<root>
  <Paths>
    <Path>  res001.zip    </Path>
    <Path>  res002.zip    </Path>
    <Path>  bwres001.zip  </Path>
  </Paths>
</root>
```

   You can also combine Zip file paths with normal file system paths as well, so that you can have additional assets in unzipped folder (this is required, for example, by streamed FMOD sound banks).

   If your unzipped folder is called `resunpacked`, then `paths.xml` will look like this:

```
<root>
  <Paths>
    <Path>  res001.zip    </Path>
    <Path>  res002.zip    </Path>
    <Path>  bwres001.zip  </Path>
    <Path>  resunpacked    </Path>
  </Paths>
</root>
```

25.4. Prepare the game executable

- If this has not already been done, compile the final release of your game's executable. This can be done in the VisualStudio's **Configuration Manager** dialog box (accessed by the **Build → Configuration Manager** menu item).

  The **Active Solution Configuration** drop-down list must be set to **Consumer_Release**.

- Copy binaries to their final location in the redistributable directory structure. The final structure is quite flexible, as long as the resource paths are specified as relative to the executable. For example, if the paths.xml described in the previous section is used, then the final structure would look like:

  - `InstallDir/bwclient.exe`
  - `InstallDir/res001.zip`
  - `InstallDir/res002.zip`
  - `InstallDir/bwres001.zip`

- `InstallDir/resunpacked/`

Chapter 26. Shared Development Environments

As the workflow of creating a game requires a large number of people working on a numerous components simultaneously within a variety of environments it is nescessary to ensure that everybody can work together in as seamless a manner as possible. This chapter aims to outline the key areas in which interaction is required and the recommended methods to avoid conflicts.

Currently there are three areas that have been identified that may cause potential interaction conflict for an unprepared development team:

1. Windows and Linux cross platform development.

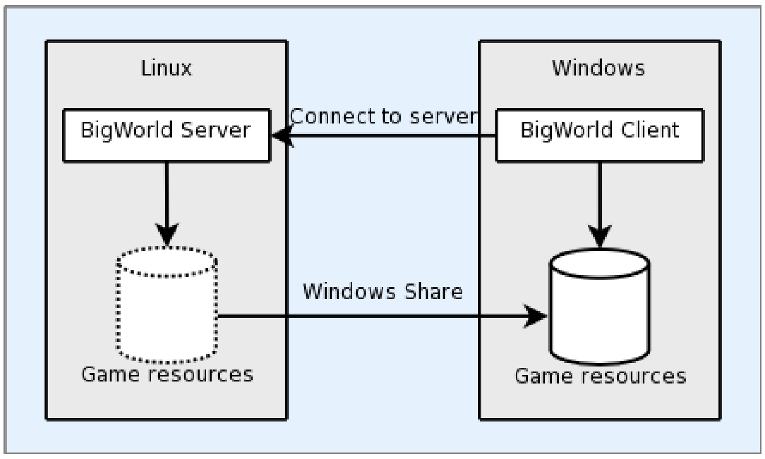
2. Using BigWorld with a Version Control System.

3. DBMgr database conflicts.

26.1. Windows and Linux cross platform development

For anyone not familiar with both Windows and Linux, running a BigWorld server on a Linux box to test game scripts and assets can be intimidating and error prone. Since designers and artists typically do most of their work on Windows, the process of synchronising files between Windows and Linux machines can be tedious.

The solution outlined below aims to simplify this task by having all assets and game scripts reside on a Windows machine, with a Linux machine (which can be shared among multiple users) hosting and running a BigWorld server for each user that requires their own development environment.



Sharing game resources between Windows and Linux

This solution can be summarised as follows:

1. A game developer on a Windows machine creates a network share of the root BigWorld directory (*i.e.*, the directory containing `bigworld`, `fantasydemo`, and `src` folders).

2. On the Linux machine, the Windows share from Step 1 is mapped to a directory and the relevant `<res>` directories and used when a BigWorld server is started.

Cross-mounting development resources has been found within the BigWorld offices to be the most effective method for Windows based developers and artists to work, as all editable files reside on the machine they are working on.

Note

This solution intentionally keeps the server binaries on the Linux box.

Running server executables that exist on Samba mounted filesystems can cause unexpected problems, and is not recommended.

Running server binaries from NFS mounted filesystems works correctly and is a recommended alternative.

26.1.1. Sharing resources from Windows

For the purposes of this example we assume that all the game resources have been checked out into a directory called `C:\BigWorld`.

To share the `C:\BigWorld` directory on the Windows machine, follow the steps below for your version of Windows.

26.1.1.1. Windows XP

1. Browse to the `C:\` drive in Explorer.
2. Select the `BigWorld` directory and right-click it.
3. In the context menu, select the **Sharing and Security...** menu item.
4. On the **mf Properties** dialog box, select the **Share This Folder** option button.
5. In the **Share Name** field, type the name to share the folder by (in our example, **mf-win**).
6. Click the **Permissions** button.
7. In the **Permission For mf** dialog box's **Group or User Names** list box, select the **Everyone** item.
8. In the **Permissions For Everyone** list box's **Full Control** entry, select the **Allow** check box.

26.1.1.2. Windows 7

1. Browse to the `C:\` drive in Explorer.
2. Select the `BigWorld` directory and right-click it.
3. In the context menu, select the **Properties** menu item.
4. Select the **Sharing** tab.
5. Click the **Advanced Sharing...** button.
6. In the **Advanced Sharing** dialog box, select the **Share this folder** check box.
7. If necessary, click the **Permissions** button to enable all users access privileges to this share.
8. Click **OK** when finished.

26.1.2. Accessing Windows share from Linux

To assist the process of mounting the Windows share, BigWorld provides the script `setup_win_dev`. The location of this script may differ depending on your edition.

Indie Edition	For customers using the Indie edition, `setup_win_dev` will be installed into `/opt/bigworld/current/server/bin` by the server RPM package. This directory has also been placed into your `$PATH` so you can run `setup_win_dev` from any directory.
Commercial Edition	Customers using the Commercial edition can find the setup_win_dev script located in `bigworld/tools/server/install/setup_win_dev.py`.

Please note, however, that it was designed for developers working at BigWorld, and hence it uses default values appropriate for BigWorld as well. Before artists and game programmers use it, a sysadmin or programmer should edit this file to change the defaults to values appropriate for your development environment.

26.1.2.1. Assumptions and Requirements

This `setup_win_dev` script has following assumptions:

- The server binaries can be accessed on the Windows share.
- Your username on the Windows box is the same as your username on the Linux box.
- You are using CentOS 5 or later.
- Linux kernel with CIFS module. This should be contained within the default CentOS kernel.

The script will display a list of prerequisites upon startup, which are reproduced here for convenience:

- The user running the script has been entered into the `/etc/sudoers` file on the Linux machine.

  For details see the system manual page with the command '**man sudoers**'.

- You know the location of your home directory on the Linux machine.

  This can generally be discovered by running the following command:

  ```
  $ echo $HOME
  /home/alice
  ```

- You have shared the top level BigWorld directory from your Windows machine.

  For details on how to achieve this see “Sharing resources from Windows” on page 190 .

- You may also require the Samba client programs. To install the Samba client, run the following command as the root user:

  ```
  # yum install samba-client
  ```

26.1.2.2. Mapping a Windows share onto Linux

Once the requirements outlined above have been met, or any necessary modifications have been made to your environment, running the `setup_win_dev` script will guide you through mounting a Windows share using Samba onto the Linux machine.

Outlined below is a simple run through of the `setup_win_dev` program discussing each step.

When the program is first run, it attempts to establish root user privileges using the **sudo** command. This enables the program to interact with the system devices nescessary to provide access to your Windows share.

This step may not be nescessary if you have recently performed another command using sudo. Enter the password for the account you are currently logged in as.

```
$ setup_win_dev
NOTE: If you are immediately prompted for a password, enter your *own*
      password not that of the root user.

* Validating user has 'sudo' privileges
Password:
```

Next we see that the program is preparing a destination directory for the Windows share to be placed under. This directory defaults to `$HOME/bigworld_windows_share`.

```
* Setting up destination location for Windows resources
```

The next step involves entering information regarding the location of the Windows machine and the name of the shared resources. If you are uncertain about any of the details attempt to access your Windows machine from another machine in the network to establish the machine name and share name.

```
* Querying location of remote resources

Enter the hostname of your Windows machine: mywindowsmachine
Enter the share name of the shared BigWorld directory: BigWorld_indie
```

You now need to input the username and password required to access the Windows machine. The username will default to the username of your unix account, however if your Windows login is different simply enter that here.

```
We now need the username and password required to connect to the Windows share
Username [alice]: bob
Password:
Confirm password:
```

The `setup_win_dev` program now outputs the resource name to be used when accessing the Windows share. This resource name can be used by other Samba tools such as smbclient if you are having troubles connecting.

```
Using remote location: '//mywindowsmachine/BigWorld_indie'
```

Finally you will be asked if you wish to have the Windows share always available on the Linux machine. This allows you to reboot or shutdown the Linux machine whenever you need to without having to remount the Windows share. If you choose 'yes' a new file that is only readable by your user will be created in `$HOME/.bw_share_credentials` containing your username and password.

```
Do you want to automount your Windows share each time this Linux box boots?
This will place a file in your home directory containing a clear-text copy
of your password that is only readable by your user. [yes]
```

The setup_win_dev program will now attempt to make the Windows shared resources available for you.

```
Patched /etc/fstab successfully
```

```
//mywindowsmachine/BigWorld_indie is mounted at
 /home/alice/bigworld_windows_share
* Windows directory successfully mounted
```

26.2. Using BigWorld with a Version Control System

It is strongly recommended that a version control system such as CVS, SVN or Perforce is used while developing a game using BigWorld. In doing so you allow numerous people within your development team to remain up to date with changes and enable access to all parts of the project resources regardless of the development platform of an individual.

26.2.1. Customers using the Commercial Edition

Most recipients of an SVN distribution should place the entire release received from BigWorld into their version control system. This ensures that any changes to the BigWorld source code and resources are propagated to all the game developers at once.

Some files should not be committed into the version control system. Please review the section “Files to exclude from version control” on page 193 for further details.

26.2.2. Customers using the Indie Edition

26.2.2.1. Creating a project repository

Customers using the Indie edition should only commit their own project directories into version control.

Indie customers should only commit their own project directories into version control.

For example in the case of a new game called “my_game” it is recommended to commit the directory `C:\BigWorld\my_game` into your version control system.

Some files should not be committed into the version control system. Please review the section “Files to exclude from version control” on page 193 for further details.

26.2.2.2. Checking out an existing project

When setting up a new client machine run the installation procedures outlined in the Client Installation Guide and then checkout your project into the new installation.

When setting up a new server machine run the installation procedures outlined in the Server Installation Guide. You will then need to checkout your project into the home directory of the user running the server, or follow the instructions outlined in “Windows and Linux cross platform development”on page 189 to use resources mounted from a Windows machined. After preparing the server and the game resources for use you will also need to ensure that the .bwmachined.conf file has been updated accordingly. Details on the .bwmachined.conf file can be found in the Server Installation Guide.

26.2.3. Files to exclude from version control

There are numerous files that are automatically generated while running a the BigWorld Technology Suite which are only relevant to the user currently running a program. These files should be excluded from your version control system to avoid conflicts with other users. Each version control system provides its own mechanism to ignore or exclude files. For example Subversion allows you to set a directory property `svn:ignore` to a list of file match patterns for that directory.

Below is listed a set of files and directories that should be considered for adding exclusion rules to your version control repository and configuration files.

26.2.3.1. General exclusion rules

Application log files such as `python.log` or `worldeditor.log` should not be committed into your repository.

```
*.log
```

When you run the game client or the tools, some resources will be created on-disk as 'processed' or 'compiled' versions of source files. These files are regenerated on demand based on comparing the timestamp of the source with the timestamp of the automatically generated file. These files should not be committed into your repository.

```
*.dds        # Compressed texture map files
*.anca       # Compressed animation files
*.font       # Processed font files
font/*.dds   # Generated font bitmaps
```

Python scripts used for client and server game logic will generate a compiled byte-code file when they are first run or updated. As these files will be changing frequently during development they should not be included in the repository to help reduce clutter with each changeset.

```
*.pyc
```

26.2.3.2. Tools specific exclusion rules

The art pipeline tools automatically generate user preference files when they are run. As these will differ between artists they should be excluded from the repository.

```
bigworld/tools/worldeditor/options.xml
bigworld/tools/worldeditor/resources/graphics_preferences.xml

bigworld/tools/particleeditor/options.xml

bigworld/tools/modeleditor/options.xml
```

The art tools Asset Browser also generates history files as it is being used.

```
bigworld/tools/modeleditor/resources/ual/history.xml
bigworld/tools/modeleditor/resources/ual/favourites.xml

bigworld/tools/particleeditor/resources/ual/history.xml
bigworld/tools/particleeditor/resources/ual/favourites.xml

bigworld/tools/worldeditor/resources/ual/history.xml
bigworld/tools/worldeditor/resources/ual/favourites.xml
```

WorldEditor will create a `space.localsettings` file when creating a new space.

```
<your_game>/res/spaces/<your_new_space>/space.localsettings
```

WorldEditor will also create two files containing a space map. Both these files must be committed to revision control or neither.

```
<your_game>/res/spaces/<your_space>/space.thumbnail.dds
<your_game>/res/spaces/<your_space>/space.thumbnail.timestamps
```

The BigWorld game client will also generate a preferences file in the directory it is run from.

```
# Substitute 'fantasydemo' for your game name
fantasydemo/game/preferences.xml
```

26.3. DBMgr database conflicts

For customers using a MySQL database to store persistent data, shared development environments can present an issue with multiple servers contending for the same database.

The database used by DBMgr is exclusive per server cluster instance so it is nessecary for multiple users running a server on the same machine to use different databases. To do this requires adding or modifying the the <res>/server/bw.xml configuration file entries for `dbMgr/host` and `dbMgr/databaseName`. Specifically the `databaseName` should be unique per user. For more information on these options refer to the Server Operations Guide section “DBMgr Configuration Options”.