CC_CANOE Stereo Rendering Library

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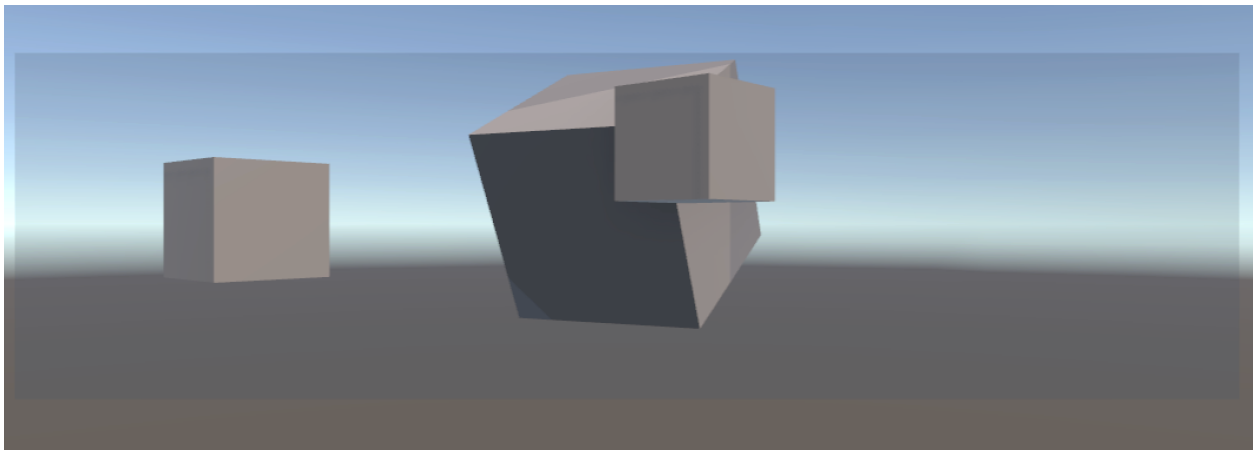
This code base provides off-axis stereoscopic 3D rendering for Unity. This is the basis for proper 3D rendering in systems like display walls, CAVEs, CAVE2s, CyberCANOEs, where the stereo image displayed is correctly rendered according to a user's head position and orientation. This also ensures that objects in the virtual world appear to be correctly sized when seen from the real world- in other words, a 1 meter cube looks like it's really 1 meter in size.

Using the Code

To use the code, start with the project template (preferably using Unity 2021 and up). Run the project and you should see a simple scene with 3 cubes.



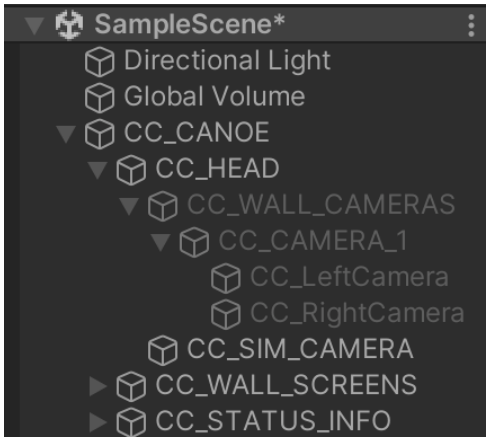
Try pressing the following keys to play with the various options:

0 = toggle wall vs simulator view
9 = toggle stereo on/off
8 = cycle through stereo rendering modes (side-by-side, top-bottom, interlaced)
7 = swap left and right eye images
-/+ = decrease and increase eye-separation (interaxial) distance

Try pressing 0 9 8 8 8 8 7 7 7 7 0 and watch what happens after each key press.

This code only supports Unity's Universal Render Pipeline (URP) as Unity is gradually deprecating the old built-in render pipeline. So if you are using / purchasing assets on the Unity asset store make sure they support URP, especially those that have shaders.

The part of the scene hierarchy that is most relevant is the one under CC_CANOE as shown here →



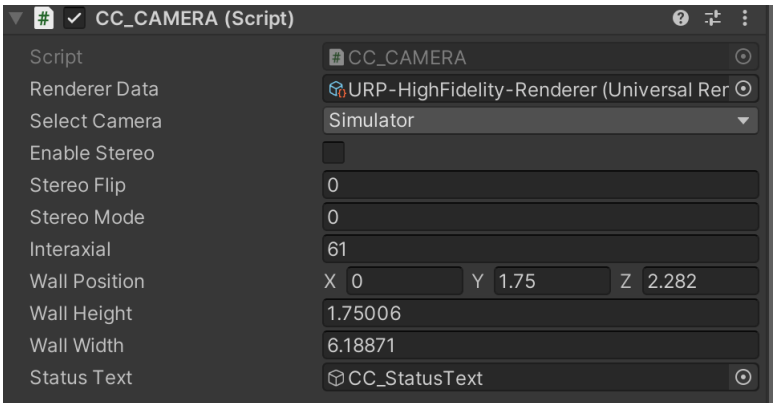
Think of CC_CANOE as the spaceship that moves through the virtual space and you are standing inside that spaceship looking out the window in front of you. To move CC_CANOE through space you simply adjust the position and orientation of the CC_CANOE gameobject.

CC_HEAD is the gameobject representing your head. Your head resides within the CC_CANOE. If you are using some kind of tracker (like Vive or Kinect), you will need to feed the tracker's head data to CC_HEAD by directly setting its position and orientation. If you don't intend to do any kind of head tracking or tracking in general, just leave CC_HEAD alone. It is currently set to place your head at the center of the CC_CANOE looking along the positive Z axis. It is also defaulted to a Y value (height) of 1.75m to emulate the perspective of an average 5'10" male.

CC_HEAD camera should remain OFF. It doesn't really hurt to leave it on. But there is no need. Just leave it off. If you wish to change your scenes background or near and far clipping planes, do it to CC_HEAD. These changes will be propagated to the stereo rendering cameras.

CC_WALL_SCREENS - contains a CC_SCREEN_1. CC_WALL_SCREENS is essentially the window in your spaceship. In technical terms, these determine the position of the projection screen and therefore it should be set to the same position as the *physical* display wall. By default it is set to 6.18m x 1.75m to emulate LAVA's 3D display wall. Also by default this display is placed at position (0,1.75,2.282).

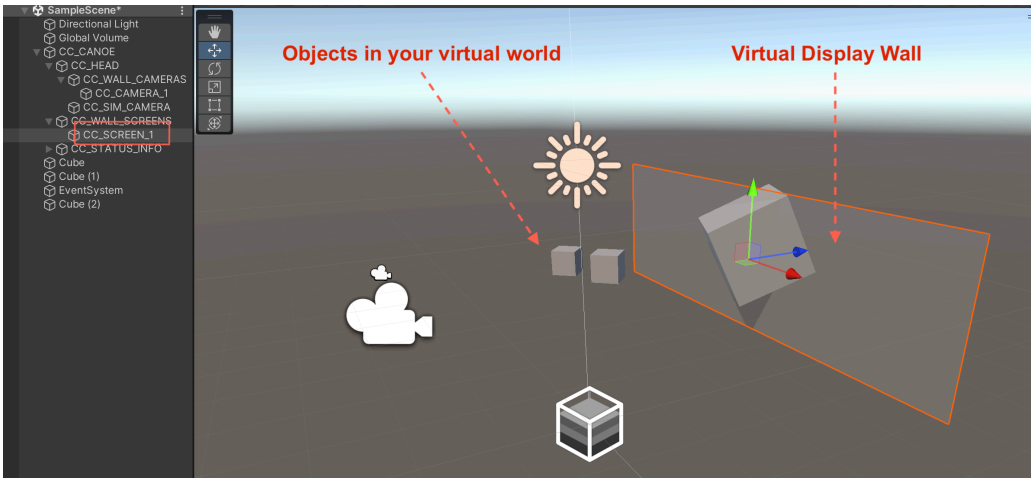
When using the Unity *editor*, you can adjust the size and position of CC_WALL_SCREENS to match your physical wall by adjusting Wall Position, Wall Width and Wall Height in the CC_CANOE script (attached to CC_HEAD)



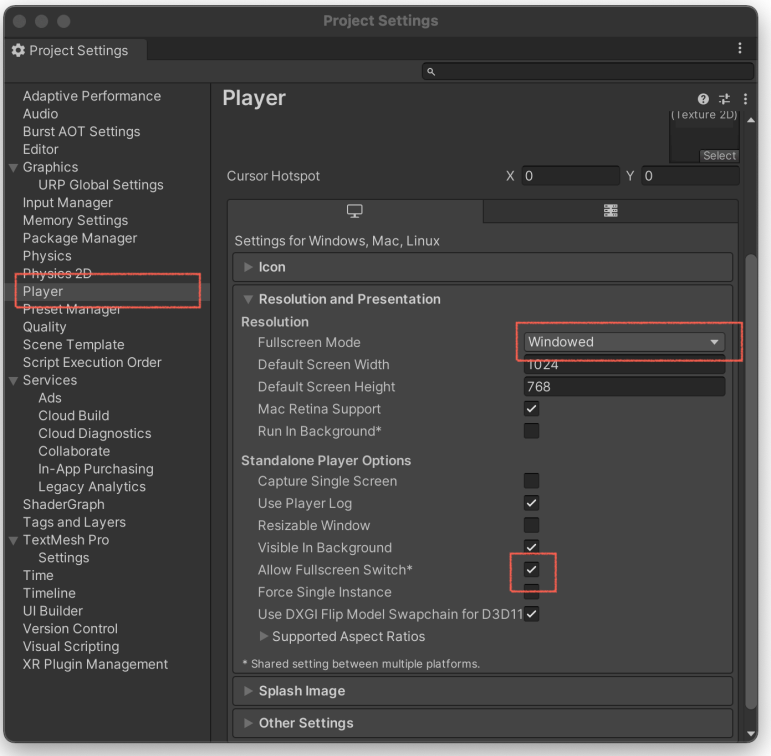
When running your *standalone application* however you can set this information in the XML file (take a look at CCUnityConfig.xml in CCUnityConfig folder, for an example) so that the proper

stereo configuration is loaded during runtime. The CCUnityConfig folder should be placed at the same directory level as your application's .exe file so it has access to it.

Lastly, CC_SIM_CAMERA is the simulator camera. This is really a clone of the CC_HEAD camera. The simulator view draws a virtual display wall (ghosted grey plane CC_SCREEN_1) in the scene so you can get a sense of where the objects in the virtual world are relative to the display wall.



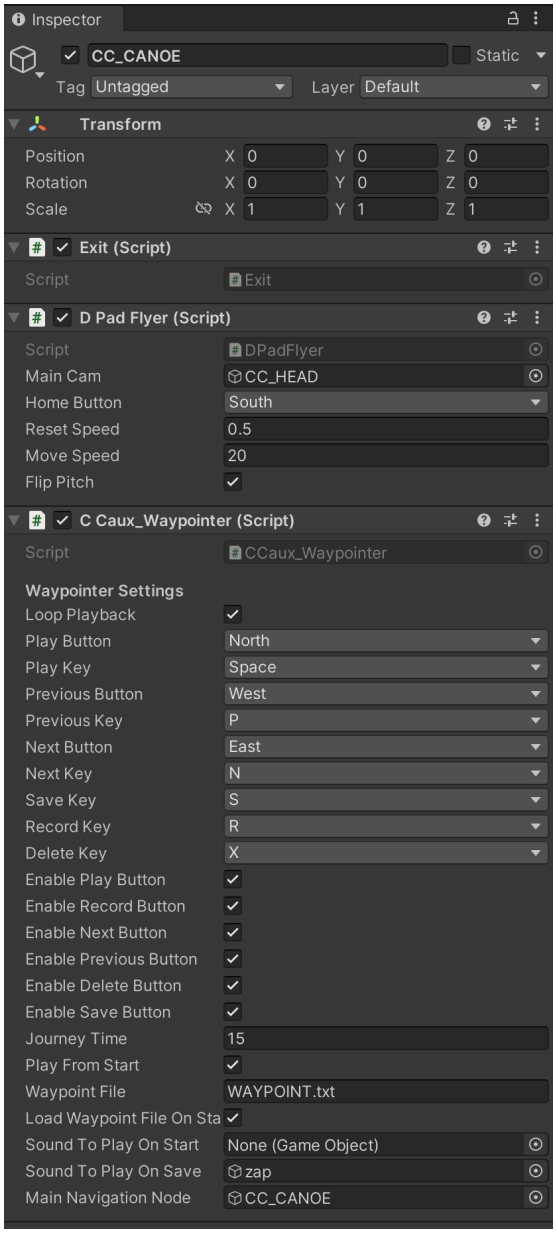
NOTE:
When building your Unity application for LAVA's 3D wall (Pele), make sure the following are set in Edit->Project Settings.



Also in CCUnityConfig.xml, make sure the following is set: <fullscreen>0</fullscreen>

Enhancements

If you look at the CC_CANOE game object there are also two attached scripts (DPadFlyer and CCaux_Waypointer). Those scripts can be found in the Navigation folder.



The DPadFlyer lets you use a PC Xbox-like game controller to move around the scene. The CCaux_Waypointer lets you set waypoints in the scene and either move back and forth quickly between way points or travel through all the waypoints like a pre-scripted movie.

The game controller mappings for DPadFlyer are:

- **Left joystick** – Move forwards/backwards and strafe.
- **Right joystick** – Pitch and Yaw.
- **Left/Right triggers** – Roll.
- **Left/Right shoulder buttons** – Move Up and Down.
- **A button on game controller** – hold this down to go back to the origin.

The user-interface controls for the CCaux_Waypointer are:

- **Y button on game controller** (or SPACEBAR) – start/stop waypoint movie.
- **X and B buttons** on game controller – go to previous and next waypoint.

- **R key on keyboard** – record current waypoint
- **X key** – delete current waypoint
- **S key** – save all the waypoints into a file.
  When your program loads, it will automatically load this same file.
  Waypoint file name is set in the CCaux_Waypointer control panel (pictured above).

The waypoint script essentially records the position and orientation of whatever you designate as the main navigation node (in this case the CC_CANOE is the navigation gameobject). When the waypoint script flies from waypoint to waypoint it will modify the position and orientation of the CC_CANOE gameobject.

If you wish to have the waypoint playback run in conjunction with a musical soundtrack, add an audio sample gameobject to your scene and drag it into the “Sound to Play On Start” property in CCaux_Waypointer. Then set the Journey Time to the length of audio sample in seconds. The waypoint script will ensure all the waypoints are traversed within that duration.

Note: the waypoint script will also loop the waypoint traversal if desired. In that case, the music will also be looped. Anytime during playback you can stop the movie and use the game controller to fly around the scene.

How It All Works (if you care)

CC_WALL_CAMERAS are the cameras that support rendering of the virtual world. The scene is rendered in 3 ways:

1. Simulator view (monoscopic view which is essentially same as CC_HEAD)
2. Wall view (CC_HEAD view adjusted for off-axis projection)
3. Stereo Wall views - which includes off-axis projection with interleaving, side-by-side, top-bottom rendering modes.

CC_CAMERA_1 is the center off-axis camera. CC_CAMERA_1's camera characteristics (like near and far clipping plane) are a copy of CC_HEAD. So whatever you set in CC_HEAD will be copied by your CC_CAMERA_1 cameras.

CC_LeftCamera and CC_RightCamera are created dynamically by CC_CAMERA_1. They are a copy of CC_CAMERA1 except they are offset horizontally by a distance determined by eye separation distance (Interaxial distance).

Scripts

CC_CAMERA.cs (attached to CC_HEAD)- this script coordinates everything: setting up the cameras, checking for key presses to switch between different rendering modes, telling the render pipeline which material to use to render the correct stereo mode, resizing the render textures whenever the screen size changes.

CC_CAMERAOFFSET.cs (attached to CC_CAMERA_1)- this script does the off-axis projection calculations for a camera. This is embedded in every camera that requires off-axis projection rendering, namely: CC_LeftCamera, CC_RightCamera, and CC_CAMERA_1.

CC_CAMERASTEREO.cs (attached to CC_CAMERA_1) - this script does the work of creating and setting up the cameras. The script sets up CC_CAMERA_1 as the center camera showing the non-stereo off-axis projection image. The off-axis projection image is the actual correct image that is projected on the display wall. Not the simulator camera.

The script also dynamically creates CC_LeftCamera and CC_RightCamera. It is important to note that these are the only cameras that have Post Processing enabled as they are the ones which are part of the stereo rendering pipeline (more later).

CC_CONFIG.cs - loads XML file of configurations to set up the wall size, wall resolution, wall position, stereo mode, etc.. This file is only opened when you are running in Application mode. It will be ignored when you are running in the Unity editor.

Stereo Rendering

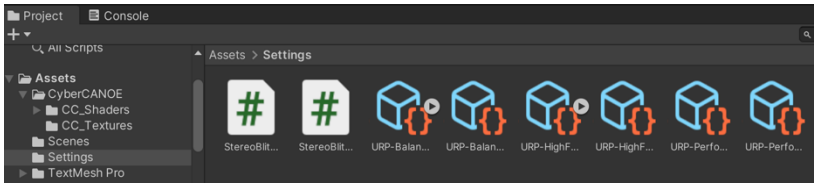
Stereo rendering is performed by taking the left and right render textures from CC_LeftCamera and CC_RightCamera and giving them to a shader to merge into a stereo picture.

3 shaders support the 3 main stereo rendering types: StereoInterlaceSG, StereoSideBySideSG, StereoTopDownSG. These are all implemented in Unity as shader graphs.

Shaders can only do the work they need to do by being attached to materials.
Therefore there are 3 materials: CC_INTERLACE, CC_SIDEBYSIDE, CC_TOPBOTTOM.

All shaders take the same inputs except the interlace shader which also takes the vertical resolution of the screen as input. The vertical resolution is given to the interlace material in the CC_CAMERA script (look at SetStereoMode function).

There are also scripts in Assets>Settings:

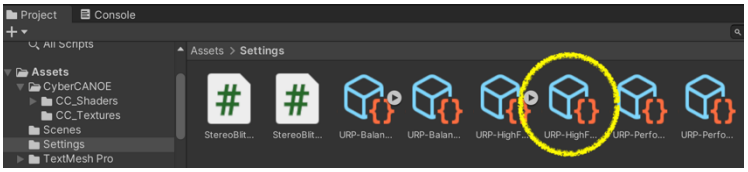


StereoBlitFeature.cs - this sets up the custom rendering pipeline to accept the 3 types of materials (Material1ToBlit, Material2ToBlit, Material3ToBlit). Material1ToBlit is the material for interlaced stereo. Material2ToBlit is material for the side-by-side stereo. Material3ToBlit is material for the top-bottom stereo. MatertialToBlit is the current material being rendered in the render pipeline.

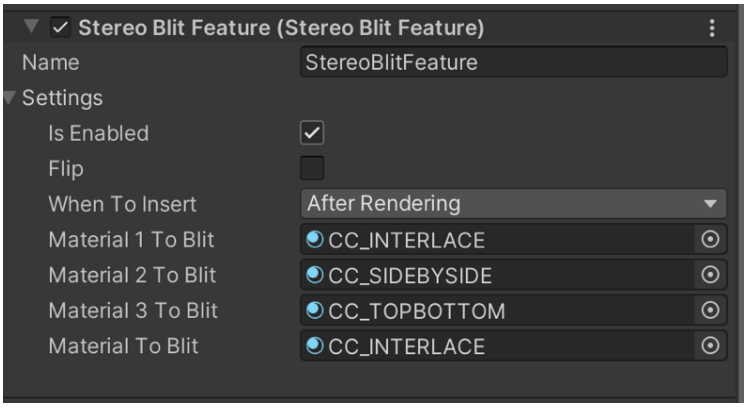
The Flip parameter is set to true if you wish to invert the stereo (i.e. swap left and right eye images). In the CC_CAMERA script it is toggled by pressing “7”.

StereoBlitRenderingPass.cs - this does the work of taking the left and right eye images and running them through the chosen shader, and blitting the outcome to the display framebuffer for viewing.

Also in the Settings folder you will see URP-High Fidelity-Renderer. This is how we pass the rendering parameters into the pipeline.

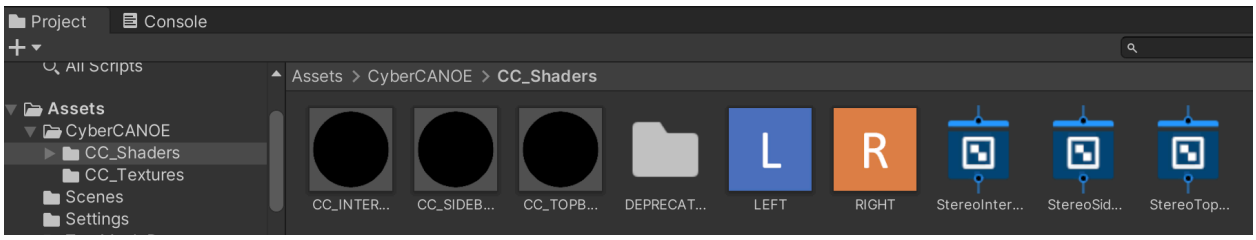


If you click on it and look at the bottom of the Inspector, you will see the settings exposed by StereoBlitFeature. There is no need to alter any of this.



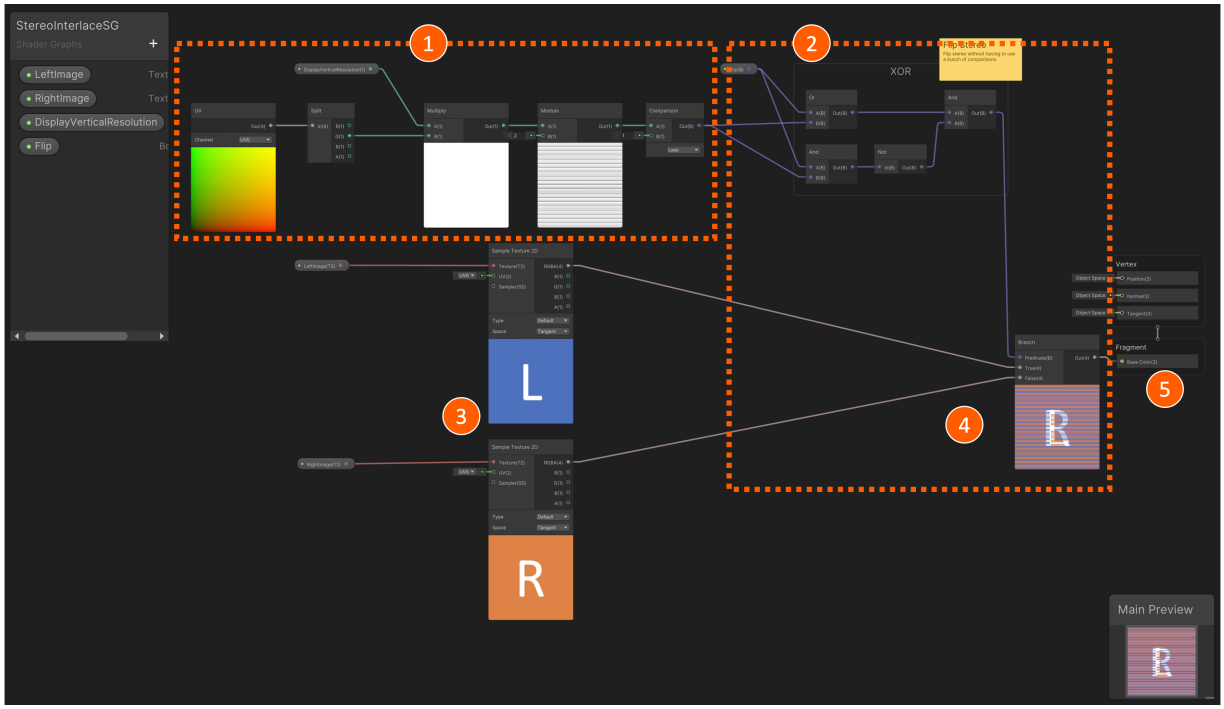
The Stereo Rendering Shaders

These are housed in the CC_Shaders directory of the CyberCANOE directory.



There are 3 shader graphs (StereoInterlaceSG, StereoSideBySideSG, StereTopBottomSG) and 3 materials that use the shaders (CC_INTERLACE, CC_SIDEBYSIDE, CC_TOPBUTTOM).

Interlace Shader



[1] Take the UV whose x and y values range between 0 and 1, and extract the y component (i.e. the vertical component of the texture). Multiply this floating point value by the vertical height in pixels of the input image and take the modulo of 2. This yields a sequential series of 0s and 1s.

[2] We feed this series of 0s and 1s into the Branch node to select the scanlines from the left image and the right image[3], and then place them into the resulting texture[4] that is finally fed to the fragment shader [5].

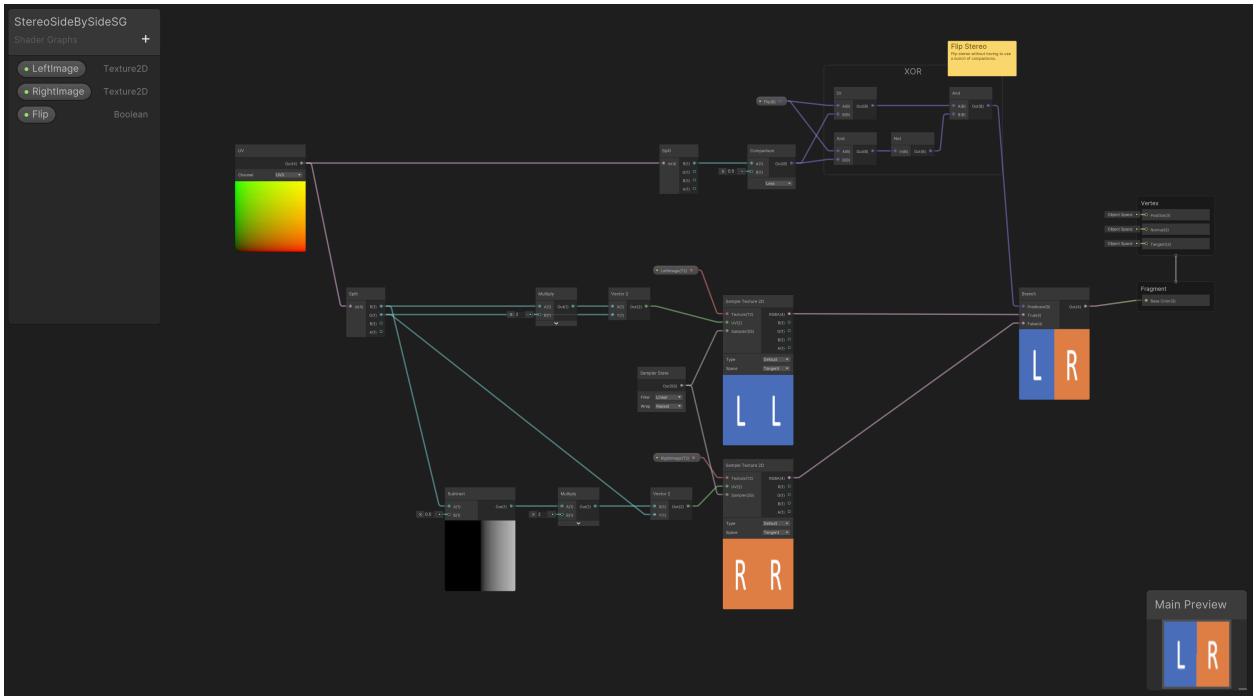
This is essentially what the shader code would look like in CG:

```
float4 frag(v2f_img IN) : COLOR0
{

    if (fmod(IN.uv.y * InterlaceValue, 2.0) < 1.0)
    {
        return tex2D(LeftTex, IN.uv);
    }
    else
    {
        return tex2D(RightTex, IN.uv);
    }
}
```

The XOR in [2] used to create the XOR logic to flip the interlacing if the Flip stereo option is set to true. Flip means we swap the left and right eye images. Unity does not have an XOR operator node.

Side-by-Side Shader



This is the CG code we are essentially achieving:

```
            float4 frag(v2f_img IN) : COLOR0
            {
                // If considering a pixel on the left half of screen
                if (IN.uv.x < 0.5)
                {
                    // Retrieve texel from left texture map at texture
location
                    // x * 2, y
                    return tex2D(LeftTex, float2(IN.uv.x*2.0,
IN.uv.y));
                }
                else {
                    // Retrieve texel from right texture map at
texture location
                    // (x - 0.5)*2, y
                    return tex2D(RightTex, float2((IN.uv.x-0.5)*2.0,
IN.uv.y));
                    }
            }
```

Top-Bottom Shader

The top-bottom shader is essentially the same as the side-to-side shader except we are stacking the left eye image on top of the right eye image.