Android and OpenGL

Android Smartphone Programming

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OpenGL Introduction

- Short for: Open Graphics Library[4].
- Enables creation of 2D and 3D graphics.
- Special API for embedded systems available on Android: *OpenGL ES API*.
- Two important classes: *GLSurfaceView* and *GLSurfaceView.Renderer*.

OpenGL Introduction

Important Classes

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GLSurfaceView View to draw and manipulate objects using OpenGL.

GLSurfaceView.Renderer Interface defining methods to draw (render) graphics.

- Add renderer to GLSurfaceView using *GLSurfaceView.setRenderer()*.
- Extend GLSurfaceView to capture touch screen events.
- Extend Android manifest when using OpenGL ES 2.0:

```
<!-- Tell the system this app requires OpenGL ES 2.0. -->
<uses-feature android:glEsVersion="0x00020000" android:required="true" />
```

```java
class MyGLSurfaceView extends GLSurfaceView {
  public MyGLSurfaceView(Context context){
    super(context);
    setRenderer(new MyRenderer());
    // Called when using OpenGL ES 2.0
    setEGLContextClientVersion(2);
  }
}
```

OpenGL Introduction

GLSurfaceView.Renderer

- Includes three methods to be implemented to draw graphics.

onSurfaceCreated() Called once when creating the GLSurfaceView.

Should include all actions to do only once.

onDrawFrame() Called on each redraw of GLSurfaceView.

Do all drawing and redrawing of graphic objects here.

onSurfaceChanged() Called when the geometry of GLSurfaceView changes, for example size screen or orientation.

Add code to respond to those changes.

- Two different OpenGL ES API versions available: 1.0 (together with version 1.1 extensions) and 2.0.
- Both usable to create high performance graphics for 3D games and visualizations.
- Grapic programming for one of the versions differs significantly to programming for the other version.
- Version 1.0/1.1 is easier to use as there are more convenience methods available.
- Version 2.0 provides higher degree of control, enabling creating of effects that are hard to realize in version 1.0/1.1.

- Shapes are graphic objects to be drawn in OpenGL.
- Shapes are defined using three-dimensional coordinates.
- Coordinates get written into *ByteBuffer* that is passed into the graphics pipeline for processing.
- Coordinate format: [X, Y, Z]
- Examples: Center of view: [0,0,0], top right corner: [1,1,0], bottom left corner: [-1,-1,0].

Displaying Graphics

Example: Defining Triangle

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```java
class Triangle {
  private FloatBuffer vertexBuffer; ...
  public Triangle() {
    // initialize vertex byte buffer for shape coordinates (4 bytes per coordinate)
    ByteBuffer bb = ByteBuffer.allocateDirect(triangleCoords.length * 4);
    // use the device hardware's native byte order
    bb.order(ByteOrder.nativeOrder());
    // create a floating point buffer
    vertexBuffer = bb.asFloatBuffer();
    // add the coordinates to the FloatBuffer
    vertexBuffer.put(triangleCoords);
    // set the buffer to read the first coordinate
    vertexBuffer.position(0);
}}
```

Vertex Shader Contains code for rendering the vertices of a shape.

Fragment Shader Contains code for rendering the face (visible front) of shape with colors or textures.

Program OpenGL ES object containing shaders used.

- At least one vertex shader and one fragment shader needed to draw a shape.
- Both shaders must be compiled and then added to the program.

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Mapping Coordinates for Drawn Objects

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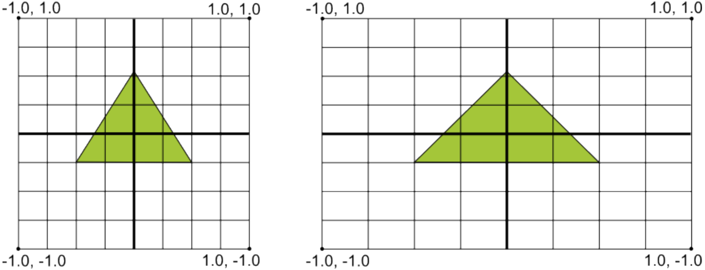
- Problem: Device screen is no square, but OpenGL assumes that[1].
- The picture shows what happens. Left: How it should look. Right: How it looks in horizontal orientation.
- Solution: Use *projection modes* and *camera views* to transform coordinates.



- Create *projection matrix* and *camera view matrix*.
- Apply both to the OpenGL rendering pipeline.
- Projection matrix recalculates coordinates of the graphic objects to adjust the screen size.
- Camera view matrix creates transformation that shows object from specific eye position.

Displaying Graphics

Example in OpenGL ES 1.0: Projection Matrix

- Create and use projection matrix in onSurfaceChanged() of the GLSurfaceView.Renderer implementation.
- Use geometry of device seen to recalculate coordinates.

```java
public void onSurfaceChanged(GL10 gl, int width, int height) {
  gl.glViewport(0, 0, width, height);
  float ratio = (float) width / height;
  // set matrix to projection mode
  gl.glMatrixMode(GL10.GL_PROJECTION);
  // reset the matrix to its default state
  gl.glLoadIdentity();
  // Define and apply the projection matrix
  gl.glFrustumf(-ratio, ratio, -1, 1, 3, 7);
}
```

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Example in OpenGL ES 1.0: Methods

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- Define a projection matrix in terms of six planes.

```
public static void frustumM (float[] m, int
    offset, float left, float right, float
    bottom, float top, float near, float far)
```

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Example in OpenGL ES 1.0: Camera Transformation Matrix

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- Apply camera view in onDrawFrame() of the GLSurfaceView.Renderer implementation.
- Use GLU.gluLookAt() to create a transformation simulating the camera position.

```
public void onDrawFrame(GL10 gl) {
  ...
  // Set GL_MODELVIEW transformation mode
  gl.glMatrixMode(GL10.GL_MODELVIEW);
  // reset the matrix to its default state
  gl.glLoadIdentity();
  // When using GL_MODELVIEW, you must set the camera view
  GLU.gluLookAt(gl, 0, 0, -5, 0f, 0f, 0f, 0f, 1.0f, 0.0f);
  ...
}
```

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Example in OpenGL ES 1.0: Methods

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- Define a transformation in terms of an eye point, a center of view, and an up vector.

```
gluLookAt(GL10 gl, float eyeX, float eyeY,
    float eyeZ, float centerX, float centerY,
    float centerZ, float upX, float upY, float
    upZ)
```

1. Define a Projection[5].
2. Define a Camera View.
3. Apply Projection and Camera Transformations on all objects to draw.

- Step 1 and 2 very similar to OpenGL ES 1.0.

Displaying Graphics

Example in OpenGL ES 2.0: Step 3

- Apply Projection and Camera Transformations on all objects to draw.
- Edit *draw* method of a shape:

```java
public void draw(float[] mvpMatrix) {...
  // get shape’s transformation matrix
  matrix = GLES20.glGetUniformLocation(mProgram, "uMVPMatrix");
  // Apply projection and view transformation
  GLES20.glUniformMatrix4fv(matrix, 1, false, mvpMatrix, 0);
  // Draw the shape
  GLES20.glDrawArrays(GLES20.GL_TRIANGLES, 0, vertexCount);
  ...
}
```

- Rotation can be simply added using OpenGL ES 2.0
- Create rotation matrix and combine it with projection and camera view transformation matrices.
- Extend *onDrawFrame* method.

Displaying Graphics

Adding Motion Example

```java
float[] mRotationMatrix = new float[16];
// Create a rotation transformation for the triangle
long time = SystemClock.uptimeMillis() % 4000L;
float angle = 0.090f * ((int) time);
Matrix.setRotateM(mRotationMatrix, 0, mAngle, 0, 0, -1.0f);
// Combine the rotation matrix with the projection and camera view
Matrix.multiplyMM(mMVPMatrix, 0, mRotationMatrix, 0, mMVPMatrix, 0);
// Draw shape
mTriangle.draw(mMVPMatrix);
```

Touch Screen Interaction

- Can be implemented by overriding the method *onTouchEvent(MotionEvent)* of the class *View*.
- *MotionEvent* gives you various information about where the event happened and how.
- Example: *long MotionEvent.getDownTime()* returns the time in ms when user started to press down.
- Also possible to recover *historical*/old coordinates of the event[3].
- Easy simulation in the emulator possible: Click, hold and move the mouse.

Notes

- Class *Random* can produce a random number[6].
- Class *Sensor* is used to access sensors of the cellphone, e.g. the gyroscope[8].
- Class *MediaPlayer* enables playing of sounds[2].
- Usage: Put a sound file into folder *res*/*raw*/.
- Supported file formats include ogg vorbis, wav, mp3 and more.

```
MediaPlayer mediaPlayer = MediaPlayer.create(
    context, R.raw.soundfile);
mediaPlayer.start();
```

Summary

- Drawing with OpenGL takes place on *GLSurfaceView*.
- *GLSurfaceView.Renderer* is responsile to draw the shapes.
- Important to decide which OpenGL ES version to take.
- Shapes are defined using three-dimensional coordinates.
- Different shaders needed to draw a shape.
- *Projection matrix* is used to adjust graphics to the device screen.
- *Camera transformation matrix* is used to simulate a camera position.
- Rotation motion can be added using an additional matrix.
- Touch screen interaction can be implemented overriding method *onTouchEvent*.

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