Android and OpenGL
Android Smartphone Programming

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Short for: Open Graphics Library\textsuperscript{[4]}.

Enables creation of 2D and 3D graphics.

Special API for embedded systems available on Android: \textit{OpenGL ES API}.

Two important classes: \textit{GLSurfaceView} and \textit{GLSurfaceView.Renderer}.
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:

```xml
<uses-feature android:glEsVersion="0x00020000" android:required="true" />
```
class MyGLSurfaceView extends GLSurfaceView {
  public MyGLSurfaceView(Context context) {
    super(context);
    setRenderer(new MyRenderer());
    // Called when using OpenGL ES 2.0
    setEGLContextClientVersion(2);
  }
}

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.

Graphic 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]`. 
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.
Problem: Device screen is no square, but OpenGL assumes that\textsuperscript{[1]}.

The picture shows what happens. Left: How it should look. Right: How it looks in horizontal orientation.

Solution: Use \textit{projection modes} and \textit{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.
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);
}
```
Define a projection matrix in terms of six planes.

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

```java
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);
    ... 
}
```
Define a transformation in terms of an eye point, a center of view, and an up vector.

```c
1 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\textsuperscript{[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.
Apply Projection and Camera Transformations on all objects to draw.

Edit \textit{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.
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);
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.
- 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.

```
1 MediaPlayer mediaPlayer = MediaPlayer.create(
        context, R.raw.soundfile);
2 mediaPlayer.start();
```
Drawing with OpenGL takes place on `GLSurfaceView`.

`GLSurfaceView.Renderer` is responsible 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`. 
**Android Developers.**
Mapping Coordinates for Drawn Objects.

**Android Developers.**
Media Playback.

**Android Developers.**
MotionEvent.

**Android Developers.**
OpenGL.

**Android Developers.**
OpenGL ES 2.0: Applying Projection and Camera Views.

**Android Developers.**
Random.

**Android Developers.**
Tutorial: Displaying Graphics with OpenGL ES.

**Android Developers.**
Using the Gyroscope.