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Android Programming

Custom 2D Graphics and Games

1. Custom 2D Graphics

Android support 2D graphics via its own library in packages `android.graphics.drawable` and `android.view.animation`. (Android does not support AWT/Swing.)

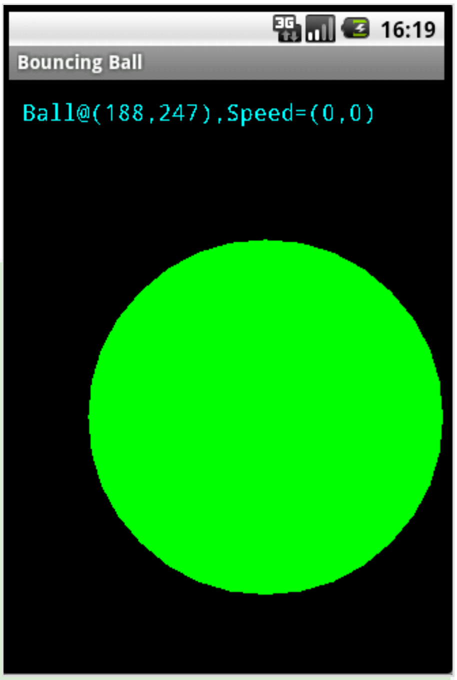
[TODO] more

2. Example 1: Bouncing Ball

Let us illustrate custom 2D graphics with the classical bouncing ball.

2.1 Example 1a: Simple Bouncing Ball

Create a project called "`BouncingBall`", with application name of "`Bouncing Ball`" and package "`com.mytest`". Create a main activity called "`BouncingBallActivity`", with layout name "`activity_bouncing_ball`" and title "`Bouncing Ball`".



```
Ball@(188,247),Speed=(0,0)
```

`BouncingBallActivity.java`

```
package com.mytest;

import android.app.Activity;
import android.os.Bundle;
import android.view.View;

public class BouncingBallActivity extends Activity {
   /** Called when the activity is first created. */
   @Override
   public void onCreate(Bundle savedInstanceState) {
      super.onCreate(savedInstanceState);
      View bouncingBallView = new BouncingBallView(this);
      setContentView(bouncingBallView);
   }
}
```

Dissecting `BouncingBallActivity.java`

In method `onCreate()`, we construct an instance of our own custom `View` (called `BouncingBallView` to be written next), and set it as the content view of the main activity.

BouncingBallView.java

```
package com.mytest;

import android.content.Context;
import android.graphics.Canvas;
import android.graphics.Color;
import android.graphics.Paint;
import android.graphics.RectF;
import android.graphics.Typeface;
import android.view.View;

public class BouncingBallView extends View {
   private int xMin = 0;          // This view's bounds
   private int xMax;
   private int yMin = 0;
   private int yMax;
   private float ballRadius = 80; // Ball's radius
   private float ballX = ballRadius + 20;  // Ball's center (x,y)
   private float ballY = ballRadius + 40;
   private float ballSpeedX = 5;  // Ball's speed (x,y)
   private float ballSpeedY = 3;
   private RectF ballBounds;      // Needed for Canvas.drawOval
   private Paint paint;           // The paint (e.g. style, color) used for drawing

   // Constructor
   public BouncingBallView(Context context) {
      super(context);
      ballBounds = new RectF();
      paint = new Paint();
   }

   // Called back to draw the view. Also called by invalidate().
   @Override
   protected void onDraw(Canvas canvas) {
      // Draw the ball
      ballBounds.set(ballX-ballRadius, ballY-ballRadius, ballX+ballRadius, ballY+ballRadius);
      paint.setColor(Color.GREEN);
      canvas.drawOval(ballBounds, paint);

      // Update the position of the ball, including collision detection and reaction.
      update();

      // Delay
      try {
         Thread.sleep(30);
      } catch (InterruptedException e) { }

      invalidate();  // Force a re-draw
   }

   // Detect collision and update the position of the ball.
   private void update() {
      // Get new (x,y) position
      ballX += ballSpeedX;
      ballY += ballSpeedY;
      // Detect collision and react
      if (ballX + ballRadius > xMax) {
         ballSpeedX = -ballSpeedX;
         ballX = xMax-ballRadius;
      } else if (ballX - ballRadius < xMin) {
         ballSpeedX = -ballSpeedX;
         ballX = xMin+ballRadius;
      }
      if (ballY + ballRadius > yMax) {
         ballSpeedY = -ballSpeedY;
         ballY = yMax - ballRadius;
      } else if (ballY - ballRadius < yMin) {
         ballSpeedY = -ballSpeedY;
         ballY = yMin + ballRadius;
      }
   }

   // Called back when the view is first created or its size changes.
   @Override
   public void onSizeChanged(int w, int h, int oldW, int oldH) {
      // Set the movement bounds for the ball
      xMax = w-1;
      yMax = h-1;
   }
}
```

Dissecting `BouncingBallView.java`

To perform custom drawing, we create our own custom `View` class (called `BouncingBallView`) by extending the `android.view.View` base class, and override the `onDraw()` method to program custom rendering.

We first declare variables to keep track of the bounding box (`xMin`, `xMax`, `yMin`, `yMax`) and the ball (x and y position and speed, radius).

In the overridden `onDraw()`, we use `Canvas.drawOval(RectF bounds, Paint paint)` to draw a circle. The `drawOval()` method takes two arguments: a `RectF` (rectangle in float) which specifies the bounds of the circle, and a `Paint` object carrying the paint properties such as the color and the style. For the `RectF` object, we use `RectF.set(float left, float top, float right, float bottom)` to specify its bounds with the current ball's position. For the `Paint` object, we construct an instance with default settings, and change the drawing color via `Paint.setColor()`. We then call the `update()` helper method to update the position of the ball, considering possible collision with the bounding box. After a small delay (via `Thread.sleep()` to suspend the current thread), we invoke `View.invalidate()` to inform the Android graphics sub-system to re-draw the view.

In the `update()` helper method, we move the ball in the x and y directions according to its speeds. We then check for possible collision with the bounding box. If collision occurs, we adjust the position and speed of the ball accordingly.

We also override the `onSizeChanged(int w, int h, int oldW, int oldH)` method, which is called back when the `View` is first displayed and whenever the `View`'s size changes. We set the bounding box width and height according to the `View`'s weight and height.

2.2 Example 1b: Bouncing Ball with a Status Message

Let's us include a status message to display the ball's center (x,y) and speed in the form of "`Ball@(x,y),Speed=(x,y)`".

`BouncingBallView.java`

Modify the `BouncingBallView.java` to include these codes:

```
import java.util.Formatter;
......
public class BouncingBallView extends View {
   ......

   // Status message to show Ball's (x,y) position and speed.
   private StringBuilder statusMsg = new StringBuilder();
   private Formatter formatter = new Formatter(statusMsg);

   // Constructor
   public BouncingBallView(Context context) {
      super(context);
      ballBounds = new RectF();
      paint = new Paint();
      // Set the font face and size of drawing text
      paint.setTypeface(Typeface.MONOSPACE);
      paint.setTextSize(16);
   }

   // Called back to draw the view. Also called after invalidate().
   @Override
   protected void onDraw(Canvas canvas) {
      // Draw the ball
      ballBounds.set(ballX-ballRadius, ballY-ballRadius, ballX+ballRadius, ballY+ballRadius);
      paint.setColor(Color.GREEN);
      canvas.drawOval(ballBounds, paint);

      // Draw the status message
      paint.setColor(Color.CYAN);
      canvas.drawText(statusMsg.toString(), 10, 30, paint);

      // Update the position of the ball, including collision detection and reaction.
      ......
   }

   // Detect collision and update the position of the ball.
   private void update() {
      ......

      // Build status message
      statusMsg.delete(0, statusMsg.length());   // Empty buffer
      formatter.format("Ball@(%3.0f,%3.0f),Speed=(%2.0f,%2.0f)", ballX, ballY,
            ballSpeedX, ballSpeedY);
   }

   // Called back when the view is first created or its size changes.
   @Override
   public void onSizeChanged(int w, int h, int oldW, int oldH) { ...... }
}
```

Dissecting `BouncingBallView.java`

We allocate a `StringBuilder` as the buffer for our status message. In the `onDraw()`, we use `Canvas.drawText()` to draw the status message. We use `Paint.setTypeFace()`, `Paint.setTextSize()`, `Paint.setColor()` to set the font face, size and color for the text.

In `update()`, we write the ball's current position and speed in the buffer.

2.3 Example 1c: Bouncing Ball - Handling Key Inputs

Let's modify our program to enable key-control. The keyboard can generate two main events:

1. Key down: when a key is pressed down.
2. Key up: when a key is lifted, always preceded by a key-down event.

The `View` processes these events via the `onKeyUp()` an `onKeyDown()` event handlers:

```
// In android.view.View
// Call back when a key is pressed down/up
public boolean onKeyDown (int keyCode, KeyEvent event)
public boolean onKeyUp (int keyCode, KeyEvent event)
```

We shall use the DPAD's left, right, up, down key to increase the speed in the respective direction; center key to halt the ball; keys `'A'` and `'Z'` to increase or decrease the radius of the ball.

`BouncingBallView.java`

Modified as follows:

```
.......
import android.view.KeyEvent;

public class BouncingBallView extends View {
   ......
   // Constructor
   public BouncingBallView(Context context) {
      ......
      ......
      // To enable keypad
      this.setFocusable(true);
      this.requestFocus();
   }
   ......
   ......

   // Key-up event handler
   @Override
   public boolean onKeyUp(int keyCode, KeyEvent event) {
      switch (keyCode) {
         case KeyEvent.KEYCODE_DPAD_RIGHT: // Increase rightward speed
            ballSpeedX++;
            break;
         case KeyEvent.KEYCODE_DPAD_LEFT:  // Increase leftward speed
            ballSpeedX--;
            break;
         case KeyEvent.KEYCODE_DPAD_UP:    // Increase upward speed
            ballSpeedY--;
            break;
         case KeyEvent.KEYCODE_DPAD_DOWN:  // Increase downward speed
            ballSpeedY++;
            break;
         case KeyEvent.KEYCODE_DPAD_CENTER: // Stop
            ballSpeedX = 0;
            ballSpeedY = 0;
            break;
         case KeyEvent.KEYCODE_A:    // Zoom in
            // Max radius is about 90% of half of the smaller dimension
            float maxRadius = (xMax > yMax) ? yMax / 2 * 0.9f  : xMax / 2 * 0.9f;
            if (ballRadius < maxRadius) {
               ballRadius *= 1.05;   // Increase radius by 5%
            }
            break;
         case KeyEvent.KEYCODE_Z:    // Zoom out
            if (ballRadius > 20) {   // Minimum radius
               ballRadius *= 0.95;   // Decrease radius by 5%
            }
            break;
      }
      return true;  // Event handled
   }
}
```

Dissecting `BouncingBallView.java`

To process the key event, we override the `onKeyUp()` or `onKeyDown()` methods of the `View` class. We adjust the ball's parameters based on the key inputs. Take note that to enable key inputs, we need to set the `View` to be focusable, and request for the focus.

2.4 Example 1d: Bouncing Ball - Handling Touch Inputs

Let's modify our program to enable touch-control. The touch screen can generate events such as "touch-down", "touch-up" and "touch-drag".

The `android.view.View` class processes these events via the `onTouchEvent()` event handlers:

```
// In android.view.View
// Call back when screen is touched
public boolean onTouchEvent (MotionEvent event)
```

The `MotionEvent` contains these methods:

- `getX()` and `getY()`, which return the x and y co-ordinates respectively.
- `getAction()`, which returns the type of action in constant such as `ACTION_DOWN` (finger touches screen), `ACTION_MOVE` (fired continuously whenever the touched finger moves to a new co-codinates), and `ACTION_UP` (touched finger lifts up).

Alternatively, you can use `setOnTouchListener()` to register a listener object that implements the `OnTouchListener` interface and override the `onTouch()` method.

We shall increase/decrease the speed according to the touch gradient.

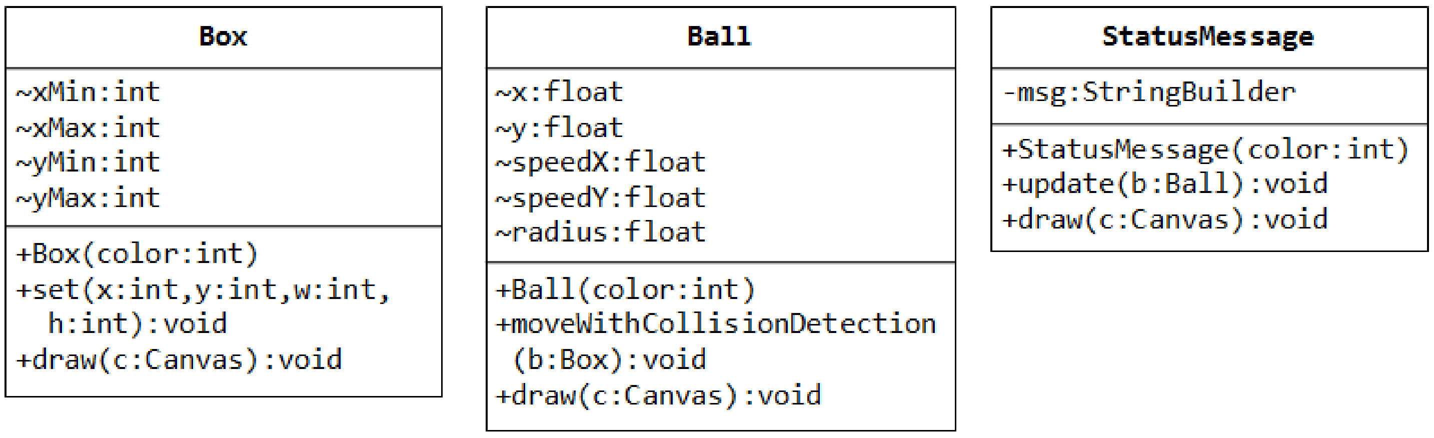
`BouncingBallView.java`

```
......
import android.view.MotionEvent;

public class BouncingBallView extends View {
   ......

   // For touch inputs - previous touch (x, y)
   private float previousX;
   private float previousY;
   ......

   // Constructor
   public BouncingBallView(Context context) {
      .......
      // To enable touch mode
      this.setFocusableInTouchMode(true);
   }

   // Touch-input handler
   @Override
   public boolean onTouchEvent(MotionEvent event) {
      float currentX = event.getX();
      float currentY = event.getY();
      float deltaX, deltaY;
      float scalingFactor = 5.0f / ((xMax > yMax) ? yMax : xMax);
      switch (event.getAction()) {
         case MotionEvent.ACTION_MOVE:
            // Modify rotational angles according to movement
            deltaX = currentX - previousX;
            deltaY = currentY - previousY;
            ballSpeedX += deltaX * scalingFactor;
            ballSpeedY += deltaY * scalingFactor;
      }
      // Save current x, y
      previousX = currentX;
      previousY = currentY;
      return true;  // Event handled
   }
}
```

To enable and handle touch input, we override the `View.onTouchEvent()` to provide the touch-event handling codes. We need to invoke `View.setFocusableInTouchMode(true)` to enable touch inputs.

2.5 Example 1e: Bouncing Ball - Object-Oriented Design

Let's separate the ball, box and status message from the `View` to their own classes, as illustrated in the following class diagram:



```
Box
~xMin:int
~xMax:int
~yMin:int
~yMax:int
+Box(color:int)
+set(x:int,y:int,w:int,
  h:int):void
+draw(c:Canvas):void
```

```
Ball
~x:float
~y:float
~speedX:float
~speedY:float
~radius:float
+Ball(color:int)
+moveWithCollisionDetection
 (b:Box):void
+draw(c:Canvas):void
```

```
StatusMessage
-msg:StringBuilder
+StatusMessage(color:int)
+update(b:Ball):void
+draw(c:Canvas):void
```

Box.java

The `Box` class represents the rectangular bounding box. We maintain the bounds (`xMin`, `xMax`, `yMin`, and `yMax`) as `int` instance variables with package access. The `set()` method is to be used to set its bounds. `set()` takes four arguments: top-left x and y, width and height for safer operation. The `draw()` method render this shape via `Canvas.drawRect()`.

```
package com.mytest;

import android.graphics.Canvas;
import android.graphics.Paint;
import android.graphics.Rect;

public class Box {
   int xMin, xMax, yMin, yMax;
   private Paint paint;  // paint style and color
   private Rect bounds;

   public Box(int color) {
      paint = new Paint();
      paint.setColor(color);
      bounds = new Rect();
   }

   public void set(int x, int y, int width, int height) {
      xMin = x;
      xMax = x + width - 1;
      yMin = y;
      yMax = y + height - 1;
      // The box's bounds do not change unless the view's size changes
      bounds.set(xMin, yMin, xMax, yMax);
   }

   public void draw(Canvas canvas) {
      canvas.drawRect(bounds, paint);
   }
}
```

Ball.java

We keep the ball's center (x, y), speed and radius as instance variables with package access. We choose float for these variables as it may involve in mathematically operations. The method `moveWithCollisionDetection()` moves the ball (according to its speed), and adjusts the position and speed of the ball if collision occurs. The method `draw()` renders this shape via `Canvas.drawOval()` method.

```
package com.mytest;

import android.graphics.Canvas;
import android.graphics.Paint;
import android.graphics.RectF;

public class Ball {
   float radius = 80;      // Ball's radius
   float x = radius + 20;  // Ball's center (x,y)
   float y = radius + 40;
   float speedX = 5;       // Ball's speed (x,y)
   float speedY = 3;
   private RectF bounds;   // Needed for Canvas.drawOval
   private Paint paint;    // The paint style, color used for drawing

   // Constructor
   public Ball(int color) {
      bounds = new RectF();
      paint = new Paint();
      paint.setColor(color);
   }

   public void moveWithCollisionDetection(Box box) {
      // Get new (x,y) position
      x += speedX;
      y += speedY;
      // Detect collision and react
      if (x + radius > box.xMax) {
         speedX = -speedX;
         x = box.xMax-radius;
      } else if (x - radius < box.xMin) {
         speedX = -speedX;
         x = box.xMin+radius;
      }
      if (y + radius > box.yMax) {
         speedY = -speedY;
         y = box.yMax - radius;
      } else if (y - radius < box.yMin) {
         speedY = -speedY;
         y = box.yMin + radius;
      }
   }

   public void draw(Canvas canvas) {
      bounds.set(x-radius, y-radius, x+radius, y+radius);
      canvas.drawOval(bounds, paint);
   }
}
```

StatusMessage.java

The `StatusMessage` class maintains the message in a `StringBuilder` (for efficiency). It has a `update()` method, which takes the ball as argument, and update the ball's position and speed in the buffer. The `draw()` method renders the message via `Canvas.drawText()`.

```
package com.mytest;

import java.util.Formatter;
import android.graphics.Canvas;
import android.graphics.Paint;
import android.graphics.Typeface;

public class StatusMessage {
   // Status message to show Ball's (x,y) position and speed.
   private StringBuilder statusMsg = new StringBuilder();
   private Formatter formatter = new Formatter(statusMsg);
   private Paint paint;

   // Constructor
   public StatusMessage(int color) {
      paint = new Paint();
      // Set the font face and size of drawing text
      paint.setTypeface(Typeface.MONOSPACE);
      paint.setTextSize(16);
      paint.setColor(color);
   }
   public void update(Ball ball) {
      // Build status message
      statusMsg.delete(0, statusMsg.length());   // Empty buffer
      formatter.format("Ball@(%3.0f,%3.0f),Speed=(%2.0f,%2.0f)", ball.x, ball.y,
            ball.speedX, ball.speedY);
   }

   public void draw(Canvas canvas) {
      canvas.drawText(statusMsg.toString(), 10, 30, paint);
   }
}
```

`BouncingBallView.java`

The `View` class is greatly simplified after removing the ball, box and status message. It contains only the overridden methods. It constructs a `Box`, a `Ball`, a `StatusMessage` in its constructor. In the `onDraw()`, it draws the ball, box, status message, perform the updates, and `invalidate()` the view to force a re-draw. The `onSizeChange()` sets up the `Box`'s bounds. The `onKeyUp()` process the key inputs and changes the `Ball`'s parameters such as speed and radius.

```
package com.mytest;

import android.content.Context;
import android.graphics.Canvas;
import android.graphics.Color;
import android.view.KeyEvent;
import android.view.View;

public class BouncingBallView extends View {
   private Ball ball;
   private Box box;
   private StatusMessage statusMsg;

   // For touch inputs - previous touch (x, y)
   private float previousX;
   private float previousY;

   // Constructor
   public BouncingBallView(Context context) {
      super(context);

      box = new Box(0xff00003f);  // ARGB
      ball = new Ball(Color.GREEN);
      statusMsg = new StatusMessage(Color.CYAN);

      // To enable keypad
      this.setFocusable(true);
      this.requestFocus();
      // To enable touch mode
      this.setFocusableInTouchMode(true);
   }

   // Called back to draw the view. Also called after invalidate().
   @Override
   protected void onDraw(Canvas canvas) {
      // Draw the components
      box.draw(canvas);
      ball.draw(canvas);
      statusMsg.draw(canvas);

      // Update the position of the ball, including collision detection and reaction.
      ball.moveWithCollisionDetection(box);
      statusMsg.update(ball);

      // Delay
      try {
         Thread.sleep(30);
      } catch (InterruptedException e) { }
```

```java
      invalidate();  // Force a re-draw
   }

   // Called back when the view is first created or its size changes.
   @Override
   public void onSizeChanged(int w, int h, int oldW, int oldH) {
      // Set the movement bounds for the ball
      box.set(0, 0, w, h);
   }

   // Key-up event handler
   @Override
   public boolean onKeyUp(int keyCode, KeyEvent event) {
      switch (keyCode) {
         case KeyEvent.KEYCODE_DPAD_RIGHT: // Increase rightward speed
            ball.speedX++;
            break;
         case KeyEvent.KEYCODE_DPAD_LEFT:  // Increase leftward speed
            ball.speedX--;
            break;
         case KeyEvent.KEYCODE_DPAD_UP:    // Increase upward speed
            ball.speedY--;
            break;
         case KeyEvent.KEYCODE_DPAD_DOWN:  // Increase downward speed
            ball.speedY++;
            break;
         case KeyEvent.KEYCODE_DPAD_CENTER: // Stop
            ball.speedX = 0;
            ball.speedY = 0;
            break;
         case KeyEvent.KEYCODE_A:    // Zoom in
            // Max radius is about 90% of half of the smaller dimension
            float maxRadius = (box.xMax > box.yMax) ? box.yMax / 2 * 0.9f  : box.xMax / 2 * 0.9f;
            if (ball.radius < maxRadius) {
               ball.radius *= 1.05;   // Increase radius by 5%
            }
            break;
         case KeyEvent.KEYCODE_Z:    // Zoom out
            if (ball.radius > 20) {  // Minimum radius
               ball.radius *= 0.95;  // Decrease radius by 5%
            }
            break;
      }
      return true;  // Event handled
   }

   // Touch-input handler
   @Override
   public boolean onTouchEvent(MotionEvent event) {
      float currentX = event.getX();
      float currentY = event.getY();
      float deltaX, deltaY;
      float scalingFactor = 5.0f / ((box.xMax > box.yMax) ? box.yMax : box.xMax);
      switch (event.getAction()) {
         case MotionEvent.ACTION_MOVE:
            // Modify rotational angles according to movement
            deltaX = currentX - previousX;
            deltaY = currentY - previousY;
            ball.speedX += deltaX * scalingFactor;
            ball.speedY += deltaY * scalingFactor;
      }
      // Save current x, y
      previousX = currentX;
      previousY = currentY;
      return true;  // Event handled
   }
}
```

BouncingBallActivity.java

No change.

2.6 Example 1f: A Refreshing Thread

[TODO]

REFERENCES & RESOURCES

Latest version tested: Android SDK r15, Android 2.3, 3.2, 4.0, Eclipse 3.7.1
Last modified: November, 2011