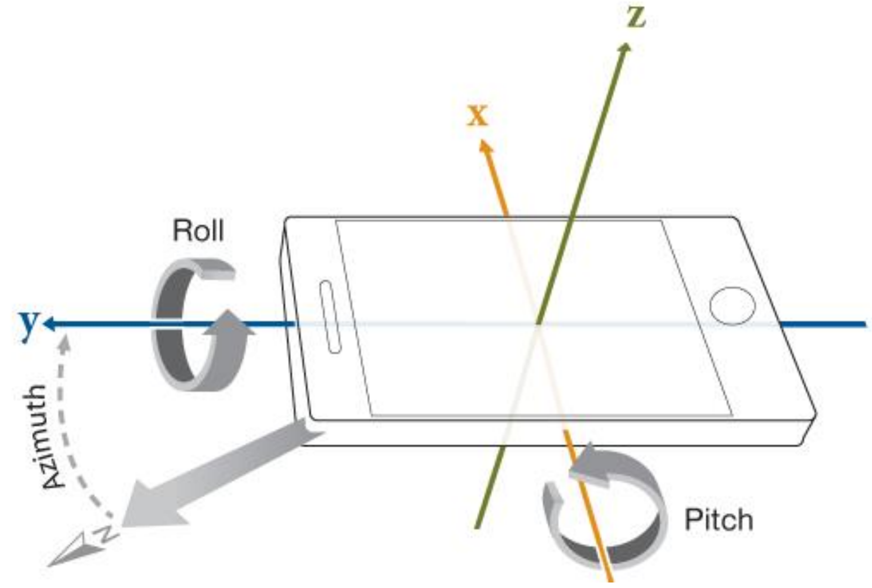
CS371m - Mobile Computing

Sensing and Sensors



Sensors

- "I should have paid more attention in Physics 41"
- Most devices have built in sensors to measure and monitor
  - motion
  - orientation (aka position of device)
  - environmental conditions
- sensors deliver raw data to applications

Sensor Framework

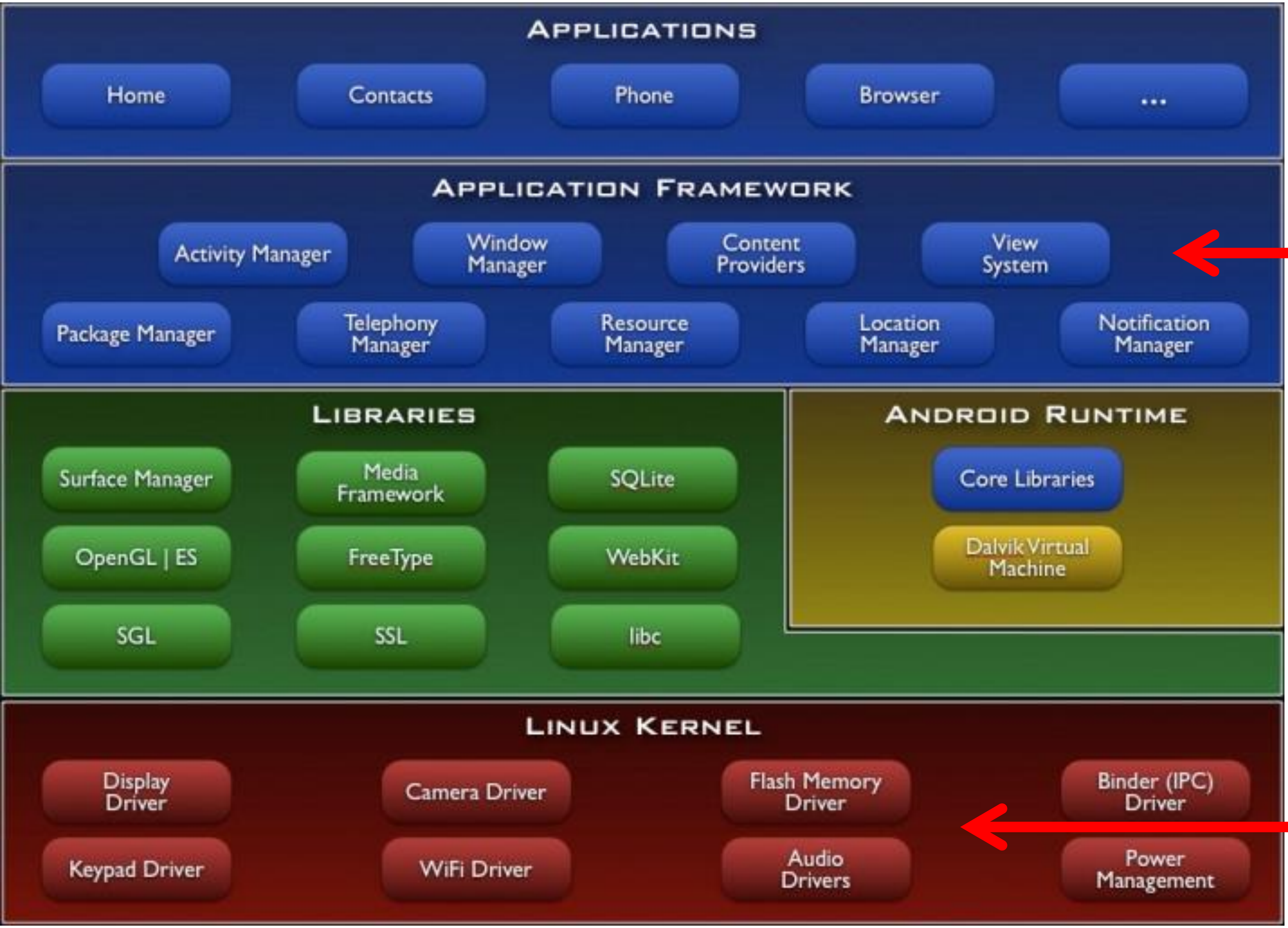
- Determine which sensors are available on a device.
- Determine an individual sensor's capabilities, such as its range, manufacturer, power requirements, and resolution.
- Acquire raw sensor data and define the minimum rate at which you acquire sensor data.
- Register and unregister sensor event listeners that monitor sensor changes.

http://developer.android.com/guide/topics/sensors/sensors_overview.html

Sensor Framework Classes

- SensorManager
  – conduit between your classes and Sensors
- Sensors
  – abstract representations of Sensors on device
- SensorEventListener
  – register with SensorManager to listen for events from a Sensor
- SensorEvent
  – data sent to listener

Recall: Android Software Stack



AND SENSOR MANAGER

AND SENSOR DRIVERS

TYPES OF SENSORS

Types of Sensors

- Three main classes of sensors:
- motion (acceleration and rotational forces)
  - accelerometers, gravity sensors, gyroscopes, rotational vector sensors, step detector
- environmental (ambient air temperature and pressure, illumination, and humidity)
  - barometers, photometers, and thermometers.
- position (physical position of a device)
  - orientation sensors and magnetometers

Types of Sensors

- Hardware sensors
  - built into the device
- Software sensors
  - takes data from hardware sensors and manipulates it
  - from our perspective acts like a hardware sensor
  - aka synthetic or virtual sensors

Types of Sensors - Dev Phone - Older

```
Sensor: KR3DM 3-axis Accelerometer, STMicroelectron
Sensor: AK8973 3-axis Magnetic field sensor, Asahi
Sensor: AK8973 Orientation sensor, Asahi Kasei Micr
Sensor: GP2A Light sensor, Sharp
Sensor: GP2A Proximity sensor, Sharp
Sensor: K3G Gyroscope sensor, STMicroelectronics
Sensor: Gravity Sensor, Google Inc.
Sensor: Linear Acceleration Sensor, Google Inc.
Sensor: Rotation Vector Sensor, Google Inc.
```

- accelerometer, linear acceleration, magnetic field, orientation, light, proximity, gyroscope, gravity

Sensor Types - (Sensor Class)

int	TYPE_ACCELEROMETER	A constant describing an accelerometer sensor type.
int	TYPE_ALL	A constant describing all sensor types.
int	TYPE_AMBIENT_TEMPERATURE	A constant describing an ambient temperature sensor type.
int	TYPE_GAME_ROTATION_VECTOR	A constant describing an uncalibrated rotation vector sensor type.
int	TYPE_GEOMAGNETIC_ROTATION_VECTOR	A constant describing the geo-magnetic rotation vector.
int	TYPE_GRAVITY	A constant describing a gravity sensor type.
int	TYPE_GYROSCOPE	A constant describing a gyroscope sensor type.
int	TYPE_GYROSCOPE_UNCALIBRATED	A constant describing an uncalibrated gyroscope sensor type.
int	TYPE_LIGHT	A constant describing a light sensor type.
int	TYPE_LINEAR_ACCELERATION	A constant describing a linear acceleration sensor type.
int	TYPE_MAGNETIC_FIELD	A constant describing a magnetic field sensor type.
int	TYPE_MAGNETIC_FIELD_UNCALIBRATED	A constant describing an uncalibrated magnetic field sensor type.
int	TYPE_ORIENTATION	*This constant was deprecated in API level 8. use* `SensorManager.getOrientation()` *i*
int	TYPE_PRESSURE	A constant describing a pressure sensor type.
int	TYPE_PROXIMITY	A constant describing a proximity sensor type.
int	TYPE_RELATIVE_HUMIDITY	A constant describing a relative humidity sensor type.
int	TYPE_ROTATION_VECTOR	A constant describing a rotation vector sensor type.
int	TYPE_SIGNIFICANT_MOTION	A constant describing a significant motion trigger sensor.
int	TYPE_STEP_COUNTER	A constant describing a step counter sensor.
int	TYPE_STEP_DETECTOR	A constant describing a step detector sensor.
int	TYPE_TEMPERATURE	*This constant was deprecated in API level 14. use* `Sensor.TYPE_AMBIENT_TEMPERATUR`

Sensor Capabilities - Dev Phones - Older

```
KR3DM 3-axis Accelerometer - minDelay: 20000, power: 0.23
max range: 19.6133, resolution: 0.019153614
AK8973 3-axis Magnetic field sensor - minDelay: 16667, power: 6.8
max range: 2000.0, resolution: 0.0625
GP2A Light sensor - minDelay: 0, power: 0.75
max range: 3626657.8, resolution: 1.0
GP2A Proximity sensor - minDelay: 0, power: 0.75
max range: 5.0, resolution: 5.0
K3G Gyroscope sensor - minDelay: 1190, power: 6.1
max range: 34.906586, resolution: 0.0012217305
Rotation Vector Sensor - minDelay: 20000, power: 13.13
max range: 1.0, resolution: 5.9604645E-8
Gravity Sensor - minDelay: 20000, power: 13.13
max range: 19.6133, resolution: 0.019153614
Linear Acceleration Sensor - minDelay: 20000, power: 13.13
max range: 19.6133, resolution: 0.019153614
Orientation Sensor - minDelay: 20000, power: 13.13
max range: 360.0, resolution: 0.00390625
Corrected Gyroscope Sensor - minDelay: 1190, power: 13.13
max range: 34.906586, resolution: 0.0012217305
```

Types of Sensors - Dev Phone - Newer

```
SensorTest        GP2A Light sensor Sharp
SensorTest        GP2A Proximity sensor Sharp
SensorTest        BMP180 Pressure sensor Bosch
SensorTest        MPL Gyroscope Invensense
SensorTest        MPL Accelerometer Invensense
SensorTest        MPL Magnetic Field Invensense
SensorTest        MPL Orientation Invensense
SensorTest        MPL Rotation Vector Invensense
SensorTest        MPL Linear Acceleration Invensense
SensorTest        MPL Gravity Invensense
SensorTest        Rotation Vector Sensor Google Inc.
SensorTest        Gravity Sensor Google Inc.
SensorTest        Linear Acceleration Sensor Google Inc.
SensorTest        Orientation Sensor Google Inc.
SensorTest        Corrected Gyroscope Sensor Google Inc.
```

Sensor Capabilities - Dev Phone - Newer

```
GP2A Light sensor - minDelay: 0, power: 0.75
max range: 646239.5, resolution: 1.0
GP2A Proximity sensor - minDelay: 0, power: 0.75
max range: 5.0, resolution: 5.0
BMP180 Pressure sensor - minDelay: 20000, power: 0.67
max range: 1100.0, resolution: 0.01
MPL Gyroscope - minDelay: 10000, power: 6.1
max range: 34.90656, resolution: 0.57246757
MPL Accelerometer - minDelay: 10000, power: 0.139
max range: 19.6133, resolution: 0.038344003
MPL Magnetic Field - minDelay: 10000, power: 4.0
max range: 8001.0, resolution: 0.012
MPL Orientation - minDelay: 10000, power: 10.239
max range: 360.0, resolution: 1.0E-5
MPL Rotation Vector - minDelay: 10000, power: 10.239
max range: 1.0, resolution: 1.0E-5
MPL Linear Acceleration - minDelay: 10000, power: 0.5
max range: 10240.0, resolution: 1.0
MPL Gravity - minDelay: 10000, power: 10.239
max range: 19.6133, resolution: 0.038344003
Rotation Vector Sensor - minDelay: 10000, power: 10.239
max range: 1.0, resolution: 5.9604645E-8
Gravity Sensor - minDelay: 10000, power: 10.239
max range: 19.6133, resolution: 0.038344003
Linear Acceleration Sensor - minDelay: 10000, power: 10.239
max range: 19.6133, resolution: 0.038344003
Orientation Sensor - minDelay: 10000, power: 10.239
max range: 360.0, resolution: 0.00390625
Corrected Gyroscope Sensor - minDelay: 10000, power: 10.239
max range: 34.90656, resolution: 0.57246757
```

Types of Sensors

- TYPE_ACCELEROMETER
  - hardware
  - acceleration in m/s^2
  - x, y, z axis
  - includes gravity

Types of Sensors

- TYPE_AMBIENT_TEMPERATURE [deprecated)]
  - hardware
  - "room" temperature in degrees Celsius
  - no such sensor on dev phones
  TYPE_GRAVITY
  - software or hardware
  - just gravity
  - if phone at rest same as
  TYPE_ACCELEROMETER

Types of Sensors

- TYPE_GYROSCOPE
  - hardware
  - measure device's rate of rotation in radians / second around 3 axis
- TYPE_LIGHT
  - hardware
  - light level in lx,
  - lux is SI measure illuminance in luminous flux per unit area

Types of Sensors

- TYPE_LINEAR_ACCELERATION
  - software or hardware
  - measure acceleration force applied to device in three axes excluding the force of gravity
- TYPE_MAGNETC_FIELD
  - hardware
  - ambient geomagnetic field in all three axes
  - uT micro Teslas

Types of Sensors

- TYPE_ORIENTATION [deprecated]
  - software
  - measure of degrees of rotation a device makes around all three axes
- TYPE_PRESSURE
  - hardware
  - ambient air pressure in hPa or mbar
  - force per unit area
  - 1 Pascal = 1 Newton per square meter
  - hecto Pascals (100 Pascals)
  - milli bar -   1 mbar = 1hecto Pascal

Types of Sensors

- TYPE_PROXIMITY
  - hardware
  - proximity of an object in cm relative to the view screen of a device
  - usually binary (see range, resolution)
  - typically used to determine if handset is being held to person's ear during a call
- TYPE_RELATIVE_HUMIDITY
  - ambient humidity in percent (0 to 100)

Types of Sensors

- TYPE_ROTATION_VECTOR (ABSOLUTE)
  - hardware or software
  - orientation of device, three elements of the device's rotation vector
- TYPE_ROTATION_VECTOR
  - orientation sensor
  - replacement for TYPE_ORIENTATION
  - combination of angle of rotation and access
  - uses geomagnetic field in calculations
  - compare to TYPE_GAME_ROTATION_VECTOR

Availability of Sensors

Sensor	Android 4.0 (API Level 14)	Android 2.3 (API Level 9)	Android 2.2 (API Level 8)	Android 1.5 (API Level 3)
TYPE_ACCELEROMETER	Yes	Yes	Yes	Yes
TYPE_AMBIENT_TEMPERATURE	Yes	n/a	n/a	n/a
TYPE_GRAVITY	Yes	Yes	n/a	n/a
TYPE_GYROSCOPE	Yes	Yes	n/a[1]	n/a[1]
TYPE_LIGHT	Yes	Yes	Yes	Yes
TYPE_LINEAR_ACCELERATION	Yes	Yes	n/a	n/a
TYPE_MAGNETIC_FIELD	Yes	Yes	Yes	Yes
TYPE_ORIENTATION	Yes[2]	Yes[2]	Yes[2]	Yes
TYPE_PRESSURE	Yes	Yes	n/a[1]	n/a[1]
TYPE_PROXIMITY	Yes	Yes	Yes	Yes
TYPE_RELATIVE_HUMIDITY	Yes	n/a	n/a	n/a
TYPE_ROTATION_VECTOR	Yes	Yes	n/a	n/a
TYPE_TEMPERATURE	Yes[2]	Yes	Yes	Yes

Sensor Capabilities

- Various methods in Sensor class to get capabilities of Sensor
- minDelay (in microseconds)
- power consumption in mA (microAmps)
- maxRange
- resolution

Triggered Sensors

- Android 4.4, API level 19, Kit-Kat added *trigger* sensors
- TYPE_SIGNIFICANT_MOTION
- TYPE_STEP_COUNTER
- TYPE_STEP_DETECTOR

USING SENSORS EXAMPLE

Using Sensors - Basics

- Obtain the *SensorManager* object
- create a *SensorEventListener* for *SensorEvents*
  - logic that responds to sensor event
  - varying amounts of data from sensor depending on type of sensor
- Register the sensor listener with a *Sensor* via the SensorManager
- Unregister when done
  - a good thing to do in the onPause method

Using Sensors

```
private void createSensor() {
    sensorManager =
            (SensorManager) getSystemService(Context.SENSOR_SERVICE);

    showSensors();

    sensorManager.registerListener(sensorEventListener,
            sensorManager.getDefaultSensor(Sensor.TYPE_LINEAR_ACCELERATION),
            SensorManager.SENSOR_DELAY_UI);
```

- registerListener(SensorEventListener, Sensor, int rate)
- rate is just a *hint*
- SENSOR_DELAY_NORMAL, SENSOR_DELAY_UI, SENSOR_DELAY_GAME, or SENSOR_DELAY_FASTEST, or time in microseconds (millionths of a second)

SensorEventListener

- Interface with two methods:
  - void onAccuracyChanged (Sensor sensor, int accuracy)
  - void onSensorChanged (SensorEvent event)
    - Sensor values have changed
    - this is the key method to override
    - don't do significant computations in this method
  - don't hold onto the event
    - part of pool of objects and the values may be altered soon

Listing Sensors on a Device to Log

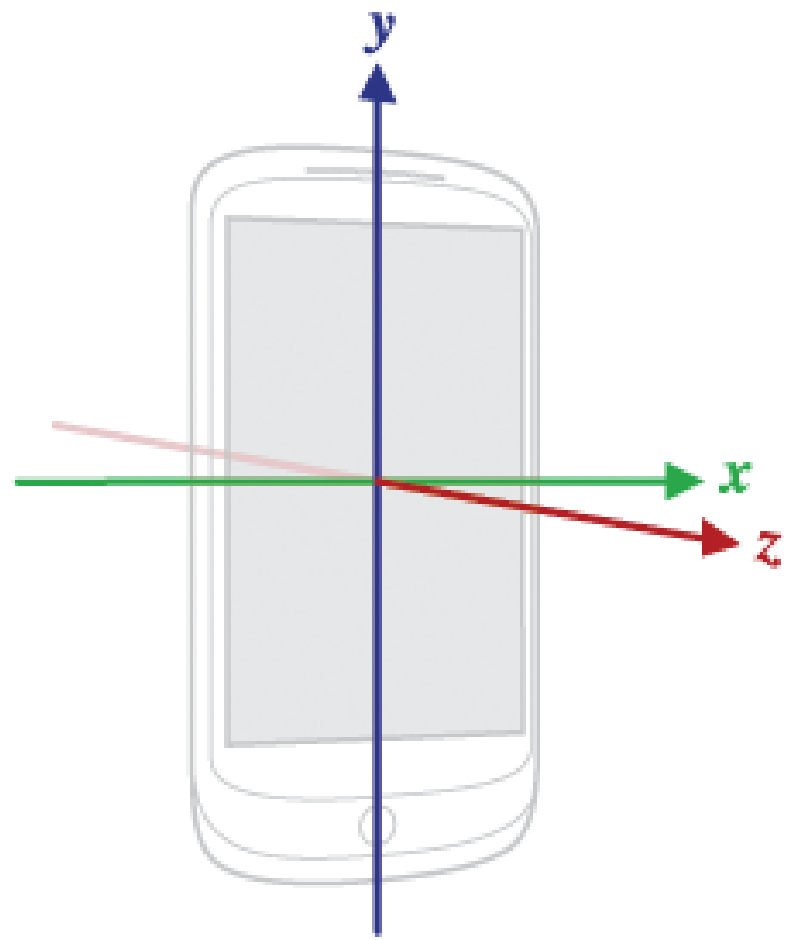
```java
private void showSensors() {

    List<Sensor> sensors
            = sensorManager.getSensorList(Sensor.TYPE_ALL);

    Log.d(TAG, sensors.toString());

    for(Sensor s : sensors) {
        Log.d(TAG, s.getName() + " - minDelay: "
             + s.getMinDelay() + ", power: " + s.getPower());
        Log.d(TAG, "max range: " + s.getMaximumRange()
                + ", resolution: " + s.getResolution());
    }
}
```

Simple Sensor Example

- App that shows acceleration
  - TYPE_ACCELEROMETER
- options to display current
- … or maximum, ignoring direction
- Linear Layout
- TextViews for x, y, and z
- Buttons to switch between max or current and to reset max

Sensor Coordinate System

- For most motion sensors:
- +x to the right
- +y up
- +z out of front face
- relative to device
- based on natural orientation of device
  - tablet -> landscape



Clicker

- With the device flat on a surface what, roughly, will be the magnitude of the largest acceleration?

A. 0 m/s^2

B. 1 m/s^2

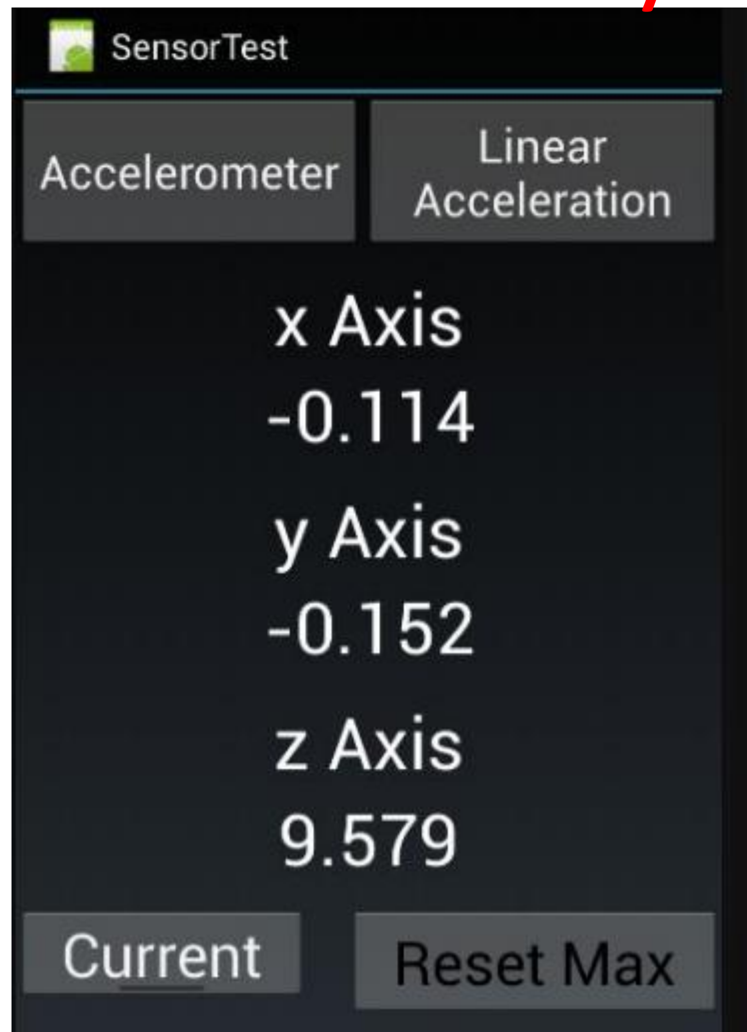
C. 5 m/s^2

D. 10 m/s^2

E. 32 m/s^2

Accelerometer - Includes Gravity

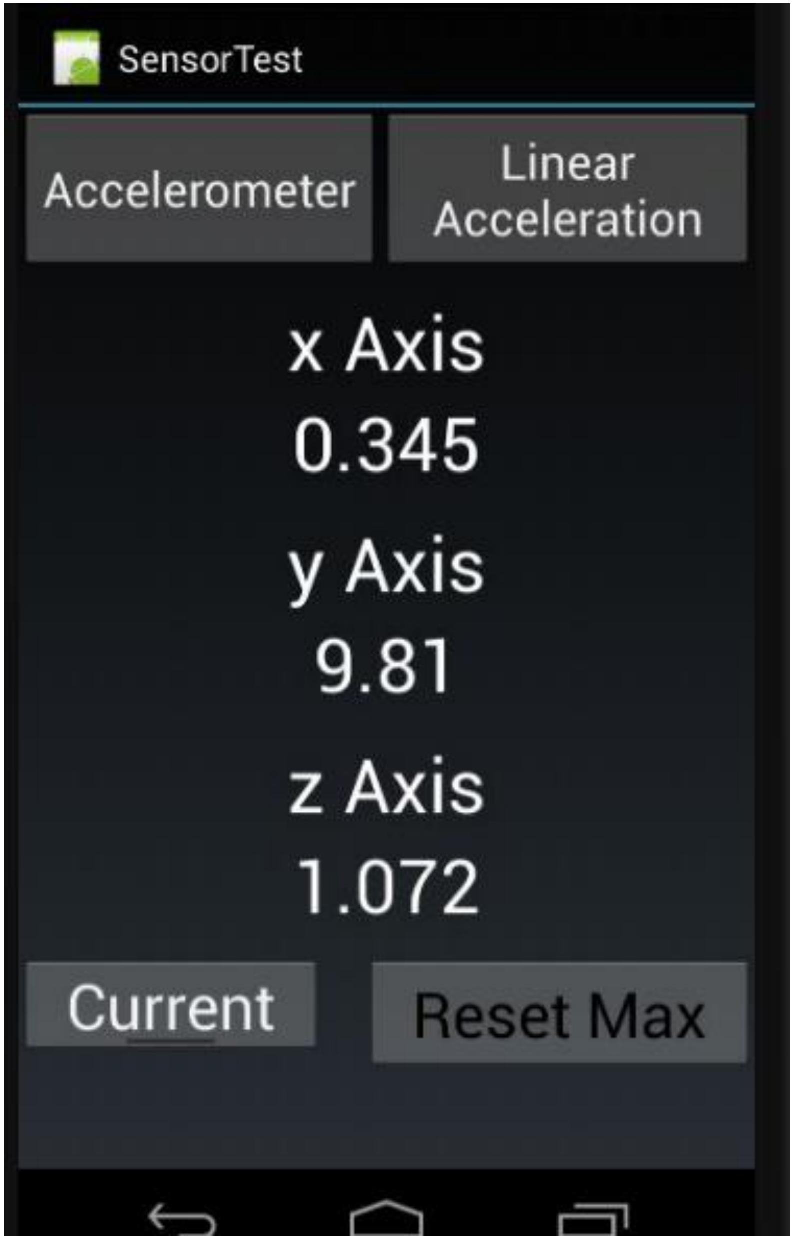
- Sensor. *TYPE_ACCELEROMETER*
- Device flat on table
- *g* ~= 9.81 m/s^2
- Clearly some error




```
SensorTest    i: 0, zerovalue: -0.19007805
SensorTest    i: 1, zerovalue: -0.42606363
SensorTest    i: 2, zerovalue: 9.776483
```

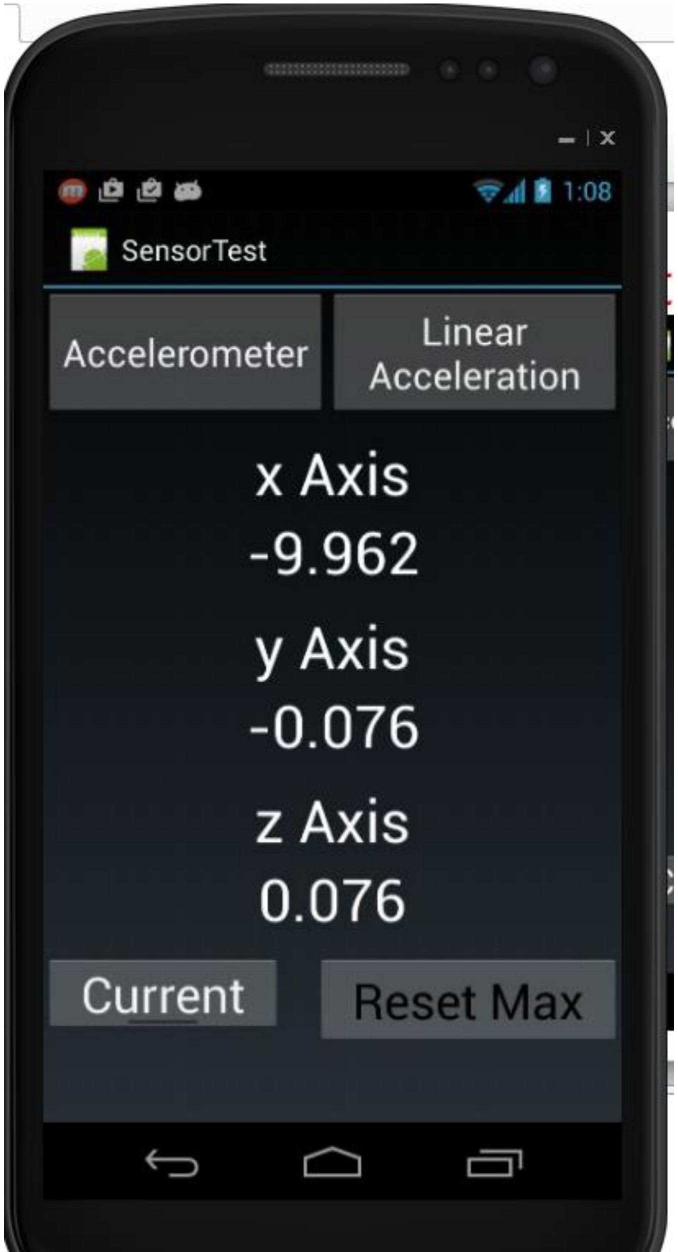
Sensor Coordinate System

- Hold phone straight up and down:



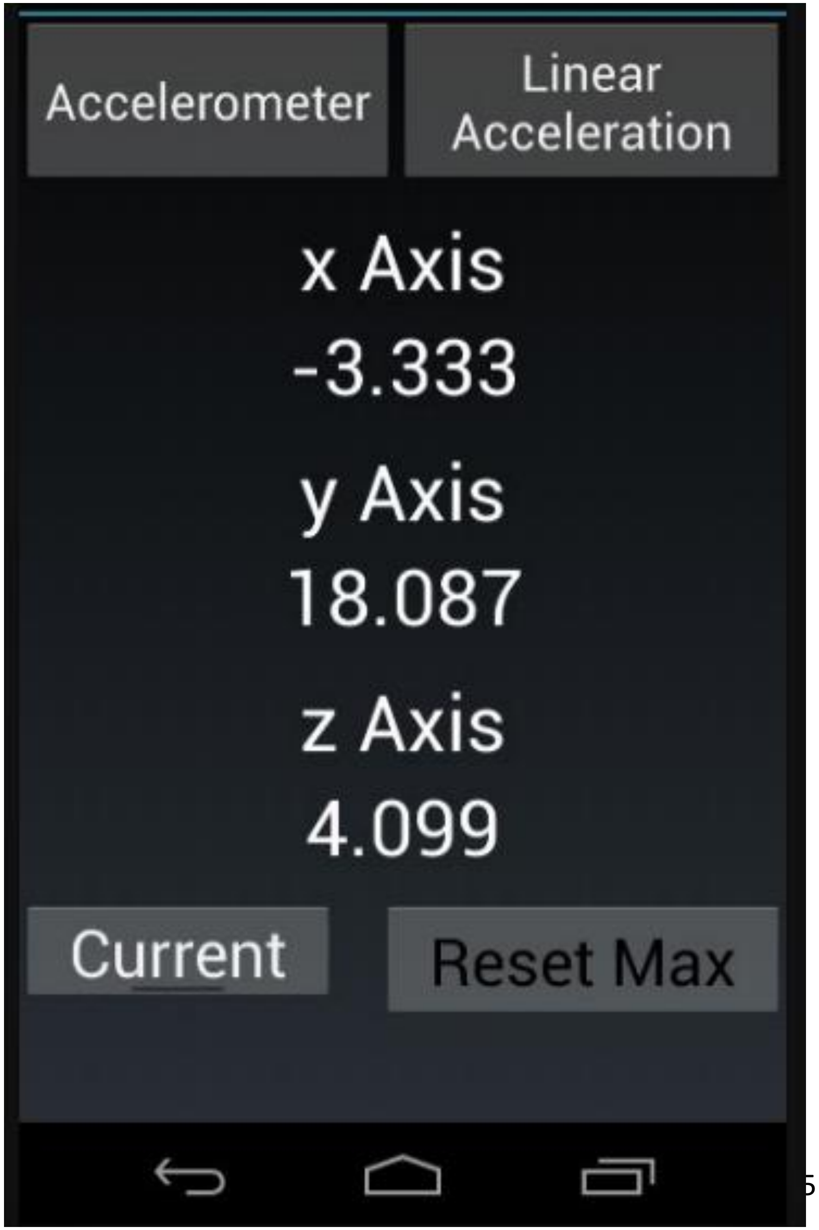
Sensor Coordinate System

- Hold phone on edge



Sensor Coordinate System

- Hold phone straight up and down and pull towards the floor:



Getting Sensor Data

```
private void createSensor() {
    sensorManager =
            (SensorManager) getSystemService(Context.SENSOR_SERVICE);

    showSensors();

    sensorManager.registerListener(sensorEventListener,
            sensorManager.getDefaultSensor(Sensor.TYPE_LINEAR_ACCELERATION),
            SensorManager.SENSOR_DELAY_UI);
```

- registerListener
  - sensorEventListener
  - Sensor -> obtain via SensorManager
  - rate of updates, a hint only, or microseconds (not much effect)
- returns true if successful

SensorEventListener

```
private SensorEventListener sensorEventListener =
        new SensorEventListener() {
            @Override
            public void onSensorChanged(SensorEvent event) {
                // Log.d(TAG, event + "");

                // accelerationValues[0].setText("" + event.values[0]
                if(displayCurrent)
                    displayCurrent(event);
                else
                    displayMax(event);

                // displayCurrentRotation(event);
            }
```

Display Max

```
private void displayMax(SensorEvent event) {
    for(int i = 0; i < maxVals.length; i++)
        if(Math.abs(event.values[i]) > maxVals[i]) {
            maxVals[i] = (float) Math.abs(event.values[i]);
            float value = ((int) (maxVals[i] * 1000)) / 1000f;
            accelerationValues[i].setText("" + value);
        }


}
```

Recall, max range of linear acceleration on dev phone is 19.613 + gravity = 29.423
- a baseball pitcher throwing a fastball reaches 350 m/s^2 or more (various "physics of baseball" articles)

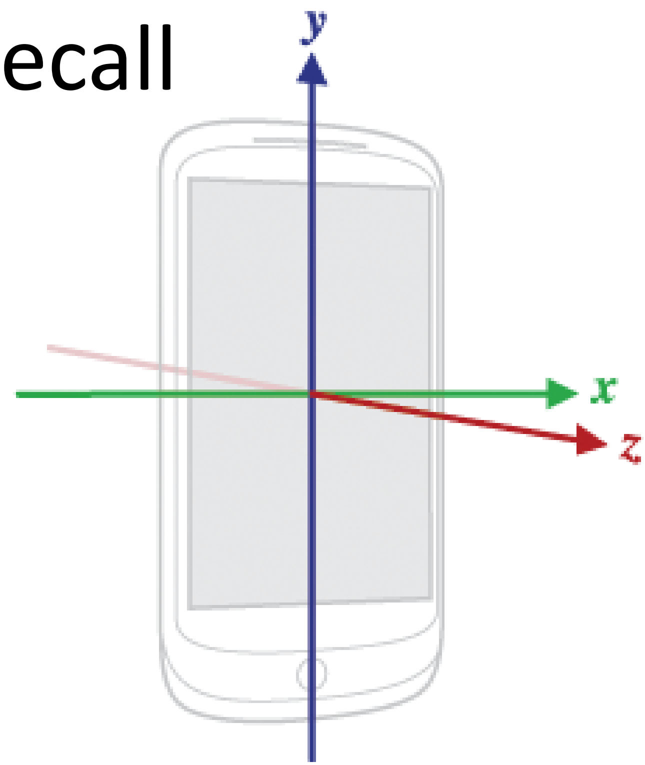
Display Current

```
private void displayCurrent(SensorEvent event) {
    if(!zeroingComplete)
        gatherZeroData(event);

    for(int i = 0; i < accelerationValues.length; i++) {
        float value = event.values[i];
        value = ((int) (value * 1000)) / 1000f;
        accelerationValues[i].setText("" + value);
    }
}
```

- Lots of jitter
- Not a laboratory device
  - simple sensors on a mobile device

Linear Acceleration

- At rest of table
- Recall



- units are m/s^2

Zeroing out

- Take average of first multiple (several hundred) events and average
  - shorter time = more error
- Potential error
  - should be 0 at rest

SensorTest	i: 0, zerovalue: 7.4665865E-4
SensorTest	i: 1, zerovalue: -0.003574672
SensorTest	i: 2, zerovalue: -0.02909316

```
i: 0, zerovalue: -0.0035472375
i: 1, zerovalue: -0.0018564985
i: 2, zerovalue: -0.022586245
```

Rate of Events

- 1000 events
- SensorManager.SENSOR_DELAY_UI
  - times in seconds: 21, 21, 21
  - 21 seconds / 1000 events
- SensorManager.SENSOR_DELAY_FASTEST
  - times in seconds: 21, 21, 21
- Recall delay of 20,000 micro seconds
- $2x10^4$ x $1x10^3 = 2x10^7$ = 20 seconds

USING SENSORS

Using Sensors

- Recall basics for using a Sensor:
  - Obtain the *SensorManager* object
  - create a *SensorEventListener* for *SensorEvents*
    - logic that responds to sensor event
  - Register the sensor listener with a *Sensor* via the SensorManager

Sensor Best Practices

- Unregister sensor listeners
  - when done with Sensor or activity using sensor paused (onPause method)
  - sensorManager. unregisterListener(sensorListener)
  - otherwise data still sent and battery resources continue to be used

Sensors Best Practices

- verify sensor available before using it
- use getSensorList method and type
- ensure list is not empty before trying to register a listener with a sensor

Sensors Best Practices

- Avoid deprecated sensors and methods
- TYPE_ORIENTATION and TYPE_TEMPERATURE are deprecated as of Ice Cream Sandwich / Android 4.0

Sensors Best Practices

- Don't block the onSensorChanged() method
  - recall the resolution on sensors
  - 50 updates a second for onSensorChange method not uncommon
  - when registering listener update is only a hint and may be ignored
  - if necessary save event and do work in another thread or asynch task

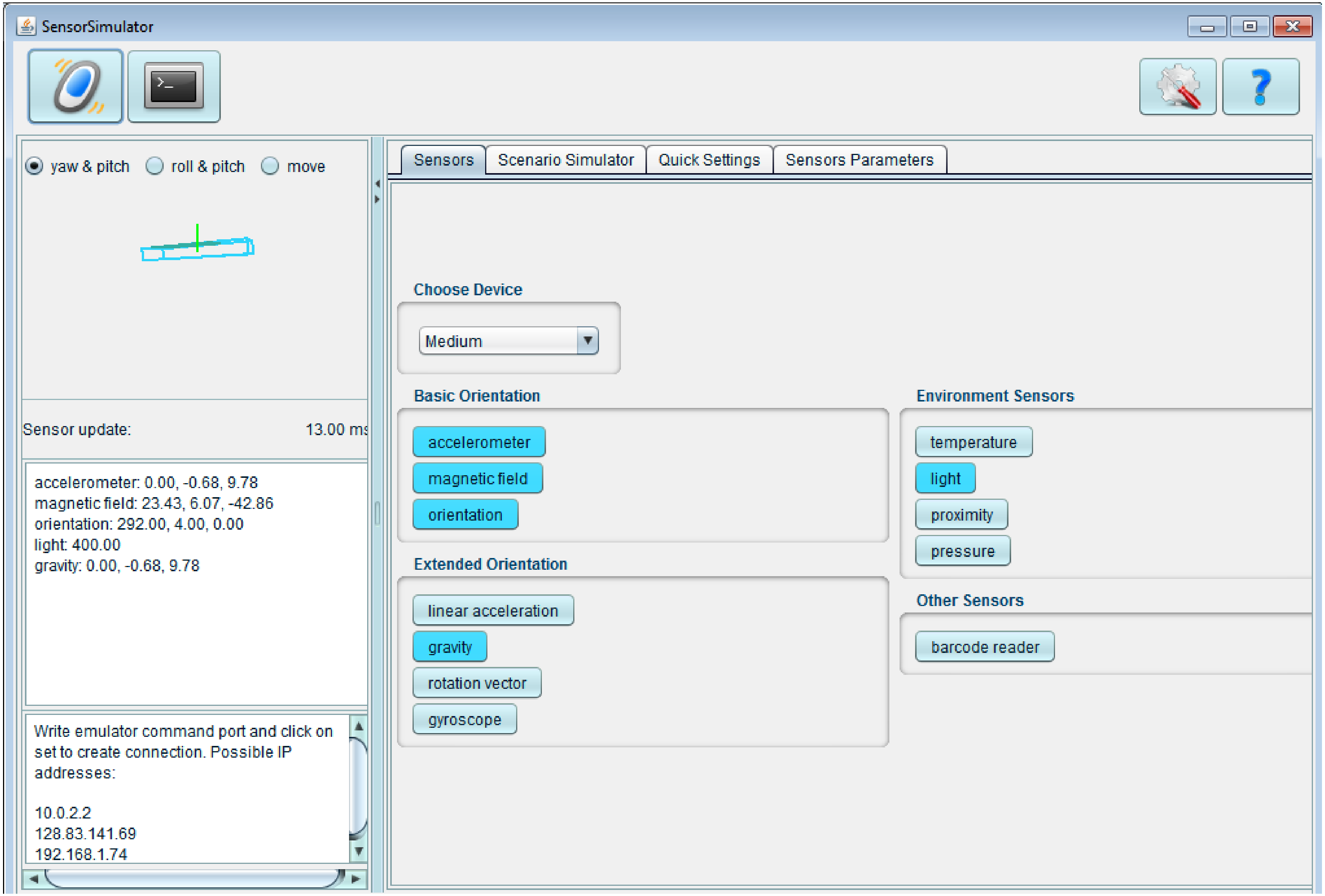
Sensor Best Practices

- Testing on the emulator
- Android SDK doesn't provide any simulated sensors
- 3rd party sensor emulator
- http://code.google.com/p/openintents/wiki/SensorSimulator

SensorSimulator

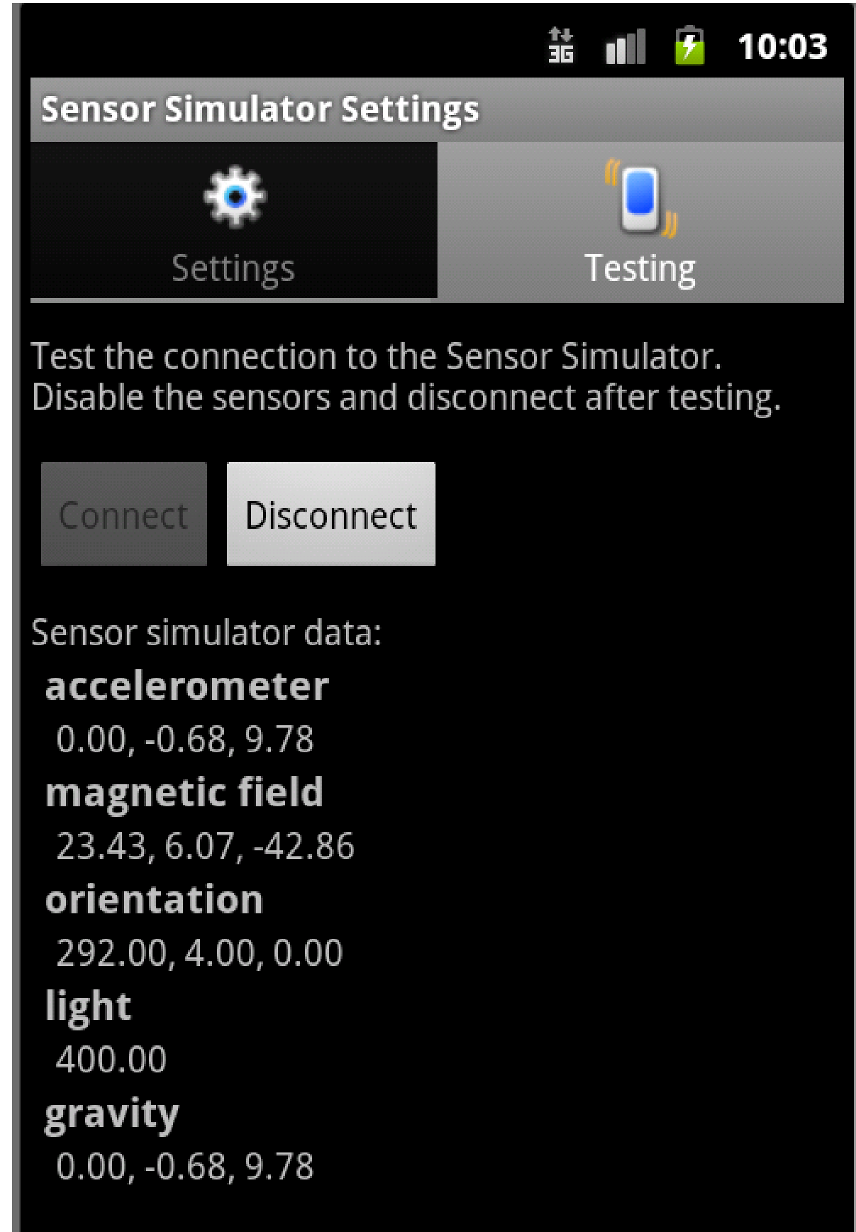
- Download the Sensor Simulator tool
- Start Sensor Simulator program
- Install SensorSimulator apk on the emulator
- Start app, connect simulator to emulator, start app that requires sensor data
- Must modify app so it uses Sensor Simulator library

Sensor Simulator



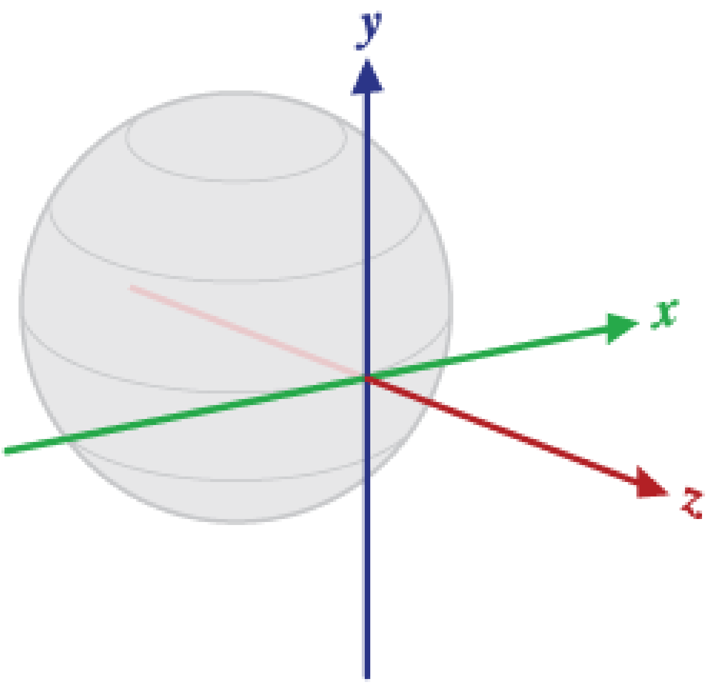
Sensor Simulator

- Mouse in Sensor Simulator controls device, feeds sensor data to emulator
- Can also record sensor data from real device and play back on emulator



Sensing Orientation

- Orientation of the device
- x - tangential to ground and points roughly east
- y - tangential to the ground and points towards magnetic north
- z - perpendicular to the ground and points towards the sky



http://developer.android.com/reference/android/hardware/SensorEvent.html

Orientation Sensor

- Deprecated
- Instead use the Rotation vector sensor
- **int TYPE_ROTATION_VECTOR**

SENSOR SAMPLE - MOVING BALLS

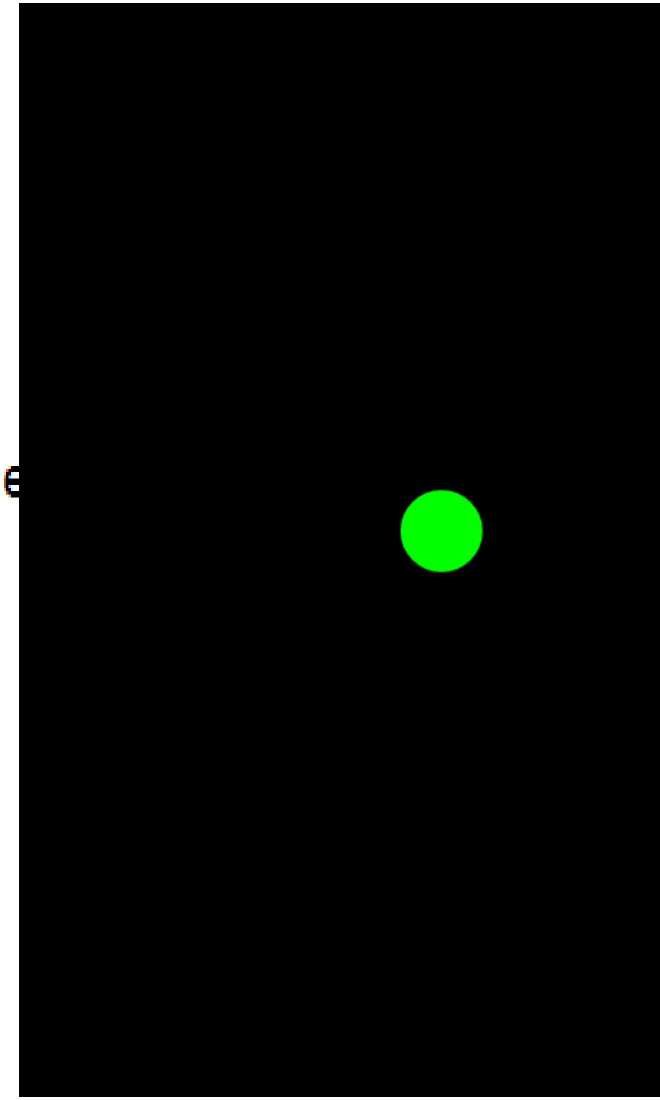
Sensor Sample - Moving Ball

- Place ball in middle of screen
- Ball has position, velocity, and acceleration
- acceleration based on linear acceleration sensor
- update over time, based on equations of motion, but fudged to suit application

Sensor Sample - Moving Ball

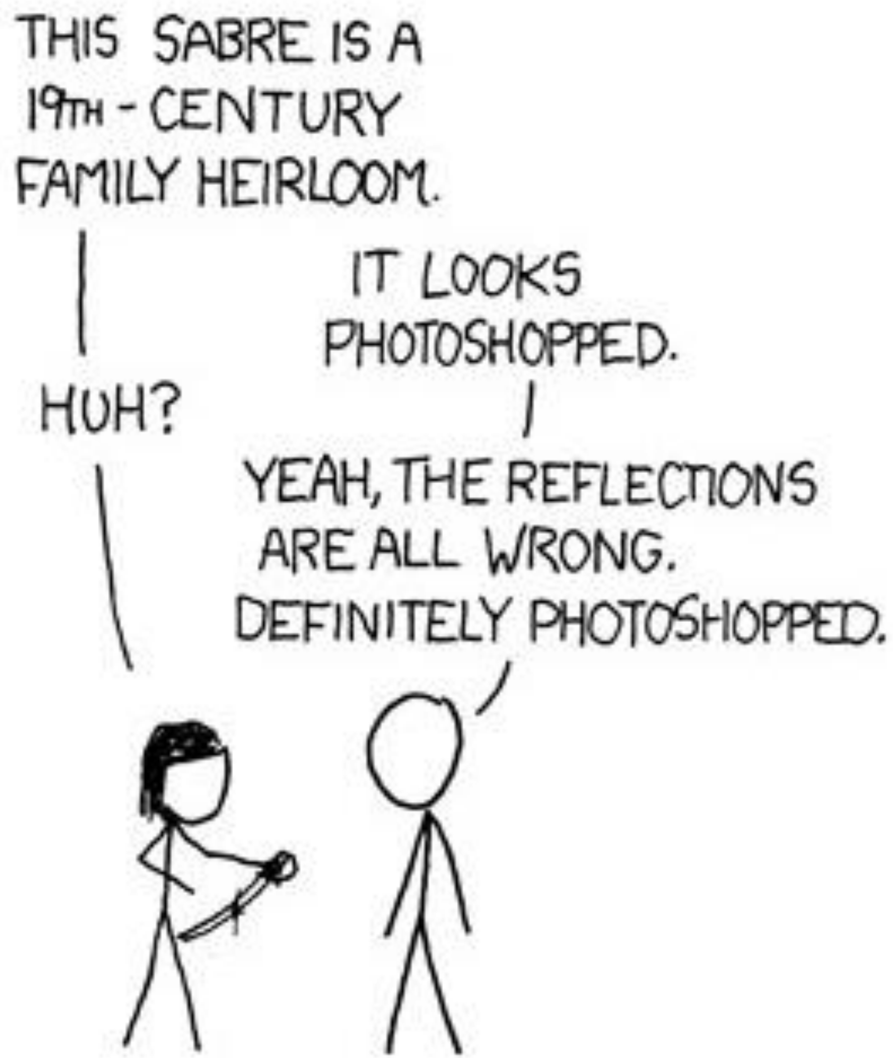
- Gross Simplification
- **velocity set equal to acceleration**

```
public void onSensorChanged(SensorEvent e
    //set ball speed based on phone tilt
    // speed set equal to acceleration
    mBallVelocity.x = -event.values[0];
    mBallVelocity.y = event.values[1];
```



Reality is Unrealistic

- "When exposed to an exaggeration or fabrication about certain real-life occurrences or facts, some people will perceive the fictional account as being more true than any factual account."



Reality is Unrealistic

Sensor Sample - Moving Ball

- Alternate Implementation

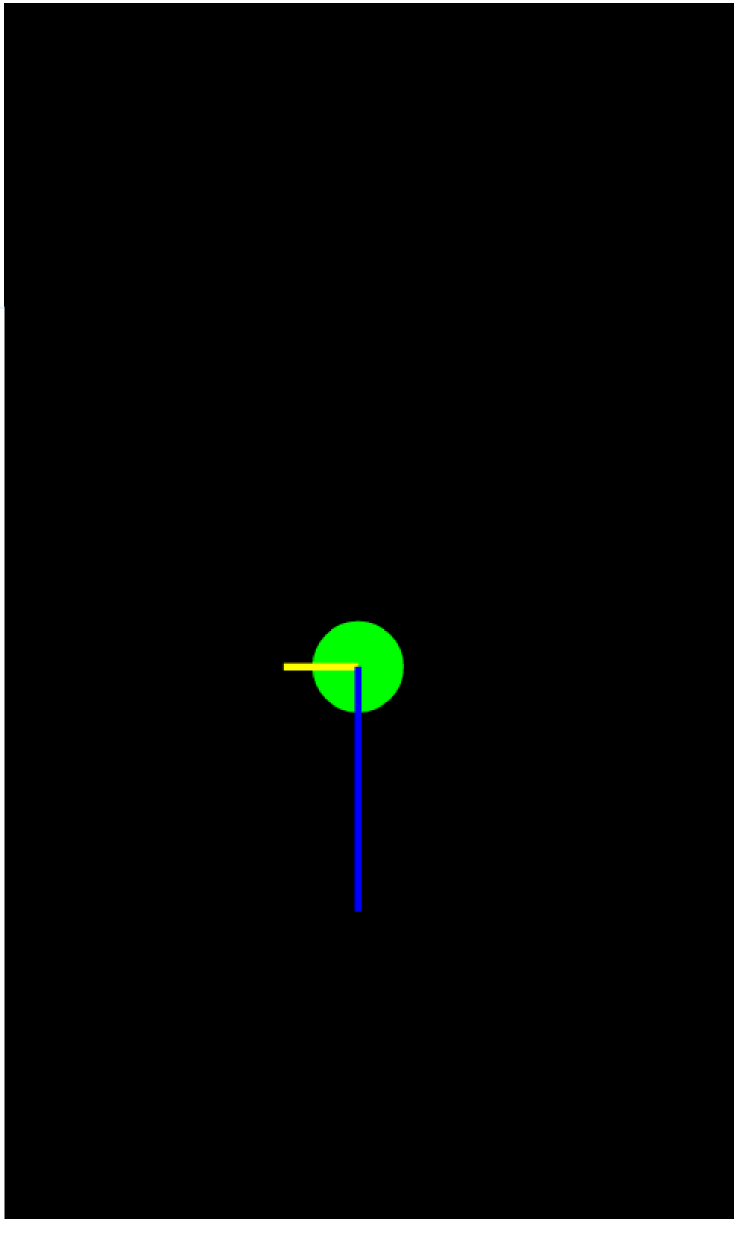
```
// try more realistic movement
float xA = -event.values[0];
float yA = event.values[1];
float aveXA = (xA + mPrevXAcc) / 2;
float aveYA = (yA + mPrevYAcc) / 2;
long currentTime = System.currentTimeMillis();
long elapsedTime = currentTime - mPrevTime;
mBallVelocity.x += aveXA * elapsedTime / 1000 / ACC_FUDGE_FACTOR;
mBallVelocity.y += aveYA * elapsedTime / 1000 / ACC_FUDGE_FACTOR;

mPrevXAcc = xA;
mPrevYAcc = yA;
mPrevTime = currentTime;
```

- position updated in separate thread which redraws the view

Sensor Sample

- Draw lines for x and y velocities

```
//called by invalidate()
@Override
protected void onDraw(Canvas canvas) {
    super.onDraw(canvas);
    mPaint.setStrokeWidth(1);
    mPaint.setColor(0xFF00FF00);
    canvas.drawCircle(mX, mY, mR, mPaint);

    mPaint.setStrokeWidth(3);
    mPaint.setColor(0xFFFFFF00);
    canvas.drawLine(mX, mY,
            mX + vX * 15, mY, mPaint);
    mPaint.setColor(0xFF0000FF);
    canvas.drawLine(mX, mY,
            mX, mY + vY * 15, mPaint);
```



Sensor Sample - TBBT

- Inspired by http://tinyurl.com/bxzaspy and http://tinyurl.com/6nhvnnv

TBBT Sound Effect App

Responding to Events

```
private class LinAccListener implements SensorEventListener {
    public void onSensorChanged(SensorEvent event) {
        if(event.sensor.getType() == Sensor.TYPE_LINEAR_ACCELERATION) {
            float x = event.values[0];
            float y = event.values[1];
            float z = event.values[2];
            float acc = (float)Math.sqrt( x * x + y * y);
            // Log.d("BBT", "" + acc);
            if(acc > 31) {
                Log.d("BBT", "" + acc);

                if(soundPlayer != null && !soundPlayer.isPlaying()) {
                    soundPlayer.start();
                    picture.setImageResource(R.drawable.crack);
                }
            }
        }
    }
```

Changing Images

- Use of an Image View
- Initial Image set in onCreate
- new image set in onSensorChange
- register listener with MediaPlayer
- on completion reset image

```
@Override
public void onCompletion(MediaPlayer mp) {
    picture.setImageResource(R.drawable.shake);
}
```