CMSC436: Programming Handheld Systems

Fall 2017

Sensors

Today’s Topics

Sensor & SensorManager

SensorEvent & SensorEventListener

Filtering sensor values

Example applications

Sensors

Hardware devices that measure the physical environment

- Motion
- Position
- Environment

Some Example Sensors

Motion - 3-axis Accelerometer

Position - 3-axis Magnetic field

Environment - Pressure

Sensor Types

int TYPE_MOTION_DETECT

int TYPE_GRAVITY

int TYPE_AMBIENT_TEMPERATURE

int TYPE_ACCELEROMETER

int TYPE_ALL

Some Sensor Methods

```
float getResolution()
float getPower()
int getReportingMode()
int getMinDelay()
float getMaximumRange()
```

SensorEvent

Represents a Sensor event

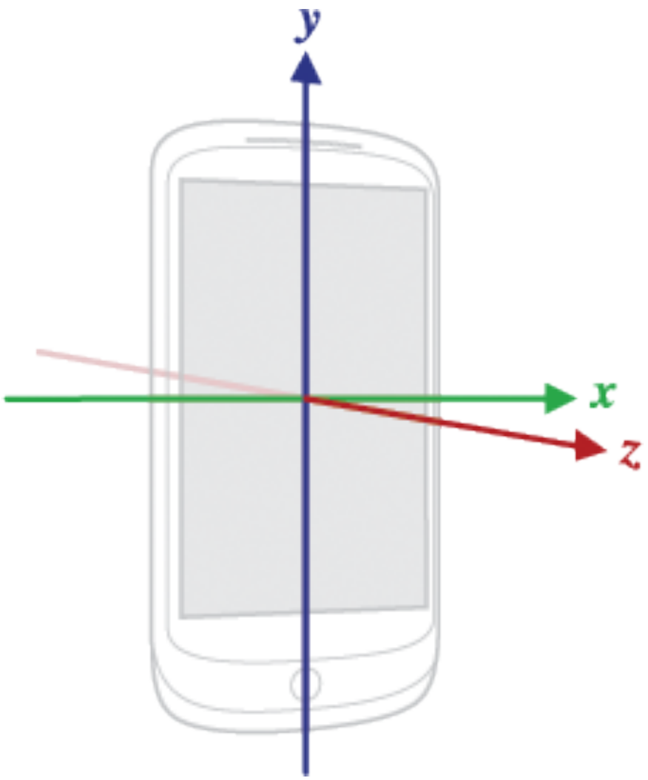
Data is sensor-specific

- Sensor type
- Time-stamp
- Accuracy
- Measurement data

Sensor Coordinate System

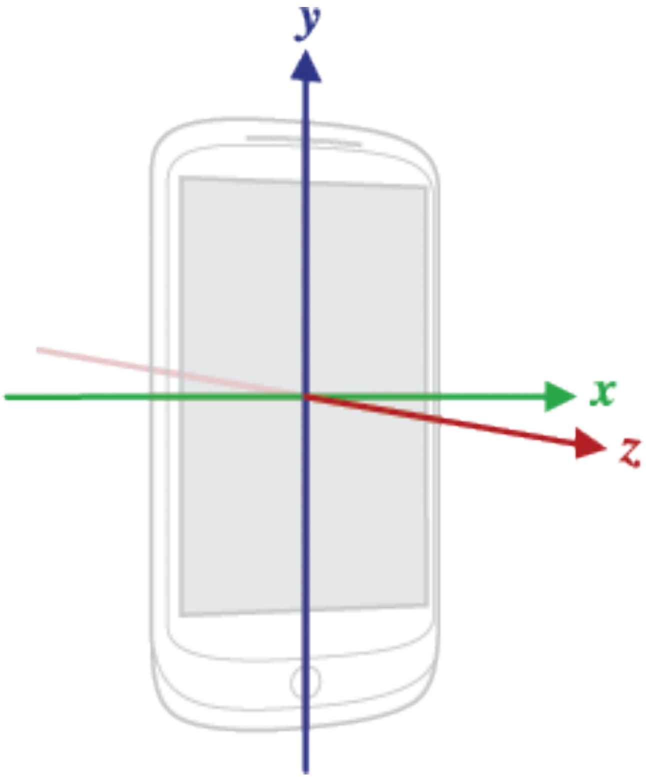
When default orientation is portrait & the device is lying flat, face-up on a table, axes run

- X – Left to right
- Y – Bottom to top
- Z – Down to up



Sensor Coordinate System

Coordinate system does not change when device orientation changes



SensorManager

System service that manages sensors

Get instance with

- getSystemService(Context.SENSOR_SERVICE)

Access a specific sensor with

- SensorManager.getDefaultSensor(int type)

Some Sensor Type Constants

Accelerometer - Sensor.TYPE_ACCELEROMETER

Magnetic field - Sensor.TYPE_MAGNETIC_FIELD

Pressure – Sensor.TYPE_PRESSURE

Some SensorManager Methods

List<Sensor> getSensorList (int type)

Sensor getDefaultSensor (int type)

SensorEventListener

Interface for SensorEvent callbacks

SensorEventListener

Called when a sensor’s accuracy has changed

```
void onAccuracyChanged(
                        Sensor sensor, int accuracy)
```

Accuracy Constants

SENSOR_STATUS_ACCURACY_HIGH

SENSOR_STATUS_ACCURACY_MEDIUM

SENSOR_STATUS_ACCURACY_LOW

SENSOR_STATUS_NO_CONTACT

SENSOR_STATUS_UNRELIABLE

SensorEventListener

Called when sensor values have changed

- void onSensorChanged(SensorEvent event)

Note: This method should not keep a reference to the SensorEvent

Registering for SensorEvents

Use the SensorManager to register/unregister for SensorEvents

Registering for SensorEvents

To register a SensorEventListener for a given sensor

```
public boolean registerListener (
                    SensorEventListener listener,
                    Sensor sensor, int rate)
```

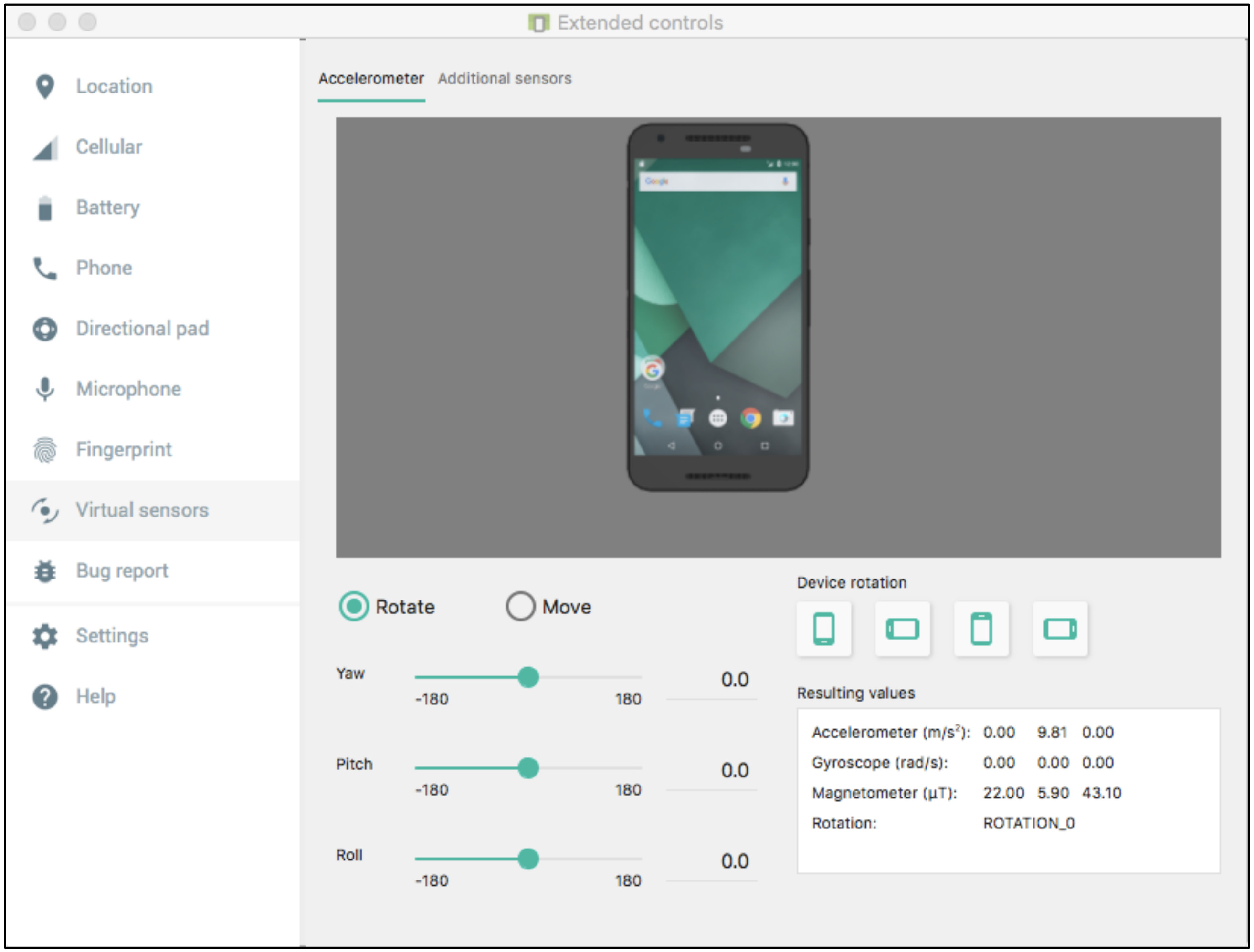
Registering for SensorEvents

Unregisters a listener for the sensors with which it is registered

```
public void unregisterListener (
                        SensorEventListener listener,
                        Sensor sensor)
```

SensorRawAccelerometer

Displays the raw values read from the device’s accelerometer



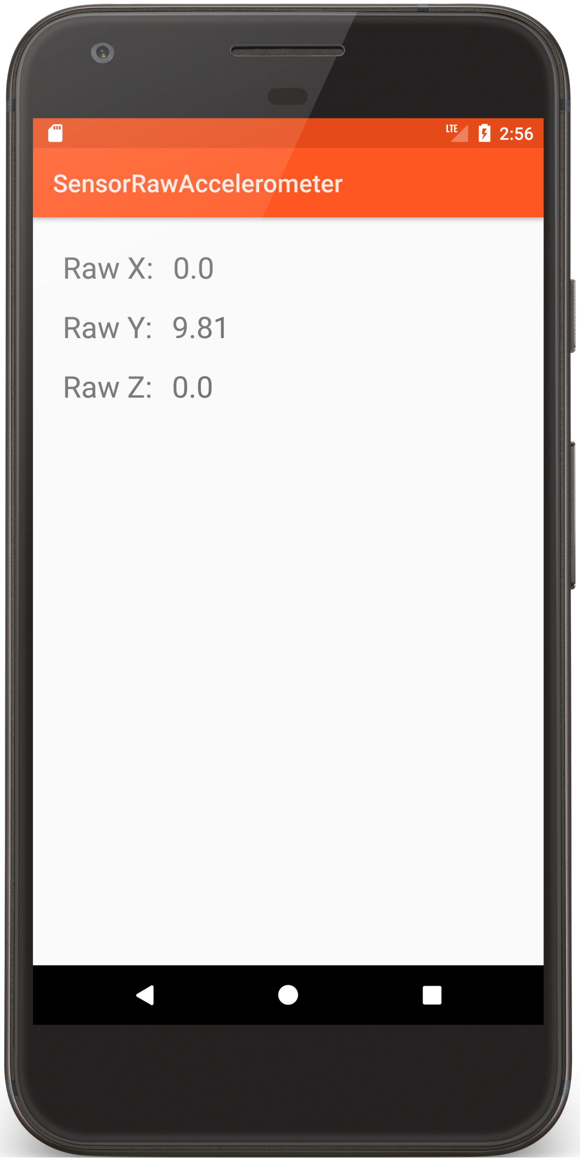
Yaw 0.0

Pitch 0.0

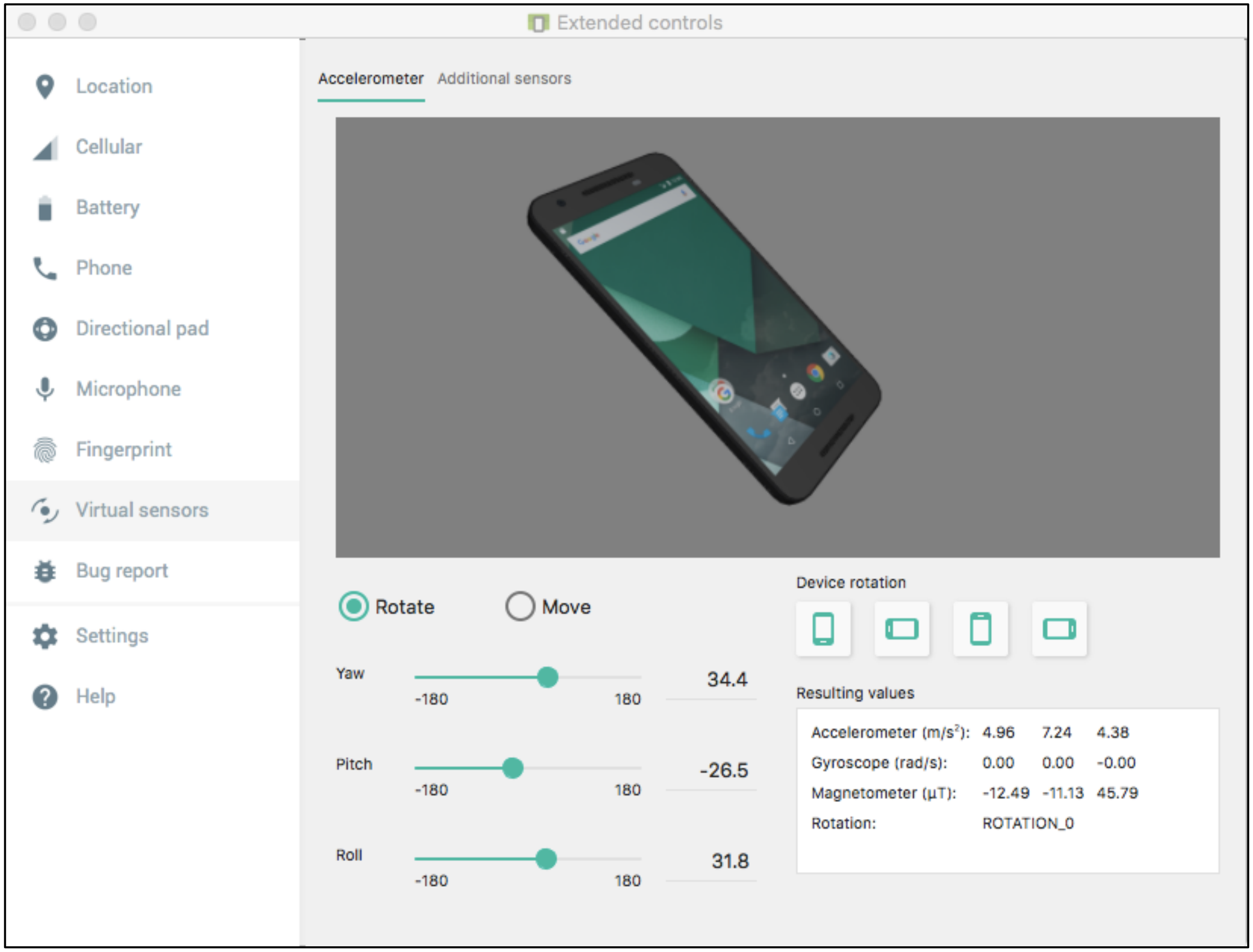
Roll 0.0

Resulting values

```
Accelerometer (m/s²):  0.00   9.81  0.00
Gyroscope (rad/s):     0.00   0.00  0.00
Magnetometer (μT):     22.00  5.90  43.10
Rotation:              ROTATION_0
```



```
Raw X:  0.0
Raw Y:  9.81
Raw Z:  0.0
```



● Rotate ○ Move

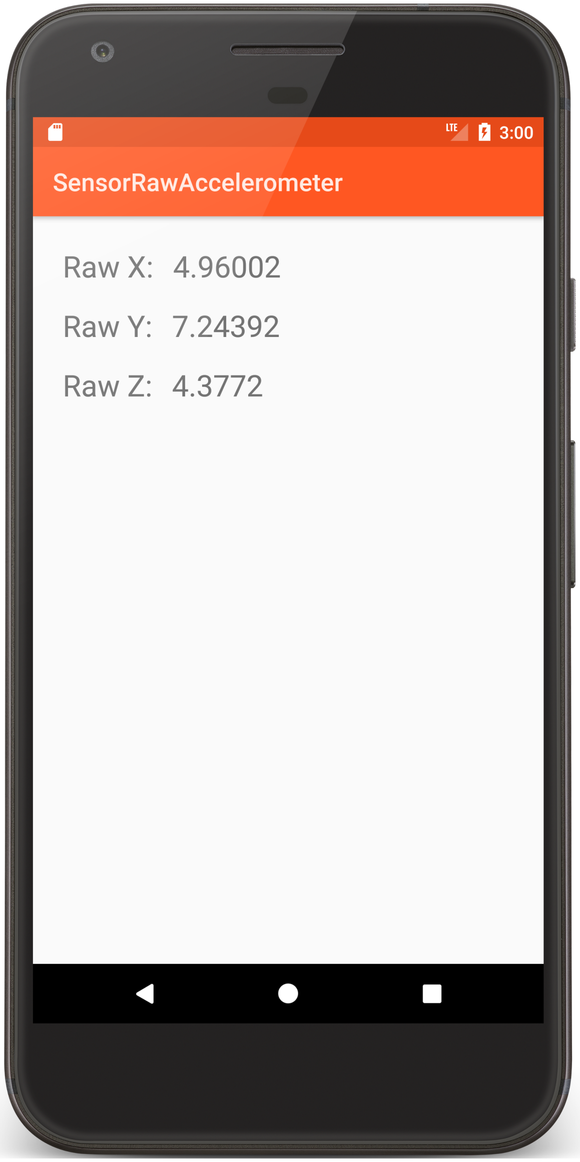
Yaw 34.4

Pitch -26.5

Roll 31.8

Resulting values

```
Accelerometer (m/s²):  4.96    7.24    4.38
Gyroscope (rad/s):     0.00    0.00    -0.00
Magnetometer (µT):     -12.49  -11.13  45.79
Rotation:              ROTATION_0
```



Raw X: 4.96002

Raw Y: 7.24392

Raw Z: 4.3772

```
public void onCreate(Bundle savedInstanceState) {
    super.onCreate(savedInstanceState);
    setContentView(R.layout.main);
    mXValueView = findViewById(R.id.x_value_view);
    mYValueView = findViewById(R.id.y_value_view);
    mZValueView = findViewById(R.id.z_value_view);

    // Get reference to SensorManager
    mSensorManager = (SensorManager) getSystemService(SENSOR_SERVICE);

    // Get reference to Accelerometer
    if (null != mSensorManager) {
      mAccelerometer = mSensorManager
          .getDefaultSensor(Sensor.TYPE_ACCELEROMETER);
    }
    if (null == mAccelerometer) finish();
  }
```

```
// Register listener
protected void onResume() {
   super.onResume();
   mSensorManager.registerListener(this, mAccelerometer,
         SensorManager.SENSOR_DELAY_UI);
   mLastUpdate = System.currentTimeMillis();
}

// Unregister listener
protected void onPause() {
   mSensorManager.unregisterListener(this);
   super.onPause();
}
```

```
  // Process new reading
  public void onSensorChanged(SensorEvent event) {
    if (event.sensor.getType() == Sensor.TYPE_ACCELEROMETER) {
      long actualTime = System.currentTimeMillis();
      if (actualTime - mLastUpdate > UPDATE_THRESHOLD) {
        mLastUpdate = actualTime;
        float x = event.values[0], y = event.values[1], z = event.values[2];
           // update values on display
        }
    }
  }

  public void onAccuracyChanged(Sensor sensor, int accuracy) {
    // Not implemented
  }
}
```

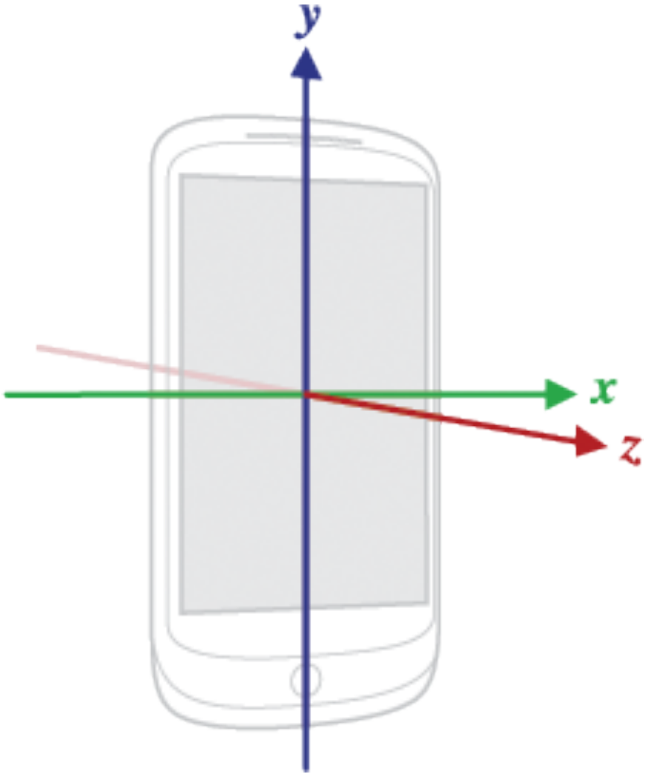
Accelerometer Values

If the device were standing straight up, the accelerometer would ideally report:

X ≈ 0 m/s2

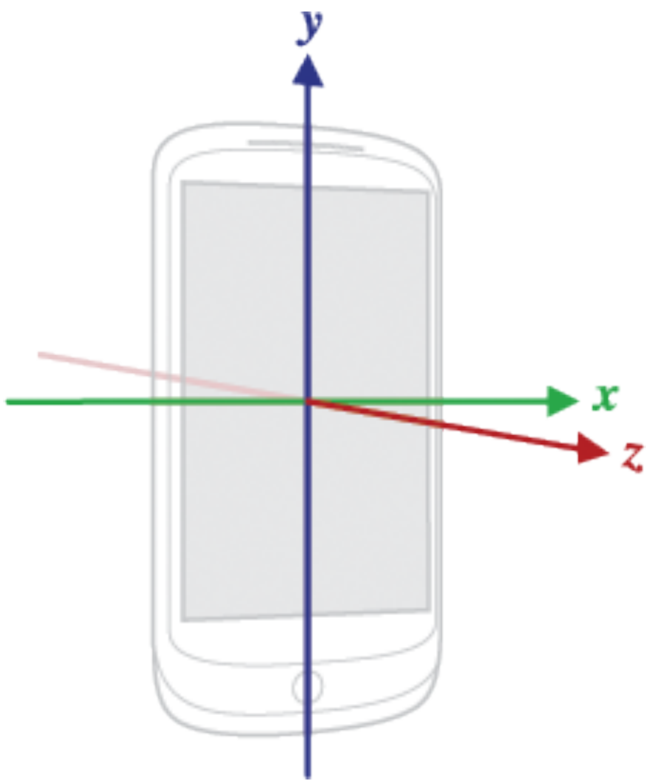
Y ≈ 9.81 m/s2

Z ≈ 0 m/s2



Accelerometer values

But these values will vary due to natural movements, non-flat surfaces, noise, etc.



Filtering Accelerometer Values

Two common transforms

- Low-pass filter
- High-pass filter

Low-Pass Filter

Deemphasize transient force changes

Emphasize constant force components

Carpenter’s Level

High-Pass Filter

Emphasize transient force changes

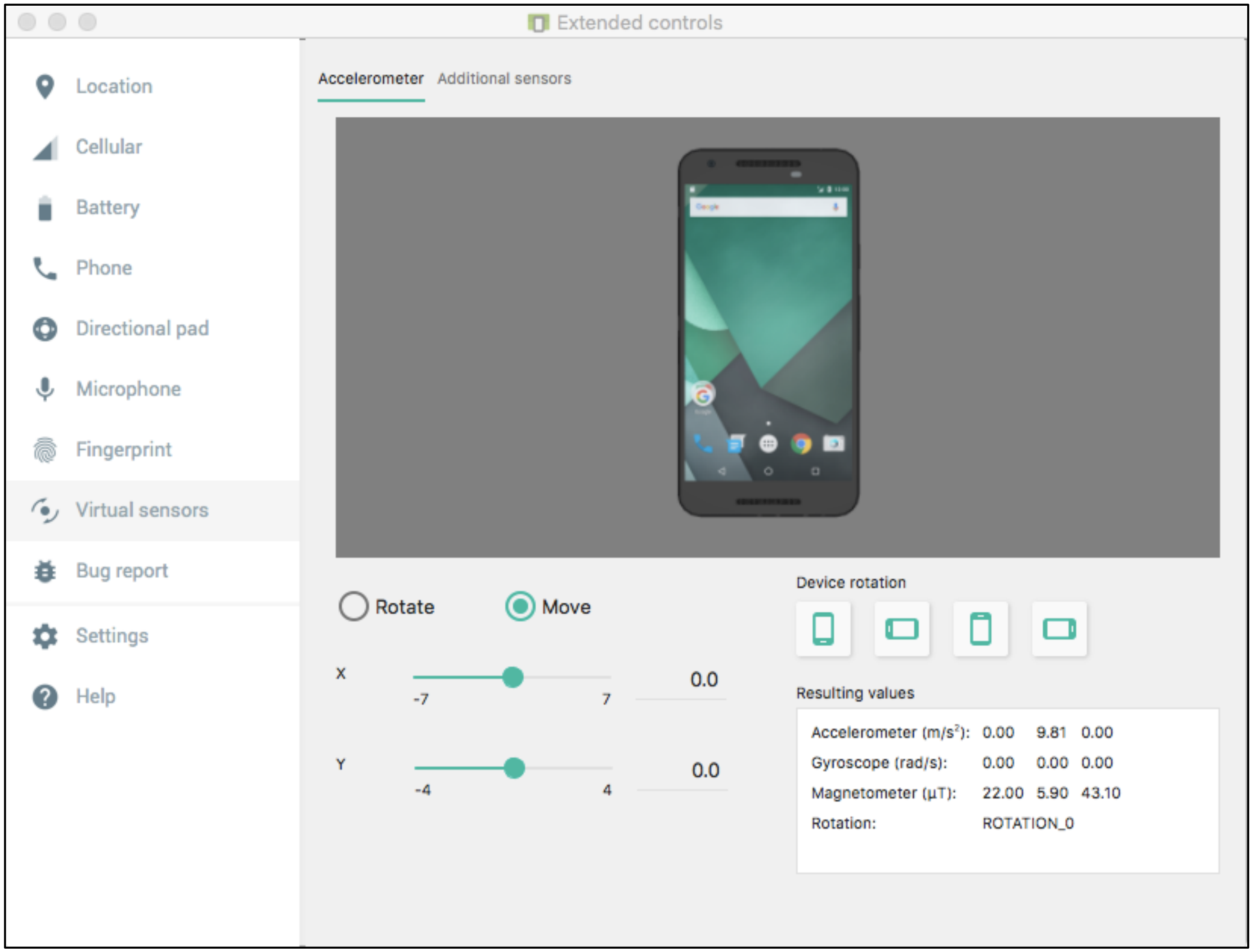
Deemphasize constant force components

Percussion
Instrument

SensorFilteredAccelerometer

Applies both a low-pass and a high-pass filter to raw accelerometer values

Displays the filtered values



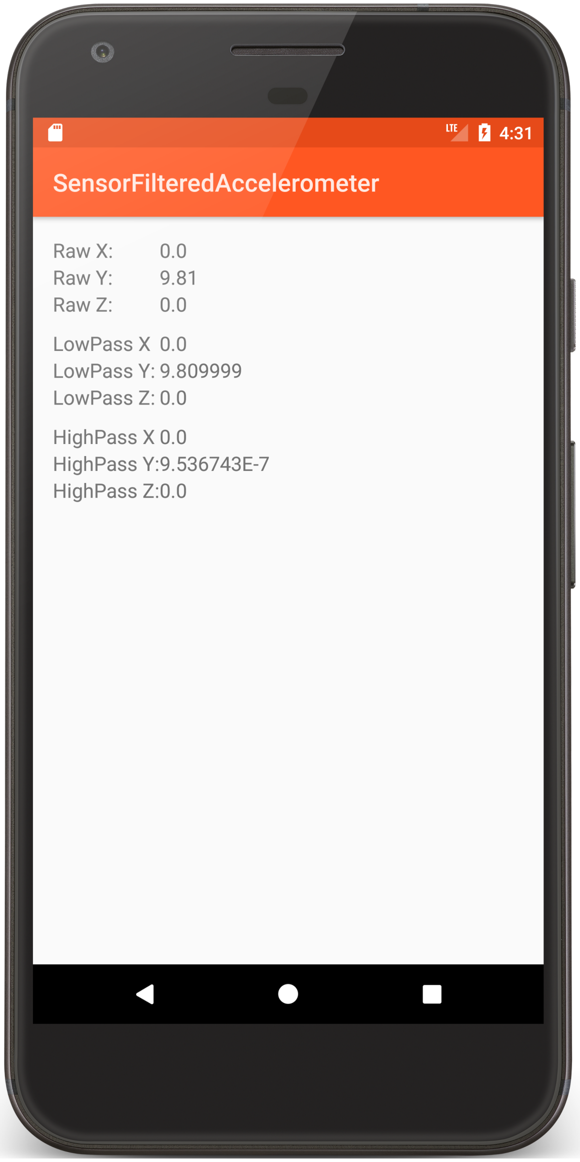
○ Rotate ● Move

X -7 7 0.0

Y -4 4 0.0

Resulting values

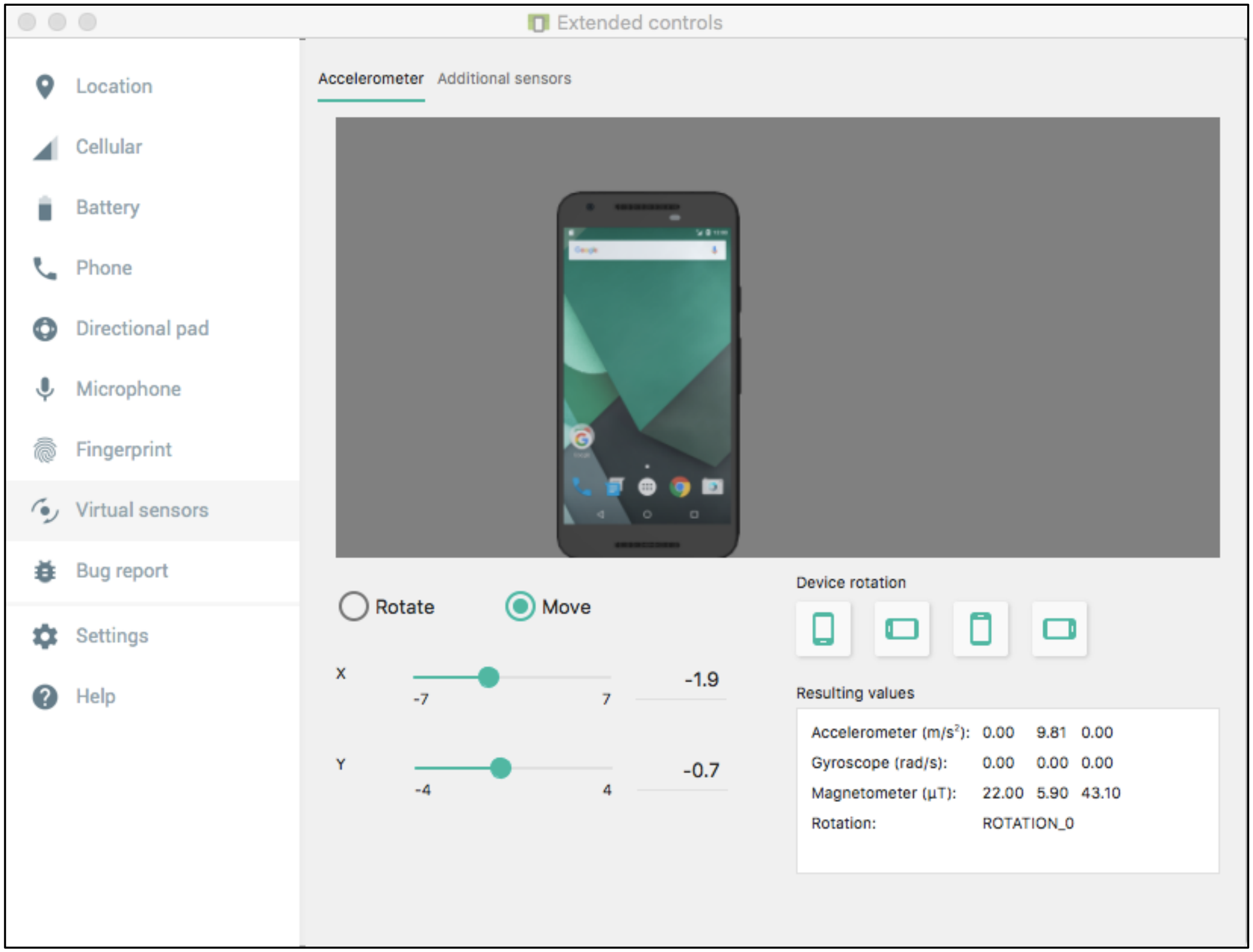
```
Accelerometer (m/s²):  0.00   9.81  0.00
Gyroscope (rad/s):     0.00   0.00  0.00
Magnetometer (µT):     22.00  5.90  43.10
Rotation:              ROTATION_0
```



```
Raw X:     0.0
Raw Y:     9.81
Raw Z:     0.0

LowPass X  0.0
LowPass Y: 9.809999
LowPass Z: 0.0

HighPass X 0.0
HighPass Y:9.536743E-7
HighPass Z:0.0
```



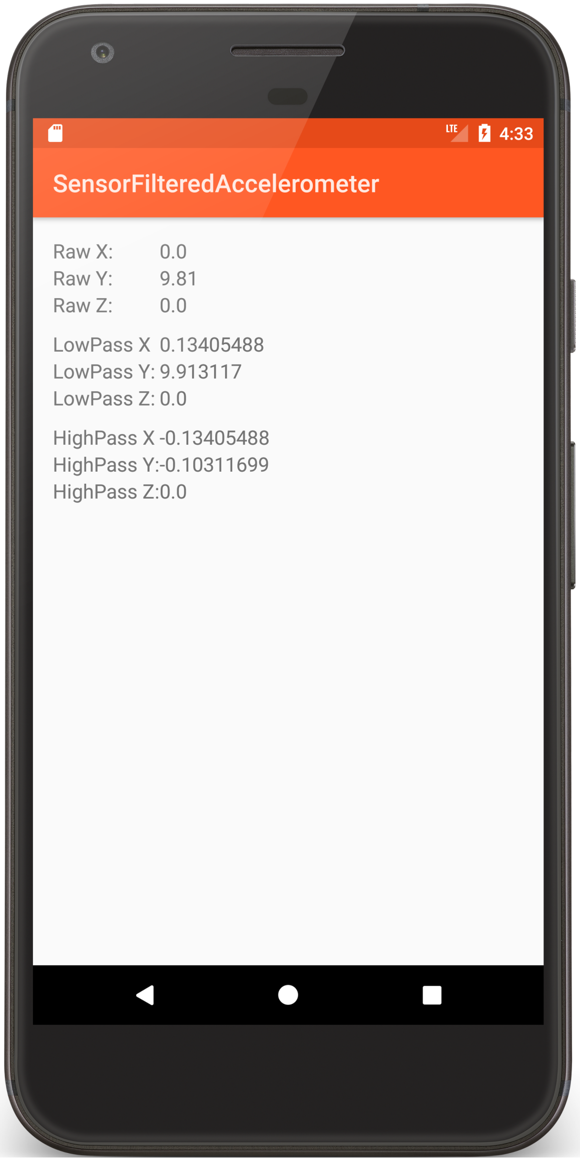
○ Rotate ● Move

X -7 7 -1.9

Y -4 4 -0.7

Resulting values

```
Accelerometer (m/s²):  0.00    9.81   0.00
Gyroscope (rad/s):     0.00    0.00   0.00
Magnetometer (μT):     22.00   5.90   43.10
Rotation:              ROTATION_0
```



SensorFilteredAccelerometer

```
Raw X:      0.0
Raw Y:      9.81
Raw Z:      0.0

LowPass X  0.13405488
LowPass Y: 9.913117
LowPass Z: 0.0

HighPass X -0.13405488
HighPass Y:-0.10311699
HighPass Z:0.0
```

```
public void onCreate(Bundle savedInstanceState) {
 …
// Get reference to SensorManager
    mSensorManager = (SensorManager) getSystemService(SENSOR_SERVICE);

    if (null != mSensorManager) {
      // Get reference to Accelerometer
      mAccelerometer = mSensorManager
          .getDefaultSensor(Sensor.TYPE_ACCELEROMETER);
      if (null == mAccelerometer) finish();

      mLastUpdate = System.currentTimeMillis();
    }
  }
```

```java
// Register listener
    protected void onResume() {
        super.onResume();
        mSensorManager.registerListener(this, mAccelerometer,
                SensorManager.SENSOR_DELAY_UI);
    }

    // Unregister listener
    protected void onPause() {
        super.onPause();
        mSensorManager.unregisterListener(this);
    }
```

```
// Process new reading
public void onSensorChanged(SensorEvent event) {
    if (event.sensor.getType() == Sensor.TYPE_ACCELEROMETER) {
        long actualTime = System.currentTimeMillis();
        if (actualTime - mLastUpdate > 500) {
            mLastUpdate = actualTime;

            float rawX = event.values[0];
            float rawY = event.values[1];
            float rawZ = event.values[2];

            // Apply low-pass filter
            mGravity[0] = lowPass(rawX, mGravity[0]);
            mGravity[1] = lowPass(rawY, mGravity[1]);
            mGravity[2] = lowPass(rawZ, mGravity[2]);
```

```
// Apply high-pass filter
mAccel[0] = highPass(rawX, mGravity[0]);
mAccel[1] = highPass(rawY, mGravity[1]);
mAccel[2] = highPass(rawZ, mGravity[2]);

mXValueView.setText(String.valueOf(rawX));
mYValueView.setText(String.valueOf(rawY));
mZValueView.setText(String.valueOf(rawZ));

mXGravityView.setText(String.valueOf(mGravity[0]));
mYGravityView.setText(String.valueOf(mGravity[1]));
mZGravityView.setText(String.valueOf(mGravity[2]));

mXAccelView.setText(String.valueOf(mAccel[0]));
mYAccelView.setText(String.valueOf(mAccel[1]));
mZAccelView.setText(String.valueOf(mAccel[2]));
```

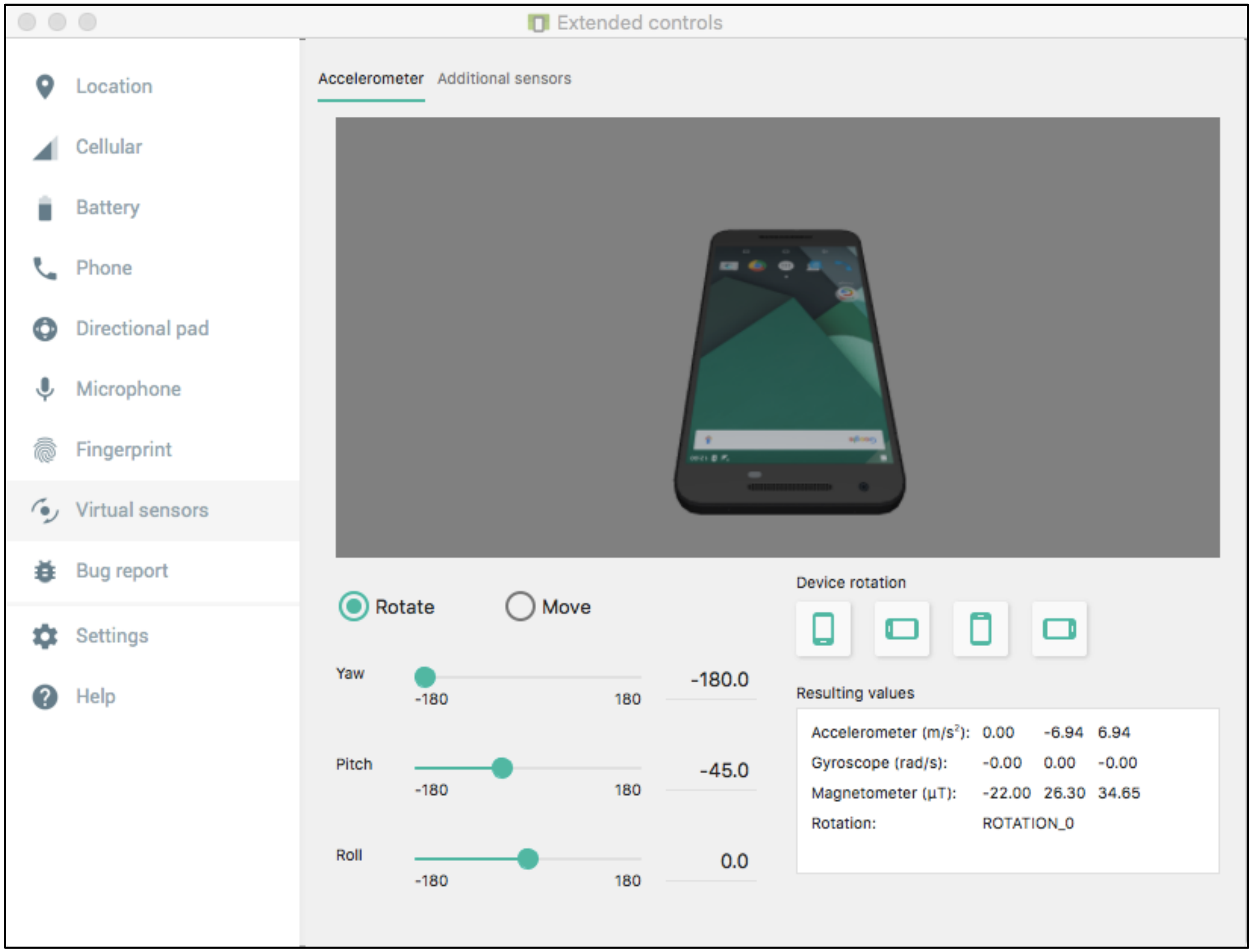
```java
// Deemphasize transient forces
private float lowPass(float current, float gravity) {
    float mAlpha = 0.8f;
    return gravity * mAlpha + current * (1 - mAlpha);

}

// Deemphasize constant forces
private float highPass(float current, float gravity) {
    return current - gravity;
}
```

SensorCompass

Uses the device’s accelerometer and magnetometer to orient a compass



● Rotate ○ Move

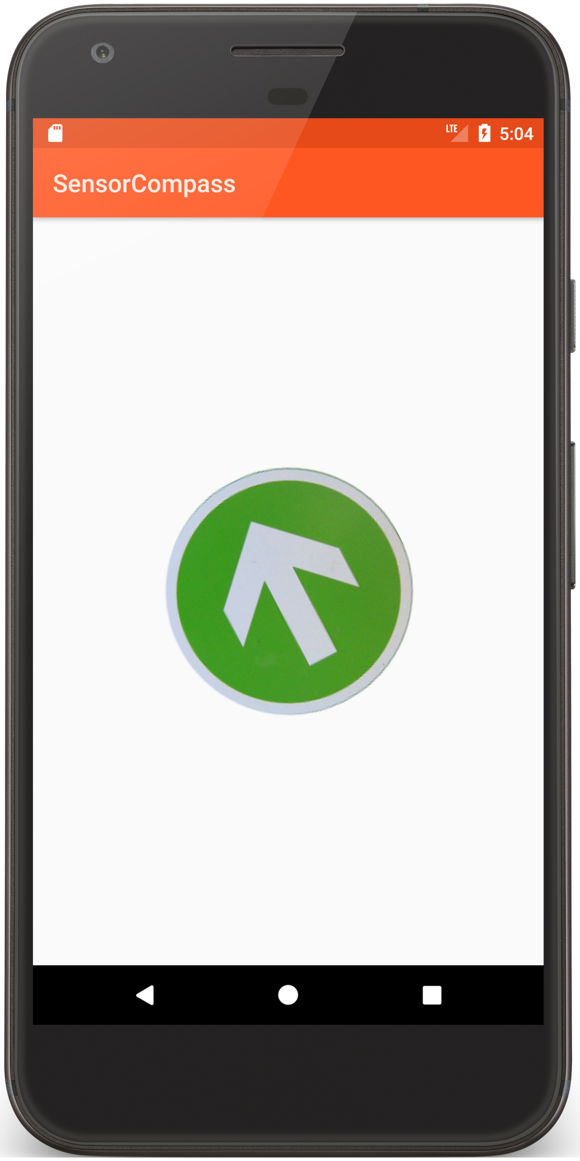
Yaw -180.0 (-180 … 180)

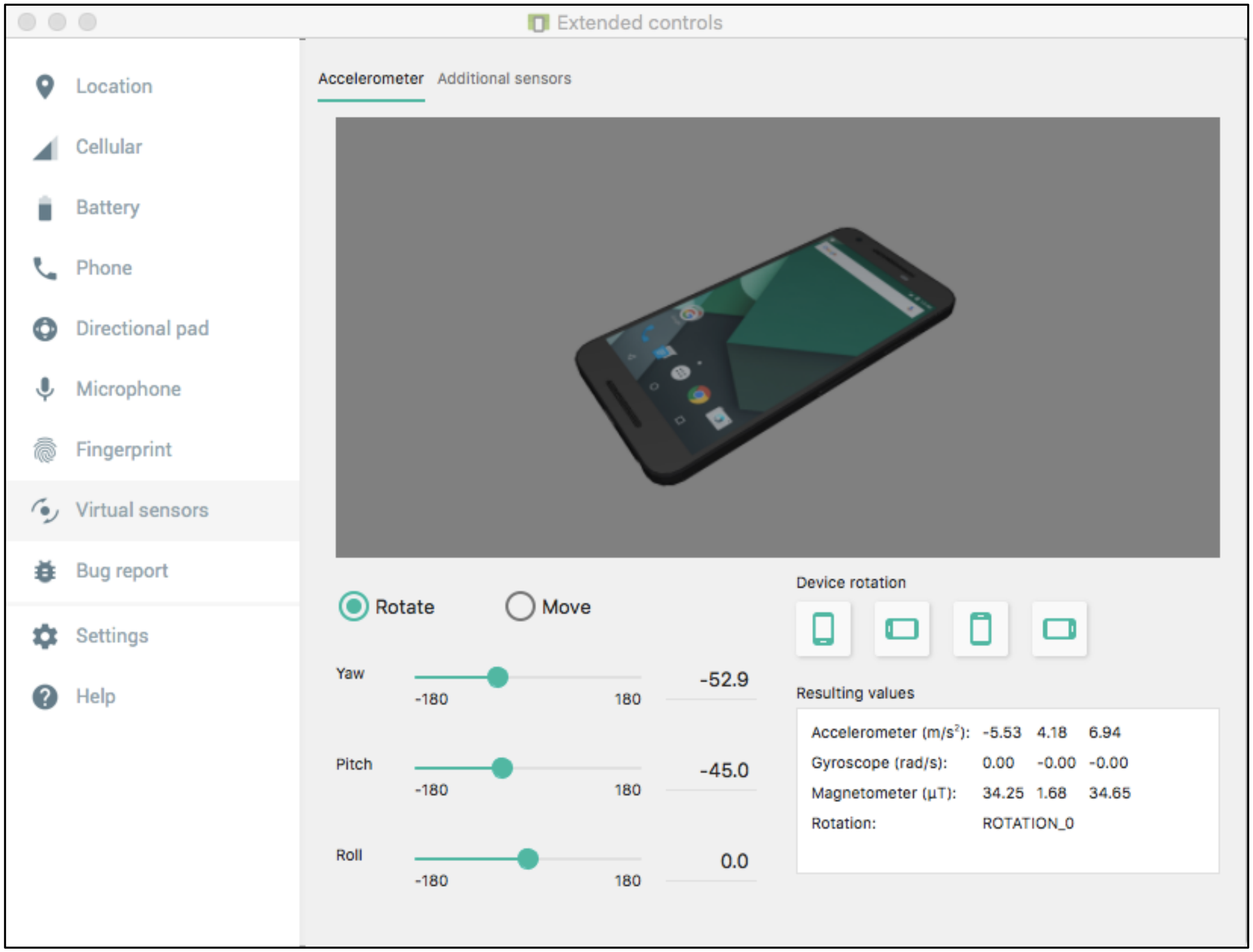
Pitch -45.0 (-180 … 180)

Roll 0.0 (-180 … 180)

Resulting values

```
Accelerometer (m/s²):  0.00    -6.94   6.94
Gyroscope (rad/s):     -0.00   0.00    -0.00
Magnetometer (μT):     -22.00  26.30   34.65
Rotation:              ROTATION_0
```





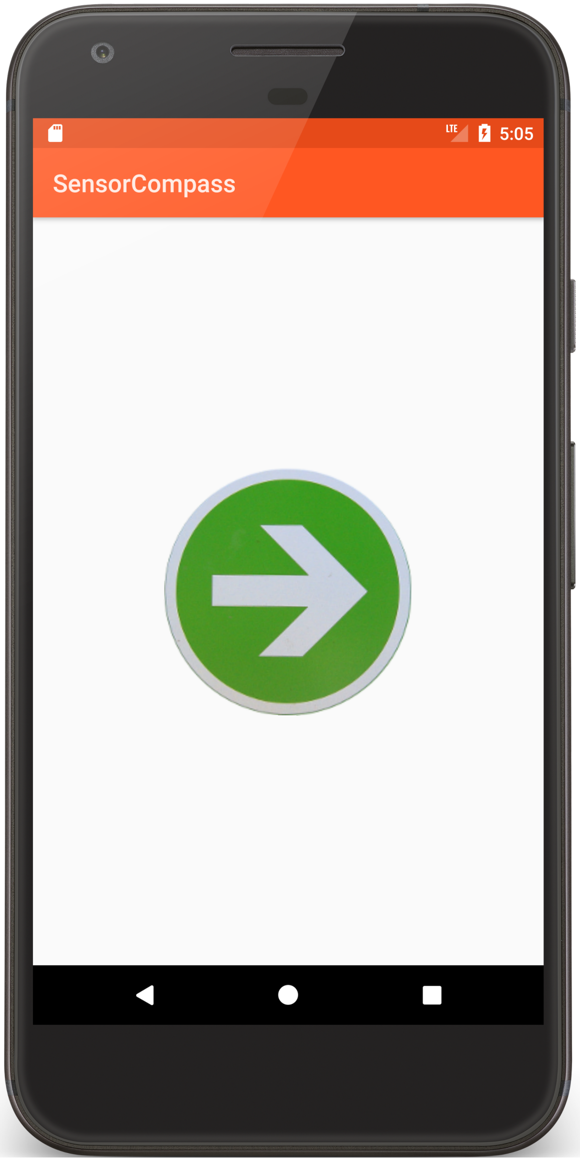
● Rotate ○ Move

Yaw -180 180 -52.9

Pitch -180 180 -45.0

Roll -180 180 0.0

```
Accelerometer (m/s²):  -5.53  4.18   6.94
Gyroscope (rad/s):     0.00   -0.00  -0.00
Magnetometer (μT):     34.25  1.68   34.65
Rotation:              ROTATION_0
```



```
protected void onCreate(Bundle savedInstanceState) {
    …
    // Get a reference to the SensorManager
    mSensorManager = (SensorManager) getSystemService(SENSOR_SERVICE);
    if (null != mSensorManager) {
      // Get a reference to the accelerometer
      accelerometer =
                 mSensorManager.getDefaultSensor(Sensor.TYPE_ACCELEROMETER);
      // Get a reference to the magnetometer
      magnetometer =
                 mSensorManager.getDefaultSensor(Sensor.TYPE_MAGNETIC_FIELD);
    }
    // Exit unless both sensors are available
    if (null == accelerometer || null == magnetometer)
      finish();
  }
```

```
onResume() {
    super.onResume();

    // Register for sensor updates
    mSensorManager.registerListener(this, accelerometer,
        SensorManager.SENSOR_DELAY_NORMAL);
    mSensorManager.registerListener(this, magnetometer,
        SensorManager.SENSOR_DELAY_NORMAL);
  }

  protected void onPause() {
    super.onPause();

    // Unregister all sensors
    mSensorManager.unregisterListener(this);
  }
```

```java
public void onSensorChanged(SensorEvent event) {
    // Acquire accelerometer event data
    if (event.sensor.getType() == Sensor.TYPE_ACCELEROMETER) {
      mGravity = new float[3];
      System.arraycopy(event.values, 0, mGravity, 0, 3);
    }
    // Acquire magnetometer event data
    else if (event.sensor.getType() == Sensor.TYPE_MAGNETIC_FIELD) {
      mGeomagnetic = new float[3];
      System.arraycopy(event.values, 0, mGeomagnetic, 0, 3);
    }

    // If we have readings from both sensors then  use the readings to compute the
    // device's orientation and then update the display.
    if (mGravity != null && mGeomagnetic != null) {
      float rotationMatrix[] = new float[9];
   ...
```

```
// Users the accelerometer and magnetometer readings to compute the device's
// rotation with respect to a real-world coordinate system
boolean success = SensorManager.getRotationMatrix(
                                rotationMatrix, null, mGravity, mGeomagnetic);
if (success) {
   float orientationMatrix[] = new float[3];
   // Returns the device's orientation given the rotationMatrix
   SensorManager.getOrientation(rotationMatrix, orientationMatrix);
   // Get the rotation, measured in radians, around the Z-axis
   // Note: This assumes the device is held flat and parallel to the ground
   float rotationInRadians = orientationMatrix[0];
   // Convert from radians to degrees
   mRotationInDegrees = Math.toDegrees(rotationInRadians);
   // Request redraw
   mCompassArrow.invalidate();
   // Reset sensor event data arrays
   mGravity = mGeomagnetic = null;
 …
```

Next Time

Maps & Location