# What can Android Sense for you?

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# About Us

*Greg:* Consultant
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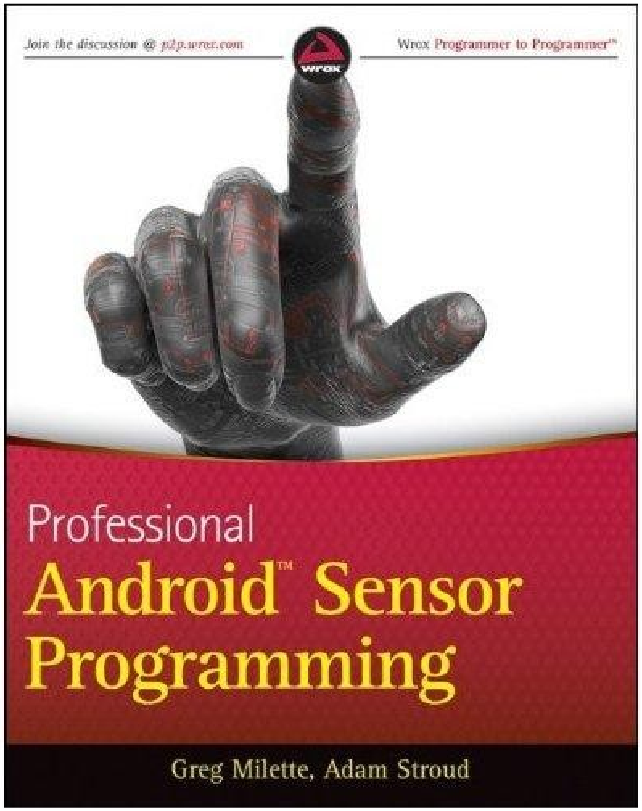
Digital Recipe
Sidekick App

*Adam*: Lead Android Developer for Runkeeper

RunKeeper

We wrote this book



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Professional
Android™ Sensor Programming

Greg Milette, Adam Stroud

# What is a "Sensor"

A capability that can capture measurements about the device and its external environment.

# Sooo many sensors...

Camera

Microphone

NFC Scanner

Speech Recognition

Physical Sensors

Location Service

# Why use Sensors?

Android Sensors can:

- ***Hear*** claps and singing
- ***See*** Android Logos
- ***Understand*** obscure spoken language
- ***Scan*** for NFCs (and do cool stuff)
- ***Locate*** *a device*
- ***Determine*** device position

# Location Service

Using Android to determine where you are

# Android Location Service

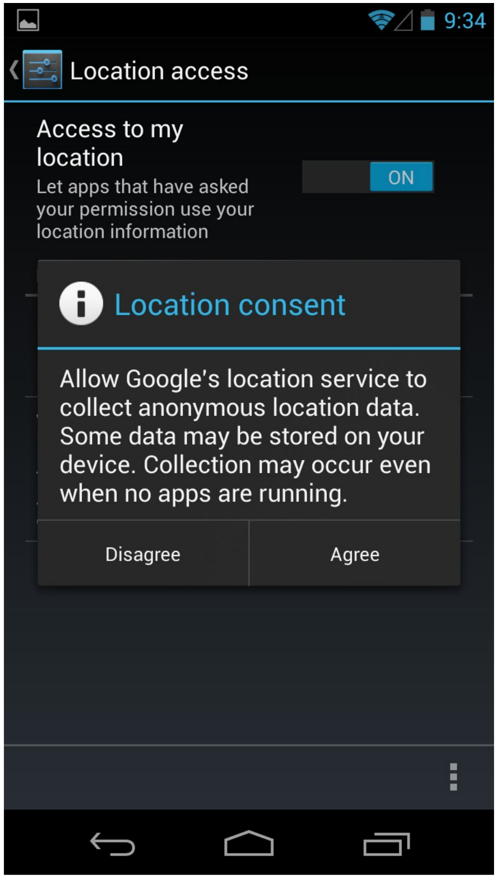
Provides location based functionality in Android

- Determine Device Location
  - Latitude
  - Longitude
  - Altitude
- Geocoding
  - Address-to-location translation
- Proximity Alerts
  - Notifications when device enters a specified area

# Sources of Location Data

- A location provider is a source of location information
- Android has "three-ish" location providers
  - Network Provider
  - Makes use of Wifi access points and mobile network
  - GPS Provider
  - Uses GPS hardware on device
  - Passive Provider
  - Uses whatever other apps are currently using

# Network Provider



Access to my location

Let apps that have asked your permission use your location information

Location consent

Allow Google's location service to collect anonymous location data. Some data may be stored on your device. Collection may occur even when no apps are running.

- Wifi Access Points
  - MAC addresses and strength of nearby access points recorded
- Mobile Network
  - Uses distance/strength of cell towers
- Queries Google Location Service
  - Different from local location service
  - Data is somewhat crowd-sourced

# GPS Provider

- Uses on-board GPS hardware along with global GPS system
- Most phones take advantage of A-GPS
  - Assisted GPS (A-GPS)
  - GPS information is downloaded using mobile network

# How GPS Works

- GPS receiver contacts multiple GPS satellites
- Data is transmitted from satellite to GPS receiver
- Distance from satellite is computed using transmission time and speed of radio signal
- Distance from multiple satellites are used to determine position

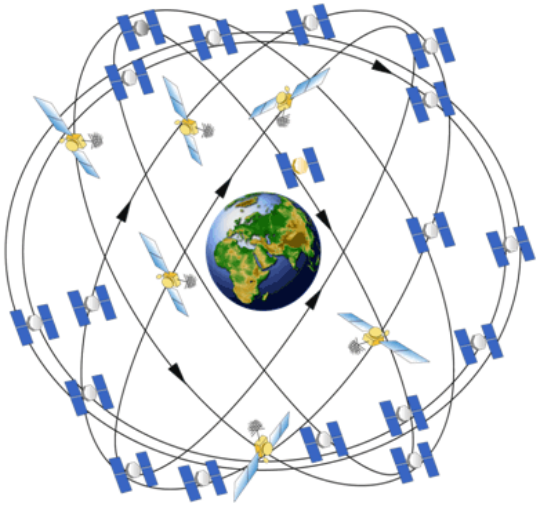
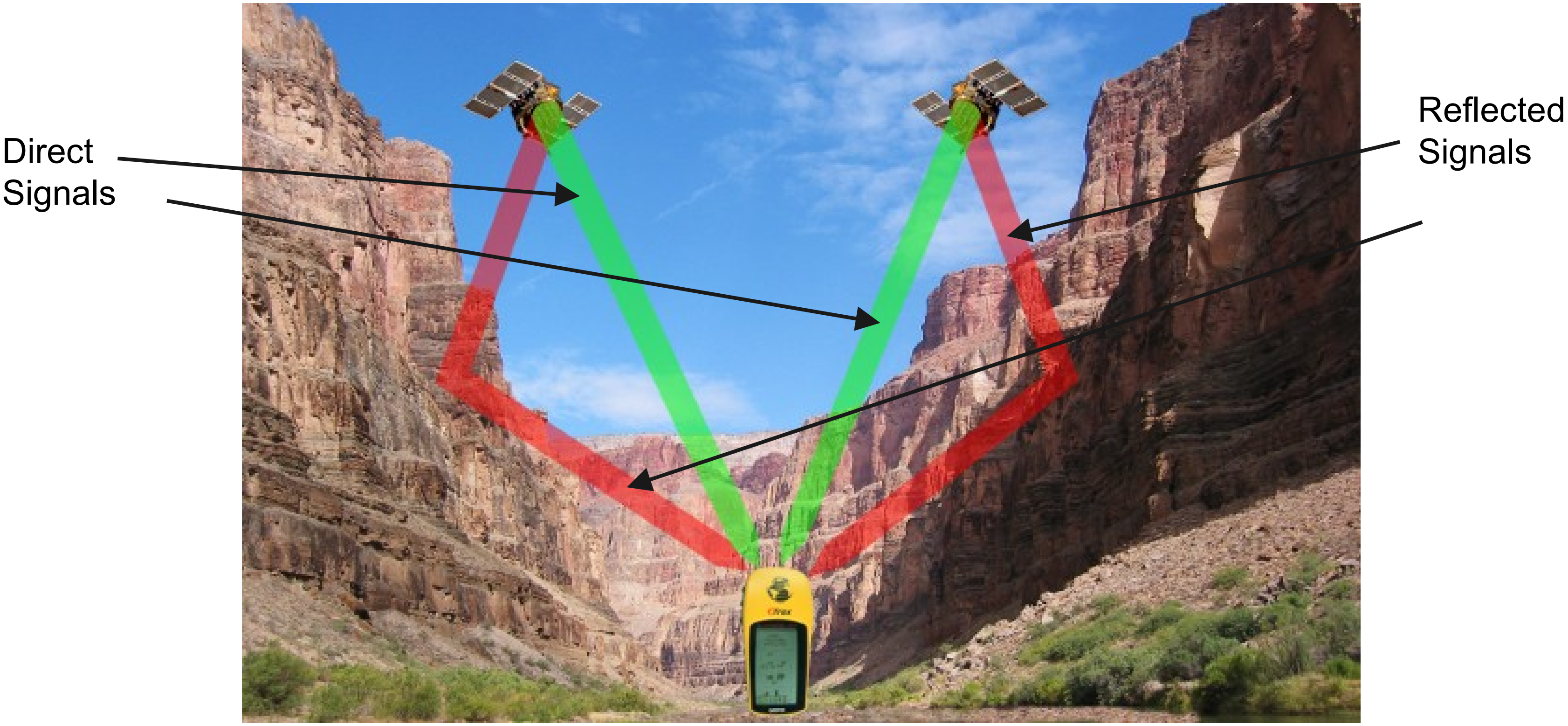


Image Src: http://www.gps.gov/multimedia/images/

# Problems with GPS

- Signal can face interference
  - Environmental conditions
  - Vegetation
  - Atmospheric conditions
  - Signals travel slower though gases
- Not all phones have quality GPS hardware
  - Low power GPS hardware can cause slow location fix
- Need clear line of sight to sky
  - Unlikely to work indoors
- Multipath Problems

# GPS Multipath



Direct Signals

Reflected Signals

By GPS_tracking_satellites.jpg: Vaughan Weather Navstar-2.jpg: NASA Canyon_midday.jpg: Realbrvhrt at en.wikipedia derivative work: Javiersanp [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

# Network Provider Comparison

| | GPS Provider | Network Provider |
|---|---|---|
| **Time to First Fix (TTFF)** | High | Low |
| **Power Consumption** | High | Low |
| **Accuracy** | High | Low |
| **Supports Altitude** | True | False |
| **Supports Bearing** | True | False |
| **Supports Speed** | True | True |

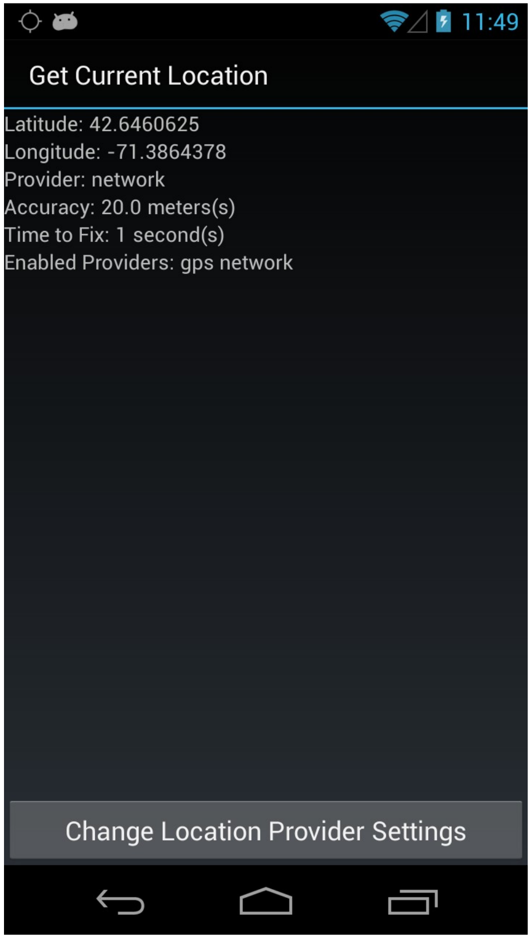
# Location Permissions

- Use of the location service requires Android permission(s)
- `ACCESS_COARSE_LOCATION`
    - Network Provider
- `ACCESS_FINE_LOCATION`
    - Network Provider
    - GPS Provider
    - Passive Provider

Note: No need to include multiple permissions to use Network and GPS providers

# Demo: Get Current Location

- Use all enabled providers
- Displays information about location
  - Latitude
  - Longitude
  - Time to fix
  - Provider of location information
- Allows user to enable/disable location provider



Latitude: 42.6460625
Longitude: -71.3864378
Provider: network
Accuracy: 20.0 meters(s)
Time to Fix: 1 second(s)
Enabled Providers: gps network

# Location Service API

- `LocationManager`
  - System service that provides access to location information
- `LocationListener`
  - Interface containing callback methods for processing location events
- `Location`
  - Contains location data from provider
- `LocationProvider`
  - Representation of the source of location data

# Requesting Location Data

- Implement `LocationListener`
  - `onLocationChanged()`
  - `onProviderDisabled()`
  - `onProviderEnabled()`
  - `onStatusChanged()`
- Register `LocationListener` with `LocationManager`
- Process `Location` object in `onLocationChanged()`
- Unregister `LocationListener`

# Get LocationManager Reference

```
private LocationManager locationManager;


@Override
protected void onCreate(Bundle savedInstanceState)
{
    super.onCreate(savedInstanceState);
    setContentView(R.layout.current_location);


    locationManager =
       (LocationManager)
getSystemService(LOCATION_SERVICE);
}
```

# Register LocationListener

```
@Override
protected void onResume()
{
  // Retrieve only providers that user has enabled
  enabledProviders = locationManager.getProviders(true);


  for (String enabledProvider : enabledProviders) {
    // Request location information from provider.
    // The current class implements LocationListener
    locationManager.
     requestLocationUpdates(enabledProvider, 0, 0, this);
}
```

# Process Location Data

```
@Override
public void onLocationChanged(Location location)
{
  // Read location data and update display
  latValue.setText(String.valueOf(location.getLatitude()));
  long.setText(String.valueOf(location.getLongitude()));

providerValue.setText(String.valueOf(location.getProvider()));

accuracyValue.setText(String.valueOf(location.getAccuracy()));


  // Compute time to fix and update display
  long timeToFix = SystemClock.uptimeMillis() - uptimeAtResume;
  timeToFixValue.setText(String.valueOf(timeToFix / 1000));
}
```

# Unregister LocationListener

```
@Override
protected void onPause()
{
  super.onPause();

  // Remove listener from location manager
  locationManager.removeUpdates(this);
}
```

# Summary

- Android provides multiple sources of location data
- Location API is relatively simple to use
- Requesting location data can affect battery life
- Choice of location provider depends needs of app

# Physical Sensors

Allowing Android to sense it's place in the world

# Sensors and Smartphones

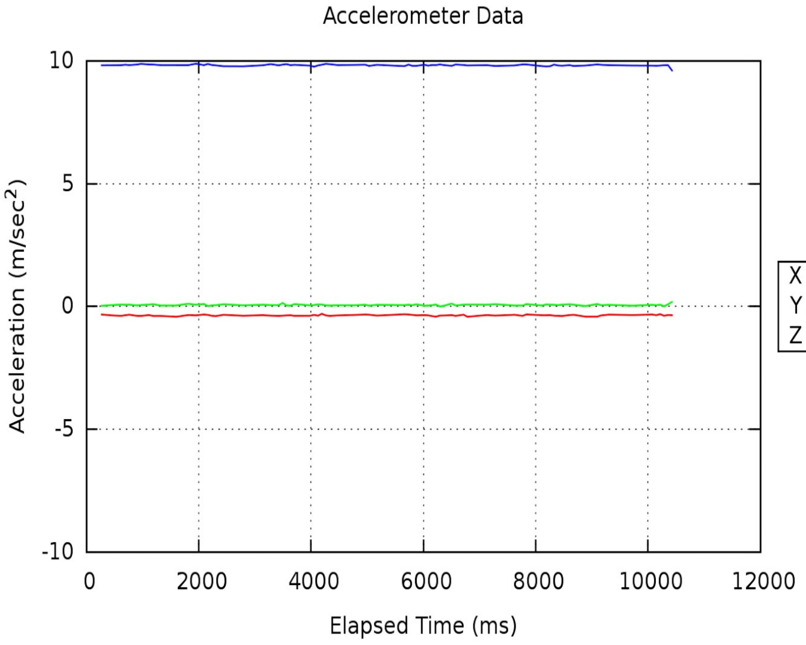
- Previously, disjoint, separate pieces of hardware
- Now, unified on a single device that is mobile
- Use of these sensors allows apps to inject contextual based information to their algorithms

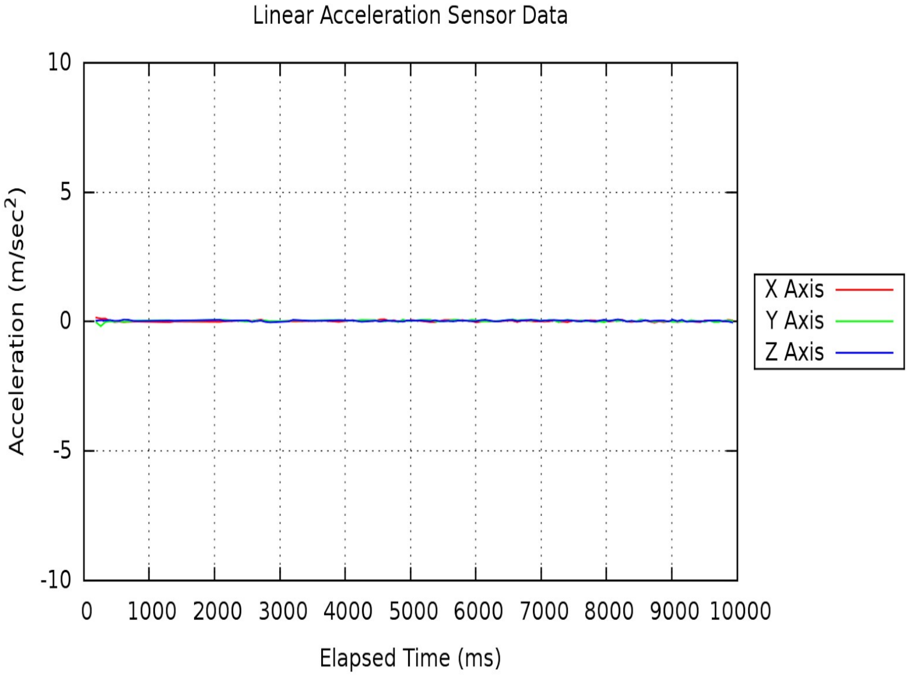
# Types of Sensors

- Hardware (Raw) Sensors
    - Provide raw data from a sensor
    - Represents data from a single physical sensor
- Software (Synthetic/Virtual) Sensors
    - Provides abstraction layer on top of raw sensors
    - Combine data of multiple raw sensors
    - Modifies raw sensor data to simplify consumption
    - Different devices may have different implementations

# Hardware vs. Software

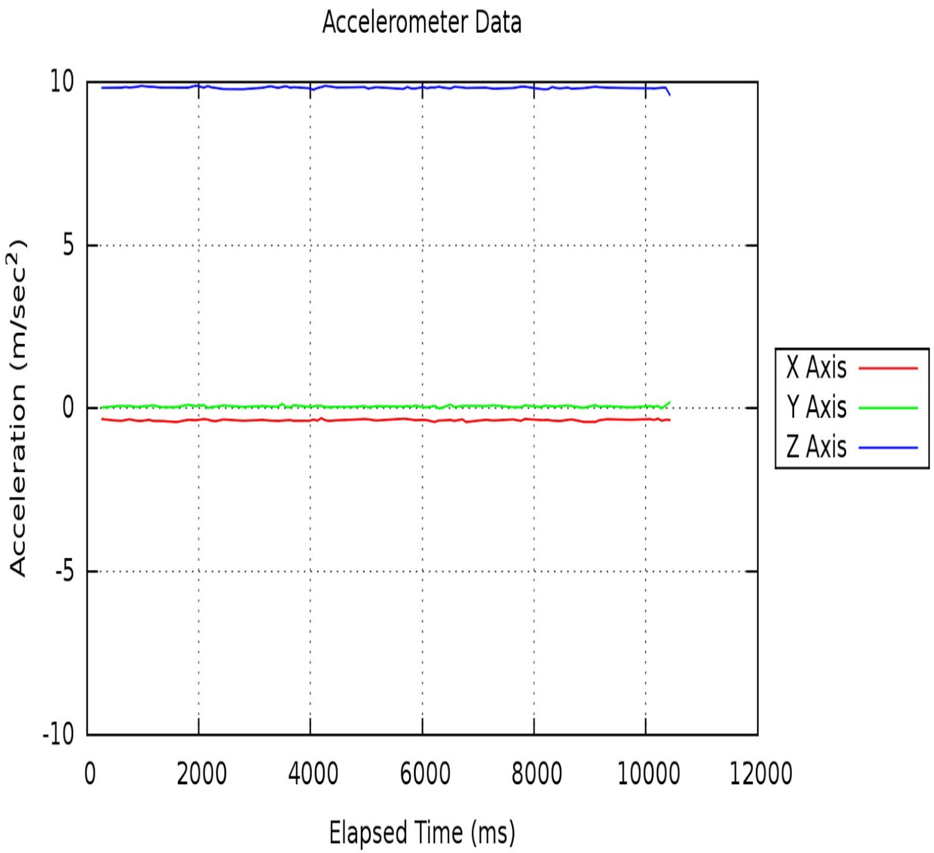
Data-set was captured with device laying flat on it's back



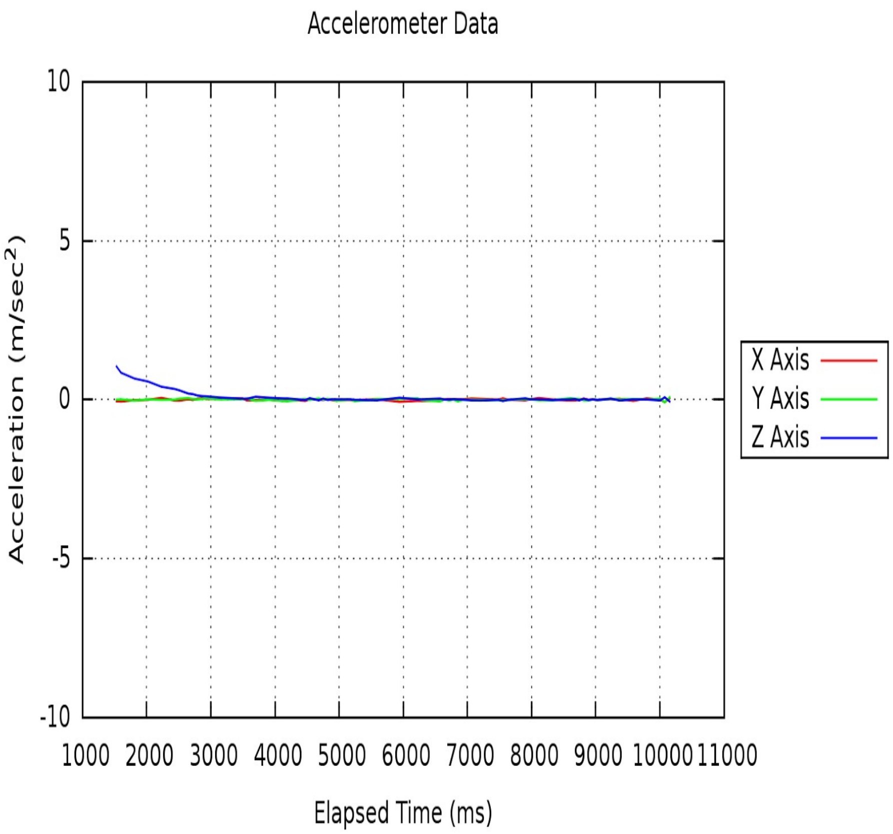


# Hardware + Filter Example

Raw Data



Filtered Data



# Types of Sensor Data

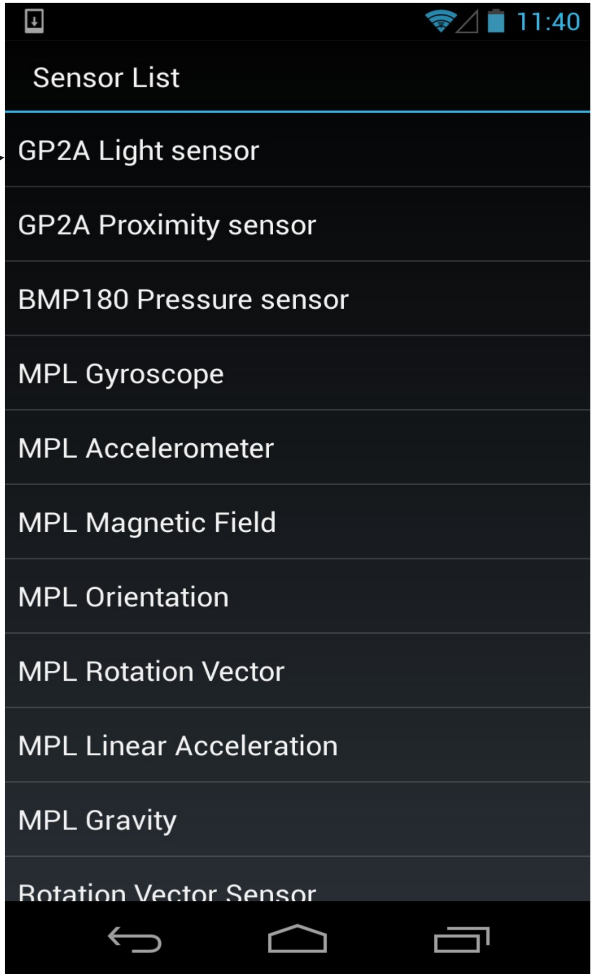
Device sensors can provide three types of data:

- Environmental
  - Monitor conditions of the external environment
- Motion
  - Detect/determine the movement of a device
- Position
  - Determine the position and orientation of a device

# Environmental Sensors

- Ambient Temperature
  - Room Temperature
- Ambient Light
  - Illumination
- Atmospheric Pressure
- Relative ambient air humidity
- Device Temperature
  - Device temperature
  - Worked differently across devices
  - Deprecated in favor of Ambient temperature

# Demo: Live Sensor Data



Sensor List

GP2A Light sensor

GP2A Proximity sensor

BMP180 Pressure sensor

MPL Gyroscope

MPL Accelerometer

MPL Magnetic Field

MPL Orientation

MPL Rotation Vector

MPL Linear Acceleration

MPL Gravity

Rotation Vector Sensor

Light Sensor

Pressure Sensor

# Motion Sensors

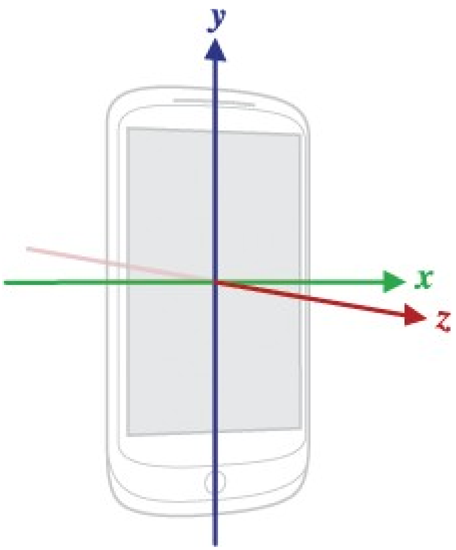
- Accelerometer
  - Force and direction of acceleration (3-axis)
- Gravity (Software)
  - Isolates force of gravity by passing accelerometer data through a low-pass filter
- Linear Acceleration (Software)
  - Isolates acceleration data by passing accelerometer data through a high-pass filter

# Motion Sensors Cont.

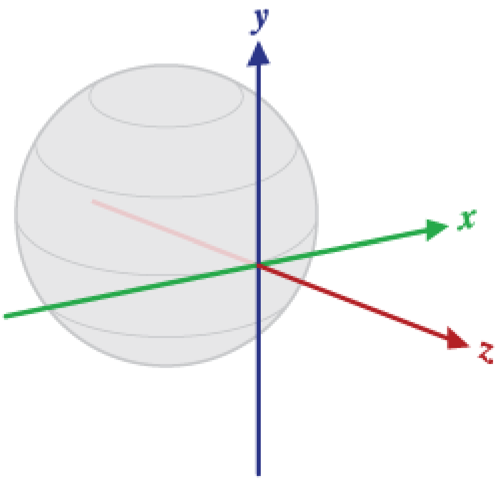
- Gyroscope
  - Angular speed around an axis (rate of rotation)
- Rotation Vector (Software)
  - Uses accelerometer, magnetometer and gyroscope to determine orientation of device

# Coordinate Systems

Device Coordinate System



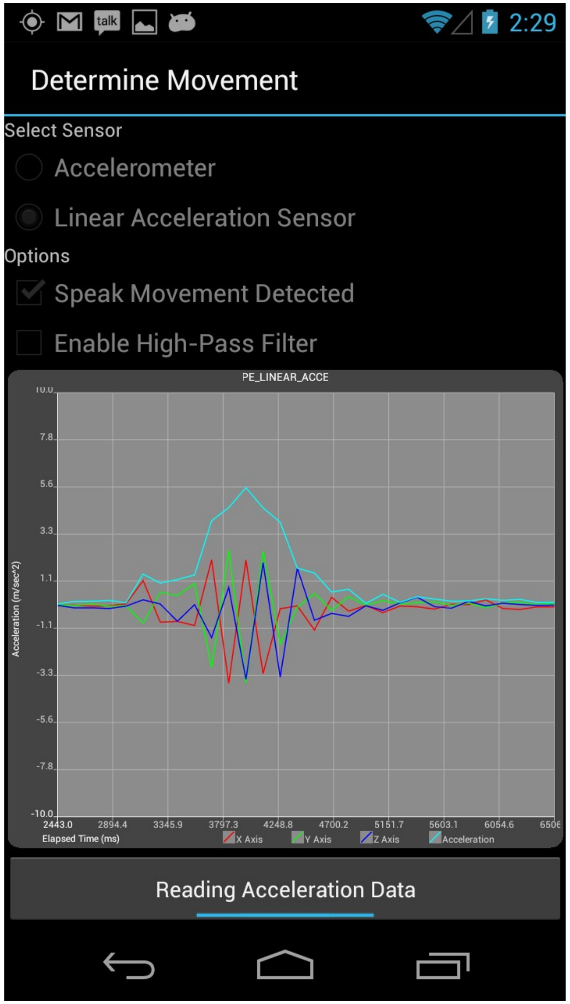
Global Coordinate System



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

# Demo: Detecting Movement

- Detects movement using accelerometer and linear acceleration sensors
- Conditionally passes data through a high-pass filter
- Computes total acceleration to detect movement (same algorithm can be used to detect shake)



Determine Movement

Select Sensor

○ Accelerometer

● Linear Acceleration Sensor

Options

☑ Speak Movement Detected

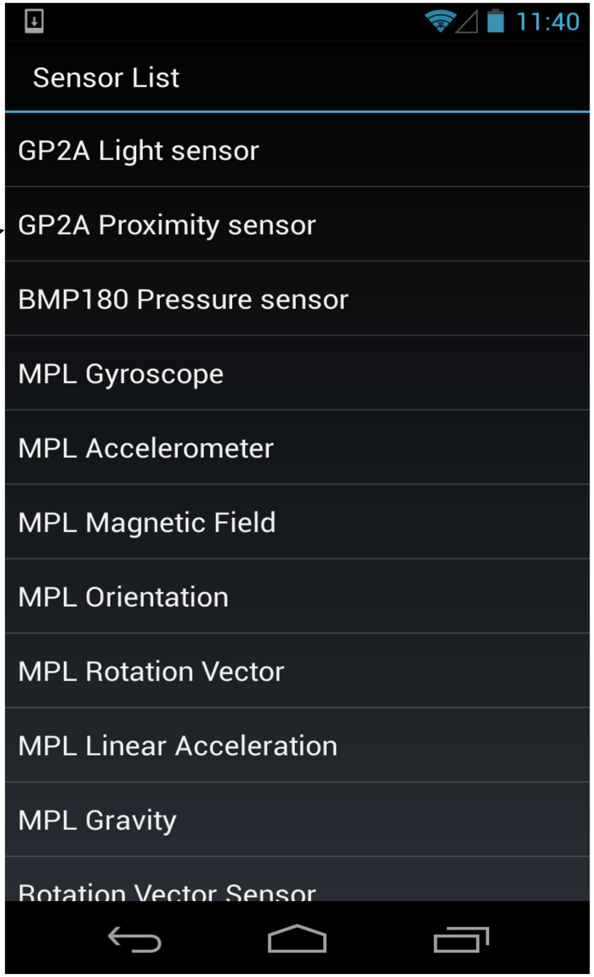
□ Enable High-Pass Filter

Reading Acceleration Data

# Position Sensors

- Magnetic field
  - Geomagnetic field for x, y and z axis
- Proximity
  - How close an object is to the front of a device
- Orientation (Software, deprecated)
  - Computes the azimuth, pitch and roll of a device

# Demo: Proximity Sensor

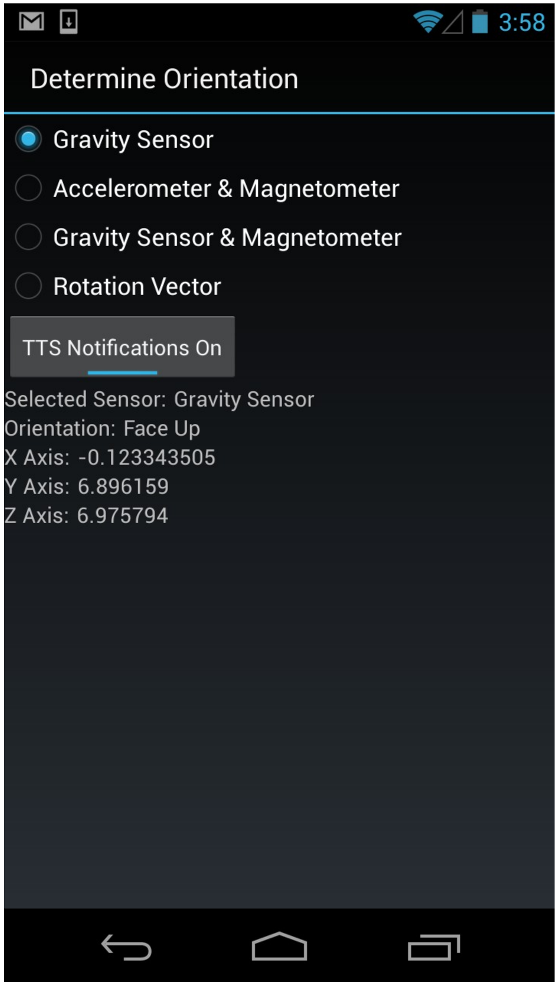


Sensor List

- GP2A Light sensor
- GP2A Proximity sensor
- BMP180 Pressure sensor
- MPL Gyroscope
- MPL Accelerometer
- MPL Magnetic Field
- MPL Orientation
- MPL Rotation Vector
- MPL Linear Acceleration
- MPL Gravity
- Rotation Vector Sensor

Proximity Sensor

# Demo: Determine Orientation



Determine Orientation

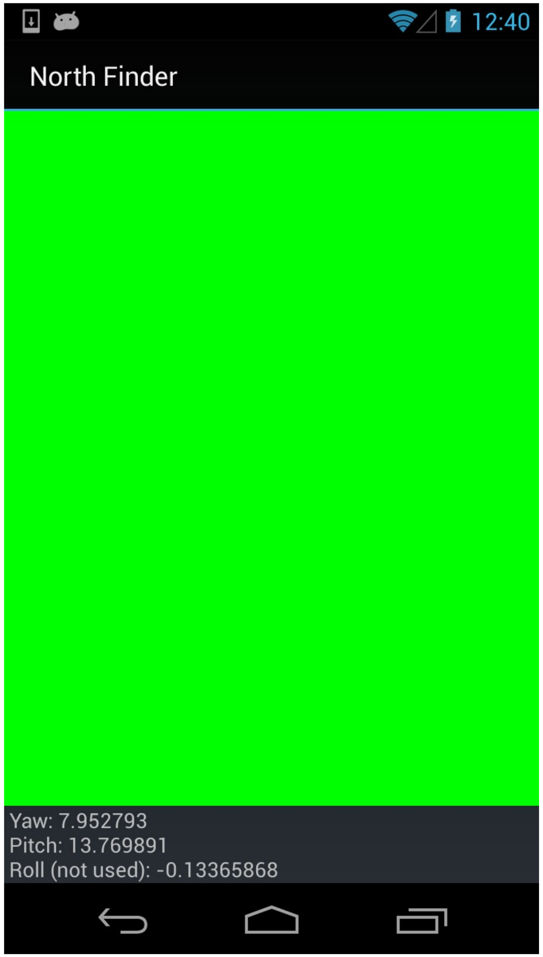
● Gravity Sensor
○ Accelerometer & Magnetometer
○ Gravity Sensor & Magnetometer
○ Rotation Vector

TTS Notifications On

```
Selected Sensor: Gravity Sensor
Orientation: Face Up
X Axis: -0.123343505
Y Axis: 6.896159
Z Axis: 6.975794
```

- Use different approaches to determine if device is face-up or face-down
- Provide insight to data

# Demo: North Finder



```
Yaw: 7.952793
Pitch: 13.769891
Roll (not used): -0.13365868
```

- Indicates when phone's camera is pointed within 20 degrees of north.
- Basis for augmented reality app.
- Direction of camera is determined using the rotation vector sensor

# Problems with Sensor Data

- Drift
  - Slow wandering of values that are read
- Noise
  - Random fluctuation of a measured value
- Zero Offset (Bias)
  - Constant value applied to sensor readings
- Time Delays/Dropped Data
  - A busy device can cause incorrect timestamps, or dropped data.

# Handling Sensor Error

- Re-zeroing
  - Re-calibrate offset that is applied to sensor data
- Sensor Fusion
  - Combining data from multiple sensors
- Filters
  - Low-Pass
  - Filters out high-frequency noise
  - High-Pass
  - Emphasizes higher-frequency/transient components
- Use of software sensors
  - Many already use fusion and/or filtering

# Summary

- Android provides multiple different sensors which apps can utilize
- Prefer software sensors over hardware sensors
- Sensor API usage pattern is very similar to the Location API usage
- After you access the sensor data, the real work begins

# Audio Analysis

Goal: Analyze audio recordings captured from microphone

Analyze:

- Amplitude only
- Raw audio

# Example: Clapper

# MediaRecorder API

```
int getMaxAmplitude()
```

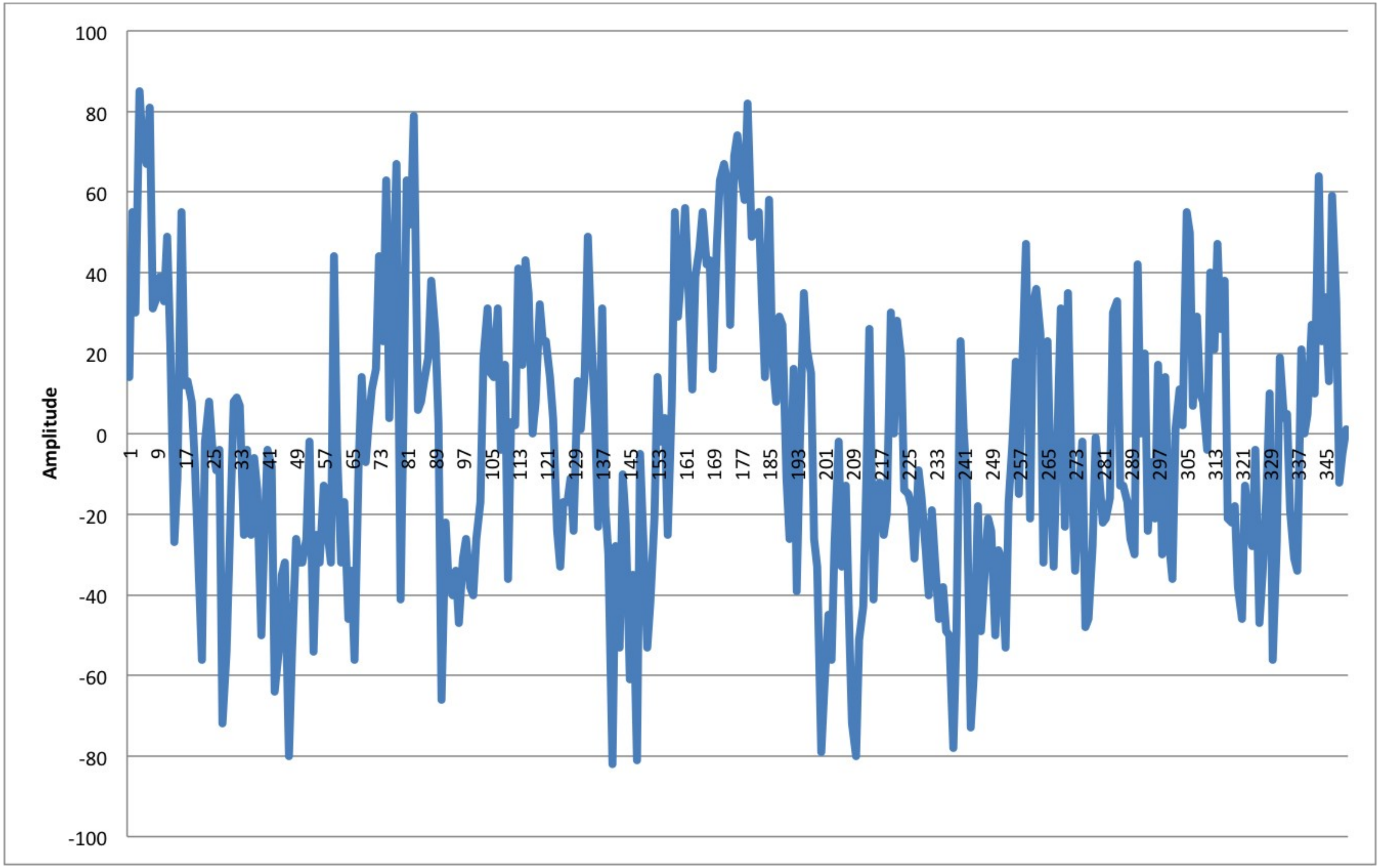
Returns the maximum absolute amplitude that was sampled since the last call to this method.

# MediaRecorder Usage

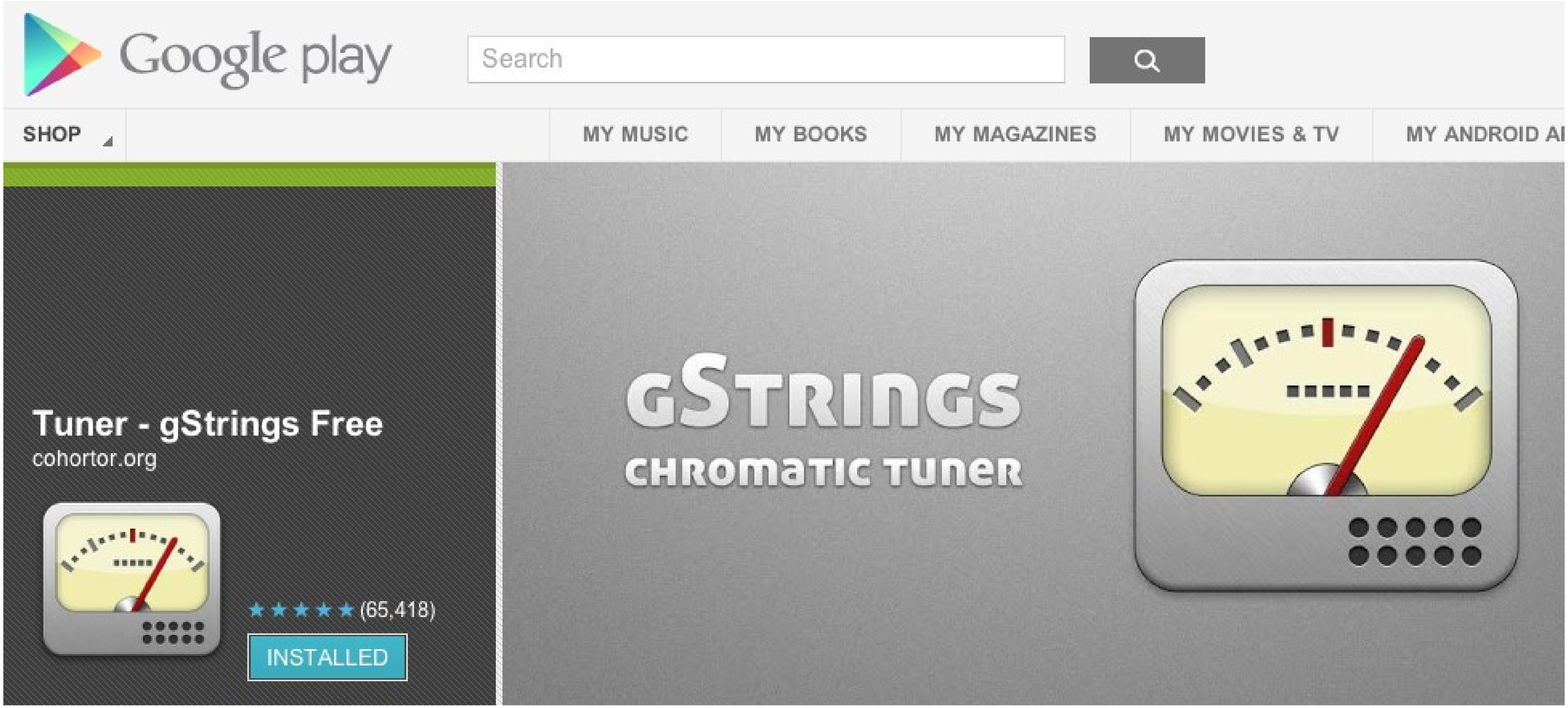
```
MediaRecorder recorder = prepareRecorder();

while (continueRecording) {
 waitClipTime();
 int maxAmplitude =
    recorder.getMaxAmplitude();
 continueRecording = process(maxAmplidue);
}
```

# Recorded Audio



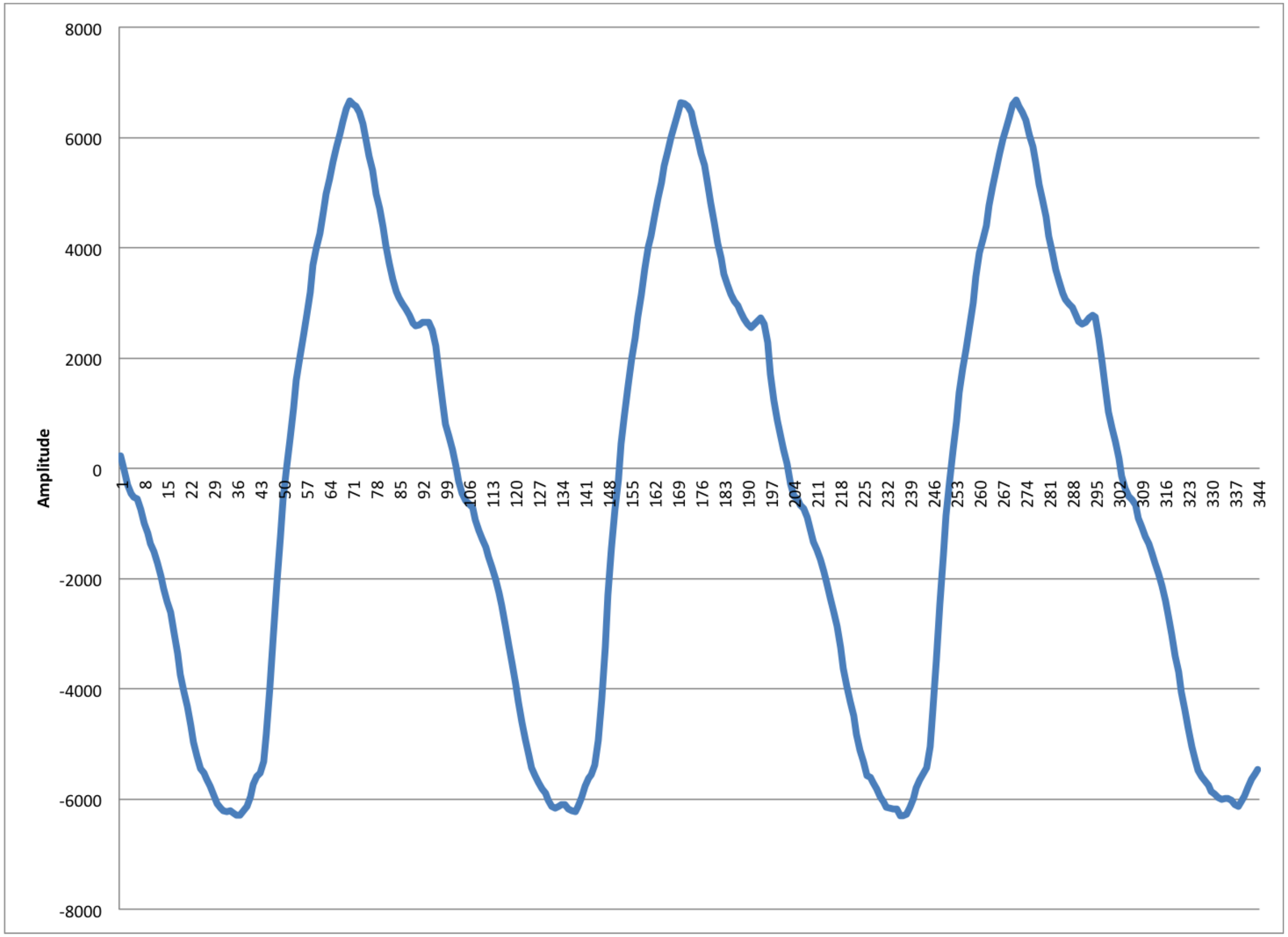
# Example: Guitar Tuner



# Calculate Volume: Root Mean Squared

```
private double rootMeanSquared(short[] nums)
{
    double ms = 0;
    for (int i = 0; i < nums.length; i++)
    {
        ms += nums[i] * nums[i];
    }
    ms /= nums.length;
    return Math.sqrt(ms);
}
```

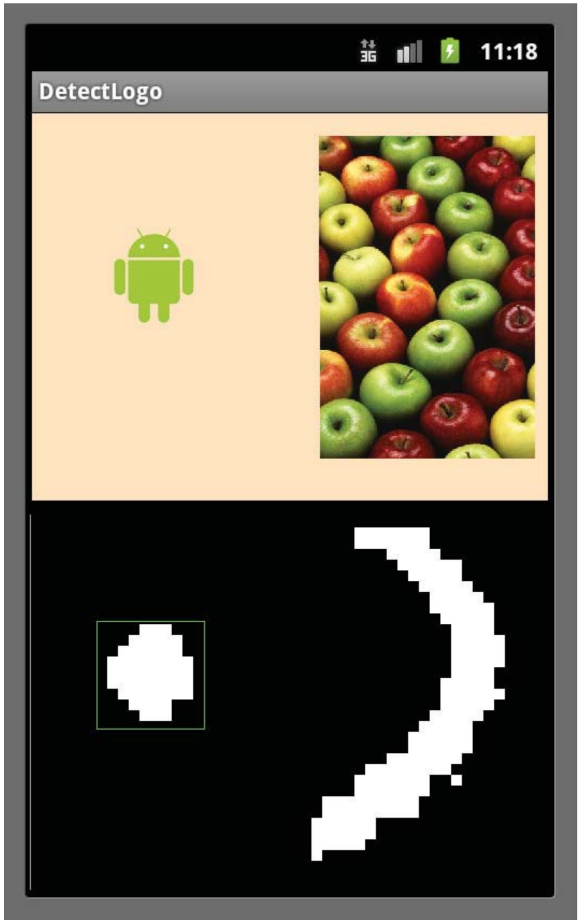
# Estimate Frequency: Zero Crossing



# Demonstration

# Images

Goal: Analyze images from camera



# Image: How it works

- Control the camera
  - Focus
  - Work with phone hardware
- Process image efficiently
  - Make it smaller
  - Convert to black and white
- Detect
  - Find biggest continuous block

# Converting to gray

```
RgbAbsDiffGray radg = new RgbAbsDiffGray(Color.GREEN);

Gray8Threshold g8t = new Gray8Threshold(-48, true);

mSeqThreshold = new Sequence(radg);

mSeqThreshold.add(g8t);
```

# Demo: Logo detection

# Speech Commands

Goal: Understand your spoken commands

Challenge: Recognize hard to recognize words

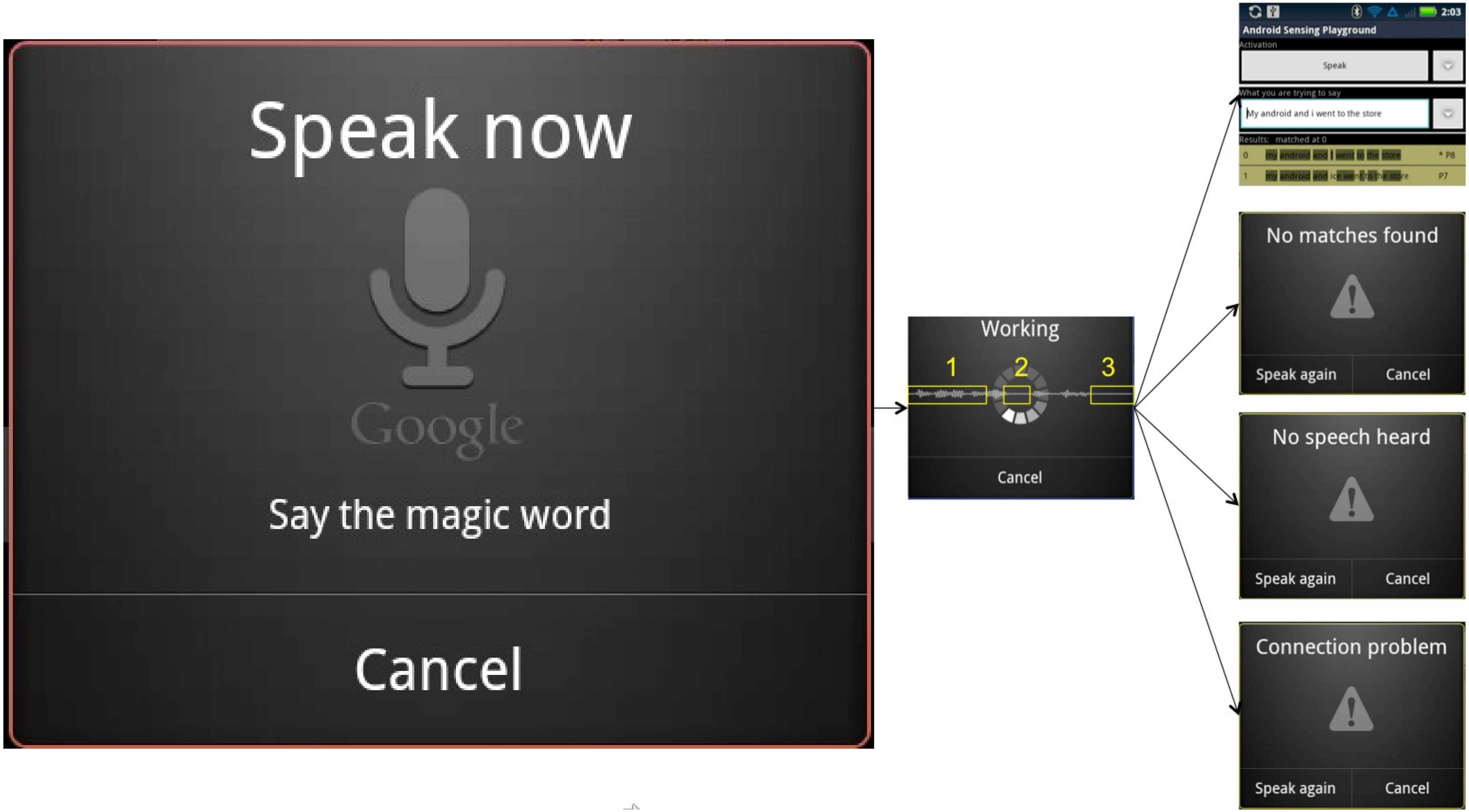
# Collect speech with: RecognizerIntent

```
Intent intent = new Intent
(RecognizerIntent.ACTION_RECOGNIZE_SPEECH);


intent.putExtra
(RecognizerIntent.EXTRA_LANGUAGE_MODEL,
RecognizerIntent.LANGUAGE_MODEL_WEB_SEARCH);


intent.putExtra
(RecognizerIntent.EXTRA_PROMPT,"Speak");
```

# Android collects speech using dialogs and beeps



Speak now

Say the magic word

Working

No matches found

No speech heard

Connection problem

Android Sensing Playground

Activation: Speak

What you are trying to say: My android and i went to the store

Results: matched at 0

| | | |
|---|---|---|
| 0 | my android and i went to the store | * P8 |
| 1 | my android and ice went to the store | P7 |

# Recognition Results

```
protected void onActivityResult(int requestCode, int resultCode, Intent
data) {
        if (requestCode == VOICE_RECOGNITION_REQUEST_CODE){
            if (resultCode == RESULT_OK) {
                List<String> heard =
                        data.
                        getStringArrayListExtra
                                (RecognizerIntent.EXTRA_RESULTS);
                //Your code here
            }
        }
    }
```

# Challenge:

Example recognition results:

"how much human"

"how much for a min"

"how much cannon"

"how much Human"

"how much planning"

# Phonetic Matching

Cumin (C550)

Cumen (C550)

Kingman (K525)

Komen (K550)

Canon (C550)

Cannon (C550)

Human (H550)

Time (T5000)
Thyme (T500)
Whine (W500)
Mind (M530)

# Demos

Android Sensor Playground

# NFC

Goal: Quick access to features

How:

- Write custom tag data
- Register to start when user scans tag

# Characteristics of NFC tags

- Different storage sizes
  - Not much (Enough for a URL)

- Robustness
  - Survive a washer cycle?
  - Sticker

# Write tag data with MIME type as JSON

```
private NdefMessage createNdefFromJson(){
 String mimeType= "application/root.gast.speech.activation"
 byte[] mimeBytes = mimeType.getBytes(Charset.forName("UTF-8"));
 byte[] id = new byte[0];
 byte[] data = new byte[0];
 NdefRecord record =
  new NdefRecord(NdefRecord.TNF_MIME_MEDIA, mimeBytes, id, data);
 NdefMessage m = new NdefMessage(new NdefRecord[] { record });
return m;
}
```

# Respond to tag scan with MIME type

```
<activity android:name=".speech.activation.SpeechActivationNfcTagReceiver"
>
  <intent-filter>
    <action android:name="android.nfc.action.NDEF_DISCOVERED" />
    <category android:name="android.intent.category.DEFAULT" />
    <data android:mimeType="application/root.gast.speech.activation" />
  </intent-filter>
</activity>
```

# NFC Demo

IT assets tracking

# Combinations of sensors: NFC, Speech Timer

1. Scan NFC
2. Trigger speech recognition
3. Timer goes off and says the time

# Great Android Sensing Toolkit (GAST)

Code:

http://www.github.com/gast-lib

App (the name is Android Sensor Playground):
https://play.google.com/store/apps/details?id=root.gast.playground&hl=en

# Contact Info

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