Smartphone Hardware Sensors

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Zeitmaschinen – Smartphone Sensors
Overview

- Accelerometer
- GPS
- Gyroscope
- Magnetometer
- Luxmeter
- Microphone
- Proximity Sensor
Accelerometer

- Measures **proper acceleration** (acceleration it experiences relative to *freefall*), felt by people or objects
- **Units**: m/s\(^2\) or g
- Most **smartphone** accelerometers trade large value range for high precision, iPhone 4 range: ±2g, precision 0.018g

<table>
<thead>
<tr>
<th>Example</th>
<th>G Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing on earth at sea level</td>
<td>1g</td>
</tr>
<tr>
<td>Bugatti Veyron from 0 to 100 km/h (2.4s)</td>
<td>1.55g</td>
</tr>
<tr>
<td>Space Shuttle, maximum during launch and reentry</td>
<td>3g</td>
</tr>
<tr>
<td>Formula 1 car, peak lateral in turns</td>
<td>5-6g</td>
</tr>
<tr>
<td>Death or serious injury</td>
<td>50g</td>
</tr>
<tr>
<td>Shock capability of mechanical Omega watches</td>
<td>5000g</td>
</tr>
</tbody>
</table>

Example G Force
Accelerometer

- Acceleration is measured on 3 axes

- Orientation of sensor (and coordinate system) varies among different devices
Accelerometer

- Space flight accelerometer:

- Smartphone accelerometer (piezoelectric):
Location sensors detect the location of the smartphone using either

- **GPS**

- Lateration/Triangulation of **cell towers** or **wifi networks** (with **database** of known locations for towers and networks)

- Location of **associated** cell tower or wifi network
GPS

- Connection to 3 satellites is required for 2D fix (latitude/longitude), 4 satellites for 3D fix (altitude)
- More visible satellites increase precision of positioning
- Typical precision: 20-50m, maximum precision: 10m
GPS

- **Caveats**
  - GPS will not work **indoors**
  - GPS quickly **kills** your **battery**
  - A location **fix** takes a **long period of time** (30s...12m), **A-GPS** helps
  - **Buildings** **reflect** and **occlude** satellite **signals** — thereby reducing precision of positioning in **urban environments**

- Smartphones can try to automatically select the best-suited **alternative** location provider (gps, cell towers, wifi), mostly based on **desired precision**
Gyroscope

- Detects the **current orientation** of the device, or **changes in the orientation**
- **Precisely**: orientation can be **computed** from the **angular rate** that is detected by the gyroscope, expressed in rad/s on 3 axis:
Gyroscope

- **iPhone 4**: MEMS (microelectromechanical system) gyro: displacement of vibrating proof mass

Source: [http://www.ifixit.com/Teardown/iPhone-4-Gyroscope-Teardown/3156](http://www.ifixit.com/Teardown/iPhone-4-Gyroscope-Teardown/3156)
Magnetometer

- Measures the **strength** of earth’s magnetic field
- **Strength** is expressed in **tesla [T]**
- iPhone 4 magnetometer range: ±2mT

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<tr>
<th>Example</th>
<th>Field strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth’s magnetic field on the equator (0° latitude)</td>
<td>31µT (0.00031T)</td>
</tr>
<tr>
<td>Typical fridge magnet</td>
<td>5mT (0.005T)</td>
</tr>
<tr>
<td>Strong neodymium magnet</td>
<td>1.25T</td>
</tr>
<tr>
<td>MRI system</td>
<td>1.5T – 3T</td>
</tr>
</tbody>
</table>

- **Pro tip**: prolonged exposure to a fridge magnet decalibrates your iPhone 4’s magnetometer for at least a week ;-)
Magnetometer

- Smartphones provide raw magnetometer data and a computed compass bearing

Applications

- **Compass**, of course – rotate maps/interfaces/graphics according to bearing
- **Tricorder**, detect magnets, force fields, klingon shield strength ;-)

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Demo