Sensors and Mobile Devices

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Deriving the Where and Why of Motion.
Sensors

- **Sensors: Connecting Users and Devices**
  - The way for a machine to understand the user
Sensors

• Connecting with ‘Hidden Interfaces’
  – Keyless car unlocking with proximity
    • Walk to the car and it unlocks
  – Spinning around with AR
    • To see around you
  – Siri and asking a question
    • Lift phone to start Siri
  – Walk to a thermostat
    • It detects your arrival
Sensors

- Connecting
  - Phone connects to Wifi at home
  - Checkins at your favorite café
    - Automatic based on location
  - Turn off phone calls in car
    - Set to “driving” mode
  - Location based clothing ad’s
    - Get coupon for jeans when shopping for jeans.
Sensor solutions

- Require Sensors, Software and Systems
  - Sensors detect the world
  - Software interprets and understands
  - Systems provide the user experience
Sensor Software

- Consumer sensors
  - Need corrections for drift

- Software corrections
  - Makes up for deviations in sensors
  - “Save a dime and fix it in software”

- Separates the wheat from the chaff
  - Rejecting spurious touches of palm or cheek
  - Correcting for sensor drift
  - Rejecting corner cases: bad GPS in cities
  - Ignoring bad magnetic environments: elevator
Mobile phone sensors

How many sensors in a SmartPhone?

Source: Internet
Mobile phone sensors

- Accelerometer
- Gyroscope
- Magnetometer
- Barometer
- Proximity
- Light sensor
- Touch screen
- GPS
- WiFi
- Bluetooth
- GSM/CDMA Cell
- NFC: Near Field
- Camera (front)
- Camera (back)

14 sensors!
Capacitive Touch

- Capacitive Touch Sensors
  - The most obvious sensor, but so invisible.
  - Touch is so fundamental

- Innovations
  - Proximity detection: ~30cm
  - Machines can know when you are near.
  - Phones can sleep when away and wakeup before you can touch.
Proximity: Touchless Touch

- Advanced touchless interfaces
  - Sony Xperia Sola
    - Tracks 3D motion of finger above the screen
    - Up to 22mm
  - Eyesight™ Gesture Tech
    - Uses camera & machine vision algo
    - Detects swipes, taps, and waves without touching.
Proximity: Touchless Touch

• Optical Proximity Sensor
  – Measures distance to nearest surface based on amplitude of received signal

• Multiple Sensors
  – detect motion in two axes
Accelerometer

- Measures gravity in the world frame and dynamic acceleration in the body frame.
- If the device is still, however, we only see gravity.
- Then we can easily measure tilt.

\[
\begin{align*}
\bar{a}_{\text{body}} &= \frac{d^2}{dt^2} \bar{p}_{\text{body}} - \mathbf{R}_{\text{body}}^{\text{world}} \; \mathbf{g}_{\text{world}} \\
&\cong -\mathbf{R}_{\text{body}}^{\text{world}} \; \mathbf{g}_{\text{world}} \; \text{(when still)}
\end{align*}
\]
Accelerometers

• Its really three sensors in one
  – Vibration sensor
  – Tilt sensor
  – Position sensor (coarse)

• Used to measure:
  – Portrait-landscape Orientation
  – Orient maps with compass
  – Pedometry (step counting)
  – Tilt and turn games
Gyroscope

- Gyros don’t measure angle!
  - They measure the rate of change
  - Body rates: rotation about each axis
- Rates are relative to a starting point, so one must know the start to know the end.
  - Depend on Accel/Mag for start
- Integrate to get angle
Magnetometer

- Used to measure rotation
- Absolute orientation reference for gyroscope
- Vastly differing technologies:
  - Hall effect, AMR, Magneto-Impedence, Spin Tunnel Junction

Note: An earth field is about 350mG.
Note: 10mGauss = 1uTesla.
Barometer

- Measures altitude relative to reference point

![Barometer Chart](Sensorsmag.com)

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Floor detection in ST building in Castelletto, Italy
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![Baseline Chart](Melexis.com)
Cameras

- Most smart phones have two cameras
  - Front & Rear
- Used for
  - Computer Vision
  - Attitude
  - Augmented Reality
  - Face detection for focus
  - Smile detection
Cameras

- **Augmented Reality**
  - It’s like a game portal into the real world
  - Data is overlaid on reality as seen through the camera
  - Can provide:
    - travel tips based on location
    - ads based on a page code

- **How?**
  - Need position and orientation
  - GPS for world position
  - XL/MG for heading/elevation
Microphone

- All phones have one microphone
- Many have three microphones
- Cancellation of background noise
- Beam steering for voice focusing
Virtual Sensors

- Fused combinations of sensors
  - Accel + Mag + Gyro + Baro
- Results
  - Attitude
  - Heading
  - Translation
- Context for the user
  - In hand. On Table. In Car.
  - In Elevator. On Train. Walking.
Crowd-sourced sensors

- **Waze** – Traffic crowd sourcing
  - Share velocity/position info between drivers for better routing

- **iShake / QuakeCatcher**
  - Crowd-sourced acceleration data to detect epicenter
  - Detects quakes in seconds

- **WiFi navigation maps**
  - Track and correlate GPS/WiFi
  - Build and heal WiFi fingerprint maps
Indoor Navigation

- Indoor is tricky
  - GPS is too weak; multi-path
- Alternatives
  - GSM: 50-100m
  - WiFi: 10-20m
  - BlueTooth: 10-20m
  - Inertial: <10m for <1min
- WiFi first proven in 2001
- Implementation is hard
  - Need location databases
  - Apple, MSFT, Google are building these
  - Many others are close
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Sensors are everywhere

- **Biometric Ear Buds (Apple patent)**
  - Measure: blood oxygen, body temp, heat flux, heart rate

- **Smart garments/shoes (Apple patent)**
  - Measure location and report to your phone over bluetooth

- **Thermostat**
  - Tracks your use and presence in the house; auto-adapts
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Thank you

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Deriving the Where and Why of Motion.
Pedestrian Dead Reckoning

- **PDR**: Pedestrian Dead Reckoning
  - Adds constraints that improve INS
  - Bounds the velocity estimate based on periodicity in walking motion
  - Sensors are typically placed on shoes to get zero velocity
  - Advanced algorithms can handle hand-held motion

Source: Thesis of Sidney P. Kwakkel

Source: TasteOfHome.com
Value chain

Accelerometer
Gyroscope
Magnetometer
Touch screen
GPS Navigation

Image: Invensense