The Promise of MEMS to LBS and Navigation Applications

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Status of RF Technologies

- **GNSS**
  - GPS
  - GLONSS
  - Galileo
  - QZSS
  - COMPASS
  - IRNSS

- **Alternatives to GNSS**
  - Cellular Technology
  - Wireless Sensor Network
    - WiFi
    - IMES

- **GNSS + Wireless Technologies**
  - Assisted GPS
  - Enhanced GPS
  - Ultra Wide Band
With the increased number of satellites, more sophisticated GNSS receivers, and new wireless alternatives, consumers will be able to operate in a wider range of conditions (outdoor/indoor).

However:
- GNSS - Not always available and inaccurate due to multipath
- Wireless (Wi-Fi, cell location…):
  - Infrastructure is expensive and not always present
  - Sparse networks or poorly surveyed networks are inaccurate
Status of Inertial Technology

Size/Performance/Price

- **Nav**
  - Expensive ($20k+) & not portable

- **Tactical-I**

- **Tactical-II**

- **Consumer**
  - Micro-Electro-Mechanical Systems (MEMS)
  - Low-cost & inaccurate

Now
Harnessing the Power of Sensor ....

- GPS
- Magnetometer
- Accelerometers
- Barometer
- Gyros
- Wi-Fi
- Cameras
- E.g. Samsung Galaxy Note
  - ST Micro. 3-gyroscopes
  - Kionix 3-accelerometers
  - Bosch barometer
  - Broadcom GPS
  - High resolution camera
- Processor
  - 1.5 GHz ARM
  - Android OS 2.3
  - 20-100 Hz sensor data
- Other Android devices such as Samsung Galaxy Nexus and Motorola Xoom phones are all have similar capabilities
Challenges Facing MEMS for Portable Navigation Applications
A user should be able to operate their mobile device in any orientation w.r.t. their body or vehicle frame while navigating.

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<tr>
<th>Limitation of Current Technology</th>
<th>Solution</th>
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<tbody>
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<td>Current solutions using sensors &amp; wireless require constraining or tethering of the mobile to the platform in a defined orientation. E.g. fixed to belt or dash-mounted.</td>
<td>The misalignment between the moving platform frame (e.g. person or vehicle) and mobile device frame is continually corrected so the device can be used without constraints.</td>
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A user should be able to operate their mobile device when walking, driving or on other moving platforms (e.g. subway) while navigating.

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<td>Current solutions using sensors for navigation are application specific and use different algorithms for walking and driving.</td>
<td>Optimal algorithms are chosen based on autonomous detection of walking or driving. Furthermore, when driving, the algorithms can accept any available vehicle sensor information to improve the navigation results.</td>
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The user should be provided with a seamless navigation solution in all scenarios and environments, even for long periods without any wireless positioning updates (e.g. from GPS, Wi-Fi, cell).

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<td>Traditional navigation solutions drift very quickly w.r.t. time when navigating with sensors only and without wireless updates.</td>
<td>Advanced sensor error modelling and intelligent application of platform motion updates provide large enhancements when navigating without wireless updates, even for long durations.</td>
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Example: A MEMS-based Accelerometer along the vertical direction (cost = $2-3)
Possible Ways to Improve the Positional Accuracy?

- Use of additional velocity aiding in body frame
  - Zero Velocity Update (ZUPT) when possible
  - Non-holonomic constraints
  - Odometer

- Integration Filter Level - Advanced Algorithm
  - Unscented Kalman filter (UKF)
  - Integration of EKF/UKF and Artificial Neural Network (ANN)

- Sensor Level (multi-sensors, barometers, mags)

- Backward Smoothing
Portable

Mobile advertising

Mobile device and user orientation

Tracking applications

Trusted Positioning
Special thanks to our test subjects!
Samsung Galaxy Nexus: invensense MPU-3050 gyroscopes, BMA180 accelerometers, BMP085 barometer, and SiRF Star IV GPS
Indoor Navigation with Samsung Galaxy Nexus

- 9 minutes indoors without GPS or WiFi, multi-floor, stairs (up/down), elevator (up/down), total travel distance about 450 metres distance
- Maximum error of 6 metres, ~1.5% error of distance travelled
Samsung Note Indoor Elevation Estimation - Calgary

2nd Floor

1st Floor (Elevator Stop)

Indoor Ground Floor

Inside Elevator

3.9m

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Vehicle

Assisted driving & enhanced safety

Trusted Positioning
**$100 T-VN vs $40,000 System**

- **GPS-only** > 100 metres
- **T-VN real-time (GPS+ 1G + 3A + OBDII)** < 5.9 metres 95%
- **DGPS/INS**: 1-2 m 95% in post mission

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DGPS/INS: 1-2 m 95% in post mission
Smartphones - INS-only Performance

- 55 metres of error after 7 minutes and 2,200 metres distance travelled (about 2.5% of the traveled distance) – NO speed sensors
MEMS inertial sensors have shown promising performance today for both mobile and vehicle applications.

Testing of smart phone level MEMS-based sensors and Trusted Positioning sensor fusion software clearly shows that MEMS-based inertial sensors can meet the requirements for indoor LBS, consumer navigation applications and vehicle assisted driving applications.
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