Future trends in pervasive positioning

Prof. Heidi Kuusniemi
Department of Navigation and Positioning,
Finnish Geospatial Research Institute,
National Land Survey, Finland

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Agenda

- Introduction
- Key trends in positioning
- Different positioning technologies and accuracy
  - GNSS, WLAN, inertial, visual, acoustic, LiDAR, RFID
  - Enhancements: sensor fusion, map matching, cooperation
- Threats
- Conclusions
  - the future for reliable positioning
Introduction (1)

- The full capabilities of civilian Global Positioning System (GPS) were made public only around 15 years ago.
- Today, nearly every mobile app employs it.
- The total number of Global Navigation Satellite System (GNSS) devices in use is about 5.8 billion units (GNSS Market Report 2017, GSA), and it is predicted to grow to almost 8 billion by 2020—more than one device per person on the planet.
Introduction (2)

Satellite navigation market segments

Source: European GNSS Agency’s GNSS Market Report 2017
Satellite navigation related revenue

Source: European GNSS Agency’s GNSS Market Report 2017

Cumulative revenue by segment 2015-2025

Different market segments have different operation environments and requirements for accuracy and reliability.
Positioning/timing play a key role in several broad technology trends

- Internet of Things
- Ubiquitous positioning
- Big Data
- Augmented reality
- Crowdsourcing for LBS
- Automated Vehicles
- Geo-fencing
- Geolocation for emergency services
- mHealth
- Smart Cities

GNSS = Global Navigation Satellite Systems
PNT = Position, Location, Time

Source: European Space Agency
New and emerging GNSS trends by market segment (1)

- **LBS**: More and more smartphones integrate multi-constellation GNSS
- **Road**: GNSS helps answers the need of Autonomous Driving (AD) for reliable and accurate positioning.
- **Aviation**: The aviation market continues to increasingly rely on GNSS, including rotocraft and unmanned vehicles
- **Search and Rescue (SAR)**: Beacon manufacturers are developing solutions for Aircraft Distress Tracking leveraging GNSS
- **Timing & Sync**: GNSS timing is at the core of many critical infrastructures, including telecoms, energy, finance

Source: European GNSS Agency
New and emerging GNSS trends by market segment (2)

- **Rail**: GNSS-enabled solutions can offer enhanced safety for lower cost, e.g. in railway signaling
- **Maritime**: GNSS has become the primary means of obtaining PNT information at sea
- **Agriculture**: GNSS applications represent a key enabler for the integrated farm management concept
- **Surveying**: Falling device prices drive the democratisation of mapping

Source: European GNSS Agency
Positioning technologies

- GNSS functions mainly in open sky environments but the majority of potential users are in urban and indoor conditions where GNSS usage is limited (w.r.t. LBS & Road).

- With rapid advances in sensor technologies and wireless communications, various positioning methods and systems have been developed.

- Determining the locations of moving objects with different accuracy:
  - Typically satellite-based positioning outdoors.
  - Typically WLAN and self-contained sensors indoors.
Positioning technologies (2)

Reliable positioning is needed despite the situation

- Dense forests, urban and indoor environments

- While exposed to jamming or spoofing
Positioning technologies (3)

Sensors
- Accelerometers
- Gyroscopes
- Digital compasses
- Camera
- Microphone

Radio signals
- GNSS
- Bluetooth
- RFID/NFC
- WLAN
- Cellular network & Digital TV
GNSS

Accuracy around 5 m with consumer-grade devices (code) and centimeter-level with professional devices and reference networks (phase)

- Low-cost consumer receivers use only code-based range for positioning
- Carrier phase observations and reference networks enable higher accuracy
Next generation GNSS (1)

- The future European **Galileo**, the Russian **Glonass**, and the Chinese **BeiDou** are similar systems with the U.S. **GPS**
- Also **GPS** is being modernized: civil and military signals on new frequencies (L2 and L5)
With improved features and more satellites and frequencies, multi-GNSS leads to improved availability, accuracy, and reliability.
# GNSS for Mobile Precise Positioning

**FinnRef**

![Map of Finland with GNSS and PPP-RTK points](image)

## Key Benefits

<table>
<thead>
<tr>
<th></th>
<th>DGNSS</th>
<th>RTK</th>
<th>PPP with SSR</th>
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<tbody>
<tr>
<td><strong>Professional Accuracy</strong></td>
<td>0.5 m</td>
<td>Up to 0.05 m</td>
<td>~0.1 m</td>
</tr>
<tr>
<td><strong>Mass-Market Accuracy</strong></td>
<td>1 m</td>
<td>0.5 m</td>
<td>0.5 m</td>
</tr>
<tr>
<td><strong>Well standardized in professional use</strong></td>
<td>Existing and freely available service</td>
<td>Well standardized in professional use</td>
<td>Improved privacy, low server load</td>
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</table>

**DGNSS** = Differential GNSS  
**PPP** = Precise Point Positioning  
**RTK** = Real Time Kinematic  
**SSR** = State Space Representation
WLAN fingerprinting (1)

- Positioning requires two steps:
  - Generation of a “fingerprint” database based on the statistical distribution of received signal strength indicators (RSSI)
  - Estimating the position the real-time RSSI measurements, database, and an appropriate algorithm (e.g. nearest neighbor search)

Accuracy around 5-10 m (depending on the amount of available base stations)

Colour = signal strength
WLAN fingerprinting (2)

Conferest localization app at #FIGWW2017 based on WLAN fingerprinting (HERE positioning technology)
Inertial sensors

- Inertial sensors continuously measure specific force (from which acceleration can be deduced) and rotation rates, from which position, velocity, and attitude can be derived.
- Inertial sensors need periodic updates from absolute positioning systems.

**Accuracy varies: 1 cm - kms**

![Diagram of sensor coupling types]

- **GNSS code and carrier range and phase measurements**
- **Raw GNSS RF signals**
- **Processed GNSS PVT**
- **INS acceleration and angular velocity**
- **Tightly-coupled**
- **Deep/Ultratightly-coupled**
- **Loosely-coupled**
- **Position**
- **Velocity**
- **Orientation**
Visual Positioning

1. Image databases give an absolute position of the user:
   - Database of images attached with position information
   - Images matched to the images in database
   - When a match is found, the position is inferred.

2. User heading and translation/odometry can be observed from consecutive images
   - Heading+translation used to provide relative positioning (similar to inertial sensors)

Accuracy around 5 m (depending on the quality of database or lighting)
Acoustic Positioning

Transmitter \((x, y, z)\) (near-field sound source)

Accuracy around 1 m

Source: Ling Pei et al., FGI
LiDAR for improved positioning

- Light Detection And Ranging (LiDAR) has high accuracy in ranging, wide area view and low data processing requirements.
- Transmitting a laser pulse and calculating distance to surrounding constructions based on the signal return time.
- Reliability is highly dependent on the distance and reflectivity of different objects.
- Robust to light conditions.
- Increasingly found in vehicles.
- Cost a significant drawback.
RFID in positioning

- Radio Frequency Identification (RFID) is a wireless radio technology
- Provides information about RFID tag’s proximity, carried by the user, to the RFID reader => requires infrastructure
- Can be used locally as complementary positioning technology in some specific points (e.g. tunnels)
- Positioning performance is dependent on the RFID technology used and of the density of the RFID reader network
Sensor Fusion

- Data fusion = mathematical tools for combining measurements

Peyret F. (2013), Standardization of performances of GNSS-based positioning terminals for ITS (Intelligent Transport System) applications
Cooperative positioning

- Peer-to-peer and cooperative positioning bring together capabilities of Satellite Navigation and Communication Systems
- Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication are key enablers
More than just position information...

Results of indoor and outdoor positioning systems

## Threats to positioning

### GNSS Vulnerabilities

- **Jamming**: Broadcast of an interference signal.
- **Spoofing**: Broadcast of synthetic GNSS signals to try to trick a GNSS receiver.
- **Meaconing**: Re-broadcast of real satellite signals after a brief delay in order to create errors in the GNSS receiver.
- **Un-intended narrowband and wideband interferences**.

### Non-GNSS Vulnerabilities

- **Database intentional and unintentional corruption**: many non-GNSS positioning methods rely on some training databases; outliers or fake data in such databases can corrupt the location estimate.
- **User privacy**: most network-centric location solutions make the user vulnerable to various privacy leaks or theft of location information.
- **Other malicious attacks on the physical or virtual infrastructure of the localization engine**.
Conclusions – reliable navigation in the future (1)

- Means for navigation and positioning:
  - Signals intended for navigation
    - Multi-GNSS
  - Other radio navigation systems
    - Dedicated WLAN, Bluetooth, RFID tags and UWB emitters
    - Self-contained sensors
  - Signals of Opportunity
    - Not intended for positioning but freely available
      - WLAN, Bluetooth, Cellular, DTV, AM, FM, (5G?)
  - Natural signals
    - Magnetic field, gravity
    - Landmarks
Conclusions – reliable navigation in the future (2)

- Accuracy, availability and reliability
  - Sufficient accuracy to support autonomous vehicles
    - Carrier-phase utilization of GNSS
    - Inertial measurement units
  - Interference resilience
    - Backup-systems
  - Seamless positioning from outdoors to indoors
- Interoperability among different location-based services and providers
  - Mobile users should receive useful information services independently of their current location and LBS provider
- Protection of personal location information and information security of localization
Thank you!

@KuusniemiHeidi
@robguinness

heidi.kuusniemi@nls.fi
robert.guinness@nls.fi