Precise GNSS Positioning – *Not just a niche technology*

Chris Rizos

Precise Positioning... *what does it mean?*
Precise Positioning... a spectrum of users...

Precise Positioning is an “augmented accuracy” form of positioning with performance over-and-above that provided by the “standard” GNSS service. Precise Positioning is a civilian innovation that addresses the needs of certain market segments.
**GNSS Error Sources**

- Satellite Clock
- Satellite Orbit
- Ionospheric Delay
- Tropospheric Delay
- Antenna Phase Centre
- Receiver Clock

The methods (& their effectiveness) used to mitigate or eliminate these error sources **distinguish** the different classes of Precise Positioning.

**GNSS Market Segments...**

**SoL, Mission/Liability Critical**
- Aviation
- Rail
- Maritime & inland waterways
- Ambulance / Police / Fire
- Search & Rescue
- Personal protection
- Dangerous goods transport
- ERP, tolls

**Mass Market**
- Personal mobility
- Cars, trucks & buses
- Geosense, telematics & LBS
- Tracking
- Personal outdoor recreation, sport
- IoT, others...

**Professional**
- Mining, port operations & machine guidance
- Timing
- Advanced ITS
- Geodesy & science
- Meteorological
- Mapping
- GIS
- Surveying
- Precision agriculture
- Offshore engineering / hydrography
- Construction / Civil engineering
- Space & POD

**High integrity** (error-free)
- High inter-operability, inter. & industry stds

**Low cost**
- Low power cons., small size, ease of use, ubiquitous, consumer electronics, etc

**High accuracy**
- Complex HW/SW, expensive, CORS infrastructure
Precise GNSS Positioning Modes...

- **Augmented** GNSS, using PR measurements in “quasi-Single Point Positioning” mode, e.g. SBAS
- **High accuracy differential positioning**, using CPH measurements, e.g. RTK
- **High accuracy absolute positioning**, or Precise Point Positioning (PPP), using CPH measurements

All require contributions from terrestrial “base stations” (or CORS)... *Albeit with a variety of network configurations, HW, measurement algorithms, & service provision options*

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**Precise Positioning... variety of modes...**

- Baseline/network & RTK
- PPP
- SBAS

Few mm 1 cm 2 cm < dm 1 dm few dm sub-m

Science  
Surveying  
Engineering & construction  
Deformation surveys  
Datum  
Geodetic POD  
Machine automation  
CTF agriculture  
Offshore engineering  
Precision agriculture  
GIS  
Hydrography  
Mapping  
LPONL  
Disaster response  
ITS
Space-Based Augmentation System (SBAS)

Low-cost (HW & free SBAS signal access), single-frequency (i.e. L1), universal PR-based SPP (i.e. all chipsets SBAS-capable), seamless GEO satcoms (i.e. via Rx frontend), regional/national CORS (i.e. not global), designed for aviation (but non-aviation apps hamstrung by ICAO/RTCA approval processes)

Correction messages for atmospheric, orbit & sat clock errors (via GEO “GNSS-like” satcom link)
- Wide Area Augmentation System (WAAS) – U.S.
- Multi-functional Satellite Augmentation System (MSAS) – Japan
- Quasi-Zenith Satellite System (QZSS-L1Sa) – Japan
- European Geostationary Navigation Overlay System (EGNOS) – E.U.
- GPS-Aided Geo-Augmented Navigation (GAGAN) – India
- System for Differential Corrections & Monitoring (SDCM) – Russian Federation
- BDSBAS, and others

**Differential CPH-based Positioning**

DGNSS w.r.t. CORS... Real-time (RTK) or post-processing (baselines or network)
Differential CPH-based Positioning

GNSS Constellation(s)

High-cost technology, multi-freq, multi-GNSS, high-accuracy (i.e. CPH measurement modelling), considerable local CORS infrastructure (i.e. rapid AR), terrestrial comms, typically commercial services, address high productivity apps (i.e. DGNSS-RTK), availability issues (i.e. loss-of-lock & AR)

Local CORS Network

DGNSS w.r.t. CORS...
Real-time (RTK) or post-processing (baselines or network)

Precise Point Positioning

GNSS Constellation(s)

Precise GNSS Satellite Orbit & Clock Correction streams (Real-time link, via Satcom or internet)

Global CORS Network

Multi-freq CPH & PR measurements

Other models & files
**Precise Point Positioning**

High-cost technology, multi-freq, multi-GNSS, complex CPH measurement modelling, longer time-to-AR w.r.t. DGNSS-RTK (for standard PPP), modest global CORS infrastructure (for standard PPP), GEO satcoms (but also other options), high productivity (PPP-RTK) requires similar CORS density as DGNSS-RTK, proprietary commercial systems (but free IGS-RTS), same availability issues as other CPH-based techniques.

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**Precise Positioning... who uses it?**
GNSS Market Studies... what do they say?

All chipsets will be SBAS-capable... but very few will be multi-freq & support CPH-based PNT
ICG Experts Meeting: GNSS Services, Vienna, Austria, 15-18 December 2015

GNSS Revenue Predictions...

Cumulative core revenue 2013-2023

- Rail: 0.2%
- Surveying: 4.5%
- Agriculture: 1.9%
- LBS: 53.2%
- Road: 38.0%
- Maritime: 1.1%
- Aviation: 1.0%
- Timing Sync: 0.1%

LBS Trends

Almost 3 bin mobile applications currently in use rely on positioning information

Key market trends:
- The LBS market continues to grow with high-end devices now commonly making use of multi-constellation and hybrid positioning.
- The development of successful apps continues to drive the global growth of the smartphone market.
- Current sensor applications leveraging new location information make up almost half of the total, with games and entertainment representing the largest categories.

Apps

- Navigation, social networking, travel, games, entertainment, fitness and sports, health, etc.
- On average, more than 76 apps per device are downloaded by users, although titles of apps have not changed more than 11 for an app.
- Downloads of apps that rely on location data were 72.5bn in 2014, up from 2.2bn in 2014.

App stores

- Google and Apple dominate the app store market with more than 50 billion downloads combined from the two stores in 2013.
- Google has surpassed the Apple app store in terms of downloads and app store revenue, Apple prévu that higher margin in a state of low competition.

Total unique apps in store - December 2014

- Google Play: 1.2m apps
- Apple: 1.7m apps
- Windows Phone: 0.4m apps
- Amazon: 0.2m apps
- Blackberry: 0.1m apps

Market trends... but do they identify new markets (as opposed to new “apps”)?
Road transport market trends

New applications will double the size of the market in the next ten years

A look into the near future: GNSS supporting autonomous driving

Autonomous vehicles can take over a great deal of the work currently performed by humans, thanks to their ability to sense the environment, navigate, and, if combined with connected vehicle solutions, communicate with other vehicles and infrastructure. Widespread adoption of autonomous driving can reduce traffic accidents and improve traffic flow, as well as improve driver comfort.

Autonomous vehicles are enabled by the combination of different technologies and sensors, allowing the GNSS to identify the optimal path of action. GNSS plays a key role in providing relevant inputs for integrated navigation, such as vehicle location and speed. Multiple coordination, horizontal protection levels, and advanced detection techniques provided by common vision in GNSS will be combined.

Market trends... but is the past a good predictor of future markets?

GNSS Market Size Predictions...

Cumulative core revenue 2013-2023

Do these numbers tell the whole story?

Do these numbers even make sense?
**GNSS PP Benefits - Australia**

- Largest user group for DGNSS-RTK techniques
- High-cost, high CORS infrastructure requirements
- Recent study\(^1\) found productivity gains with potential *cumulative* benefit AUD$73B to $134B over next 20 years - *in agriculture, construction and mining alone*
- Also, significant *environmental benefits*, through greatly improved fuel efficiency, as well as improved safety through increased automation

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\(^1\)“Economic benefits of high resolution positioning services”, Allens Consulting Group, for CRC-SI & Vic. DSE, Nov 2008
Economic Benefits – Agriculture

• GNSS machine guidance (RTK) applied widely in the grain, cotton, sugar and other broad-acre agricultural sectors
• Use of “control traffic farming” (CTF) can significantly reduce input costs (fuel, labour, etc.), study findings:
  – Annual yields up 10%
  – Fuel and oil costs reduced 52%
  – Labour costs reduced 67%
• (Similar findings in other countries)
• Sub-metre “precision agriculture” via SBAS (or similar)
• Benefits also for specialised small-scale agriculture using “farm-robots”, e.g. vinticulture, orchards, etc.
• Increasing use also for livestock management

Economic Benefits – Construction, Surveying...

• In civil engineering, machine guidance via DGNSS-RTK can deliver significant increases in automation, accuracy, and improved on-site safety
• Productivity improved by as much as 30%
• No alternative technology for cm-level accuracy surveying, mapping & geodesy... e.g. techniques based on terrestrial line-of-sight (lasers, microwave) or ultrahigh-cost space techniques (SLR, VLBI, etc)
Precise Positioning... what about the future?

ITS is more a vision than a coherent program... Comprising many elements... harnessing ICT to improve future transport efficiency, safety & lower environmental costs...

Advanced ITS, C-ITS, ADAS are coming very soon... the “driverless vehicle”
Advanced ITS applications...

Positioning in vehicles is going from Passive to Active...
From supporting simple navigation to information about traffic to warnings about hazards to actively avoiding hazards to supporting self-drive modes

Need Precise & Reliable positioning, as well as Robust multi-sensor positioning...

GNSS techniques for Advanced ITS applications

<table>
<thead>
<tr>
<th>Technique Option</th>
<th>Status</th>
<th>Accuracy range</th>
<th>Cost</th>
<th>C-ITS applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Current</td>
<td>1-10 m</td>
<td>Low</td>
<td>Vehicle navigation, location-based services, road traffic management</td>
</tr>
<tr>
<td>B</td>
<td>Current SBAS Commercial WADGNSS</td>
<td>Future SBAS design for multiple-GNSS</td>
<td>0.1-1m (utilising SBAS and V2V relative positioning)</td>
<td>Low</td>
</tr>
<tr>
<td>C</td>
<td>Smoothed terrestrial DGPS</td>
<td>Smoothed DGNSS</td>
<td>0.1-1 m</td>
<td>Medium</td>
</tr>
<tr>
<td>D</td>
<td>RTK</td>
<td>Combined PPP and RTK (seamless)</td>
<td>0.01-0.1m</td>
<td>Medium to High</td>
</tr>
<tr>
<td>E</td>
<td>PPP</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Source: Feng, Higgins and Millner for ARRB, April, 2013)
Positioning requirements...

<table>
<thead>
<tr>
<th>Type</th>
<th>Level</th>
<th>Accuracy Requirement</th>
<th>Research prototype</th>
<th>Communication Latency (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V2I: absolute</td>
<td>Road-level</td>
<td>5.0 Metre</td>
<td>Metre</td>
<td>1.5</td>
</tr>
<tr>
<td>(V2I = Vehicle to</td>
<td>Lane-level</td>
<td>1.1 Sub metre</td>
<td>Sub metre</td>
<td>1.0</td>
</tr>
<tr>
<td>Infrastructure)</td>
<td>Where-in-lane-level</td>
<td>0.7 Decimetre</td>
<td>Decimetre</td>
<td>0.1</td>
</tr>
<tr>
<td>V2V: relative</td>
<td>Road-level</td>
<td>5.0 Meter</td>
<td>Sub metre</td>
<td>0.1</td>
</tr>
<tr>
<td>(V2V = Vehicle to</td>
<td>Lane-level</td>
<td>1.5 Sub metre</td>
<td>Decimetre</td>
<td>0.1</td>
</tr>
<tr>
<td>Vehicle)</td>
<td>Where-in-lane-level</td>
<td>1.0 Decimetre</td>
<td>Centimetre</td>
<td>0.01-0.1</td>
</tr>
</tbody>
</table>

All need some form of Precise Positioning... in both the “absolute” and “relative” sense


Its more than GNSS...

Multi-sensor systems

But GNSS is still essential for providing “absolute coordinates”, and to reference mapping data
**Its more than GNSS...**

But GNSS is still essential for providing "absolute coordinates", and to reference mapping data

**PP is more than a niche GNSS technique...**

- **Significant PP applications**
- **Expect increase use of GNSS PP in ITS (& other) applications**
- **Variety of PP modes provides considerable flexibility for current & new GNSS applications**