GNSS Precise Point Positioning

A Fad or the Future of Satellite Navigation and Positioning?

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IAG WG 4.5.2: Precise Point Positioning and Network RTK

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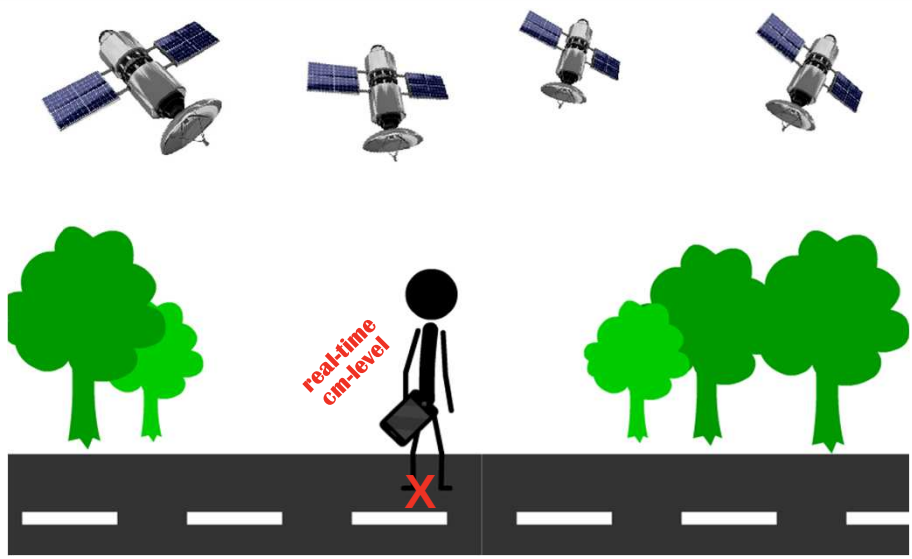
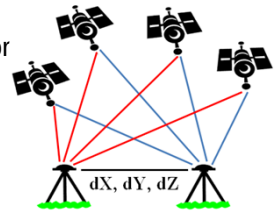
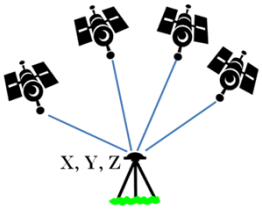


Imagine being able to turn on a GNSS receiver anywhere (outdoor) anytime and able to achieve centimetre level precision in real-time, without a GNSS base station and without having to connect to a CORS network.

Evolution of High Precision GNSS

- **1980s:** Early commercial single-frequency post-processing around early 1980s; Differential service for marine applications; Commercial dual-frequency around 1988
- **1992:** First commercial Real-Time Kinematic (RTK) solutions followed by Network RTK (NRTK)
- **Late 1990s:** Birth of Precise Point Positioning (PPP)
- **Now:** A hybrid system of "PPP-RTK"





High Precision GNSS Service Quality Matrix

GOOD	FAST	CHEAP

Source: Schrock (2013), ProSurv
Horvath (2012), PPP-RTK Workshop

Anatomy of PPP

- **Precise Point Positioning (PPP)** allows a dual-frequency GNSS user to determine position at the decimetre / centimetre error level in kinematic / static mode using precise satellite orbits and clocks

Standard Positioning Service

Broadcast orbit and clock information
+
User satellite tracking information
=
m-level user position estimates

Precise Point Positioning

Precise orbit and clock information
+
User satellite tracking information
+
Additional error modelling
=
dm- to cm-level user position estimates

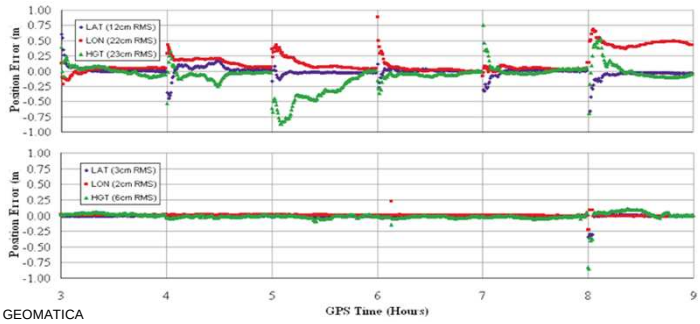
Use and Applications

- Commercial applications:
  - Trimble CentrePoint™ RTX™
  - NavCom Global StarFire™ Service
  - Fugro's Precise (Point) Positioning Service
    - XP, G2
  - Veripos Ultra (Ultra²) and APEX (APEX²) Service

PPP is **feasible** for positioning and navigation in **remote areas** or regions of **low GNSS reference stations**

Challenges in PPP

- PPP can be most certainly **CHEAP** and even **GOOD**, but the challenge lies in the realm of **FAST**
- Search for a "sweet spot", i.e., trade-offs between precision and convergence time
- Why can't PPP provide *instantaneous centimetre level* precision in real-time like RTK?



Source: Bisnath and Collins (2012), GEOMATICA

What is PPP-RTK? (1)

- **Two kinds of RTK:**

1. **Observation Space Representation (OSR)**
   - rely on "observations" (e.g., observations from a base station)
   - OSR describes lump sum of GNSS errors
   - example: RTK services use network of reference stations and RTK rovers use observations of reference station(s)

RTK-OSR

2. **State Space Representation (SSR)**
   - rely on "error states" products (e.g., clock, orbit, atmosphere models)
   - SSR describes each individual GNSS error
   - example: PPP uses observations of single GNSS receiver and state space information (e.g. IGS products) derived from global or regional network

RTK-SSR

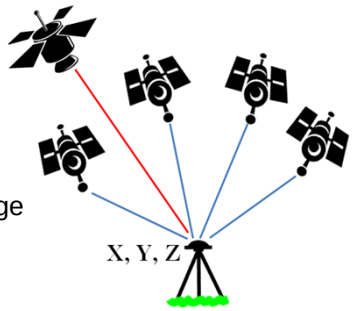
What is PPP-RTK? (2)

- **Distinction between PPP vs RTK**
  - **CORS network size**
    - RTK service: local, regional
    - PPP service: wide area, global
  - **CORS network dependence**
    - RTK user: No network = no solution
    - PPP user: What network?

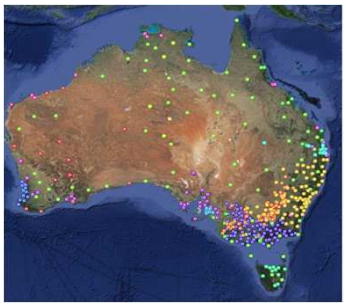
- **PPP-RTK ???**
  - Looks 'suspiciously' like RTK
  - Prefer the term RTK-SSR!!

Does PPP Have a Future?

- Low infrastructure
- Computationally effective
- Small data files (corrections) for transmission
- Changing GNSS landscape – Opportunities
  - new systems, new signals, new frequencies, ……
- Transmission of corrections from GNSS satellites, e.g., QZSS LEX (L6/E6) signal
  - similar to broadcasting navigation message



Do We Still Need CORS Network?



Terima Kasih
&
Thank you

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How Good is a PPP Solution?

Processing Mode	RMS (cm)		
	East	North	Up
Daily static	<0.5	<0.5	<1
Hourly static	~4	~2	~3
Post-processed kinematic	~5	~4	~10
Real-time kinematic	<10	<10	<20

Source: Geng (2010), PhD thesis

High Precision GNSS Service Quality Matrix

	RTK/NRTK	PPP	RTK-SSR/PPP-RTK
GOOD Precision/Accuracy	Centimetre	Decimetre	Centimetre
FAST Initialisation time	Fast initialisation	Long convergence	Fast initialisation
CHEAP Base station	Dense network	Sparse network	Dense network

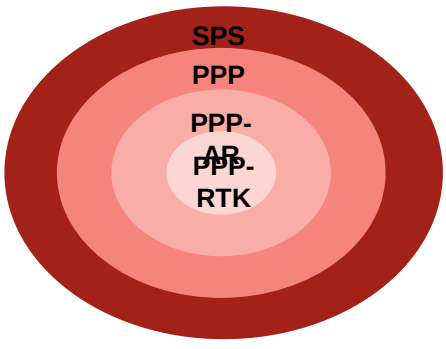
Source: Schrock (2013), ProSurv
Horvath (2012), PPP-RTK Workshop

Dilemma (trade-off):

- **GOOD** service **CHEAP** won't be **FAST**
- **GOOD** service **FAST** won't be **CHEAP**
- **FAST** service **CHEAP** won't be **GOOD**

PPP Scalability

- Broadcast orbits & clocks
  - SPS
- Precise orbits and clocks
  - PPP
- Precise orbits and clocks + hardware delays
  - PPP-AR
- Precise orbits and clocks + hardware delays + local augmentation (ionosphere)
  - PPP-RTK or PPP-ICAR



Source: Collins (2013), PPP Workshop

Will We Need New Rover Equipment?

Trimble Positioning Services

JOHN DEERE

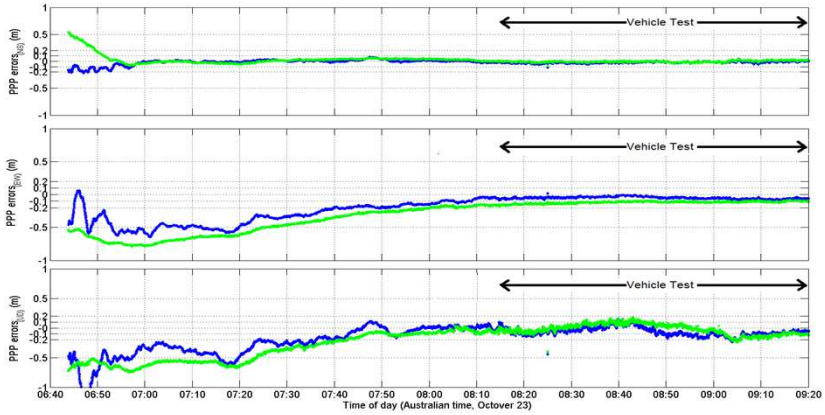
FUGRO

veripos ON TARGET

Real-Time Kinematic Test in Australia

- Date: 23 October 2013
- Location: Centennial Park, Sydney, Australia
- Reference frame: ITRF2008 → GDA94
- Observations: dual-frequency, GPS only
- PPP mode: real-time kinematic
- Orbits and clocks:
  - IGS (CLK11)
  - QZSS MADOCA (LEX signal transmission)
- NRTK: CORSnet-NSW
- Ground truth: NRTK solutions
- Vehicle speed: ~20 km/h

Real-Time Kinematic PPP Performance



	QZSS LEX (PPP)		IGS (PPP)	
	STD	RMS	STD	RMS
East (cm)	2	5	3	9
North (cm)	2	3	2	4
Up (cm)	8	10	6	7