



Hourly Precise Point Positioning with Ambiguity Resolution

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PPP: precise positioning at only a single station using GPS when precise satellite orbits and clocks are provided

Absolute positioning without any reference stations

Reduction of computation burden and financial cost





Position accuracy of Precise Point Positioning

Daily PPP estimates can achieve mm accuracy with real-valued ambiguities

Hourly PPP estimates can usually reach sub-dm accuracy with real-valued ambiguities

In relative positioning, estimates within 2 hours can achieve mm accuracy in EN and cm in H with integer ambiguities Ambiguity resolution to improve hourly PPP estimates

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In past studies, 99% of published documents about PPP did not attempt to resolve ambiguities

Ambiguity resolution in relative positioning



Differencing between satellites to remove errors in receivers: clock bias, hardware delays ...

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Double difference ambiguities are integers in estimation





Differencing between satellites to remove errors in receivers: clock error, hardware delays ...

How about errors in satellites?



Single difference ambiguities at a single station are not integers in estimation



Uncalibrated hardware delay (UHD): a bias originating in frequency oscillators in the receivers and satellites





Gabor et al (1999): theoretical model for determination of UHD; unstable UHD



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Laurichesse et al (2007): mix UHD with satellite clock estimates







Determination of UHD within each continuous tracking period of a satellite pair by a regional network

Convenient in practice, and still retain high precision











Network solution to determine UHD

>IERS conventions 2003
>Differential Code Biases
>Absolute phase centre variation & Phase wind-up
>Saastamoinen + Niell mapping function
>Horizontal tropospheric gradient

PPP to test ambiguity resolution at a single station

>IERS conventions 2003
>Differential Code Biases
>Absolute phase centre variation & Phase wind-up
>Saastamoinen + Niell mapping function

NOTE: Models should be consistent



LAMBDA (Least-squares AMBiguity Decorrelation Adjustment)



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Only ambiguities with averaged elevation angles larger than 15 degrees

Subset ambiguity resolution in case of possible biases in their real-valued estimates





Ratio values: index of reliability in ambiguity resolution



Ambiguity resolution at a single station is fairly reliable
Total fixing rate achieves 97.8%

Static test: accuracy improvement of position

Station	Float Solutions (cm)				Fixed Solutions (cm)				3D
	East	North	Up	3D	East	North	Up	3D	Improvement
BRUS	3.3	1.4	2.8	4.5	0.4	0.4	1.3	1.5	67.8%
CAGL	4.8	1.9	4.0	6.5	1.0	0.8	2.0	2.4	63.8%
DUBR	5.6	1.9	3.3	6.8	0.4	0.6	1.3	1.4	78.7%
GOPE	4.5	1.8	2.9	5.7	0.3	0.4	1.5	1.6	72.1%
GRAS	2.4	1.1	2.4	3.6	0.4	0.4	1.3	1.4	60.6%
HERS	4.1	1.3	2.4	5.0	0.3	0.4	1.2	1.3	74.1%
LAMA	3.8	1.5	2.6	4.8	0.7	0.6	1.4	1.7	65.1%
MAR6	3.3	1.6	2.3	4.3	0.7	0.7	1.5	1.8	58.7%
MAS1	5.4	1.4	4.6	7.2	0.5	0.6	2.5	2.6	64.0%
MDVJ	3.1	1.2	2.2	4.0	0.4	0.7	1.6	1.8	55.7%
NSSP	3.8	1.3	3.1	5.1	0.5	0.5	1.8	1.9	62.3%
POLV	4.0	1.9	3.0	5.3	0.4	0.5	1.7	1.8	66.2%
POTS	3.6	1.4	2.8	4.8	0.3	0.4	1.3	1.4	70.0%
REYK	4.0	2.0	3.2	5.5	0.5	0.6	2.2	2.3	58.2%
TRO1	1.5	1.1	1.8	2.6	0.3	0.3	1.2	1.3	51.6%
VILL	4.1	1.5	3.4	5.6	0.4	0.5	1.5	1.6	70.5%
ZIMM	3.1	1.2	2.4	4.1	0.4	0.4	1.2	1.3	68.2%
Total	3.9	1.5	3.0	5.1	0.5	0.5	1.6	1.7	66.1%

Improvement: East~87.2% North~66.7% Up~46.7%





Data from 1:36:32am to 7:36:32am on 27/11/2004

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Pre-determined precise baseline lengths between receivers



Kinematic test: baseline length differences (cm)



Improvement: Bias ~ 2.2cm - 0.3cm85.0%RMS ~ 2.6cm - 1.1cm57.1%



Determination of UHD

- Determine UHD within each continuous tracking period by a regional network
- > Inspect its feasibility on a larger or even global scale

Accuracy Improvement

- ➤ Hourly static positions: improved by up to 66%
- Kinematic baselines within one hour: improved by up to 57%
- Static horizontal components at sub-cm level & vertical ones better than 2 cm



Hourly PPP ambiguity resolution may lead to comprehensive applications of PPP in engineering and geosciences







Thank you for your attention!

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