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How to use free RTK Software?

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How can we set up RTK by ourselves?

- If you use commercial correction services or via satellites, you don't have to set up. All you need is just rover receiver and maybe software (receiver includes RTK engine).
- If you need to set up base stations by themselves, you can use RTKLIB or if you can prepare Ntrip caster, it is easy for you to conduct. Please contact us if you need any helps.

RTK Practice



- Post processing: Observation and Navigation data are required (RINEX).
- Real-Time: Communication link and differential data reception are required (RTCM/NTRIP).

2 receivers were set simultaneously

- Trimble NetR9 with Trimble antenna
- u-blox M8P with YOKOWO antenna

- For the equal comparison, same settings were applied.
- GPS/BEI + Instantaneous.

Similar test using u-blox

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u-blox M8P results



The performance of RTK : M8P is better than M8T (probably the PLL of M8P is more robust and precise than M8T...)

NetR9 results



RTKLIB (real-time : RTKNAVI)

- Connect <u>u-blox M8P</u>
- Execute RTKNAVI
- RTK was valid using NTRIP of base station (NetR9) via the same antenna under perfect condition (GQB).
- GQR was also valid but GLONASS ambiguity resolution is set OFF.

Please check them by yourself after you go back to home. If you need an information how to set the reference station, please refer to the website (GNSS TUTOR).

http://www.denshi.e.kaiyodai.ac.jp/gnss_tutor/experiment.html

How to connect (my desktop)



RTKNAVI - Options

Type	Opt Cmd	Format	ġ	Opt
Serial	▼	u-blox	•	
NTRIP Client	•	RTCM 3	¥	
Serial	*	RTCM 2	-	410
				155
	Type Serial NTRIP Client Serial o Base Station 0.00000000	Type Opt Cmd Serial Image: Client Image: Client	Type Opt Cmd Format Serial 	Type Opt Cmd Format Serial Image: Constraint of the series

If you set GQR and it doesn't fix, please try it again by changing the setting of Integer Ambiguity Res "OFF".

Options	×	Options		X	Options
Setting <u>1</u> Setting <u>2</u> Output Statistics P	Positions Files Misc	Setting1 Setting2 Output Statistics	Positions Ei	es <u>M</u> isc	Setting1 Setting2 Output Statistics Positions Files Misc
Positioning Mode	Kinematic 🔹	Integer Ambiguity Res (GPS/GLO/BDS)	Cont 🔻 C	FF - ON -	Lat/Lon/Height (deg/m) 👻
Frequencies / Filter Type	L1 Forward	Min Ratio to Fix Ambiguity	3.0		90.000000000 0.00000000 -6335367.6285
Elevation Mask (°) / SNR Mask (dbHz)	15 🔻	Min Confidence / Max FCB to Fix Amb	0.9999	0.20	Antenna Type (*: Auto) Delta-E/N/U (m)
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Ionosphere Correction	Broadcast 🔹	Min Fix / Elevation (°) to Hold Amb	10	0	Base Station
Troposphere Correction	Saastamoinen 💌	Outage to Reset Amb / Slip Thres (m)	5	0.050	Lat/Lon/Height (deg/m) 💌
Satellite Ephemeris/Clock	Broadcast 🔹	Max Age of Diff (c) / Sume Solution	20.0		35,666334610 139,792200800 59,7410
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Excluded Satellites (+PRN: Included)		Number of Filter Iteration	1		Station Position File
🔽 GPS 📃 GLO 📄 Galileo 🔽 QZSS	SBAS BeiDou	Baseline Length Constraint (m)	0.000	0.000	
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u-blox M8P DGNSS (GB)





Limited Coverage of RTK

- Normally, the coverage of RTK is 10-20km. It strongly depends on the *ionospheric activity*.
- But, the recent commercial RTK engine can cover up to <u>50-100km</u>.
- Also, you can use <u>VRS/FKP correction service</u>. The commercial company produces real-time correction data (Ntrip) using several base stations.
- <u>QZSS will provide similar correction data through</u> <u>the L6 signal (inside Japan). It is challenging because</u> <u>message bit-rate is 2Kbps.</u>

PPP does not have limitation in area

- PPP provides precise orbit and clock of GNSS.
- It means that you have to remove <u>ionospheric/tropospheric errors</u> as much as possible. It takes <u>5-30 minutes</u> and depends on the ionosphere model you have.
- QZSS is going to test PPP correction data through the L6 signal. In fact, we have tested it for serval years by JAXA (MADOCA).

RTKLIB Practice (2)

Car data and field test

- Car data is post-processed using RTKLIB
- Homework
- RTK field test using u-blox M8P (8 groups)

Car data

- 2017/7/19 8:24:20 8:57:20 (GPST)
- Total 9900 epochs in 5Hz
- Near university campus (normal urban)
- <u>u-blox M8T</u> and <u>Trimble NetR9</u> for both Rover and reference station
- You can compare these two receivers
- Single-frequency or dual-frequency ?
- What is the best setting ?

Settings of u-blox M8P

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Frequencies / Filter Type	L1 T Forward T	Min Ratio to Fix Ambiguity	3		90.00000000 0.00000000 -6335367.6285
Elevation Mask (°) / SNR Mask (dBHz)	15 🔻 🛄	Min Confidence / Max FCB to Fix Amb	0.9999	0.25	Antenna Type (*: Auto) Delta-E/N/U (m)
Rec Dynamics / Earth Tides Correction	OFF V OFF V	Min Lock / Elevation (°) to Fix Amb	0	0	♥ 0.0000 0.0000 0.0000
Ionosphere Correction	Broadcast 👻	Min Fix / Elevation (°) to Hold Amb	10	0	Base Station
Troposphere Correction	Saastamoinen 💌	Outage to Reset Amb/Slip Thres (m)	5	0.050	Lat/Lon/Height (deg/m) 🔻
Satellite Ephemeris/Clock	Broadcast 🔹	Max Age of Diff (s) / Sync Solution	30.0	01	35.666334610 139.792200800 59.7410
		Max Age of Diff (s) 7 Sync Solduori	30.0		Antenna Type (*: Auto) Delta-E/N/U (m)
		Reject Threshold of GDOP/Innov (m)	30.0	30.0	- 0.0000 0.0000 0.0000
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GPS GLO Galileo QZSS	SBAS V BeiDou	Baseline Length Constraint (m)	0.000	0.000	

PLOT



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If you remove QZS,

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If you use NetR9,



If you use dual-frequency,

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Comparing two POS files (RTKPLOT)



What happens if you click "1-2"?

RTKPLOT 1-2





- Please try to find the best setting of RTKLIB using the <u>u-blox data</u> (both ref and rover).
- "Best" means <u>highest number of fixes within 30cm</u> <u>based on POSLVX file.</u>

Simultaneous data is required



PPP (Precise Point Positioning)

• Feature

- with Single Receiver (No Reference Station)
- Efficient Analysis for Many Receivers
- Precise Ephemeris
- Conventionally Post-Processing

Applications

- GPS Seismometer
- GPS Meteorology
- POD (Precise Orbit Determination) of LEO Satellite
- Precise Time Transfer

Static PPP vs Kinematic PPP

Kinematic PPP Station: IGS CONZ (Chile)



2010/2/27 6:28-6:45 GPST Interval: 1 s

Static PPP Station: GEONET 0837



2009/1/1-2009/12/31 Interval: 1day

PPP using RTKLIB

- I will use 24h raw-data/15s interval of NetR9 same as precious test.
- If you need centimeter level, you should use dual-frequency receiver.
- You can download other files required in PPP as follows.

items	website
Precise ephemeris	ftp://cddis.nasa.gov/gps/products/mgex/1984/
Precise clock	ftp://cddis.nasa.gov/gps/products/mgex/1984/
Satellite antenna information	ftp://igs.org/pub/station/general/
erp file	ftp://cddis.nasa.gov/gps/products/mgex/1984/

PPP static setting

RTKPOST ver.2.4.3 b26	x
Time Start (GPST) Time End (GPST) Interval Unit 2018/03/16 06:27:00 2018/03/16 08:29:32 1 s 24]н
RINEX OBS ?	
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RINEX OBS: Base Station	
C:¥Users¥nobu¥2018¥共同研究¥ITSジャパン¥program¥glonass¥data¥5245kaiyodai.18c -	
RINEX NAV/CLK, SP3, FCB, IONEX, SBS/EMS or RTCM	
C:¥Users¥nobu¥2018¥GSPASE¥webinar¥data¥24h_15s¥ref.rnx	·
C:¥Users¥nobu¥2018¥GSPASE¥webinar¥data¥24h_15s¥gbm19845.sp3	• []
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PPP static results

(0,0,0) are the RTK fixed solutions based on F3/GEONET in GSI.



Past important questions

Multi-GNSS RTK



In total, 3+2+1=6 ambiguities have to be resolved. But, we actually need 9 satellites ! It also can be applied in RTKLIB

Required satellite number for reliable RTK

 We have to discuss the number of ambiguities because LAMBDA method strongly depends on the number of ambiguities. With more satellites, the reliability of AR increases.

Receiver	environment	Required
Dual-frequency	Open sky	5
	Urban	10
Single-frequency	Open sky	10
	Urban	20

There is a contradiction because the number of usable satellites in urban areas is sure to decrease compared with open sky areas...

Why is the availability of denseurban areas so bad ?



What is the best mode in RTK ? Or what do these modes mean ?

etting <u>1</u>	Setting2	Output	Statistics	Positions	<u>Files</u>	lisc
Intege	er Ambiguit	y Res (GP	S/GLO/BDS)	OFF 🔻	ON - ON
Min Ra	itio to Fix /	Ambiguity		0	OFF	
Min Confidence / Max FCB to Fix Amb				I	nstantaneo	0.25
Min Lock / Elevation (°) to Fix Amb					PP-AR	0
Min Fix / Elevation (°) to Hold Amb				1	0	0
Outage to Reset Amb/Slip Thres (m)				5	1	0.050
Max Age of Diff (s) / Sync Solution				3	0.0	ON
Reject Threshold of GDOP/Innov (m)				3	0.0	30.0
Max # of AR Iter/# of Filter Iter				1		1
Baseline Length Constraint (m)			0	.000	0.000	
Load)[Save		0	K Cancel	

Please remember that RTKLIB is not designed for the purpose of navigation under **dense-urban areas** although it can be used even in the raw-data obtained in urban areas.

Answer is actually difficult...

- Mr. Takasu developed those modes based on his own ideas. It means that there is no reference paper.
- I can say that "LAMBDA + Ratio test" are always used in RTK (kinematic).
- Each mode has each characteristics.

Kinematic modes	explanation
Instantaneous	Only single epoch observation data is used to resolve ambiguities
Continuous	Kalman Filter is used.
FIX and HOLD	Once the reliable correct ambiguities are resolved, those ambiguities information are retained.

Suitable test environment

Kinematic modes	Suitable test environment
Instantaneous	The accuracy of float solutions is like DGNSS. In the case of open sky condition, instantaneous mode should be OK. You can see the real performance of your receiver because if the accuracy of code-phase is not so good, you can't obtain the better RTK results.
Continuous	The accuracy of float solutions will be better as time passes without cycle slips. If you have many overpasses (which means cycle-slips), the RTK performance is similar to the instantaneous mode. Open sky and semi-urban: continuous > instantaneous Urban : continuous = instantaneous (maybe)
FIX and HOLD	The accuracy of float solutions will be same as continuous mode. The only difference is reliable correct ambiguities are retained. If these ambiguities are not correct, you will see wrong fixed solutions for a several time (be careful). Open sky and semi-urban: hold > continuous > instantaneous Urban : hold = continuous = instantaneous (maybe)

You need a reference system to evaluate RTK test results



RTK performance differs with the time



Any questions ?

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Actual Steps of RTK

- After this summer school, please check the followings regarding the process of RTK to deepen your understanding !
- 1. Generating "double difference"
- 2. Finding "integer ambiguities"
- 3. Baseline processing

1. DD (Double Difference)

$$\begin{split} \Phi_{ub}^{ij} &\equiv \lambda ((\phi_{u}^{i} - \phi_{b}^{i}) - (\phi_{u}^{j} - \phi_{b}^{j})) \\ &= \rho_{ub}^{ij} + c (dt_{ub}^{ij} - dT_{ub}^{ij}) - I_{ub}^{ij} + T_{ub}^{ij} + \lambda N_{ub}^{ij} + d_{ub}^{ij} + \varepsilon_{\phi} \\ &= \rho_{ub}^{ij} - I_{ub}^{ij} + T_{ub}^{ij} + \lambda N_{ub}^{ij} + d_{ub}^{ij} + \varepsilon_{\phi} \\ dt_{ub}^{ij} &= dt_{u}^{ij} - dt_{b}^{ij} = 0, \\ dT_{ub}^{ij} = dT_{ub}^{i} - dT_{ub}^{ij} \approx 0 \end{split}$$

(short Baseline and same

antenna type)

 $I_{ub}^{ij} = I_{ub}^i - I_{ub}^j \approx 0, T_{ub}^{ij} = T_{ub}^i - T_{ub}^j \approx 0, d_{ub}^{ij} = d_{ub}^i - d_{ub}^j \approx 0$

 $B_{\mu b}^{ij} = (\phi_{\mu 0} - \phi_{0}^{i} + N_{\mu}^{i}) - (\phi_{b 0} - \phi_{0}^{i} + N_{b}^{i}) - (\phi_{\mu 0} - \phi_{0}^{j} + N_{\mu}^{j}) + (\phi_{b 0} - \phi_{0}^{j} + N_{b}^{j}) = N_{\mu b}^{ij}$

Without reference station,

it is impossible to remove "receiver And satellite clock error" completely ! Generate new observation which means double difference.

> Why do we say the baseline limitation of RTK ? (10-100 km or more) It strongly depends on each RTK engine !



Memo for Misra & Enge: http://gpspp.sakura.ne.jp/ diary200608.htm

2. Integer Ambiguity Resolution

$$P_{rov_ref}^{sv1_sv2} = r_{rov_ref}^{sv1_sv2} + \varepsilon_{p,rov_ref}^{sv1_sv2}$$

$$\phi_{rov_ref}^{sv1_sv2} = r_{rov_ref}^{sv1_sv2} + N_{rov_ref}^{sv1_sv2} + \varepsilon_{\phi,rov_ref}^{sv1_sv2}$$

- Once you can resolve <u>integer N</u> in carrier phase double difference, you get accurate position about 1 cm.
- It can be imagine that the pseudo-range (code) accuracy is quite important.
- Code-phase is noisy (1 m-) but absolute distance
- Carrier-phase is accurate but includes integer ambiguity

3. Test results on the rooftop

- double difference of 10 m baseline-



- 1. Reference satellite GPS PRN 16 and target satellite is GPS PRN 8
- 2. Which is code-phase double difference ?
- 3. If you subtract from right to left, what happen ?

$$P_{rov_ref}^{sv1_sv2} = r_{rov_ref}^{sv1_sv2} + \varepsilon_{p,rov_ref}^{sv1_sv2}$$

$$\phi_{rov_ref}^{sv1_sv2} = r_{rov_ref}^{sv1_sv2} + N_{rov_ref}^{sv1_sv2} + \varepsilon_{\phi,rov_ref}^{sv1_sv2}$$



4. (Carrier DD) - (Code DD)



The unit is meterDivided by wavelengthThe unit is cycle0.19029 m... (L1)

Probably, we guess the integer ambiguity between PRN16 and PRN8 is about - 40 ? In fact, the average of this right results was - 41.3

5. What is the correct ambiguity ?

- "Integer least square method" tells us "– 42" in a single epoch !
- If you know the <u>3 or more ambiguities</u>, you can estimate the user position with the level of carrier phase because only 3 unknowns remains.
- Then, (dx, dy, dz) can be estimated and finally,
- (X_user, Y_user, Z_user) = (X, Y, Z) + (dx, dy, dz)



6. Test results (dx, dy, dz)



Std. = 2.8 mm

Std. = 4.0 mm



7. Convert to horizontal positions



(X_user, Y_user, Z_user)

I am repeating myself, RTK tells you only dx, dy, dz. You have to decide the precise reference positions !