How QZSS Contributes to Positioning Performance in Large Asian Cities ?

ICCAS-SICE 2009

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Motivation

Background

One of the Key technologies for ITS is GNSS
QZSS will be launched in summer of 2010.
QZSS would bring large benefits to users especially in urban canyon…
East Asia has a huge population. RGNSS > WGNSS

Viewpoints in this study

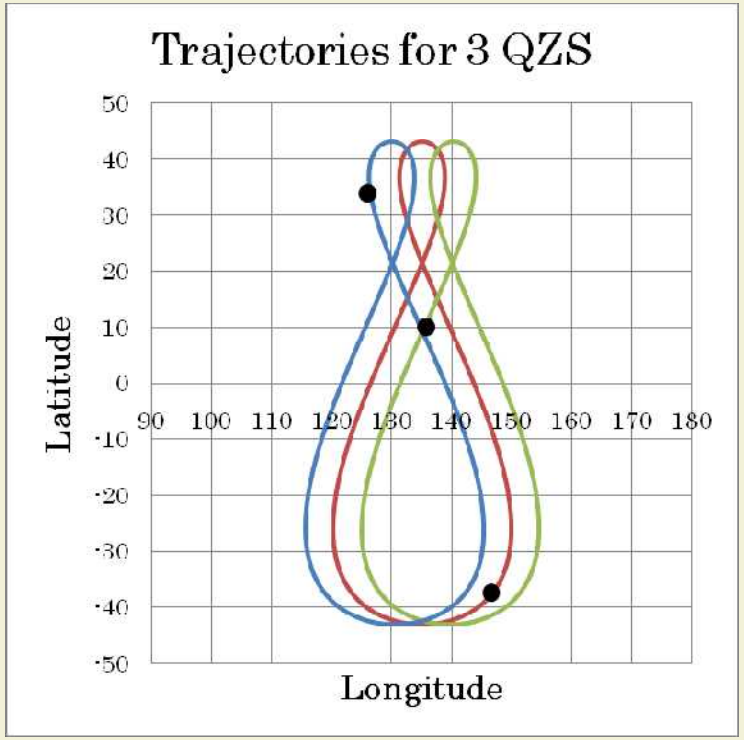
It is important for us to show the performance of the **combined GPS-QZSS**.
Low-cost receivers are used for the fundamental navigation service.
DGPS is widely used at present, but **stand-alone service** is still important.
There is no problem under open sky… but **under urban canyon** ?

↓

The objective of this paper is to show the benefits by QZSS in large Asian cities.

Satellite Constellation

- The GPS configuration used is GPS YUMA almanac of GPS week 488 2009. The date is January 1st in 2009.
- The QZSS configuration used is the most likely constellation referring to the article by JAXA.



Software Based Simulator

- The software simulator generates pseudo-range and carrier-phase. Several errors are considered in this simulation.

* *Tracking Errors* (based on the equation)

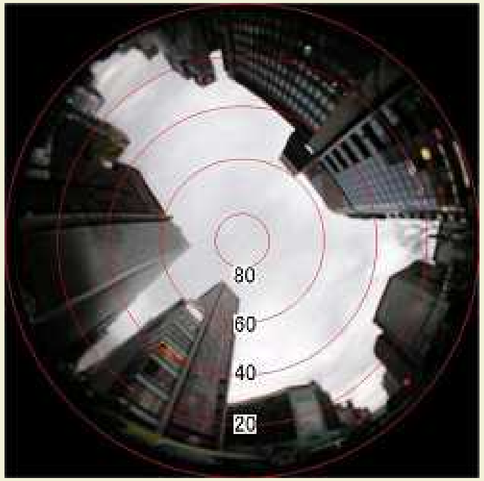
* *Ephemeris (inc. clock) Errors* (deduced from the difference between IGS final and ephemeris

* *Ionospheric Errors* (deduced from the difference between dual-frequency based and broadcast model)

We have to be careful that the solar activity is very low at present. The ionospheric errors in 2008 will be approximately lower than the one-third of the ionospheric errors in 2001.

Effects of Urban Canyon

- As a configuration of obstacle, mask angle is used. Different mask angles are set at 15, 30 and 45 degrees.
- From the real configuration in the dense urban area in Tokyo, the rate of interrupted sky is mostly from 0.6 to 0.7. When we set the mask angle 45 degrees, the rate of interrupted sky is 0.75 (30 degrees: 0.57, 15 degrees: 0.31).

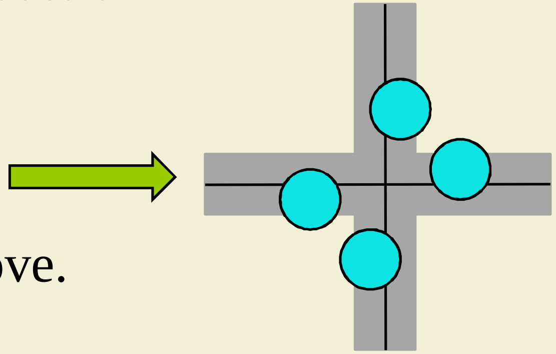


3 lanes in each way
The rate of interrupted sky ≈ 0.6

Typical case of masking condition in Tokyo

Intersections with High Frequency of Traffic Accidents

- Several intersections which have had many accidents in the last few years were chosen from the statistics of intersection accidents in Tokyo.
- Sky pictures were taken by the fish-eye lens at these intersections (several points at each intersection).
- Five intersections are selected randomly from the above.



	#1	#2	#3	#4	#5
Rate of interrupted sky	0.59	0.56	0.59	0.50	0.76

Multipath Errors ?

- Multipath reflection effect is not considered.

The effect of urban canyon could be simulated to some degree by considering mask angle because the influence of large DOP is dominant in urban canyon.

Since even low-cost receiver is going to have a better correlation technique, the long-delayed strong multipath will be reduced in the near future.

Low-cost receiver has already used the advantage of robust Doppler frequency (almost not affected by multipath).

Doppler Aiding Performance (low-cost high-sensitivity receiver)

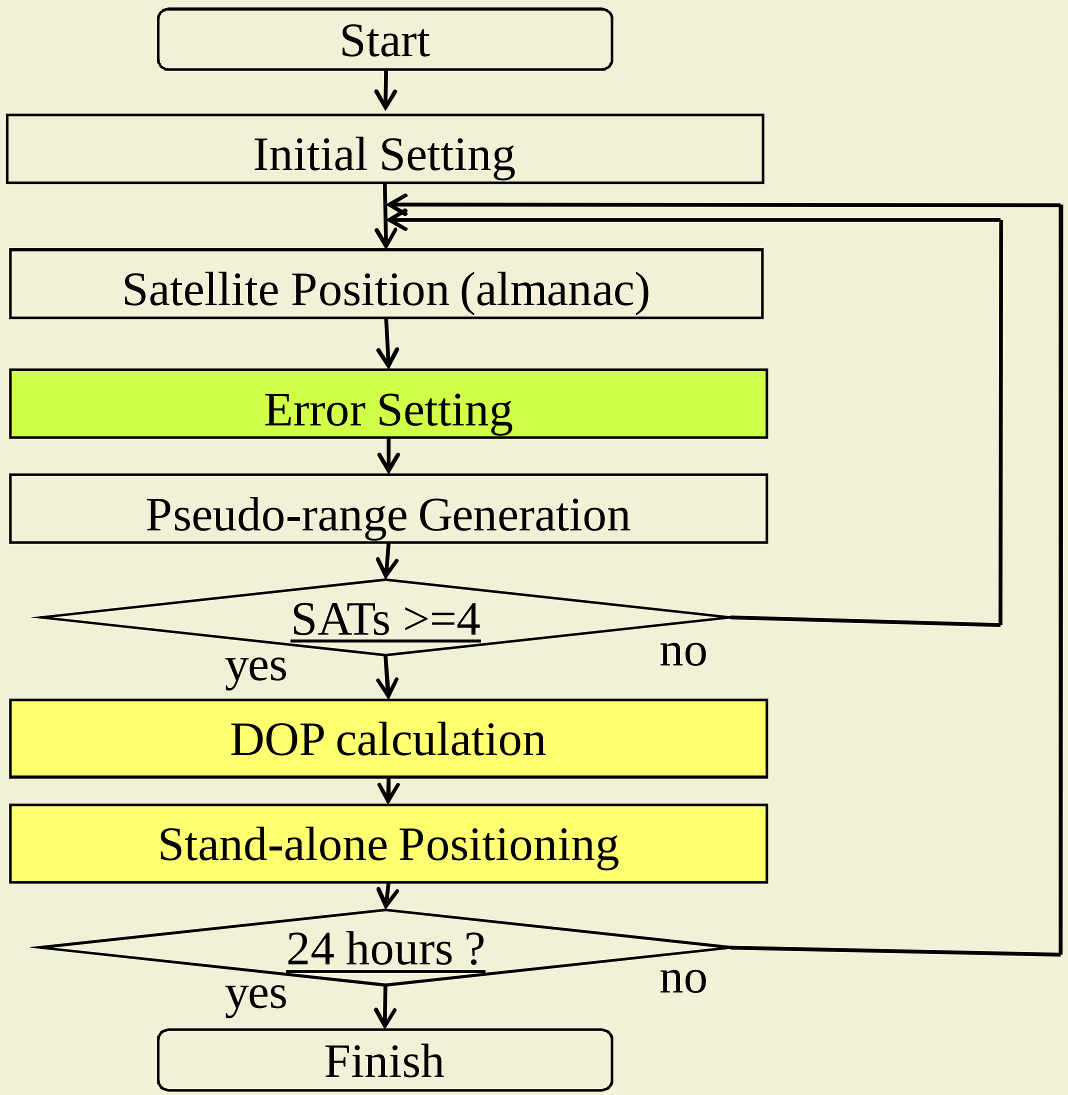
This place is surrounded by many high-rise buildings in Tokyo

Only Pseudo-range

Pseudo-range + Doppler aiding

Doppler aiding is quite effective to reduce multipath errors but good satellite constellation is still required to maintain good performance.

Flowchart



Start
Initial Setting
Satellite Position (almanac)
Error Setting
Pseudo-range Generation
SATs >=4
yes
no
DOP calculation
Stand-alone Positioning
24 hours ?
yes
no
Finish

Scenarios

- Several scenarios have been evaluated. Each scenario uses a different model and mask angles (15, 30 and 45).

Constellation for each scenario

	Constellation
Scenario1	GPS
Scenario2	GPS + 3QZS
Scenario3	GPS + 6 QZS
Scenario4	GPS + 3 GPS

Locations of selected cities

	Latitude	Longitude
Beijing	39.55	116.26
Seoul	37.32	126.58
Tokyo	35.68	139.90
Shanghai	31.06	121.22
Bangkok	13.45	100.32
Singapore	1.17	103.51
Sydney	-33.53	151.10

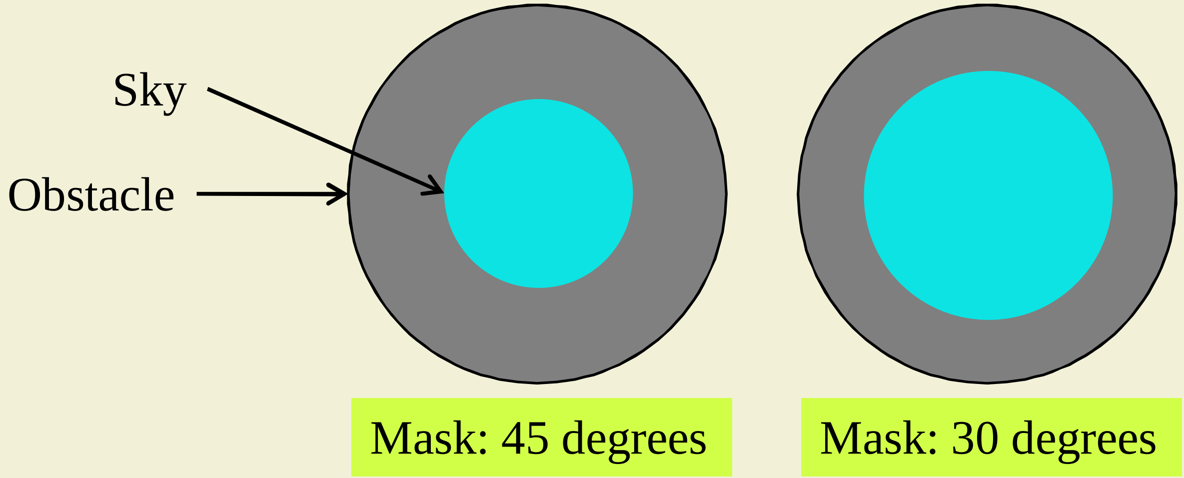
Test and Results

- Period1: 1day (1/1/2009)
- Period2: 1 year (to check long period orbit)
- Interval: Every 30 seconds
- Performance Criteria:

  Number of Visible Satellites

  DOP

  Stand-alone Positioning without Doppler or Carrier Aid



Number of Visible Satellites

Mask: 45 degrees   max/min/1day average/(1year average)

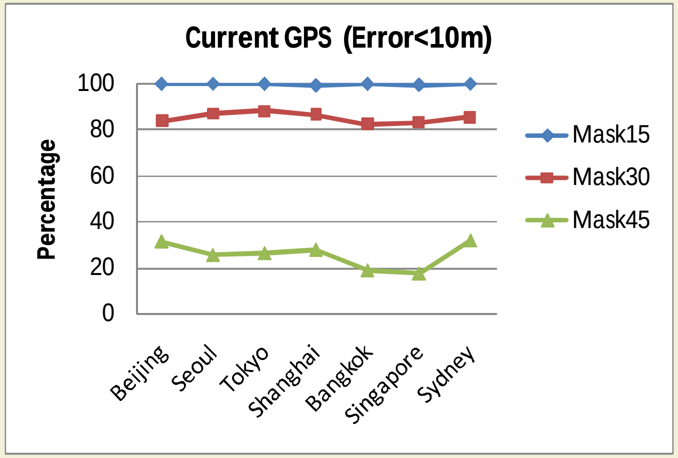
	GPS	GPS+3QZS	GPS+6QZS	GPS+3GPS
Beijing	7/1/3.1 (3.2)	9/2/4.7 (4.7)	10/4/6.2	7/2/3.5
Seoul	6/1/3.0 (3.1)	8/2/4.7 (4.7)	9/4/6.4	6/1/3.3
Tokyo	6/1/3.1 (3.1)	8/2/4.8 (4.8)	9/4/6.4	6/1/3.3
Shanghai	6/1/3.1 (3.2)	8/3/4.8 (4.9)	9/4/6.4	6/1/3.4
Bangkok	5/0/2.6 (2.6)	7/1/3.8 (3.9)	9/2/5.7	6/0/3.0
Singapore	4/1/2.6 (2.6)	6/1/3.6 (3.6)	7/2/4.9	5/1/2.9
Sydney	6/1/3.1 (3.1)	7/2/4.5 (4.5)	9/3/5.8	6/1/3.6

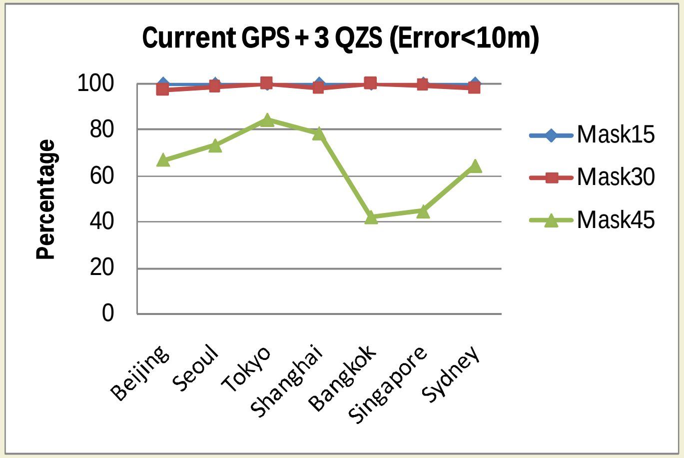
Mask: 30 degrees   same manner

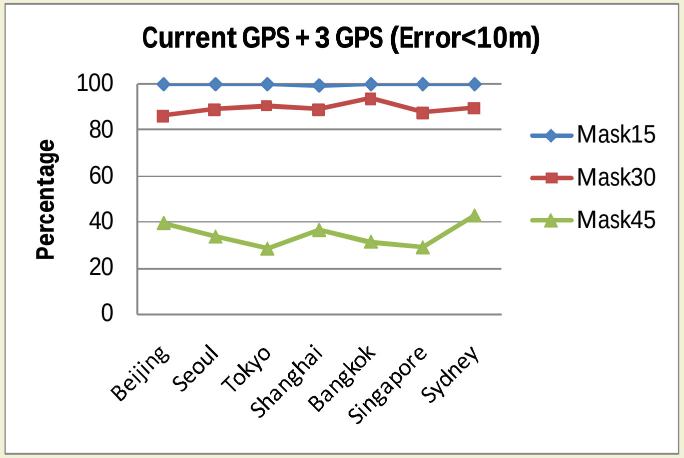
	GPS	GPS+3QZS	GPS+6QZS	GPS+3GPS
Tokyo	7/3/5.1 (5.1)	9/5/7.1 (7.1)	10/6/7.8	8/3/5.5
Bangkok	8/3/5.2 (5.2)	10/5/7.4 (7.4)	13/8/9.8	9/3/5.7
Singapore	7/2/4.8 (4.8)	10/4/7.3 (7.3)	13/7/10.1	8/2/5.3

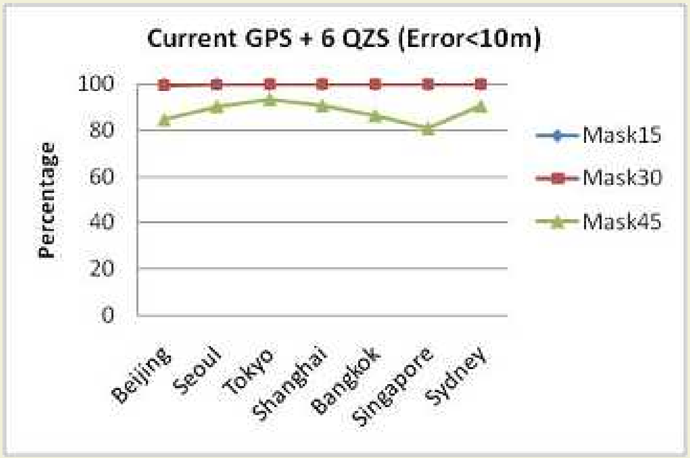
Stand-alone Positioning Performance

Percentage meets with horizontal errors is below 10 m.









How QZSS contributes to RTK ?

- For the traffic accident prevention, high accuracy positioning (RTK) is required.
- From our many RTK tests in the urban area,

* Correct fixing percentage of RTK: 70 - 100% (depends on condition, NVS)

* At least 4 visible satellites

* The more visible satellites, the better RTK performance.

- RTK performance in Tokyo was estimated according to the above factors.

<u>10km baseline is assumed</u>

		GPS	GPS+3QZS	GPS+6QZS
Mask30	4≥	94%	100%	100%
	RTK	57-82%	67-95%	69-99%
Mask45	4≥	37%	92%	100%
	RTK	19-28%	55-79%	66-94%

Summary and Future Plans

- The performance of general stand-alone positioning in large Asian cities is analyzed for different scenarios of the present GPS and combined future GPS-QZSS system.
- The results show that adding QZS clearly improves the availability and positioning performance in selected large Asian cities.
- In east Asia, QZS stays at high elevation for a long time. Even at low latitudes including Bangkok and Singapore, QZS stays at medium elevation for a long time.
- The result also indicates that more than 6 QZS satellites will be required if we need more robust navigation in the dense urban area.
- We will analyze another constellation such as 3 QZS + 3 GEO. Other world-wide GNSS will have to be considered.

Thank you

Percentage meets with PDOP < 10

	GPS	GPS+3QZS	GPS+6QZS	GPS+3GPS
Beijing	80/13	93/39	96/52	83/18
Seoul	85/10	96/44	99/59	89/13
Tokyo	82/10	96/52	100/79	86/13
Shanghai	85/9	94/44	97/57	87/14
Bangkok	82/6	98/21	100/54	86/12
Singapore	67/3	92/17	100/47	75/8
Sydney	78/10	93/35	99/68	83/20

Temporal Horizontal Errors in Tokyo (GPS+3QZS, Mask 45)