

Development of Centimeter Level Positioning Mobile Based Application

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Abstract— In recent years, Google announced the availability of GNSS (Global Navigation Satellite System) raw measurements from Android 7 [1, 2]. This was the first time that developers could access carrier, code measurements and decoded navigation messages from the smartphone. Therefore, these reasons could lead to increased GNSS performance as it opens the door to more advanced GNSS processing techniques that have been restricted to professional GNSS receivers. This paper is the development of an android application for collecting raw measurements from GNSS in standard RINEX files and using The Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) service to assess the accuracy of coordinates. The results demonstrate that the length of the observing sessions significantly affects the position determination accuracy. The accuracy of the coordinate of a longer observing session can provide more accuracy of the coordinate. The result of the 60-minute GPS + GLONASS observation period can archived the horizontal error of 2.4 cm at 66.7% confidence level.

Keywords— GNSS; PPP; Precise point positioning; RINEX; Raw measurements; Google location API; Android Smartphone.

I. INTRODUCTION

Nowadays, smartphone with positioning function is a kind of low-cost receiver widely used in transportation, smart farm, precision agriculture, automation system, geological and environmental monitoring due to its convenience. Furthermore, the application of the dual-frequency GNSS chips embedded in smartphones allows the smartphone to record dual-frequency GNSS observations.

PPP [3] is a positioning technique that removes or models GNSS system errors to provide a high level of position accuracy from a single receiver. A PPP solution depends on GNSS satellite clock and orbits corrections, generated from a network of global reference stations. Once the corrections are calculated, they are delivered to the end-user via satellite or over the Internet. These corrections are used by the receiver, resulting in decimeter-level or better positioning with no base station required.

The Geodetic Survey Division (GSD) of Canada developed the Canadian Spatial Reference System Precise Point Positioning (CSRS-PPP) service [4]. This service provides a single-point positioning solution for users in static or kinetic modes. The CSRS estimates are processed from carrier phase or code range observations of both single and double

frequency receivers. PPP coordinates are referred to as the North American Datum (NAD 1983) as well as to the (ITRF) system. PPP results are based on precise GPS orbits and clock products. Results can be improved through the use of better user-end equipment, and through the dynamics and duration of the observations.

Marcin Malinowski [5] explained the satellite observations using the PPP method were conducted with the use of specialist applications such as Bernese GPS Software, GIPSY, TerraPos, NAPEOS, EZSurv, or open-source RTKLib. Alternatively, one can use permanent internet services, which perform the calculation using the PPP technique such as CSRS-PPP, APPS, GAPS and magicGNSS. Moreover, presented the results of a comparative analysis concerning the accuracy of the position of the Professional GNSS receiver based on observations lasting between 0.5 to 6 hours with the use of PPP service.

Karol Dawidowics, et al [6] presented an analysis of positioning accuracy in PPP mode using a Professional GNSS receiver. The CSRS-PPP results showed that horizontal accuracies of about 5 cm and vertical accuracies of 10 cm are achievable provided 0.5 hours of open sky, low multipath dual-frequency GPS-only data. Adding GLONASS observation could not improve the accuracy of the results.

The aim of this paper was to develop the GNSS Record Android Application for collecting raw measurements in standard RINEX files and using the PPP technique to find the accuracy of position and present the methodology for the utilization of the Google Location API for the development of the GNSS Android Application. Moreover, we propose the experimental results that can be obtained from the developed application.

II. METHODOLOGY

This research developed an Android application called "GNSS Record" based on the location API level 24 as implemented in Android 7 to collect RAW measurement from GNSS in RINEX format and upload files to online PPP Web service in order to assess the accuracy of coordinates. To process the observations, the CSRS-PPP Web service was chosen. The CSRS-PPP can assess the positioning accuracy of both GPS and GLONASS constellations, and the L1 L2 frequency also. Although the GNSS Record application can record L5 frequencies, CSRS-PPP can not process.

Therefore, the different observation conditions of the experiment consist of GPS-only observation and GPS + GLONASS observation. For the frequency, we use the L1 frequency to record RAW measurements.

Surveying for reference coordinate is performed using professional GNSS receivers (ComNav T300), using the RTK survey technique to obtain accurate coordinates around the Rama VIII Bridge Park. Later, using a smartphone with a built-in GNSS receiver (Xiaomi Mi8 and Huawei Honor8) installed with the GNSS Record application, collecting the raw measurement data of the satellite with different observing conditions to be upload to assess the accuracy of coordinates using the online CSRS-PPP service.

This research creates metrics of experimental conditions in the form of test scenarios. To avoid the rising heat from the sun while recording raw measurements that cause the smartphone to turn off, we use the time between 6:00 AM and 11:00 AM.

At the last step, the coordinate result of the experiment from the smartphone is calculated the horizontal error (2D) to assess the accuracy of the coordinates obtained in each of the different observing conditions.

III. RINEX FILE STRUCTURE AND DEVELOPMENT

The android operating system has an interface called API (Application Programming Interface) that allows users to access the system's functionalities. Access to the GNSS measurements in the Android devices was added in API level 24 embedded in Android 7 using the GNSS Measurement and GNSSClock classes [1]. The API includes all the elements to generate a complete standard RINEX file that consists of the pseudorange, carrier phase, the doppler, the carrier-to-noise density expressed in C/N₀ (dBHz) and satellite ID.

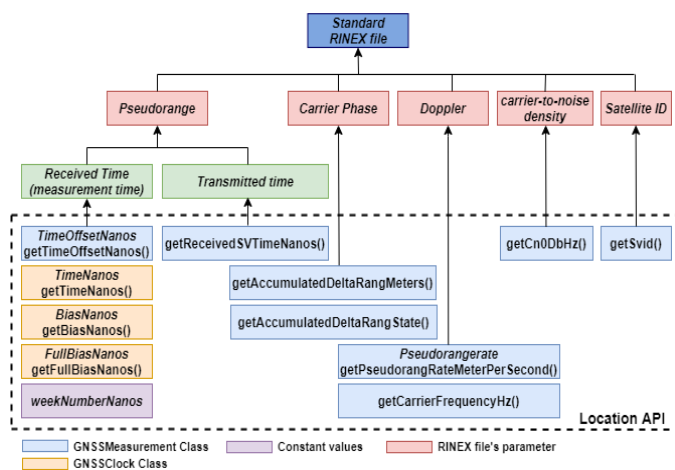


Figure 1. The structure of RINEX creation from Android API.

From The structure of RINEX creation (Fig. 1), we can develop the GNSS Record Android Application for collecting raw measurement from GNSS in standard RINEX files and can upload files to online PPP Web service. The GNSS Record has 3 main features: 1) Views the current satellite 2)

Shows the current location on the map 3) Records the satellite data to a RINEX files.



Figure 2. The GNSS Record application's main screen.

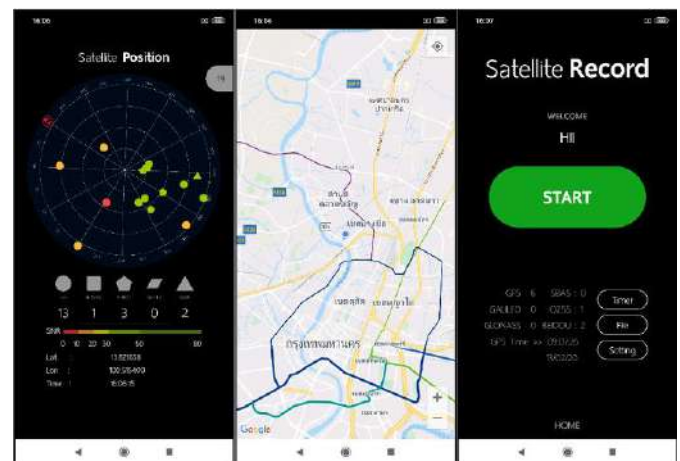


Figure 3. The GNSS Record application's main 3 features screen.

CSRR-PPP service system (Fig. 4) shows an overview of accurate satellite coordinate acquisition systems.

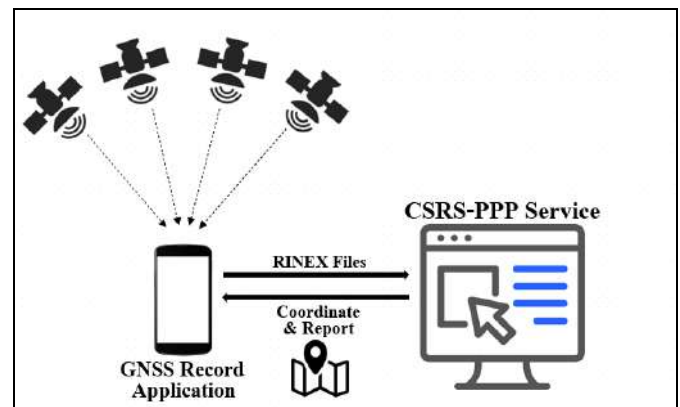


Figure 4. CSRR-PPP service system.

IV. EXPERIMENTAL AND RESULTS

A. Setup and Test Scenario

The satellite receiver equipment for the experiment was as follows.

- The ComNav T300 is a Professional GNSS receiver that is used to find the accurate reference coordinate for comparison with the coordinate (UTM coordinate) obtained from smartphones.
- The Xiaomi Mi 8 (Fig. 5) is a dual frequency smartphone with a Broadcom BCM47755 chip embedded that can receive L1 / E1 and L5 / E5 signals from GPS, Galileo, Beidou and GLONASS satellites.
- The Huawei Honor 8 (Fig. 5) is a single-frequency smartphone that can receive L1/E1 signals from GPS, Beidou, and GLONASS satellites.



Figure 5. Huawei Honor 8 single-frequency smartphone and Xiaomi Mi 8 dual-frequency smartphone.

As shown in Fig. 6-7, the setup of the experiment to record raw measurements data from satellites.



Figure 6. Setup of ComNav T300 Pro-GNSS receivers at Reference Coordinate (The Rama VIII bridge park in Thailand).



Figure 7. Setup of Smartphone on top of a ESD rubber sheet at Reference coordinate (The Rama VIII bridge park in Thailand).

Normally, we use a smartphone to record raw measurement data for 5 hours, the smartphone's battery remains about 10-20%. So we use the length of the observing session to experiment for a maximum of 5 hours and a minimum of 15 minutes. Table I is the test scenario that can express the different observing conditions.

TABLE I. SUMMARY OF THE TEST SCENARIO

TS	Devices	Technique	GNSS	The length of the observing session (Minute)
R1	ComNav T300	RTK	BDS, GPS, Glonass, Galileo	-
A1	Huawei Honor8	PPP/Static	GPS-L1	15
A2				30
A3				60
A4				180
A5				300
B1	Xiaomi Mi8	PPP/Static	GPS-L1, Glonass-L1	15
B2				30
B3				60
B4				180
B5				300

B. Experimental Result

As shown in Table II is the use of a professional GNSS receiver with RTK observation techniques to find the reference UTM coordinate (RC).

TABLE II. RESULTS OF R1 TEST SCENARIO

Session	UTM Coordinate	
	North (m)	East (m)
1	1522513.305	661602.890
2	1522513.305	661602.889
3	1522513.304	661602.887
4	1522513.302	661602.888
5	1522513.304	661602.888
Average of Reference Coordinate	<u>1522513.304</u>	<u>661602.888</u>

As shown in Table III-VII is the use of the Huawei Honor 8 and Xiaomi Mi 8 Smart Phone with PPP-Static observation techniques to find the UTM coordinate of A position and calculate the differences of coordinates between Professional GNSS Receiver and smartphone. As a measure of accuracy, the plane difference vector (2D) is computed using Equation (1) and (2).

$$\delta_{N,E} = RC - SC \quad (1)$$

Where

$\delta_{N,E}$ Difference in coordinate

RC Reference Coordinate from Professional GNSS receiver

SC Coordinate from Smartphone

$$\text{Horizontal error (2D)} = \sqrt{\delta_N^2 + \delta_E^2} \quad (2)$$

TABLE III. RESULTS OF A1, B1 TEST SCENARIO (THE LENGTH OF THE OBSERVING SESSION: 15 MINUTES)

GNSS	Device	15 Minutes Session	Difference in coordinates		Horizontal error (2D) (m)
			δ_N (m)	δ_E (m)	
GPS	Xiaomi Mi8-A	1	0.034	-0.126	0.131
		2	-0.411	0.509	0.654
		3	0.179	-0.323	0.369
		4	-0.771	0.270	0.817
		5	-1.272	0.219	1.291
	Xiaomi Mi8-B	1	0.061	-0.405	0.410
		2	0.228	0.151	0.273
		3	-1.211	0.989	1.564
		4	-3.370	-1.035	3.525
		5	-0.686	0.736	1.006
	Huawei Honor8	1	0.114	-0.749	0.758
		2	-0.520	-0.317	0.609
		3	-0.627	0.563	0.843
		4	-1.005	0.396	1.080
		5	-1.047	1.332	1.694
GPS+ Glonass	Xiaomi Mi8-A	1	0.104	-0.229	0.252
		2	-0.094	0.238	0.256
		3	-0.363	0.131	0.386
		4	-0.771	0.620	0.989
		5	-0.860	0.037	0.861
	Xiaomi Mi8-B	1	0.062	-0.409	0.414
		2	0.475	-0.006	0.475
		3	0.027	-0.027	0.038
		4	0.027	-1.028	1.092
		5	-0.269	0.921	0.959
	Huawei Honor8	1	-0.424	-0.197	0.467
		2	0.174	-1.049	1.063
		3	0.051	0.147	0.156
		4	-1.371	1.640	2.138
		5	-0.424	-0.822	0.925

TABLE IV. RESULTS OF A2, B2 TEST SCENARIO (THE LENGTH OF THE OBSERVING SESSION: 30 MINUTES)

GNSS	Device	30 Minutes Session	Differences in coordinates		Horizontal error (2D) (m)
			δ_N (m)	δ_E (m)	
GPS	Xiaomi Mi8-A	1	0.017	-0.160	0.161
		2	0.003	0.178	0.178
		3	0.025	-0.157	0.159
		4	-0.851	0.351	0.921
		5	-1.565	-0.003	1.565
	Xiaomi Mi8-B	1	0.186	-0.335	0.383
		2	0.234	-0.094	0.252
		3	-2.011	0.947	2.223
		4	-2.961	-0.933	3.105
		5	-0.550	0.683	0.877
	Huawei Honor8	1	-0.171	-0.438	0.470
		2	-0.555	-0.094	0.563
		3	-0.619	0.444	0.762
		4	-0.890	0.388	0.971
		5	-1.057	1.232	1.623
GPS+ Glonass	Xiaomi Mi8-A	1	0.078	-0.084	0.115
		2	-0.244	0.081	0.257
		3	-0.049	0.127	0.136
		4	-0.805	0.577	0.990
		5	-0.879	-0.064	0.881

	Xiaomi Mi8-B	1	0.327	-0.237	0.404
		2	0.352	0.047	0.355
		3	0.078	0.155	0.174
		4	-0.334	-0.989	1.044
		5	-0.083	0.649	0.654
	Huawei Honor8	1	-0.210	-0.093	0.230
		2	0.033	-0.640	0.641
		3	0.057	0.435	0.439
		4	-1.399	1.790	2.272
		5	-0.787	-0.960	1.241

TABLE V. RESULTS OF A3, B3 TEST SCENARIO (THE LENGTH OF THE OBSERVING SESSION: 60 MINUTES)

GNSS	Device	1 hours Session	Differences in coordinates		Horizontal error (2D) (m)
			δ_N (m)	δ_E (m)	
GPS	Xiaomi Mi8-A	1	-0.032	0.003	0.032
		2	0.339	-0.028	0.340
		3	-0.092	0.178	0.200
		4	-0.557	0.337	0.651
		5	-0.795	0.145	0.808
	Xiaomi Mi8-B	1	0.204	-0.199	0.285
		2	0.207	-0.086	0.224
		3	-1.583	0.391	1.631
		4	-1.539	-0.360	1.581
		5	-0.269	0.477	0.548
	Huawei Honor8	1	-0.276	-0.438	0.518
		2	-0.556	0.194	0.194
		3	-0.763	0.356	0.842
		4	-1.027	0.564	1.172
		5	-0.873	0.991	1.321
GPS+ Glonass	Xiaomi Mi8-A	1	0.002	-0.064	0.064
		2	-0.024	-0.002	0.024
		3	-0.252	0.369	0.447
		4	-0.925	0.656	1.134
		5	-0.562	0.073	0.567
	Xiaomi Mi8-B	1	0.336	-0.039	0.338
		2	0.275	-0.027	0.276
		3	0.239	-0.152	0.283
		4	-0.285	-0.343	0.446
		5	0.120	0.692	0.702
	Huawei Honor8	1	-0.152	-0.233	0.278
		2	-0.065	-0.336	0.342
		3	-0.413	0.227	0.471
		4	-1.192	1.516	1.929
		5	-0.978	-0.591	1.143

TABLE VI. RESULTS OF A4, B4 TEST SCENARIO (THE LENGTH OF THE OBSERVING SESSION: 180 MINUTES)

GNSS	Device	3 hours Session	Differences in coordinates		Horizontal error (2D) (m)
			δ_N (m)	δ_E (m)	
GPS	Xiaomi Mi8-A	1	0.124	-0.051	0.134
		2	0.125	-0.079	0.148
		3	-0.363	0.173	0.402
	Xiaomi Mi8-B	1	-0.468	0.020	0.468
		2	-1.001	-0.009	1.001
		3	-0.827	0.080	0.831
	Huawei Honor8	1	-0.554	-0.032	0.555
		2	-0.799	-0.356	0.875
		3	-0.865	0.483	0.991

GPS+ Glonass	Xiaomi Mi8-A	1	-0.238	0.208	0.316
		2	-0.547	0.339	0.483
		3	0.212	0.441	0.703
	Xiaomi Mi8-B	1	0.212	-0.249	0.327
		2	0.117	0.146	0.187
		3	0.180	-0.175	0.251
	Huawei Honor8	1	-0.343	-0.102	0.358
		2	-0.529	0.154	0.551
		3	-0.906	0.873	1.258

TABLE VII. RESULTS OF A5, B5 TEST SCENARIO (THE LENGTH OF THE OBSERVING SESSION: 300 MINUTES)

GNSS	Device	5 hours Session	Differences in coordinates		Horizontal error (2D) (m)
			δ_N (m)	δ_E (m)	
GPS	Xiaomi Mi8-A	1	-0.006	-0.074	0.074
	Xiaomi Mi8-B	1	-0.435	-0.001	0.435
	Huawei Honor8	1	-0.675	0.179	0.698
GPS+ Glonass	Xiaomi Mi8-A	1	-0.343	0.151	0.375
	Xiaomi Mi8-B	1	0.189	0.021	0.190
	Huawei Honor8	1	-0.490	-0.442	0.660

The results in Table III-VII were summarized for maximum and minimum 2D error values for different observing conditions as Table VIII. The minimum 2D error was on the centimeter or decimeter levels in all observing session. The maximum 2D error value of almost of all was greater than, but if the 5h observation length was used, the 2D error would be reduced to less than 1m.

Table VIII also shows the number of observation sessions that yield 2D errors value of less than 50 cm and 1 m.

TABLE VIII. THE MINIMUM AND MAXIMUM ERROR (2D) OF THE DIFFERENT OBSERVING CONDITIONS

GNSS	Length of observing session (Minute)	Min. 2D Error (cm)	Max. 2D Error (cm)	Number of Observation Session	
				2D Error < 50 cm.	2D Error < 1 m
GPS	15	13.1	352.5	26.7%	60.0%
	30	16.0	310.5	40.0%	73.3%
	60	3.2	163.1	40.0%	73.3%
	180	13.4	100.1	44.4%	88.9%
	300	7.4	69.8	66.7%	100.0%
GPS+ Glonass	15	3.8	213.8	53.3%	80.0%
	30	11.5	217.2	53.3%	80.0%
	60	2.4	192.9	66.7%	80.0%
	180	18.7	125.8	66.7%	88.9%
	300	19.0	66.0	66.7%	100.0%

V. CONCLUSIONS

In this paper, we developed an android application called "GNSS Record" and assess the accuracy of the position

determination using smartphone take on the Rama VIII bridge park Bangkok Thailand with the different observing conditions. The different observation conditions consist of GPS-only observation and GPS + GLONASS observation.

The experimental results showed that the length of the observing sessions significantly affects the position determination accuracy. The accuracy of the coordinate with longer observing session can provide more accuracy of the coordinate. The result of the 60-minute GPS+GLONASS observation period can be archived 2D error at 2.4 cm with the confidence level where the 2D error less than 50cm at 66.7% and less than 1m at 80.0%.

The GNSS Record application that is developed can record L5 signals to RINEX file. However, CSRS-PPP current services not supported L5 frequency. In the future, the researcher will find other ways to process with other specialized programs related to survey work.

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