Possibility of Centimeter Positioning Accuracy with Ambiguity Resolution from Android GNSS Raw Measurements

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Abstract

In this research, we improve the partial ambiguity resolution strategy of LAMBDA for Android-based GNSS data. The results show that it is possible to fix the ambiguity in an open sky environment, and an accuracy of 1 and 2 centimeter on horizontal and vertical is achieved. However, when the data suffer from large cycle slip, it will be hard to fix the ambiguity and lead to a float solution with sub-meter to meter accuracy.

1 Introduction

With the open of raw GNSS measurement APIs by Google, GNSS precise positioning from smartphone is possible for common GNSS users [1]. Data quality including observation noise, carrier-to-noise density ratio, cycle slip performance has been assessed by numerous researchers [2,3]. Furthermore, submeter positioning accuracy is achieved from static and vehicle-based kinematic data from Android device [4,5]. Started from 2021, Google hosts the Smartphone Decimeter Challenge. With various real Android GNSS data, a precision of near 1 m positioning error is achieved during the challenge [6].

With the availability of carrier phase observation from Android devices, it provides the possibility of ambiguity resolution with the real-time kinematic (RTK) technique. Although submeter positioning accuracy is already enough for most Android users, it is still of interest for GNSS community to explore the possibility of centimeter positioning accuracy from Android GNSS raw measurements. Besides, an ambiguity-fixed solution will also improve the protection level of the result. However, due to the large observation noise and multipath from smartphone, it is a big challenge to fix the ambiguity of carrier phase. Li et al explored the possible of ambiguity resolution from Android GNSS raw measurements, and successful of ambiguity resolution in RTK is realized and result of centimeter is achieved [7]. However, in their experiment, and external geodetic antenna is used to improve the data quality, which is not applicable in normal smartphone positioning.

Therefore, the purpose of this research is to explore the possibility of ambiguity resolution from Android GNSS raw measurements with its internal antenna.

2 GNSS RTK model

Under the short baseline RTK positioning mode, the double difference (DD) observation model can effectively attenuate the satellite ephemeris error, atmospheric delay error, receiver clock bias, and receiver hardware delay and can preserve the integer value of the double-differenced ambiguity [8]. The BDS/GPS double-differenced carrier phase and pseudorange observations can be expressed as:

$$\begin{cases} \lambda \cdot \nabla\Delta\Phi_{rb}^{jk} = \nabla\Delta\rho_{rb}^{jk} - \lambda N_{rb}^{jk} + \varepsilon_{rb}^{jk} \\ \nabla\Delta P_{rb}^{jk} = \nabla\Delta\rho_{rb}^{jk} + e_{rb}^{jk} \end{cases} \tag{1}$$

In Equation (1), b and r represent the base station and the rover station; j and k represent the reference and non-reference satellites; $\nabla\Delta$ is the double difference symbol; P and Φ are the code and carrier phase observations; ρ is the geometry distance between the receiver and satellite; λ is the wavelength; N denotes the carrier phase ambiguity; ε_{rb}^{jk} and e_{rb}^{jk} denote the observation noise of double-differenced carrier phase and double-differenced pseudorange. In short baseline RTK positioning mode, the parameters to be estimated are:

$$\mathbf{x} = (\mathbf{r}_r^T, \mathbf{v}_r^T, \mathbf{B}_1^T, \mathbf{B}_2^T, \mathbf{B}_3^T)^T \tag{2}$$

where $\mathbf{r}$ and $\mathbf{v}$ are the three-dimensional position vector and velocity of the rover station; $\mathbf{B}_i = (\mathbf{B}_i^1, \mathbf{B}_i^2, \cdots, \mathbf{B}_i^{m-1})^T$ is the DD carrier-phase ambiguities in cycle.

Using the traditional extended Kalman Filter, one can estimate the parameters in Equation (2). Then, the widely used Least-squares Ambiguity Decorrelation Adjustment (LAMBDA) method is used to fixed the carrier-phase ambiguities [9].

For RTK with Android GNSS measurements, it is hard to fix the ambiguities due to the large observation noise and multipath, especially for the low elevation satellites. To best get the ambiguity fixed solutions, the partial ambiguity resolution (PAR) method is proposed here. Detailed strategy of the proposed PAR can be referred to our recent research [10].

On the other side, for PAR, if more satellites are removed, the chance of false (incorrect) fixing will increase [11]. It is also known that, when the threshold of the ratio test in LAMBDA increases, the fix rate will decrease, but with fewer false fixes. To properly set this threshold, the chi-square test is employed [12]:

$$c = \chi_{\alpha}^{2}(n) \tag{3}$$

where c is the threshold of the ratio test, n is the number of input ambiguities in LAMBDA, $\chi_{\alpha}^{2}(n)$ is the chi-square distribution with n degrees of freedom and significance level α.

3 Experiment and Results

To evaluate the performance of Android GNSS raw measurement, and explore the possibility of ambiguity resolution, a static and kinematic experiment with a Xiaomi 8 smartphone is set up. Note that the Xiaomi 8 is able to track L1 and L5 signals from GPS and Galileo, but only L1 signals from BDS and QZSS. The data is collected using the GEO++ application and then analyzed using our self-developed software named Net_Diff [13].

3.1 Static experiment

The smartphone is placed on the rooftop at Tokyo University of Marine Science and Technology. A Trimble Net R9 receiver with a distance of less than 5 m is used as the reference station in RTK. A one-hour data is collected on November, 8, 2018.

Figure 1 and Figure 2 shows the satellite visibility and sky view during the static test. It can be seen that the average satellite number is about 17, which is enough for RTK. However, it is strange that only two BDS satellite is tracked.

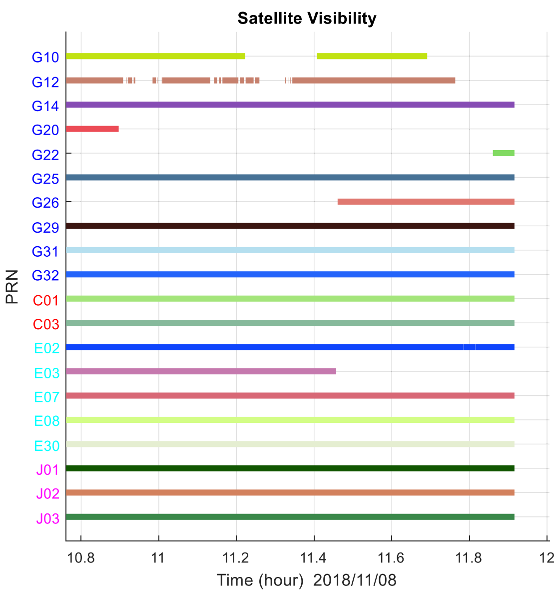

Figure 1. Satellite visibility of the static data

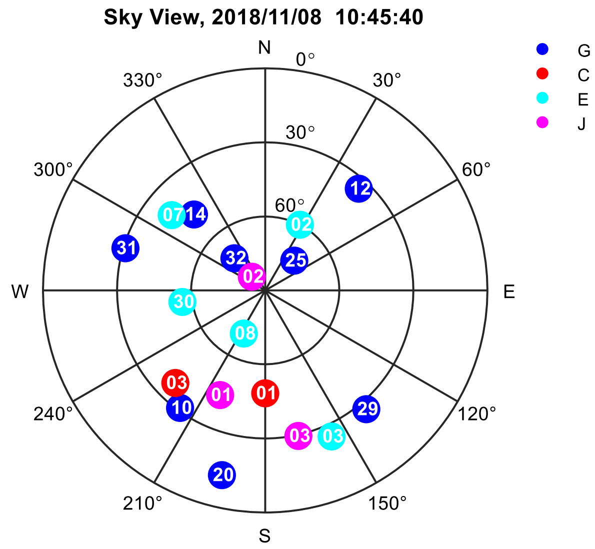

Figure 2. Sky view of the static data

The cycle slip performance is a key factor in Android GNSS raw measurement. Figure 3 shows the cycle slip numbers during the test. It is seen that most of the time, only one or two satellites suffers from cycle slip. However, at about 11:48, due to the loss of carrier phase observations, many cycle slips happen, which will affect the RTK performance.

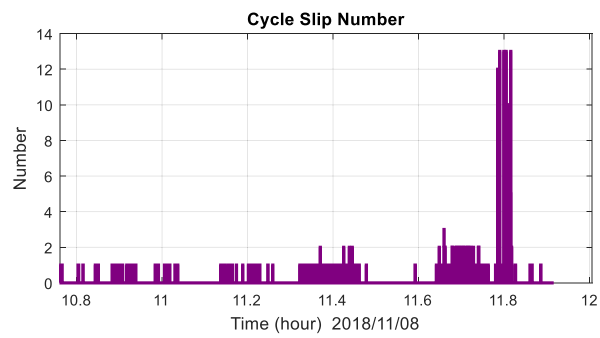

Figure 3. Cycle slip performance of the data

Figure 4 shows the RTK performance of the whole data. It proves that a fixing rate of almost 99% is achieved. By excluding the result during 11:48, which has large cycle slip, a fixing rate of 100% is achieved, as shown in Figure 5.

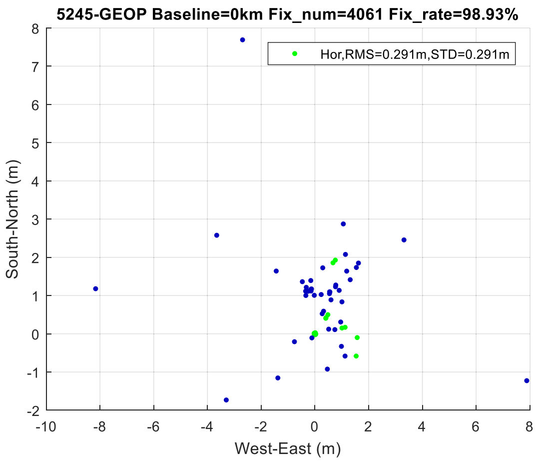

Figure 4. RTK result with the while data

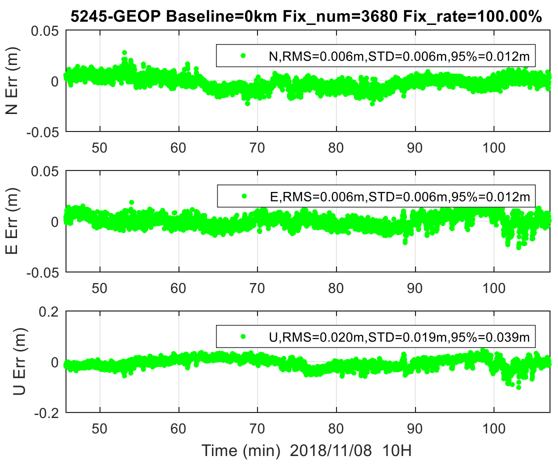

Figure 5. RTK result by excluding the large cycle slip period

4 Conclusions

In this research, we improve the partial ambiguity resolution strategy of LAMBDA for Android-based GNSS data. The results show that it is possible to fix the ambiguity in an open sky environment, and an accuracy of 1 and 2 centimeter on horizontal and vertical is achieved. However, when the data suffer from large cycle slip, it will be hard to fix the ambiguity and lead to a float solution with sub-meter to meter accuracy.

Note that the experiment is based on an open sky environment and static test. For real users, kinematic test should be carried out for more test, which will be our further analysis.

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