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Significance of accuracy comparison in real-time kinematic and single point positioning on-board applications in vehicles

Taufan Zandy Andrian, Uke Kurniawan Usman, Muhammad Irfan Maula
Department of Telecommunication Engineering, School of Electrical Engineering, Telkom University, Indonesia

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ABSTRACT

Vehicle tracking using the positioning system that is used today is the single point positioning method implementation, but the accuracy of the method is still inadequate for further features to be applied. Therefore, an accuracy improvement is needed. By applying the Real Time Kinematic (RTK) method which has a centimeter level of accuracy, the IndiCar webapp made by PT. Telkom Indonesia offers further features in driving, such as sudden vehicle movements detection, to accidents indications. Accuracy comparisons can also be made to define how significant the difference in accuracy of the two methods. The tests show quite significant results. At single point positioning, the largest deviation is at 20 m and the smallest at 1.0960 m, while in the RTK method, the largest deviation is at a value of 80 cm while the smallest at 0.92 cm. The standard deviation value is then used in the calculation of accuracy. With CEP calculations, the single point positioning method produces accuracy at 5.4659 m, while the RTK method provides a more precise level of accuracy, with a value of 18.22 cm. These results show that the RTK method can be an alternative, to improve accuracy in the use of positioning systems.

Corresponding Author:

Taufan Zandy Andrian
Department of Telecommunication Engineering
School of Electrical Engineering, Telkom University
Bandung, Indonesia
Email: taufanzandy@student.telkomuniversity.ac.id

1. INTRODUCTION

Positioning system is one of the technologies that continues to be developed. Various methods were created in order to be able to adjust human needs, such as single point positioning which is already commonly used. The application of single point positioning on vehicles has been quite a lot done. Generally, the application of a positioning system on vehicles is intended for the use of security and navigation. Single point positioning with the merger of GPS, GLONASS, and BeiDou provides an accuracy of about 5 meters [1]. With this accuracy, security and navigation requirements can already be met. But with increased accuracy, a number of advanced features can be applied that can increase safety and comfort in driving. Real-time kinematic (RTK) offers a higher accuracy value in the positioning of a device. In fix solutions, RTK can produce a level of precision of up to 5 cm [2]. The increase in accuracy compared to single point positioning is due to the correction data on the RTK obtained from the comparison of the location of the rover device with the base station and sent via an internet connection. Beside the accuracy level difference between the single point positioning and real-time kinematic method in some literature, the real-world implementation can show a different result, affected by some factors. This study aims to compare the accuracy level produced by the single point positioning and real-time kinematic method, that being applicated on-board, in daily used vehicles, to show the significance level from the accuracy difference.

2. METHOD
2.1. Global Navigation Satellite System
GNSS is one of the most commonly used techniques to determine the exact position of various objects [3]. According to Hofmann and Wellehof, GNSS is a space-based positioning system consisting of one or more constellations of satellites and augmentation infrastructure needed to support activity objectives in the form of position and navigation that is available for 24 hours wherever the user is located on the entire surface of the earth [4]. GNSS become the most important part in this study, where the main data that being processed is the GNSS data.

2.1.1. Augmentation System
To support the level of accuracy produced by the GNSS, the signals transmitted by the GNSS satellite are then monitored using reference points located on the earth's surface, this system is also known as the Ground Based Augmentation System or GBAS. In addition to GBAS, there is another augmentation system used by GNSS, namely the Satellite Based Augmentation System (SBAS). SBAS is a GNSS augmentation system that has a very wide coverage based on satellites. SBAS is a system designed to improve GNSS services [5].

2.1.2. GNSS Receiver
The utilization of GNSS in the positioning process, requires an object that is tracked for its existence to receive signals from GNSS satellites. GNSS signal reception can be performed by a special device called a GNSS receiver. This device works by receiving signals from the GNSS satellite, then processing the data sent into a coordination point for the location of the device. In this study, this device has a role as a rover or the moving object, and a base station which is the component that sent the correction data.

2.2. Single Point Positioning
Single Point Positioning is the most common positioning technique that is instantaneous, but less accurate [6]. This technique is also known as standalone or standard GNSS. Single point positioning works by utilizing only signals and data sent from the GNSS satellite and then received by the GNSS receiver without any correction data. This way of working causes single point positioning to produce a fairly low level of accuracy, where the accuracy is only about 3-5 meters. This method used in this study as daily positioning system sample.

2.3. Real Time Kinematic
Another method used as a comparison in the positioning system in this study is real-time kinematic (RTK). RTK is a satellite navigation technique widely used to improve the accuracy of position data obtained from GNSS [7]. Correction data is the main key in the accuracy improvement of position data processed using RTK, the correction data is a differentiator between RTK and other positioning system methods.

2.4. Calculation Parameter
2.4.1. Latitude and Longitude
In determining the position of an object on the surface of the earth, a coordinate system is used to act as an address so that the location of the object being tracked can be known. This global address consists of two numbers, namely the latitude number, and the longitude number. This coordinate system is also used as the address of the object in this research. The latitude number indicates the location of the object to be in the northern or southern part of the equator. While the longitude line determines the location of the object to be in the eastern or western part of the meridian line. [8]

2.4.2. Standard Deviation
In the positioning system, standard deviation is used to determine how far the deviation of each location point generated by the GNSS receiver. The more they obtained standard deviation value approaches the value of 0, indicating the system results in a higher accuracy value. The standard deviation can be calculated using the following formula [9]:

$$\sigma = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n}} \tag{1}$$

with σ = Standard deviation, Σ = Total value, x = Value in the data group, $\bar{x}$ = Average values in the data group, n = amount of data in the data group.

2.5. Accuracy Calculation
In comparing accuracy, the first stage that must be done is to know the level of accuracy. Therefore, it is necessary to calculate the level of accuracy in both method of positioning systems. The first calculation is

done by calculating the twice the distance root mean square or known as 2DRMS. This method gives an output in the form of a radius of a circle which is the approximate area of the position of the object with a probability level of 95%. The calculation of the 2DRMS can be carried out using the following formula:

$$2DRMS = 2\sqrt{(s\varphi)^2 + (s\lambda)^2} \tag{2}$$

where $s\varphi$ is the standard deviation of geographic latitude, and $s\lambda$ is the standard deviation of geographic longitude [10]

Another calculation that can help with accuracy measurements is circular error probability or CEP, which resulting the radius of a circle with the centre point of the actual position of an object, containing an approximate position with a probability of 50% [11]. The CEP formula used in this study is:

$$CEP = 0{,}59(\sigma x + \sigma y) \tag{3}$$

with σx as the standard deviation of the easting value, and σy as the standard deviation of the northing value.

2.6. RTKLIB

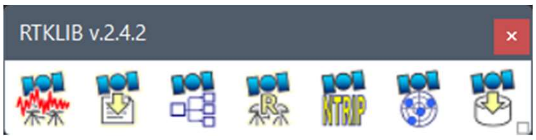

Figure 1. RTKLIB Application [12]

The RTKLIB application was created with the aim of facilitating the implementation of various positioning system methods to produce varying degrees of accuracy according to needs. The positioning system method includes single point positioning and RTK, so the RTKLIB application is very useful to implement both positioning system in this study.

2.7. TCP Server Program

In this research, a program with a role as a TCP server is needed, where the program becomes the main communication in sending the rtklib application output data to the IndiCar server, which then becomes an output in the form of tracking the position of the vehicle tracked on the IndiCar webapp display. The TCP server program created in this study was built using the JavaScript programming language.

2.8. IndiCar

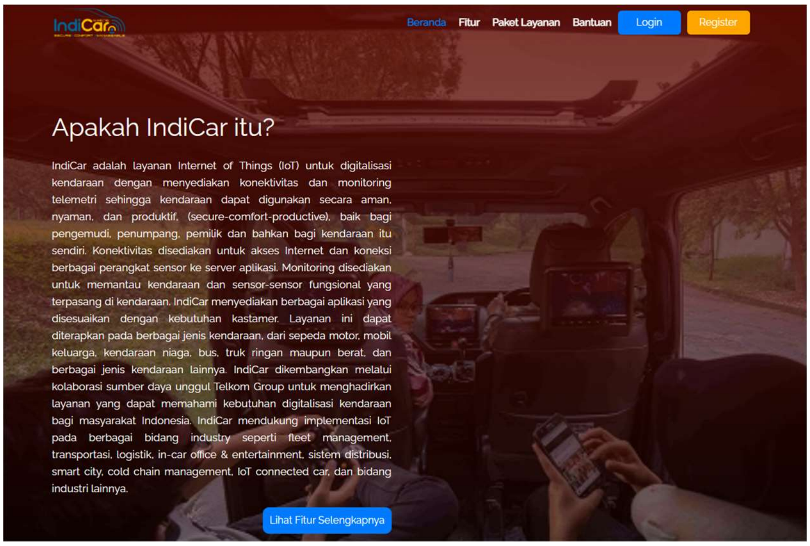

Figure 2. IndiCar Webapp [13]

Webapp IndiCar has a target of digitizing vehicles so that they can convert common vehicles into smart vehicles. This is very useful both in the use of individuals and institutions or companies where users can track and also detect various parameters on their vehicles that have been installed by Indicar. This webapp can also show the track that has ben passed by the rover, so the tracking image from the positioning system can be compared while monitoring the rover using IndiCar webapp.

2.9. Significance Test
The significance test confirms whether the hypothesis that has been made is accepted or rejected. There are several types of significance tests, one of which is the t-test that been used in this study. The t-test works by determining the t-stat value that can be determined by the calculation as follows [14]:

$$t - stat = \frac{X_1 - X_2}{\sqrt{\frac{(n_1-1)S_1{}^2+(n_2-1)S_1{}^2}{n_1+n_2-2}(\frac{1}{n_1}+\frac{1}{n_2})}} \quad (4)$$

where X = average value of data group, n = number of data in data group,S = standard deviation in data group

3. RESULTS AND DISCUSSION
3.1. System Model Design
In this study, the design of the systems that been used to achieve the study objective shows inside the following picture

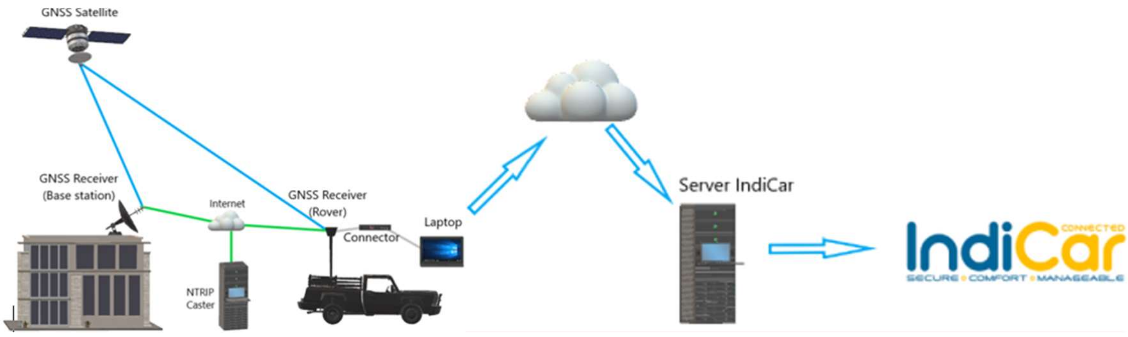

Figure 3. Research System Design

Figure 3 explains how the system works where the data used comes from the GNSS satellite received by the GNSS receiver, the data is then sent and processed using a laptop with a windows operating system. The data is then sent to the IndiCar server via the internet, after the data is received, the output of the entire data processing can be displayed on the IndiCar webapp in the form of a plot of the path traveled by the vehicle being tracked. The workings of the system can be described in the following flow chart

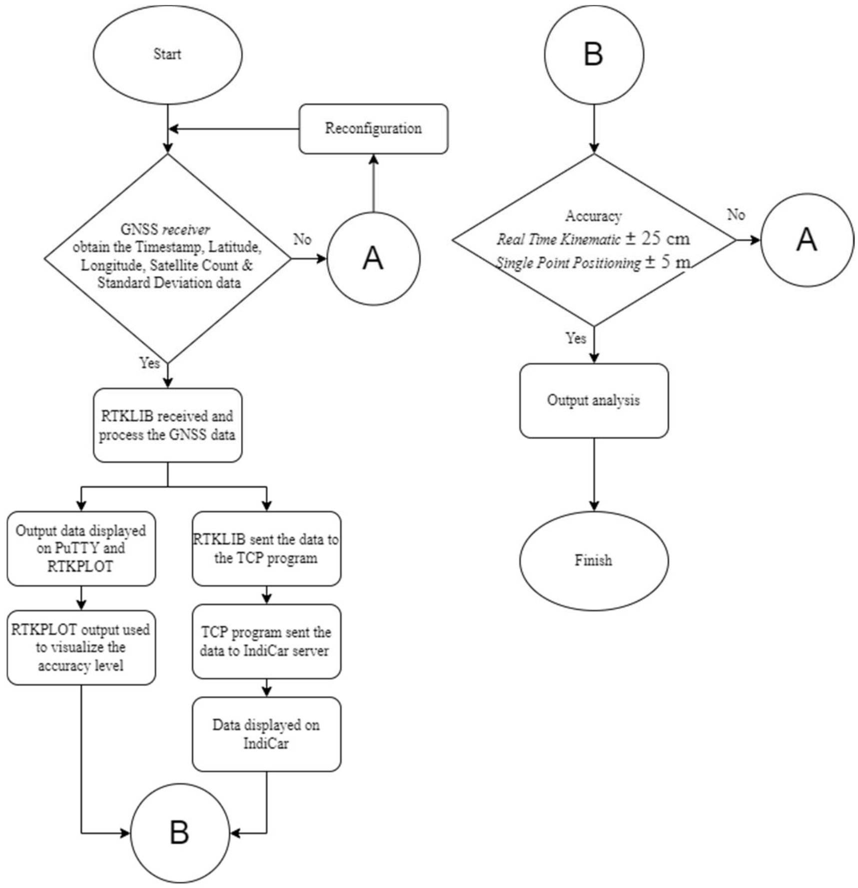

Figure 4. Working System Flow Chart

3.2. Testing and Result

3.2.1. Single Point Positioning Testing and Result

The output of the PuTTY application is then used as data in text format so that it can be processed more easily. The data used is the standard deviation value. The value is determined based on latitude and longitude data, after the value is known, the next stage is to calculate the level of precision using equations 2 and 3 as follows:

- Known:
  $s\varphi$ or σx = 2,9186 m
  $s\lambda$ or σy = 6,3457 m
- CEP = 0,59 ($\sigma x + \sigma y$)
  = 0,59(2,9186 + 6,3457)
  = 0,59(9,2643)
  = 5,4659 m
- 2DRMS = $2\sqrt{(s\varphi)^2 + (s\lambda)^2}$
  = $2\sqrt{(2{,}9186)^2 + (6{,}3457)^2}$
  = $2\sqrt{(4{,}8338) + (40{,}2679)}$
  = $2\sqrt{45{,}1017}$
  = 13,4315 m

From the calculation results, it is known that the value of the accuracy level of using the single point positioning method is 5.4659 m. The value can then be visualized by plotting the accuracy value, the radius displayed with the blue circle indicates the value of 2DRMS and the red circle shows the CEP value as follows:

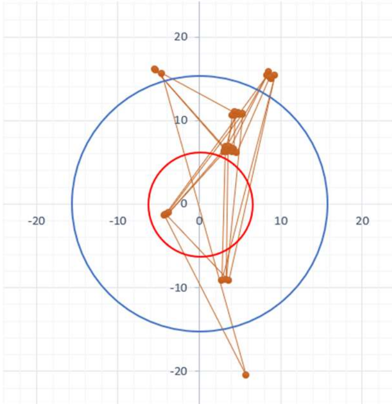

Figure 5. Single Point Positioning Plotting

In Figure 5, it is shown that the distribution of standard deviation data in the use of the single point positioning method has a probability of 95% at a radius of 13.4315 meters based on the calculation of 2DRMS. Using CEP calculations, the probability level of 50% of the standard deviation data distribution is at a radius of 5.4659 meters. The distribution of data that is outside the 2DRMS area, is the deviation data when the system condition is unstable.

In addition to the appearance of plotting, visualization of the level of accuracy can also be seen from the display of tracks passed by the rover on the IndiCar webapp. The output of the IndiCar webapp can be seen as follows:

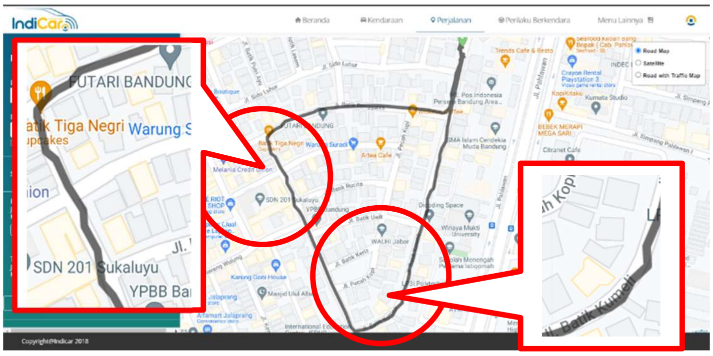

Figure 6. Single Point Positioning IndiCar Output [13]

From the latitude and longitude data obtained using the GNSS receiver, then the IndiCar webapp pours the data into the form of a track passed by the rover. Various output resulted by several applications in the system, strengthen each other result in determining the accuracy value of the single point positioning method applied to this study.

3.2.2. Real-Time Kinematic Testing and Result

The GNSS receiver data displayed in the PuTTY application is then processed with the main data of the standard deviation from the latitude and longitude values. The value is then entered into equations 2 and 3, to determine the level of precision of the accuracy in the real-time kinematic positioning system method, the two equations can be described as follows:

- Known:
  $s\varphi$ or σx = 0,1114 m
  $s\lambda$ or σy = 0,1975 m
- CEP = 0,59 ($\sigma x + \sigma y$)
  = 0,59(0,1114 + 0,1975)
  = 0,59(0,3089)
  = 0,1822 m

- 2DRMS $= 2\sqrt{(s\varphi)^2 + (s\lambda)^2}$
  $= 2\sqrt{(0{,}1114)^2 + (0{,}1975)^2}$
  $= 2\sqrt{(0{,}0124) + (0{,}0390)}$
  $= 2\sqrt{0{,}0514}$

= 0,4534 m

After obtaining the accuracy value of the real-time kinematic method of 18.22 cm, the value is visualized into plotting. Visualization can be done by utilizing the output in the form of plotting where the blue circle describes the value of 2DRMS and the green circle shows the CEP value as follows:

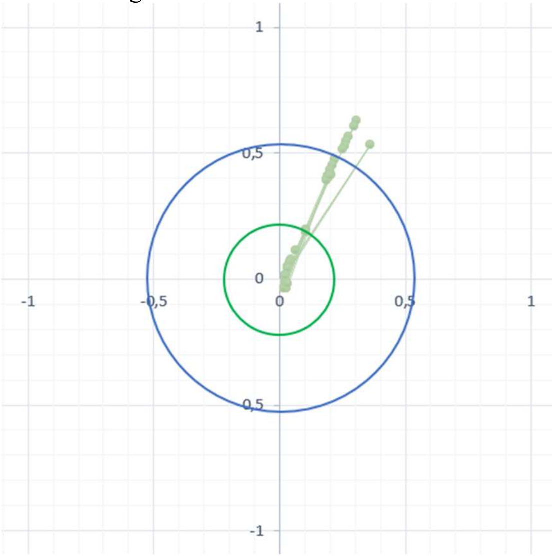

Figure 7. Real-Time Kinematic Plotting

Utilizing the 2DRMS calculation, the plotting in Figure 7 shows the distribution of data at a probability level of 95% is at a radius of 45.34 centimeters. While the CEP calculation produces a radius of 18.22 centimeters for data distribution with a probability of 50%. There are a number of data that are outside the radius of 45.34 centimeters, these data indicate a decrease in system stability during the testing process.

Using the IndiCar webapp, the track displayed is an adjustment of the rover's position point to the road conditions in the test area overview. The track traversed by the rover can be seen in the following image.

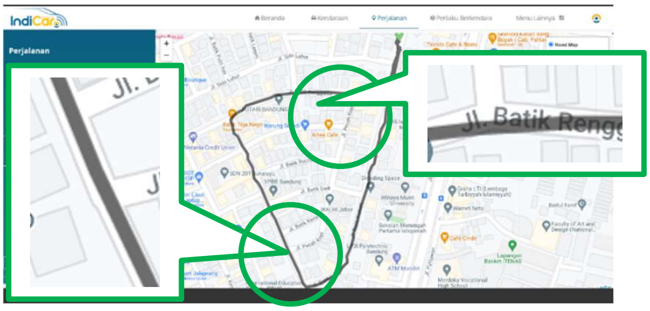

Figure 8. Real-Time Kinematic IndiCar Output [13]

The display on the IndiCar webapp facilitates the observation process, where the level of accuracy and stability of the system can be seen from the shape of the track passed by the rover. The use of the positioning system method, both single point positioning and real time kinematic also produces different track shapes.

3.2.3. Significance Test Result and Analysis

Significance testing is carried out by conducting a t-test and p-test, the results of the test can be displayed in the form of a table obtained based on calculations using the SPSS application as follows:

Table 1. Significance Test Result

Description	Method		t-table	t-stat	p-value
	RTK	SPP			
Standard Deviation Easting					
Mean	0.109	2.861	2,009575	-5.244	<0.001
Standard Deviation Northing					
Mean	0.194	6.221	2,009575	-5.950	<0.001

Hypothesis:
H_0 : $\mu1 = \mu2$: There is no significant difference from real-time kinematic accuracy and single point positioning
H_1 : $\mu1 \neq \mu2$: There is a significant difference in accuracy in real-time kinematic and single point positioning

In the calculation of the t-test, two data from two groups can be said to have a significant difference if the significance value or probability value of the calculation result is less than 0.05. Based on the calculation results using the t-test in Table 1, it can be seen that the probability value (p-value) both in the standard deviation easting data and the standard deviation northing data has a probability value smaller than 0.05. This means that standard deviation easting and standard deviation northing between RTK and single point positioning have significant differences.

4. CONCLUSION

Referring to the results of testing and analysis on the system that has been carried out, the following conclusions are obtained:

1. Environmental factors affect the performance of the GNSS receiver module, where in an environment with a large number of trees, as well as the area around high buildings, a considerable deviation is obtained in the standard deviation data group. Based on testing, the single point positioning method produces a value with the largest deviation at 20 m and the smallest deviation at 1.0960 m, while the real-time kinematic method has the largest deviation at a value of 80 cm and the smallest deviation at a value of 0.92 cm.
2. The standard deviation easting and standard deviation northing values of the single point positioning method have values at 2.9186 m and 6.3457 m, while the real-time kinematic method produces more precise values of 0.1114 m and 0.1975 m. The comparison of data indicates that the system stability of the real-time kinematic method can produce more accurate values, where the overall value of the standard deviation group is below 1 meter.
3. In the calculation of 2DRMS, the single point positioning method produces a value of 13.4315 m, while the result of the real-time kinematic method is at 45.34 cm. The accuracy value of the CEP calculation also provides a considerable difference, where the single point positioning method has an accuracy value of 5.4659 m, while the real time kinematic provides a better accuracy value at 18.22 cm. This value indicates that the real-time kinematic method has a more precise level of accuracy than the single point positioning method.
4. The t-stat value of the comparison between the single point positioning method and the real-time kinematic method in the standard deviation easting data group is at -5.244, and -5.950 in the standard deviation northing data group. Both groups of data, resulted in a t-table value of 2.009575. The comparison between the t-stat value and the t-table, answers one of the hypotheses that when $\mu1$ is not equal to $\mu2$, there is a significant difference in the accuracy of the two positioning system methods being compared. Another test, the p-test, produced a p-value that shows the comparison of the standard deviation data group between the single point positioning method and the real-time kinematic method having a significance level above 90%.
5. More precise accuracy value in the use of the real time kinematic method, resulting in a better and more stable tracking form compared to the single point positioning method. The tracking results can facilitate the monitoring process, where the display of the position of the vehicle being tracked is more in line with the actual position of the vehicle, at an accuracy level range of 20 centimeters or better.

This study can be improvised and also be more complete if the advance feature in driving is being tested, using a smaller device, using 5G technology, and do research of some internet connection parameter that affect the real-time kinematic system performance.

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