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Dead Reckoning Performance Improvement by Optimizing Heading Angle Using RTK-FIX Solution in Satellite Invisible Environment

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Automated vehicles and driver assistance systems require accurate and reliable vehicle positioning. The required accuracy is less than 0.3 m in plane error. The Global Navigation Satellite System (GNSS) includes a positioning method called RTK (Real Time Kinematic)-GNSS, of which the FIX solution is capable of cm-class position estimation. Since there is also a method to determine the reliability of the FIX solution, there is a high possibility that the required accuracy can be achieved at locations where the FIX solution is available. However, in environments such as tunnels and under elevated railway tracks, GNSS cannot be used, so it is necessary to use DR (Dead reckoning) for position estimation. On the other hand, since DR estimates position by integrating the heading angle and wheel speed values obtained from the gyro sensor, the position error increases as the running time increases.

The objective of this study is to improve the performance of position estimation during DR. Specifically, the first step is to clarify the main sources of DR errors. Next, we propose a method to improve the DR position estimation performance by using the FIX solution just before DR for those factors.

Among the error factors during DR, those that are thought to particularly affect position estimation performance include initial position, initial heading angle, slip angle, yaw rate error variation, and wheel speed. The study first examines the effects of these error factors on position estimation performance during DR. For this purpose, the values measured by a high-precision sensor were used for the error factors, while the other values were measured by a conventional method, and DR was performed for 10 seconds and the results were compared with the true position. Here, POSLV220 is used as a high-precision sensor for evaluation. The course used was the urban area of Odaiba, Tokyo. When DR was performed for 10 seconds, it was confirmed that the initial heading angle had the greatest effect on the position estimation performance.

Therefore, this study proposes a method to improve the performance of the initial heading angle. The proposed method estimates the initial heading angle by fitting the trajectory for several tens of seconds immediately before DR to the FIX solution.

The evaluation test was conducted on a 15[km] course in Odaiba, Tokyo. Figure 1 shows the evaluation course. mosaic-X5 from Septentrio is used as the GNSS receiver and ADIS16475 from Analog Devices is used as the IMU. The FIX solution used in the proposed method is a PPP-RTK solution using CLAS, and the reliability of the FIX solution is determined by the FIX solution reliability determination method. POSLV220 is used as a reference to compare with conventional methods.

Figure 2 shows the histograms of the heading angles estimated by the proposed and conventional methods, and Figure 3 shows their cumulative frequencies. Figure 2 shows that the proposed method has a higher frequency of small heading errors than the conventional method. The percentage of achieving an heading error of 0.15[deg] in Figure 3 shows that the proposed method achieves 93.2[%], which is an improvement of 3[%] compared to the conventional method. The reason for focusing on 0.15[deg] is that if the average speed of the car is 40[km/h] (11.1[m/s]), the target value of the heading angle is $\tan^{-1}(0.3/(11.1\times 10)) = 0.15$[deg] when the error is to be within 0.3[m] after 10 seconds of DR.

Fig. 1 Evaluation Course

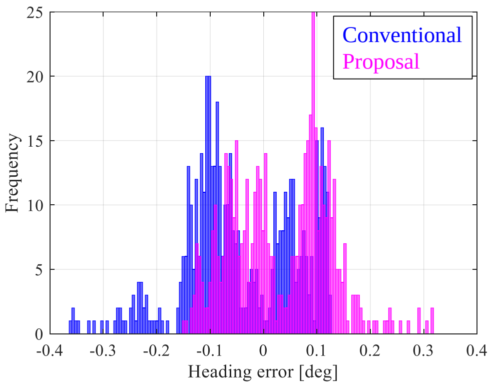

Fig. 2 Histogram of heading error

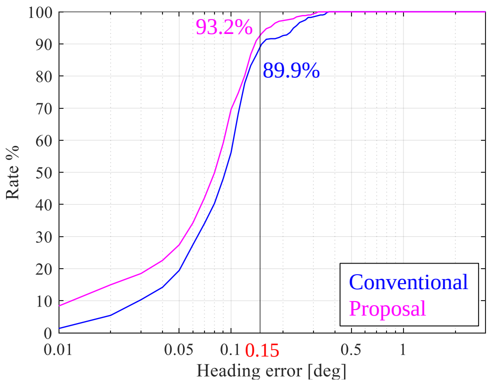

Fig. 3 Cumulative frequency of heading error