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Research on the GNSS Augmentation System Based on the AIS

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Abstract

At present, the Global Navigation Satellite System (GNSS) has become an important satellite navigation system in the maritime domain. In order to guarantee marine navigation safety, the GNSS augmentation system based on the automatic identification system (AIS) is presented, and the basic system structure of two solutions and transport mechanisms of differential augmentation information are given in this paper. The experimental results show that the developed system can greatly improve the positioning accuracy of offshore moving vehicles to enhance marine navigation safety.

Keywords: Automatic identification system; Global navigation satellite system; Augmentation system; Positioning accuracy

Introduction

The International Maritime Organization (IMO) adopted a minimum performance standard for shipborne receivers of the Beidou satellite navigation system in 2014 and recognized it as the World-Wide Radio-Navigation System (WWRNS). The Marine Safety Committee (MSC) recognized the Galileo system as the WWRNS. To date, there are four independent systems for the satellite navigation system of global maritime applications, namely GPS, GLONASS, Beidou and Galileo. The MSC adopted "Performance Standards for Multi-System Shipborne Radio Navigation Receivers" (MSC.401 (95)) in April 2015 and required governments to ensure that ships were loaded with multi-system shipborne radio navigation receivers after December 31, 2017. The receiver uses at least two independent satellite navigation systems of the WWRNS. These specifications of the IMO will greatly expand the applied range of multiple GNSS satellite navigation systems in the maritime world. In recent years, research on the maritime applications of GNSS has been widely carried out; in particular, research on the Beidou marine augmentation system has achieved important results. For example, references [1-4] show the augmented service research on GNSS dual systems using the coastal directing differential GPS conducted by the Navigation Guarantee Centers of East China Sea and North China Sea [5,6]. Because of the coastal beacon working in the intermediate frequency (IF) band, the ship must use an IF receiver to receive a differential augmented signal, which limits the application range of the augmented information. AIS is mandatory on vessels according to the IMO requirements; thus, the use of AIS to broadcast a differential signal will improve the positioning accuracy of the Beidou system equipped with AIS equipment on vessels to ensure navigation safety. The research on the augmented signal of the GNSS broadcasted by using an AIS base station can be found in references [7,8], but the coverage of the augmented signal is limited by the transmission distance of the AIS signal. The coverage is about 35 nautical miles, and ships cannot use the augmented signal beyond the coverage area. For example, a large number of fishing vessels work along the coast in China beyond the coverage of the augmented signal, and dense ships pose a hidden danger to navigation safety. In order to take full advantage of the AIS maritime signal transmission function to provide high-precision positioning information for areas that cannot be covered by the augmented signal of the base station, this paper proposes a new method of GNSS augmented signal broadcasted by using any AIS ship station, gives the system architecture and signal transmission mechanism, and proves the use value of this method by experiments.

Research on the GNSS Augmentation System Based on the AIS

There are many factors that affect the positioning accuracy of the GNSS, and the most important factors are satellite ephemeris errors, atmospheric delay error and satellite clock errors [9]. The estimated value of each error is given in Table 1. The table shows the decreasing degree of positioning accuracy with the increasing distance between the user and the base station. Therefore, in the augmentation system based on the AIS shore station that has been applied so far, due to the problem of the augmented signal coverage and the reduction of the positioning problem, it is necessary to study an effective system that is able to provide the augmented service in the waters far away from the AIS shore station. In order to solve this problem, this paper presents two GNSS augmentation system solutions based on AIS. The system structure of Solution 1 is shown in Figure 1. In Figure 1, the ship with the reference station generating the augmented signal should work in the anchoring state, and this is suitable for anchoring or search-and-rescue watching ships in the fishery. The system structure of Solution 2 is shown in Figure 2. In Figure 2, the ship that is able to receive the augmented signal of the shore station can relay the augmented signal when it is at a certain distance from the shore station, which is suitable for a large fishery. Some of the ships work in the coverage of the augmented signal and some are out of the coverage area.

To further illustrate the principles of the two solutions, logical block diagrams of systems are given. The logical block diagram of Solution 1 is shown in Figure 3. The reference position of the anchored ship with a GNSS differential reference station is obtained by data processing. The differential correction message outputted by the reference station is analyzed by the data processor and encoded in the RTCM-104 format, and packaged according to the transmission protocol of AIS, then sent by the AIS to surrounding users so that the positioning accuracy of

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users is improved. The logical block diagram of Solution 2 is shown in Figure 4. In Figure 4, the AIS transceiver receives the augmented signal sent by the shore station, and the ship station uses the augmented signal to improve its own positioning; meanwhile, the augmented signal is outputted to the data processor and the AIS transmitting message is packaged by the data processor.

Type of error	GNSS	DGNSS (Interval/km)			
		0	100	200	500
Satellite clock error	2.4	0	0	0	0
Satellite ephemeris error	2.4	0	0.04	0.13	0.22
Atmospheric delay error: ionospheric error	3.0	0	0.73	1.25	1.60
Atmospheric delay error: tropospheric error	0.4	0	0.40	0.40	0.40
Error noise of the receiver on the base station and multipath error		0.50	0.50	0.50	0.50
Error of the receiver on the base station: measurement error		0.20	0.20	0.20	0.20
Error of DGPS(RMS)		0.54	0.99	1.42	1.75
Error of the user's receiver	1.0	1.0	1.0	1.0	1.0
Equivalent range error of the user(RMS)	4.66	1.14	1.40	1.74	2.01
Positioning accuracy(2DRMS)HDOP=1.5	14.0	3.4	4.2	5.2	6.0

Table 1: Error estimation for the point positioning and differential positioning GNSS: Global Navigation Satellite System.

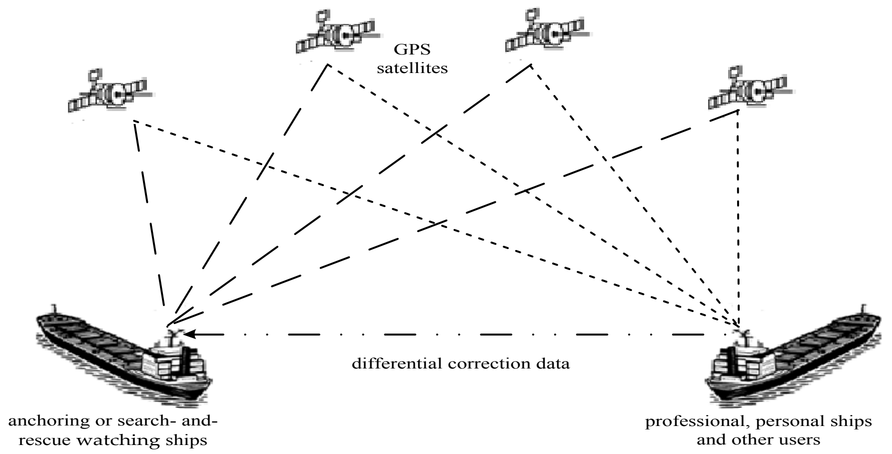

Figure 1: Solution 1 of the GNSS augmented system based on the automatic identification system (AIS).

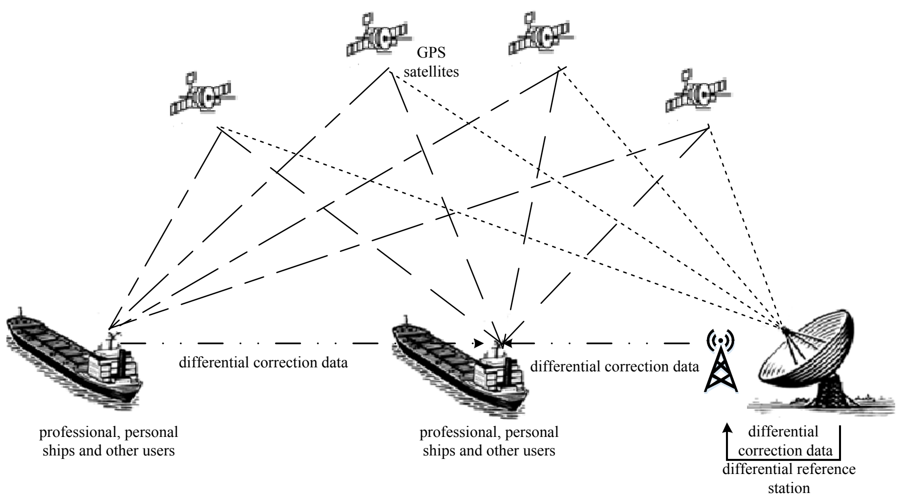

Figure 2: Solution 2 of the GNSS augmented system based on AIS.

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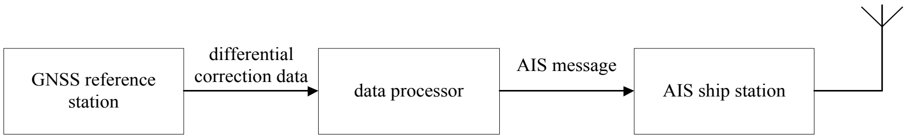

Figure 3: The logical block diagram of Solution 1 for the GNSS augmentation system based on the AIS.

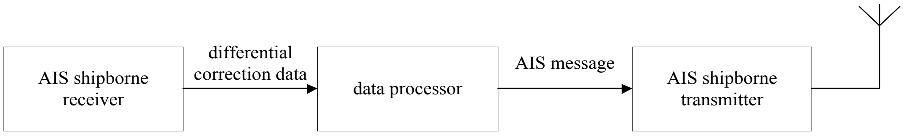

Figure 4: The logical block diagram of Solution 2 for the GNSS augmentation system based on the AIS.

GNSS Differential Augmented Information Transmission and Experiments

According to the logical block diagrams of the augmented system for Solution 1 and Solution 2, the transmission of the GNSS differential augmented information is based on the information transmission protocols of the two systems: namely, the recommendation ITU-R M.1371 and the RTCM-104 protocol of the AIS. The following describes the transmission principles of the augmented information for Solution 1 and Solution 2, respectively.

The transmission principle of the augmented information based on the anchoring station

Referring to the logic block diagram of Solution 1 in Figure 3, the position of the anchoring ship with a GNSS differential reference station is obtained by the method of data processing. The augmented information outputted by the reference station is sent by the serial port in a binary data stream. The data processor analyzes the binary augmented information of GNSS and packages the message in the RTCM-104 format. Due to the ship anchoring with the AIS ship station instead of the AIS base station, the differential information cannot be used to broadcast the special message, namely the 17th message. Here, the 8th broadcast message of the AIS binary message is used to broadcast the differential correction information; that is, the augmented information. In summary, the processing flow of the augmented information is shown in Figure 5.

According to the above principle, the experiment for broadcasting a binary data stream by the AIS ship station is carried out. The experimental system is shown in Figure 6. The first AIS ship station, named ship station 0, was located at the administration building of Dalian Maritime University and the second AIS ship station, named ship station 1, was located at the Fujiazhuang sea area, which is 5 nautical miles from the administration building. The third AIS ship station, named ship station 2, was located at the Laotie Mountain which is 20 nautical miles from the administration building. Using the AIS binary broadcast data to broadcast the differential correction, ship station 1 and ship station 2 directly received the differential correction transmitted by ship station 0 and corrected their positioning accuracy. The corrected positioning accuracy is shown in Table 2.

The experimental results show that the positioning accuracy of ship station 1 and ship station 2 can be improved by using the differential correction broadcasted by the GNSS augmented system based on the AIS.

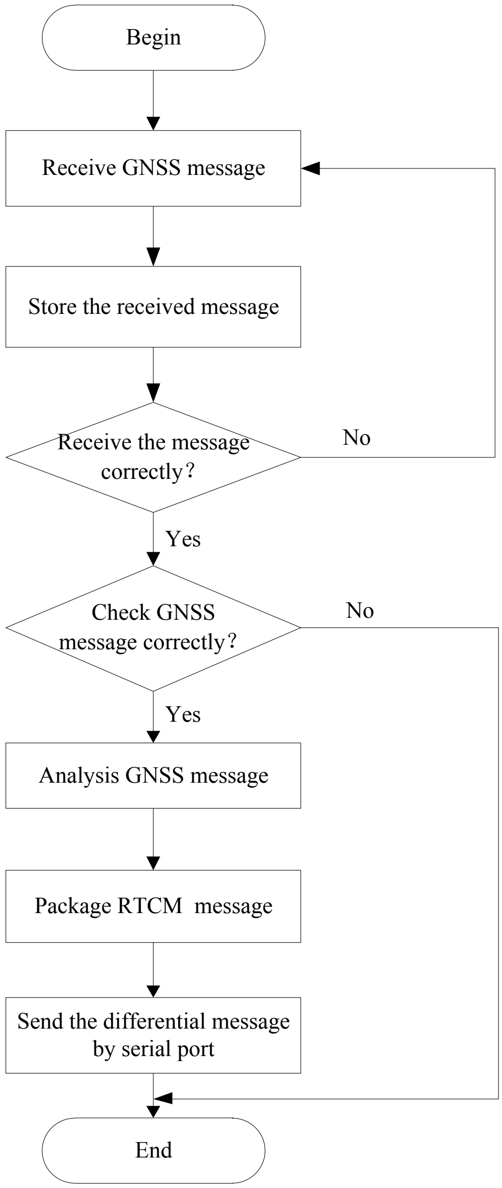

Figure 5: The processing flow of the augmented information for Solution 1.

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The transmission principle of the augmented information based on the ship station relay

Referring to the logic block diagram of Solution 2 in Figure 4, the ship station which is about 30 nautical miles from the shore station can receive the differential augmented information broadcast by the shore station with the 17th message. When the shipboard data processor recognizes the position of the ship in this area, the augmented information is packaged secondarily, namely the binary data package. The differential correction—that is, the augmented information—is broadcast by using the 8th binary broadcast message. In summary, the processing flow of the augmented information is shown in Figure 7.

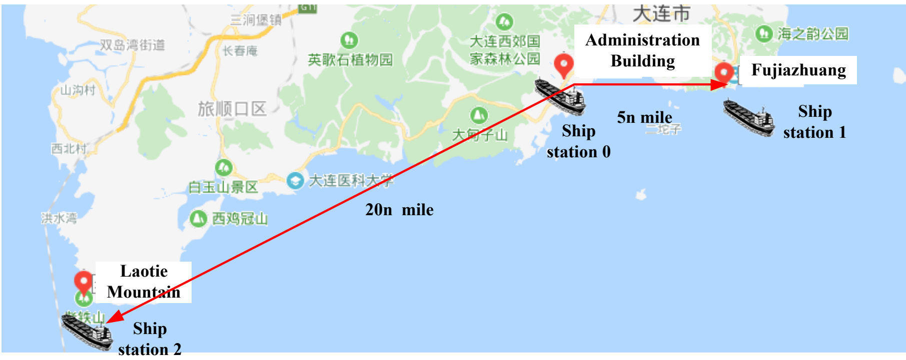

Figure 6: The experiment for the binary data stream broadcasted by the AIS ship station.

Receiving station / Transmitting station	Ship station 1	Ship station 2
Ship station 0	2.8(2σ)	3.1(2σ)

Table 2: The positioning accuracy of ship station 1 and ship station 2 in Solution 1(unit/m).

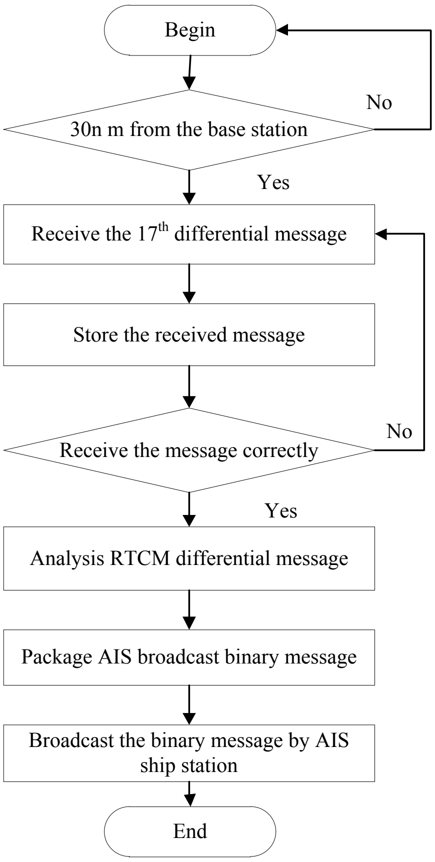

Figure 7: The processing flow of the augmented information for Solution 2.

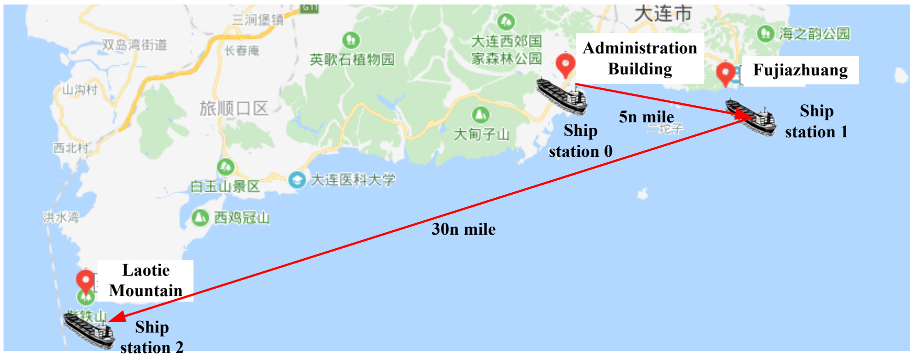

Figure 8: The experiment for the binary data stream relayed by the AIS ship station.

Receiving station / Transmitting station	Ship station 1	Ship station 2
Ship station 0	×	3.3(2σ)

Table 3: The positioning accuracy of ship station 2 in Solution 2 (unit/m).

According to the above principle, the experiment for relaying a binary data stream by the AIS ship station is carried out. The experimental system is shown in Figure 8. The first AIS ship station, named ship station 0, was located at the administration building of Dalian Maritime University, and the second AIS ship station, named ship station 1, was located at the Fujiazhuang sea area, which is 5 nautical miles from the administration building. The third AIS ship station, named ship station 2, was located at the Laotie Mountain, which is 30 nautical miles from Fujiazhuang. Using the AIS binary broadcast data to relay the differential correction, ship station 1 relayed the differential correction transmitted by ship station 0 and corrected the positioning accuracy of ship station 2. The corrected positioning accuracy of ship station 2 is shown in Table 3.

The experimental results show that the positioning accuracy of ship station 2 can be improved by using the differential correction, relaying the GNSS augmented system based on the AIS.

From the above, using the differential correction of the GNSS given by the pseudo-range differential principle, the user can receive the correction directly transmitted by the ship station or secondarily relayed by the ship station to correct the positioning data, which can improve the accuracy.

Discussion

In waters where the differential augmented signal of the AIS shore station cannot be covered, and in order to improve the positioning accuracy of a ship in waters with dense ships, such as in a fishery, this paper proposes two solutions. The principle, information processing and transmission flow of the two solutions are described in detail, and experimental results are illustrated in brief. Since the AIS is widely used in the field of ship navigation and collision avoidance, the extended application of GNSS augmented information based on the AIS has important practical significance for extending the applied range of GNSS and ensuring navigation safety.

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References

1. The Maritime Safety Committee (2014) ANNEX 18: Resolution Msc.379 (93) Performance Standards For Shipborne Beidou Satellite Navigation System (Bds) Receiver Equipment.
2. The Maritime Safety Committee (2014) Recognition of the BeiDou Satellite Navigation System (BDS) as a component of the World-Wide Radio-navigation System.
3. The Maritime Safety Committee (2016) Recognition of Galileo as a component of the WWRNS.
4. The Maritime Safety Committee (2015) Performance Standards for Multi-System Shipborne Radio navigation Receivers.
5. Liu J, Yi Y (2015) Radio bacon, research on differentiated Beidou satellite navigation system and its application. China Maritime Safety 2: 28-32.
6. Tang W, Cui J, Hui M, Deng C (2016) Performance Analysis for BDS Phase-smoothed Pseudorange Differential Positioning. J Navigation 1: 1-13.
7. Feiyu P (2014) Research and Implementation of DGNSS Correction Message Broadcasting System Based on AIS Base Station. Dalian Maritime University.
8. Wancai X (2013) Research and Implementation of GNSS Differential System Based on AIS. Dalian Maritime University.
9. Aigong X, Xiaodong H, Ximin C, Changdong J, Aiguo L, et al. (2009) Principles and Applications of Global Satellite Navigation Systems. China University of Mining and Technology Press.