Emergency ship positioning and distribution system for radio disturbance

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Abstract. Global Navigation Satellite System (GNSS) has been used as a key position, navigation and timing (PNT) input in applications or services provided by ships. However, GNSS is vulnerable to space-vehicle failures, solar disturbances, unintentional radio interference and deliberate jamming. Despite these weaknesses, GNSS has become a key element not only of maritime navigation, but also of critical national infrastructure, often without any backup being provided. In autonomous ships, the use of various integrated systems increases and the dependence on the location data of GNSS increases. Therefore, in the event of a GNSS failure, it is impossible to guarantee the safe operation of the ship and it has various accident possibilities. In this paper, we propose and describe the system newly that can collect PNTs from various equipment to detect anomalies, and measure and distribute PNTs from digital sextants, which are backup systems, when anomalies occur. In the future, we will verify the performance of the implemented system by a test with the full mission bridge simulator provided by the Kongsberg.

1. Introduction

As the need for autonomous ships is increasing worldwide, various research and development in related fields are underway. Accordingly, various technologies for the safe operation of ships have been developed. Global Navigation Satellite System (GNSS) is used as a key position, navigation and timing (PNT) input in applications or services provided by ships. However, GNSS is vulnerable to space-vehicle failures, solar disturbances, unintentional radio interference and deliberate jamming. Despite these weaknesses, GNSS has played an important role as a key component not only of maritime navigation, but also of critical national infrastructure, often without any backup being provided[1][2].

In autonomous ships, the use of various integrated systems increases and the dependence on the location data of GNSS increases. Therefore, in the event of a GNSS failure, it is impossible to guarantee the safe operation of the ship and it has various accident possibilities[3]. Therefore, although it is compatible with GNSS, it needs a complementary system independent of GNSS, and if an abnormality of GNSS is detected, a system that can provide the PNT and provide the information to systems that need it on board or off board is needed.

we propose and describe the system newly that can collect PNTs from various equipment to detect anomalies, and measure and distribute PNTs from digital sextants, which are backup systems, when anomalies occur.
2. Configuration of system
The proposed Emergency Ship Positioning and Distribution System (EPDS) enables rapid identification and use of ship positions without GNSS in radio disturbance situations. The system consists of Position Comparator (PC), Digital Sextant Unit (DSU) and Position Distributor (PD) as shown in Figure 1.

![Figure 1. System Configuration](image)

2.1. PC
The PC acquires various ship positions in connection with GNSS and DSU, and displays and compares the acquired ship positions on an ENC. In the case of coastal voyage, ship position is calculated by geonavigation through electronic drawing. It also includes an algorithm that recognizes an abnormal situation such as a distinct location difference or jamming for each identification means and analyzes the cause. If it is judged to be an abnormal situation, an alarm is generated in connection with the General Alarm System (GAS).

2.2. DSU
The DSU uses the sextant to calculate the location information based on celestial navigation. In the traditional way, the officer measures the altitude value of the celestial body with a sextant and then draws it on the chart to calculate the position of the ship.

DSU is equipped with an algorithm that obtains the current position using the measured altitude value and the DR(dead-reckoning) position to quickly calculate the position. In addition, it is equipped with a wired/wireless communication interface so that the position and measurement time can be stored in a database for information about ships.

2.3. PD
It is equipped with an algorithm that determines the priority by considering all the acquired ship positions for each –position fixing means. Also, in case of an emergency, it is possible to automatically transmit position and distribute it manually if necessary. PD is developed to be compatible with each other to interface with the legacy device. It is developed to be connected to the navigation system based on the commercial ship network standard IEC61162-450.
3. Design of EPDS

Table 1 shows the key factors for EPDS design.

| Unit | Key factors |
|------|-------------|
| PC | - Module for receiving ship position and data format conversion for each navigation system  
     - Server support for log management such as storage, deletion, and inquiry of position logs  
     - Automatic/manual module for optimal ship determination  
     - GAS interlock  
     - Electronic drawing calculation module  
     - Display of ship position according to the system operation mode |
| DSU | - Ability to calculate/store/transmit a position more quickly than a legacy sextant  
     - Compute and process celestial-based position and display it on the monitor  
     - Position saving function over 2 weeks  
     - Transmit position to PC |
| PD | - Provides data compatibility with IEC 61162-450 data for data receiving equipment data format |

3.1. PC Design

The PC should be able to interconnect with the existing navigation system of the ship, and calculate and display the position of ship. In addition, the PC has the function of supporting decision-making by identifying and analyzing anomalies caused by jamming and excessive errors by comparing the fixed position from various means.

![Figure 2. Configuration and data flow of PC](image-url)
NMEA0183-1/2 and IEC61162-450 interfaces must be provided to communicate with the existing navigation system, PD and GAS. Figure 3 shows the Computer Software Configuration Item (CSCI) of the PC.

Figure 3. CSCI of PC

Data Processing CSC (Computer Software Component) is a module for receiving and analyzing various signal signals, converting them to IEC61162-450, and controlling UDP communication. Serial Communication Processing CSU (Computer Software Configuration Unit) receives the IEC61161-1/2 format data for each navigation system through serial communication and analyzes it in the IEC61162-1/2 Analysis CSU. The IEC 61162-1/2 to IEC61162-450 CSU converts the analyzed IEC61161-1/2 format data into IEC61162-1/2 packets. UDP Communication Control CSU performs IEC61161-450 packet transmission management function from Ship Position Signal Connector to L3 switch.

The UDP Packet Processing CSU processes the IEC61162-450 packets received from the L3 switch and performs DB management functions for log management such as storage, deletion, and inquiry of position information logs in the Data Log Management CSU. The Abnormal Detection CSU compares the position of each navigation device to detect anomalies, and the Optimal Position Decision CSU determines the position. When an abnormal situation occurs, GAS Interconnection CSU generates an alarm for an abnormal situation and propagate it to GAS. The ENC Display CSU expresses these data on ENC. Position Display CSU displays various ship’s positions, and Electronic Drawing CSU is a module for calculating ship position through terrestrial navigation.

3.2. DSU Design
When the officer observes the celestial body using the legacy sextant, the altitude information is received from the celestial-based position calculator through the encoder, and through this, the position is calculated through internal processing. The computed position and observation data are transmitted to a storage server through wireless communication and stored and managed.

Figure 4 shows the signal and system diagram of the DSU.
The CSCI of DSU is shown in Figure 5.

![Digital Sextant Unit](image)

**Figure 4.** Configuration of DSU

The CSCI of DSU is shown in Figure 5.

![Digital Sextant CSCI](image)

**Figure 5.** CSCI of DSU

The Position Calculator CSU calculates the position line with the observation altitude, then processes the correction value through the altitude measurement of the celestial body, and calculates and displays the ship position through the observation altitude and the current time. Interface CSU performs interworking function between ship position storage servers. The Position Management CSU performs the function of storing the calculated information on the position information storage server. Interface CSU transmits the measurement time of the celestial body to the position calculator to calculate the position and performs the function of transmitting the position to the PC.

3.3. **PD Design**

The composition of PD is shown in Figure 2, and the CSCI is shown in Figure 6.

![Position Distributor CSCI](image)

**Figure 6.** CSCI of PD
The configuration is similar to PC. UDP Packet Processing CSU can receive IEC61162-450 format data for each navigation system through serial communication, and IEC61162/450 Analysis CSU can analyze received data for IEC61162-450 format for each navigation system. Finally, the IEC61162-450 to IEC61162-1/2 CSU functions to convert the analyzed IEC61162-450 format data into IEC61161-1/2 packets.

4. Conclusion
We propose and describe the system newly that can collect PNTs from various equipment to detect anomalies, and measure and distribute PNTs from digital sextants, which are backup systems, when anomalies occur. In the future, we will verify the performance of the implemented system by a test with the full mission bridge simulator provided by the Kongsberg.

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