Visualization System for the Positioning of Sunken Vessels Using Underwater Acoustic Devices

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***Abstract*— In the event of a vessel sinking accident, it takes a lot of manpower, equipment, and time to search for lost vessels due to difficulties in securing underwater vision. If the searching work in the water is extended, excessive costs are incurred, and pollution of the marine environment may occur due to corrosion of ships and oil spills. In this paper, we introduce the visualization system for the underwater positioning using an underwater signal generator, a floating signal receiver and an underwater positioning algorithm to monitor the position of the sunken vessel. It can be minimized the human and material resources by maximizing the efficiency of underwater rescue and search operation for sunken vessels. In addition, it is expected that it can be used for various purposes such as submarine tracking, underwater monitoring and tracking the location of underwater rescue workers, underwater leisure sports, and so on through the minimizing of signal generation devices.**

Keywords-sunken vessel; acoustic transducer; floating signal receiver; underwater positioning algorithm; visualization system.

I. INTRODUCTION

This paper introduces the Sunken Vessel Position Identification System (SVPIS), which determines and visualizes the underwater position of a sunken vessels using an underwater signal generator and a floating signal receiver based on the short baseline (SBL) method as shown in Figure 1 [1][2]. As maritime traffic steadily increases worldwide, maritime accidents such as ship sinking continue to occur. When a ship sinks underwater, the ship may be lost by movement in the water by tidal currents or waves at the accident site. In addition, there are frequent cases of giving up the sunken ship due to excessive costs for the salvage of the ship. Wrecked ships whose salvage has been abandoned or failed are not identified visually at the water surface, which may cause secondary accidents with other ships, or cause marine environmental pollution due to corrosion of the hull or leakage of oil or chemicals [3]-[5].

A representative technology currently used to determine the location of the sunken ship is the Emergency Position Indication Radio Beacon (EPIRB) system. The EPIRB is deployed on the water surface of the sinking location and transmits the sinking location using a GPS signal. So, it is possible to know the initial location of the ship where the sinking accident occurred, but if the sunken ship moves underwater by tidal currents or waves, it cannot be tracked. In order to solve these problems, a method of tracking the location of a sunken ship by connecting a ship and a buoy with a cable may be used. However, this type has problems that cables can be cut by underwater floats or tidal differences and can be tangled during deployment in the event of an accident. Therefore, divers should be deployed to search the expected location of the ship, but it is difficult to identify and track the sunken ship due to the limited visibility, which takes excessive time and costs.

In SVPIS used in this work, the underwater signal generator emits an acoustic signal that is received by the floating signal receiver, which is floating on the surface of the water. The position of the sunken ship can be determined by utilizing the time differences of the acoustic signal arriving at each floating signal receiver and the GPS coordinates of the receivers. Once the position of the sunken vessel is determined, the SVPIS can visualize its location using a display unit in the visualization system. This allows the user

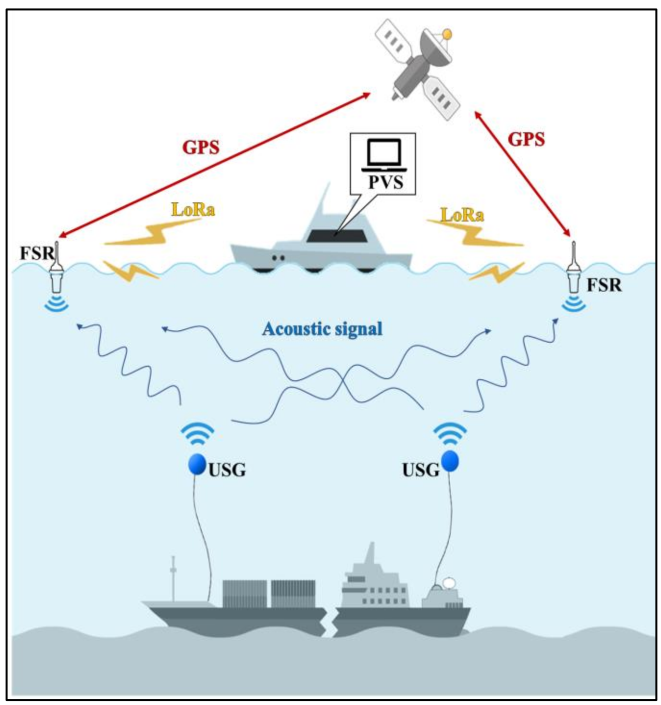

Figure 1. Overview of Sunken Vessel Position Identification System.

to see the precise location of the sunken vessel and plan any necessary recovery or salvage operations.

The rest of the paper is organized as follows: Section II introduces the components of the SVPIS and their respective roles, Section III describes the data flows necessary to visualize the position of the sunken vessel, on-site weather, and data measured by built-in sensors. Section IV details the underwater positioning algorithm using time difference of arrival to each Floating Signal Receivers, and shows the example of the visualization system for the sunken ship. And Section V summarize the lessons learned, conclusions and future work.

II. COMPONENTS FOR THE SVPIS

The components for the SVPIS include the Underwater Signal Generator (USG), the Floating Signal Receiver (FSR) and the Positioning & Visualization System (PVS).

A. Underwater Signal Generator

When the ship sinks, the USG attached to the hull is automatically deployed by water pressure and rises about 10 meters in the water while remaining connected to the cable, generating an acoustic signal. The USG contains an underwater acoustic transducer that can be attached to the bow or stern of the ship. The composition of the USG is illustrated in Figure 2.

B. Floating Signal Receiver

The main functions of the FSR are to receive acoustic signals from the USG while floating on the water surface and to transmit the received acoustic signal information with GPS information to the PVS. The FSR can be configured in various forms depending on the specific requirements, commonly including acoustic signal receiver modules, GPS modules, communication modules, and sensors (such as temperature, flow velocity, and turbidity sensors). Additionally, sensors may be added or excluded, or may also be manufactured in the form of a movable drone.

C. Positioning & Visualization System

The PVS comprises portable hardware that can calculate the location of the sunken ship using data obtained from the FSR and system software that visualizes the determined position based on GIS. The position of the sunken ship can be calculated based on the data received from the FSR via LTE or LoRa networks on rescue ships, the location (GPS coordinates) of each FSR, and sensor data. The accuracy of deriving the location of sunken ships will be improved through continuous research, including the application of noise filtering techniques, deep learning algorithms, and so on.

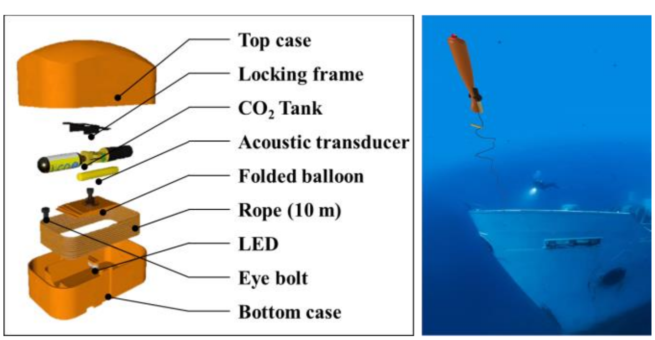

Figure 2. Composition of USG.

III. DESIGN CONCEPT OF SVPIS

Figure 3 presents an overall schematic diagram of SVPIS, illustrating the data flow and connections between devices. In the event of a sinking accident involving a vessel, the USG operates through water pressure caused by water flowing into it, generating acoustic signals. The rescue boat deploys the FSR on the surface of the water, which receives sound wave signals emitted by the USG. The time of arrival (TOA) of the acoustic signal at the FSR, along with the GPS coordinates of each FSR and the data measured by the built-in sensors, is transmitted to the PVS via LoRa communication. Using positioning algorithms based on the TOAs and GPS coordinates of each FSR, the PVS calculates the position of the USG, which corresponds to the location (coordinates) of the sunken vessel. The PVS then visualizes the positions of the sunken vessel and FSRs, displaying measured data from the built-in sensors, and field weather data provided via the APIs, on the visualization system screen.

IV. POSITIONING AND VISUALIZATION

The positioning algorithm of SVPIS calculates the difference in distance between each FSR and the USG by measuring the time difference between the times of arrival (TOA) of the signals received by different FSRs. This difference, combined with the known GPS coordinates of the FSRs, can be used to calculate the position of the USG, which corresponds to the location of the sunken vessel. In general, the time difference of arrival (TDOA)-based positioning algorithm uses either the "Least Square algorithm" [6] that obtains a solution by linearization or "Ho and Chan's algorithm" [7] that obtains a solution without linearization. In this work, the Least Square algorithm is used to derive the relative position of the USG by measuring the TDOA of each FSR. The absolute coordinates of the USG, which corresponds to the location of the sunken ship, are then calculated using the GPS coordinates of the FSRs as shown in Figure 4. However, in underwater environments, variations in sound wave velocity due to changes in water temperature or turbidity, as well as reflected sound waves by the water

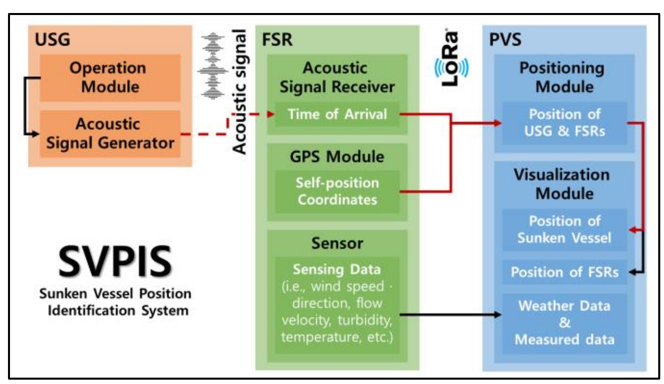

Figure 3. Schematic diagram of SVPIS.

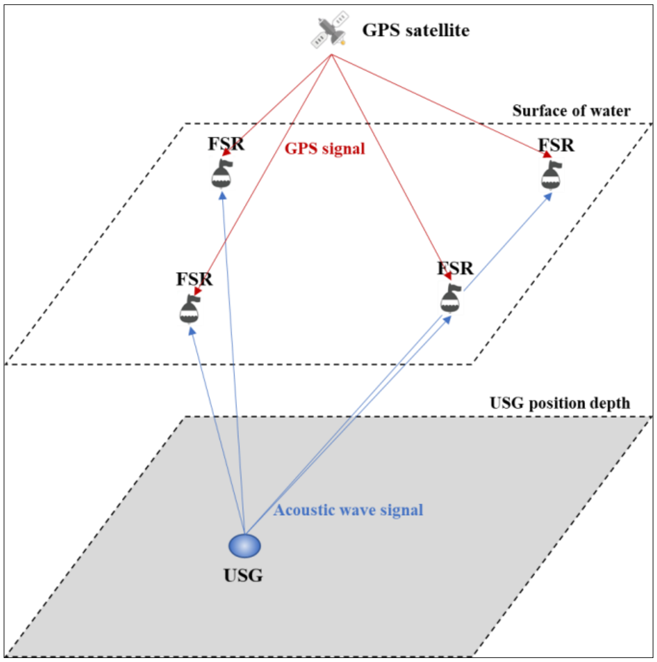

Figure 4. Underwater positioning.

surface or floating objects, can lead to inaccurate positioning results. Therefore, further studies are required to develop techniques that can increase the accuracy of underwater positioning by applying various technologies such as noise filtering technology, artificial intelligence modules, and others.

Figure 5 shows an example of a visualization system for tracking and monitoring the location of a sunken ship. The locations of the FSR and the sunken ship are indicated by icons on the GIS map, and the latitude/longitude coordinates and depth information of the sunken ship are informed by text. This information may be visualized on a three-dimensional map if necessary.

V. CONCLUSION

It has been introduced the Sunken Vessel Position Identification System, which uses underwater acoustic devices to rapidly and accurately calculate the position of a submerged vessel by measuring the time difference between the signals received by multiple FSRs in real-time. This allows for faster response times in rescue and recovery operations. The simplicity and efficiency of the SVPIS design, along with the use of relatively low-cost components, make it a cost-effective solution for underwater vessel positioning. Therefore, it has the potential to become a generic technology for responding to marine safety accidents through the positioning and tracking of sunken ships. Furthermore, improving the salvaging rate of sunken ships can reduce marine pollution caused by ship corrosion or oil spills.

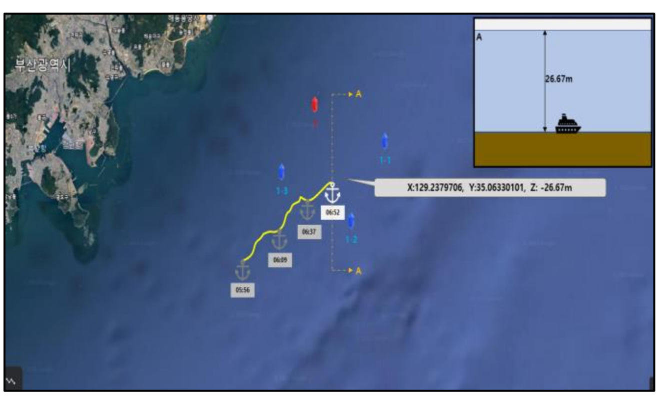

Figure 5. Visualization of position and tracking history for sunken vessel.

In the near future, the SVPIS is expected to be used for searching for drownings, tracking the location of underwater rescue workers, and underwater leisure sports by minimizing the size of signal generation devices. To achieve this, continuous research is needed to improve the accuracy of underwater positioning technology and achieve a more efficient SVPIS.

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