A New Localization Scheme Using Gyro Sensor for Underwater Mobile Communication Systems

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***Abstract*—Efficient underwater localization is a challenging issue as the need for underwater convergence systems increases. In this paper, we present a method of position recognition for underwater mobile devices equipped with pressure and gyro sensors. In the proposed scheme, at least two cooperating surface nodes (or one surface node having two separate transducers) and two discrete-time data are required to recognize position. The main idea and procedure are addressed here and its prototype and experimental results will be provided in a following research paper.**

Keywords-underwater mobile communication systems; underwater acoustic communication; localization; position recognition; gyro sensor.

I. INTRODUCTION

Recently, there has been increased interest in underwater convergence systems, e.g., smart fish farm, mission-critical underwater robot, immersive marine leisure activities, water quality monitoring and maintenance. For these applications, the use of moving objects, such as underwater device, vehicle, drone, or mobile sensor node, would be very helpful if deployed together. Meanwhile, one of the major problems related to the underwater systems supporting mobility is location awareness because radio frequency (RF) based global positioning system (GPS) that is commonly used in terrestrial networks does not work in underwater.

Some studies focused on the localization of underwater wireless acoustic sensor network (UWASN) can be found in the literature [1]–[4]. Typically, in range-based schemes, three dimensional localization is simplified to a problem estimating the coordinates in two dimensions owing to Time of Arrival (ToA) measurement and a pressure sensor. In this work, we propose an efficient localization scheme utilizing a gyroscope in which the degree of freedom for an estimate of location is reduced.

The rest of this paper is organized as follows. Section II addresses the general system model of underwater localization. Section III describes the main principle and procedure of the proposed location awareness scheme. In Section IV, concluding remarks on the direction for further work close the article.

II. SYSTEM MODEL

A conceptual diagram of range-based underwater localization is shown in Figure 1, where three anchor nodes, A_1, A_2, and A_3, are located at water surface and an object is launched underwater. It is assumed that ToA is measured at each anchor and a pressure sensor is mounted at the object. Then, an anchor node, e.g., A_1, easily knows the projected radius r_1 from the distance information d_1 and the water depth information D_1. Since other anchor nodes can calculate their projected radii in a similar way, the location of the object is finally determined as the intersection of three circles.

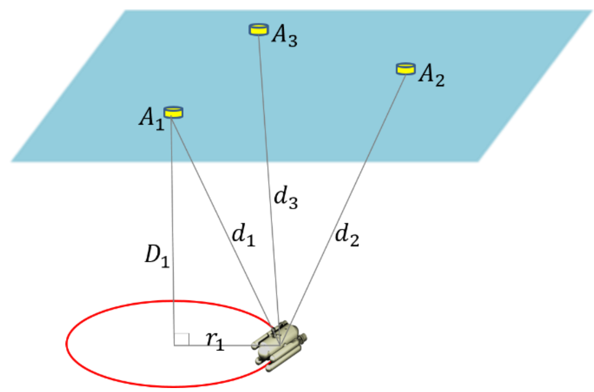

Figure 1. Range-based underwater localization.

III. PROPOSED LOCALIZATION SCHEME

A. Gyroscope-Assisted Localization

The basic assumption of the proposed range-based localization scheme is that two anchor nodes are placed at water surface and a mobile object equipped with a gyroscope exists underwater. Then, the main idea is as follows. At an arbitrary time, each anchor node extracts its projected radius from distance and depth information. The red-colored solid circles in Figure 2 represent the trajectories with the radii of r_1 and r_2, which informs us that the object is located at either X or X'. After a predetermined time, the entities taking part in the localization process repeat the same task, i.e., the object provides distance and depth information again and

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two anchor nodes acquire the blue-colored dotted trajectories as shown in Figure 2, which means that the current possible locations of the object are Y or Y'. Consequently, there remain four candidates on the movement of the object: 1) X to Y, 2) X to Y', 3) X' to Y, 4) X' to Y'. Further, since the object reports the direction of its movement acquired from a gyroscope to anchor nodes, an estimate among four candidates is finally chosen and the localization process is terminated.

It is noted that the accuracy of the proposed scheme will be improved if the number of time samples or anchor nodes increases. Also, a single anchor node having two transducers apart from each other could replace the two anchor nodes shown in Figure 2.

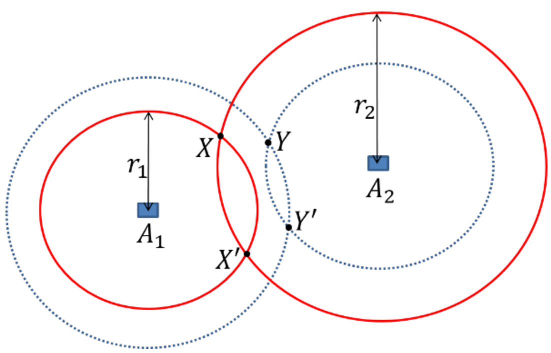

Figure 2. Top view of proposed localization with two anchor nodes and two time samples.

B. *Localization Procedure*

The specific procedure of the proposed localization scheme is given as follows.

- A master anchor node (or an onshore station or an anchor node having two transducers) initiates a localization process.
- The master anchor node sends a broadcasting message underwater.
- The moving object responds to it with depth information and two anchor nodes calculate each projected radius from the acquired depth information and the estimated distance information.
- After a predetermined time, the master anchor node sends the broadcasting message again.
- The moving object responds to it with the direction of movement as well as depth information, and then the two anchor nodes calculate each projected radius again.
- The master anchor node calculates the location of the moving object based on the trajectories provided at two time instants and the direction information and this terminates the localization process.

IV. CONCLUDING REMARKS

In this article, an idea of gyroscope-assisted localization for underwater mobile communication systems has been proposed. The direction of movement as well as range and depth information is utilized in the algorithm to help find location. The proposed scheme reduces the number of anchors required for the position recognition of an underwater moving object at the expense of complexity increase for the use of a gyro sensor.

As subsequent work, it is worth investigating other simple and efficient schemes for underwater localization using multiple sensors, specifically focused on acceleration sensor and magnetometer sensor. The implementation and verification of the proposed schemes are also challenging problems to be addressed.

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