Towards Underwater Augmented Reality Interfaces to Improve the Navigation Experience

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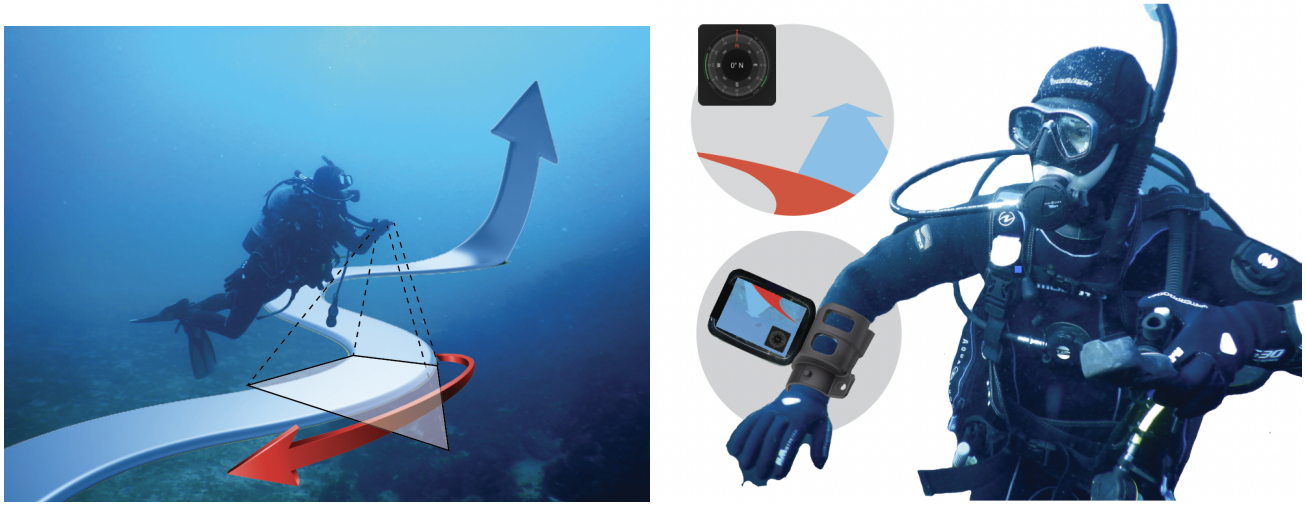

Figure 1: Concept of an AR-based underwater navigation system

ABSTRACT

In this paper, we present initial work towards evaluating augmented reality interfaces to enhance underwater navigation. We propose a conceptual framework that combines real-time GPS coordinates fetched from an Aqua-Fi module with computer vision approach to overlay a first-person view (FPV) rendering real-time AR-generated arrows pointing in the direction of the exit point of the dive. The system will allow the diver to trace the progression of the dive and easily find the way out in low visibility and high turbidity conditions. We present an initial requirements analysis based on test dives of the researchers to understand the problem domain better and an initial proposed system with early feasibility tests. We are testing an integrated AR system (inertial motion sensing, GPS and Computer Vision, DolphinSLAM [6]) with visual feedback for a first test, yet are considering also haptic and other modalities for interaction.

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CCS CONCEPTS

• **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability.

KEYWORDS

Aquatic navigation, SLAM, AR-based navigation

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1 MOTIVATION

The current state of the art in recreational underwater navigation is the use of a compass and safety lines while entering caves and caverns. Although more sophisticated positioning solutions are available in commercial diving such as M-Code, hand-held sonar devices, Long baseline acoustic positioning (LBL), ultra-short baseline acoustic positioning (USBL), or short baseline acoustic positioning (SBL) there is a general lack of a fully immersive navigation tool, which extends beyond 2D numerical geo-coordinate displayed on a dive computer.[8, 9] We propose a first 360 degree augmented reality interface solution which enables to navigate in low visibility - high turbidity environments and obtain real-time navigation instruction on a watertight screen. Building upon the strengths of the bio-inspired open-source DolphinSLAM algorithm and capabilities of an underwater Aqua-fi wireless connectivity module we propose

an interface capable of providing an augmented reality navigation experience to a disoriented diver.

The contributions of this paper are as follows: (1) we propose to adapt AR systems for underwater exploration to this end we show an initial framework description (2) we describe the requirements analysis of the system from initial test dives in different environments. (3) From the requirements we are testing individual technologies to be combined for the initial prototype test.

2 APPROACH AND CONCEPT

The proposed system includes software that processes real-time GPS coordinates captured using an Aqua-Fi module attached to the tank of the diver. Furthermore, the diver is required to carry device perception cues and motion detectors such as small sonar, doppler velocity log (DVL), and inertial measurement unit (IMU). Those sensors collect data which is then fed into the DolphinSLAM, an open-source localization and mapping algorithm for underwater environments. The main feature available to the diver is the ability to trace underwater the route taken during the dive similar to widely-used running trackers used on the surface (For visualization of the route feature see Figure 2).

From the descent, the software traces the route and calibrates the coordinates, and renders them into augmented reality navigation arrows pointing in the direction in which the subject is moving (marked in blue on Figure 1). Once the user selects the option "End the journey" the watertight device capable of running the software can be pointed in any direction and a red arrow pointing towards the exit would appear. This feature allows a disoriented diver to find out quickly in which direction the exit point can be found. Given that AR software requires strong internet connectivity the prototype needs to be combined with an Aqua-Fi internet module, which operates up until 20 meters depth and can be easily mounted on top of the air tank. [2] Figure 3 provides a schematic overview of the inputs needed for the interface to render visual feedback. As mentioned in the introduction the software is compatible with other geo-location systems providing real-time diver information such as LBL, SBL, and USBL. In the proposed solution the real-time data collected regarding the geo-location of the diver and odometry data is fed to the unity and vuforia-engine based software which returns a render of a virtual arrow pointing towards the exit and mapping the route of the diver. We see three main use-cases of such technology for both recreational and technical diving.

(1) Establishing universal marking of diving routs
(2) Real-time sport activity tracking
(3) Improving safety in high turbidity environments

3 DISCUSSION AND FUTURE STEPS

Ghaffarivardavagh et al. identified providing unbiased geolocation as the biggest challenge for underwater robotics [5]. This is why the proposed system builds on strengths of the Aquafi module. Aquafi connectivity was previously tested for high fidelity visual applications by Kong et.al. and the research concluded that high resolution information was succesfully transfered to the surface even from depths of 46m [1, 7].

Acknowledging that it is not always feasible to be equipped with an Aqua-Fi module or additional DVL and IMU devices, we would like to propose a simplified system compatible with our software for well-frequented dive sites. Building upon the Bruno et.al. research from the University of Calabria [4] which concluded that one can use succesfully QR codes for underwater AR-systems, we propose usage of QR codes with unbiased GPS coordinates to improve geolocation calibration in challenging underwater environments. Such markings can be placed on the seabed of well-established dive sites. This alternative although has many limitations can be used in cases when the Aqua-Fi module is not available.

Given that the authors did not find much research on feasibility of Image Target usage under turbid water conditions, which is an essential step for QR code geolocation calibration we conducted an experiment testing whether Unity and vuforia engine-based Image target can be recognised in lower visibility. (Figure 4.)

Figure 2: Pictures from initial test dives and requirements analysis to assess current navigation problems, showing also the two proposed evaluation environments: the pool and the open sea.

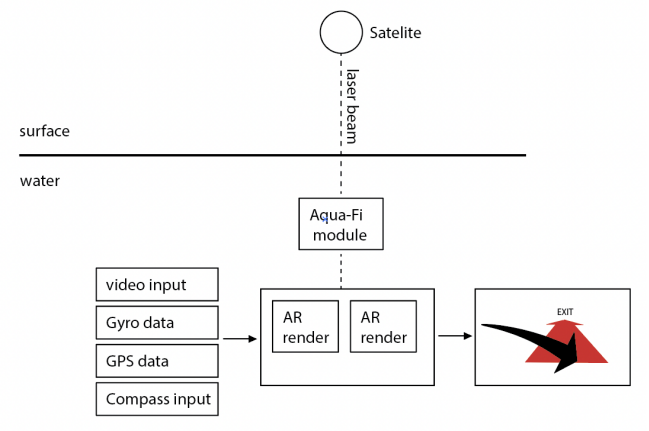

Figure 3: Navigation system inputs

Figure 4: Testing Image targets (1000 yen bill) in no-turbidity (left) and high turbidity (right) environments

In a next step, we will test the setup using a system combining a waterproof tablet and a action camera for computer vision (waterproof go-pro) in the two environments outlined in Figure 2.

Furthermore, the proposed solution can be improved with a Simultaneous localization and mapping with the extended Kalman filter (EKF-SLAM) algorithm, which excels in tasks such as unknown environment reconnaissance and simultaneous localization of the subject. [3] The authors recognize the limitations of GPS technology in aquatic environments. This unique challenge although at shallower depths can be combated using the Aqua-Fi module at larger depths requires different technologies. This is why the interface needs to be compatible with multiple formats and techniques of fetching the real-time positioning of the diver. Based on the initial research of underwater haptics from the University of Tokyo Rekimoto laboratory [10] we suggest that the mounting armband for the screen with vibrotactile actuators allowing for the interface to extend beyond visual interactivity and navigation could be a feasible extension.

4 CONCLUSION

This work has described an AR-based underwater navigation system based on geo-location coordinates fetched from the Aqua-Fi module and information gathered by perception cues and processed with the DolphinSLAM algorithm. The AR-based navigation system has a particular advantage of being a visual navigation system translating odometry data into simple visual cues. To date there have been no open-source Ar-based navigation systems for aquatic environments, hence the authors of this paper aspire to develop the proposed prototype into a fully-fledged open-source resource.

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