Development of Hovering Type Underwater Robot for Ecological Surveillance

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Abstract—Recently, various forms of ocean energy such as wave, tidal, marine current, and ocean thermal energy conversion are considered as source of alternative clean energy because of the increased oil price, international political issues, and global warming issues, etc. For this reason, underwater robot is believed to play a key role in both development and protection of the ocean. Until now, underwater robots typically called AUV (Autonomous Underwater Vehicle) have been used for relatively simple tasks such as underwater data gathering for wide area. This is a kind of off-line data gathering. If any information can be extracted during the operation, overall tasks could be more reliable and its efficiency would be increased. However, it is hard for underwater robots to solve recognition issues compared to other ground robots in that the underwater environment often deals with many challenging dynamic uncertainties. With this in mind, we developed a hovering type underwater robot for surveillance of the ocean, which is named as yShark. In the paper, we introduce a big picture of yShark in terms of system design, sensor specifications as well as initial results of example studies for visual recognition.

I. INTRODUCTION

With the increased oil price, international political issues, and global warming issues, the ocean has been considered as sources of alternative clean energy again. There are various forms of ocean energy sources that could be converted to electricity such as wave, tidal, marine current, and ocean thermal energy conversion. Recently, a detailed long-term plan for ocean renewable energy development has been released in Korea. Since many of underwater robotic technologies are still in early stage, various fields of researchers should make contributions to this plan. Until now, underwater robots typically called AUV (Autonomous Underwater Vehicle) have been used for relatively simple tasks such as underwater data gathering for wide area[1], [2]. This is a kind of off-line data gathering and no one can extract any information during the operation. Accordingly, nobody can confirm whether task is complete or not until its post data processing is finished. If useful information can be synthesized from underwater environment on site, it could increase efficiency of mission. This functions could offer potential chance to be using in monitoring underwater equipments for ocean energy generation, scientific purposes, other industrial fields, and military operations. In this paper, a brief description of a new underwater robot, named yShark is presented. yShark is designed for research work of underwater robotic intelligence including perception, cognition, probability based decision-making, machine learning, localization and mapping, etc. The remainder of this paper describes initial results of underwater visual recognition using yShark in structured environment.

II. DEVELOPMENT OF YSHARK

A. Hardware System

Fig. 1 shows yShark we developed. It is about 1.9m long, 1.2m wide, and weighs 70kg. There are two aluminum pressure vessels; one for two lithium polymer battery packs, the other for a computer control system and sensor processing units where the computer controls the power and signal of all devices. The control system consists of 3 PC104s (Lippert 1.8GHz) that communicate through a high-speed internal network; a main control computer, an optical and sonar device processing computer, and an acoustic signal processing computer. yShark can be commanded through wireless LAN when it is on the surface. The operating system is Microsoft Windows XP with Real Time eXtension (RTX). For the purpose of debugging and real-time visualization, all the data from the control system and the forward underwater camera are obtained through fiber optical communication.

B. Sensor System

Underwater camera: There are 2 underwater cameras (Bowtech Divecam-550C), one is facing front to search objects, and the other one is facing downward to get bottom images which could be utilized to build an underwater map by mosaicing, and later it could be applied to map based navigation. NTSC Video signal is converted by NTSC to USB converter and is sent to image processing computer. To get better searching, 2 LED lights(LED Multi-SeaLite Matrix) support front camera, but no light for downward camera.

Acoustic signal processing: Most important information source of underwater environment is sound. yShark has stereo hydrophone with amplifiers. This system obtains and amplifies underwater sound, and then sends it to acoustic signal processing computer, where we could find feature of target and direction of target through frequency analysis by real-time. Expected real-time bearing error is about 30 degrees using FFT and correlation for artificial sound sources synthesized by known frequencies. Artificial sound source tracking looks pretty simple, but actually, considering natural underwater environment there are lots of difficulties mainly due to noise and unknown multi-path.
Obstacle Avoidance Sonar (OAS): To avoid any collision with unknown objects, there is an OAS system which has 8 transducers; forward, 45 degree left, 45 degree right, left, right, backward, upward, and downward. Each ping of transducer needs processing time of approximately 100 msec. The processing system consists of 2 CPUs for parallel processing with maximum sampling rate of 2Hz. Effective range is from 0.3 to 30m with 1cm resolution. On horizontal space, underwater robot can find distances to objects using this system. Also, it can measure altitude and clearance when the robot is positioned under an object.

Depth Sensor: Depth can be measured by typical underwater pressure sensor (Mensor Series 6000).

Imaging Sonar: Currently, Tritech FLS is employed to scan the environment. The scanned images are analyzed using an image processing computer just like horizontal optical image. However, because the robot needs to keep its position during the scanning process of FLS, main control computer and image processing computer should work synchronously in order to provide non-distorted images which is a challenging task. To get more accurate and reliable images, we are testing DIDSON separately before installing it on yShark.

Doppler Velocity Log (DVL): DVL measures velocity of horizontal motion, and this motion data is considered to be relatively accurate. yShark is equipped with NavQuest Micro 600. One of the widely applied strategies to measure relative position is AHRS and DVL navigation with EKF. In order to extend its performance, image information could be fused.

C. Software System

The system software architecture including a robot middleware plays a very important role in managing intelligent robot [3], [4], [5]. Basically, underwater robot software architecture has almost same requirements. However, some weightings of requirements are different. We are considering some points as followings:

Limitation of resources: Recent robot systems are built based on high-speed network which allows remote intelligence and configuration of low cost hardware in a robot and powerful CPU in a server seems to be available. However, because of low bandwidth of underwater communication, underwater robots have to handle whole responsibility within given robot computing resources. Recently developed commercial middlewares are good for typical service robots which need functions to handle multimedia data and information generating from outside, like weather information. These functions bring unnecessary load to underwater robot system. Although the commercialized middlewares are developed without hardware dependencies, lots of customizing time and cost are needed for underwater subsystems because the companies supply drivers and modules for well-known sensors and hardware systems.

Lack of accessibility: Underwater robots are not allowed to be accessed by typical wireless network while the system is working, and acoustic telemetry modem (ATM) is not fast and reliable enough to debug algorithm in real-time. A middleware should provide an independent channel only for development and test.

Unstable sensor information: An ordinary robot system has a number of sensor systems, and the performance of a robot is dependent on the quality of sensors. Underwater sensors based on sonar are known to be unstable and inaccurate to be used in robot control system directly. Therefore, well-tuned filtering algorithms and sensor fusion algorithms are needed, and some rooms in a middleware are needed for these algorithms.

III. EXAMPLE STUDY OF RECOGNITION

A. Target Recognition

Due to the harsh conditions in underwater environments, vision-based recognition is still in the early stages even for artificial underwater object. However, as mentioned previously, visual information and processing could be a key factor for almost all of the tasks for underwater robots. Therefore, in order to make detection and tracking easy, specially designed artificial landmark could be used to give us a better chance of detection. In this research, the target objects have been designed in the way that by keeping certain altitude, the robot obtains the same 2D landmark shapes regardless the viewpoint changes. The designed target objects are shown in Fig. 2.

As it is one of the state-of-the-art methods of feature-based image matching, SURF has been tested for our purpose of object detection. But, the feature-based approach like SURF for the target object detection was not successful and it has been concluded that this approach was not suitable for the designed target objects[8], [9]. Considering both the characteristics of the designed target objects and the underwater environments, the template matching-based technique can be used to localize the position of the interesting objects in images based on the probabilistic approach. This method is more effective on the two dimensional objects since it utilizes direct comparisons between the template and the input image. Fig. 2 shows some of the feasibility test results using the proposed template matching based technique which is a weighted sum of template matchings with/without adaptive thresholding. This result is still sensitive to distance variation, but considering visibility is limited, we could make it more robust using a couple of templates[7].

B. Pose Estimation using Visual information

Based on underwater target detection technologies, we estimate 3D pose of underwater robots with respect to a special target, simple pattern board. The key contribution of our approach is to find out approaching angle and relative distance between the robot and landmark of docking station without using expensive devices[10].

That is, 4 correspondences of point pairs (8 points in total) are needed to solve for a homogeneous transformation between the image coordinate frame and the reference pattern frame. Since our pattern board has 36 points in total, the resulting system is overdetermined, hence the system is solvable. In order to estimate a reliable pose of the robot, it is essential to label each corner of the pattern board correctly. Although
OpenCV offers a reasonably reliable function to find corners of the chessboard pattern, the function fails if the pattern board is occluded or some corners are out of the camera field of view when the robot approaches to a close position of the pattern board. There is one gray box in the middle while all others are either black or white. It is for the algorithm to be able to locate the origin reliably. Defining the left top corner of grayed box as origin of the board, all other corners could be labeled with respect this origin by sequentially scanning around the board with a labeling window.

In current water condition like as in Fig. 3 and Fig. 4, we can calculate accurate 3D pose within about 3 or 4 meters to the target, and now we are trying to develop algorithms to extend this range with design of new pattern board which allows easy detection and more accurate pose estimation.

IV. CONCLUSION

In promoting the various forms of ocean energy such as wave, tidal, marine current, and ocean thermal energy conversion, underwater robot is believed to play a key role in both development and protection of ocean. For this, we need more intelligent underwater robots which show recognition, decision-making, and action. However, even in case of recognition, it is hard for underwater robots to solve this problem due to many challenging dynamic uncertainties. As efforts of research, we developed a hovering type underwater robot, yShark for surveillance of the ocean. In this paper, we present a brief overview of system and initial results of example studies for recognition. This result is going to be utilized to increase performance of surveillance.

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REFERENCES