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AUVs in Lake Observation*

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Abstract: *This paper proposed the use of Autonomous Underwater Vehicles (AUVs) for lake observation. The performance of the proposed system is demonstrated at the lake Biwa in Japan using the test-bed AUV the "Twin-Burger 2" available at the University of Tokyo. The proposed AUV system is capable of moving autonomously to predetermined locations carrying different kinds of sensing equipment for lake survey and sensors for navigation. In this system, the predetermined path of the AUV is marked by laying an underwater cable. At the lake Biwa the Twin-Burger 2 successfully followed the cable while collecting information on the environment. In situations where the cable was lost from the image a search algorithm was activated and if not recovered the vehicle will come to the surface.*
Keywords: *Lake Biwa, AUV, Cable tracking, lake's survey*

1. Introduction

In order to save the lakes and rivers from progressive environmental deterioration, it is necessary to observe the quality of water frequently. With the use of pointwise monitoring techniques it is very difficult to cover the entire lake in a short period. Therefore there is a high demand for a monitoring system which is capable of moving to predetermined locations carrying different kinds of sensing equipment.

At present there are two types of mobile systems, which we could think of: Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs)(R.Blidberg 1991). ROVs have their own problems due to the umbilical cable connected with the mother ship, such as entangling with the environmental objects and damage to the cable due to twisting and tension. In this paper we propose and demonstrate the use of an AUV for lake monitoring. In the experiment, laying an underwater cable indicated the predetermined route of the vehicle. The test bed vehicle "Twin-Burger" (Fujii, 1993) available at the University of Tokyo was used to demonstrate the system at the Lake Biwa, Japan. The AUV carrying the monitoring sensors plus its own sensors for navigation, successfully guided it's way along the cable. The main advantage of such a system is that it is possible to carry out frequent measurement of the lake condition along a predetermined path. In this paper we discuss the navigating algorithms and the kind of sensors which are fused together to carry out this operation.

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2. System overview

The proposed system consists of an AUV and a cable laid on the lake bed to indicate the desired path for the AUV. This way the complex path planning is not necessary. The cable following is carried out by looking through the CCD camera mounted in front of the vehicle. Navigational system of the vehicle will provide the necessary data for navigation and the acoustic height sensor will provide the altitude of the vehicle

In the proposed system, the vehicle has different modes of operation as shown in Fig. 1. The initial mode is called the waiting mode. In this mode the AUV awaits a start command from the transponder system and will switch onto the descending mode once the start command is received. This mode will be active until the AUV reaches a defined height from the cable. The height information is collected from the acoustic height sensor.

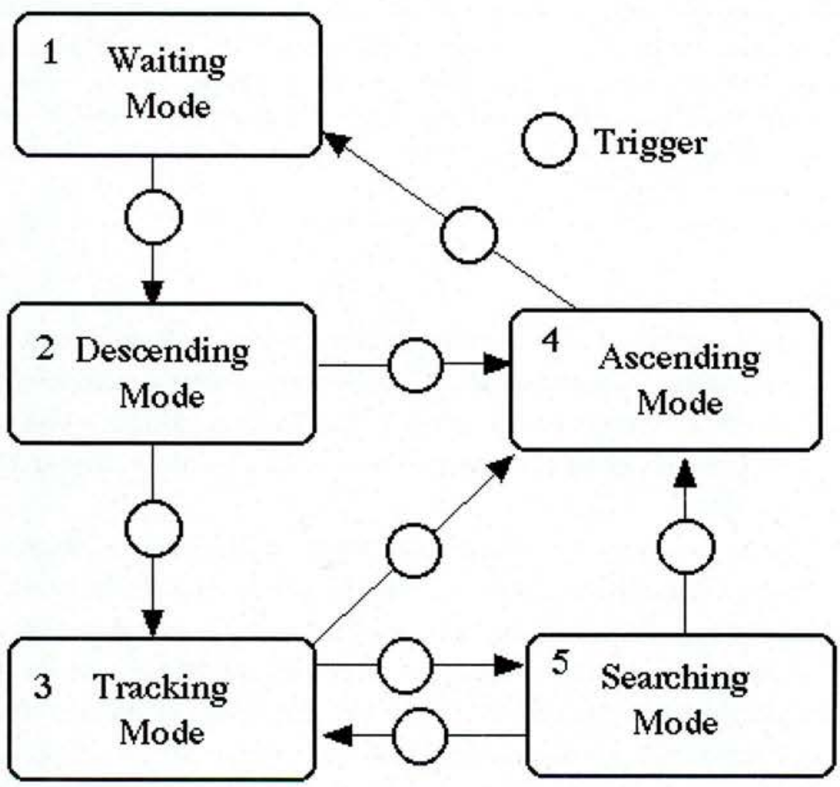

Fig. 1: Modes of Operation of the AUV

At the defined altitude vehicle activates the tracking mode and will follow the cable up to the defined location using the visual data captured by the CCD camera mounted in front of the vehicle (Balasuriya *et al.* 1996). The schematic diagram of the tracking system is shown in Fig. 2. The image data from the CCD camera are processed and the position of the cable with respect to the AUV is calculated. Using the relative position of the cable, the path of the AUV is derived. The control of the actuators of the AUV is done according to the path generated. During the tracking mode if the cable is lost from the image of the CCD camera mounted on the AUV the vehicle will activate the searching mode which will search the cable in different directions and once found will switch back to the tracking mode. If the cable is still missing after carrying out the search then the vehicle will come to the surface. The next mode of operation is to ascend to the surface and stop the operation.

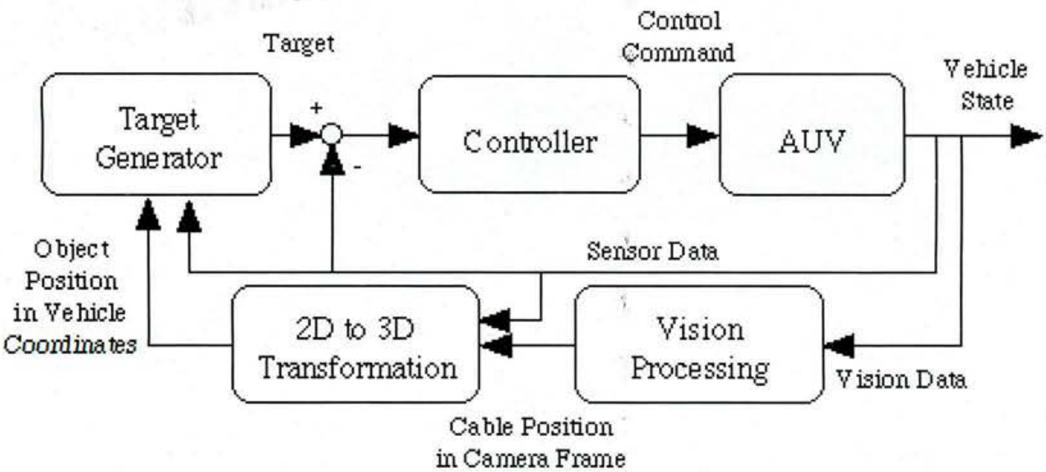

Fig. 2 The schematic diagram of the Tracking System

3. Experiment at the Lake Biwa

The test bed AUV the "Twin-Burger 2" shown in Fig. 3 was used to demonstrate the performance of the proposed system at the lake Biwa, Japan. Twin-Burger 2 is equipped with ranging sonars placed in all directions, two CCD cameras, two forward thrusters, two vertical thrusters and one side thruster. Top two hulls carry the processing units (fourteen T-800 transputers), interfacing hardware and actuator hardware while the lower hull carries NiCd batteries.

The desired path of the mission was indicated by laying a yellow color hose as shown in Fig. 4. The depth of that area is around 4 m. The Twin-Burger 2 was placed at the starting point and the waiting mode is activated.

Using the transponder the vehicle is triggered to the descending mode. The AUV descends to the lake bed by keeping a constant heading and with no surging. The height information captured by the down looking acoustic sensor is used in the feedback control loop of the vehicles acutators to descend to the lake bed. The image data from the CCD camera of the Twin-Burger is used only in the tracking mode. The AUVs cruising speed target during tracking is 0.2 $m \cdot s^{-1}$. In all other modes the speed was kept at 0 $m \cdot s^{-1}$.

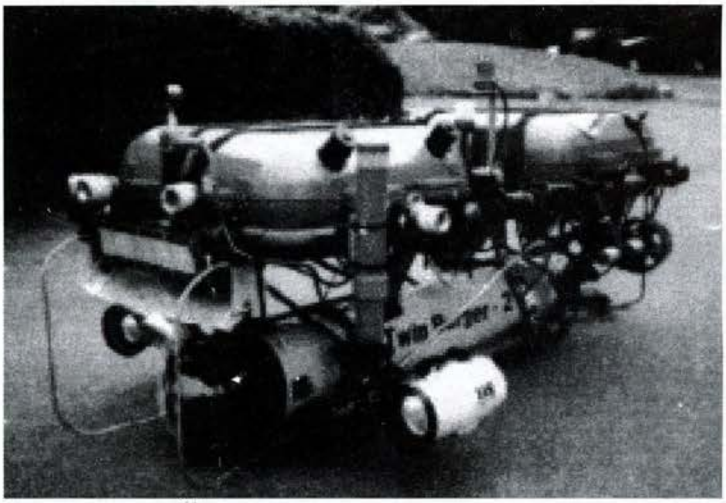

Fig. 3: Twin-Burger 2

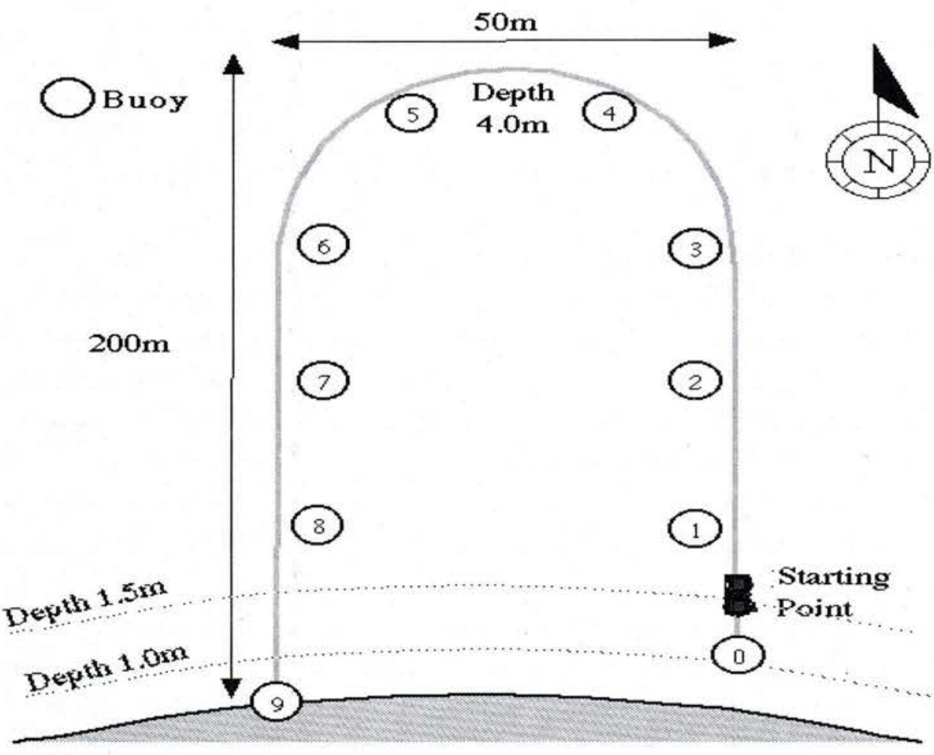

Fig. 4: Cable Setting at Lake Biwa

4. Results

Fig. 5 shows the steering modes of the Twin-Burger during the lake observation mission. It can be seen that the vehicle carried out a smooth operation between the sampling times 200 s and 520s. The switching into the search mode very frequently is due to the invisibility of the cable when covered by waterweeds. At the biwako mission the vehicle came to the surface after travelling a distance of about 180 m due to the invisibility of the cable. The altitude data in Fig. 6 shows that the vehicle had travelled at a height of about 1.25 m above the lake bed. The surge data shows that the vehicle had cruised with 0.2 m·s^{-1} during the period from 200 s to 520 s. The results shows that the Twin-Burger successfullly followed the cable when it was visible to the CCD camera mounted on the AUV. Also it can be seen that the vehicle search the cable once it disappears from the image. In case when the cable cannot be recovered then the AUV is intelligent enough to come to the surface.

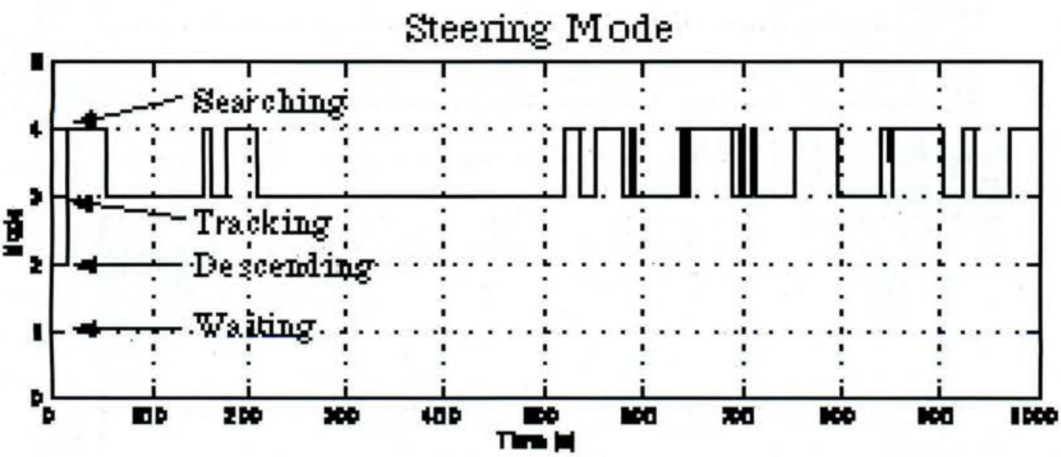

Fig. 5: Steering Modes

5. Conclusions

In this paper, is it proposed to use AUVs for the survey of lake environment. It is demonstrated that the desired path in which the data is necessary can be indicated by placing a cable on the lake bed. This will allow the AUV to follow the cable while sensing environmental information. AUV movement is very smooth compared to the movement of ROVs enabling continuous and smooth data acquisition of the environment. Untetheredness of the AUV makes it more flexible in movement and avoids distruction surrounding objects. Using AUVs it is possible to carry out repetitive surveys in a defined lake area. As a result, data on a particular area will be available at shorter intervals. Using acoustic links these data can be made available to the land systems in real time. Finally, it can be concluded that AUVs could play a major role in routine lake environment survey.

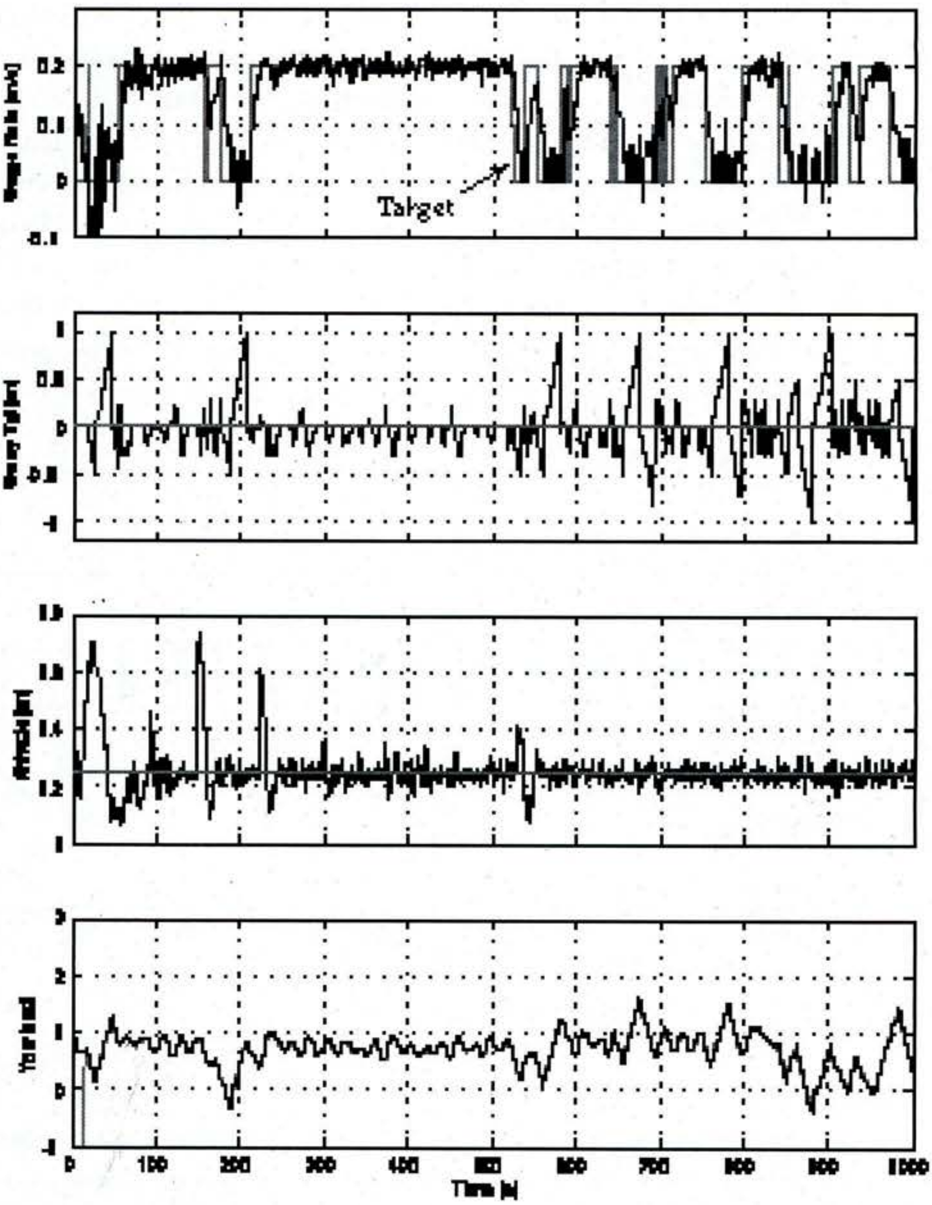

Fig. 6 Dynamics of Twin-Burger 2

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