Docking Technique for Manta-type UUV and its Experimental Studies in Water Tank Environment

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***Abstract*—We present an underwater docking technique for a manta-type unmanned undersea vehicle (UUV) which is under development in Korea Institute of Robot and Convergence (KIRO). The manta-type UUV is a test-bed vehicle for demonstrating an autonomous docking technique in the water tank [1]. There are two cameras mounted in front of the vehicle for vision-based underwater localization around docking station. There is a range sonar array mounted in front of the vehicle. This sonar is used for obstacle avoidance, and also can be used as a simultaneous localization and mapping (SLAM) solution in a partially known environment. In this paper, we show the results of a remote docking experimentation performed in the water tank for the manta-type UUV. From the results, we verify the docking performance of a manta-type UUV and applicability of the developed docking station.**

Keywords—underwater docking technique, manta-type unmanned undersea vehicle, vision-based underwater localization, obstacle avoidance, simultaneous localization and mapping, docking station

I. Introduction

A manta-type unmanned undersea vehicle (UUV) is a test-bed to develop and demonstrate an autonomous docking technique on a docking station installed in the water tank of $12\ (\mathrm{L}) \times 8\ (\mathrm{W}) \times 6\ (\mathrm{H})\ [\mathrm{m}]$. It has been developed small and lightly to be operated in the water-tank environment. As shown in Fig. 1, it has oblate shape to dock easily on a docking station. The UUV takes 4 degree of freedom (DOF) motion in the water (yaw, surge, pitch, and roll) by operating two horizontal thrusters and horizontal hydroplanes complexly. There are inertial measurement unit (IMU), attitude and heading reference system (AHRS), depth sensor, two cameras and range sonar array. Especially, two cameras and range sonar array are utilized as vision-based underwater localization and simultaneous localization and mapping (SLAM) solution in a partially known environment. Below Table 1 shows the general specifications of manta-type UUV [2].

In this paper, we verify the docking performance of a manta-type UUV and applicability of the docking station in the water tank environment by operating manta-type UUV remotely.

Fig. 1. Manta-type UUV

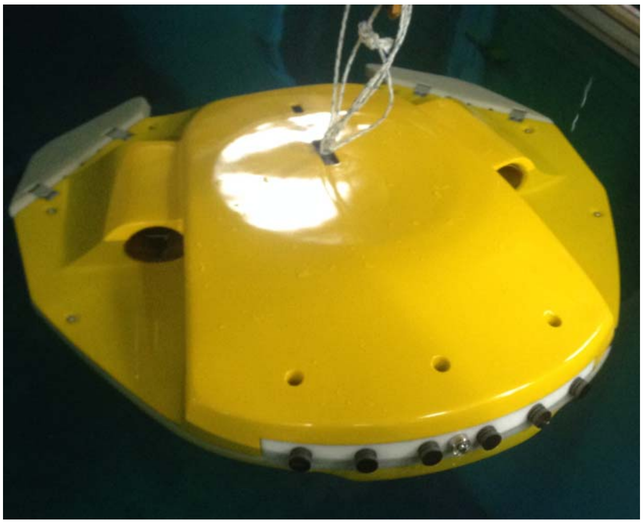

TABLE 1. GENERAL SPECIFICATIONS

Item		Specifications
Dimension		1.0(L) x 1.0(W) x 0.3(H) m
Weight		63.30 kg
Depth rating		100 m
Battery system		Lithium-ion(7S-2P), 382.2W
Thrust system		2 x thruster of 90W and 2.2kgf
Stern planes		2 x step motor, 8.4N·m, 0.088deg(resolution)
Sensor system	Camera	768(H) x 494(V)
	IMU	Gyro ARW 0.2deg/√hr, Accelerometer VRW 0.04mps/ √hr
	AHRS	<0.7deg(yaw), <0.4deg(roll, pitch)
	Depth sensor	0.1% FS, <100m
	Range sonar array	0.3~10m, 0.01m resolution

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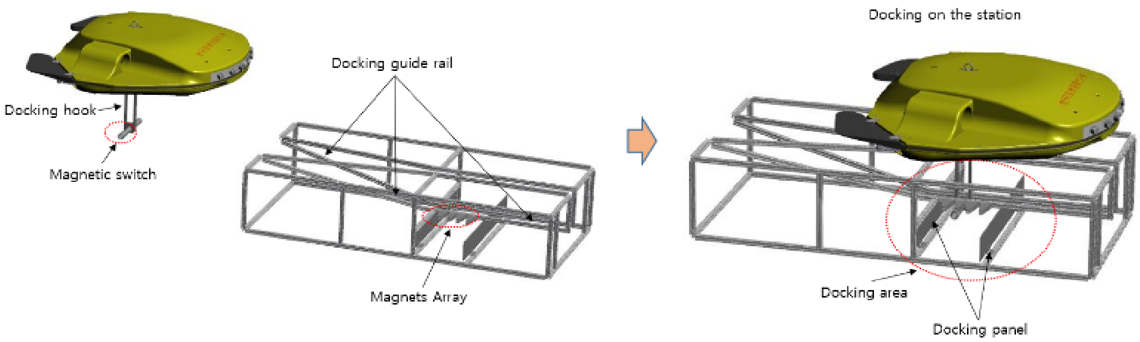
Fig. 2. Design of underwater docking station for manta-type UUV



II. Docking Station

Research objective of this work is development of an autonomous docking technique for a manta-type UUV. We develop an autonomous technique to accurately approach and dock on the docking station.

As shown in Fig. 2, when the UUV try to dock on the docking station, the UUV is induced along with docking guide rail by a docking hook. The magnet array and switch are installed in the docking station and hook, respectively, so that the vehicle get state information as the vehicle places on the docking station. The UUV also can swim autonomously and launch itself further from the docking station. The docking panel is designed foldable to prevent the UUV getting out the docking zone easily. A grid pattern is located in front of the docking station for vision-based localization as Fig. 3.

Fig. 3. Docking station and pattern on the tank floor

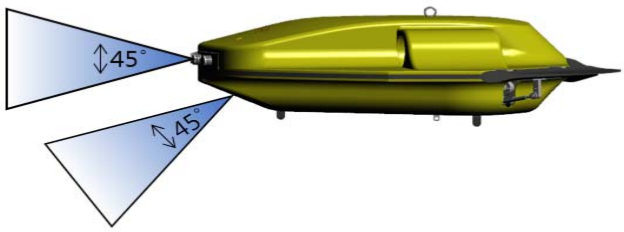
III. Docking Technique

The autonomous docking technique includes vision-based underwater localization and a SLAM solution in partially known environment.

Vision-based underwater localization

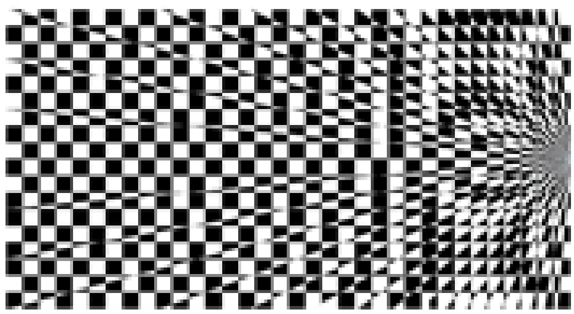
There are two cameras mounted in front of the vehicle: one of them faces forward and the other one is tilted downward as Fig. 4. Their field of view is 45 degree.

Fig. 4. Camera angles of vehicle



These two cameras are used for vision-based underwater localization and path planning near the docking station. To get accurate location information, pattern are designed not to overlap with each other as shown in Fig. 5 [3].

Fig. 5. Grid pattern



We use the template matching method for localizing the manta-type UUV around the docking station. We extract the edge information from the pattern image of the downward. Extracted edge information is compared with previously calculated value as shown in Fig. 6. We can see the result of template matching in Fig. 7, which can be practically used for guidance of the UUV near to the docking station accurately [4].

Fig. 6. Template matching

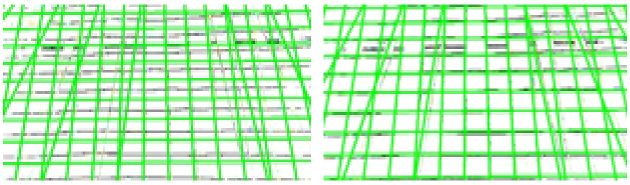
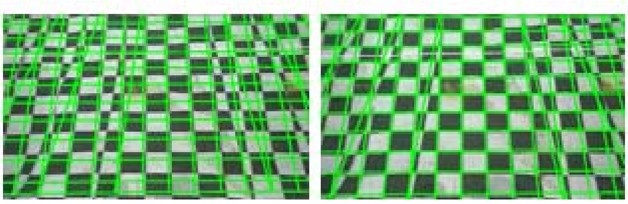


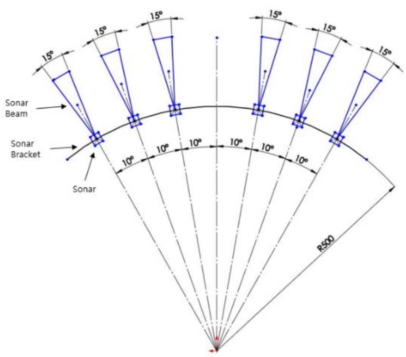
Fig. 7. Result of Template matching



A. *Obstacle avoidance and SLAM*

The manta-type UUV utilizes a range sonar array mounted in front of the vehicle for obstacle avoidance and SLAM from the partially known environment information. The array is made up with six range sonars as Fig. 8. Each range sonar has a 15 ° beam angle and 10 m detection distance. By using inverse modeling and occupancy grid mapping algorithm, we can achieve obstacle avoidance and path planning [5] [6].

Fig. 8. Beam shape of range sonar array



IV. EXPERIMENTAL STUDIES IN THE WATER TANK ENVIRONMENT

We demonstrate remote docking of manta-type UUV to verify docking performance. We installed a docking station on the bottom of the water tank and operated the vehicle remotely as shown in Fig. 9 and 10. We verify four DOF motion performance of the UUV and the structural applicability of the docking station. The results of this experimentation show that the UUV and docking station can be applied to autonomous docking technique.

Fig. 9. Docking station on the tank floor

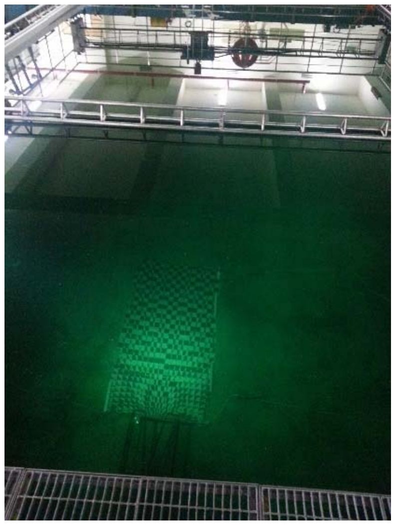
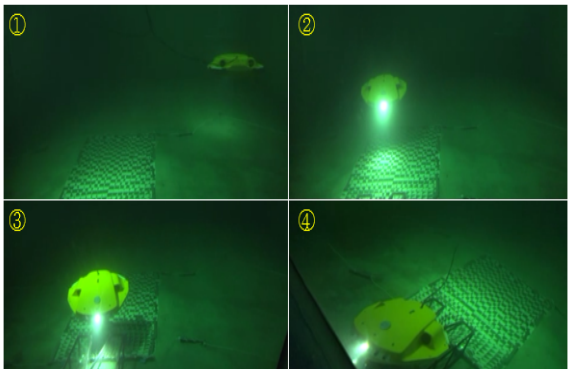


Fig. 10. Remote docking experiment



V. CONCLUSIONS

We developed the manta-type UUV and demonstrated remote docking test in the water tank. In our experimentation, we utilized various raw data information for developing vision-based localization, guidance algorithms, SLAM, and vehicle motion control. From the results, we verified the performance of the UUV and the applicability of the docking station.

ACKNOWLEDGMENT

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