19. MODELING AND PRELIMINARY DESIGN OF UNDERWATER ROBOT FOR INSPECTION

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ABSTRACT

By advancing robotic perception technology, the development of Autonomous Underwater Vehicles caught attention in certain application such as oceanology and surveying. This paper proposes an innovative approach for the design of a highly maneuverable underwater robot with 4 degrees of freedom. The mission of the aforementioned AUV is to inspect the inaccessible flooded mines and collect geological data during 5 hours of operation. Following, the configuration and mechanical design of the thrusters and pendulum mechanism are outlined. Further, low-level control architecture for real-time operating of eight thrusters is presented. Besides, dynamic modelling of the system, hydrodynamic terms and transformation matrix based on Euler angle are identified.

Keywords—Underwater robot, Motion control, ROV design

INTRODUCTION

During recent years the design of Remotely Operated Underwater Vehicle (ROV) is extended significantly, particularly ROVs which are inspired by underwater species such as [1]. Furthermore, Autonomous Underwater Vehicle (AUV) are more advanced in terms of navigation, perception and power consumption [2] .

the project UNEXMIN investigates to utilize the capabilities of the fully autonomous sea robot to prospect flooded mines, where technological challenges hindered human accessibility to mine for years. UNEXMIN ”Autonomous Underwater Explorer for Flooded Mines” aim to deliver valuable graphical and geological information. Following , describes the design of the platform, propulsion system, buoyancy and etc. that have been used in the robot. Note that the mechatronic architecturing unit and navigation is out of the scope of this paper.

SPHERICAL DESIGN

To achieve a decent design, a number of factors must be taken into account during the development phase. A streamlined outer shape is critical for sufficient efficiency, particularly where a number of components such as vision sensors, instrumentation and thrusters will be assembled over the robot structure. Moreover maneuverability of the robot is required in order to pass through narrow spaces. After a number of trials, a sphere shape structure is chosen as the main platform. This sphere consider as close frame pressure hull to include all the components inside. The sphere is water tight (60 bar) and it consists of upper and lower semi sphere with the thickness of 7 mm aluminum. According to table 1, the weight of the robot is 106 kg and the diameter is 60 cm.

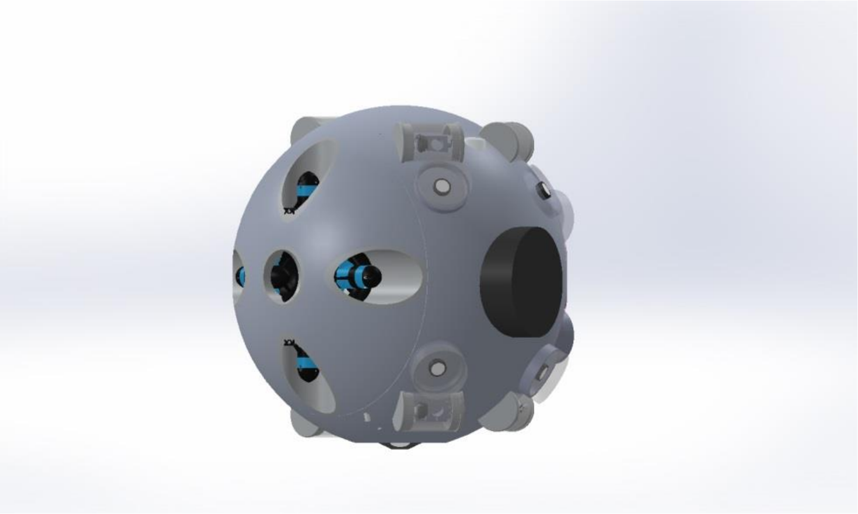

Figure 6: Robot CAD design

The characteristic of the environment that the robot need to be driven indicate a certain degree of freedoms. Complete horizontal and vertical motion is a necessity in this application. Hence, as it will be explained in section 'propulsion unit', a propulsion system consists of several thrusters covered surge, heave and heading control of the robot. On the other hand, the robot is equipped with ballast control for vertically long displacement. Furthermore, the advantage of utilizing a pendulum system for pitch angle is described later in the following section briefly [3].

The robot is also equipped with 6 cameras and 6 laser scanners for the navigation, the configuration of 4 cameras and a laser scanners in bow and 2 cameras and s laser scanner in stern provide a sufficient observation angle to control the robot autonomously. Moreover, the robot is advanced with multibeam sonar, inertia navigation sensor and laser beam.

Table 1 Robot specification

Parameters	
Weight	***106***
Size ø	***0.6 m***
Velocity	***0.5 m/s***
DOF	***5***
Operating depth	***500 m***
Number of thrusters	***8***

PROPULSION UNIT

As it is described in the introduction, The robot has 8 thrusters which are distributed on port and starboard side inside a cross-shaped manifold symmetrically. To be precise, there are 4 thrusters in each side, two in horizontal and two in vertical orientation. Therefore, the 4 horizontal thrusters configuration can contribute to surge and heading control motion. On the other hand, the 4 vertical thrusters provide heave motion when the robot position need to be accurately control alongside the shafts or galleries. Note that off the center (CG) location of the vertical thruster can also provide roll motion, however this degree of freedom won’t be actively controlled.

Each thruster is a 12 volt brushless motor about 350 g dry weight, which comes with a speed controller with CAN protocol communication. Maximum power produced by each thruster would be 350 watts.

BUOYANCY CONTROL

Having a buoyancy system for AUV operating in deep sea is quite common in view of the fact that, it lowers the amount of energy consumption in compare with thrusters. In this context, controlling the velocity of the robot over a certain vertical path can effect on energy consumption reduction.

The buoyancy control in our application is about changing the volume of the sphere only when the robot follows the long vertical path. In this design, the variable volume is about 4 liters, while the transformer oil will be pumped from the reservior to the bladder in order to minimize or maximize the buoyancy effect. The pump is controlled via a brushless motor which has the same speed controller as the thrusters. About 80% percent of the bladder is full, while the robot is overlapping with the water surface (the initial position of the robot inside the water). As the robot increase the depth from the water surface, the volume of bladder drops which simultaneously effect on the stability of the robot.

PENDULUM MECHANISM

Primary, the idea of rotating a mass around the center of the gravity of the robot is developed in order to pitch and maintain the robot in certain angle independent from te propulsion system. Hence the pitch control can be implemented simultaneously during surge or heave or individually on a spot. This method also yields wider angle for a navigation system such as multibeam sonar.

The weight of 3 batteries (6kg) over a supporting structure is used to build a pendulum structure with the radius of 7.5 cm from the center, which is correspond to center of volume; and a stepper motor drives the mechansim through a gear.

Note that converging the center of gravity and center of volume is a keystone through out the whole design process, owing to the fact that it directly affects on robot instability. That being said, the vatiable buoyancy control and pitch angle always alter the robot stability. Hence, maintaining the center of gravity the lower than center of gravity is always critical.

CONCLUSION

The paper addresses an innovative design layout for an underwater robotic platform which can be utilized for inspection, navigation and collecting geological data. As stated above, the sphere structure is modeled and propulsion system, buoyancy and pendulum mechanism are under development. Concurrently, Low-level control is in progress which will be extended to the high level of control, where the certain path can be followed by the robot in order to stabilize the dynamic equation of motion.

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