Development of Underwater Mobile Robot AQUA-X with New Maneuvering Method

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ABSTRACT

An Unmanned underwater vehicle is a type of robot that can maneuver under the sea surface without any human operator. The first Autonomous Underwater Vehicles was developed by the University of Washington in 1957 (Blidberg, 2013). In the last few decades, the researchers and manufactures are successful in the development of several different types of UAV and they built more than 200 AUVs, such as the well-known REMUS by WHOI (Allen, 1997), MIT Sea Grant's Odyssey (Bovio, 2006), or P-SURO (Hong, 2010).These UAV are best suitable in military and many other commercial applications such as underwater surveillance, environment monitoring, underwater cable fault and oil ricks maintanence (Christopher, 2003). As the demand of high accuracy and smooth navigated UAV's are spreading to many commercial and specially milatery applications, it becomes a chalange for the researchers. In this research article a new manuvering method is proposed for Underwater mobile robot, which use four (4) propellers that are specially placed in Cartesian Coordinate Configuration with parallel arrangement to provide the batter thrust and also for navigation purpose without use of actuated fins. This project intends to design and develop test bed autonomous and semi-autonomous underwater vehicle named AQUA-X Robot as a platform for further research as well as to applied in numerous field such as hydrographic surveys, mine counter measure (MCM) operation, environmental monitoring, search and salvage operation, fishery operation, scientific sampling and mapping, underwater acoustic research just namely a few as in (Arshad, 2004).

INTRODUCTION

The AQUA-X underwater robot has four fixed-pitch propellers mounted at the four ends of an aerodynamic body frame. Owing to aerodynamic body frame, this underwater robot is dynamically elegant, inexpensive, and simple to design and construct. It is a non-holonomic vehicle, and has limitless on its power thrusts compare to body frame. It can be navigate in deep seawater with less recovery to surface operation time and does not require large safety distances to operate. With four propellers, dynamic braking is easily archive by reversing the rotation of propeller.

Conventionally, only one propeller use to provide thrust and actuated fins to navigate the underwater robot. In this research, four (4) propellers is presented with placed specially in Cartesian Coordinate Configuration with parallel arrangement to provide the thrust and also for navigation purpose without use of actuated fins. Thus, simplifying the mechanical actuator and yet provide better thrust. This concept was first proposed by Prof. Keigo Watanabe in International Conference on Instrumentation, Control & Automation (ICA2009) as described detail in (Keigo, 2009).

It is essential for underwater robot to perform a desire task even in a dangerous and inaccessible environment. The research methodologies developed in this paper can brings various efforts in the areas of autonomous underwater vehicle (AUV) and remote-operated vehicle (ROV) which is highly maneuverable navigation and extremely powerful thrust with dynamic braking. Combining together with high performance computing processor equipped with real-time control algorithm will result to high performance autonomous underwater vehicle and yet able to perform the task and mission with higher precision and endurance enough with large scale area covered as stated in (BIAN, 2008), (Jeunnette, 2001), (Graver, 2006) and (Wilson, 2009). In addition, the underwater robot navigation dynamics and control aspects can be incorporated into research of students of higher learning to initiate and explore the endless underwater and water-surface engineering applications.

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MATERIAL AND METHODS

The proposed design of underwater robot AQUA-X comprises of a central hollow body with four (4) propellers which are specially placed in "X" shape Cartesian Coordinate Configuration as shown in Fig. 1. This arrangement can able to provide the powerful thrust force and also help in smooth navigation of AUV. This proposed design has two main advantages over conventional type of AUV (Button, 2009). In conventional type AUVs the fin actuation which used for its maneuvering required quit complex mechanical control linkages, while proposed design required no mechanical linkages, for smooth navigation it uses fixed pitch propeller and by changing its motor direction and speed vehicle can maneuver easily as per requited path. Beside that four individual propellers provides greater thrust to underwater robot body frame and thus the individual propeller store less kinetic energy during navigation and provide better and soft maneuvering. The Fig. 2 shows the complete prototype of AQUA-X underwater robot. This method makes it simpler and easy to control and maintain.

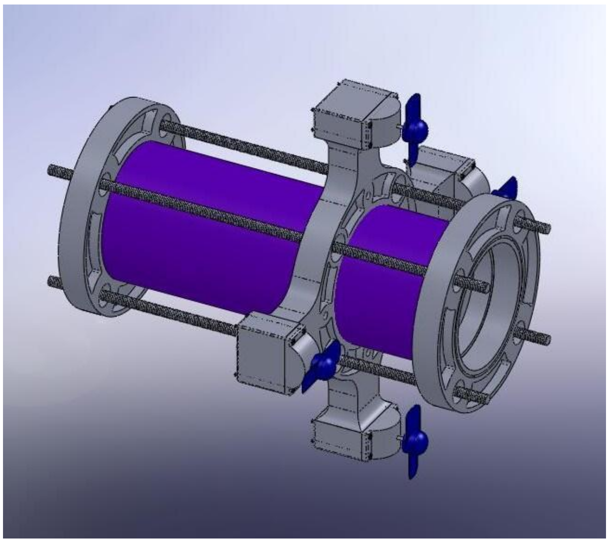


Fig. 1: Concept Design of AQUA-X Robot

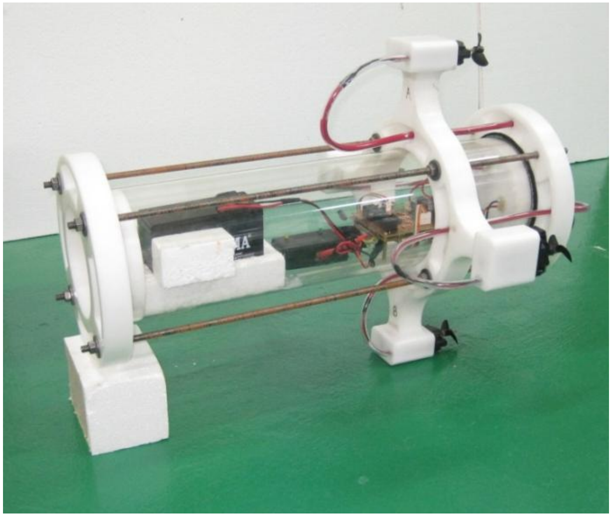


Fig. 2: Prototype of AQUA-X Robot.

Architecture:

AQUA-X underwater mobile robot has a specific specially design power system architecture with on-board data processing unit which is embedded communication module along with positioning module. AQUA-X robot also has a safety feature to detect the preset inner pressure to avoid over-limit pressure that AQUA-X Robot can sustained. Those systems are visualized in Fig. 3 below.

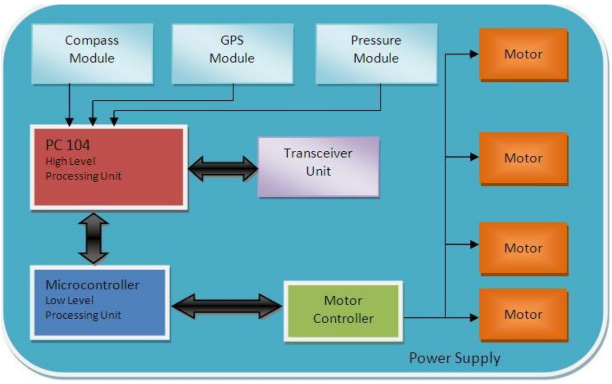


Fig. 3: System Architecture of AQUA-X Robot

Propeller Configuration:

AQUA-X underwater mobile robot has the four (4) propellers is presented with placed specially in Cartesian Coordinate Configuration with parallel arrangement. There are two type of propeller use for AQUA-X underwater mobile robot which is pusher type and puller type. These propellers are conFig.d in contra position for each pair of propeller to minimal the counter torque that effect on the robot body as shown in Fig. 4 below.

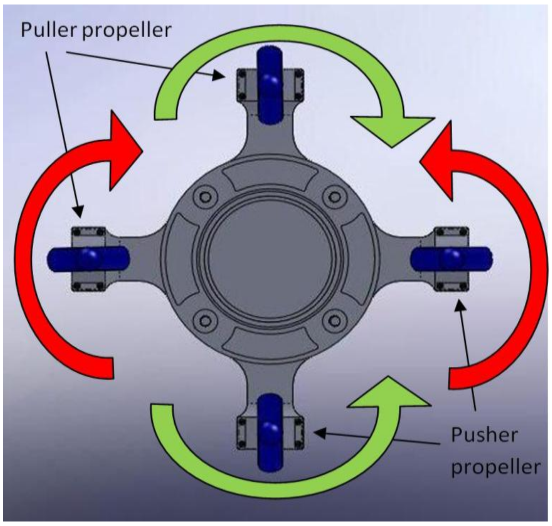
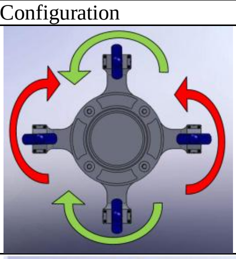
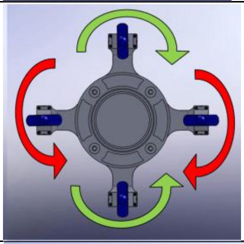
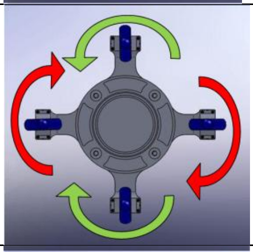
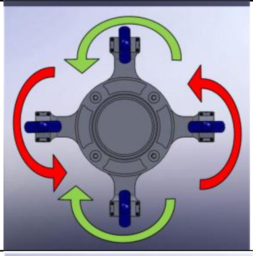
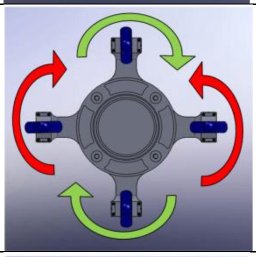
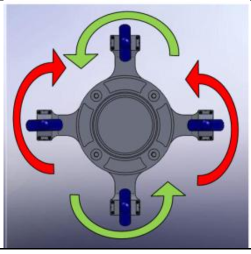


Fig. 4: Propeller configuration of AQUA-X Robot

However, propeller rotation direction in Fig. 4 is valid only for moving forward direction. All pusher and puller propeller will produce the thrust to backward which is yield the forward movement. In other case, this dual type of propeller will rotate accordingly to desired direction of movement. The more detail information can be found in Table 1 below.

These propellers are driven by 12VDC brush DC motor controlled by motor controller. Motor controller was designed to operate in bi-directional motor control to drive the motor in clockwise direction and counter-clockwise direction with speed control of 10 KHz PWM frequency. In our initial experiment, we using 100% duty cycle of PWM frequency.

Table 1: Propeller Configuration of AQUA-X Robot

Configuration	Description
	Forward direction – All thrust to the back
	Backward direction – All thrust to the front
	Right Direction – Thrust at left to the front – Thrust at right to the back – Thrust at top to the front – Thrust at bottom to the front
	Left Direction – Thrust at left to the back – Thrust at right to the front – Thrust at top to the front – Thrust at bottom to the front
	Up Direction – Thrust at left to the front – Thrust at right to the front – Thrust at top to the back – Thrust at bottom to the front
	Down Direction – Thrust at left to the front – Thrust at right to the front – Thrust at top to the front – Thrust at bottom to the back

Discussion:

Open Loop Control:

At initial stage, the AQUA-X underwater mobile robot was programmed with open loop control algorithm to determine the maneuver ability of AQUA-X Robot. The command sent from computer via HyperTerminal which is serially connected using wireless transceiver system. The open loop control system is visualized as Fig. 5 below.

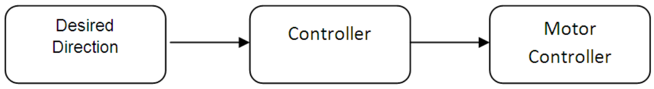


Fig. 5: Open loop system of AQUA-X Robot

Specification:

The AQUA-X Robot is made from white delrin material which is has tensile strength at 10,000psi per ASTM D638 also it can sustain the impact strength at 2.3ft.-lbs./in per ASTM D256. The body was designed using CAD software and fabricated using CNC machine. The technical information can be found in Table 2 below.

Table 2: Technical information of AQUA-X Robot

Item	Description
Weight	15kg
Power Source	12VDC
Thrust Power	5kg/motor (add)
Type of Propeller	Pusher and Puller
Dimension	50cm (W) x 72cm (L) x 50cm (H)
Additional Weight (ballast)	5-7kg

Conclusion:

In this paper, the proposed new motion control scheme for underwater mobile robot is the key to overcome the mentioned above problem, this research present the implementation of quadrotor concept in underwater mobile robot. The propellers are mounted at the four ends of an aerodynamic body frame. Owing to aerodynamic body frame, this underwater robot is dynamically elegant, inexpensive, and simple to design and construct. It is a non-holonomic vehicle, and has minimal limitation on its power thrust compare to body frame.

Future Work:

To gain the stability in controlling the attitude and altitude of AQUA-X Robot, we will develop the non-holonomic control algorithm which is derived from model hardware based reference. Also the AQUA-X robot will stabilized it own translational and rotational positioned about x, y, z Cartesian Coordinate and desired roll, pitch and yaw angle using Lyapunov stability theory as explained detail in (Zainah, 2011).

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