Development of Control System For An Autonomous Underwater Vehicle

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ABSTRACT—*In this paper we plan to develop an efficient control system for an autonomous underwater vehicle, for surveillance of wells, ponds, canals etc. It moves inside the water to obtain profile of various water beds and bodies. An embedded module is designed to control and monitor complete AUV in water. The control system uses closed loop PID controller which can control precise movement of propellers and thrusters, to maintain a stable direction-finding path. This embedded module is sub-divided into control system, propulsion, navigation, safety and data acquisition.*

1, INTRODUCTION

Underwater vehicles need to fulfill two challenges, to be able to stay underwater and to maneuver. The vehicle can be designed so that they stay underwater, either vehicle can be made neutral buoyant, or they can use thrusters to remain underwater. They need propellers to be able to go underwater, move around underwater and come back up tothe surface. Submarines can be dynamic or static. Propellers play an important part in the maneuvering of the vehicle. Propellers produce forward thrust by accelerating fluid back. It depends on the speed of rotation of the propeller as well as at its pitch angle. With a small pitch angle, the amount of fluid pushed back is small, and therefore less forward thrust is produced, but propeller speed increases. When the pitch angle is higher, the blades rotate slower but produce more thrust by pushing more fluid back. Propellers can be designed to have fixed pitch, or can be made such that the pitch of the propeller can be changed in real time by an actuator.

2, MATERIAL SELECTION OF STRUCTURE

Material selection is an important factor in the design of underwater vehicle. The material selected should be basedon following criteria:

(i).Resistant to corrosion.

(ii).High strength to weight ratio.

(iii).Affordable and availability.

(iv).Ease to fabricate.

Considering all these parameters mild steel is used for the frame. The main advantage of mild steel is it is commonly used and there is much knowledge about it. The disadvantage of this material is low strength to weight ratio. Aluminium has high strength to weight ratio but it is anodic so it vulnerable to corrosion and welding is costly and has to be done precisely at a constant temperature.

3, TYPE OF DIVING

The submarine dives and SURFACES by gaining/losing its weight known as static diving. In case of dynamic diving, the thrusters have to be operated continuously to stay at a particular depth whereas it is not required in static diving. Hence the power requirement of the AUV is minimized by the use of Static diving which eventually increases the performance of the AUV but the control design becomes much more complicated than dynamic diving. If the system failure occurs during its operation it will not reach surface of the water, so the dynamic diving is preferred over static diving.

4, BUOYANCY:

There are mainly three types of buoyancy namely positive, negative and neutral. When the density of the underwater vehicle is lesser than the density of water it is positive buoyant i.e. it floats on the water surface, whereas when the density becomes greater than the density of water it becomes negative buoyant and the underwater vehicle sinks, the buoyancy can be determined by the following equation-

Total Volume of the components = 0.013143866 m3

Total Buoyant force exerted

$$F_b = \rho * V * g$$

$$= 1000 * 0.013143866 * 9.81 = 128.941 \text{ N}$$

Where,

ρ=density of the fluid

V=Volume of the immersed body

g=gravitational force

But the total weight

$$W = m*g$$
$$= 4.35*9.81 = 42.67 \text{ N}$$

Now,

If Buoyant force > Total weight of the AUV

The system becomes positive buoyant.

5, CONTROL SYSTEM DESIGN

Autonomous vehicles are capable of taking decisions by their own as per the algorithm set by programmer or by the self learning. For this to come true a highly efficient control system needs to be implemented. A control system consists of hardware and software, which can perform data acquisition, conditioning, and actuation.

Two main controllers are designed in this project, the heading and the depth controller, respectively. Heading controller will move the AUV at desired translation direction. The inner loop of heading controller consists of Yaw angle controller, which calculates the desired yaw angle required for sway maneuvering. The depth controller is used to keep the vehicle at the desired depth. So in all heading and depth controller works as a master controller while the yaw controller works as a slave of heading controller. We are using PID controller for robust control design.

PID stands for Proportional, Integral and Differential. It is used in control feedback loop for making the system stable and less prone to environment noise. It makes system more stable, robust and it improves system response characteristics like time response and frequency response. The system could be as simple as a thruster (DC motor) or as complex as a complete manufacturing plant.

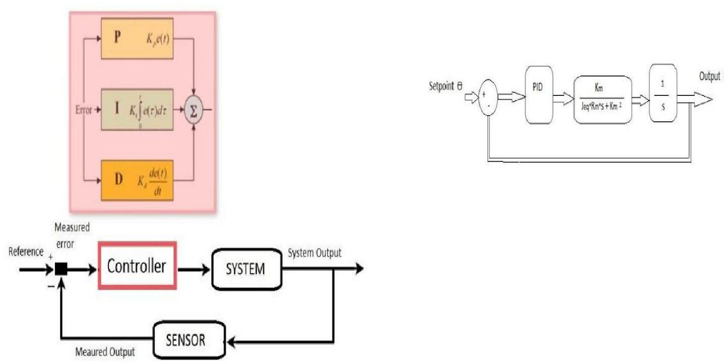


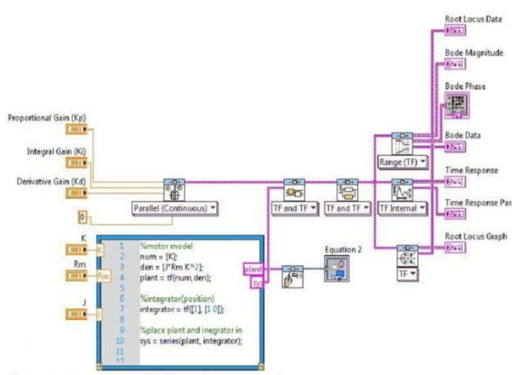
Figure 1 PID Controller

Sensor will feedback he output response value to the comparator which will subtract it from reference value (also called as a set point). The comparison of the reference and the measured output results in an error value which is used in calculating proportional, integral, and derivative responses. These three responses are then summed to obtain the controller output. This output is then used as a input to system which we wish to control. For example taking a case of DC motor, the controller output is more or less current as per the set point. This current then will decide the RPM of motor.

Following is the Plant model of thruster (DC Motor) where Jeq stands for Moment of inertia of motor, Km is the torque constant.

5.1, Heading Control System Design :

This section describes the solution to the problem of controlling the heading of AUV in a horizontal plane. The surge motion is executed by horizontal thrusters and the heave motion is executed by vertical thrusters. By controlling the current flow through motor the speed of AUV can be controlled. This speed can be calculated by the accelerometer sensor, which will give be used to give feedback

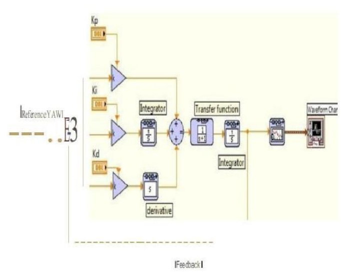


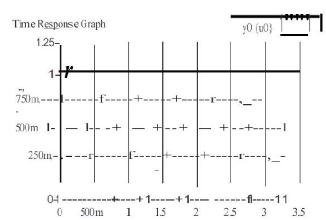
for controller and thus helps in precise maneuvering.

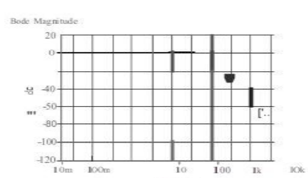
Figure 3 Block Diagram of Heading Controller

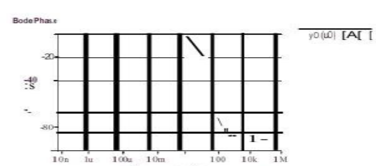
6, YAW ANGLE CONTROLLER DESIGN:

Yaw angle controller is a part of heading controller. The yaw angle will make sure the motion of AUV in Y-axis. When the AUV has to take a side path, it uses differential motion through adjusting rpm and rotation of one of its horizontal thrusters. This controller will adjust the desired yaw angle and correct it to reference angle. It takes feedback value from digital compass sensor.



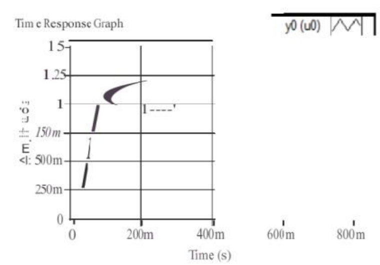


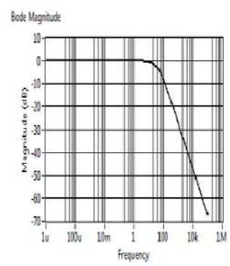


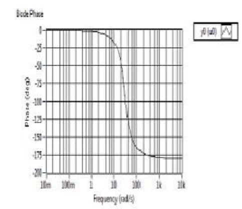


` **YAW Angle Controller Design** Time(s)

RESULTS







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BIOGRAPHY

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