INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title:
Design Development and Control of a Compact Autonomous Underwater Vehicle

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SHORT ABSTRACT

Unmanned Underwater Vehicles (UUVs) are robotic devices used for various underwater applications. UUVs have gained popularity in scientific community because of their potential applications ranging from military and research establishments to marine industries. Most of these devices are expensive, bulky and developed for deep ocean applications. To extend the benefits of this technology to small-scale industries and general public, affordable compact AUVs are need of the hour. Here the design and development of an affordable compact underwater robot is presented. After identifying the design requirements, the robot model is designed using 3D modeling software ``SOLIDWORKS". Matlab optimization toolbox is used for the estimation of optimal position of internal components. Shape optimization with Ansys Fluent is carried out for drag coefficient minimization. The designed model has been analyzed using Finite Element Analysis to ensure its structural integrity in the underwater environment. Here stress analysis is used to show that the UUV with glass fiber composite body can withstand the underwater pressure at 100m depth with 1.8 factor of safety. Computational Fluid Dynamics (CFD) study is used to estimate the drag and lift coefficients, and the maximum velocity of the robot. The validated design is used to manufacture the UUV body using glass fiber composite. The developed robot is neutrally buoyant and has a three-part modular structure. This robot has 4 Degrees of Freedom (DOF) and uses three thrusters for propulsion. It has a closed-frame watertight enclosure, which houses different essential components such as battery, depth and temperature sensors, camera, Raspberry pi computer, Pixhawk controller and thrusters. During operation, the robot is connected to the computer on the ground using tethered connect for transmission of live underwater footage, sensor data, and control signal. Detailed cost analysis of the developed robot is also presented. The robot was successfully tested in a swimming pool, nearby river, and lakes, and the results are discussed.

AUVs have to navigate complex underwater environments autonomously based on its algorithms. Accurate kinematic and dynamic model of an AUV, guidance, control and localization technique are vital components in navigation, which helps an AUV to follow the defined path. This thesis presents development of a trajectory tracking controller for the developed AUV. First, kinematic and dynamic model of the underwater robot are developed. Using detailed CAD model of the AUV, inertia and buoyancy parameters are estimated. Hydrodynamic damping parameters are estimated using simulations carried out with CFD software package ANSYS Fluent. 3D added mass coefficients are estimated numerically using strip theory. The developed AUV model is validated with experimental results. A 3D guidance system is developed to follow the generated path by way-point technique using Line-of-Sight (LOS) strategy. An Inertia navigation system is used to estimate the position and orientation of the AUV to be use in feedback loop of a closed loop controller. Initially, Close loop PD controller was developed which resulted in a constant steady state error due to under actuation. Then a classic PID controller is developed which eliminated the steady state error and successfully simulated for multi way-point path. PID controller gain has to be tuned for individual path, thus an adaptive Fuzzy-PID controller is designed to handle variation in the path. This controller is compared with the PID controller and results are discussed. A robust Neuro-Fuzzy controller is developed to handle dynamic environmental forces and unknown system behavior. Here a neural network model of the system is fitted with the experimental data and the fitted model is used with the PID system to adapt to different working environments. A comparative simulation of both the controllers under external disturbance force is carried out to showcase the robustness of the controllers. Objective of this work is to develop an robust non-linear adaptive control strategy for the navigation of the newly developed AUV on a predefined path. Such affordable compact systems can bring significant benefit to the small-scale marine industries, can create new opportunities, and help monitor and preserve underwater ecosystems.

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