INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Dynamics and Control of Snake Robot in Uncertain Underwater Environment

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Thesis Submitted to the Department/ Center	:	Mechanical Engineering Department
Date of completion of Thesis Viva-Voce Exam	:	27-02-2025
Key words for description of Thesis Work	:	Underwater Snake Robot, Sliding Mode Control, Radial Basis Function Neural Network, Super Twisting Sliding Mode Control

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SHORT ABSTRACT

In recent years, researchers are interested in understanding living creatures and replicating their movement, structure, and cognition to develop biomimetic robots. Extracting these features, the biomimetic robots are developed for suitable environmental conditions and their applications. The snake is a versatile creature that can be found on land and in water environments with similar motion. Therefore, the mimicking of a snake can be used for wide applications in both environments. The motion of a snake is very sensitive to environmental conditions because of its crawling nature and that makes it a challenging problem to understand dynamics and control perspectives in a robotic system. The snake robot consists of the multi-links and joints that make it a complex mechanical system and controlling this system in an adaptive environment is a challenge. Therefore, the design of an appropriate control scheme for the complex dynamical system and modification in the mechanical system (that leads to dynamics) to get more suitable solutions become important. The main objective of the present work is to study the motion dynamics and design of a control scheme for a snake robot in uncertain underwater environment. Hence, it is proposed to study the motion dynamics of a snake robot and its control strategies in uncertain underwater conditions. The snake robot, consisting of 9 links and 8 joints, is considered under the assumption of planar motion with negligible added mass effect.

The thesis is focus on designing control strategies with existing mathematical model of the snake robot. The virtual holonomic constraints (VHCs) are used to derive the reduced dynamics of a mathematical model for a snake robot. The benefit of this method is that it determines the control objective for the head link of the snake robot with the entire robot following it. The sliding mode control (SMC) approach is used where the sliding surfaces are designed based on the angular position and tangential velocity tracking of head-link of the snake robot. Here, the chattering effect is reduced by improving the reaching law of the SMC scheme. In first study, the super twisting sliding mode control (STSMC) scheme is proposed that has a minimum chattering effect. The results are compared qualitatively and quantitatively with SMC and adaptive sliding mode control (ASMC) scheme. The dynamical uncertainties in the drag forces and fluidic torque acting on the snake robot during the motion are considered and estimated lumped value in control algorithm. The control scheme is improved in the second study by introducing the uncertainties estimation using the neural network approach. In this, the radial basis unction neural network (RBF-NN) is used for the estimation of the uncertain part of a dynamical system and that is inputted to ASMC scheme. So, ASMC scheme with RBF-NN is used for the motion control of a snake robot. Additionally, in this study, the generation of the reference trajectory for the path following of a snake robot operating in the presence of water currents along with dynamical uncertainties is addressed. The stability of a proposed scheme is demonstrated through Lyapunov stability analysis.

The modification in the mathematical model of the snake robot by introducing different mechanical components such as pumps and thruster and then designing the control scheme for it. In third study, the snake robot dynamics are modified to 3D motion in the underwater environment along with the added mass effect. In this, the buoyancy variation technique is proposed for the vertical motion of a snake robot which is found in many underwater creatures. The horizontal motion of a snake robot is the serpentine motion as considered earlier. The combination of these two motions results in the 3D motion of a snake robot. The external disturbances are considered along with dynamical uncertainties in this work. The horizontal motion is controlled using existing STSMC and the vertical motion is achieved using the pump operations. For that, the event-based control scheme and PD control scheme are proposed. Moreover, the proposed dynamics are verified using the simscape multibody environment where the equation of motion is not required explicitly. In fourth study, the snake robot is considered with a thruster on the tail. The effect of thrust force on each link of a snake robot is studied in this work and the actor-critic neural network with the STSMC scheme is proposed for the motion control of a snake robot. The neural network estimates the dynamical system that is inputted to the STSMC scheme. The proposed control approach is verified with the existing STSMC scheme and the effectiveness of this scheme is compared in terms of chattering indicators and control effort.

In addition to the above studies, various actuator failure cases are studied. As snake robot has many actuators, there may be a chance of failure. Therefore, the control scheme is designed such that the robot motion can be sustained in the presence of the actuator failure. In this, the snake robot is constructed in the simscape multibody environment. The RBF-STSMC scheme is proposed to deal with various uncertainties and actuator failure. The proposed control scheme is compared with the existing control scheme and that performance of snake robot. These studies will help to develop the experimental set-up of underwater snake robot and its control applications.