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Development of a Robotics and Sliding Mode Controller for Industrial Automation

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Abstract

This research focuses on designing technique to assess how well systems like shank-foot orthoses, inchworm robots, advanced heavy water reactors, and autonomous underwater vehicles perform . A solid foundation in a variety of fields is necessary to fully understand the intricacies of robotics and other complex nonlinear processes; Think about computer science, mathematics, mechanical engineering, industrial engineering, electrical engineering, control engineering, and instrumentation engineering. As a result, the research extends beyond the typical engineering boundaries. Designing the system's velocity, true location, and acceleration. In order to operate the manipulator of the inchworm robot, the second contribution presents the Grey Wolf-Second order Sliding Mode operate (GW SoS MC). By using the weighting function in GW-SoS MC, this method improves the control capabilities of SoS MC and lessens the chattering problem of SMC.

Keywords: Development, performance, traditional models, Robotics, Mode Control.

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Introduction

Applications for this controller include yaw angle control of an autonomous underwater vehicle, joint angle control for an inchworm locomotion mechanism, position control of a shank-foot orthosis, and stabilizing spatial oscillations in a sophisticated heavy water reactor. The goal is to develop a reliable controller that ensures precise linear and angular position control, even in highly nonlinear and unpredictable environments, which is crucial for stabilizing reactions in large-scale nuclear plants. For quite some time, the field of Sliding Mode Control (SMC) has captivated many researchers [1]. This work represents over three years of dedicated research by the author. Recently, the theory behind sliding mode control has seen significant advancements. While this technique provides a mostly elegant mathematical approach to various challenges, it does come with its own set of limitations. Extending classical sliding mode control to adaptive second-order sliding mode control is sometimes required to handle these problems, particularly when working with unrealistic assumptions on plant behavior, system uncertainties, and nonlinearities [2].

In today's world, robotics and their applications in different industries, utility services, medical treatments, and even household appliances play a significant role in developed countries. There's been a rapid rise in interest in industrial robotics, with robots being widely adopted across many sectors to help cut production costs. They're commonly used for tasks like lifting, enhancing cognitive functions, exoskeletons, navigation, locomotion, medical surgeries, and even entertainment [3]. Robots can operate intelligently on their own, thanks to the training they receive. Ultimately, it's humans who guide the activities of these diverse robots through logical training, which is primarily based on mathematical modelling and programming. This approach allows robots to learn and remember things in a straightforward and flexible manner.

Review of Literature

Most cutting-edge sliding mode controllers use ingenious techniques like fuzzy sets and neural networks. This is primarily because other probabilistic models, such as composite controllers and partial derivatives, have issues with computational efficiency and perform poorly in unexpected problem areas. Neural networks have demonstrated exceptional performance among the many intelligent controllers for efficient sliding mode control, particularly in robotic systems such as milling head processes. They have their own set of difficulties, despite the fact that they have advantages including accuracy in learning without requiring prior information, ease of use, and applicability for real-time applications [4]. These include a discrepancy between the problem space and the properties of the system, challenges in adopting accurate weight functions, and regularization issues. These difficulties are related to one another. For example, precisely adjusting weight functions helps improve the network's learning process. However, there were no notable advances because the updated model that was given was in derivative form. Another problem we've talked about is the increased discrepancy between the sliding mode function and the real system data. Therefore, a good regularization function is essential. Accurate weight functions may help decrease that gap for improved predictions, but they also run the risk of overfitting. On the one hand, there are still issues with neural networks for sliding mode functions [5].

Materials and Methods

A significant amount of design variable adjustment is often required for the sliding mode functions documented in the literature. Unfortunately, there hasn't been much guidance in the literature on how to appropriately select these design variables based on the best available knowledge. While neural network-assisted sliding mode control is outperforming traditional methods, current system models still need to be much improved [6].

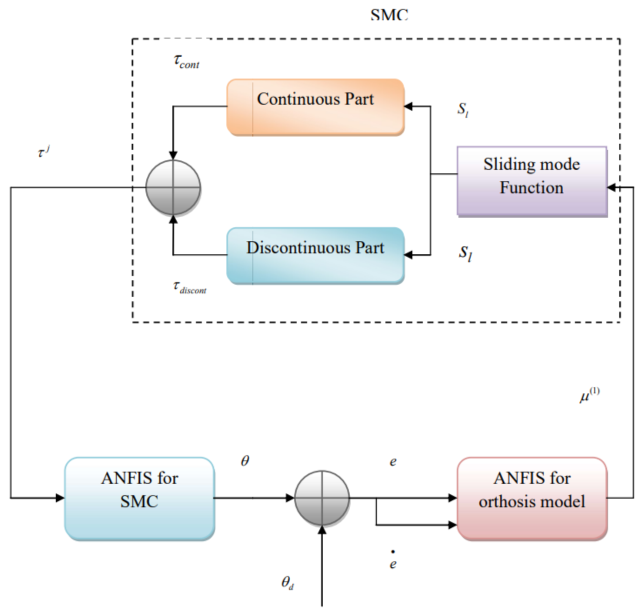
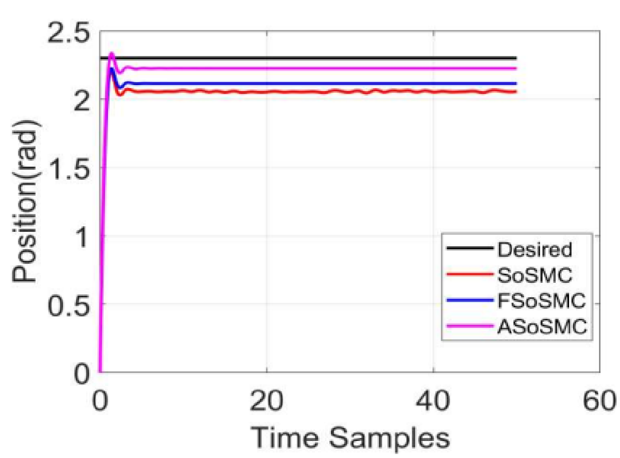


Fig. 1: Estimation of Wearer's Torque

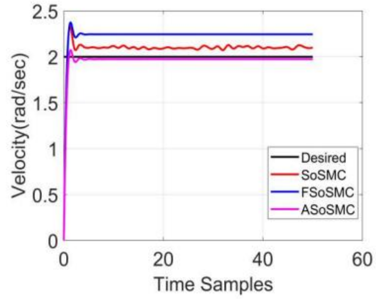
The upper segment and the bottom segment comprise this actuated orthosis. The lower section can move freely because of its great flexibility around the knee joint. It is fastened to the subject's shank foot immediately [7]. Furthermore, the actuated orthosis's two segments are connected. The tracking faults will gradually decrease until they are zero while the mobile robot keeps tracking. As a result, the mobile robot using the suggested approach is used to follow the route in surroundings with obstacles.

Results and Discussion

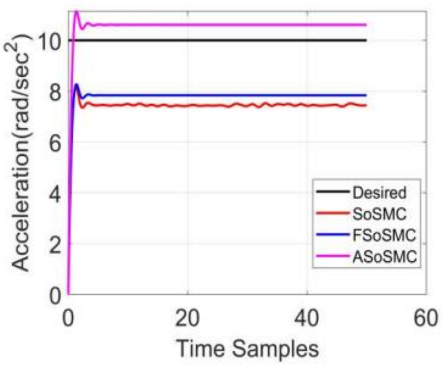
A Robust Neural Network-Based ASoSMC Design for a 1-DOF Planar Robot: The single rotating degree of freedom (DOF) of the knee joint is the focus of the Shank Foot Orthosis System. The upper portion, which is attached to a brushless DC motor (BLDC) and an actuation mechanism, is the active part of the orthosis system [8]. The torque required to move the leg in the desired direction must be supplied by the actuator. Furthermore, the shank foot's range of motion is restricted to 0° to 120°. Here, 0° denotes the knee joint orthosis's maximum extension, 90° denotes the user's resting position, and 120° denotes the orthosis's maximum bend.



(a)



(b)



(c)

Fig. 2: Performance Comparison of Actual (a) Position, (b) Velocity, and (c) Acceleration of the Orthosis System with First Set of Desired Values.

The actual position, acceleration, and velocity of the shank foot orthosis system are compared to the desired values in Figure 2. The black line on the graphs indicates the necessary position, acceleration, and velocity of the orthosis system.

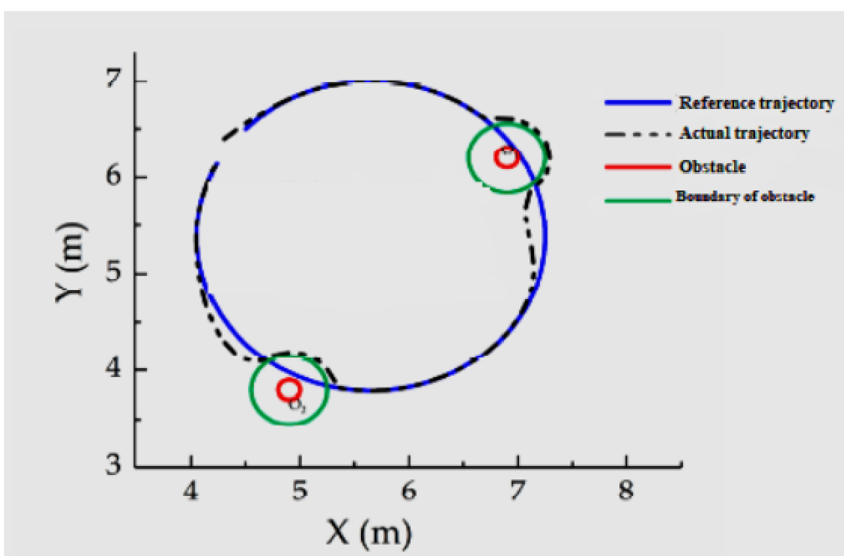


Fig. 3: Trajectory tracking and Obstacle avoidance

Here, we compare the estimated real position, velocity, and acceleration obtained from the proposed ASoSMC with the desired values in addition to employing more traditional methods like SoSMC and FSoSMC.

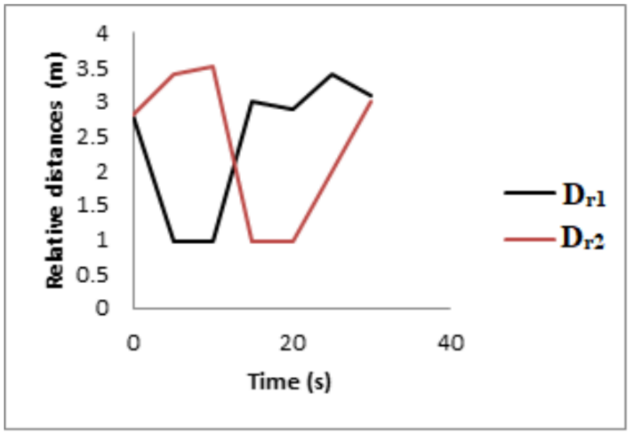


Fig. 4: Relative Distances within the Robot and Obstacles

The first set of desirable values is being compared to the estimated real values; ideally, the actual values should be as near to the desired ones as feasible, regardless of whether they are slightly above or below that target range.

Conclusion

This work highlights four key contributions related to ASoSMC topics. An ASoSMC model for controlling the shank foot orthosis system was presented in the initial contribution. In order to comprehend the entire movements in this model, we evaluated the system's velocity, acceleration, and actual position by examining the ultimate torque. By modifying the positive gains in GW-SoSMC, this method improved the control capabilities of SoSMC while also lowering the chattering problem linked to SMC. In the third contribution, we used the GW-SoSMC approach to create a unique system to manage the state vectors in AHWR. The GW-SoSMC for yaw angle control in an AUV was evaluated in the fourth and last contribution. The primary objective of this study was to prevent errors in the system. We can improve the AUV system's control performance and lessen the chance of chattering with this suggested effort.

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