Abstract

This thesis focuses on advancing sliding mode control using difference equations with minima to stabilize and observe dynamical systems. It addresses challenges in existing discrete-time reaching laws, such as chattering and high control effort, and enhances robustness related to quasi-sliding mode bandwidth. The research also develops discrete-time twisting-like and super-twisting-like algorithms, aiming for finite-time convergence and stability.

We begin by presenting two reaching laws for discrete-time systems, based on a difference equation with minima. These laws effectively eliminate chattering and enhance robustness. Theoretical analysis and simulations validate the method's ability to achieve sliding mode in unperturbed cases and quasi-sliding mode under disturbances.

We then expand reaching laws based on difference equations with minima to include rate-regulatory function-based laws, utilizing a proportional term to accelerate the sliding variable's rate of change. This rate is upper-bounded by design parameters, offering a distinct advantage. Comparative analysis confirms that the proposed method outperforms others in terms of effectiveness.

Further, the thesis also investigates the Lyapunov characterization of discrete-time sliding mode using difference equations with minima. We derive Lyapunov conditions for finite-time input-to-state stability in perturbed systems, providing insights into settling time. Simulations demonstrate the proposed laws' superior performance, achieving minimal ultimate bounds for the sliding variable with satisfactory transients.

In the further expedition, we developed discrete-time twisting-like and super-twisting-like algorithms based on difference equations with minima, distinct from traditional Euler-discretized methods. These designs ensure convergence to an equilibrium for unperturbed systems and to an invariant set for perturbed systems within finite time. Additionally, we adapted the discrete-time super-twisting algorithm to create a robust observer that

estimates unknown states of a perturbed pendulum system in finite time.

Finally, we apply the proposed reaching law based on difference equations with minima to a coupled tank system. Our analysis demonstrates the approach's robustness and adaptability to real-world conditions. Successful implementation is detailed, with simulation and experimental results showcasing effective water level control under both unperturbed and perturbed conditions, affirming the efficacy of the proposed laws.