Chapter 9

Summary and Future Perspectives

In the brief, we summarize the work done in the thesis by pointing out the main results, limitations and proposed future investigations.

9.1 Research Summary

This thesis presents two innovative DDC schemes based on DSMC tailored for DTS operating under disturbances and unknown dynamics. The primary contributions lie in developing robust, MFAC strategies that achieve finite-time convergence while minimizing design complexity and control effort.

A central theme of the work is the use of the CFDL and minimum-operator-based DSMC techniques, which together form a simplified yet powerful DDC framework. These approaches exhibit improved disturbance rejection and reduced QSMD without relying on detailed system models, making them suitable for complex, nonlinear environments. Numerical simulations and experimental validation on a liquid-level control system confirm the practical feasibility of the CFDL-MDSMC controllers.

In addressing prescribed performance control (PPC) challenges, the thesis proposes an adaptive DSMC design using the Full Form Dynamic Linearization (FFDL) method and an error transformation function (ETF) to handle constrained tracking errors. The resulting schemes outperform traditional methods by maintaining errors within predefined asymmetric bounds with reduced control input, as demonstrated through simulations on a single-link robotic manipulator.

A novel contribution integrates minimum-operator-based reaching laws (RLs) with a multi-rate output feedback (MROF) mechanism to eliminate switching control inputs, thereby mitigating chattering and reducing dependency on full-state feedback. Comparative results show significant improvement over prior art, including reduced steady-state error, enhanced precision, and robustness.

Further, the study introduces an adaptive RL-based DSMC with improved gain adaptation using ceiling functions and minimum operators, offering enhanced convergence rates and better reaching time estimation, while avoiding chattering. Theoretical analysis and simulations underscore its advantages under bounded disturbances.

The thesis also demonstrates a discrete-time recursive backstepping control for a two-degree-of-freedom (2-DOF) helicopter system. By leveraging an Euler-discretized model, the controller achieves finite-time trajectory tracking of pitch and yaw angles, validated through both simulations and physical experiments.

Finally, two novel DSMC laws are proposed for a magnetic levitation system, addressing limitations in conventional DSMC techniques. These strategies ensure fast convergence, reduced chattering, and practical applicability, paving the way for future experimental validations.

Overall, the thesis significantly advances the field of discrete sliding mode and data-driven control by offering low-complexity, high-performance strategies suitable for real-world DTS with unknown or partially known dynamics.

9.2 Limitations and Proposed Future Investigation

- Future research of DDC could explore extending the developed methods to more complex, multi-variable systems and integrating them with adaptive or learning-based control strategies to enhance performance in dynamically changing environments. For instance, incorporating reinforcement learning (RL) or model predictive control (MPC) could enable the continuous updating of control policies based on real-time interactions with the system.

- Future research of PPC based DDC will focus on extending this approach to multi-agent systems and addressing the consistency challenges associated with PP.

- Additionally, real-time experimental work will be prioritized to validate theoretical models and algorithms developed for DDC-PPC based framework in practical scenarios.

- Future research will also focus on theoretical developments for multiple PP and their associated performance metrics.

- Systems with more pronounced nonlinearities and higher-dimensional dynamics are also planned as part of future work for the proposed MROF-DSMC technique, along with the implementation of the same on a test bench or real system.