Thesis Title: Development of optimized advanced control laws for trajectory tracking of a quadcopter

Thesis Abstract: Unmanned aerial vehicles (UAVs) have undergone remarkable advancements, particularly in the realm of quadcopters, which have demonstrated the ability to manipulate objects and undertake diverse tasks. These strides are attributed to sophisticated control systems, novel actuation and sensing technologies, and improved insights into the quadrotor's aerodynamic effects and gyroscopic moments. This thesis presents a comprehensive investigation into the development of optimized advanced control laws for trajectory-tracking quadcopters. The research begins by formulating a nonlinear model of the quadcopter using Lagrange formalism within the MATLAB ODE-45 environment. This model incorporates gyroscopic moments and aerodynamic effects, yielding a holistic representation of the quadcopter's dynamics. Subsequently, four innovative optimized control laws are proposed: Conditioned Adaptive Barrier-Based Double Integral Super Twisting Sliding Mode Controller (CABDIST-SMC), Barrier Function Double Integral SMC, Barrier Function Integral SMC, and Barrier Function-Based SMC. These control laws address attitude, heading, position, and altitude trajectory tracking. To ensure system stability, a Lyapunov stability analysis is conducted, affirming the asymptotic stability of the quadcopter. The performance evaluation encompasses a 3D-helical complex trajectory, facilitating a comprehensive assessment of the proposed controllers. Comparative analyses are performed against traditional control strategies, including backstepping SMC, optimized adaptive SMC via particle swarm optimization, and improved adaptive SMC. Furthermore, the Improved Grey Wolf Optimization algorithm has been employed on the gains of the proposed control laws to optimize their performance. Six performance indices (i.e., mean absolute percentage error, root mean square error, integral square error, integral absolute error, integral time absolute error, and integral time square error) have been used to evaluate the performance of each optimized control law. In addition to that, a hardware-in-loop validation test is executed using the C2000 Delfino MCU F28379D launchpad, substantiating the efficacy of the proposed control laws in real-world scenarios. Notably, the CABDIST-SMC control law emerges as the top performer, showcasing exceptional results across all evaluated metrics. Its superior performance is confirmed through minimal deviations during real-time implementation. This research work contributes a robust framework for the development of optimized advanced control laws, accentuating the potential of quadcopters for precise trajectory tracking. The proposed control strategies offer substantial advancements over traditional methods, affirming their suitability for both civilian and military applications. The comprehensive evaluation and validation processes provide confidence in the effectiveness of the proposed control laws, paving the way for further enhancements in UAV technology.