Trajectory planning is an important topic in many applications including unmanned air vehicles, underwater vehicles, spacecraft rendezvous, and industrial and agriculture manipulators. It is still an open problem to rapidly find an optimal trajectory which takes dynamic and environmental constraints into consideration. In this dissertation, a unified, varying manifold based optimal trajectory planning method inspired by several predator-prey relationships is investigated to tackle this challenging problem.

Biological species, such as hoverflies, ants, and bats, have developed many efficient hunting strategies. It is hypothesized that these types of predators only move along paths in a carefully selected manifold based on the prey's motion in some of their hunting activities. Inspired by these studies, the predator-prey relationship is organized into a unified form and incorporated into the trajectory optimization formulation, which can reduce the computational cost in solving nonlinear constrained optimal trajectory planning problems. Specifically, the three motion strategies studied here are: motion camouflage, constant absolute target direction, and local pursuit.

The special characteristics of the unified varying manifold formulation lead to two initial guess strategies that are able to enhance the convergence rate and speedup the trajectory optimization procedure: (1) obstacles can be avoided in the initial guess by tuning the reference point; (2) necessary conditions on the speed constraint can be satisfied in the initial guess by tuning the path control parameters.

The following simulations have been conducted to show the advantages of the proposed methods: supersonic aircraft minimum-time-to-climb, ground robot obstacle avoidance, and micro aerial vehicle minimum energy trajectory problems.

The results show that the proposed methods can find the optimal solution with higher success rate and faster convergent speed as compared with some popular methods. Among these three motion strategies, the method based on the local pursuit strategy has a relatively higher success rate than those of the other two motion strategies.

In addition, the optimal trajectory planning method is incorporated into a receding horizon framework to find optimal trajectories with unknown parameters updated in each planning horizon using an Extended Kalman Filter.

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The public is welcome to attend.