Guidance Law for Surveillance by UAVs Using Curve Paths

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1 INTRODUCTION & OBJECTIVE

Unmanned Aerial Vehicles (UAVs) are increasingly deployed in surveillance and monitoring due to their ability to cover large areas, access hazardous regions, and reduce risks to human operators [1, 2]. Fixed-wing UAVs, however, face turning constraints that limit the effectiveness of conventional circular or elliptical surveillance paths.

Generalized curve paths, such as Lame´ curves (super ellipses), provide smooth closed trajectories that approximate rectangular or arbitrary boundaries while respecting UAV kinematics [3]. The objective of this work is to design a stable, fast-converging guidance law for generic curve path tracking and to integrate a fluid-inspired obstacle avoidance strategy, enabling safe and efficient UAV surveillance in cluttered environments.

2 METHODS OF ANALYSIS

A vector field guidance law based on a shaping function is developed, where the desired heading, ψ_d, is defined as the sum of the tangent heading, ψ_t, and a shaping term, ψ_o. Unlike earlier formulations, the exponential shaping function ensures smooth convergence with vanishing derivatives near the path, preventing oscillations.

Stability analysis is performed using a Lyapunov function, proving that the tracking error ($\beta - 1$) converges asymptotically to zero for arbitrary initial conditions.

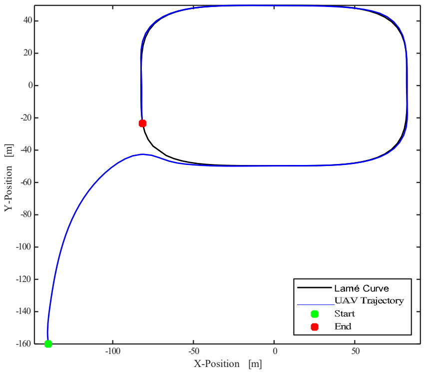
For obstacle avoidance, a potential fluid-inspired vector field is superimposed on the nominal curve path guidance. A continuous weighting function blends the curve-heading with a tangential avoidance direction, ensuring smooth transitions. Then a dual-path selection rule chooses the minimum-deviation trajectory (left or right bypass).

Simulations were performed in MATLAB/Simulink for a fixed-wing UAV model at a constant speed of 15 m/s, with a heading controlled by a PD feedback law.

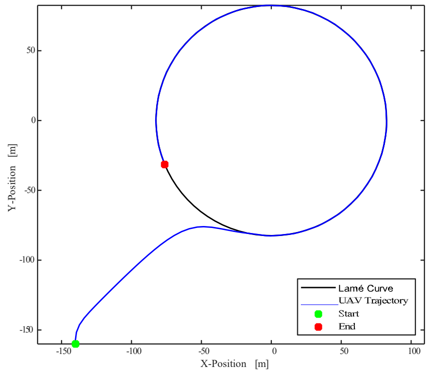
3 RESULTS AND/OR HIGHLIGHTS OF IMPORTANT POINTS

Key highlights of the proposed method are:

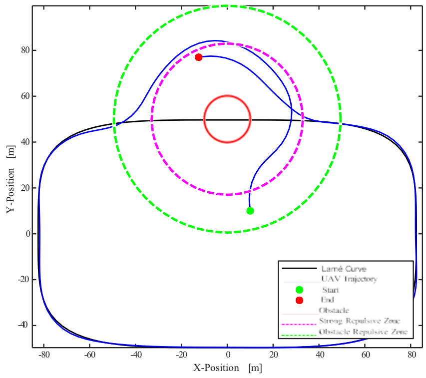
- **Improved convergence:** Faster path convergence compared to the reference method [3], with up to 15% shorter convergence distance.
- **Stable tracking:** The exponential shaping function eliminates oscillatory corrections near the boundary.
- **Obstacle avoidance:** The UAV successfully bypasses obstacles located directly on the curve path and rejoins smoothly downstream.
- **Generality:** The method is effective for circular, elliptical, Lame´, and other curve trajectories.



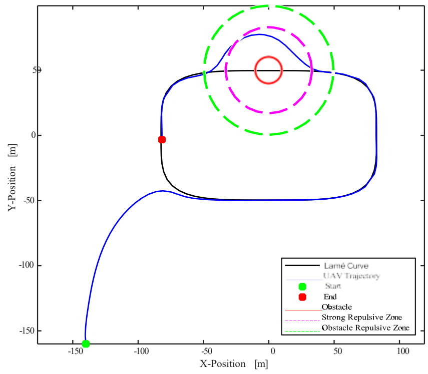
(a) UAV Trajectory Converging Lame Curve



(b) Tracking performance for a circular path, demonstrating smooth alignment with the boundary



(c) Inner bypass trajectory in the presence of an obstacle, where the UAV safely rejoins the curve path



(d) Outer bypass trajectory showing obstacle avoidance with minimal deviation from the desired path

Figure 1: Representative UAV surveillance trajectories for different scenarios

4 CONCLUSIONS

This work introduces an improved curve-path–based guidance law that ensures faster convergence, and robust obstacle avoidance. The proposed strategy provides computational efficiency suitable for real-time implementation in UAV surveillance missions.

Future work will address cooperative multi-UAV coordination and experimental validation in real flight scenarios.

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