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Trajectory tracking control of a quadrotor: A comparative study of PSO and FPA-optimized PID controllers

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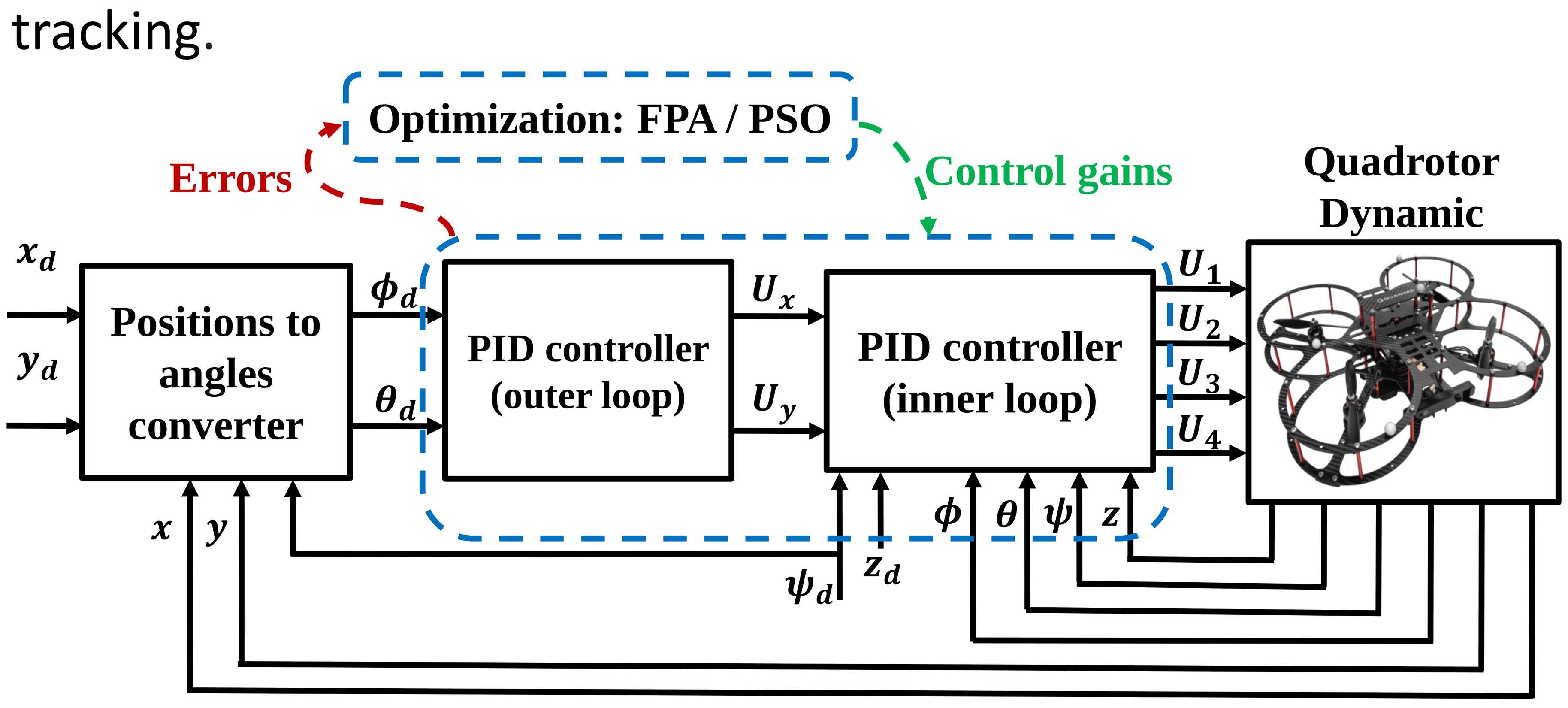
INTRODUCTION & AIM

Quadrotors play a central role in modern aerial robotics, where accurate trajectory tracking is essential for reliable operation. Conventional PID controllers remain widely used, yet their efficiency strongly depends on proper parameter tuning. Metaheuristic optimizations provide powerful alternatives to manual adjustment. This study investigates and compares two bio-inspired algorithms—Particle Swarm Optimization (PSO) and Flower Pollination Algorithm (FPA) for PID tuning in quadrotor trajectory tracking. The goal is to assess their impact on controller performance: stability, precision, and rapidity.

METHOD

The controller structure consists of two main loops: the inner loop, directly connected to the quadrotor, is responsible for attitude stabilization, while the outer loop is designed to regulate the horizontal positions (x, y) required for trajectory tracking.



Two metaheuristic algorithms, Flower Pollination Algorithm (FPA) and Particle Swarm Optimization (PSO), are employed to optimize the proportional–integral–derivative (PID) controller gains for quadrotor trajectory tracking. The objective function J is defined as a combination of the Integral of Time Absolute Error (ITAE) and an overshoot penalty term:

$$J = \int_0^t t(e_x + e_y + e_z) + \alpha(OS_x + OS_y + OS_z)dt$$

Where:

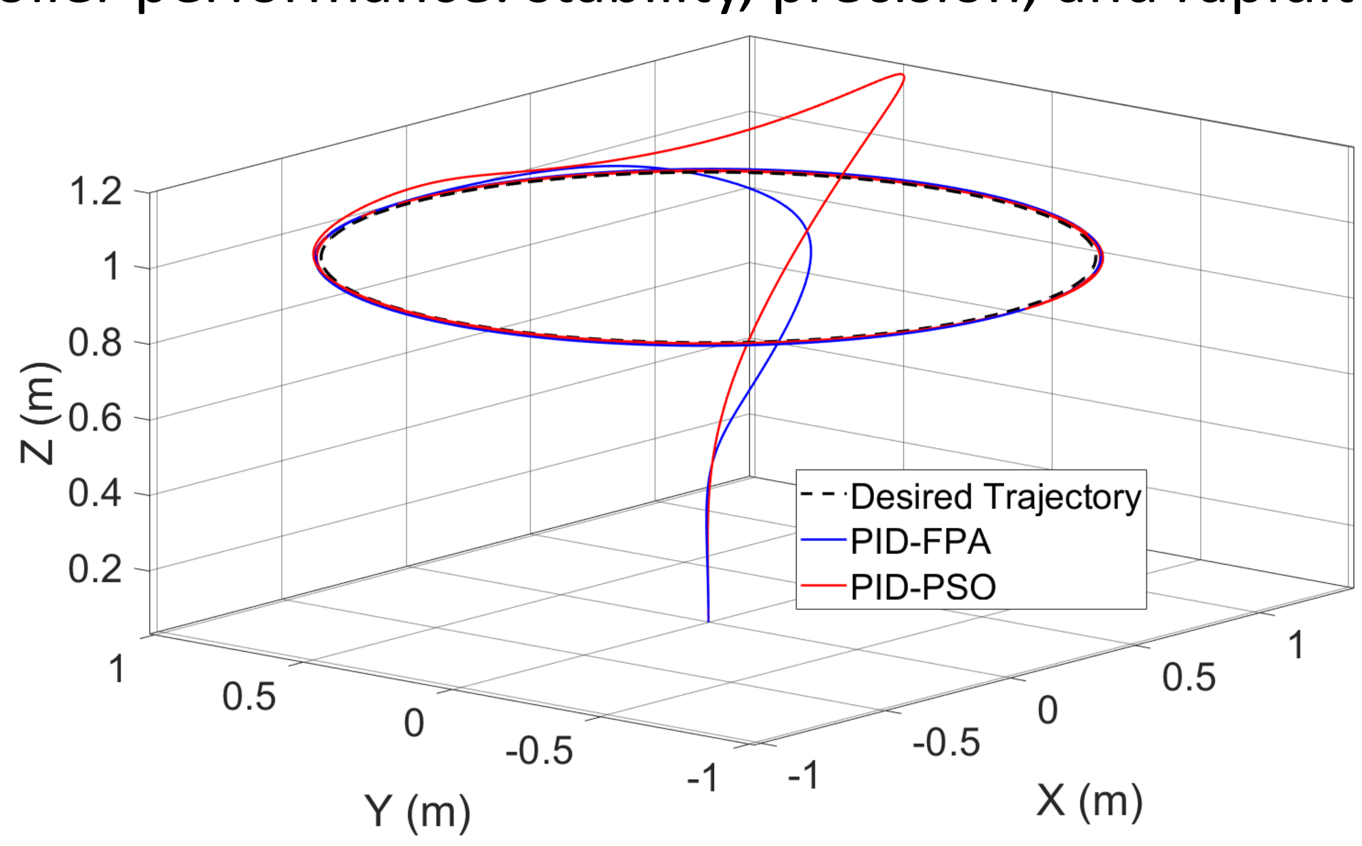
e_x, e_y and e_z are the position errors .

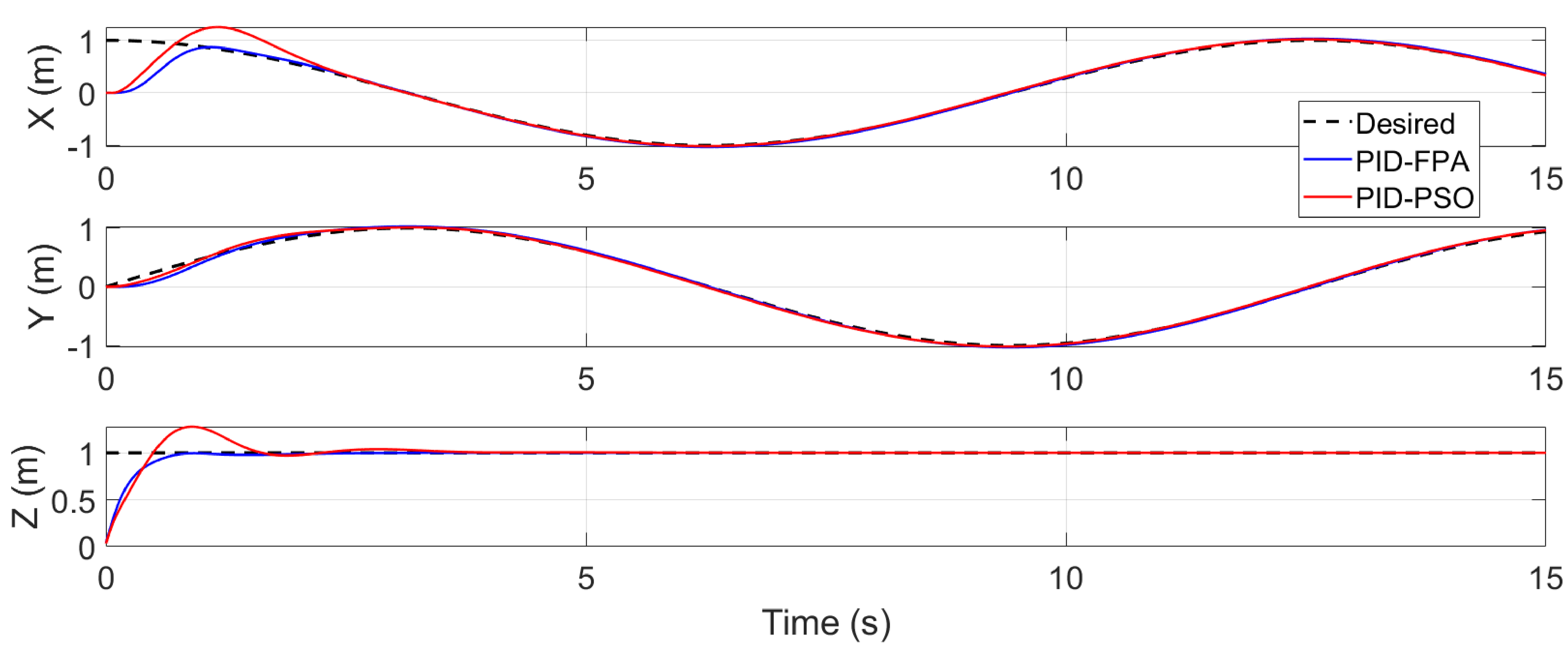
OS_x , OS_y and OS_z : Maximum overshoot in each axis.

α: The weighting factor that adjusts the importance of overshoot minimization relative to tracking accuracy.

RESULTS & DISCUSSION

A circular trajectory with a radius of 1 m and a constant altitude of 1 m was used to evaluate the performance of the optimized PID controllers. The 3D trajectory tracking comparison between the desired path, PID-FPA, and PID-PSO.





The results demonstrate that the PID-FPA controller outperforms the PID-PSO controller in terms of accuracy and dynamic response. Specifically, the FPA-based tuning provides faster convergence to the desired trajectory, with lower overshoot and a shorter settling time compared to the PSO-based controller. This indicates that the FPA optimization achieves a better balance between stability and precision, making it more effective for quadrotor trajectory tracking .

CONCLUSION

This work optimized PID controllers for quadrotor trajectory tracking using FPA and PSO. A modified objective function combining ITAE with an overshoot penalty was applied to improve stability. Simulation results on a circular trajectory showed that PID-FPA achieved faster response, lower overshoot, and shorter settling time compared to PID-PSO. These results confirm the effectiveness of FPA for accurate and robust quadrotor control.

FUTURE WORK / REFERENCES

Future research will address real-time implementation of controllers on experimental quadrotor platforms .

Reference: Ghiloubi, I. B., Abdou, L., Lahmar, O., & Drid, A. H. (2025). Quadrotor trajectory tracking under wind disturbance using backstepping control based on different optimization techniques. Engineering Proceedings, 87(1), 93