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Quadrotor trajectory tracking under wind disturbance using backstepping control based on different optimization techniques

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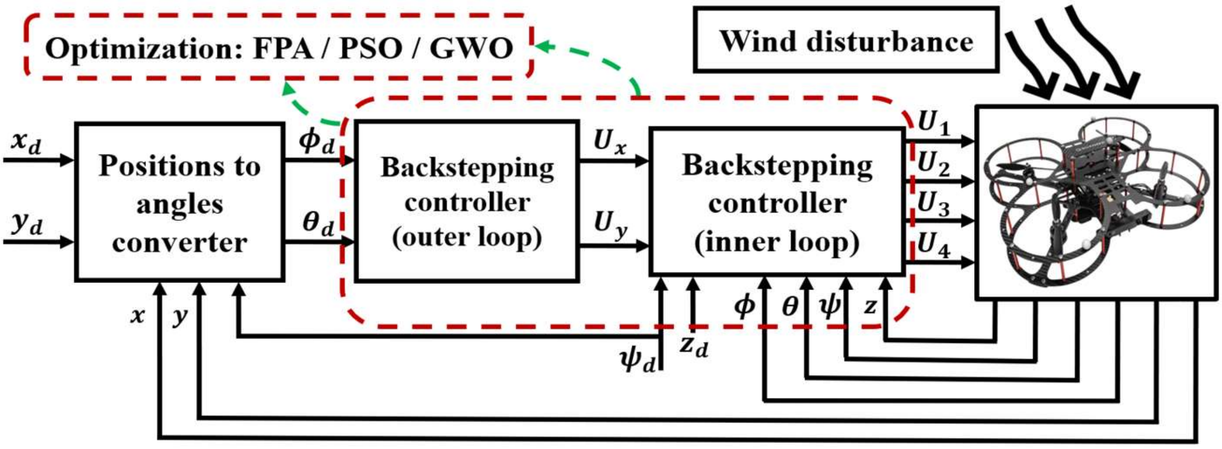
INTRODUCTION & AIM

This presentation proposes an optimized backstepping controller based on three different techniques: Flower Pollination Algorithm (FPA), Particle Swarm Optimization (PSO), and Grey Wolf Optimization (GWO) to ensure the trajectory tracking of a six-degree-of-freedom (6DOF) quadrotor. The goal is to identify the best method in terms of stability, speed, and precision, and to test the robustness of the selected method against external wind forces applied to the controlled drone.

METHOD

The quadrotor in controlled by applying backstepping to find the control laws U_1, U_2, U_3 and U_4 based on Lyapunov function : $f(\varepsilon) = \frac{1}{2}(\varepsilon)^2$ such that ε is the error between the desired position and the quadrotor's position, this applies to the three angular positions (Roll ϕ, Pitch θ, and Yaw ψ) and the three linear positions (x, y, and z). Integral Squared Error "$is\varepsilon$" is the objective function to be minimized through the optimization techniques tested in this work:

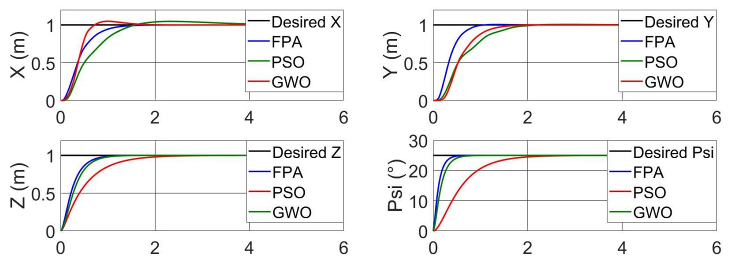
$$is\varepsilon = \int_0^t (\varepsilon_\phi)^2+(\varepsilon_\theta)^2+(\varepsilon_\psi)^2+(\varepsilon_x)^2+(\varepsilon_y)^2+(\varepsilon_z)^2 dt$$



RESULTS & DISCUSSION

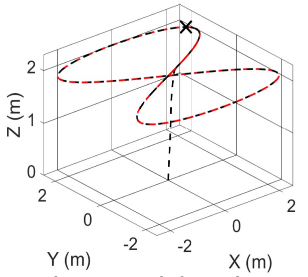
The following figure shows the step responses of the system for these desired positions:

$$[x_d \quad y_d \quad z_d \quad \psi_d] = [1\,m \quad 1\,m \quad 1\,m \quad 25°]$$

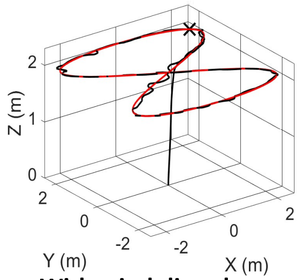


Based on the obtained results, the techniques provide an optimization that stabilizes the developed backstepping controller. However, the chosen method is the FPA-based backstepping, due to its superior response time, which is crucial for the high-speed requirements of autonomous flying robots.

External forces are applied to the system simulating the wind disturbance to test the robustness of the chosen method.



Without wind disturbance



With wind disturbance

The quadrotor almost follows the desired trajectory to complete the flight mission, which demonstrates the robustness of the controller against wind disturbances.

CONCLUSION

The proposed controller yields very satisfactory results but exhibits poor performance. This study selects the backstepping method based on FPA as the best approach, and it shows good results in terms of robustness during testing under wind disturbance.

FUTURE WORK / REFERENCES

Experimental application of the proposed controller.