Quadrotor motion analysis and control in wind field environment

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Abstract:

Small quadrotors have become more and more popular in recent years due to vertical take-off and landing capability, simple design, and low cost. Its applications involve rescue missions, aerial imaging, product delivery, reconnaissance, infrastructure inspections, etc.

Many of the usages require outdoor flying and then the random wind field could affect the quadrotor motion significantly due to its small size. Four propellers and six degree-of-freedom make the system underactuated and unstable. During the flight in the vicinity of obstacles, dangerous situations might occur. To improve the overall mission performance the drone behavior in the strong wind must be understood precisely. In this work, a novel approach was described to explore quadrotor dynamics in such, generally unknown apriori, windy conditions. State of the art literature review was performed and a research gap was identified.

Numerical simulation was used to study the quadrotor dynamics (Fig. 1). Commercially available drone DJI Mavic 2 Pro was used as a test platform in cross-configuration. Mass and moments of inertia of the object were obtained using CAD models and experiments. The rigid body with six degree-of-freedom, a nonlinear mathematical model was used to describe the motion of the platform. Several simplifying assumptions were formulated. A set of coordinate frames was introduced to describe the object's motion.

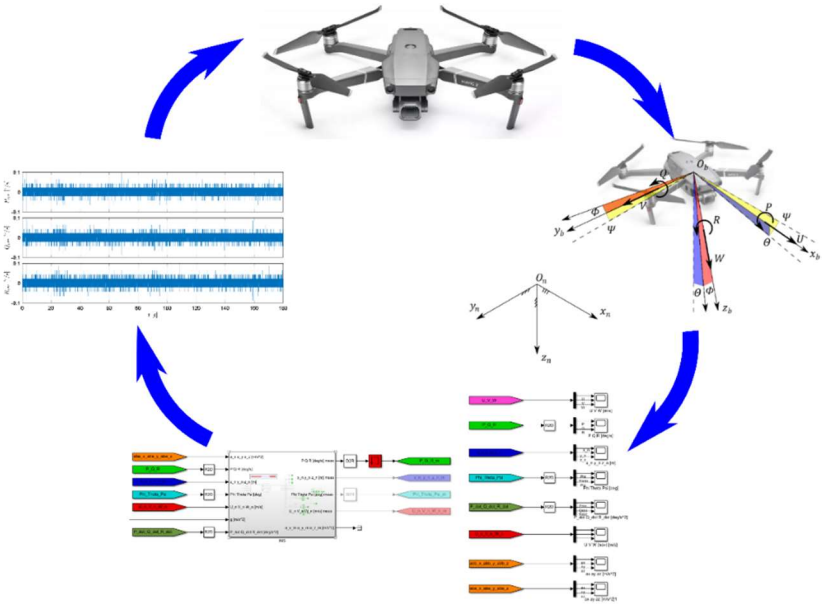

Fig. 1 Quadrotor motion analysis workflow

The forces and moments were calculated as a sum of gravity, aerodynamic and propellers generated loads. It was assumed that the object uses an inertial navigation system to obtain information about attitude, velocities, and position. A simplified motor model was presented. Wind field was included in

the simulation. An autopilot model based on proportional-integral-derivative controllers in cascade configuration was developed to control the angular rates and attitude of the object. The model was implemented in MATLAB/Simulink R2020b. Modular simulation architecture was applied which enables to study of the model's subsystems fidelity on the overall simulation performance.
A set of numerical experiments was evaluated. The examples of flight parameters and trajectories in form of graphs are presented. Some example scenarios were discussed in detail.
The contributions of this paper are the high-fidelity numerical simulation of the quadrotor and the study of its motion in the wind field. It was found that wind gusts could degrade the quadrotor mission performance. System nonlinearities cannot be neglected in realistic simulation analysis. Wind wield might cause that angular rotor speed could saturate. As a result, drift in object position might occur. Nevertheless, even using a simple PID-based control strategy it is possible to achieve the assumed mission goals.
The obtained results might be used for further analysis of quadrotor behavior. A more detailed model could be developed in the future and some flight trials should be also considered.

Keywords: quadrotor, wind field estimation, simulation