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School of MACE, The University of Manchester.

Development of rotorcraft UAVs for urban operations

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1 Background

Quadrotor helicopters have emerged as a design alternative to conventional helicopter designs for UAV in the range of a few kg. They are envisaged for operations in the urban environment where hover capabilities as well as manoeuvrability are required. Quadrotors are mechanically simple and are typically controlled by varying the rotational speed of individual fixed-pitch rotors. Whilst previous published work on Quadrotors predominantly focused on control strategies, the quadrotor configuration design and forward flight performance has been left largely unexplored. The present research studies the relationship between quadrotor configuration (geometric arrangements, choice of propulsion configuration) and initial sizing (physical length scale, mass, power) on the resulting flight performance. The aim of this work is to improve quadrotor performance in forward flight.

2 Method

Simulation model and wind tunnel testing A quadrotor simulation model was developed that considers fuselage and rotor aerodynamics as well as the performance of electric motors and power supplies. The rotor model is based on a numerical blade element method with a 1st order linear inflow model and a hingeless rotor flapping model. Windtunnel experiments were conducted on fixed and variable-pitch rotors and full-scale quadrotors. For full-scale quadrotor experiments two actual quadrotor airframes and a quadrotor testrig with adjustable rotor spacing were used. Trimmed level flight conditions were determined using a closed-loop feedback system and a six-component force balance underneath the model.

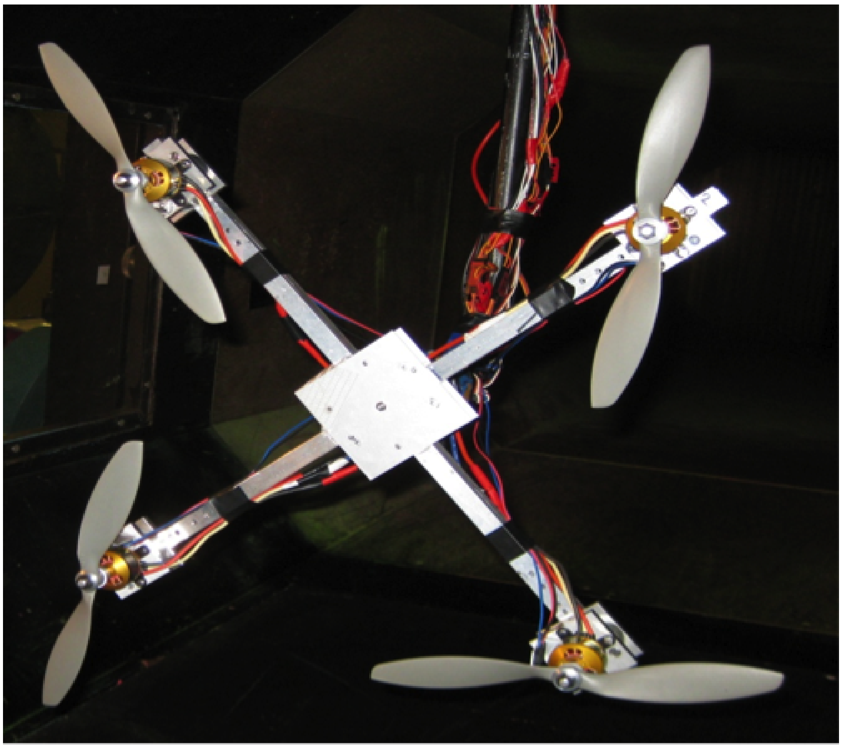

Figure 1: Quadrotor test-rig with adjustable rotor spacing, flight orientation and force balance position

3 Results

The rotor simulation model for typical level flight conditions was successfully validated using single rotor wind tunnel tests. The forward flight trim conditions, power requirement and individual rotor-motor efficiencies were determined as a function of rotor spacing, flight orientation, take-off weight and CG position. The performance limits were found to be different than for conventional helicopters, because the maximum quadrotor flight speed is reached if any of its four motor-rotor system saturates – even if the total installed power on the vehicle has not been reached. High speed performance and control authority can be improved if a quadrotor is flown in an x-configuration (two rotors at the front/rear) and has a fuselage aerodynamics and CG position that minimise the pitching moment and equalises the loading between the individual rotors. Further performance improvements can be realised by introducing variable-pitch rotor systems on quadrotors and using operational procedures to exploit maximum endurance and maximum range conditions in the autonomy mode.