Defence Science Journal, Vol. 61, No. 4, July 2011, pp. 337-345, DOI: 10.14429/dsj.61.1086


# Design/Development of Mini/Micro Air Vehicles through Modelling and Simulation: Case of an Autonomous Quadrotor

N.K. Gupta[*], R. Goel[†], and N. Ananthkrishnan[‡]

[*]*IDeA Research & Development (P) Ltd, Hadapsar, Pune- 411 013*
[†]*EADS-Astrium, Friedrichshafen 88090, Germany*
[‡]*Korea Advanced Institute of Science and Technology, Daejeon 305-701, South Korea*
*E-mail: nitin@idearesearch.in*

**ABSTRACT**

Design and development of an autonomous quadrotor micro aerial vehicle is undertaken following a systematic approach. A fairly detailed model was constructed and simulations were then carried out with the purpose of refining the baseline design, building a controller, and testing the flying qualities of the vehicle on a ground-based flight simulator. Following this, a smooth transition to rig and flight testing has been enabled in a cost- and time-effective manner, meeting all the design requirements.

**Keywords:** Modelling, simulation, micro air vehicle, quadrotor

## NOMENCLATURE

| | |
|---|---|
| $A$ | Rotation matrix |
| $Ap$ | Area of rotor |
| $B$ | Body-fixed frame |
| $D$ | Drag moment |
| DOFs | Degrees of freedom |
| FwI | Forces due to translational velocity and wind |
| $G$ | Gear ratio |
| $h$ | Altitude of vehicle |
| $I$ | Inertial frame |
| $I_{xx}, I_{yy}, I_{zz}$ | Quadrotor moments of inertia about body *x, y, z* axes, respectively |
| $I_{ct}$ | Inertial counter torque |
| $J$ | Moment of inertia matrix |
| $J_p$ | Moment of inertia of single rotor |
| $k_d$ | Aerodynamic drag moment coefficient |
| $k_i$ | Current constant of motor |
| $k_r$ | Friction coefficients due to rotational velocities |
| $k_s$, $k_u$ | Friction coefficients due to translational velocities |
| $k_t$ | Aerodynamic thrust coefficient |
| $k_v$ | Speed constant of motor |
| $L$ | Distance of centre of rotor from origin |
| $M$ | Matrix relating Euler time derivatives with body angular rates |
| $M_f$ | Friction torque |
| $M_g$ | Gyroscopic moments |
| $m$ | Mass of quadrotor vehicle assembly |
| $P$ | Pitch of rotor blade |
| $R$ | Resistance of motor |
| $R_p$ | Radius of rotor |
| $T$ | Thrust force |
| $V$ | Voltage applied to motor |
| $w$ | Wind velocity |
| $\dot{X}_i^{'}, \dot{Y}_i^{'}$ | Forward and sideward velocities in the horizontal plane |
| $\dot{X}_i, \dot{Y}_i$ | Velocities in inertial frame |
| $\alpha$ | Angular speed of rotor |
| $\varphi, \theta, \psi$ | Euler angles |
| $\varphi_b, \theta_b$ | Commanded base Euler angles |
| $\tau$ | Torque |
| $\tau t$ | Disturbance torque |
| $\tau m$ | Motor torque |
| $\omega$ | Angular rates of quadrotor in body frame |

### Subscripts

| | |
|---|---|
| 1, 2, 3, 4 | Rotor numbers |
| *b* | Coordinate in body frame |
| *c* | Commanded value |
| *d* | Desired value |
| *i* | Coordinate in inertial frame |
| *o* | Obtained value |

## 1. INTRODUCTION

There has been an explosion of interest in micro and mini aerial vehicles over the last decade and what was once perhaps a hobby for the aviation enthusiast is now a full-fledged area of research and development[1,2]. The interest has been fuelled by the prospect of their use in various civilian forums[3] in addition to the usual military applications. With the availability of low-cost and commercial off-the-shelf components, building and flying mini and micro air vehicles has become an integral part of capstone design courses in aerospace engineering programmeme in many universities. In fact, universities have been a significant source of research

Received 23 March 2011, published online 25 July 2011