MODELLING AND ANALYSIS OF A TRICOPTER

Saurabh Kumar

Gaurav Kr. Naik

Department of Industrial Design
National Institute of Technology Rourkela
Rourkela - 769008, Orissa, India.

MODELLING AND ANALYSIS OF A TRICOPTER

Thesis submitted in partial fulfilment
of the requirement for the degree of

Bachelor of Technology

in

Industrial Design

by

Saurabh Kumar (Roll: 110ID0265)
Gaurav Kr Naik (Roll: 110ID0269)

under the guidance of

Prof. BBVL Deepak

Department of Industrial Design
National Institute of Technology Rourkela
Rourkela - 769008, Orissa, India.
May 2014

May 07, 2014

Certificate

This is to certify that the work in the thesis entitled ***Modelling and Analysis of Tricopter*** by Saurabh Kumar and Gaurav Kr. Naik is a record of an original research work carried out under my supervision and guidance in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Industrial Design. Neither this thesis nor any part of it has been submitted for any degree or academic award elsewhere.

Prof. BBVL Deepak
Department of Industrial Design
National Institute of Technology Rourkela

Acknowledgment

I owe deep gratitude to the ones who have contributed greatly in completion of this thesis. Foremost, I would also like to express my gratitude towards my project advisor, Prof. BBVL Deepak for believing in me and providing me with the opportunity to work in this challenging area. His dedication has motivated me to work for excellence.

I am grateful to Prof. B.B. Biswal for providing useful insights into my project and always being with me whenever I needed him. I would like to thank all my friends and lab-mates for their encouragement and understanding. Their help can never be penned with words.

Saurabh Kumar, Gaurav Kr. Naik

ABSTRACT

Unmanned aerial vehicles (UAVs) can generally be defined as a “device used or intended to be used for flight in the air that has no on-board pilot”. Tricopter is one such UAV. Here we present new results to compute the kinematic and dynamic analysis for a tricopter mini-rotorcraft. The orientation and control of tricopter according to the parametric equation is also shown. The transformation of all the parameters from one co-ordinate to another co-ordinate is done. It include body frame of reference and earth frame of reference. Hence mathematical modelling of the tricopter is done. The relation or dependence of position on the angular speed of motor/s is shown by plotting three dimensional position versus time graph in MATLAB by considering different cases. A well dimensioned and rendered CAD 3D model of the intended tricopter is designed in CATIA and further rendered in Autodesk Showcase.

CONTENTS

LIST OF SYMBOLS AND ACRONYMS

Symbols	**Definition**
a	Linear acceleration.
g	Gravity.
G	Global frame.
$\sum f$	Total force acting on tricopter.
f_g	Force due to gravity.
f_G	Force acting on mass centre.
$F_{gravity}$	Force due to gravity.
F_{thrust}	Thrust force.
I	Moment of inertia.
k	Proportionality constant.
m	Mass.
Q	Transformation matrix.
v	Linear velocity.
V_G	Linear velocity in global frame.
w	Angular velocity.
X_B, Y_B, Z_B	Co-ordinate axis in local frame.
X_G, Y_G, Z_G	Co-ordinate axis in global frame.
u_G, v_G, w_G	Components of velocity along the x, y, z axis.
$\dot{u}_G, \dot{v}_G, \dot{w}_G$	Time derivative of velocity component.

w1, w2, w3	Rotational speed of three motors
φ, θ, Ψ	Euler angles: roll, pitch, and yaw, respectively.
τ	Total torque.
α	Angular acceleration.

CHAPTER 1

INTRODUCTION

To encourage missions in dangerous situations, flying stages that are little, spry and can take of vertically are of investment. A stage that satisfies these necessities is a UAV (Unmanned Aerial Vehicle) as a multicopter joined with a great control framework. A multicopter is a rotorcraft that has more than two rotors, in light of the fact that a rotorcraft with two rotors is called helicopter (bicopter). Multicopters have altered cutting edges with a pitch that are not conceivable to control, as it accomplishes for a helicopter (through the swashplate), to control the bearing of the rotor push. Rather, the rate of the rotors are shifted to accomplish movement control of a multicopter. For a tricopter, there is additionally a servo joined that can tilt one of the engines and by that accomplish a change in movement. Multirotor air ships are regularly utilized within model and radio controlled activities due to the straightforward development and control. Because of the amount of rotors, the extent of them doesn't have to be substantial in examination with a helicopter that just has one rotor to actuate enough drive to lift it up. Uavs are frequently utilized within spots where it is troublesome for a man to work in, for example, perilous situations, soak landscape and so forth. It is likewise a suitable and a modest apparatus for observation. A Polaroid mounted on a multicopter is an exceptionally adaptable approach to study a region. UAVs can without much of a stretch be intended for a particular mission and all things considered it is an exceptionally adaptable apparatus.

This theory is about displaying and dissection of a tricopter. It is an airplane with three rotors and a tail servo. This has the focal point of a helicopter with brisk yaw developments, additionally the preference of a quadcopter that is a more vigorous stage with its four rotor edges than a helicopter is with its just principle rotor to incite push power.

1.1 Objective

The objective of our project is to design a tricopter that can be used for surveillance purposes. We also aim to do the kinematic and dynamic analysis of motion of the copter and also we aim to do the force analysis of the derived. Then we propose to design and develop the working model of the system and control it autonomously.

1.2 Literature Review

An unmanned elevated vehicle (UAV), otherwise called an automaton, is an air ship without a human pilot ready for. Its flight is controlled either independently by machines in the vehicle or under the remote control of a pilot on the ground or in an alternate vehicle. The commonplace launch and recuperation system for an unmanned airplane is by the capacity of a programmed framework or an outside specialist on the ground.

There are a wide mixture of UAV shapes, sizes, designs, and aspects. Generally, Uavs were basic remotely guided flying machine, yet self-governing control is progressively being utilized.

A multirotor[1] or multicopter is a rotorcraft with more than two rotors. Multirotors frequently utilize settled-pitch cutting edges, whose rotor pitch does not shift as the sharpened pieces of steels turn; control of vehicle movement is attained by differing the relative pace of every rotor to change the push and torque transformed by each.

Because of their simplicity of both development and control, multirotor air ship are as often as possible utilized as a part of model and radio control airplane ventures in which the names quadcopter, hexacopter and octocopter are regularly used to allude to 4-, 6- and 8rotor helicopters, separately.

Radio controlled multirotors are progressively utilized as a low-plan choice to make elevated photography and features of locales and structures.

A tricopter is a multicopter that is lifted and moved by three rotors. Tricopters are considered rotorcraft, instead of altered-wing flying machine, in light of the fact that their lift is produced by a situated of rotating restricted-harmony airfoils. Dissimilar to most helicopters, tricopters by and large utilize symmetrically pitched cutting edges; these could be balanced as a gathering, a property known as 'aggregate', yet not separately based upon the sharpened steel's position in the rotor plate, which is called "cyclic" (see helicopter). Control of vehicle movement is attained by changing the pitch and/or pivot rate of one or more rotor circles, subsequently transforming its torque load and push/lift aspects.

Because of their simplicity of both development and control, tricopter flying machine are often utilized as novice model airplane ventures.

A tricopter has a little servo that permits it to tilt the back rotor and in this way alter its yaw heading. To quicken forward, the back velocity is expanded.

The primary mechanical segments required for development are the casing, propellers (either settled-pitch or variable-pitch), and the electric engines. For best execution and least difficult control calculations, the engines and propellers ought to be set 120 degrees separated. As of late, carbon fiber composites have gotten mainstream because of their light weight and structural firmness.

The electrical parts required to develop a working tricopter are like those required for a current RC helicopter. They are the Electronic Speed Control module, ready for-or controller board, and battery. Ordinarily, an interest remote control is likewise used to take into account human data.

Tricopters and different multicopters additionally frequently have the capacity of self-governing flight. Numerous current Flight Controllers use programming that permits the client to check "route-focuses" on a guide and afterward have their quadcopter travel to those areas and perform undertakings, for example, arriving or picking up elevation.

Tricopters, for example, arriving or picking up altitude.and different multicopters additionally frequently have the capacity of self-sufficient flight. Numerous current Flight Controllers use programming that permits the client to check "route-focuses" on a guide and afterward have their quadcopter travel to those areas and perform undertakings.

A vertical take-off and landing[2] (VTOL) airplane is one that can drift, take off, and arrive vertically. This characterization incorporates altered-wing flying machine and also helicopters and other airplane with fueled rotors, for example, cyclogyros/cyclocopters and tiltrotors. Some VTOL flying machine can work in different modes too, for example, CTOL (conventional take-off and landing), STOL (short take-off and landing), and/or STOVL (short take-off and vertical Landing). Others, for example, a few helicopters, can just work by VTOL, because of the flying machine needing arriving rigging that can deal with level movement. VTOL is a subset of V/STOL (vertical and/or short take-off and Landing).

Furthermore the pervasive helicopter, there are presently two sorts of VTOL air ship in military administration: art utilizing a tiltrotor, for example, the Bell Boeing V-22 Osprey, and flying machine utilizing guided plane push, for example, the Harrier crew. As a rule, VTOL airplane equipped for V/STOL use it wherever conceivable, since it ordinarily fundamentally builds takeoff weight, extent or payload contrasted with immaculate VTOL.

A micro air vehicle (MAV), or micro airborne vehicle[3], is a class of unmanned aeronautical vehicles (UAV) that has a size limitation and may be self-governing. Advanced art could be as little as 15 centimeters. Advancement is determined by business, examination, government, and military purposes; withinsect-sized airplane apparently expected later on. The little art permits remote perception of perilous situations difficult to reach to ground vehicles. Mavs have been assembled for side interest purposes,[4][5], for example, elevated apply autonomy challenges and aeronautical photography.

In January 2010, the Tamkang University (TKU) in Taiwan acknowledged independent control of the flight elevation of a 8-gram, 20-centimeter wide, fluttering-wing MAV. The MEMS Lab in the TKU has been creating Mavs for a few years, and since 2007 the Space and Flight Dynamics (SFD) Lab has joined the examination group for the advancement of independent flight of Mavs. Rather than conventional sensors and computational gadgets, which are excessively overwhelming for most Mavs, the SFD joined a stereo-vision framework with a ground station to control the flight altitude,[6][7] making it the first fluttering-wing MAV under 10 grams that acknowledged independent flight.

In 2008, the TU Delft University in the Netherlands created the littlest ornithopter fitted with a Polaroid, the Delfly Micro, the third form of the Delfly extend that began in 2005. This variant measures 10 centimeters and weighs 3 grams, marginally bigger (and noisier) than the dragonfly on which it was demonstrated. The imperativeness of the Polaroid lies in remote control when the Delfly is beyond anyone's ability to see. Be that as it may, this form has not yet been effectively tried outside, despite the fact that it performs well inside. Analyst David Lentink of Wageningen University, who took an interest in the advancement of past models, Delfly I and Delfly II, says it will take in any event a large portion of a century to copy the competencies of bugs, with their low vitality utilization and huge number of sensors eyes, as well as whirligigs, wind sensors, and substantially more. He says fly-measure ornithopters ought to be conceivable, given the tail is decently outlined. Rick Ruijsink of TU Delft refers to battery weight as the most serious issue; the lithium-particle battery in the Delfly micro, at one gram, constitutes a third of the weight. Fortunately, advancements around there are even now going quick, because of interest in different other business fields.

Ruijsink says the reason for these specialty is to comprehend creepy crawly flight and to give handy utilization, for example, flying through breaks in cement to look for quake exploited people or investigating radioactivity-debased structures. Spy offices and the military additionally see potential for such little vehicles as spies and scouts.

Robert Wood at Harvard University created a considerably more modest ornithopter, at only 3 centimeters, however this specialty is not self-sufficient in that it gets its energy through a wire. In 2013 the gathering has attained controlled flight inside a movement following framework.

In right on time 2008 the United States organization Honeywell gained FAA approbation to work its MAV, designated as gmav in the national airspace on an exploratory premise. The gmav is the fourth MAV to get such regard. The Honeywell MAV utilization ducted push for lift, permitting it to takeoff and land vertically and to float. It is likewise equipped for "fast" advance flight, as indicated by the organization, however no execution figures have been discharged. The organization additionally states that the machine is light enough to be conveyed by a man. It was initially created as a feature of a DARPA project, and its beginning provision is relied upon to be with the police bureau of Miami-Dade County, Florida.

In 2012, the British Army sent the sixteen gram Black Hornet Nano Unmanned Air Vehicle to Afghanistan to help infantry operations.

In June 2013, at the Paris Air Show, Parrot advertised they have sold in excess of 500,000 Ar.drone quadrocopters.

1.2.1 Flight Principle Of Tricopter

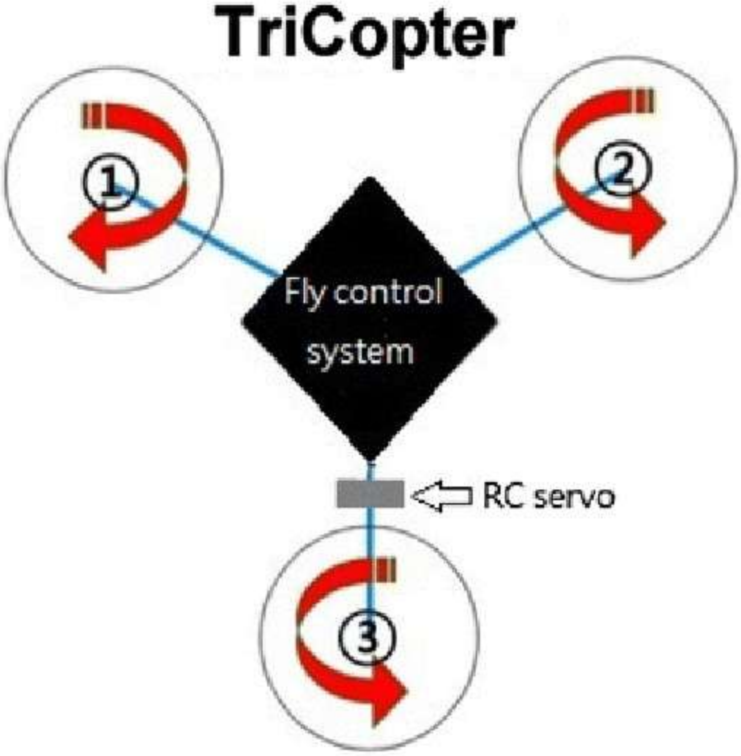

Fig 1.1 - The Flight Principle Of The Tri-Rotor

Given below is the flight principle of the tri-rotor

Fly forward: When flying forward, motors 1 and 2 must decelerate, while motor 3 on the tail axis must accelerate. As a result, the fuselage of the tricopter is inclined forwards, so it flies towards the same direction. On the contrary, when flying backwards, motors 1 and 2 must accelerate, while motor 3 must decelerate.

Fly to the right direction: When the tri-rotor flying robot flies to the right direction, motor 1 on the left side must accelerate, while motor 2 on the right side must decelerate, so as to allow the fuselage to incline to the right side and make the tricopter fly to the right direction.

Clockwise yaw: When the tri-rotor flying robot yaws in the clockwise direction, it needs to use the RC servomotor and linkage to drive the propeller of the motor 3 inclined in the left side. When the motor 3 rolls, it will generate the clockwise yaw torque, so as to make the tri-rotor flying robot yaw in the clockwise direction.

CHAPTER 2

KINEMATIC AND DYNAMIC ANALYSIS

2.1 Mathematical Model

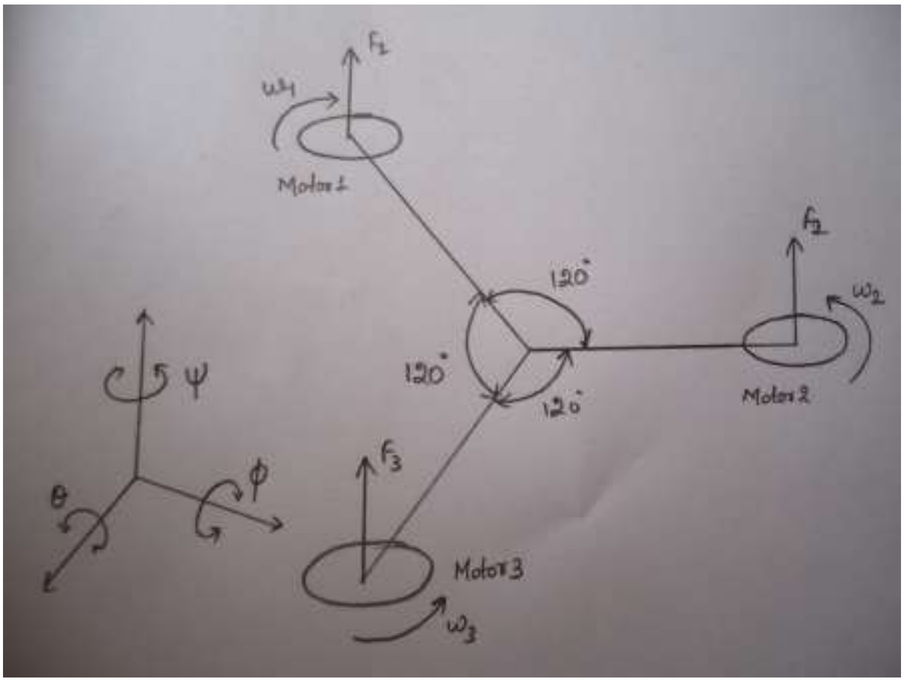

Fig 2.1 - Three rotor rotorcraft scheme

The above figure is a diagram of the dynamic equation of the tricopter in which the lower right side is the diagram of the dynamic equation of yaw control. That is because in yaw control, RC servomotor drives the tail axis to change the declination angle of the tail axis.

2.2 Moment of inertia of tricopter

Figure 3 is the diagram of the moment of inertia of the tri-rotor flying robot. When calculating the inertia torque of the tri-rotor flying robot, we assume the fuselage is rectangular shape, the three motors are cylindrical in shape; furthermore, the inertias of the round rods of the axes are neglected.

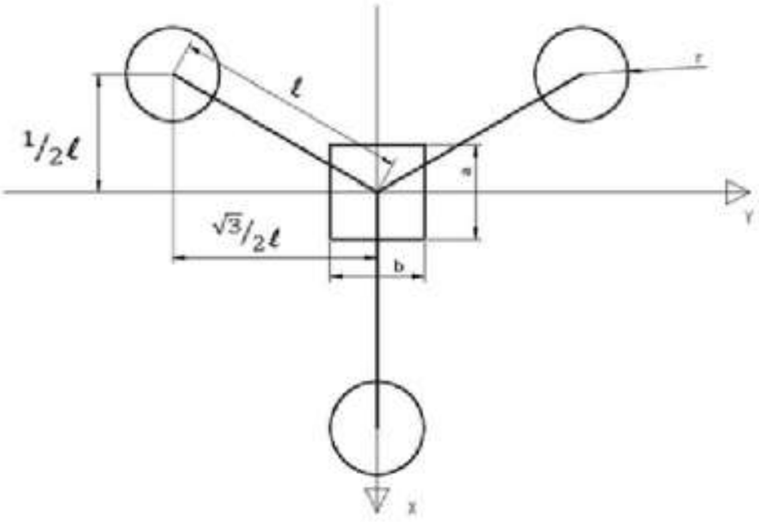

Fig. 2.2- Moment of inertia of each axis

Moment of inertia of each axis

The total moment of inertia about *x*-axis

$$Ixx = \frac{3}{2}ml^2 + \frac{1}{12}mob^2 + \frac{1}{12}m(3r^2 + h^2)$$

Moment of inertia about axis y: The total moment of inertia about y-axis:

$$Iyy = \frac{3}{2}ml^2 + \frac{1}{12}moa^2$$

Moment of inertia about axis y: The total moment of inertia about y-axis:

$$Izz = \frac{1}{12}mo(a^2 + b^2) + 3ml^2$$

2.3 System Modelling

To be able to use the control methods, a dynamic model of the tricopter needs to be derived.

This means that the tricopter has to be mathematically described.

2.3.1 Co-ordinate system

There are 3 different co-ordinate systems of interest that needs to be defined. The local, which is seen as the body fixed co-ordinates of the tricopter and denoted by B and global, which is co-ordinate system of earth and denoted by G.

The tricopter has three arms formed as Y and a rotor is placed at the end of each arm. The coordinate system for tricopter will be defined as in fig.

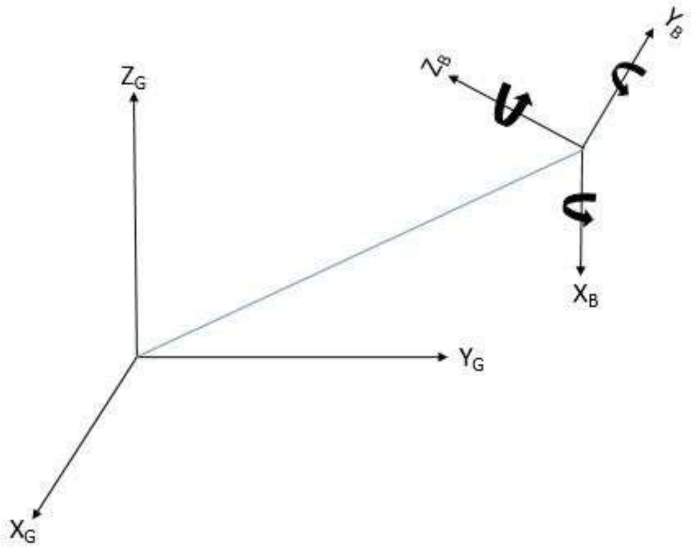

Fig. 2.3- Coordinate of the tricopter helicopter

The X_B axis is defined in the direction straight ahead seen from the view of the tricopter and Y_B axis to the right. The Y_B axis is defined straight down from the center of mass of the tricopter. The Y_B axis can be seen as the desired forward direction during a flight.

The relation between tricopter's(Body) co-ordinate system and co-ordinate system of earth can be described in a mathematical way with the rotation matrix $Q_{xyz}^{\varphi\theta\Psi}$. The rotation is represented with euler angles which is represented with (φ, θ, Ψ) and is the angle around $X_{B,}$ Y_B and Z_B axes respectively. The rotation applied to each of the base vectors and the total rotation is done by first rotating the Z_B axis with an angle Ψ, then done by first rotating the Y_B axis with an angle θ and at last the X_B axis with an angle ϖ.

$$Q^{\varpi\theta\Psi}{}_{xyz}=Q^{x}{}_{\varpi}Q^{y}{}_{\theta}Q^{z}{}_{\Psi}$$

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & c\varpi & s\varpi \\ 0 & -s\varpi & c\varpi \end{pmatrix} \begin{pmatrix} c\theta & 0 & -s\theta \\ 0 & 1 & 0 \\ s\theta & 0 & c\theta \end{pmatrix} \begin{pmatrix} c\Psi & s\Psi & 0 \\ -s\Psi & c\Psi & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$= \begin{pmatrix} c\theta c\Psi & c\theta s\Psi & -s\theta \\ s\varpi s\theta c\Psi - c\varpi s\Psi & s\Psi s\theta s\varpi - c\varpi c\Psi & s\varpi c\theta \\ c\varpi c\theta c\Psi + s\theta c\Psi & s\Psi s\theta c\varpi - c\varpi c\Psi & c\varpi c\theta \end{pmatrix}$$

2.3.2 Input and Output Signals

To be able to control the tricopter and determine a dynamical model of it, the i/p and o/p signals of the system have to be defined.

The tricopter has three electrical motors with rotors which will create an airflow which induces a thrust force to lift the tricopter. This force as well as corresponding torque is proportional to square of the angular velocity of rotating blades.

The angular velocity and tilt angle will give the tricopter 4 signals to control its movement: three rotor velocities and the tilting angle. These input signals affect the orientation and translational of the rotorcraft. By approximating the tricopter as a rigid body with 6 degrees of freedom, the states of the system that describes the motion can be defined as $(x, y, z)^G$, $(u, v, w)^G$, $(\varpi, \theta, \Psi)^G$, $(p, q, r)^B$. These are the position and velocity of the tricopter in the co-ordinate system G but also rotational angles in G and angular rates in B respectively.

2.4 Physical motion model

To be able to express the dynamical model of the aircraft, the translational and rotational equations have to be derived.

2.4.1 Translation

Mass multiplied by with the time derivative of the translational speed vector is equal to the directional force vector;

$$mV_G = \sum f$$

The gravitational force is separated from the externals because it is acting on the mass centre and is therefore not inducting any torque on the centre of mass. The force equations are-

$$m\dot{V}_G = \sum f$$

$$= f_G + f_g\,(gravity)$$

$$= Q_{xyz}^{\varpi\theta\Psi}(f_B)_{ext} + [0\ 0\ \ -mg]$$

$$\dot{u}_G = \frac{1}{m}[(F^x{}_B)_{ext}\, c\theta c\Psi + (F^y{}_B)_{ext}\, c\theta s\Psi - (F^z{}_B)_{ext} s\theta]$$

$$\dot{v}_G = \frac{1}{m}[(F^x{}_B)_{ext}\,(s\varpi s\theta c\Psi - c\varpi s\Psi) + (F^y{}_B)_{ext}\,(s\omega s\theta s\Psi + c\varpi s\Psi) + (F^z{}_B)_{ext}\,(c\theta s\omega)]$$

$$\dot{w}_G = \frac{1}{m}[(F^x{}_B)_{ext}\,(c\varpi s\theta c\Psi + s\varpi s\Psi) + (F^y{}_B)_{ext}\,(c\omega s\theta s\Psi - s\varpi c\Psi) + (F^z{}_B)_{ext}\,(c\theta c\omega)]$$

Absolute velocity is compared by

$$|V|_G = ((u_G)_2 + (v_G)_2 + (w_G)_2)_{1/2}$$

where $u_G = \int \dot{u}_G dt$, $v_G = \int \dot{v}_G dt$, $w_G = \int \dot{w}_G dt$,

2.4.2. Rotational

We derive the rotational equation of motion from Euler's equation for rigid body dynamics by considering the tricopter as a rigid body in the body frame –

$$\tau = I\dot{w}$$

where

$$\dot{w} = \begin{pmatrix} \dot{w}x \\ \dot{w}y \\ \dot{w}z \end{pmatrix}$$

$$I = \begin{pmatrix} Ixx & 0 & 0 \\ 0 & Iyy & 0 \\ 0 & 0 & Izz \end{pmatrix}$$

Therefore,

$$\tau = \begin{pmatrix} Ixx & 0 & 0 \\ 0 & Iyy & 0 \\ 0 & 0 & Izz \end{pmatrix} \begin{pmatrix} \dot{w}x \\ \dot{w}y \\ \dot{w}z \end{pmatrix}$$

Thus, by calculating the motor velocities the torque acting on the tricopter can be find out.

CHAPTER 3

VELOCITY MODEL SIMULATION IN MATLAB FOR POSITION DETERMINATION

Let $\sum F$ be the total force acting on the tricopter.

This $\sum F$ is due to resultant of gravity force and thrust force i.e. $\sum F = F_{thrust} + F_{gravity}$

F_{thrust} is provided by the velocities of the motors mounted at the extremes of the three ends/hands of the tricopter.

Experimental results have shown that

F_{thrust} is directly proportional to w_i^2

$F_{thrust} = k(w_1^2 + w_2^2 + w_3^2)$

We need to find out a relation between angular velocity of the tricopter and the linear velocity in order to predict the position of the tricopter with time within an interval.

The relation is given by Newton-Euler equation:

$$\begin{pmatrix} F \\ \tau \\ 0 \end{pmatrix} = \begin{pmatrix} m & 0 & 0 \\ 0 & I & 0 \\ 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} a \\ \alpha \\ 0 \end{pmatrix} + \begin{pmatrix} w \times mv \\ w \times Iw \\ 0 \end{pmatrix}$$

Where F=total force

m=mass

τ = total torque

a=linear acceleration

α=angular acceleration

I=moment of inertia

v=linear velocity

w=angular velocity

$F = ma + mvw$ -------(1)

$\tau = I\alpha + Iw^2$ -------(2)

From (1), we can conclude that

$$v = \frac{F - ma}{mw}$$

assuming acceleration to be zero

$$v = \frac{F}{mw}$$

Where $F = K(w1^2 + w2^2 + w3^2)$, K=constant

$v = K'(w1^2 + w2^2 + w3^2)/w$

$v^2 = K''(w1^2 + w2^2 + w3^2)$ since w=v/r

Now acceleration of the system-

$ma = F - mvw$

$a = (F - mvw)/m$

$= (K(w1^2 + w2^2 + w3^2) - mv(w1 + w2 + w3))/m$

$= K'(w1^2 + w2^2 + w3^2) - m(v_x + v_y + v_z)(w1 + w2 + w3)$

Where K'=K/m=const

$v = (K''(w1^2 + w2^2 + w3^2))^{1/2}$

$\vec{v} = v(\cos a\vec{i} + \cos b\vec{j} + \cos c\vec{k}$

Taking a, b, c as const=45 degree, we get

$\overrightarrow{Vx} = (K(w1^2 + w2^2 + w3^2))^{1/2}\vec{i}$

$\overrightarrow{Vy} = (K(w1^2 + w2^2 + w3^2))^{1/2}\vec{j}$

$\overrightarrow{Vz} = (K(w1^2 + w2^2 + w3^2))^{1/2}\vec{k}$

Case1. Angular velocity is constant and acceleration is zero

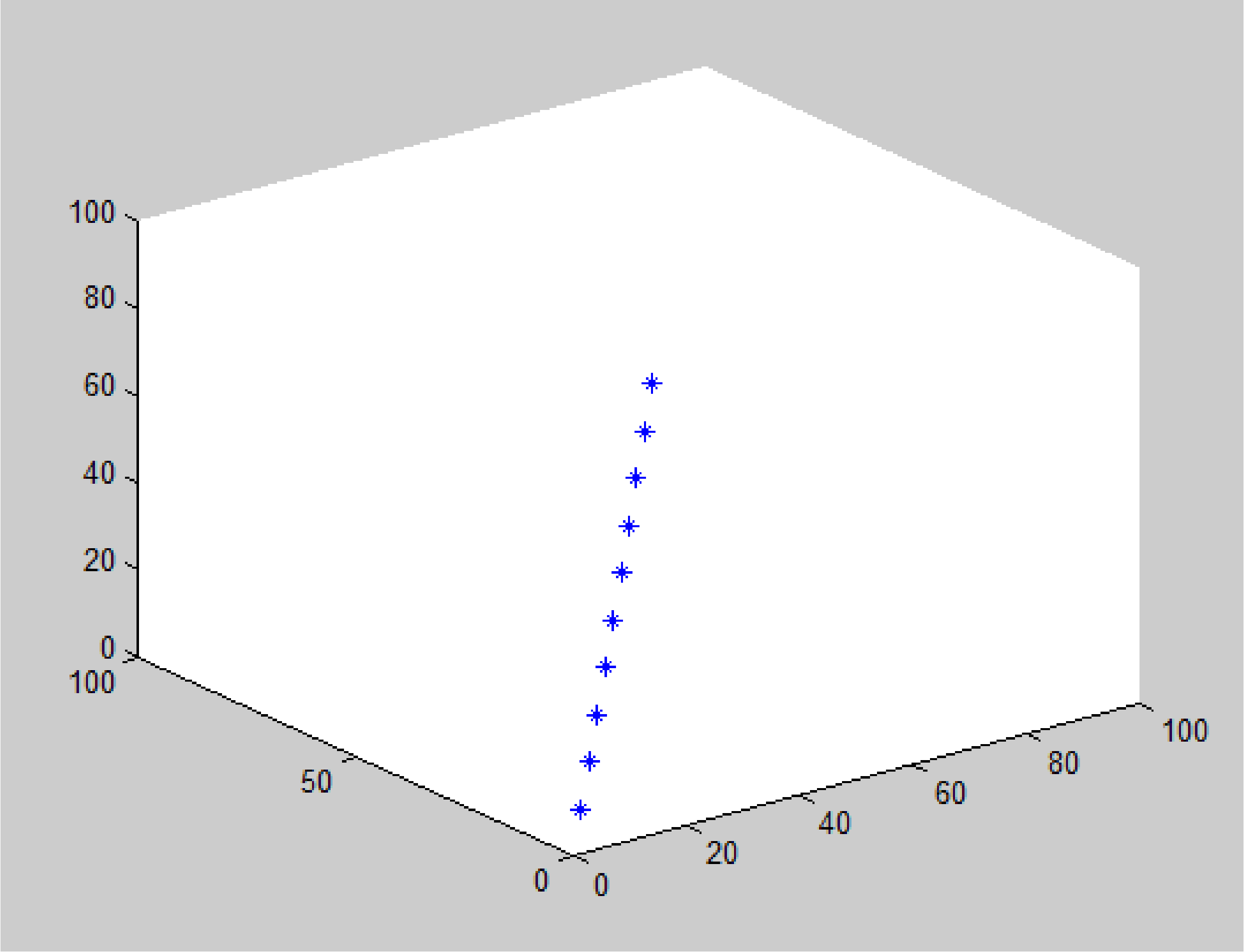

Fig. 3.1- Plot of position versus time when angular velocity is constant and acceleration is zero.

Case 2. Motors are rotating with a constant angular acceleration

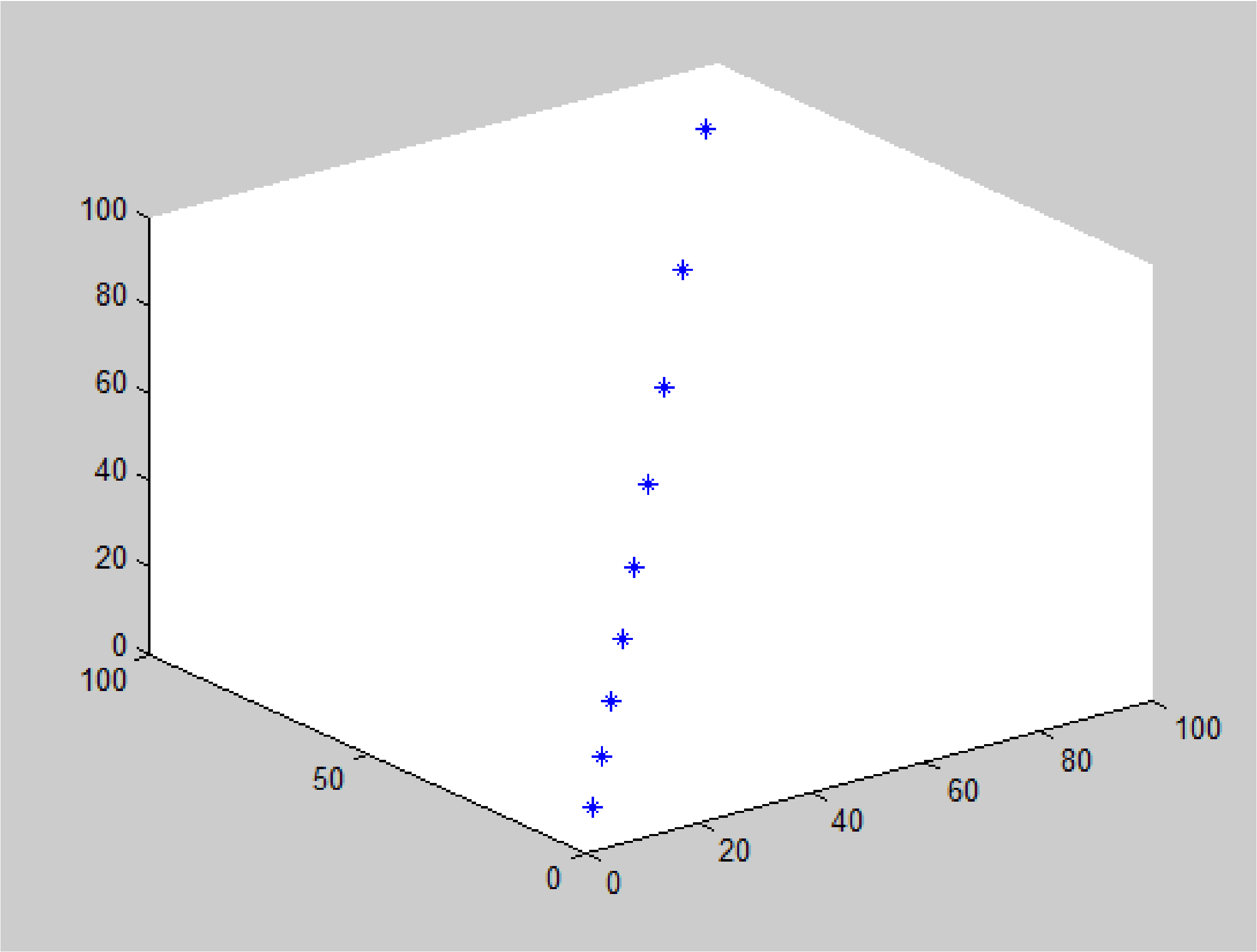

Fig. 3.2- Plot of position versus time when motors are rotating with a constant angular acceleration.

CHAPTER 4

FABRICATION OF THE TRICOPTER

4.1. Mechanical part

4.1.1. Tricopter mechanical assembly

The mechanical gathering of tricopter comprises of tri base, wings, yaw instrument, battery wellbeing, flight controller security, engine mounting and so on.

4.1.2.Central Base

The focal base is made of two layers of plywood.

Initial two equilateral triangle is cut from the plywood sheet and afterward equivalent separation are dealt with the edges from the corner and slice as per width of the wings as indicated in the CAD model.

Presently these two build are amassed with respect to over other utilizing screws leaving as much space.

4.1.3.Wings or arms

- material proposed for wings/arms of tricopter is aluminum straps.
- the aluminum wings and the control base are gathered together utilizing screws and nuts..

4.1.4.Battery safety

- special forethought must be taken for the wellbeing of the battery(acknowledging the accident plausibility).
- the battery ought to be avoided the indicating corners and so forth to abstain from penetrating probability.

- Between the two plywood focal base, the wooden box(having the measurements as of battery) ought to be altered and battery ought to be kept inside it utilizing DST(double sided tape) throughout the flight.

4.1.5. Yaw mechanism

- to control the yawing movement of the tricopter one rotor ought to have the capacity to turn ought to have the capacity to pivot about its wing/arm hub.
- to pivot it we utilize servo engine mounted on one of the wing.

4.1.6. Flight controller safety

- The flight controller board ought to be mounted such that to keep the vibrations.
- Use of a few layers of DST to mount the board.

4.2. Electronic Components

4.2.1. ESC

An electronic speed controller or ESC is an electronic circuit with the reason to fluctuate an electric engine's speed its bearing and perhaps at the same time to act an element brake. Escs are frequently utilized on electrically fueled radio controlled models, with the assortment regularly utilized for brushless engines basically giving an electronically-produced three stage electric power low voltage wellspring of vitality for the engine.

Escs intended for radio-control planes/copters generally hold a couple of wellbeing characteristics. In the event that the force originating from the battery is lacking to keep running the electric engine will decrease or cut-off force to the engine while permitting proceeded utilization of ailerons, rudder and lift capacity. This permits the pilot to hold control of the plane to float or fly on low power to wellbeing.

Specification

Continuous Current Rating	18 Amp
Burst Current Rating	22 Amp
BEC Mode	Linear
BEC	5V/ 2 Amp
LiPo Cells	2-4 Cells
Weight	19 grams
Size	24x45x11mm

4.2.2. Brushless DC motors

The DC-engine is an actuator which changes over electrical vitality into mechanical vitality (and the other way around). It is made out of two intuitive electromagnetic circuits. The first (called rotor) is allowed to turn around the second one (called stator) which is settled. In the rotor, a few gatherings of copper windings are associated in arrangement and are remotely open because of a gadget called commutator. In the stator, two or more lasting magnets force an attractive field which influences the rotor. By applying a DC-current stream into the windings, the rotor turns in view of the energy produced by the electrical and attractive association.

A dc motor can be extensively characterized into two recognized sorts of engines specifically:

- Brushed dc motor
- Brushless dc motor

As per our project we will be using brushless dc motor.

Specification

Kv (rpm/v)	924
Weight	56 grams
Max Current	17 Amps
Max Voltage	11V
Motor Length	32mm
Motor Diameter	28mm
Total Length	46mm

4.2.3. Flight controller board

The KK multicopter controller is a sort of flight control framework, which might be connected to a multirotor air craft with distinctive axes, including single-hub, double-pivot, tri-hub, quad-hub, hex-hub, eight-hub, and additionally the flying machine with fixed wings. The KK multicopter flight controller has an Atmega microchip and tri-pivot gyro that can discover the rakish speed of move, pitch, and yaw headings, and 8-channel PWM sign yield. It can control eight engines or RC servos at most so that the air ship can fly steadily.

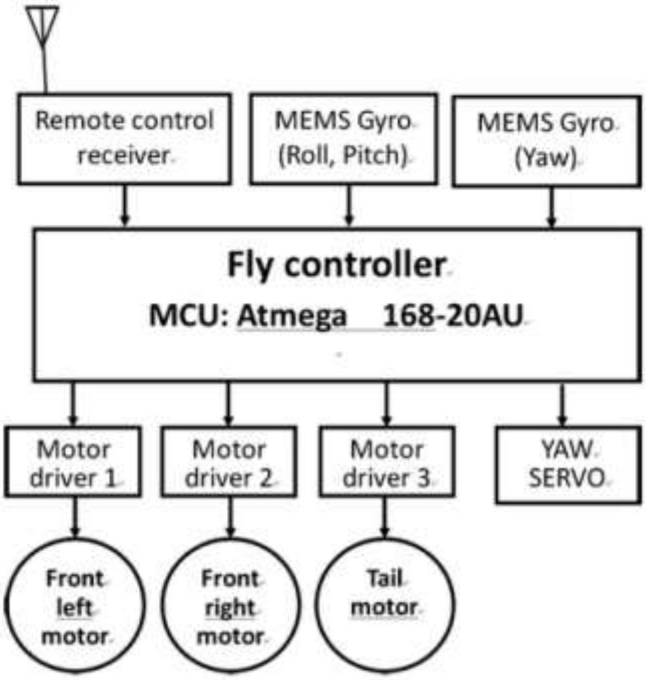

Fig. 4.1- KK fly controller board

Basic functions of KK multicopter flight controller

The tri-hub gyro-settled framework has contra-turning gyro chips, with the capacities of electronic alteration and adjustment of the quickening agent pedal and locking rotection. Figure indicates the equipment construction modeling of the flight controller connected on the tricopter in which the remote control recipient is utilized to accept the remote control indicator sent from the radio controller. Likewise, the MEMS gyro could be utilized to catch the rakish speed of the headings of move, pitch, and yaw for the three rotors. The mimicked voltage yield by the gyro could be specifically perused by the single chip atmega 168-20au on the flight controller, taking into account which the hub declination plot of the three rotors are figured. The single chip on the flight controller can control the velocity contrast between the three engines, and the declination point of the RC servos, with a specific end goal to keep up the offset motion of the three rotors.

4.2.4. Li-Po battery

Lithium Polymer (Lipo) cells are one of the most up to date and most revolutionary battery cells accessible. Lipo cells keep up a more reliable voltage over the release bend when contrasted with Nicd or Nimh cells. The higher ostensible voltage of a solitary Lipo cell (3.7v vs 1.2v for a normally Nicd or Nimh cell), making it conceivable to have a proportionate or considerably higher aggregate 23 ostensible voltage in a much littler bundle. Lipo cells ordinarily offer high limit for their weight, conveying upwards of double the limit for ½ the weight of practically identical Nimh cells. In conclusion, a Lipo cell battery needs to be deliberately observed throughout charging since cheating and the charging of a physically harmed or released cell could be a potential flame peril and perhaps even deadly. Li-poly batteries are picking up support in the realm of radio-controlled airplane due to its preferences of both easier weight and significantly expanded run times. A urging playing point of Li-poly cells is that makers can shape the battery practically anyway they kindly which could be vital in their use in micro airplanes and rotors.

Specification:

Capacity	4000 mAh
Voltage	3 Cell 11.1 V
Discharge	20C Constant & 30C Burst
Weight	306 grams
Dimensions	146x51x22mm
Balance Plug	JST-XH
Discharge Plug	Bullet Connector
Max Charge Rate	2C

.

4.2.5. Transmitter and receiver

In hardware and telecommunications a transmitter or radio transmitter is an electronic gadget which with the help of a reception apparatus, produces radio waves. The transmitter itself creates a radio recurrence rotating current, which is connected to the recieving wire. At the point when energized by this substituting current the recieving wire transmits radio waves. Notwithstanding their utilization in TV, transmitters are essentially parts a piece of numerous electronic gadget that impart by radio.

A receiver is an electronic gadget that gets radio waves and proselytes the data conveyed to them to a usable structure. It is utilized with a radio wire. The reception apparatus captures radio waves and believers them to small exchanging flows which are connected to the beneficiary and the collector removes the fancied data. The beneficiary utilization electronic channels to divided the sought radio recurrence sign from the various indicators picked by the reception apparatus, an electronic enhancer to expand the force of the indicator for further transforming lastly recoups the coveted data through demodulation

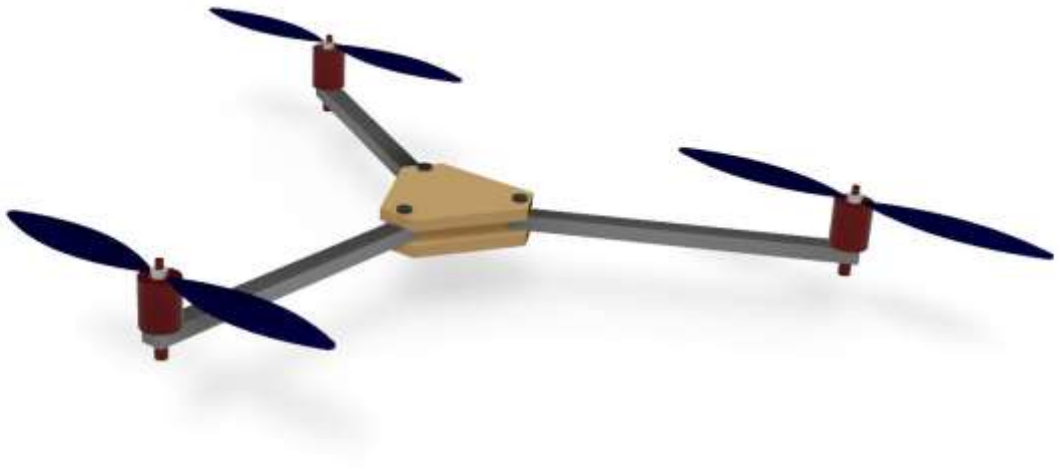

Fig. 4.2 3D CAD rendered version of tricopter

CHAPTER 5

CONCLUSION

In this report of the project that we carried out we have tried to bring out the Mathematical Model of the tricopter and derived the Translational and Rotational equations for the Tricopter as well as MATLAB simulation to predict the position of the tricopter during flight. Two separate graphs were plotted in MATLAB with varying conditions. In addition to this, specification of each parts were found out and noted down in this report. Also a separate CAD model of tricopter was being made and rendered in AUTODESK SHOWCASE. Further research can be done on how to control the path of the tricopter based on the data received from the GPS.

LIST OF FIGURES:

APPENDIX:

Programming For Velocity Model Simulation In MATLAB For Position Determination

case1.

```
x=10;
y=10;
z=10;
w1=1;
w2=2;
w3=1;
%vx=2;
%vy=2;
vx=(w1*w1+w2*w2+w3*w3);
vy=(w1*w1+w2*w2+w3*w3);
vz=(w1*w1+w2*w2+w3*w3);
% plot(,'*')
for t=1:10
    x=vx*t;
   % w1=w1+2*t;
    %w2=w2+2*t;
    %w3=w3+2*t;
    y=vy*t;
    z=vz*t;
    plot3(x,y,z,'*')
    hold on
```

```
end
xlim([0,100])
ylim([0,100])
zlim([0,100])
```

case2.

```
x=10;
y=10;
z=10;
w1=1;
w2=2;
w3=1;
%vx=2;
%vy=2;

% plot(,'*')
for t=1:10

    w1=w1+.01*t;
    w2=w2+.01*t;
    w3=w3+.01*t;
    vx=(w1*w1+w2*w2+w3*w3);
vy=(w1*w1+w2*w2+w3*w3);
vz=(w1*w1+w2*w2+w3*w3);
    x=vx*t;
```

```
    y=vy*t;

    z=vz*t;

    plot3(x,y,z,'*')

    hold on

end

xlim([0,100])

ylim([0,100])

zlim([0,100])
```

REFERENCES

[1] NOVA, “Battle Plan Under Fire – Time Line of UAVs”. Available at: http://www.pbs.org/wgbh/nova/wartech/uavs.html)

[2] Valavanis, Kimon P., ed. *Advances in Unmanned Aerial Vehicles: State of the Art and the Road to Autonomy*. Dordrecht: Springer, 2007.

[3] Premerlani, W. & Bizard, P. (May 17, 2009). *Direction Cosine Matrix IMU: Theory*. Available at: http://gentlenav.googlecode.com/files/DCMDraft2.pdf

[4] Autonomous Control for Micro-Flying Robot and Small Wireless Helicopter X.R.B, Wei Wang and Gang Song, et al[2006].

[5] Design, Analysis and Hover performance of a Rotary Wing Micro Air Vehicle, Felipe Bohorquez.

[6] PRNewswire (Feb 1, 2010). Teal Group Predicts Worldwide UAV Market Will Total Over $80 Billion in its Just Released UAV Market Profile and Forecast. *PRNewswire*. January 2011 from http://www.prnewswire.com/news-releases/teal-group-predicts-worldwideuav-market-will-total-over-80-billion-in-its-just-released-2010-uav-marketprofile-and-forecast-83233947.html

[7] Murray R., et al., *A Mathematical Introduction to Robotic Manipulation*, CRC, Boca Raton, FL 1994.