

Quad-Rotor Helicopter Kinematics and Dynamics Proposal

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Abstract—This document proposes the idea of analyzing the kinematics and dynamics of a quad-rotor helicopter as it travels through a pre-determined flight path. This analysis serves as the course project for AER 540, Intermediate Dynamics, Fall 2014.

I. INTRODUCTION AND MOTIVATION

A quad-rotor helicopter is a flying device that has four horizontal spinning rotors which produce the upward thrust needed to lift the center piece, or body of the helicopter, into the air. See Figure 1 below, courtesy of website [1], for a visual example of a quad-rotor helicopter:



Fig. 1. A visual example of a quad-rotor helicopter. Notice the four rotors.

The purpose of this course project is to analyze the kinematics and dynamics of a quad-rotor helicopter as it flies through a pre-determined flight path. The inspiration for this project came from the Michigan Autonomous Aerial Vehicles Club (MAAV). Every year, the club designs and constructs a quad-rotor helicopter to compete in a competition the subsequent August. In this competition, the goal is to have the quad-rotor helicopter autonomously navigate its own way through an obstacle course. As no human navigation input into the helicopter is allowed, its processor must use controllers that can successfully command the helicopter's actuators, i.e., the four spinning rotors, to direct the helicopter through its path. As such, it would be useful to model the quad-rotor helicopter's kinematics and dynamics as this information is needed in order to design the controllers to produce steady and stable flight through the obstacle course.

II. KINEMATICS OF THE QUAD-ROTOR HELICOPTER

Kinematics refers to the geometry of motion of a moving object. For the quad-rotor helicopter, it will follow a line for its pre-determined flight path. The characteristics of the flight path line may include:

- 1) Straight segments.
- 2) Curved segments.
- 3) Vertical/Horizontal motion.
- 4) Upward/Downward motion that is angled with respect to the ground.

The exact positions of the aggregate points that define the flight path line need to be known in order to analyze the velocities and accelerations of the helicopter. This position information is important because, for example, the helicopter would experience, for a fixed speed, significantly larger accelerations if its flight path curved excessively as opposed to smaller accelerations over only a slightly curved path.

Consideration also needs to be given to the frame of reference fixed to the helicopter body. This frame of reference may tilt or rotate with respect to the ground frame as needed to have the helicopter maneuver itself through the obstacle course.

III. DYNAMICS OF THE QUAD-ROTOR HELICOPTER

Dynamics refers to the forces that act upon an object and the resulting motion. A few considerations need to be taken into account for this portion of the analysis:

- 1) The weight of the quad-rotor helicopter.
- 2) The four spinning rotors which produce four upward thrust forces that do not point through the center of mass of the helicopter body. Thus opportunities for moments arise.
- 3) The thrust magnitudes of the four rotors determine whether the helicopter moves upward, downward, remains stationary with respect to the vertical direction, or tilts.
- 4) The helicopter needs to tilt to have the four spinning rotors produce the horizontal force components needed to maneuver the helicopter forward.
- 5) Any helicopter rotation will compromise any control as the helicopter's motion depends on the relative positions of its rotors.
- 6) The drag that is imposed on the helicopter by the surrounding air.

During the dynamics analysis phase of the project, more considerations may need to be taken into account.

IV. CONCLUSION

In this proposal, an introduction to quad-rotor helicopters was given along with the motivation for analyzing its kinematics and dynamics. After, details of what the kinematics and dynamics analysis could entail were provided.

REFERENCES

- [1] "Traxxas QR-1 Quad-Rotor Ready-To-Fly Helicopter," *Amazon.com*, Accessed September 14 2014, <http://www.amazon.com/Traxxas-Quad-Rotor-Ready-To-Fly-Helicopter-Colors/dp/B00AHXMHVA>.