Plausibility of Variable-Pitch, Variable-Tilt Quadcopters

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Abstract

The goal of this project was to design, construct and test a quadcopter that operated using both variable-pitch propellers and a variable-tilt propeller system (nacelle). With an emphasis on low weight and high functionality, we set out to design a system to achieve both of these goals and to create a more functional aircraft that would achieve a faster horizontal speed, while maintaining vertical take-off and landing capabilities. This project was focused on creating the mechanical design portion of the aircraft. Future research will need to be done on the electronic control systems to control such an aircraft.

Introduction

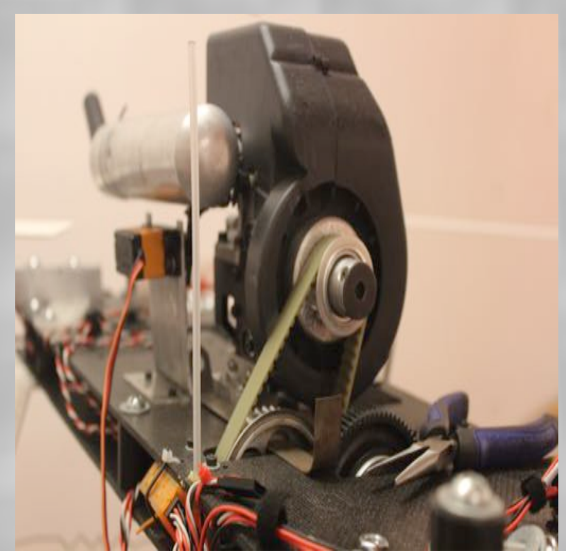
Quadcopters have become increasingly popular in the consumer market, and for good reason. They are easy to control using the onboard inertial measurement unit. However, certain physical limitations limit their capabilities, including airspeed, payload capability and endurance. These limitations put a handicap on the aircraft's effective flight envelop. Using a variable tilt nacelle system, we want to overcome these limitations to create a more functional aircraft that combines the best of rotary and fixed wing systems. Similar attempts have been performed to incorporate systems that combine both helicopter VTOL abilities with the range and speed of an aircraft, most notably the V-22 Osprey. The V-22 operates using a similar system, but only utilizes two propellers instead of four. By using four propellers, we intend to add stability and reliability that is lacking in the V-22.

Project Description

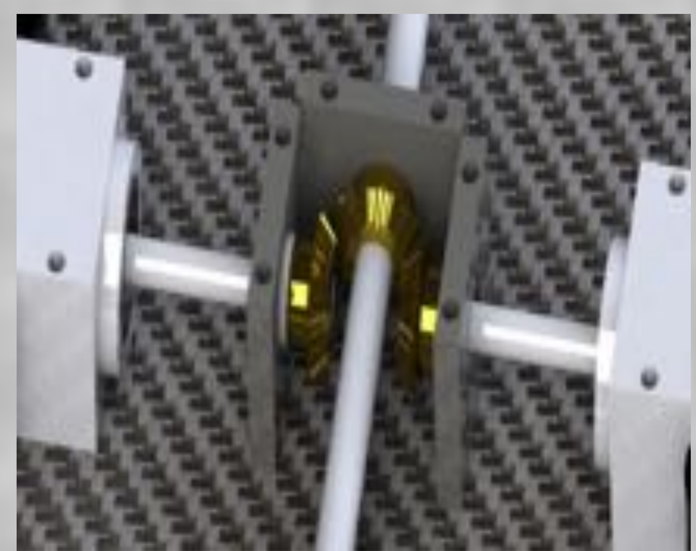
Using Computer Aided Design, I was able to virtually construct a prototype aircraft before manufacturing and assembly. Using an aircraft built by a prior senior design class, I was able to adapt it to fit our needs. The previous design involved a combustion engine and pulleys to power the propellers. Many of their designs were changed to construct the new control system. The mechanical control system is composed of three main subsystems: the power system, the variable-pitch propeller system, and the variable-titling nacelles.

Power System

One main disadvantage of modern quadcopters is their method of receiving power. While electric batteries are easy to incorporate, the poor energy density of lithium-ion batteries causes a low power-to-weight ratio. We opted for an internal combustion engine that provides power to a main shaft which runs the length of the aircraft. Power is then transferred through a series of bevel gears to the arm shafts which run inside the carbon tubes, eventually leading to the rotors themselves. All bevel gear pairs maintain a 1:1 gearing ratio, with the RPM reduction happening at the interface of the engine and the main shaft.



Combustion Engine w/ Belt Linkage to Main Shaft



Bevel Gears from Main Shaft to Arms

By using a single power source, all propellers must spin at the same speed, unlike conventional quadcopters that adjust the RPM of individual motors to control the aircraft. An increase in throttle would cause all propellers to increase speed.

Variable-Pitch Propeller System

In order to accommodate the synchronized speed of all propellers, a variable-pitch system must be used. This system allows us to control the pitch of each individual propeller, thus controlling the power that each rotor produces. By controlling the power produced by each rotor, when operating in VTOL mode, conventional quadcopter control logic can be applied. To accomplish a variable-pitch propeller system, we used a servo attached to the carbon arms to actuate the swashplate for pitch control.

Variable-Pitch Propeller System

Variable-Tilting Nacelle System

Each propeller, swashplate mechanism and servo, make up the core components of each nacelle. In order to achieve higher speeds, the thrust created by the propellers needs to be vectored. This is accomplished by twisting each nacelle in the direction of the intended motion. Using a rotating bracket assembly attached to the arms of the quadcopter, we can vector the trust by adjusting the twist of the arm through a servo arm.

Rotating Bracket Assembly

Future Research

This project's scope encompassed only the mechanical controls of this prototype aircraft. Future research will be conducted on the electronic control systems and the flight controller logic needed to fly such an aircraft. This flight controller would need to be able to articulate and integrate several control systems that affect the flight performance in multiple ways. In addition to coordinating the various servos that make up the flight control system, the flight controller will need to "think" like an aircraft and a helicopter at the same time. While a simple throttle increase in VTOL mode would cause and elevation change, with the nacelles at 45º angle, the aircraft would not only rise, but increase its forward airspeed as well. With the addition of airfoils, the flight controller must know at what angles the thrust can be vectored for certain speeds, in order to avoid stalling. The flight controller must adapt to this change to translate the pilot's commands into the intended movement.

Conclusion

The project has developed a working mechanical design for a variable pitch and tilt quadcopter. While additional research is needed on the flight controls, the mechanical system is completely capable of achieving our intended goals of creating a variable-pitch, variable-tilt quadcopter.

Complete Quadcopter Assembly

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