Quadrotor Helicopter

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Abstract

Skyline Corporation was presented a project by Dr. Choi of the Mercer University School of Engineering to design, build, and test a semi-autonomous quad-rotor helicopter prototype. The primary goal of the project was to produce a prototype capable of stable vertical translation when given a prompt from a remote user. Another specification given by the client was that the helicopter should be able to be expanded upon in future design projects.

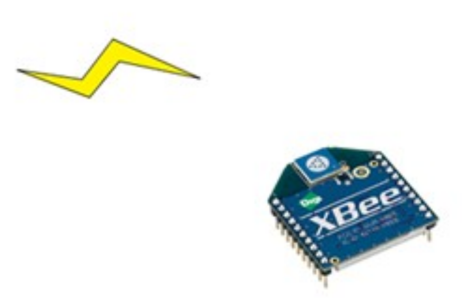
To satisfy these specifications, a working prototype was designed comprised of components that functioned together as a system. Engineering analysis was performed on all of the components to be used in the project to ensure each feature would perform as needed. To assure that the helicopter could operate wirelessly, Zigbee wireless technology was selected. To accompany the wireless system, a processing unit was chosen that would receive data from the computer commands and interpret these commands into actions. Carbon fiber was selected for the composition of the frame because of its durability and light weight. Also, adequate motors, motor drivers, and a battery were chosen that would supply enough thrust to lift the helicopter and provide an adequate amount of payload capacity. Finally, a testing stand was designed to ensure that the helicopter presented no danger to itself or to the user.

Upon completion of the design phase, construction began with initialization of the wireless system. The helicopter frame was also constructed. With the wireless technology operating sufficiently, programming code was written that could be transmitted to the processor of the helicopter. This code was formatted in such a way that the speed of the motors could be controlled; therefore, the user has the capability of raising and lowering the helicopter. Finally, the testing stand was constructed with aluminum, which provided the strength to support the helicopter while in flight.

Testing followed the construction of the helicopter. Each component of the project was analyzed, and changes were made as necessary to improve its performance. Careful consideration was given during these tests to determine if any modifications could be made that would improve the helicopter. All components that were tested proved to be operating effectively. The prototype was complete when testing was finished.

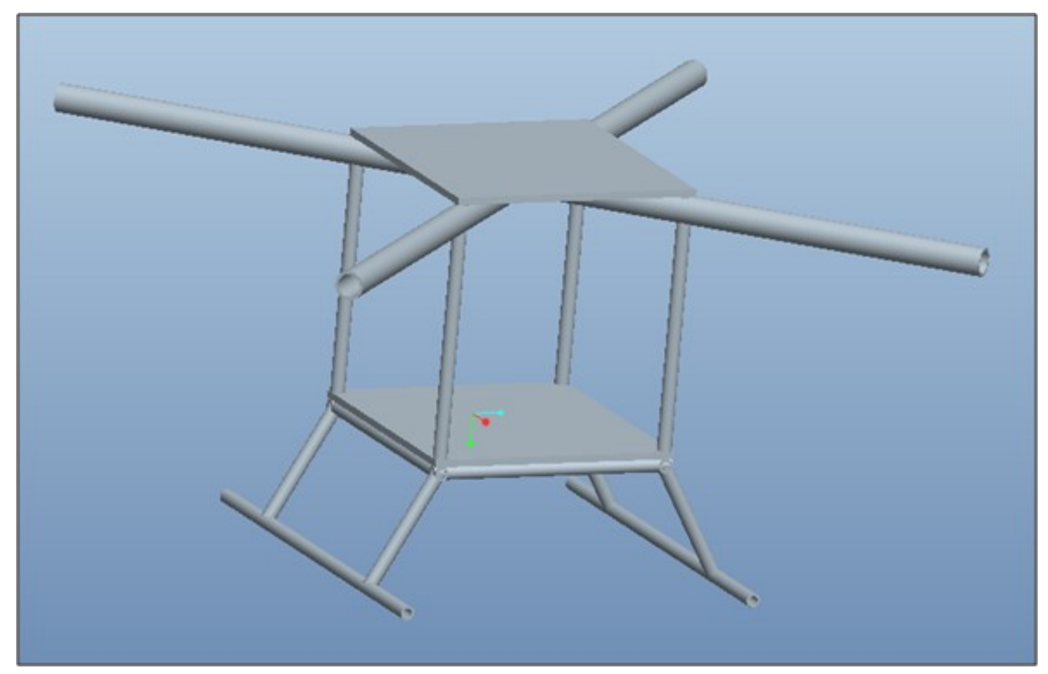
Wireless Communication

- Using Zigbee technology, two XBee modules were utilized. One module was connected to the computer via an FTDI cable, while the other module received the wireless signal on the helicopter.
- XBee modules have an outdoor range of 90 meters and an indoor range of 30 meters.



- The receiving XBee module was placed in the header pins of the Arduino Fio, which is designed specifically for use with XBee chips.
- Serial data was transmitted wirelessly in order to control the movements of the helicopter.

Proposed Design

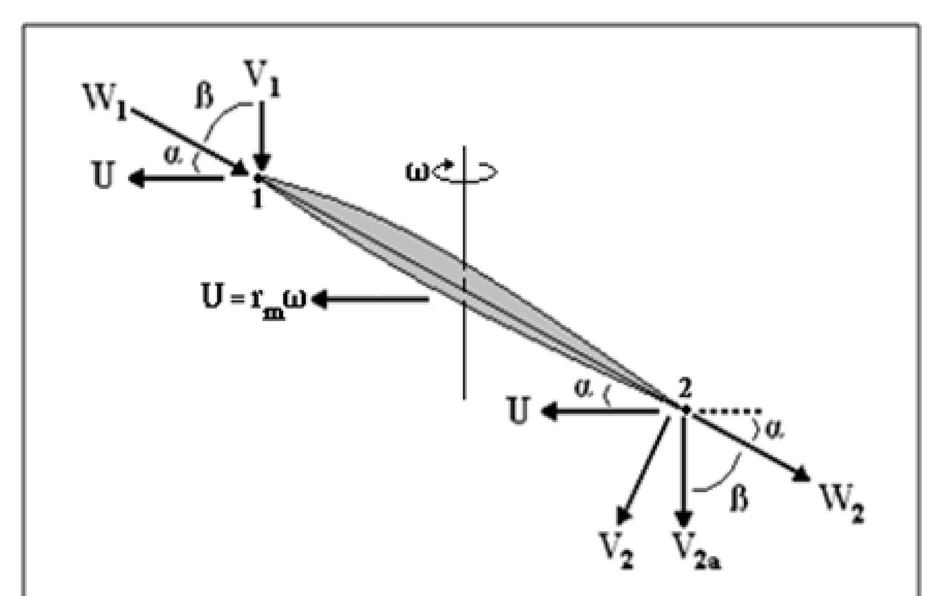


Final Design

Design Phase

In order to determine the combination of components that would best meet the client's needs, several engineering calculations were performed. One of the most important goals of the design phase of this project was to determine if the helicopter could achieve vertical translation. This involved performing lift calculations using the varying characteristics that were present with each combination of components considered. These components included the battery, motors, and propellers, with each combination producing different values for the overall lift.

The figure to the right represents a cross-section of a propeller blade, which was used to derive the final formula (bottom) needed to calculate the lift produced.



$$F_T = \rho \left(\frac{r_m \omega}{\tan\beta}\right)^2 \pi \left(r_{tip}^2 - r_{hub}^2\right)$$

Other important calculations that were performed included:

- Theoretical weight calculations using the volume and density of the material needed.
- Calculations determining the theoretical battery life during flight.

Additional design aspects included:

- A stress analysis on the frame due to applied loads.
- Choosing the vital electronic components such as the microcontroller and wireless modules that would be needed for semi-autonomous flight.

Construction/Testing Phase

Once the design phase of the project was completed, the construction and testing of the helicopter followed. The individual components chosen from the design phase were each tested separately to ensure functionality, and were then integrated into the finished prototype. The finished prototype was then tested for performance to see if it complied with the theoretical numbers obtained from the design phase.

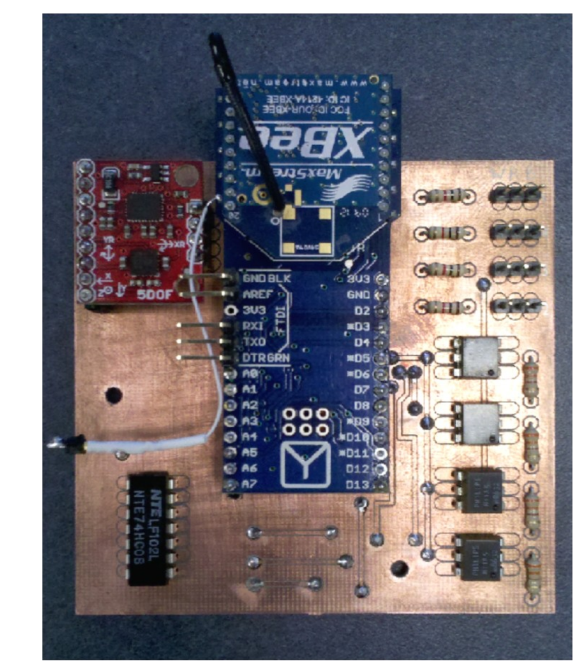
The figure to the right shows most of the components that were used in the final design. However, some of these components were not used due to design changes that arose during this stage of the project.

The finished prototype met all of the design requirements set forth by the client, with the exception of advanced flight stability.

Some of the important outcomes and values derived from testing included:

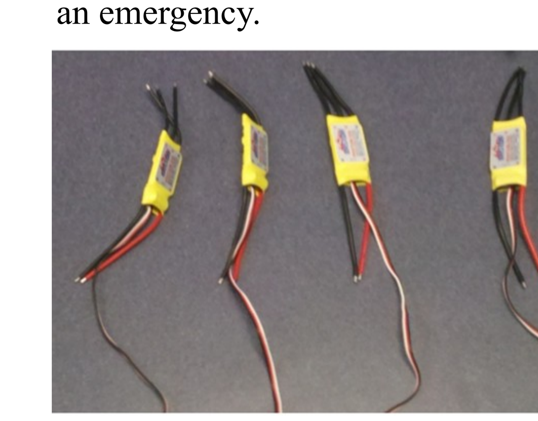
- Successful operation of all major electronic components.
- Basic computer code needed for autonomous flight.
- An actual weight of 2.67 lbs (theoretical was 2.65 lbs).
- An overall thrust value of 6.37 lbs (theoretical was 6 lbs).

Electronics

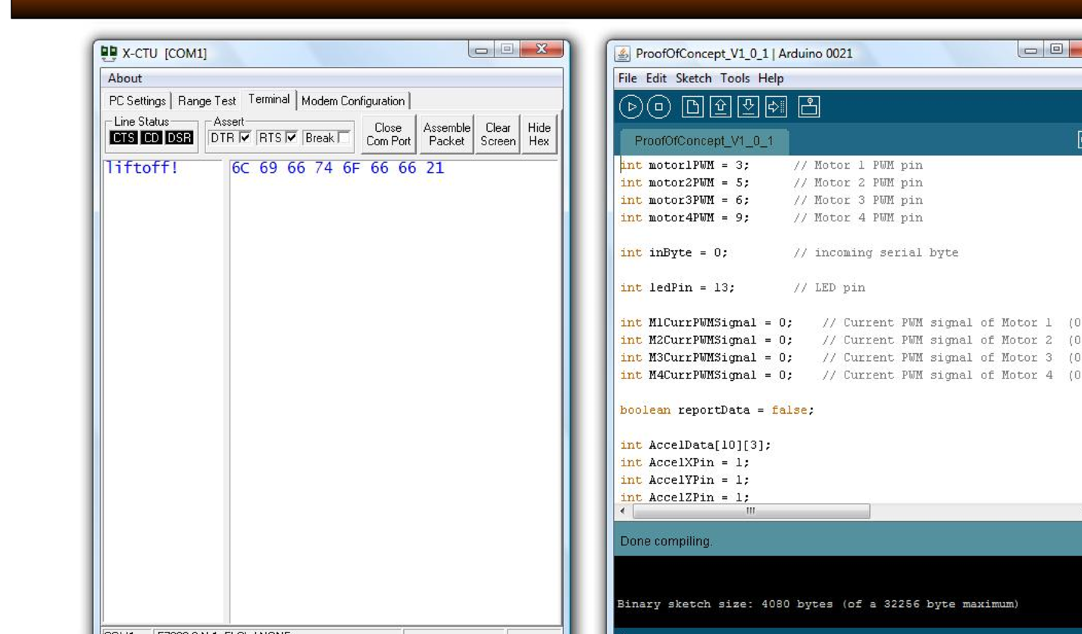


- The printed circuit board that was used on the helicopter housed all the components that were needed to drive it. Eagle Software was used for designing this board. The circuit board was designed for maximum efficiency both in weight and size.
- The components of this printed circuit board included the Arduino Fio, gyroscope/accelerometer, failsafe switch, opto-couplers, and electronic speed controller plugs.
- The failsafe was a added feature that bypassed the microcontroller in order to shut the helicopter down in case of an emergency.

- The electronic speed controllers are designed to convert a simple PWM signal into a 3-phase signal for the motors. These drivers determined how fast the motors would spin according to the PWM signal that they received.



Software



- The software component of the project primarily involved programming the Arduino Fio microcontroller using the Arduino Integrated Development Environment (top right).
- Additionally, the Zigbee wireless communication devices were configured using the X-CTU configuration tool (top left).
- Programming of and communication between the electronic devices was performed using serial communication.
- The serial communication tools primarily used was the "terminal" utility of the X-CTU configuration tool and the "serial monitor" utility of the Arduino Integrated Development Environment.

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