Quadcopter Platform for Vertical Infrastructure Inspection

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Introduction

Maintenance of vertical infrastructure, such as buildings, bridges, and telephone poles, requires regular inspection for physical damage, cracks, thermal leaks, and other potential hazards. This is typically accomplished via visual inspection or imaging with devices such as infrared cameras. To do this, people and equipment must be elevated using ladders, bucket trucks (Figure 1), or other machinery. All of these methods put workers at high risk for injury and require time consuming setup [1].

Figure 1: Use of Bucket truck for Electrical System Maintenance [2]

An aerial vehicle capable of capturing the images of infrastructure needed for maintenance could be created. Such a vehicle would save time and reduce the risk of human injury.

Project Goals

An aerial vehicle will be created with the following capabilities:

1) The vehicle must be able to **carry a payload** of cameras for inspection close to infrastructure as needed.
2) Operation of vehicle by an **unskilled operator** (less than 30 minutes of training) must be possible.
3) **Sufficient autonomy** in order to inspect a typical five story, 230,000 square foot building (e.g. Lockwood Library on UB North Campus) is required.

Vehicle Platform

A quadcopter was chosen as the aerial vehicle platform for this project. Quadcopters can hover and fly forward, backwards, and sideways. However, they are mechanically simpler than helicopters.

A commercially available **DJI F450 Phantom** with **Naza V2-Lite** flight computer (Figure 2) was assembled to serve as a platform for the build [3].

Figure 2: Base DJI F450 Quadcopter Kit with GPS Navigation

Testing revealed that this quadcopter has an endurance of 18 minutes with a 400 gram payload. This is sufficient to satisfy goals (1) and (2).

Division of Controls

In order to allow for use by an unskilled operator, the quadcopter will have some autonomy. Responsibility for the controls of the quadcopter in 3D space will be divided up as follows:

The **unskilled operator** will control the vehicle's horizontal and vertical movement along the surface of the structure (Figure 3).

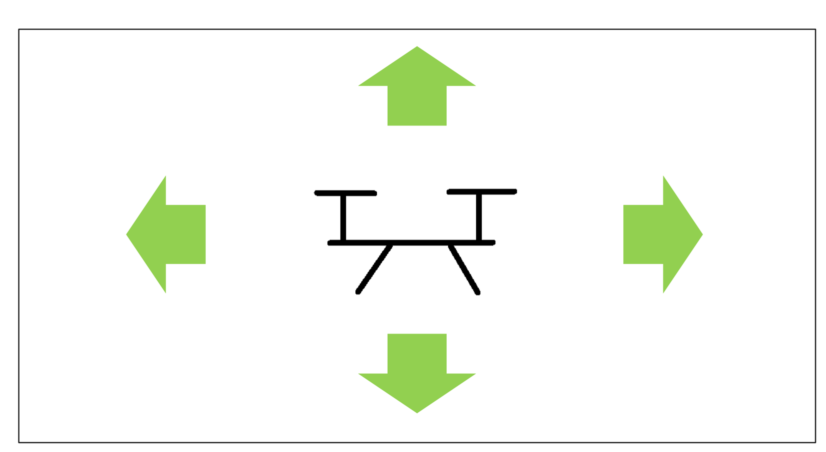

Figure 3: Dimensions controlled by unskilled operator

An **autonomous control system** on the vehicle will control the distance between the quadcopter and the infrastructure (Figure 4).

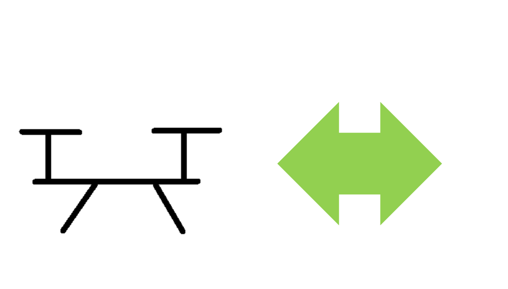

Figure 4: Dimensions controlled by autonomous control system

Hardware Additions

In order to control the quadcopter to operate as described above, additional computers and sensors need to be added. A computer to run control algorithms, Arduino board, and distance sensor were attached as shown in Figure 5.

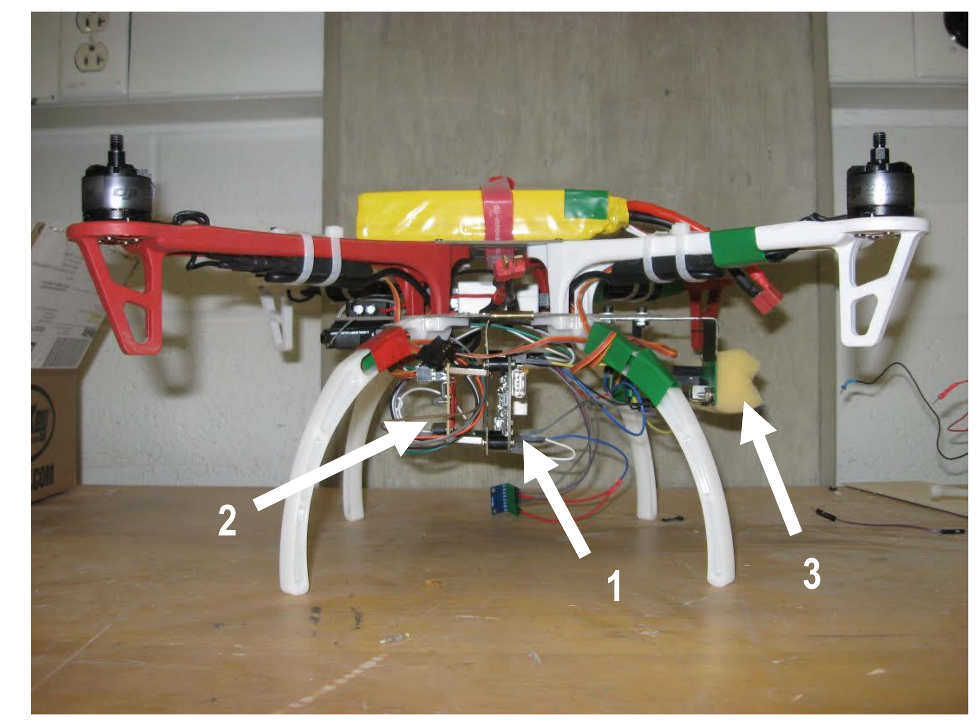

Figure 5: Quadcopter build with additional hardware attached

1) A **BeagleBone Black computer** runs autonomous control algorithms.
2) The **Arduino Nano board** combines controls from the BeagleBone and the operator.
3) An ultrasonic sonar distance sensor, the **MaxSonar MB1240 XL**, provides information about the distance between the quadcopter and infrastructure.

Control Algorithms

The distance of the quadcopter away from the infrastructure surface is regulated by a proportional control system. Data from the distance sensor is used to determine the distance the quadcopter is away from its target position away from the wall. This information serves as the independent variable in the following control equation.

$$P_{out} = K_P * (X - X_o) + P_o$$

where P_{out} is the control output, K_P is the desired gain, X is the current distance of the quadcopter away from the infrastructure surface and X_0 is the target distance of the quadcopter away from the infrastructure surface.

Control gains were determined by testing the response of the manual control stick, as shown in Figure 8.

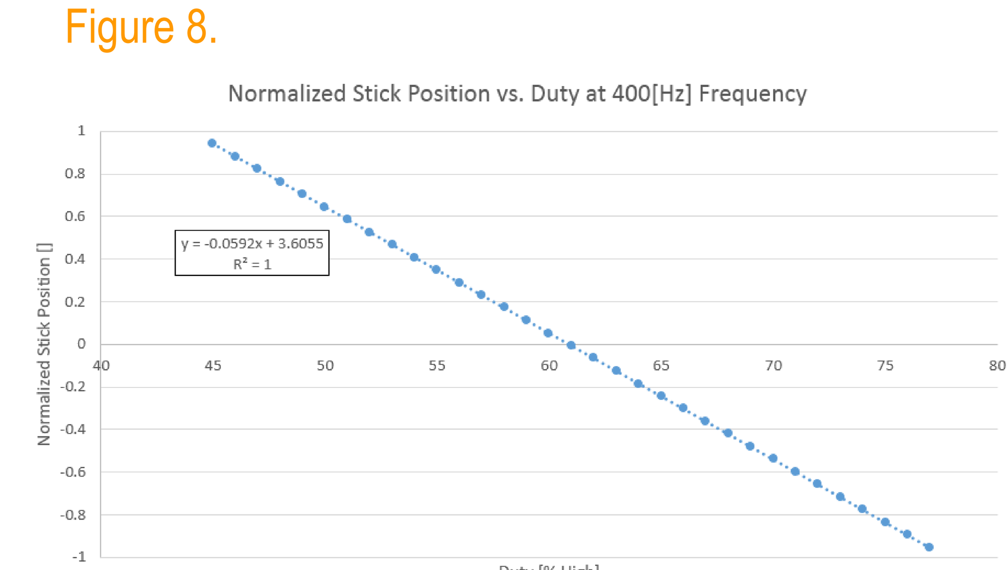

Figure 8: Normalized stick position vs. Duty

Testing and Results

The completed quadcopter (Figure 7) was flown inside Jarvis hall to test its capabilities. The vehicle was placed in front of a flat, white wall. It was then manually flown to an altitude of 10 feet above ground level before activating the autonomous control algorithms to maintain a distance of 7 feet away from the wall.

Figure 7: Flight testing of quadcopter

During the five minute test flight, the quadcopter maintained the target distance from the wall within +/- 2 feet while being maneuvered horizontally and vertically. However, the pilot took over manual control of the vehicle twice when excess roll angle threatened to crash the vehicle into the wall.

Conclusions

Feedback from the pilot after flight testing revealed that the autonomous system installed on the quadcopter made piloting easier, but not yet suitable for an "unskilled" operator.

In order to improve the current quadcopter system and complete all goals of the project, several improvements are planned:

1) Improve control algorithms by implementing proportional-integral-derivative (PID) control.
2) Add second distance sensor for stereo vision and reduced error.
3) Better protect added BeagleBone and Arduino computers in case of collisions with structures.

References

[1 Vertical Inspection of Infrastructure using a Quadcopter and Shared Autonomy Controls*: Advanced Robotics*, Dec 2013.

[2] Image courtesy of *Transmission and Distribution World:* *http://tdworld.com/electric-utility-operations/take-look-inside-lineman-s-bucket-truck*

[3] . Flame wheel ARF Kits: *DJI,* *http://www.dji.com/product/flame-wheel-arf*