Vision Based Autonomous Landing System for an Unmanned Aerial Vehicle

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1 INTRODUCTION

At present, Unmanned Aerial Vehicles (UAV) are commonly used for security purposes, research purposes, rescue purposes, monitoring, disaster management, crop management, communications and surveys. Among all kinds of UAVs, quadrotors have become popular, because they can be controlled easily and they can take off and land without using a runway.

Most autopilot systems are navigated using Global Positioning System (GPS) coordinates. GPS receivers are used to get coordinates. Most of the low cost commercial GPS modules have an error margin of about ± 2.5 meters ("NEO-6 u-blox 6 GPS modules", 2011). When considering small scale quadrotors, this is a considerable error. To assure accurate and precise landing, a vision based system was introduced to a quadcopter.

This paper discusses the vision system. The vision system uses an image of a helipad as the ground target to identify the landing point. The system consists of an on-board controller (Raspberry pi) to process images, a camera module to capture images, an Arduino controller to control the quadcopter navigation system and Pixhawk flight controller to control the quadcopter. The system was implemented and successfully tested using a quadcopter in real-time. Using the introduced vision system, the error was reduced to the range of ±0.5 meters.

2 METHODOLOGY

2.1 Vision System

The vision system uses the cascade classifier method for image processing. Object detection using cascade classifiers is an effective object detection method proposed by Paul Viola and Michael Jones in their paper, "Rapid Object Detection using a Boosted Cascade of Simple Features" in 2001. It is a machine-learning based approach where a cascade function is trained from a lot of positive (images with helipad) and negative (images without helipad) images. It is then used to detect objects in other images. ("Cascade Classification — OpenCV 2.4.13.2 documentation", 2016). Complete quadcopter with vision system is shown in Figure 1.

Figure 1: Quadrotor with complete vision system

Figure 2: Ground target used in the vision system

Here the system detects the image of a Helipad. Initially, the algorithm needs a lot of positive images (Helipad images) and negative images (Images without helipad) to train the classifier.

Matlab software is used to train the cascade classifier and after that OpenCV is used to recognize the helipad. After detecting the helipad, it draws a circle around the detected object. The coordinates of the centre of the drawn circle is used to navigate the quadcopter. The Helipad shown in Figure 2 is used as the ground target of the vision system.

1.2 Vision Based Navigation System

A navigation system is used to navigate the quadcopter according to the data acquired from the vision system. The frame size of the captured image is 256x256 pixel. The vision system gives the coordinates of the centre point of the detected helipad after capturing the image. The movement of the quadcopter is obtained according to the position of the helipad. Figure 3 shows the allocation of coordinates for the image frame and captured image is divided into nine regions as shown. Movements according to the X and Y coordinates are shown in Table 1. If the target coordinates are located in section A, B or C, the quadcopter moves forward. If the target coordinates are located in section G, H or I, the quadcopter moves backward. If it is located in section D and F, the quadcopter moves left and right respectively. If it detects the target coordinates in section E, it gives the landing command to the quadcopter.

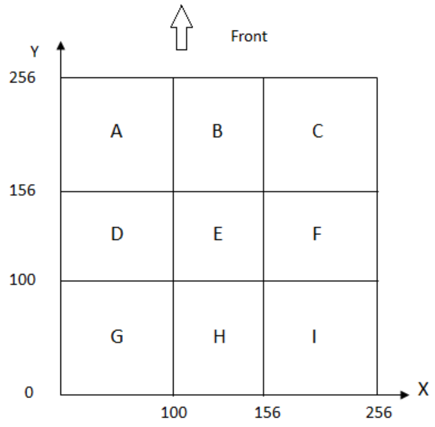

Figure 3: Allocation of coordinates for the image frame

Table 1: Movement of the quadcopter according to the centre coordinates

Section	X range	Y range	Movement
A	0-100	156-256	Forward
B	100-156	156-256	Forward
C	156-256	156-256	Forward
D	0-100	100-156	Left
E	100-156	100-156	Land
F	156-256	100-156	Right
G	0-100	0-100	Reverse
H	100-156	0-100	Reverse
I	156-256	0-100	Reverse

Usually, the quadcopter is navigated by transmitter signals. The transmitter emits 1000µs to 1900µs PWM signal. Is uses four separate signal channels for roll, pitch, yaw and throttle. Quadrotor movements according to the transmitter

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signals are shown in Table 2. Here the navigation system uses roll and pitch signals to adjust the position of the quadcopter to obtain the desired target coordinates. When the vision system takes over the controls, it bypasses the transmitter signals using Arduino. Arduino generates the PWM signals for each roll and yaw channels to obtain the necessary movement.

Table 2: Quadrotor movements according to the transmitter signals

Channel	PWM range (µs)	Movement of the quadrotor
Roll	1000 -1499	Left
	1500	Hold Position
	1501 - 1900	Right
Pitch	1000 – 1499	Forward
	1500	Hold Position
	1501 - 1900	Reverse

3 RESULTS AND DISCUSSION

3.1 Results

Trials were done for cases with GPS and with vision-based system in bright sunlight conditions.

Twenty trials were done at each case and Table 3 shows the average test data of the quadcopter navigation system for both cases. A 50m distance was applied in each direction to the system.

Then the quadcopter was set to autonomously navigate itself to the desired target and the error was measured.

Error = [Distance to desired landing point – Distance to the point which quadcopter landed]

Table 3: Navigation data without vision system and with vision system

Case	Distance to desired landing point (m)	Direction	Average Error (m)	Average Error (m)
01	50	North	+2.0	+0.4
02	50	East	+3.4	+0.5
03	50	South	-2.5	-0.3
04	50	West	+2.8	+0.5
05	50	Northeast	-2.2	-0.4

3.2 Discussion

The accuracy of GPS is dependent on the quality of the GPS receiver, the number of satellites connected to the GPS module and the position of GPS satellites etc. However, the vision-based autonomous landing system is designed to navigate and land a quadrotor in an accurate position without being affected by the GPS error. According to the test results as shown in Table 3, the GPS error was reduced to the range of ±0.5m. This system was designed to be used with any type of quadcopter to assure precise landing.

4 CONCLUSIONS AND RECOMMENDATIONS

The design and implementation of a vision-based autonomous landing system for a quadcopter was discussed in this paper and has been tested successfully.

The camera module used in the vision system has an angle of 42 degrees. ("Camera module - raspberry pi documentation", 2013) The range of the vision system can be extended by using a wide-angle camera for the vision system. The captured image frame can be divided into more sections to increase the accuracy of the vision system. The stability of the quadcopter can be improved by reducing the vibration of the quadcopter. For further developments, a vibration analysis should be carried out to reduce vibration.

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