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# VISION-BASED ONBOARD CONTROLLER FOR SAFE LANDING AND TARGET DETECTION USING UAV

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## ABSTRACT

Autonomous UAV is need in many places especially in defence because it has many features like that can 'see' and fly intelligently. Jiefei developed algorithms to process the video footage image by image, to help the **drones** know their own speed, motion, and to detect obstacles so they can reach their target detection .The fuzzy logic is used for safe landing by autorotation , most common use of autorotation in UAV is to safely land the aircraft in the event of an engine failure or tail-rotor failure. **Quadcopter** unmanned aerial vehicles are **used for** surveillance and reconnaissance by military and law enforcement agencies, as well as search and rescue missions in urban environments. **PID controller** is to reduce steady errors, to improve response and target detection. **LIDAR** is more accurate than **RADAR** as it uses shorter wavelength. While **RADAR** is used in applications where detection distance is important but not the exact size and shape of an object, like in military applications.

***Keywords:*** *Fuzzy logic, Quadcopter, LIDAR , safe landing*

## INTRODUCTION

Quardcopter, also known as a quadrotor, is one type of UAV, which is lifted and propelled by four rotors [1, 2].The quadcopter has high maneuverability, as it can hover,take off, cruise and land in narrow areas. Quadcopters have simpler control mechanism compared to the other UAVs [3].

Recently, there have been increasing interests in the UAVs applications such as surveillance, search and rescue,and object detection [4–8]. Especially, target detection is an important pre-function in the UAVs applications,as it is required for a safe landing to drone station for battery charging or some other tasks. However, detecting a target, and landing is not an easy task due to the lack of sensitivity of sensors used for this application. For these applications, image processing techniques are generally used.The autonomous quadcopter system can be divided into four processes:

1) Taking off.
2) Performing the task.
3) Detection of the ground target.
4) Safe landing.

Detecting the ground target and safe landing is the most challenging part, as any mistake in any of them can lead the quadcopter to tip over, which will cause the destruction of the quadcopter or even harm any human in its range due to the big size of the propellers and high rpm used in it.

There have been a lot of research regarding target detection and safe landing. One of the most challenging parts of target detection is the timing of the image processing. So, the best way is to use a graphical processing unit (GPU) which is optimized for imaging algorithms.

Most of the prior research shows good performance. However, they are either using a normal navigator GPS to detect the position of the target, which is not accurate, as the used GPS accuracy is limited to 7-8 m and GPS cannot work indoors, or they are using a higher specification CPUs, which is very expensive and consumes more power.

One problem with quadcopter safe landing is the ground effect. Ground effect is a nonlinear effect generated near the ground while landing. It causes the increase in thrust of the rotors that will cause floating of the quadcopter above the ground. This will make landing difficult and lead to high power consumption. The current research focuses on the problems of the previous research works. It focuses on replacing the high specification and expensive CPUs with a much cheaper one. It also focuses on overcoming the ground effect.

In order to overcome the cost problem, a vision-based target detection algorithm based on PID controller using RPi is proposed. A novel, Fuzzy logic based safe landing algorithm is developed to overcome the ground effect which exists near to the ground while quadcopter is landing. The proposed system is equipped with a USB camera connected to RPI for detecting the target and a laser rangefinder (LIDAR) for measuring the distance for safe landing.

To verify the system performance, a practical test bench based on a quadcopter and a target drone station was developed. Several experiments were conducted under different scenarios and results were obtained. The practical configuration of the proposed system is discussed in detail in Section 2. Section 3 presents the ground effect phenomenon. The proposed target detection and safe landing algorithm are explained in Section 4. Section 5 includes the simulation results of the proposed safe landing algorithm. Section 6 demonstrates the experimental results of the proposed system. Finally, the conclusion is drawn in Section 7.

## 2. Configuration of The Proposed Vision-Based Target Detection And Safe Landing System For Quadcopter

The proposed vision-based target detection and safe landing system consist of the following components: flight controller, RPi, USB camera, ESC module, RC receiver/ transmitter, BLDC motor, a LIDAR sensor, and camera gimbal with quadcopter mainframe. A block diagram of the overall system is shown in Fig. 1.

### 2.1. Flight controller

The flight controller is the brain of the quadcopter. It reads all data coming from the sensors and calculates the best commands and finally sends it to ESC module. ESC module can receive the rpm data from the flight controller and RC receiver to control the speed of each BLDC motors. The flight controller used in this work is Pixhawk flight controller. The Pixhawk flight controller has an

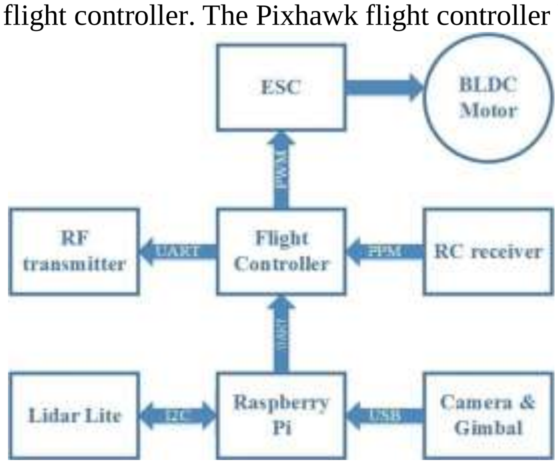



**Fig. 1. Block diagram of the overall system.**

ARM Cortex M4 CPU with a clock frequency of 168MHz. It is equipped with a 10 DOF-IMU, to measure roll, pitch, yaw, and altitude. It also has eight PWM outputs which can support up to eight BLDC motors. It also has several connectivity options for additional peripherals like UART, I2C, CAN, SPI, and

ADC, etc. The reason for utilizing the Pixhawk flight controller is because it can be interfaced easily with the ArduCopter, which is an open source code that is written in C++ and is free for modification.

**2.2. Raspberry Pi (RPI)**

The RPI is a low cost, small size computer with a wireless LAN and Bluetooth connectivity. It can be plugged into a computer monitor using an HDMI cable, and it uses a standard mouse and keyboard. It is capable of doing everything that can be done with a desktop computer. It can also help to learn various programming languages such as Python and C++.

In the current work, RPi 3 is used, because it has higher CPU performance than the previous versions. RPi 3 is good for vision-based image processing which requires fast execution time. Generally, the image processing algorithm for target detection based on PID controller and the fuzzy logic algorithm for a safe landing is implemented inside of RPi. The USB camera is connected to RPi via USB port which continuously sends the captured images to RPi. Inside of RPi, two types of control algorithms, image processing for target detection and Fuzzy logic for safe landing process the data received from the USB camera and LIDAR. This data is sent to the Pixhawk flight controller which generates the flight control commands.

**2.3. Camera and Gimbal**

The camera used in this work is a 720p USB camera. It's a cheap camera which can be directly connected to Raspberry Pi. Furthermore, a 2D-gimbal is used for allowing the camera to always face the ground while the quadcopter is hovering around.

**2.4. LIDAR-Lite Rangefinder**

LIDAR-Lite is a low power and lightweight 40 m rangefinder. This rangefinder is used due to its characteristics of low noise, high efficiency, and high range. It is used to calculate the altitude of the quadcopter that is used in the RPi for a safe landing.

**3. GROUND EFFECT**

In all types of UAVs, ground effect is the increased force near the ground in comparison to high altitude. UAV's lifting force can be divided into two parts:

1) IGE (In Ground Effect),
2) OGE (Out of Ground Effect).

IGE is a condition where the downwash of air from the main rotor can react with a hard surface (the ground) and give a useful reaction to the UAV in the form of more lift force available with less power required. OGE is the opposite of IGE, where there are no hard surfaces for the downwash to react against. For example, a UAV hovering 45m above the ground will be in an OGE condition and will require more power to maintain a constant altitude than if it was hovering at 4 m. Hence, a UAV will always have a lower OGE ceiling than IGE due to the amount of available power .IGE and OGE effect in quadcopter UAV is shown in Figs. 2 and 3. IGE effect is the most important issue to be considered when designing an auto landing controller mechanism. Therefore, the designed controller must be intelligent enough to overcome its nonlinear effect during the landing process.

**4. AUTONOMOUS VISION-BASED TARGET DETECTION AND SAFE LANDING ALGORITHM**

4.1. Vision-based target detection algorithm

A color based image processing algorithm is proposed in the current study and implemented by using Open CV library. USB camera is installed on the quadcopter and it keeps on taking snapshots continuously, which is processed by the color based target detection algorithm as shown in Fig. 4. The color-based target detection and safe landing algorithm can be divided into three main parts:

1)Target detection part(based on image processing).
2) Safe landing part (based on Fuzzy logic).
3) Stabilization control part.

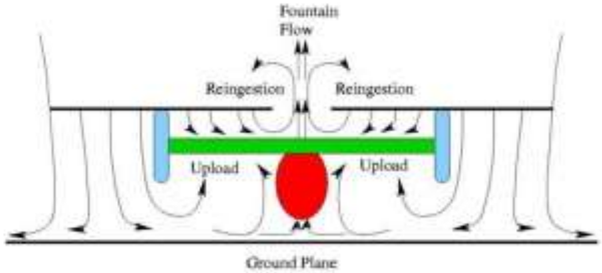



**Figure 1 : Quadcopter thrust effect under IGE.**

target detection part, the captured image is converted from RGB (Red, Green, and Blue) format to HSV (Hue, Saturation, and Value) format. Afterward, a thresholding

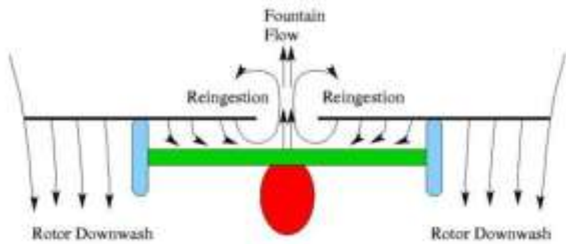



**Figure 2: Quadcopter thrust effect under OGE.**

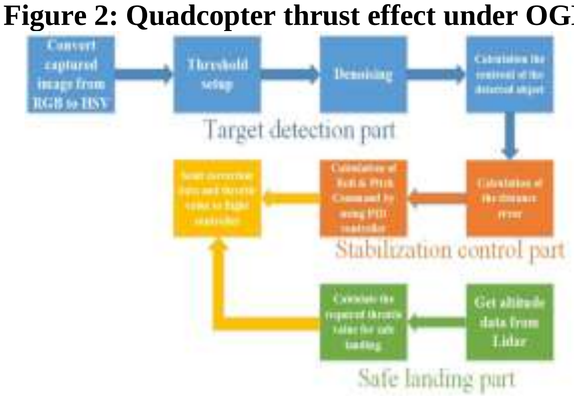



**Fig. 4. Color-based target detection and safe landing algorithm.**

is applied to the output image. The thresholding works by selecting a pixel value. If the pixel value is greater than the threshold value which is fixed in the code, the output will be white colour, otherwise, it will be black color. Then, morphology transformers are used on the output image to get rid of any noise in it. Finally, in order to calculate the centroid of the image, a 1st order spatial moments around the x-axis, y-axis and the 0th order central moments of the binary image is calculated. 0th order central moments of the binary image are equal to the white area of the image in pixels. The center of the detected white area can be stated in pixels as in (1) and (2).

xtarget = m10 =m00; (1)
ytarget = m01 =m00; (2)

where, m10 is the 1st order spatial moments around x-axis, m01 is the 1st order spatial moments around y-axis, and m00 is the 0th

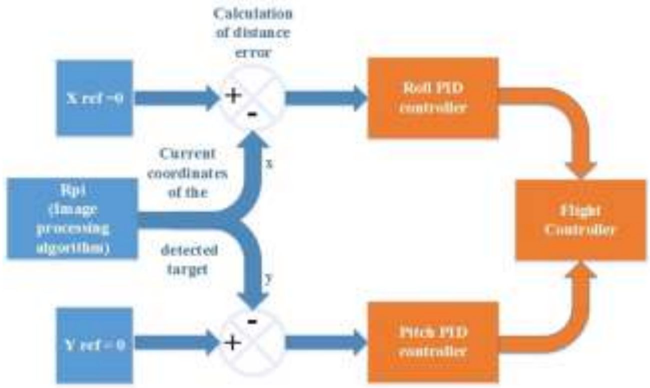



**Figure 3 Vision-based PID controller for target detection.**

order central moment. After that, the centroid of the target is compared to the centroid of the frame image. The deviation of the centroids between them is used to calculate the required roll and pitch angle for stabilization of quadcopter.

In stabilization control part, the distance error is used as an input to the PID controller. A PID controller is a feedback control mechanism commonly used in industrial control systems . In this work, PID controller which is shown in Fig.5 is utilized for generating the required roll and pitch angle commands to make the quadcopter hovering above the detected ground target.

As it is depicted in Fig. 5, image processing algorithm keeps on calculating the centroid of the detected target. These centroids are subtracted from the reference (0;0),which is the centroid of the frame image. Finally, the output of PID controller is given to the flight controller .

Simultaneously, LIDAR sensor keeps on measuring the altitude of the quadcopter. This data is used in the fuzzy logic controller to calculate the required throttle value for a safe landing. Next section will cover this part in details.

### 4.2. Fuzzy logic based safe landing algorithm

When the drone detects the colored target on the ground at a certain altitude, safe landing algorithm is activated. In this work, we utilize Fuzzy logic based safe landing algorithm which can be thought of a mixture of two kinds of landing algorithms, a position and velocity control algorithm. The flowcharts of each control algorithms are shown in Fig.6.Position control technique utilizes the current position information of the quadcopter. It continuously generates a slightly smaller throttle value than the previous one until the quadcopter lands at a ground. This control technique is safe. However, the response of this algorithm is too slow and it does not consider velocity information. Furthermore, some safety issues are present because there is no way of considering landing speed. For example, if the landing velocity is too fast, quadcopter might get crashed. Otherwise, if the landing speed is too slow, quadcopter can't land at a ground target and just hovers above the ground target.

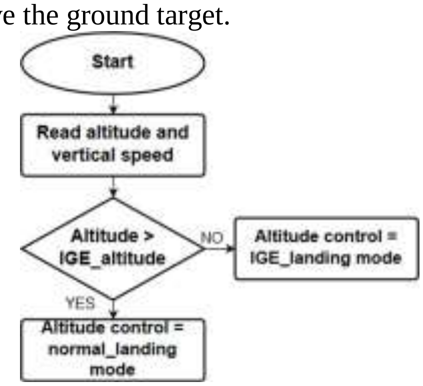
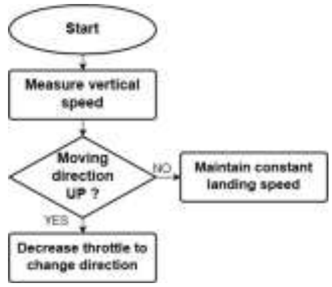



**Figure 4 (a) Flowchart of the position control algorithm.**




**(b)Flowchart of the velocity control algorithm**


**Figure 5: Block diagram of the proposed fuzzy logic controller.**

Whereas, in velocity control technique, the controller continuously generates the proper throttle value to land quadcopter at a constant speed. Similarly, almost same drawbacks are present in this method such as safety issues and slow landing.

The drawbacks of the aforementioned techniques are caused by the ground effect which exists near the ground while quadcopter is landing. Generally, some advanced auto landing algorithm should be required to compensate for the ground effect. So, a fuzzy logic based auto landing algorithm, illustrated in Fig. 6, is proposed.

The proposed fuzzy logic controller has two inputs (altitude and speed) and one output (throttle value). Rule base in the fuzzy logic controller is very important. In the current research, the above two control algorithms (position and velocity control) are considered together to build up the rule base. Generally, the fuzzy logic controller is made up of, fuzzification, rule base, the defuzzification process. The fuzzy input, output membership functions, and a rule base are designed in MATLAB/ SIMULINK.

**4.2.1 Fuzzification and designing the rule base**

Fuzzy input-output membership functions and rulebase is designed in MATLAB/SIMULINK using the Simulink fuzzy toolbox.


**Fig 6 : Operating Mode**

The universe of each input and output is carefully selected according to desired ranges.This fuzzy logic controller has two inputs and one output, 30 rules are made for optimum landing control.

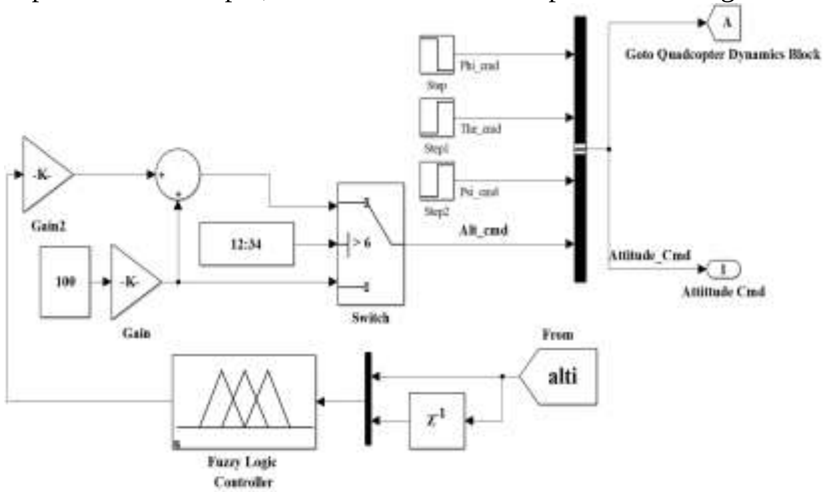



**Figure 7 Quadcopter simulation system.**

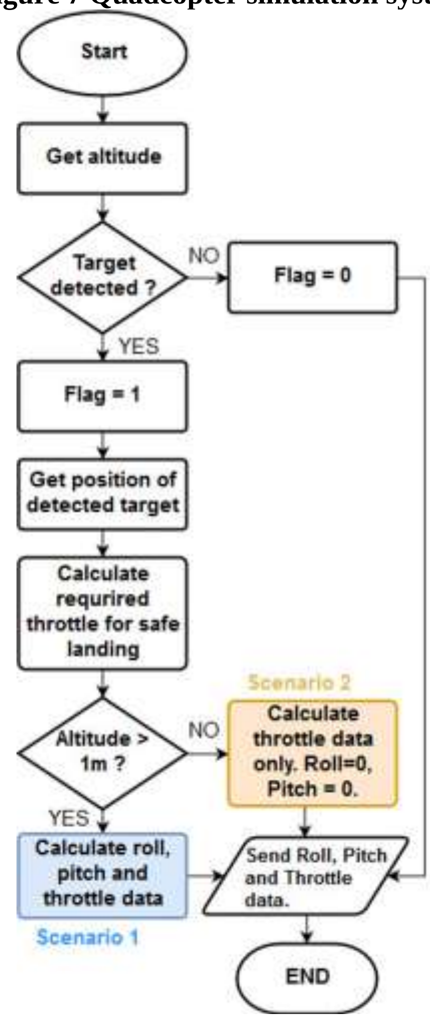



**Figure 8 : Flow chart for soft landing**

**Figure 6: Side view of the quadcopter system.**

## EXPERIMENTS

To verify the performance of the proposed target detection and safe landing algorithm, several experiments were performed indoor and outdoor. The experimental system is composed of quadcopter frame with flight controller and RPi controller which executes target detection and safe landing. Even though the RPi is not powerful enough for real-time target detection and safe landing, we tried to use the RPi owing to its low cost.

## CONCLUSION

In this paper, a vision based target detection and safe landing algorithm have been proposed. Target detection algorithm based on color is developed using PID controller for quadcopter stabilization. Also, a safe landing algorithm based on the fuzzy logic controller has been developed to overcome the ground effect.

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