COMBINING GPS AND COMPUTER VISION FOR INCREASING LANDING PRECISION OF QUADCOPTER DRONE

Submited as one of the requirements of completing the Undergraduate Program at the Department of Electrical Engineering Faculty of Engineering

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STUDY PROGRAM OF ELECTRICAL ENGINEERING
FACULTY OF ENGINEERING
UNIVERSITAS MUHAMMADIYAH SURAKARTA
2019

APPROVAL PAGE

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PUBLICATION JOURNAL

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D400 154 006

This journal has been checked and approved by :

Acc pendadaran 3/7/2019

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ACKNOWLEDGEMENT

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Abstrak

Dalam penggunaan *Unmanned Aerial Vehicle* (UAV) seperti quadcopter membutuhkan ketelitian yang sangat tepat untuk mencapai mekanisme pendaratan otomatis menggunakan *Global Positioning System* (GPS). Karena tingkat presisi GPS kurang, quadcopter akan ditambahkan kamera untuk memproses gambar yang diperoleh dari landasan untuk meningkatkan tingkat akurasi pendaratan. Landasan pendaratan dengan lingkar cincin dengan bahan spanduk dan triplek berwarna hitam dan putih disediakan untuk mencari koordinat pusat yang akan diproses untuk mengendalikan quadcopter. Algoritma yang digunakan adalah *Canny Edge detection* dan *Hough Transform* yang dikombinasikan dengan perangkat GPS. Yang pertama dilakukan untuk *Canny Edge* adalah konversi dari RGB ke *grayscale* kemudian menghilangkan *noise* dengan blur setelah itu menemukan tepi dengan menggunakan *Canny Edge detection* dan selanjutnya adalah menentukan koordinat pusat dengan metode centroid. Untuk *Hough Transform* yang pertama adalah konversi RGB ke *grayscale*, menghilangkan *noise* dengan blur, *adaptive threshold* kemudian operasi morfologis dan selanjutnya menemukan kontur lingkaran dengan metode *Hough Transform* dan terakhir menentukan koordinat pusat dengan metode centroid. Untuk mengontrol gerakan quadcopter dengan membagi frame menjadi 9 bagian dan melakukan gerakan menurut bagian tersebut secara otomatis. Pengujian dilakukan dengan lepas landas otomatis dan mendarat menggunakan perangkat GPS saja dan GPS yang dikombinasikan dengan *Canny Edge detection* dan *Hough Transform* pada ketinggian 5 m yang diukur dengan sensor barometer. Hasil pendaratan oleh perangkat GPS memiliki kesalahan rata-rata 199,2 cm. Untuk GPS dan *Canny Edge detection* dengan banner plastik memiliki rata-rata kesalahan 42,2 cm dan dengan triplek adalah 45,4 cm. GPS dan *Hough Transform* dengan banner plastik adalah 41.4 cm dan dengan triplek adalah 34,6 cm.

Kata Kunci : *Canny Edge detection,* GPS, *Hough Transform,* otomatis, pendaratan presisi*, quadcopter, Unmanned Aerial Vehicle*

Abstract

In the use of Unmanned Aerial Vehicle (UAV) such as quadcopter requires very precise accuracy to reach autonomous landing mechanism using Global Positioning System (GPS). Because the precision level of GPS is lacking, a quadcopter will be added a camera to process the images obtained from the landing pad to increase the level of accuracy of the landing. Landing pad with ring cirlce in plastic banner and plywood material in white and black is provided to find center coordinate that will be processed to control quadcopter movement. Algorithm used is Canny Edge detection and Hough Transform which is combined with GPS device. First doing for Canny Edge is conversion from RGB to grayscale then remove noise by blur after that find the edge by using Canny Edge detection and the next is determine center coordinate by centroid method. For Hough Transform the first is conversion RGB to grayscale, removing noise by blur, adaptive threshold then morphological operation and next is finding circle contour by Hough Transform method and finally is determining center coordinate by centroid method. To control quadcopter movement by dividing the frame into 9 grids and doing movement according to grid autonomously. The test is done with auto takeoff and land of GPS device only and GPS combine with Canny Edge detection and Hough Transform on altitude 5 m measured by barometer sensor. The result landing by GPS device has error average 199.2 cm. For GPS and Canny Edge detection with plastic banner has error average 42.2 cm and for plywood is 45.4 cm. GPS and Hough Transform with plastic banner is 41.4 cm and with plywood is 34.6 cm.

Keywords : autonomous, Canny Edge detection, GPS, Hough Transform, precision landing, quadcopter, Unmanned Aerial Vehicle

1. INTRODUCTION

In this modern era the development of Unmannaed Vehicle System (UAV) or commonly called as a drone. The use of drone is so many such as in the field of film, agriculture, military, hobbies, as well as shipping couriers and others. Drone that is commonly demand to use and developing is quadcopter. This type has 4 drive motors and propellers that have the form X or H in general. Quadcopter technology has the advantage of its movement system, which can move Vertical Take Off and Landing (VTOL) in other words it can take off and landing vertically. This means that the quadcopter only requires a takeoff place and landing that is not large and even very small. Quadcopter also has the ability to hover in the air.

Because of the advantages and capabilities of this quadcopter, many commercial starts up use this technology as shipping of items. Since 2017, the city of Reykjavik in Iceland became the first city to formalize the delivery of items using drones. After a year of testing, the use of drones to deliver these items are to be more effective, especially to reach areas that were difficult to access via land routes. Therefore, the largest online company in Iceland, AHA, decided to expand the shipping area by using drones (Kompas.tv, 2017).

Drone operation of quadcopter has an important landing phase if it is done incorrectly. Especially for shipping items that require precision on landings in a very narrow place or difficult access to land. Relying on Global Positioning System (GPS) for autonomous drone system is lack of the accuracy of the landing. This study, GPS will be combined with image processing to get precision on landing (Vidal, et al., 2017).

The benefits of this research are :

a) Increasing accuracy of precision drone landing in available landing pad.

b) Implementing the system of autonomous landing with high accuracy in field of use of drone.

2. METHOD

The framework of method of the research is described in figure 1.

Figure 1. Step by step Framework

The system architecture describes the overall working system of drone then for target layout design is a landing pad construction as the target with its size for quadcopter landing and also for hardware design is a construction and configuration of quadcopter. Object detection algorithms explain the algorithm to find target from landing pad and for quadcopter movement is the algorithm to control quadcopter movement according to detected object.

2.1 Architecture System

Architecture system is used as general step of input, output and communication system. The system in quadcopter design explained in figure 2.

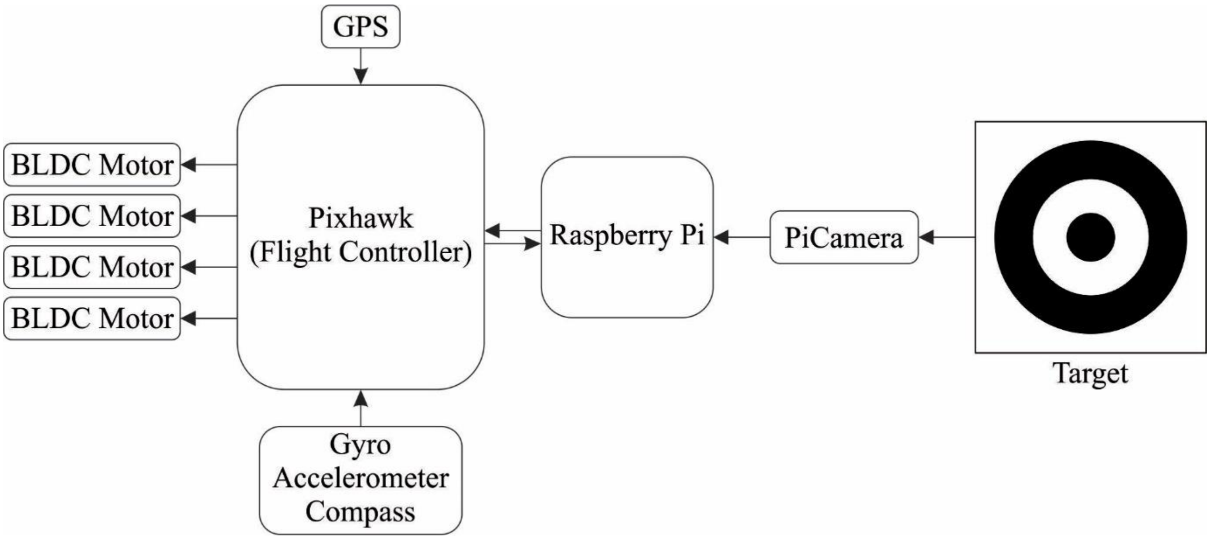


Figure 2. Block Diagram System

Block diagram system shown in figure 2, Pixhawk as a flight controller to control the movement 4 Brushless DC (BLDC) motors or called as quadcopter and get input sensors such as gyro, accelerometer, compass and GPS. Raspberry Pi to process the image or target that has been captured by PiCamera according to the algorithm used. Raspberry Pi and Pixhawk has communication each other via MAVLink protocol over a serial connection. Ground station here is Android phone to remote Raspberry Pi desktop via Wi-Fi 2.4 GHz.

2.2 Target Layout Design

For the target, landing pad has white and black ring circles with dimension 120 cm to be seen by camera with high altitude. Inside the square given 3 circles with different dimension. The biggest circle has 100 cm, medium size has 60 cm and for smallest is 25 cm. The design as shown in figure 3.

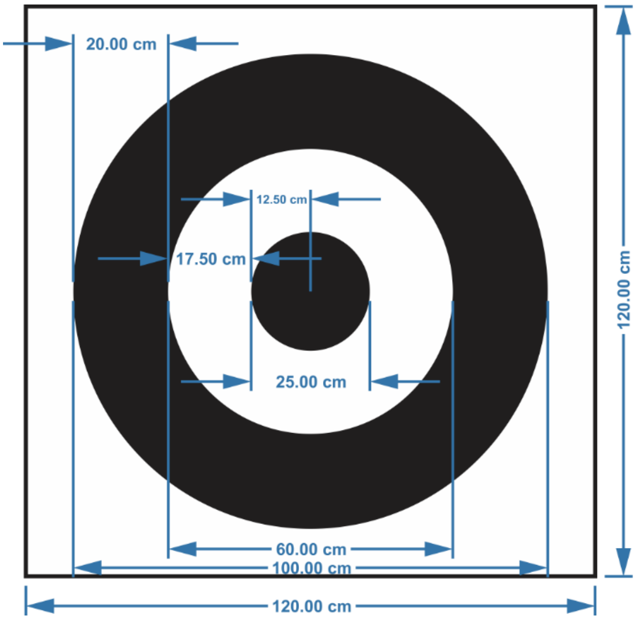


Figure 3. Landing Pad Design

The target as shown in figure 3 for precision landing made from plastic banner and plywood material. The purpose is to get better material for precision landing. These both materials are tested outside at field with altitude 5 m. Ring circle is used because when the altitude of drone is low the camera still capture the image with the smallest circle. The experiments are carried out in field with sunny weather.

2.3 Hardware Design

Design of the aircraft is multicopter with 4 brushless motors which is called by quadcopter. The frame is F450 factory made with size diagonally 450 mm. For the quadcoper according to figure 4 has components such as brushless motor, battery, Pixhawk, Raspberry Pi, PiCamera, Electronic Speed Controller (ESC) and Propeller.

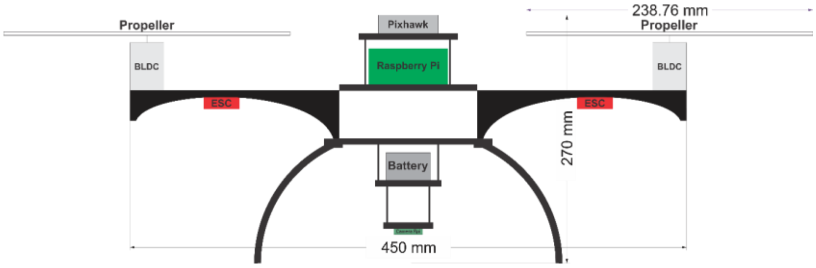


Figure 4. Quadcopter Design

2.4 Object Detection Algorithm

The algorithms of object detection are used to detect the center coordinate of cirlce. Both of algorithms will be compared to find center coordinate with Canny Edge detection and Hough Transform in both of target landing pad. The making of program script according to algorithms using Python language with library OpenCV. The Canny Edge detection and Hough Transform algorithms are shown in figure 5.

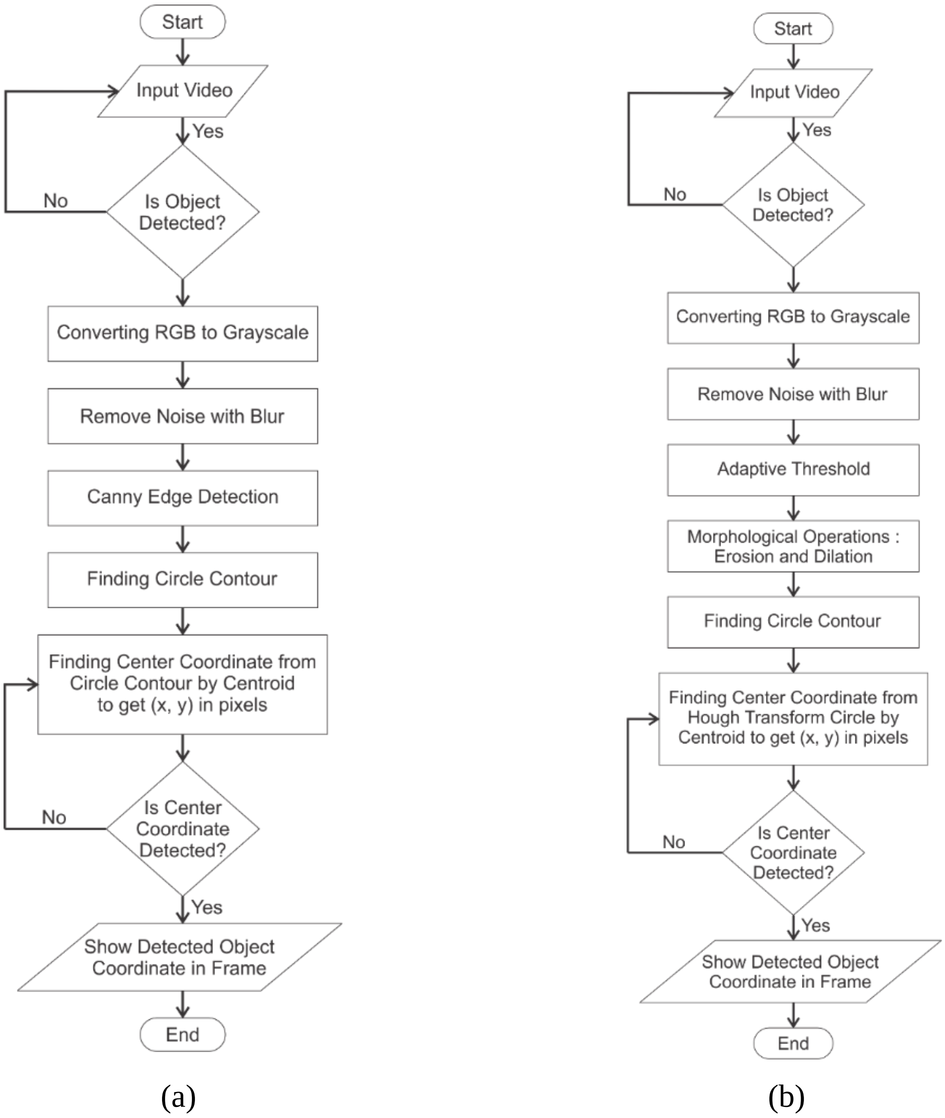


Figure 5. (a) Canny Edge Detection; (b) Hough Transform

As shown in figure 5(a) data from camera that installed on quadcopter is processed by image processing method such as conversion RGB color to grayscale to get object easier in gray color converted then removing the noise using blur. The next process is detecting edge of object using Canny Edge detection. Canny Edge detection method can minimizes the contamination on edge of detected image so it is easier to do image processing for landing place. After that is finding the contour related with the intensity of each pixel from edge detected of object. Last step is to find the center of coordinate by using centroid (x,y) in pixel from the circle which has detected to get the location to control the movement of quadcopter. For the Hough Transform algorithm as shown in figure 5(b) process the image y converting RGB to grayscale and remove the noise by blur. Then, using adaptive threshold to get desired black and white image. Morphological operation has function to resize the small size of dot become bigger size, so there is no small size with different color black or white in sharply. Next is finding the circle by Hough Transform and convert the center coordinate (x,y) by centroid method state in formula (1) and (2).

$$x = \frac{m10}{m00} \tag{1}$$

$$y = \frac{m01}{m00} \tag{2}$$

where x is the x coordinate and y is the y coordinate of the centroid.

2.5 Quadcopter Movement

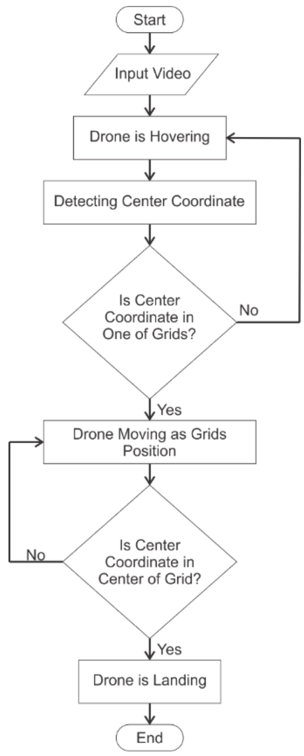


Figure 6. Flowchart Quadcopter Movement

As referred from figure 6, the quadcopter movement detects the object of landing pad as an input for the system. In certain altitude, the object target will be processed and determine center coordinate then it is decided where the coordinate is placed in the grids. If the center coordinate is not in one of the grids so the quadcopter will be hovering until the target is detected. When it is detected in one of the grids, the quadcopter will move based on the command in the grid and when the center coordinate in the middle of the grid the quadcopter will move downward or landing. The following is the grid to control quadcopter autonomously in figure 7.

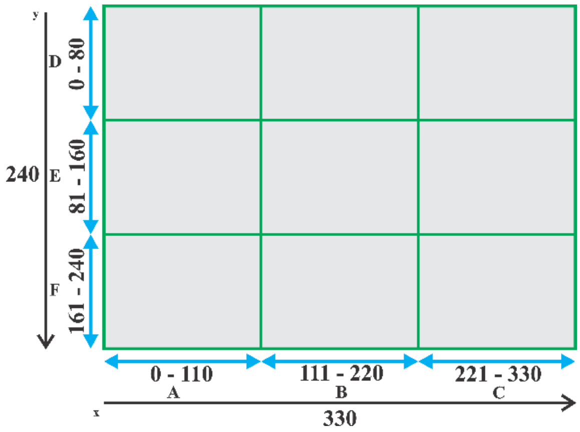


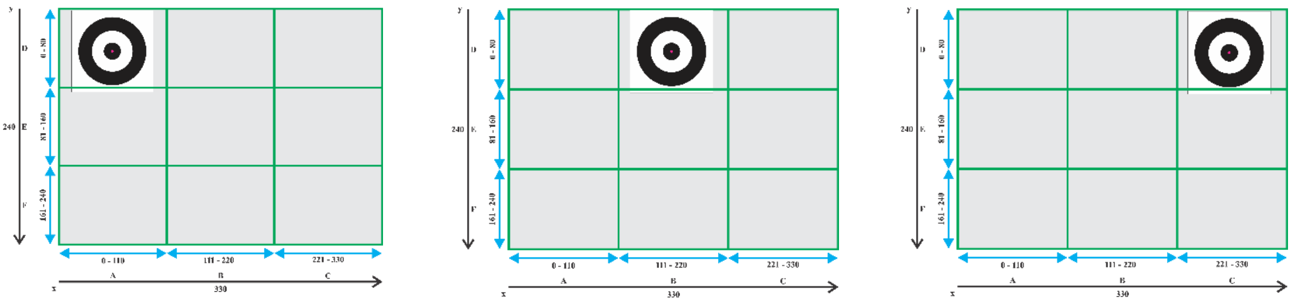
Figure 7. Grid Detection Object for Quadcopter Movement

As shown in figure 7, camera that is set in 640x480 pixel then resize into frame 330x240 pixel cause Raspberry Pi has limited speed for processing the image so smaller size of pixel is better. In this frame will be divided into 9 parts AD, BD, CD, AE, BE, CE, AF, BF and CF. There are 2 equations for dividing the frame in x and y pixel are shown in formula (3) and (4).

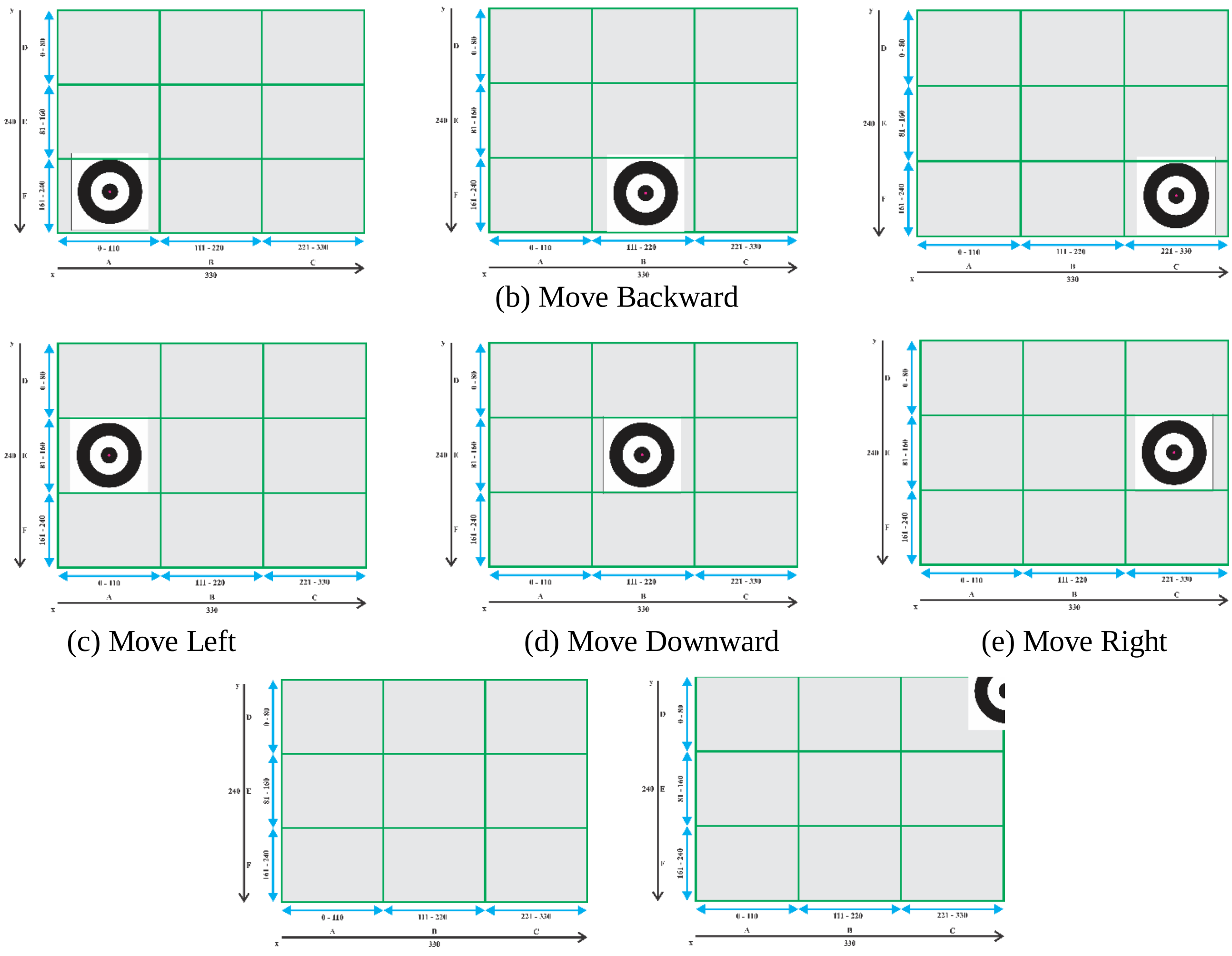
$$\text{x axis} = \frac{x\ axis}{3} \tag{3}$$

$$\text{y axis} = \frac{y\ axis}{3} \tag{4}$$

According to the x axis equation, there are 3 dividing part with each of them 110 pixel. For y axis equation, it has 80 pixel each of part. So, in x axis has range 0 – 110 (A), range 111 – 220 (B) and range 221 – 330 (C). And for y axis the range is 0 – 80 (D), range 81 – 160 (E) and range 161 – 240 (F). (Lilian, Setyawan, & Kurniawan, 2018)



(a) Move Forward



(b) Move Backward

(c) Move Left

(d) Move Downward

(e) Move Right

(f) Hovering

Figure 8. Quadcopter Movement according to Position Object in the Grids

Quadcopter will move forward if center coordinate in AD, BD and CD with x axis range 0 – 330 pixel and y axis 0 – 80 pixel. Move forward of quadcopter can be seen in figure 8(a). Quadcopter will move backward if center coordinate in AF, BF and CF with x axis range 0 – 330 pixel and y axis 161 – 240 pixel. Move backward of quadcopter can be seen in figure 8(b). Quadcopter will move left if center coordinate in AE with x axis range 0 – 110 pixel and y axis 81 – 160 pixel. Move left of quadcopter can be seen in figure 8(c). Quadcopter will move downward or landing if center coordiante is in BE with x axis 111 – 220 pixel and y axis 81 – 160 pixel. Move downward or landing of quadcopter can be seen in figure 8(d). Quadcopter will move right if center coordinate in CE with x axis range 221 – 330 pixel and y axis 81 – 160 pixel. Move right of quadcopter can be seen in figure 8(e). If the center coordinate is not in one of all grids or not detected then the quadcopter will be hovering until the quadcopter detect the target as shown in figure 8(f) (Lilian, Setyawan, & Kurniawan, 2018).

3. RESULT AND DISCUSSION

To test the performance of the system, it is tested according to the method and desired design. The experiment carried out by testing quadcopter precision landing in GPS only and GPS with camera. Then combine the algorithms of image processing are Canny Edge detection and Hough Transform toward material used for landing pad with plastic banner (reflected light) and plywood (unreflected light). All tested with speed of quadcopter movement is 0.2 m/s and altitude 5 m.

3.1 Configuration of Quadcopter and Landing Pad

The drone has been built as desired design. It has microcontroller that has been embedded with other sensor needed for quadcopter called Pixhawk controller board as the flight controller . Then, Pixhawk is connected to Raspberry Pi to command quadcopter movement. Communication between ground station and quadcopter through Wi-Fi from phone to Raspberry Pi, so Android phone remote the desktop of Raspberry Pi to run the script. Figure 9 contains a picture of the real configuration of quadcopter and table is the specification. The landing pad material with plastic banner and plywood can be checked in figure 10 which is as desired design.

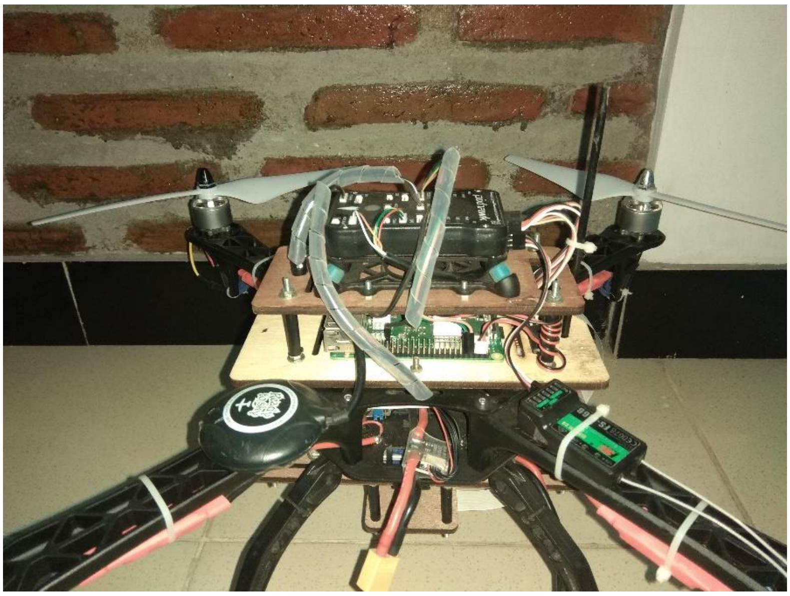
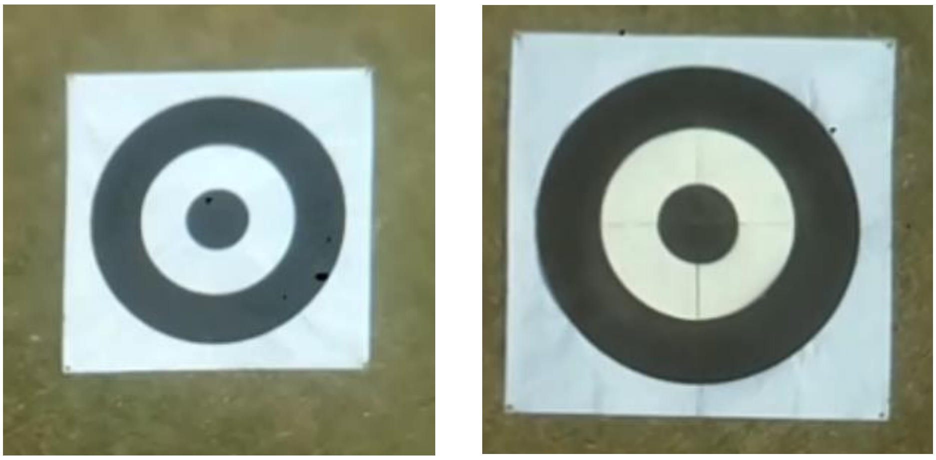


Figure 9. Shape of Quadcopter as Designed

Table 1. Quadcopter Specification

Height (cm)	27
Total Weight (grams)	1330
Frame Size (mm)	450
Motors	2312 920 kV
ESC	Simonk 30A
Battery	POWER 2800 mAh 25 C
Propeller (inch)	9 x 4.5
Safe Flight Time (min)	± 5- 7



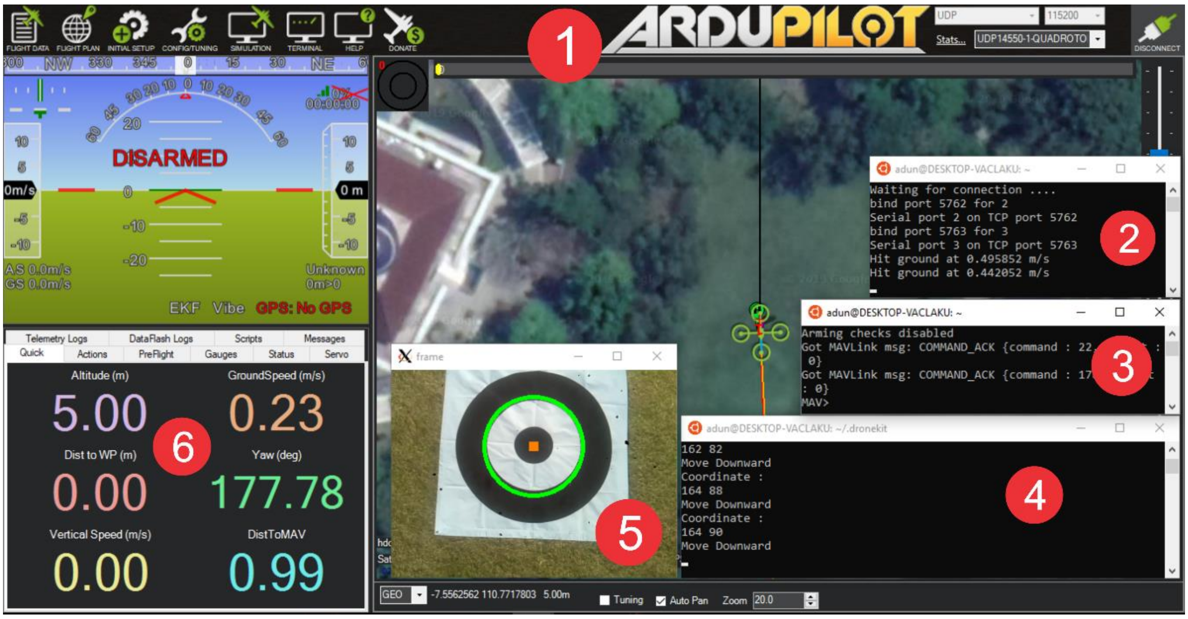
(a) (b)

Figure 10. (a) Plastic Banner Landing Pad; (b) Plywood Landing Pad

3.2 Quadcopter Movement toward Landing Pad Detection

For the movement, quadcopter was tested in drone Simulation In The Loop (SITL) before apply it in real condition using software mission planner and linux ubuntu terminal on windows 10. In drone SITL and real has similar condition for running program and result. The image captured from real application of drone in field by recording the landing pad from altitude 5 m. Script of processing and controlling quadcopter with Canny Edge detection and Hough Transform algorithm that have finished then run into drone SITL as shown in figure 11.

(a)



(b)

Figure 11. (a) Drone SITL with Canny Edge Detection Algorithm; (b) Drone SITL with Hough Transform Algorithm

Information : (1) GUI (Graphic User Interface) of GCS (Ground Control Station) mission planner; (2) Ubuntu terminal for opening connection between ubuntu and mission planner; (3) Ubuntu terminal for creating firmware of SITL in mission planner; (4) Ubuntu terminal for executing the program and output of executed program; (5) Frame output from running program in Object Detected; (6) Parameters of condition quadcopter such as altitude, compass, speed and distance to quadcopter

Library that is used to create the image processing, controlling drone and supporter of program is such as : (1) print_function from future module it means print_function used to bring the print function from Python 3 into Python 2.6+; (2) import time used for creating time sleep or delay in the program; (3) cv2 is from openCV library used for image processing; (4) mavutil from pymavlink module it means mavutil is a pythom mavlink utility function to implement the MAVLink protocol; (5) numpy is fundamental package for scientific computing with Python; (6) deque from collection is a list optimized for inserting and removing items; (7) DroneKit allows developers to create apps that run on an onboard companion computer and communicate with the ArduPilot flight controller using a low-latency link

In accordance with figure 11, number 4 shows coordinate position of center from circle detected in Object Detected windows and followed with the command of controlling quadcopter. This simulation has been tested by Canny Edge detection and Hough Transform algorithm. Experiment of quadcopter movement toward grid position has similar as desired design from the frame of image in simulation. Figure 12 shows quadcopter movement toward grid position.

(a) Move Forward

(b) Move Left (c) Move Downward (d) Move Right

(e) Move Backward

(f) Hovering

Figure 12. Quadcopter Movement toward Coordinate of Grid Position

3.3 Result of Autonomous Landing Performance

The autonomous control of quadcopter is from GPS in the system. Even for flight mission or landing moment. GPS device has error value to determine the latitude and longitude then it is not recommended to use GPS only as a landing mission. For reducing the error GPS is combined with camera to detect the landing pad.

Image processing has important role for getting precision coordinate from the target. Different algorithms will give different results. Canny Edge detection algroithm here does not use threshold as conversion of binary image, so the intensity of light is not influence at all. Another algorithm is Hough Transform using threshold, so the intensity of light has influence. These experiments have been with altitude 5 m measured by barometer sensor of quadcopter as shown in the table below.

Table 2. GPS Device Landing Performance

No	Time	Distance of Error (cm)
1	07.58 AM	236
2	08.03 AM	222
3	08.53 AM	145
4	08.55 AM	111
5	08.57 AM	282
Error Average		199.2

In testing of autonomous takeoff and landing using GPS device only has error average landing 199.2 cm. From 5 times attempt the highest error is 282 cm and lowest is 111 cm.

Table 3. GPS Device and Canny Edge Detection with Plastic Banner Target

No	Time	Distance of Error (cm)
1	11.02 AM	50
2	11.06 AM	46
3	11.08 AM	23
4	11.10 AM	43
5	11.12 AM	49
Error Average		42.2

In testing of autonomous takeoff and landing using GPS device combined with Canny Edge detection algorithm. For the landing used is plastic banner material which is reflecting light. From 5 times attempt has error average landing 42.2 cm with the highest error is 50 cm and lowest is 23 cm.

Table 4. GPS Device and Canny Edge Detection with Plywood Target

No	Time	Distance of Error (cm)
1	08.24 AM	31
2	08.26 AM	55
3	08.28 AM	48
4	08.29 AM	52
5	08.31 AM	41
Error Average		45.4

In testing of autonomous takeoff and landing using GPS device combined with Canny Edge detection algorithm. For the landing used is plywood material which is not reflecting light. From 5 times attempt has error average landing 45.4 cm with the highest error is 55 cm and lowest is 31 cm.

Table 5. GPS Device and Hough Transform with Plastic Banner Target

No	Time	Distance of Error (cm)
1	08.37 AM	33
2	08.39 AM	29
3	08.41 AM	44
4	08.43 AM	50
5	08.45 AM	51
Error Average		41.4

In testing of autonomous takeoff and landing using GPS device combined with Hough Transform algorithm. For the landing used is plastic banner material which is reflecting light. From 5 times attempt has error average landing 41.4 cm with the highest error is 51 cm and lowest is 29 cm.

Table 6. GPS Device and Hough Transform with Plywood Target

No	Time	Distance of Error (cm)
1	11.28 AM	20
2	11.31 AM	23
3	11.35 AM	59
4	11.37 AM	53
5	11.38 AM	18
Error Average		34.6

In testing of autonomous takeoff and landing using GPS device combined with Hough Transform algorithm. For the landing used is plywood material which is not reflecting light. From 5 times attempt has error average landing 34.6 cm with the highest error is 59 cm and lowest is 18 cm.

4. CLOSING

Based on this research, the analysis from results can be concluded as follows:

1) Quadcopter and landing pad design has been built and worked as desired design.
2) SITL (Simulation In The Loop) has same result with the real condition of autonomous precision landing and for reducing the error of landing distance, frame of image processing is divided by 9 grids with equal pixel range to control quadcopter movement.
3) Autonomous landing by GPS device has bad accuracy with error average is 199.2 cm, highest error is 282 cm and lowest error is 111 cm. Combining GPS and camera has reduced error landing distance. Canny edge detection algorithm with plastic banner has error average 42.2 cm and for plywood is 45.4 cm. Hough transform algorithm with plastic banner has error average 41.4 cm and for plywood is 34.6 cm.

4) Landing pad as a target has different material such as plastic banner with light reflection and plywood without light reflection has no big differences when the image is processed.

For further work the quadcopter should be in best PID setting and install rangefinder such as ultrasonic sensor to get precision altitude. For the image processing, to get image clearly and wide, need camera that has good specification such as pixel, FPS (Frame Per Second) and wide angle.

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