MINIMIZE UAV LANDING ERROR BY DEVELOPMENT OF PRECISION LANDING SYTEM BASED ON OBJECT DETECTION

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ABSTRACT

Unmanned Aerial Vehicle (UAV) or commonly known as drones have undergone various kinds of technological developments, so that they are widely utilized in any field, in this paper focuses on developing a precision landing system for drones when completed in an RFID tag mission in a warehouse, utilizing technologies such as Pixhawk, Raspberry Pi, Intel Realsense T265 for navigation, and a webcam to help detect objects for precision landing of drones. The system of precision landing combines or communicates from Intel Realsense T265 and Vision Camera, which detects a marker where the drone is landing, then Pixhawk receives the command. The addition of this object detection-based precision landing system is to minimize the drone landing error if it only utilizes Intel RealSense T265, thus the development of this precision landing system minimizes the error from the drone when landing, so that the drone still lands in a safe area or predetermined place.

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1. INTRODUCTION

In this modern era, the development of robotic technology is increasingly advanced, especially for aerial flying robots, among them are drone or unmanned aerial vehicles (UAVs) [1][2]. Initially, unmanned aerial vehicles first appeared for military research [3], then technology and industrial developers began to conduct research on unmanned Vehicles because they realized that there are some things that Humans cannot directly do, such as control, inspection, supervision and delivery [1][2][4]. Of all the types of drones, the quadcopter is the most well-known due to its level of accuracy and efficiency, and the need for and degree of accuracy and efficiency has been well researched [4][5].

It's been easy to find quadcopters lately, there's been a lot of market selling drones, especially quadruped models. This proves that the quadcopter attracts a lot of attention due to its simplicity in flight control [6][7]. Quadcopter technology is increasing every year, starting with manual and automatic control[7]. this drone is attached with four brushless motors [8], each of which generates lift and torque in the rotating area. One of the applications of autonomous quadcopter widely used in industry, ramping up an industry's production inevitably requires a large warehouse with a frequency identification (RFID) system installed. on quadcopter aircraft [9], this can facilitate inventory management to manage stock availability, monitor stock, and control how goods are delivered to consumers. In use, a quadruped with an RFID system can also be used to monitor warehouse security, with the ability to automatically detect and track goods entering and leaving the warehouse. With this quadcopter, the inventory management process can become more efficient and accurate [10].

In this case, when the inventory by drone is done, the drone that will land by this drone must have the correct way of landing [11], the reason for landing.Precision landing are needed because the drone's position is far from the pilot's position.line of sight and blocked by racks [12]. therefore, the development of this system uses a webcam to record images of the drones landing during landing [11] [13].two cameras are used is webcam and intel realSense T265, the webcam is installed face down while the Intel RealSense T265 is placed at the front [14]. The fixed face-down webcam acts as a drone detector while the Intel RealSense T265 does the drone navigation [15]. during this process, the drone moves in guided mode to approach the landing site, the drone captures the rack area by webcam [16] and when the landing site enters the In the webcam area, the drone will switch to a second guidance mode for the landing process. in the first and second tutorial steps, the drone's movement will apply the sliding mode (x and y) [14]. to determine the target using image processing and edge detection rules [17].

2. METHOD

2.1. System Design

In this part of the research describes the main system of precision landing system to drone RFID Inventory system Figure 1, the main control in this research uses Intel Realsense T265 as a calculation of the position of the drone and also as navigation of the drone [18], which is controlled through a Raspberry Pi connected to the Pixhawk Cube. The webcam used in this study functions as a detection landing mark, landing mark is a place to land the drone and also as an object that helps the drone for precision landing system, this landing mark is a square measuring 50 cm x 50 cm which is yellow in color. in this case the Raspberry also runs the landing sign detection program, the camera screen display can be opened on the monitor so that it can be seen when the drone is flying.

The precision drone landing system is guided using the intelrealsense t265 camera, the structure diagram of the precision landing strategy. At this stage the drone is paired with a raspberry pi connected to pixhawk, as for the program run by the raspberry pi in the form of a program from the guided mode for navigation of the drone and a pose program from the intelrealsense camera to view the coordinates of x and y. Open camera display and landing mark detection display using the OpenCV algorithm [19], can be seen on a PC connected to the raspberry pi via a network originating from rooter and SSH, after running the program needed for the drone precision landing system, pixhawk as the brain of the drone will execute the guided mode program command from raspberry via mavlink to ROS (MavROS) [20]. When the guided drone detects the landing site, the drone will look for the center point of the landing site as a condition of the drone landing.

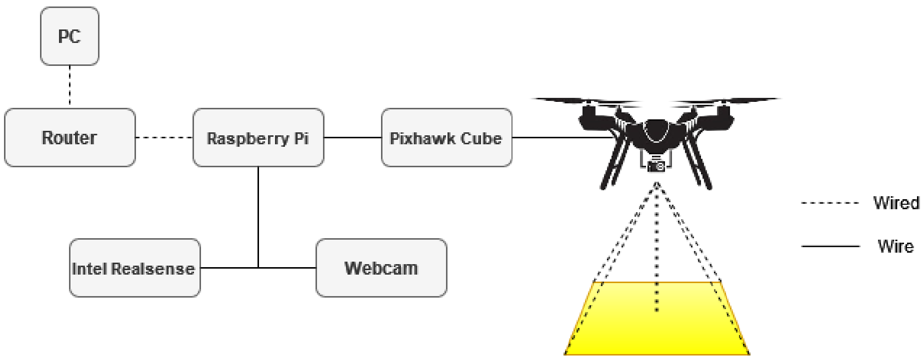

Figure 1 System Design

2.2. Precision Conditions

In this development, the precise condition of the drone at landing is one of the things to pay attention to. The unmanned aircraft will always be guided to the point of departure for landing. In addition, it is necessary to perform repeated tests to determine the accuracy of the landing. This needs to be done in case of various conditions such as miscalculation and accuracy[11], figure 2 shows the variation of accuracy and precision values.

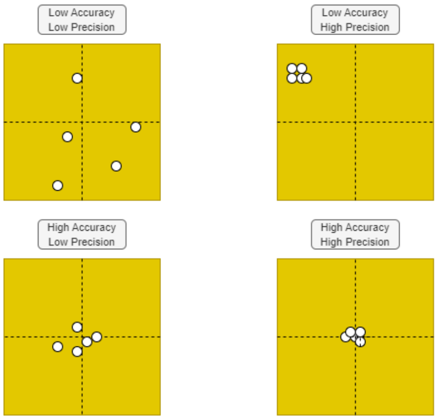

Figure 2 Position Landing

2.3. RGB Color Space

RGB is a color that represents the intensity value of the colors Red, Green, and Blue, Color in RGB is so useful that it is widely used in image processing, image processing, and also graphic design because it can provide variations in producing various colors to be shown on a computer screen [21][22]. to produce a variety of colors by combining the intensity of red, green, and blue, the value of each intensity can be set between the lowest value of 0 to the highest value of 255, in the system the combination of the intensity of red, green, and blue will create the parent color in the form of white, while if all color intensity values are set at a value of 0 will create black.

2.4. HSV Color Space

HSV in this paper is described by the shape of the HSV cone, which has been shown in figure 4 HSV stands for hue saturation and value, the hue value here is an indication of color purity while for saturation it refers to the amount of gray combined with the hue value and for value is the brightness of the color [23], if the smaller the brightness value, the color will turn dark while if the brightness value is large it will reach the true color[24][25]. it'll change over the color space from RGB color space to HSV color space equation (1), (2), and (3), utilizing the taking after condition :

$$V = max\,(R, G, B), \quad min = min\,(R, G, B) \tag{1}$$

$$S = (max - min)\,/\,max \quad (or\ S = 0, if\ \ V\ = 0) \tag{2}$$

$$H = 60\ x \begin{Bmatrix} 0 + \dfrac{G - B}{max - min}, & if\ max = R \\ 2 + \dfrac{B - R}{max - min}, & if\ max = G \\ 4 + \dfrac{R - G}{max - min}, & if\ max = B \end{Bmatrix} \tag{3}$$

$$H = H + 360, \ \ if\ H < 0$$

2.5. Flow Process Mission Precision Landing

In this section the drone will perform the mission of the drone precision landing, first the drone fly then the drone will detect or find the landing mark, then the drone will output the value of the current xyz position based on the detection results of the landing mark, then the drone will output the xy value for the distance to the center area of the landing mark and the drone will start moving based on the estimated xy distance that has been determined. after the drone moves towards the center area of the landing mark the drone will read the position value again to determine from the error whether the drone is in the right area for landing. if the results of the drone calculation are still in an area that is not suitable for landing the drone will start again estimating the xy distance to the center area of the landing, if the drone is in the right area for landing then the drone will start landing.

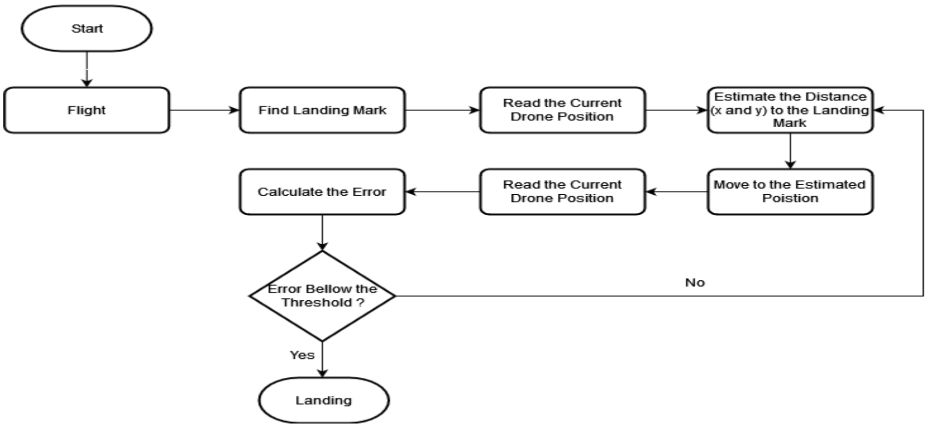

Figure 3 Mission Precision Landing

3. RESULTS AND DISCUSSION

The results of data collection in this paper are in the form of images of detected objects, namely in the form of yellow landing place markers from various conditions using object detection algorithms with OpenCV and data taken is also in the form of conditions from landing drones when landing on a predetermined landing place marker, namely a square-shaped yellow landing place with a size of 50cm x 50cm.

In the experiment of the precision landing system on the drone, in this paper it was tested four times from different directions, the first experiment was carried out by placing the landin marker in front of the drone, the second experiment the landing marker was placed to the right of the drone, for the third experiment the landing marker was placed behind the drone and in the fourth experiment the landing place was placed to the left of the drone. The distance of the 4 experiments is 70cm from the center point of the drone to the center point of the landing marker. The figure 4 is an example of the 4 experiments:

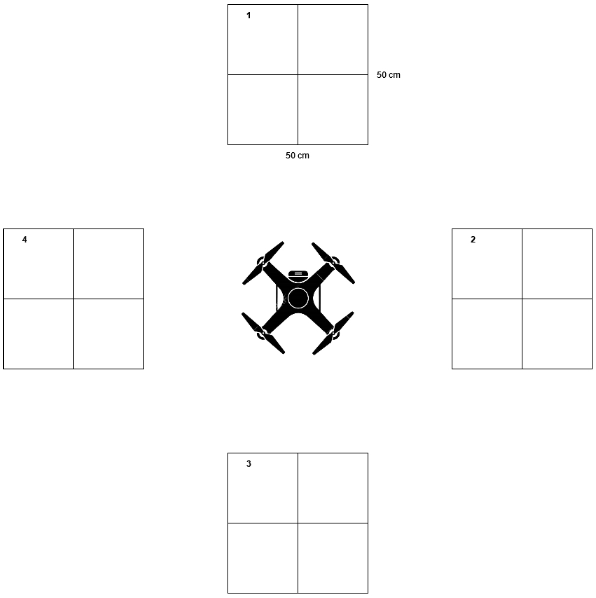

Figure 4 Fourt Experiment Testing

3.1. Landing Marker Dataset

The development of landing precision on drones in this paper uses landing markers, landing markers must be easily detected properly in order to get good landing accuracy results, landing markers used are yellow and square-shaped measuring 50cm x 50cm. in the process of detecting landing marker images by the camera there are several things or factors that need to be considered, such as conditions when there is interference in the form of other yellow objects, then the detection distance between the camera and the landing marker, and the factor of lighting to get good enough results.

In figure 5 will display the results of the detection of yellow landing markers that have been determined in the development of precision drone landing, following the results of the detection:

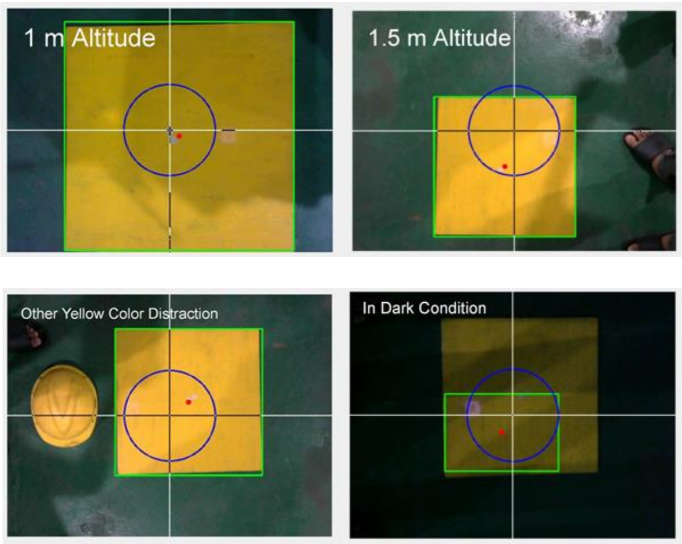

Figure 5 Condition Detection

3.2. Landing Conditions

In this paper will display the results of the landing conditions on the drone, the drone performs four precision landing experiments from the front, right, back, and left directions of the drone to see the results of the precision landing system.

3.2.1. First Landing Conditions

In the first experiment in the drone to make a precision landing at the landing marker, the position of the drone is at point xy (24cm, 23cm) these results are obtained by running the precision landing program that has been made, the following is an table 1 and figure 6 of the xy movement of the drone when landing :

Table 1. Value Movement xyz

Move XYZ Drone to Landing Marker (cm)									
NO	Current Position			Target Position			Result		
	x	y	z	x	y	z	x	y	z
1	1.5	-2.92	145.2	-2.5	71.02	145.2	-1	68	0

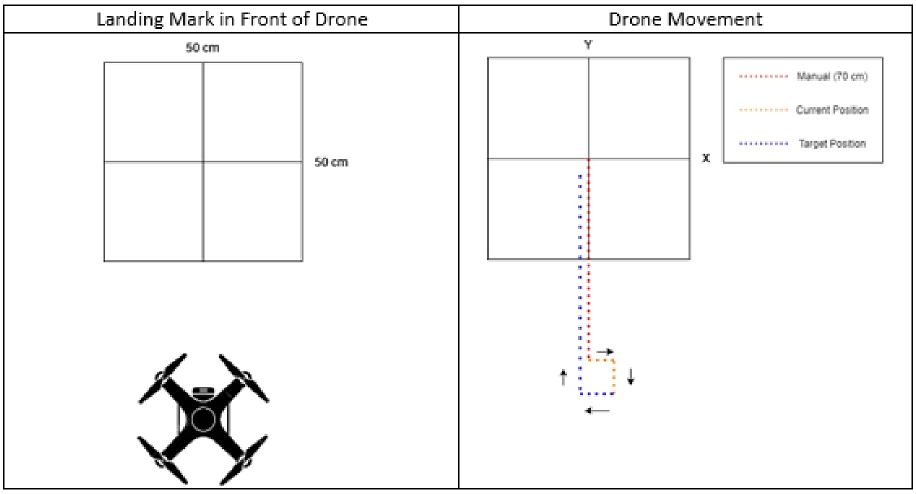

Figure 6. First Condition

In this first experiment, the landing mark is placed in front of the drone, the distance from the center point of the drone to the center point of the landing place is 70cm so the value, when the program is run, comes out the value of the current position, this value is obtained when the drone detects the edge of the landing mark and will also come out the value of the target position of the drone for landing. can be seen in the picture above, the value of the target position will be added by the current position value, these results will be compared with the distance from the center point of the drone and the landing mark that has been measured manually (4) and (5), which is 70cm.

$$x = x_{result} - x_{manual} \tag{4}$$
$$x = (-1) - 0$$
$$x = -1$$

$$y = y_{result} - y_{manual} \tag{5}$$
$$y = 68 - 70$$
$$y = -2$$

As has been determined the size of the landing place is 50 cm x 50 cm and the center point is at a value of 25 cm, so to get the value of the landing position of the drone will be reduced by a value of 25 cm. The following is the value of the landing position of the drone when it lands on the landing marker to (6) and (7) :

$$x_{Landing\ Position} = 25 - 1 \tag{6}$$
$$= 24\ cm$$
$$y_{Landing\ Position} = 25 - 2 \tag{7}$$
$$= 23\ cm$$

So the value of x and y in landing mark is 24cm and 23 cm in figure 7 :

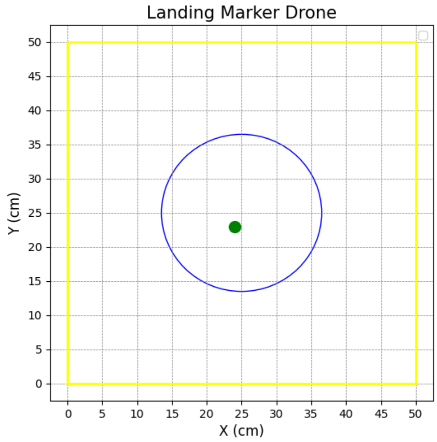

Figure 7. First Position Landing

3.2.2. Second Landing Conditions

In the second experiment in making a precision landing, the drone landed at the xy landing marker point (17.5 cm, 18cm) still in the same way as the first experiment, following table 2 and figure 8 the results of movement xy in the second experiment of precision landing :

Table 2. Value Movement xyz

Move XYZ Drone to Landing Marker (cm)									
NO	Current Position			Target Position			Result		
	x	y	z	x	y	z	x	y	z
2	-1.91	0.52	143.39	64.38	-7.72	143.39	62.5	-7	0

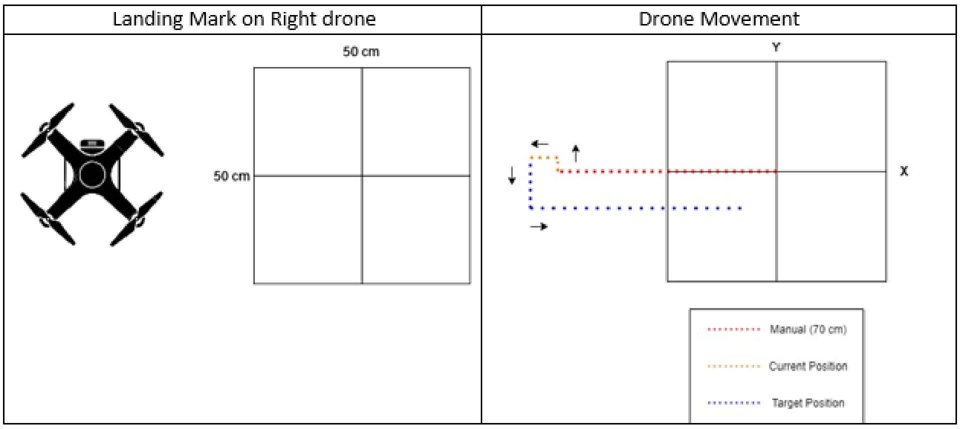

Figure 8. Second Condition

In this second experiment, the landing mark is placed on right of the drone, the distance from the center point of the drone to the center point of the landing place is 70cm so the value, when the program is run, comes out the value of the current position, this value is obtained when the drone detects the edge of the landing mark and will also come out the value of the target position of the drone for landing. can be seen in the picture above, the value of the target position will be added by the current position value, these results will be compared with the distance from the center point of the drone and the landing mark that has been measured manually (8) and (9), which is 70cm.

$$x = x_{result} - x_{manual} \quad (8)$$
$$x = 62.5 - 70$$
$$x = -7.5$$
$$y = y_{result} - y_{manual} \quad (9)$$
$$y = (-7) - 0$$
$$y = -7$$

As has been determined the size of the landing place is 50 cm x 50 cm and the center point is at a value of 25 cm, so to get the value of the landing position of the drone will be reduced by a value of 25 cm. The following is the value of the landing position of the drone when it lands on the landing marker to (10) and (11) :

$$x_{Landing\ Position} = 25 - 7.5 \quad (10)$$
$$= 17.5\ cm$$
$$y_{Landing\ Position} = 25 - 7 \quad (11)$$
$$= 18\ cm$$

the value of x and y when landing at landing mark is 17.5 cm and 18 cm in figure 9 :

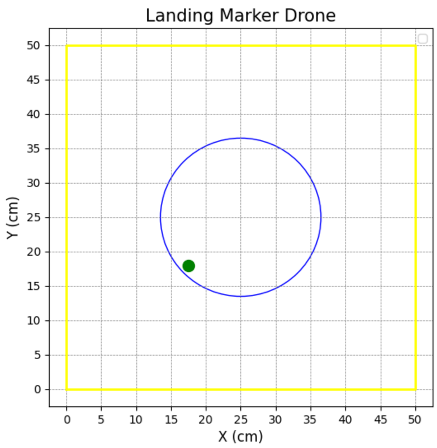

Figure 9. Second Landing Position

3.2.3. Third Landing Conditions

In this third landing condition experiment the drone landed at the xy point of the landing marker 23.7 cm and 17 cm, the result of the xy value is obtained from the movement of the drone to find the center point of the landing marker, the following is table 3 and figure 10 of the 3rd experiment :

Table 3. Value Movement xyz

Move XYZ Drone to Landing Marker (cm)									
NO	Current Position			Target Position			Result		
	x	y	z	x	y	z	x	y	z
3	-8.32	1.02	142.67	6.97	-78.97	142.67	-1.3	-78	0

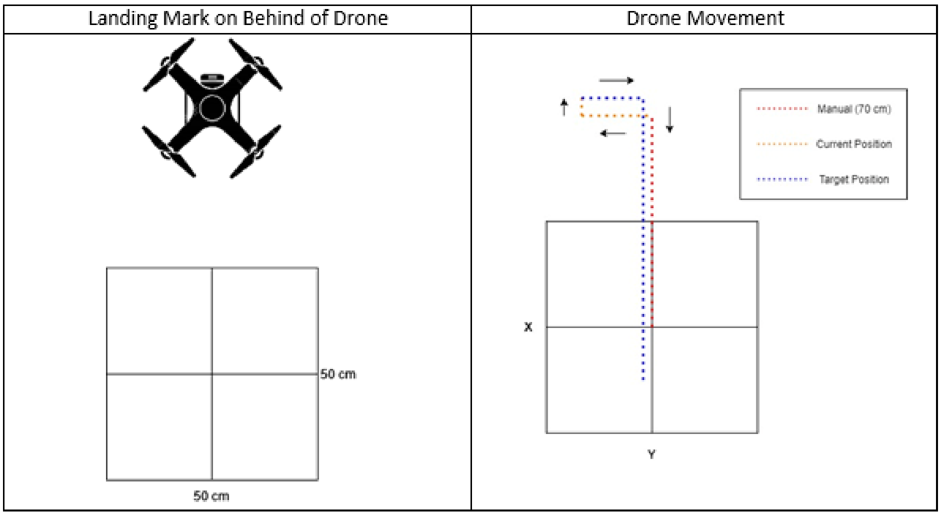

Figure 10. Third Condition

In this Third experiment, the landing mark is placed behind of the drone, the distance from the center point of the drone to the center point of the landing place is 70cm so the value, when the program is run, comes out the value of the current position, this value is obtained when the drone detects the edge of the landing mark and will also come out the value of the target position of the drone for landing. can be seen in the picture above, the value of the target position will be reduced by the current position value, these results will be compared with the distance from the center point of the drone and the landing mark that has been measured manually (12) and (13), which is 70cm.

$$x = x_{result} - x_{manual} \quad (12)$$
$$x = (-1.3) - 0$$
$$x = -1.3$$

$$y = y_{result} - y_{manual} \tag{13}$$
$$y = (-78) - 70$$
$$y = -8$$

As has been determined the size of the landing place is 50 cm x 50 cm and the center point is at a value of 25 cm, so to get the value of the landing position of the drone will be reduced by a value of 25 cm. The following is the value of the landing position of the drone when it lands on the landing marker to (14) and (15):

$$x_{Landing\ Position} = 25 - 1.3 \tag{14}$$
$$= 23.7\ cm$$

$$y_{Landing\ Position} = 25 - 8 \tag{15}$$
$$= 17\ cm$$

So the value of third testing, position drone to landing mark is 23.7 cm and 17 cm in figure 11:

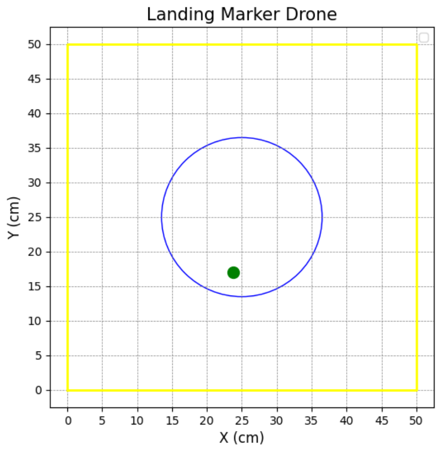

Figure 11. Third Landing Position

3.2.4. Fourth Landing Conditions

In this fourth landing condition experiment the drone landed at the xy point of the landing marker 36 cm and 21.6 cm, the result of the xy value is obtained from the movement of the drone to find the center point of the landing marker, the following is an figure table 4 and 12 of the 4th drone movement :

Table 4. Value Movement xyz

Move XYZ Drone to Landing Marker (cm)									
NO	Current Position			Target Position			Result		
	x	y	z	x	y	z	x	y	z
4	0.35	-4.61	143.56	-59.36	1.21	143.56	-59	-3.4	0

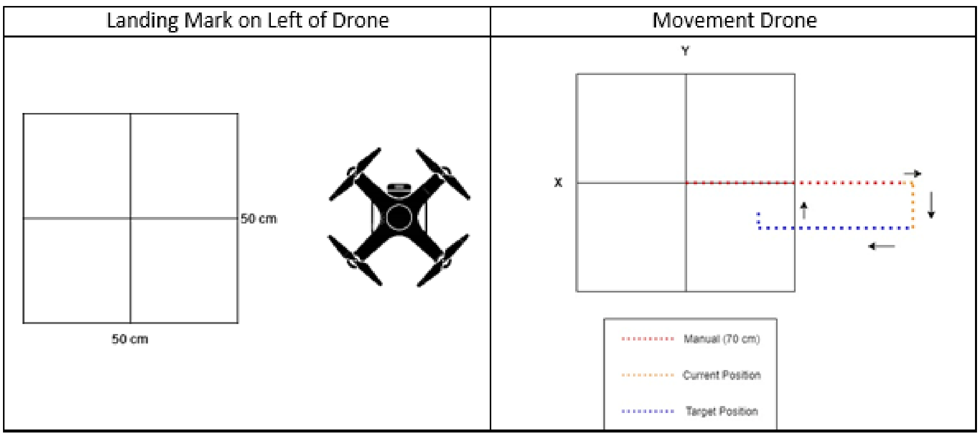

Figure 12. Fourth Condition

In this fourth experiment, the landing mark is placed on left of the drone, the distance from the center point of the drone to the center point of the landing place is 70cm so the value, when the program is run, comes out the value of the current position, this value is obtained when the drone detects the edge of the landing mark and will also come out the value of the target position of the drone for landing. can be seen in the picture above, the value of the target position will be reduced by the current position value, these results will be compared with the distance from the center point of the drone and the landing mark that has been measured manually (16) and (17), which is 70cm.

$$x = x_{result} - x_{manual} \tag{16}$$
$$x = -59 + 70$$
$$x = 11$$
$$y = y_{result} - y_{manual} \tag{17}$$
$$y = (-3.4) - 0$$
$$y = -3.4$$

As has been determined the size of the landing place is 50 cm x 50 cm and the center point is at a value of 25 cm, so to get the value of the landing position of the drone will be reduced by a value of 25 cm. The following is the value of the landing position of the drone when it lands on the landing marker to (18) and (19):

$$x_{Landing\ Position} = 25 + 11 \tag{18}$$
$$= 36\ cm$$
$$y_{Landing\ Position} = 25 - 3.4 \tag{19}$$
$$= 21.6\ cm$$

the value x and y of third testing, position drone to landing mark is 36 cm cm and 18 cm in figure 13

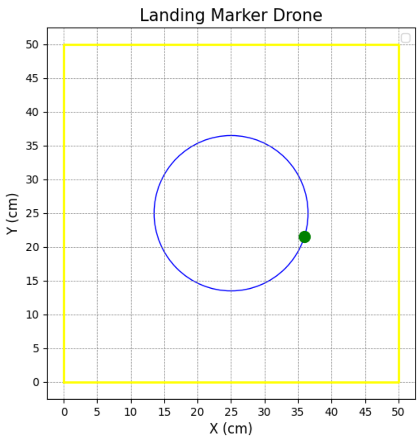

Figure 13. Fourth Landing Position

3.3. Landing Position Drone

In this section, the results of the conditions when the drone is landing will be known, this data is taken from the results of four trials from different directions, namely the front, right, back and left of the drone position. In Figure 14 the results of the four experiments on the precision landing mission have different results but are still on target in the form of drones not coming out or over landing on the landig mark. of the four experiments that have been carried out to determine accuracy and precision using formulas (20) and (21).

$$percentage_{accuracy} = \left(1 - \frac{distance}{center}\right) x\ 100\% \tag{20}$$

$$percentage_{precision} = \left(1 - \frac{x - y}{\max(x, y)}\right) x\ 100\% \tag{21}$$

Table 5. Accuracy and Precision Data

No	Position landing		Value Accuracy (%)	Value Precision (%)
	x	y		
1.	24	23	94 %	95.83 %
2.	17.5	18	71 %	97. 78%
3.	23.7	17	81 %	71.77 %
4.	36	18	64 %	50 %

Average	77.5 %	78.85 %

After doing the calculations and getting the accuracy and precision values according to table 5, it can determine the accuracy and precision based on figure 2, in figure 14 below shows the landing position of the drone, the results of the four experiments that have been carried out have an accuracy value of 77.5% and a precision of 78.85%.

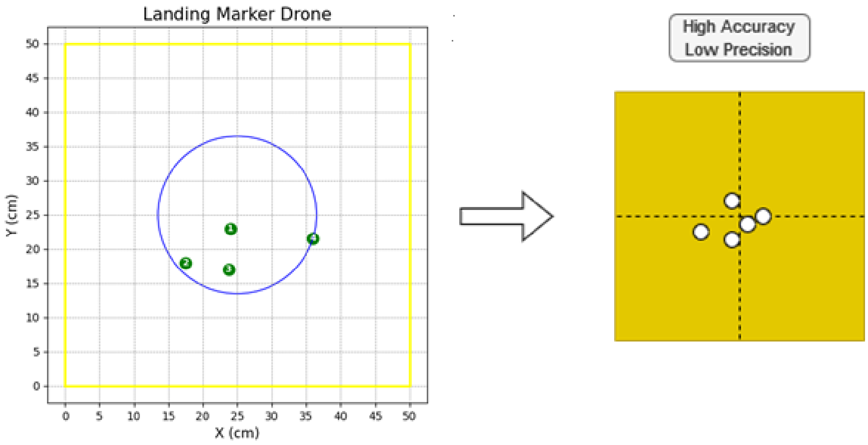

Figure 14. Condition Landing Drone

4. CONCLUSION

This research focuses on drone landing conditions on predetermined landing marks, the development of a precision landing system using object detection to assist drones in detecting yellow landing marks, initially using the IntelRealsense t265 camera as localization but when facing drone landing conditions always experience errors that are quite far from the predetermined point for drone landing, after adding a precision landing system to the drone can be seen in the results of the first experiment the xy value (24, 23) cm, the results of the second experiment the xy value (17. 5, 18) cm, the results of the third experiment xy value (23. 7, 17) cm, and the results of the fourth experiment xy value (36, 21.6) cm, from the results of the four experiments with different landing mark placements, the drone still lands on the landing mark area, if the xy value of the drone landing position is in the area outside the blue ring then when the drone lands it will overload or come out a little from the landing mark area. Based on the experimental results, it can be seen in table 5 that the accuracy value (77.5%) and precision (78.85%), so the development of this precision drone landing can minimize drone landing errors.

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