Unmanned aerial vehicle object tracking and following

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Abstract. Today, the use of Quadcopter on human activities are increasingly dominant, especially in the field of search and rescue. One of the most challenging case on SAR using Unmanned Aerial Vehicle quadcopter is tracking and following an object which is newly recognized. The system could track any kind of object which the user choose in real time and the object could be immediately recognize. After the object recognized, the quadcopter could track and follow the object with a high degree of precision. This research reports the results of design and program for quadcopter control that can track and follow a 3D objects which was initially determined first. The algorithm for tracking system used several method from image processing to extract the information from the image (feature extraction base on color), then the information will be used as a reference movement quadcopter in following the target. The object tracking system, used various methods of image processing in the domain of HSV-RGB, Camshift, and Kanade-Lucas-Tomasi Tracker to optimizing 2D tracking system and increase the success rate of the program. While the method of distance estimation using the camera calibration towards the distance. Output from the tracking system are the object coordinates (x, y, z). This information is fed back to the quadcopter Robot Operating System (ROS) as the error between the positions of the camera with the position of objects, and is known as Visual Servoing. Quadcopter control system using PID constants in the leading to the movement of the pitch, throttle, and roll, to maintain the position of quadcopter towards the target and follow an object moving forwards or backwards.

1. Introduction
Unmanned Aerial Vehicle (UAV), has now been widely used by humans for various needs, and has become a trend in usage by some. In terms of its relatively small form, the UAV is capable of working on various jobs that require small space. In addition, work that is dangerous and requires expensive costs if done by humans, then the UAV can do it with a low level of risk and costs, without reducing the value of efficiency. In this study, quadcopter type UAVs were used to include a motion control program. In its implementation, the quadcopter was integrated with a camera which can identify objects, track their movements, and then send visual information as a reference for controlling the quadcopter to follow the object. The camera sends a signal in the form of an image and then processed it to get the required output. In image processing, the process of identifying an object and tracking its movements can be carried out. Object tracking system, used several image processing methods to retrieve image information so that the object to be targeted can be determined including Eroding and Dilating in RGB domain, Camshift Algorithm in HSV domain, and Kanade-Lucas-Tomasi Tracker to optimize the 2D tracking system with success rates. Estimation method of distance between camera and object, calibration of the camera to the object by calculating the pixel area of the object so that the reference parameter of the area of the object pixel is obtained at each distance variation. The
quadcopter control system to follow objects. Object Following is a methodology that allows a device to follow a moving object. The initial object that is targeted is determined through the object tracking system, so that it will automatically be able to make the quadcopter follow a target object in 3-dimensional shape by maintaining the distance between the object and the quadcopter and keeping its position in the midpoint of the captured image camera. Although object tracking systems and following using a quadcopter have been developed, there are still limitations to use and deficiencies. In its use, the test location is still indoor or indoors. In terms of deficiencies are aspects of the stability and responsiveness of the UAV. Therefore, I will explore this research in order to create an UAV that can track and follow objects both indoors and outdoors, and have better stability and responsiveness.

2. The Proposed Method
The methods which are used in this paper are Eroding and Dilating process, Camshift Algorithm, and Kanade-Lucas-Tomasi Tracker, and will be explain in the following subsections.

2.1. Camshift Algorithm
Camshift is a further implementation of meanshift algorithm. Simply, camshift is a meanshift that is repeated continuously on each frame in the video. The camshift algorithm consists of three parts, including Back Projection, MeanShift, and Track. Back projection is a method which using the histogram of an image to show up the probabilities of colors may appear in each pixel. Using a histogram in the HSV domain, we can see the percentage of the most color values that are found in a frame. Then after getting the color value from the histogram, proceed with the MeanShift algorithm by finding modes in a set of data samples representing and and clustering in a one point. in the tracking process, MeanShift is used again in the next frame.

![Figure 1. CamShift and Back Projection Mode](image)

2.2. Eroding and Dilating
Erode and dilate are one image filtering that aims to reduce noise, isolate individual elements, join different elements in the image, and look for the intensity of bumps or holes in the image. Erode is the texture erosion of the drawing object. In the erode function, local minimum values are calculated along the area. From the Back Projection Mode frame, there is still a noise value that can be removed using Eroding the frame.

![Figure 2. Eroding and Dilating](image)

The middle side of the figure 2, shows the noise around the edge of the object being reduced or eroded. Next, the image filtering method used is dilate. Dilate is the convolution operation of an object image with a kernel. The result of dilate is the widening of the object's texture which can be shown in the left side figure 2.
2.3. Kanade – Lucas – Tomasi Tracker

Kanade - Lucas - Tomasi (KLT) Tracker is a combination of two methods from Shi - Tomasi Corner with Optical Flow. The KLT Tracker algorithm starts by looking for good features in the frame using the Shi-Tomasi Corner Detector method, by looking for pixel intensity values that exceed the threshold limit of the neighborhood. After features have been found, feature tracking is needed in the next frame known as optical flow. Many features in the frame can be represented at one point performing the coordinate averages of all feature coordinates in the object with the following equation.

$$\left( \frac{\sum features_n[x] + features_{n+1}[x]}{n.features}, \frac{\sum features_n[y] + features_{n+1}[y]}{n.features} \right)$$

(1)

2.4. Proposed Object Tracking System

The tracking system in this study aims to get the distance of the object to the camera, and the two-dimensional coordinates of the object from the video frame, captured by the quadcopter camera. The first step is to recognize and select the object to be targeted. After that, the system use the Camshift algorithm and looking at the Back Projection frame mode. After entering Back Projection Mode, the system will run the Erode process and Dilate to filter the image from noise and cover the hole in the middle of the object. Then, the system will run Kanade - Lucas - Tomasi Tracker to determine good features, and track its movements with optical flow. Features that consist of several points are represented in one point by looking for the average values of X and Y from each point, so that the exact 2D coordinates can be obtained. To get the distance between a quadcopter camera and an object, the resulting square of the Camshift can be used, along the object. From the size of the square, we can calibrate the distance of the object with the camera. In the calibration process, there are two variables, the first is the square area in pixels (X multiplied by Y), and the second is the distance between the object and the camera. Data processing can be seen in Evaluation and Experiment Result.

Figure 3. Flowchart Proposed Object Tracking System
2.5. Control System Design
The algorithm of following the object using the output of the proposed object tracking system. During the tracking process, the system obtained the distance and X-Y coordinates of the object, so the information becomes a reference for controlling the quadcopter to follow the object which being targeted. The main purpose of the following object system is to maintain the distance of the quadcopter with the object (visual servoing). Below is the flowchart that describes the flow of the object following system.

For the process of following objects, the PID control system is used to reference the value of the quadcopter motion. The coordinates of the points on the frame and the distance with the quadcopter, will be used as an error value to be entered in the PID equation and calculate the error value continuously against the time \( e(t) \), which is the value between the set point (SP) and process variable (PV). Then the value of \( e(t) \) is applied to the PID equation with reference to proportional, integral, and derivative constants. Here is the PID Controller [5] equation:

\[
    u(t) = K_p e(t) + K_i \int_0^t e(t) \, dt + K_d \frac{de(t)}{dt}
\]

3. Evaluation dan Experiment Result

3.1. Camera Calibration with Objects
Calibrating the distance of the object with the camera, is done by making a graph to get the equation between the area that consists of square pixels with distance. Following figure 5, is a graph between the original distance of measurement between the camera and the object, and the distance is compared to the area of a square pixel.
Then a quadratic equation is obtained:

\[ Y = 16832x^{0.524} \]  

The equation reflects how the pixel area of the square circumference increases with the distance between the object and the camera approaching the camera, and the area of the pixel from the circumference of the square decreases with the distance between the object and the camera away.

3.2. Eroding and Dllating data

In the image filtering stage, the image is processed erode and dilate. These results aim to get a smooth image without any noise that can interfere with the tracking process. Here are the results of image filtering with the lowest and largest distance variations.

| Distance | Eroding | Dilating |
|----------|---------|----------|
| 50 cm    | ![Image](image1.png) | ![Image](image2.png) |
| 190 cm   | ![Image](image3.png) | ![Image](image4.png) |

3.3. Proposed Object Tracking System data

On the object tracking system or track the position of moving objects. The output of both tracking systems is the distance of objects to objects and coordinates of X and Y objects on the camera. The following data in table 2 obtained from the system results obtained from the results of the tracking system with the smallest and largest measurement distance,
Table 2. Object Tracking System Result

| Distance | Tracking Result | Output of Program (Distance dan Coordinates X-Y) |
|----------|----------------|-----------------------------------------------|
| 30 cm    | ![Image](image1) | 03.1141 cm, Confidence: 0105.1753, 1.944.063  |
|          |                | 03.1141 cm, Confidence: 0105.1753, 1.944.063  |
| 190 cm   | ![Image](image2) | 13.195 cm, Confidence: 0103.1753, 1.944.063  |
|          |                | 03.1141 cm, Confidence: 0105.1753, 1.944.063  |

3.4. Testing of Tracking and Following Programs on Quadcopter
When the Object tracking system program has been able to track objects by knowing the distance to the camera and the X-Y position on the camera, the tracking program is inserted into a single board computer quadcopter to control the movement of the quadcopter with reference information from the image. Here is testing the program into a quadcopter,

![Figure 7. Indoor Testing.](image3)

![Figure 8. Outdoor Testing.](image4)

4. Conclusion and Future Work
Based on the test data and discussion that has been done, it can be concluded that the design of the tracking system object was successfully carried out. The measurement of distance to the camera uses a quadratic equation $y = 16832 X - 0.524$ and mapping coordinates of objects on the video frame using the average of the coordinates of the detected features. The tracking system program has been successfully implemented, but does not yet have data that represents quantitatively.

In measuring and making measurement systems both in terms of hardware and software, there are still many things that need to be improved. Therefore, there are several suggestions that can be done for the development of the next system including the creation of Graphical User Interface is needed to support the measurement system that is much better, and the control system is made multi-level speed, so that more control options.
Acknowledgement
This work was supported by Hibah PITTA (Publikasi Internasional Terindeks unruk Tugas Akhir Mahasiswa Universitas Indonesia) 2018 funded by DRPM Universitas Indonesia, Contract No. 2319/UN2.R3.1/HKP.0500/2018.

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