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To cite this article: P Sidi *et al* 2020 *J. Phys.: Conf. Ser.* **1450** 012082

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Applied optical flow algorithm (OFA) in automatic target tracker system to control weapon movements in the warship

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Abstract. This research has made a tracking system to track the target, the purpose of this prototype is being able to be applied in the warship cannon guns. The system principal is tracking the targets that have been chosen to be targeted by the operator. This device works with the camera as the main sensor, the camera works to provide visual data, the visual data as an object was selected and processed to be targeted. The visual data is processed using the Optical Flow Algorithm (OFA) method by calculating the brightness intensity of the reference. The next step is finding the centroid value as the centre point for distance measurement. These results were converted into a microcontroller program that will move the direction of the tracker to follow the target which captured by the camera. The results of the object tracking test on this tool from 10 attempts can detect objects with an average accuracy of 100 percent at a distance of 1 to 9 meters. For testing the target lock, this system can reach the set point value within 2 seconds with the steady state error of 0.625 percent and the selection of the best proportional constant of 0.2.

1. Introduction

Warships are one of the defence tools of a country. In combat equipment, warships have two types of combat equipment named cannons and missiles. The cannon that mounted on the front is not as accurate as a missile but has very important roles and benefits. As one form of optimization of domestic defence for the sea, cameras can be used as sensors to detect or recognize objects that may replace the role of the senses of sight in humans. One of the techniques to apply the motion tracking method is the Optical Flow Algorithm (OFA). Optical Flow is a Motion Tracking algorithm to perform searches based on motion [1]. The results of image processing are used as information to be processed by a microcontroller, the controller will move the direction of the weapons to follow the target that captured by the camera [2]. So, the cannon can move automatically and following its target. By applying this method, this research is expected to be able to improve the weapons technology in Indonesian warships.



2. Methodology

The purpose of this study is tracking and locking the targets automatically. This system utilizes image processing technology using the Optical Flow Algorithm (OFA) method. From the captured image the user can select the object to be targeted by clicking the mouse on the part of the object. So, the coordinates (x, y) can be detected. Then the selected coordinate is used to move the cannon drive motor to lock the object's movement using the PID method [3]. The following is an illustration and explanation of the system and the process of selecting, tracking and locking the targets.

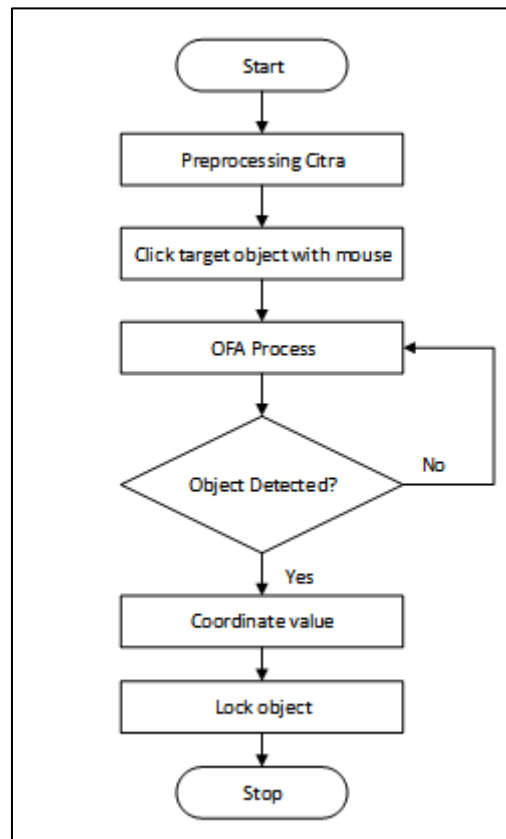


Figure 1. Flowchart system.

2.1. Pre-processing image

The first step is taking the image using the camera. In this process, the enemy ship as the main object is captured by the camera in the form of a frame. When the pre-processing process is done, this frame will be captured repeatedly to produce a video [4]. The data from this video is used as input which used by the user to determine the object. After the object is selected, the system will mark the objects with a round green symbols. Video resolution in this system is displayed with a size of 640 x 480 pixels to make the computing process work faster. This resolution setting will also reduce the memory usage. Resolution of 640 x 480 pixels is a quite ideal size, indeed not too small or large. This is due to the resolution for observation stages are quite clear.

2.2. Optical flow process

Optical Flow is a method that uses light intensity as a basis for detecting objects. It has the advantage of producing a high density movement vector [5]. In this study, the target was chosen by the operator and the system traced by optical flow with a reference to the initial light intensity of the selected target

[6]. In optical flow, the reference that has been selected will calculate the brightness intensity of the reference [7]. Assuming the reference pixel at the location (x, y, t) with intensity $I(x, y, t)$ moves as much as Δx , Δy and Δt in the next frame, brightness determination can be given:

$$I(x, y, t) = I(x + \delta x, y + \delta y, t + \delta t) \quad (1)$$

Assuming that the movement is very small or minimal, then the constraints at $I(x, y, t)$ can be developed to obtain:

$$I(x + \delta x, y + \delta y, t + \delta t) = I(x, y, t) + \frac{\partial I}{\partial x} \delta x + \frac{\partial I}{\partial y} \delta y + \frac{\partial I}{\partial t} \delta t + H.O.T$$

$$*H.O.T. = \text{Higher-Order-Terms / approach solution} \quad (2)$$

From these equations, obtained that:

$$\frac{\partial I}{\partial x} \delta x + \frac{\partial I}{\partial y} \delta y + \frac{\partial I}{\partial t} \delta t = 0 \quad (3)$$

Because it is differentiated against t , becomes:

$$\frac{\partial I}{\partial x} \frac{\delta x}{\delta t} + \frac{\partial I}{\partial y} \frac{\delta y}{\delta t} + \frac{\partial I}{\partial t} = 0 \quad (4)$$

This will produce:

$$\frac{\partial I}{\partial x} V_x + \frac{\partial I}{\partial y} V_y + \frac{\partial I}{\partial t} = 0 \quad (5)$$

Due to the derivative of the position function with respect to the time and the speed, where V_x , V_y are the x and y components of the optical flow $I(x, y, t)$ and $\frac{\partial I}{\partial x}$, $\frac{\partial I}{\partial y}$, $\frac{\partial I}{\partial t}$ is a derivative of images at (x, y, t) with their respective directions. I_x , I_y and can be written for derivatives as follows:

$$I_x V_x + I_y V_y = -I_t \quad (6)$$

2.3. Coordinate value

The coordinate value is the pixel value of x and y in the frame which took on the position of the object and chosen by the operator. This value will change according to the tracking of objects that have been tracked by the optical flow method. The following is an example of how to determine the values of x and y coordinates at 15×11 pixels frame.

The way to calculate the coordinate value in Figure 2 above is displaying the pixel grid in the image. Then, we can find out the value of coordinates by looking for the existence of a green round symbol in the frame. Starting from the top left corner of the frame the value $x = 0$ and $y = 0$.

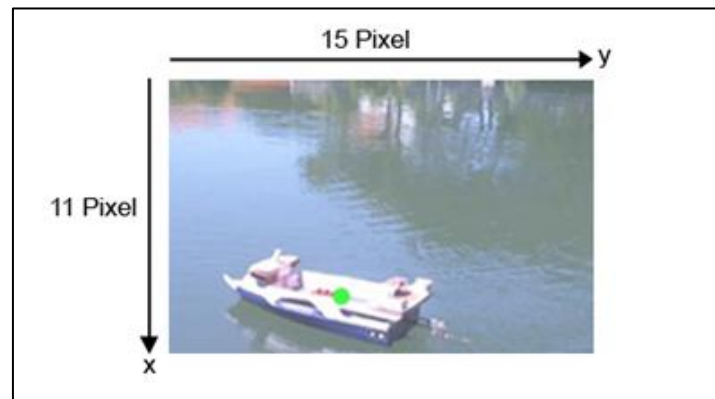


Figure 2. Original image from the camera.

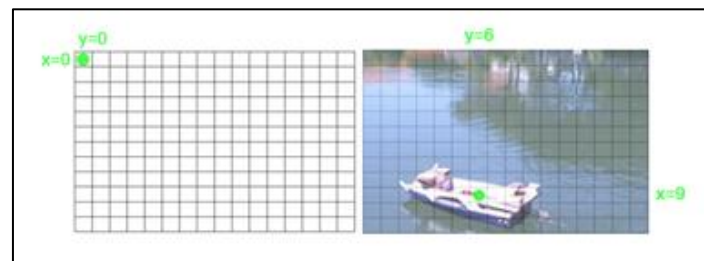


Figure 3. Calculated coordinates on the grid.

2.4. Control system lock object

The computer frame is divided into 4 parts as shown in Figure 4. So, the coordinates of the midpoint are at (320,240) pixel where the coordinates are the target position of the object. In the feature extraction block in Figure 5, the result of image is captured by the camera and selected by the operator. The object inside the selected image will be tracked by optical flow. Therefore, the object can be detected [8]. The object detection results are in the actual coordinate position (x, y) of the object. The E_x and E_y symbols are the result of the actual coordinate difference and the set point whose equation can be written as follows.

$$E_x = X_{ref} - X_{real} \quad (7)$$

$$E_y = Y_{ref} - Y_{real} \quad (8)$$

After the E_x and E_y values were obtained then the next step is entering the proportional control value to determine the servo motor movement [9-11] in the camera and cannon. The control system works to automatically maintain the position of the object at the midpoint of the computer frame as shown in the following image.

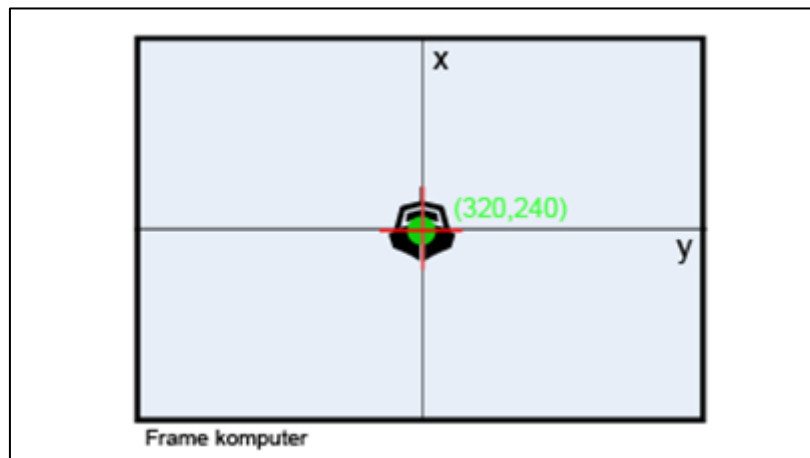


Figure 4. The final position of the object on the camera.

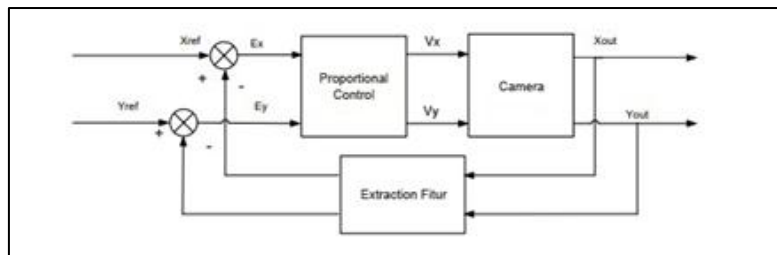


Figure 5. Block diagram of the cannon guns movement.

2.5. Hardware

Figure 6 shows some of hardware used in this research. PC is used as an image processing unit. Tasks here are like displaying a camera frame, managing the camera's catch and converting it into coordinates (x, y). The tracking results were sent to the microcontroller to be re-processed from coordinates to cannon movement.

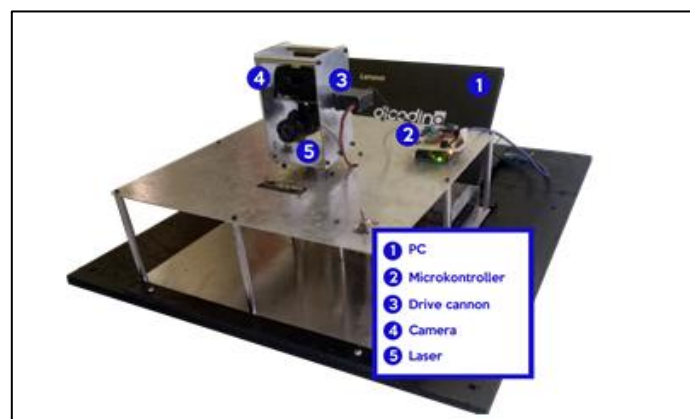


Figure 6. Hardware's connection (1) Central Processing Unit (2) Microkontroller to drive the cannon (3) Cannon driver (4) Camera (5) Laser.

The x and y axis of cannon movements are based on the results of reading the x and y coordinate on the camera frame. The image data itself is detected by the Logitech C525 camera and when the object is locked, the laser is used to indicate the accuracy of the object.



Figure 7. The details of cannon guns design.

3. Testing and data analysis

Testing tools were done with several systems that have been tested, namely testing of object tracking and testing of target locking. The following are the details of the tests that have been carried out.

3.1. Testing of object tracking

Testing of object tracking is started by using the camera to capture objects. Then, the user will select the objects using the mouse. In this case, the chosen object is the ship as shown in Figure 8. The chosen object was marked by a green round symbol. The detection and tracking of ship objects in this test is carried out as much as three times as follows.

From the carried out tests in Figures 8, 9 and 10, there are two colors of the same ship and when it was clicked on one part of the ship it is also detected 1 ship. From these results the researcher has succeeded in implementing the optical flow method by detecting objects with light intensity parameters that move on the starting pixels that have been chosen by the user to the end. To see the real performance of the OFA algorithm, this research was tested the system within 10 meters. All system results are displayed in the test Table 1.

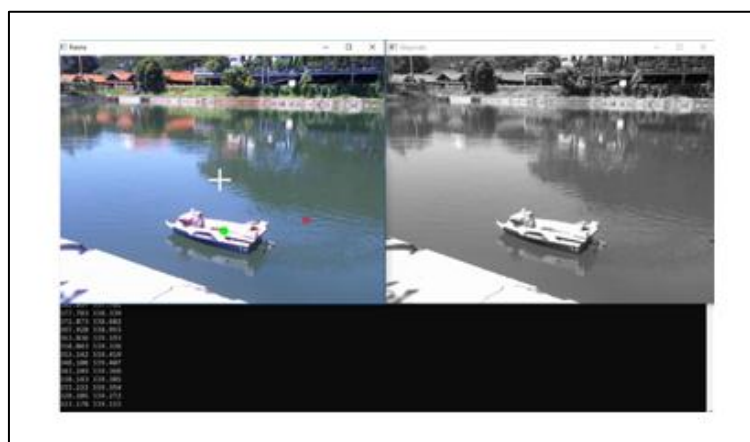


Figure 8. One ship trial section.



Figure 9. Two ships trial section.



Figure 10. Three ships trial section.

Table 1. Testing the distance of object tracking.

Image	Distance	Result	Image	Distance	Result
	2 Meters	Detected		8 Meters	Detected
	4 Meters	Detected		10 Meters	Undetected
	6 Meters	Detected			

Table 1 is the result of tracking distance based on the researchers. The results of the object tracking test on this tool from 10 attempts at a distance of 1 to 9 meters can detect objects with an average accuracy of 100%. But if the distance is more than that therefore the accuracy will decrease. Based on field observations, the decrease in tracking accuracy was depending on the dimensions of the object being tracked. Because at a long distance the object is not visible and the intensity of the light being read has changed.

3.2. Testing of target locking

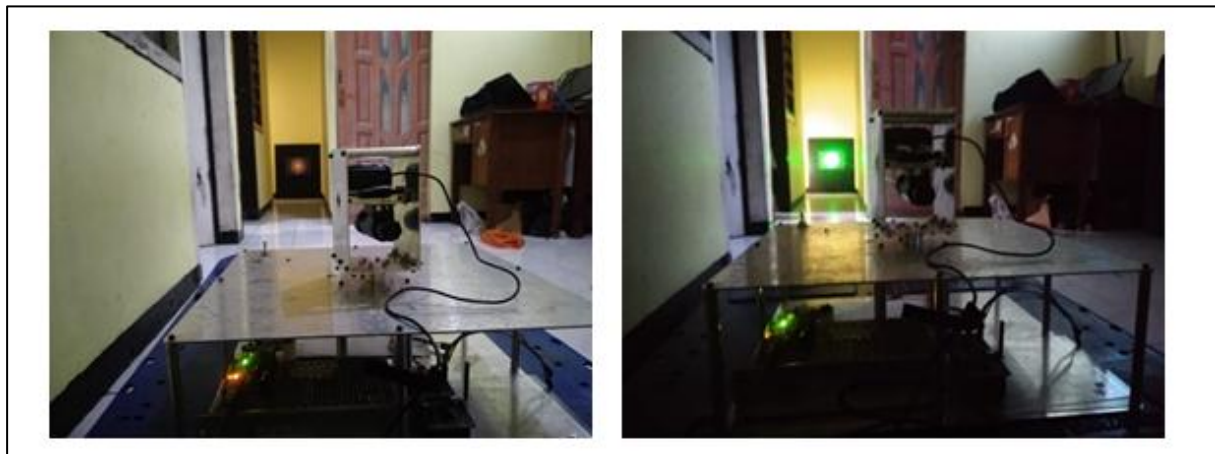


Figure 11. Target detection (left), target locking (right).

Testing the target locking system was done by camera to capture the objects. After the user selected the objects, the chosen object is the target symbol as shown in Figure 11. Due to the coordinate point is not in the desired position, the cannon drive control system works until the position of the object is in the desired position, namely the camera's midpoint. The process of shifting the position of objects is shown in the graph in Figure 12. The system can reach set points within 2 seconds and have an error steady state value of 0.625% using a proportional constant of 0.2.

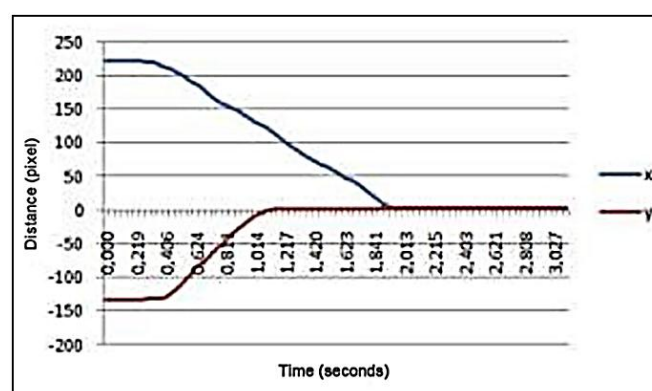


Figure 12. Graph of the system test results.

4. Conclusions

The optical flow method can be reliably performed to detect and track the position of objects reaching at a distance of 9 meters with the dimension of 100×50 centimetres, where the objects are freely chosen by the user. The results of the object tracking test on this tool from 10 attempts can detect objects with an average accuracy of 100% at a distance of 1 to 9 meters. In addition, the target locking

system can reach the set point value within 2 seconds and the steady state error is 0.625% with the selection of the best proportional constant of 0.2.

5. References

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