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Automatics Detect and Shooter Robot Based on Object Detection Using Camera

***Abstract**. Detection color and shape has been widely developed. The target detection and follower robot system has been developed by previous researchers, and in the military world there are still few who develop automatic shooting robots. From it researchers create a robot can detect and shoot targets automatic, where the camera is used to detect the target, while the navigation system uses the PID method. The robot works when it receives a command from the user to search for a predetermined target, the camera will capture, and image will processed in a mini PC to get conformity. After that, the robot will adjust the robot's position to the target, and robot moved closer to the target robot will stop and the system will shoot the target automatically. From the results of the research that has been obtained, the PID value settings that are most suitable for the system are the values of Kp 10, ki 0.9, and kd 0.5. The overall system test got a success rate of 83.3%, with the fastest time to find and shoot targets is 17 seconds. It is hoped that this research can help the military field in implementing an automatic target shooter system.*

Streszczenie.** Kolor i kształt wykrywania zostały szeroko rozwinięte. System robotów do wykrywania celów i śledzenia został opracowany przez poprzednich badaczy, a w świecie wojskowym wciąż niewiele osób opracowuje automatyczne roboty strzelające. Od niego naukowcy tworzą robota, który może wykrywać i strzelać do celów automatycznie, gdzie kamera służy do wykrywania celu, podczas gdy system nawigacji wykorzystuje metodę PID. Robot działa, gdy otrzyma polecenie od użytkownika, aby wyszukać z góry określony cel, kamera przechwyci, a obraz zostanie przetworzony na mini PC w celu uzyskania zgodności. Następnie robot dostosuje pozycję robota do celu, a robot zbliżony do celu zatrzyma się, a system automatycznie wystrzeli w cel. Z uzyskanych wyników badań wynika, że najbardziej odpowiednimi dla układu nastawami wartości PID są wartości Kp 10, ki 0,9 i kd 0,5. Ogólny test systemu uzyskał wynik 83,3%, a najkrótszy czas na znalezienie i strzelenie do celu to 17 sekund. Mamy nadzieję, że badania te mogą pomóc wojsku we wdrożeniu automatycznego systemu strzelania do celu.* (Automatyczne wykrywanie Robot Strzelającychna podstawie wykrywania obiektów za pomocą aparatu)***

Keywords: Robot, Shooter, Image Processing, Camera
Słowa kluczowe: Robot, strzelec, przetwarzanie obrazu, kamera.

Introduction

In the military sector, Indonesia's defense system weaponry technology is quite alarming. The main weapon systems (Alutsista) which are operated by the TNI are mostly between 25-40 years old; they are constantly being cared for and repaired so that they are ready to operate. Most of the spare parts for the defense equipment owned by the TNI-AD are not available, even the factory that makes it no longer produces. At this time, weapons that are on top of tanks or armored vehicles for ground combat are still manually operated by humans. Because the position of this rifle is at the top of a combat vehicle, the operator must be at the top of the tank or armored to operate it. This causes the operator's safety to be less guaranteed, either from enemy attacks or against shocks when passing through very tough terrain[1]. Along with technological developments in the field of electronics, a robot can be made for various activities, but a robot car must be made for the good of humans.[2]. So it is necessary to find a more efficient solution to the problems raised and explained, by applying technology in the military field, especially in ground combat vehicles, in addition to replacing tactical weapon personnel and ensuring safety from the enemy, a solution for a robot design system with digital image processing and automation is obtained[3].

Other research will design the ability of the robot to detect and shoot targets that can be controlled wirelessly[4]. To make the robot capable of doing this requires sensors and the application of special control methods. The robot must be able to perform image processing to recognize what object should be the target of the target through data processing with the help of a camera[5]. In detecting or recognizing objects, the camera can be used as an image sensor that can replace the role of the human sense of sight[6], [7]. The target object detected by a camera sensor can be processed or processed into an information signal[8]. There are methods that can be used in the processing of image sensors or cameras. One of the techniques is to use motion tracking color and shape detection methods with robot vision using image processing with color segmentation, HSV method, RGB is used in robot vision to search for target objects based on shape and color[9]. Robot is a robot that uses to help human activity[10], [11]. Robot vision is a robot that uses a camera as an image sensor to obtain information sources for processing as needed. The main goal of any robot design is to replace the work done by humans. In the development of sensor technology[12], [13], a sensor performance has been developed which is almost similar to the way the senses work in humans[14]. The artificial inteligence can include in the robot system[15]. Therefore, research that combines a target shooting system and a target search and detection system does not yet exist, so researchers researcher wants to make a robot that can find and shoot targets automatically which can later be applied in the military field.

Methode

Block Diagram

In order for the design and manufacture of tools to be carried out systematically and structurally, a system block diagram is made that explains the designed tool.

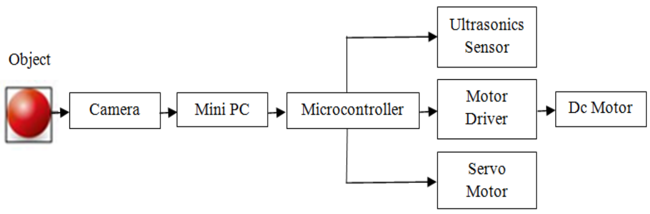

Fig. 1. Block diagram of research concepts

The explanation of the block diagram above is: The target has a color and shape that is a red ball. The camera captures the image sent in a digital image to the microcontroller Raspberry Pi.

1. The Raspberry Pi microcontroller processes image data using the method HSV image processing in detecting shapes and colors.
2. The Raspberry Pi micro controller output is in the form of the target coordinates that are sent to the Arduino Uno microcontroller to drive the dc motor actuator.
3. Ultrasonic sensors are used as distance control in positioning the robot at a shooting distance of 30cm
4. The dc motor driver functions to regulate the motor rotation from stop (0) to max motor rotation (255)
5. Four dc motors to drive the robot forward, right and left conditions.
6. Two servo motors function as a regulator of the angle of the gun barrel and as a pull the trigger gun to shoot

The robot at first does not move when it has not detected the ball target red color where the target position is stationary and not moving, the robot will move approaching the target when detecting and recognizing the target ball shape with color red, at a distance of approximately 1 meter from the red ball target then the system will lock the target shape and color with an interval of less than 5 seconds then the weapon will shoot the red ball target. Fig 2 is ilustrasion robot system.

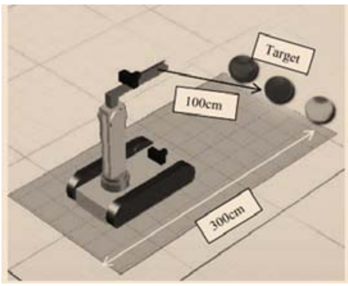

Fig. 2. Ilustration shooter system

From the illustration in Figure 2 above, it can be described as follows:

1. The robot is initially silent when it has not detected the red ball target (target is at rest).
2. The red ball target recognized by the camera is processed in diproses microcontroller using shape detection method and image processing RGB – HSV color segmentation, the microcontroller will send a signal PWM to drive the robot wheel motor.
3. When the robot moves the system will slow down to adjust the shooting distance, namely 100cm from the target with the proximity sensor HC-SR04, the robot will stop and locking the target for less than 5 seconds the microcontroller will send PWM signal to drive servo motor as trigger trigger gun in target shooting.

Design System

The system design in this study is a combination of the three elements are:

1. Mechanical design: initial concept design of shape and dimensions robot to be worked on.
2. Hardware design: in hardware design there are a collection of device modules used and there are two microcontrollers Raspberry Pi as serial vision system with Arduino uno as actuator design and manufacture of this robot.
3. Software design: for customized software design with a microcontroller that is used to process the work of the robot from target processing is detected and recognized by the shape of the color ball red until the robot moves and pulls the trigger of the gun to shoot.

Initial concepts in mechanical design, including modules, microcontrollers and several sensors are designed, built with acrylic material, measured and adjusted. The position of the camera and weapons are installed into a single unit so that when the camera is tracking it will be parallel to the direction the weapon is aiming, like the following fig 3.

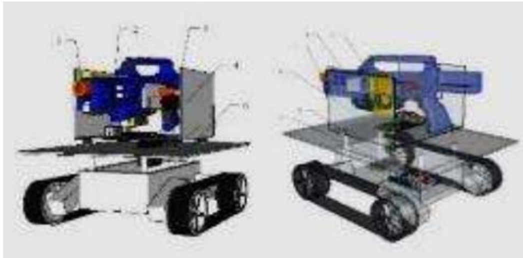

Fig. 3. Mechanics design robot

Motion Robot System

In this section, all processes are carried out by the Arduino microcontroller. Score error generated by image processing on raspberry sent via serial communication to Arduino. This is where Arduino converts the error value These are the vertical and horizontal angles. Error conversion process into a servo motor angle using PID control. PID control will determine what is the value of the angle that will be the input for the dc motor and servo. On arduino will generate a PWM signal to drive the dc motor and servo motor. Fig 4 is motion robot system.

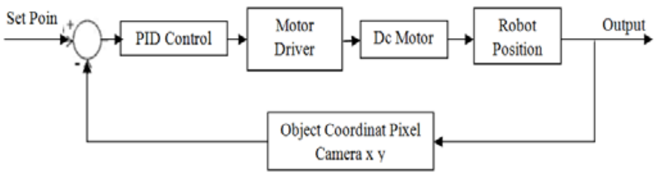

Fig. 4. Robot Motion Control System

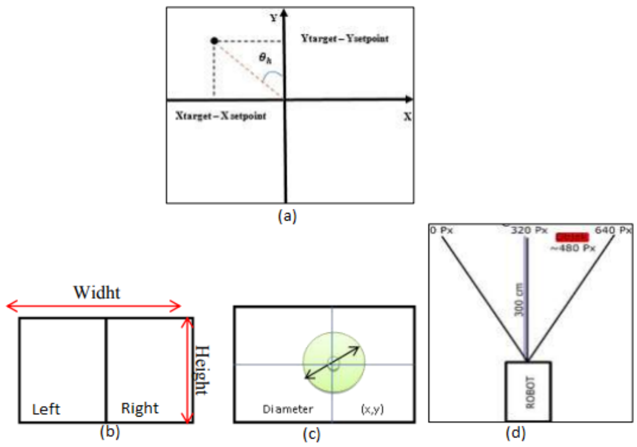

Fig. 5. (a) Coordinate conversion to be servo angle, (b) Ball coordinate, (c) Ball diameters, (d) Camera capture area.

The use of PID control in this study was implemented in Arduino uno microcontroller. Algorithm used to control servo vertical is the same including the maximum and minimum speed thresholds. Besides it is also given a minimum error threshold value to avoid the motor becoming heat due to vibration. The motor vibrates due to small angular changes. The PID control process of this system includes the search for the error value followed by The search for the integral error value is then continued with the error value derivative. The three variable values are proportional, integral, and derivative values which is then added up and used as the

PWM value for control servos. Fig 5 is target coocrdinate concep.

Result and Discussions

Ultrasonics Sensor Result

The first I/O device test is an ultrasonic sensor test where the scenario of the test is to measure the distance between the sensor and the ball using a distance measuring instrument and compare it with the sensor results. The results of the sensor testing there is a difference between the distance measured by the meter and sensor. The average of the resulting differences is 0.3 cm. Following are the test results in the table 1.

Table 1. Ultrasonics sensor result

No	Distance Real (cm)	Distance Ultrasonics (cm)	Deviation
1	10	10.3	0.3
2	20	20.2	0.2
3	30	30.3	0.3
4	40	40.3	0.3
5	50	50.2	0.2
6	60	60.2	0.2
7	70	70.3	0.3
8	80	80.3	0.3
9	90	90.3	0.3
10	100	100.3	0.3

Red Ball Tracking and Detection

This test is a test on the image processing process where there is image processing by detecting a red ball. The red ball can be detected with a program that has been made. Image processing includes several processes or libraries for detecting balls such as HSV, resize, Gaussian Blur, dilation, counturs, and masks.

Gaussian Blur

Gaussian Blur is used to remove noise in the image, this process is used to use counturs so that there are not many dots or noise detected. Gaussian Blur Result at the figure 6. The command used can be seen in the following data *blurred = cv2.GaussianBlur (frames, (11, 11), 0).*

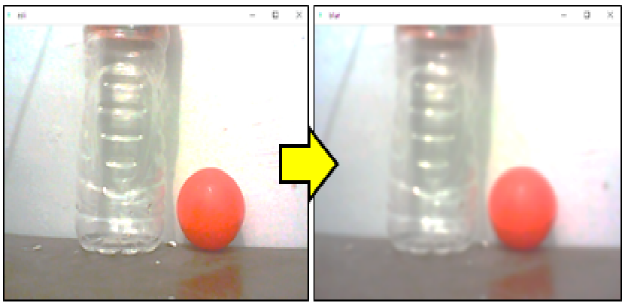

Fig. 6. Results of the Blurred Image process

HSV

In HSV it is used for the process of detecting the color of the ball. This color uses red. The hsv data for red is 10,100,255 so the top and bottom data are written as in the following data: *redLower = (0, 100, 100)*, *redUpper = (10, 255, 255)*. The data is lower data and upper data is in red. The process that was changed to HSV is the process that was done before, namely Gaussian blured. The HSV will be more perfect when processing images where lines are no longer detected in the image. Commands can be seen in the following data, *hsv = cv2.cvtColor (blurred, cv2.COLOR_BGR2HSV)*. From the hsv data, a red color will be taken with the command as below. *mask = cv2.inRange (hsv, redLower, redUpper)* After that, the red color can be detected by the process. HSV images can be seen in the figure 7.

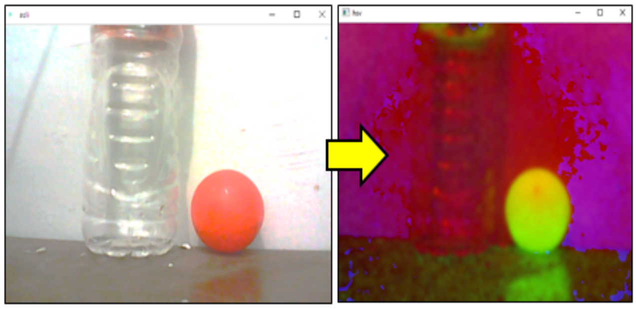

Fig. 7. Results of the HSV processing

Erosion and Dilation

Erosion and dilation are used to remove backgrounds other than red. Erosion and dilation are included in the morphological process, which is to add unnecessary pixel values. Commands can be seen in the following data *mask = cv2.erode (mask, None, iterations = 2)*, *mask = cv2.dilate (mask, None, iterations = 2*). Erosion and dilation images can be seen in the figure 8.

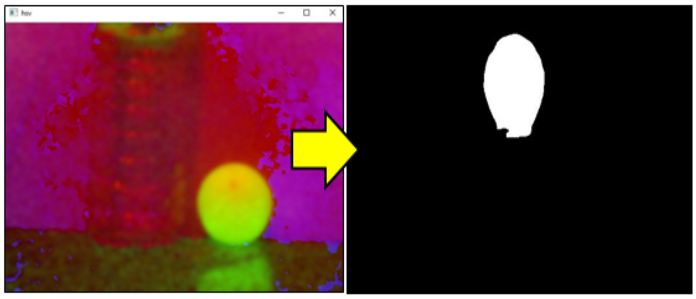

Fig. 8. Dilation and erosion

Countur

The countur in this system is used to limit the color that has been detected, the countur or shape used is a circle or circle type countur. The countur has an accuracy that depends on the camera. The countur command can be seen in the following data, *cnts = cv2.findContours (mask.copy (), cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE).Countur* images can be seen in the figure 9.

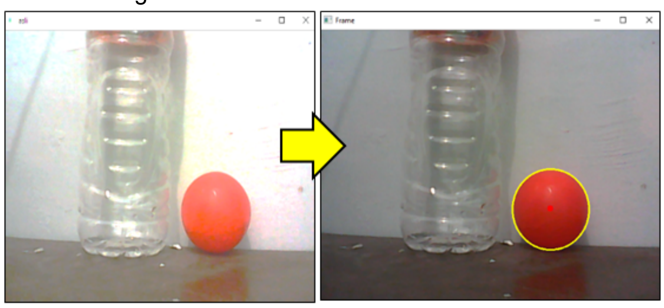

Fig. 9. Countur Detection Process Results

Shape Recognition

In testing this form is where the system will detect the shape of a circle or circle. So only the circle shape that can be detected, other than the circle shape the system will not detect the object. For this test, the shape test uses a light intensity of 96 based on the lux light meter application. the results of shape testing where only circle shapes can be detected by the program. Test results with other forms (sirens, red blocks and red blocks) in the form of figure and tables can be seen in fig 10, and tabel 2.

Fig. 10. Ball detection

In the results of testing the shape of the light intensity is testing the shape with different light intensities. To detect light intensity, the writer uses an android application, namely Lux light meter. Lux light meter can detect light intensity either bright or dark. If it is dark the application will detect the number 0 while if it is light this application will detect numbers above 50. In the test in table 1 there is a light intensity test that has detected and undetected data. In this test the robot can detect colors at a minimum light intensity of 72, if below 72 the robot cannot recognize the color.

The results of the detection distance test are the results to find out how many meters the robot can recognize the target. In this test scenario the author uses a meter to measure the distance so that it can find out the optimal detection distance. The table of test results can be seen in Table 1. In the results of the robot detection distance test, there are several distances tested, namely from 30 cm to 300 cm. In this test the robot can detect from a distance of 50 cm to 290 cm. For a distance of more than 350 cm the robot cannot detect.

Table 2. Shape, luminance and distance object detection

Object	Luminance (lux)	Distance (cm)	Result
Red Ball	50	30	Failed
Red Ball	75	40	Object Detection
Red Ball	90	50	Object Detection
Siren Light	90	70	Failed
Red Ball	98	80	Object Detection
Red Ball	109	100	Object Detection
Red Ball	118	125	Object Detection
Red Ball	130	150	Object Detection
Red Ball	137	175	Object Detection
Red Ball	142	250	Object Detection
Red Ball	156	275	Object Detection
Red Ball	167	280	Object Detection
Red Ball	168	300	Failed
Red Ball	223	300	Failed

Table 3. Data on the results of the PID

Kp	Ki	Kd	Rise Time (s)	Settling Time (s)	Steady State Error (%)
3	0.9	0.5	9.5	7.6	0.53
3	0.8	0.6	12	8.2	0.51
3	0.7	0.5	14.5	8.9	0.56
6	0.9	0.5	10,5	6.1	0.26
6	0.8	0.6	15.5	8.1	0.24
6	0.7	0.5	13.5	7.8	0.3
10	0.9	0.5	8.5	5.2	0.002
10	0.8	0.6	10.5	6.8	0.003
10	0.7	0.5	14.4	8.8	0.005

PID Test Result

In the results of the PID test on the robot, it is used to smooth the movement where the input from the PID is an ultrasonic sensor while the PID output is the PWM on the motor.The search for the values of Kp, Ki and Kd in the PID process is by hand tuning method or commonly known as trial and error. In this test, the input on the PID is a rotary encoder and the output on the PID is the motor speed value. Following are the test results in the table 3.

In table 3 there is the first PID experiment where the system has reached given setpoint where the given setpoint is 30 and the result of PID is to stop at 30. Ts (time settling) is the time required for the response curve to reach a predetermined setpoint. At setpoint 30point obtained Ts is 5.2 s. for steady state error that is the difference between the output value with the input value at steady state. Ess can be searched in the following way this. The steady state error when it gets the PID is an average of 0.01%. That means the system can approach stable and stop at a given set point. From table 1 it is obtained that the results have an average steady state error 0.01% ie with Kp = 10, Ki = 0.9 and Kd = 0.5. With the input rise time value is 8.5seconds and the settling time is 5.2 seconds. In the fig 11 is ilustrasion of PID respon graph.

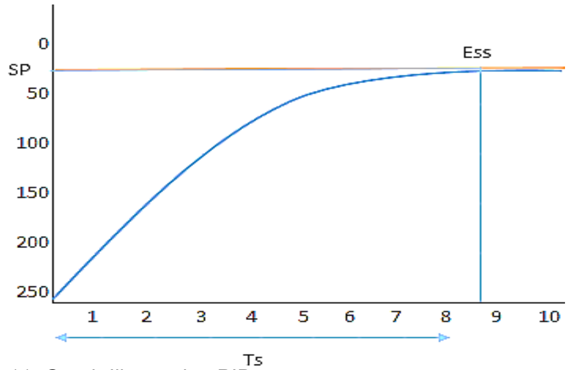

Fig. 11. Graph Illustrasion PID response

Overal System Result

In the whole system test results include all testing on the device. This test scenario is by throwing a red ball in front of the robot where the robot can approach the ball and shoot the ball automatically. Scenario process can be seen in the figure 12.

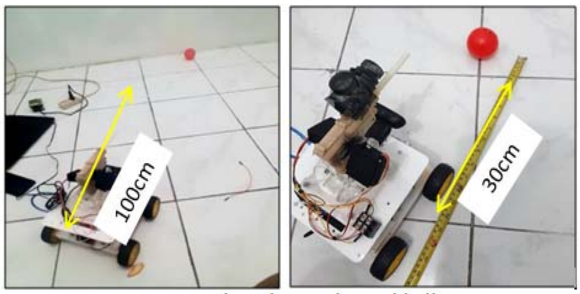

Fig. 12. Test the robot with a red ball target

The system testing is carried out by placing targets at different distances, ranging from 1 meter to 4 meters from the robot's starting point. In this test, the robot's target is a ball with a red color. from the results of the tests carried out later will get some data, including the robot stops in front of the target, the time the robot recognizes and detects the target, and the time the robot can find and shoot the target. The test results can be seen in table 4.

Table 4. Test the entire robot system based on red ball target

Target Distace (m)	Robot Detected Targets (s)	Targets Distance (cm)	Time Robot (s)	Result
1	2,7	30	38	Success
1.2	3,2	30	28	Success
1.5	2,7	30	39	Success
2	4,8	29	20	Success
2,2	4,4	29	17	Success
2.5	3,8	29	21	Success
3	5,1	29	34	Success
3.2	4,7	29	46	Success
3.5	4,2	35	-	fail
4	-	-	-	fail
4	5,6	30 cm	35	Success

In Table 2 there is a test table where the distance specified for testing is 1 to 4 meters with a red ball target. Tests were carried out as many as 11 experiments. The success rate in the trials mentioned above shows that the percentage value of the system test success is 83.3% with a failure rate percentage of 16.7% with the average time obtained in the testing process 30.8 seconds. The failure value is influenced by the size of the pixels on the camera sensor used in this design. The sensor used is 1082 pixel. If the larger the camera sensor pixel is used, the higher the accuracy rate of detecting the target, if the further detection distance according to the table above 4 meters is the farthest distance from the system test. Figure 13 is robot response basen on target.

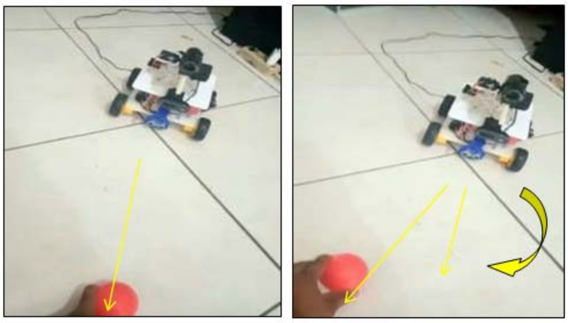

Fig. 13. Response Robot based on Target Position

Conclusions

At the conclusion this time can be seen in the data below. The data is based on device testing. Creating a robot that can detect and recognize objects in a red ball shape at rest. Build a robot that can move automatically to detect a target object in the form of a red ball. Build a robot that can fire automatically at a predetermined distance, with the aim of increasing the accuracy of the robot's fire against the target. From the test that has been obtained, the robot can detect red balls with the best luminance level of 75 lux to 95 lux, where at this luminance value the success rate of detecting objects is close to the expected conditions, stopping at a shooting distance of 30cm. From the system designed where the robot can move automatically based on the detected ball target, where in this test the robot robot is given a distance to the target between 100 cm to 400 cm, from a predetermined distance range, the system can find targets on average time of 4.12 seconds. The robot can shoot to find and shoot targets based on color and shape with a success rate of 83,3% and a failure rate of 16,3% from 11 experiments conducted with the robot's trajectory distance from the target 400 cm with an average time of 30.8 seconds. This research is expected to help the military field in implementing an automatic target shooter system.

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