International Journal of Marine Engineering Innovation and Research, Vol. 8(1), Mar. 2023. 34-42
(pISSN: 2541-5972, eISSN: 2548-1479)

Development of an Optronic Aiming System for Target Tracking on the S60 57mm Cannon Weapon Control System Using a Camera

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(Received: 09 February 2023 / Revised: 02 March 2023 / Accepted: 02 March 2023)

Abstract*— The development of technological science towards the defense of a country is growing rapidly. The country needs increasingly advanced defense technology but is constrained by an increasingly large budget due to dependence on producing countries. The state provides opportunities for technocrats to carry out research that can later create a defense technology that is inexpensive and does not burden the state budget. The artificial S60 57mm cannon is one of the cannons that functions as an air attack deterrent. The operating system of this weapon is still manual. This research will design and prototype an automatic Weapon Control System on the S60 57mm gun. In this development using the Atmega 8 microcontroller is the controller and interface for transferring data from the camera (Optronic) to the servo motor. The result of the camera position (optronics) will be followed in real-time by the gun barrel. In designing a target tracking control system automatically using the proportional control method. The results of testing the ability of the servo motor as a camera driver to follow targets or moving objects with a maximum angular speed of 15.5 degrees/second at a speed of 0.3 seconds, the average frame rate of the camera are 60 fps. c. Based on testing the servo motor using the Atmega8 microcontroller support, the reading of the angle direction of the servo motor is displayed in the Delphi software. Based on the test results, there is a difference between mathematical calculations and measurements using an arc ruler. With mathematical calculations, there is a difference with a value of 1.06 degrees per 1 degree.

Keywords— Bluetooth hc-05, Camera, Kontroler Proposional, Mikrokontroler ATmega8, Optronic.

I. INTRODUCTION[1]

Currently, many developing countries are prioritizing the procurement of the main weapons systems with domestic production. The purpose of using domestic components is to save foreign exchange and reduce dependence on foreign countries so that if there is an embargo, the country is still able to be independent in the main weapon system tools. Indonesia as a developing country also prioritizes the use of domestic components[1].

The S60 57mm cannon is one of the cannons for base defense with the basic function of repelling air attacks[2][3][4]. Cannon Operation still uses human or manual power. This research will design and modify weapon control from a manual to a camera-based controller system[5][6][7][8][9]. This research will use the Atmega 8 as a microcontroller[10][11][12][13][14]. The ATmega controller functions as an interface for transferring data from the camera (optronic) to the servo motor. his system works using target detection and tracking data or moving objects on the camera (optronic) which will be sent to the weapon control system, processed, and then sent to the servo motor as a part of the mechanics to direct the camera position, so that it can follow object movements. which is the target and the desired setting, which later results from the camera position (optronic) will be followed in real-time by the gun barrel. This cannon modification system will be carried out using the P (Proportional) Controller method which allows the realization of a more reliable system for designing an optronic aiming system (camera) for target tracking on the weapon control system using a camera.[15][16][17]. Image processing to control the gun barrel towards the target.

This research designs and manufactures a cannon directional movement operating system to track targets automatically. After that, how is the performance of the optronic aiming system (camera) as target tracking in the process of cannon movement to follow the direction of the camera as target tracking. Then implement the Proportional controller method on the plant to be made. The detection and tracking system for moving targets uses a webcam as a digital image acquisition device.

The purpose of this study is to implement the theory of the Proportional controller method on the plant so that the movement of the elevation motor and training on the Optronic (camera) can be processed by the Weapon Control System to move the direction of the cannon in tracking targets and can control its movement in achieving a set point / angular position. expected. The second goal is to design a camera system as a target monitor and delivery from optronics (cameras) to the Weapon Control System using communication equipment.

This paper consists of 4 parts. The first part discusses why this research was conducted. The second part describes the method used. the next section discusses the results of the data and discussion. The final part is the conclusion and future research of this study.

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II. METHOD

This chapter discusses the design of the system that is created. There are two outlines in the design of the Pan-Tilt system, namely in the design and manufacture of software.

A. System Description

This system uses a microcontroller with the aim of further system development. With a laptop, the system can be developed from video information and the development of image analysis through image processing. While the microcontroller is useful for adding sensors that allow it to be developed in this system and the Proportional logic controller will be run by the computer. The general system diagram is shown in figure 1.

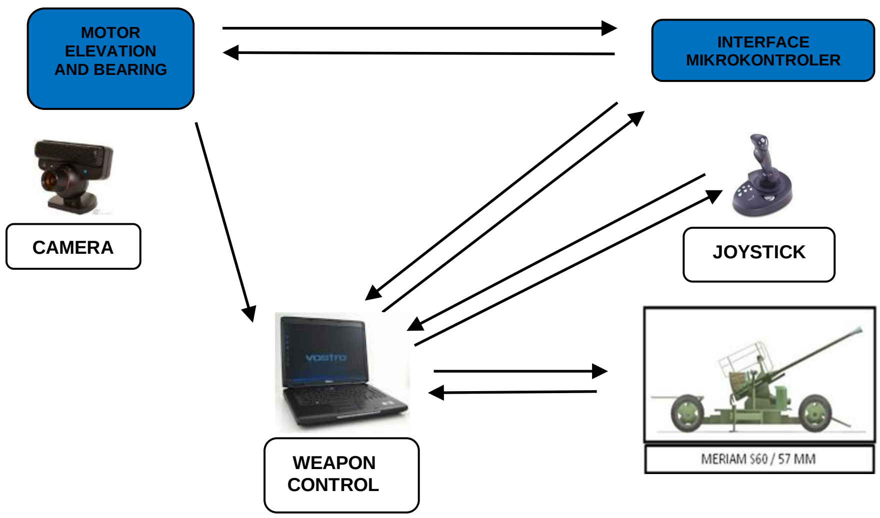

Figure 1 General System Diagram

Based on the block diagram in figure 1, it can be seen that the system in general consists of sub-systems that are interconnected to form a combined system that works interrelated with each other:

a. Camera
   Serves as a sensor to capture targets or objects.
b. Laptops and joysticks
   Serves as a movement control command and monitoring.
c. Drivers
   As a servo motor drive.

B. Camera Mechanical Control System Hardware Design.

Tests are carried out to determine the system performance of the Pan-Tilt system that has been designed[18][19][20][21][22][23][24]. Analysis of the needs for the development of tools will be made as follows:

a. The 9V DC power supply circuit as a voltage provider is taken from an adapter.
b. Design of a Pan-Tilt mount made of acrylic as the basis for placing the camera and servo motor.
c. The minimum system circuit uses Atmega8, used to control all the work of the servo motor control device because it is considered very practical and efficient with various existing facilities.
d. Servo motors are used to drive the mechanics of the camera because they are easy to control.
e. The laptop and joystick function as monitoring and controlling the movement of the camera mechanics.

Control of the camera mechanics has the following characteristics:
• Voltage to drive 9 V DC servo motor
• Training angle (right and left movement) is ± 0º ~ 180º
• The elevation angle (up and down movement) is ± 0º ~ 180º

The hardware design of the camera mechanical control system consists of a stand used as the basis for placing the tool of the system created which consists of a mount for the pan servo motor and tilt servo motor, and an electronic device to drive the servo motor on the camera mechanics.

The mechanical device used to realize Pan-Tilt uses acrylic as the basic material for Pan-Tilt. in the mechanical design it consists of a servo motor as a plant that is used as a mechanical drive for the camera mount towards training and elevation. The electronic device used is a laptop with an Atmega8 module as the microcontroller, power supply, and Bluetooth hc-05. In designing a camera mechanical control system, there is a PS3 eye-type camera as a feedback sensor.

The following will explain in general the hardware-related parts used in this final project. Between the mount of the Pan-Tilt and the tripod. To realize Pan-Tilt, acrylic is used as the basic material for Pan-Tilt, and designs are made using Corel software as shown in Figure 2.

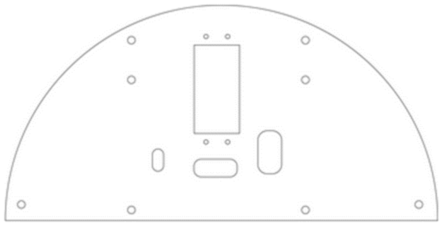

Figure 2 Servo Motor Mount Design

The design of the servo motor mount is used as a place to place the servo motor, namely in the middle, to place the servo motor, Bluetooth module, and the four spacers on the sides of the design which are used to connect the servo motor mount to the base where the Atmega8 board is placed.

The second design is the PS3 eye camera holder which functions as a place to place the PS3 eye camera and is connected to a servo motor. The ps3 eye camera holder is designed using a bracket adapted to the dimensions of the ps3 eye camera used so that it is not easily separated and is safe to use for placing the ps3 eye camera.

The ps3 eye camera and servo motor also use a U-bracket. U-bracket is a bracket that looks like the letter 'U' which is commonly used in robotics applications, namely as a support for servo motors to make joints on the arms of humanoid robots and biomimetic robots. Pan-Tilt requires 2 brackets, namely for the pan servo and tilt servo. Mount using brackets as shown in figure 3.

Figure 3 Bracket

C. Servo Motor Mechanical Device

A Servo motor is a motor that has a feedback system in the form of a potentiometer where the angle and direction of rotation can be adjusted independently. The selection of a standard 180˚ servo motor that moves the camera mount vertically and horizontally is very important in determining the combination of camera mount movements, the motor must have sufficient torque to be able to move the camera mount and compensate for the overall weight of the mechanics. In this design, we use the Hitec Standard Servo HS-645MG servo motor.

The servo motor used is a standard 180˚ servo motor, this type of servo motor is only able to move in two directions (CW and CCW) with a deflection of each

When the Ton duty cycle of the given signal is less than 1.5 ms, the rotor will rotate to the left by forming an angle that is linear in magnitude to the Ton duty cycle and will stay in that position. And conversely, if the Ton angle reaching 90˚ so that the total angle deflection from right - center - left is 180˚. Servo motor operation is controlled by a pulse width of ± 20 ms, where the pulse width between 0.6 ms and 2.4 ms represents the end of the maximum angle range. If the servo motor is given a pulse with a magnitude of 1.5 ms it reaches a 90˚ movement, if we give a pulse of less than 1.5 ms then the position is close to 0˚ and if we give a pulse of more than 1.5 ms then the position is close to 180˚.

The Servo motor will work well if the control pin is given a PWM signal with a frequency of 50 Hz. Where when the signal with a frequency of 50 Hz is reached in the Ton duty cycle condition of 1.5 ms, the rotor of the motor will stop right in the middle.

duty cycle of the given signal is more than 1.5 ms, the rotor will rotate to the right by forming a linear angle to the Ton duty cycle, and stay in that position. HS-645MG Ultra Torque as shown in figure 4.

Figure 4 HS-645MG Ultra Torque

Specifications of servo motors :
- Operating Speed: 0.24 sec/60˚ at 4.8 Volt
- Output torque: 7.7kg. cm at 4.8 volt
- Weight: 55.2g
- Size: 41 X 20 X 38 mm

III. Results and Discussion

A. Bluetooth Mechanical Device hc-05

Bluetooth HC-05 is an easy-to-use SPP (Serial Port Protocol) Bluetooth module for wireless serial communication. The HC-05 uses Bluetooth V2.0 + EDR (Enhanced Data Rate) 3 Mbps modulation using a 2.4 GHz radio frequency. This module can be used as a slave or master mode.

Hardware Specifications:
• Sensitivity -80 dBm (Typical).
• Up to +4dBm RF transmit power.
• Low power operation 1.8V – 5 V I/O.
• UART interface with acceptable baud rate programmed.
• With integrated antenna.

Software Specifications:
• Default baud rate 9600, Data bit: 8, Stop bit = 1, Parity: No Parity.
• Auto connection when the device is turned on (default).
• Auto reconnect at 30 minutes when the connection is lost due to connection range.

B. Characteristics of hc-05 Bluetooth Pins

We connect pin no. 5 (Rx) of the Bluetooth hc-05 connected to the Rx pin on the Atmega8 board and pin no. 4 (Tx) is connected to pin Tx on the Atmega8 board. So that Bluetooth can communicate directly with Atmega8, the pin connections are as follows:
a. The Vcc pin from Bluetooth is connected to 5 Volts (this Atmega8 module already has a 5V regulator on the extended board).
b. The Gnd pin is connected to 0 Volts (ground).
c. Pin no 5 (Rx is connected to the Tx pin on the Atmega8 board).
d. Pin no 4 (Tx is connected to the pin labeled Rx on the Atmega8 board).

C. Camera Module Mechanical Device

The target tracking system has a very important role in determining the success of a system. A digital camera has function as a digital image acquisition device because it must be able to produce accurate digital data according to the actual target. The ability of a digital camera can be seen from the resolution of the images captured. The greater the resolution of a camera, the more accurate the results of capturing an image. Target tracking uses the PS3 eye webcam which has the following features:
• Power consumption : DC5V, Max, 500mA
• Weight: 173g
• Video Capture: 640X480 pixels
• Output interface: standard USB
• Frame rate : - 640 X 480 at 60fps
- 320 X 240 at 120fps

Camera Ps3 eye as shown in figure 5**.**

Figure 5 Modul Camera Ps3 eye

D. Digital Joystick Mechanical Device

The joystick generates two kinds of data, namely training data and elevation data. Where the output data is in digital form so that it can be connected directly to a computer either via a USB (Universal Serial Bus) port, serial port, or parallel port which is available on the market. In this final project, the author uses a Genius MaxFighter F-31U joystick. This joystick is used to drive a servo motor to assist in searching for objects or targets. The Genius MaxFighter F-31U joystick are shown in Figures 6 and 7.

Joystick specification :
• Motor built-in for real vibration effect

Figure 6 Genius MaxFighter F-31U Joystick

- Precise control with ten buttons including trigger
- Includes Throttle/Rudder/Hat Switch controller
- Four suction cups for a stable base
- USB interface-Easy to install
- Supports Windows 7/XP/Me/2000/98

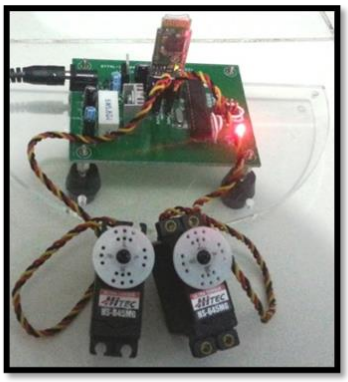

Figure 7 Genius MaxFighter F-31U

The pan-tilt module that has been designed is equipped with a mask (coating) so that it can protect the copper line from short circuits. Figure 7 is the result of the Atmega8 hardware design, namely Pan-Tilt. The two pairs of cables in the middle of the front are cables connected to the servo motor and the HC-05 Bluetooth module which is located in the middle of the top of the board.

The next step is to combine the parts that have been designed using glue, double tip back and forth, and the help of several spacers to get the desired result. The following is the design result of a Pan-Tilt stand without using a tripod as support.

The last step is to combine the parts that have been designed using glue, double tip back and forth, and the help of several spacers to get the desired result. The following is the design result of a Pan-Tilt stand without using a tripod as support. Pan-Tilt Stand Design Results as shown in figure 8.

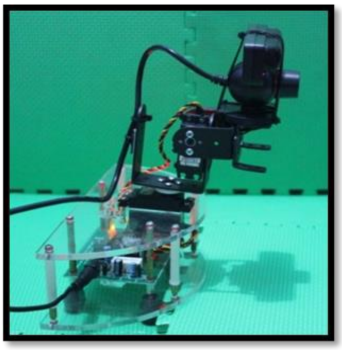

Figure 8 Pan-Tilt Stand Design

E. Mechanical Devices Pan-Tilt driver design

The hardware design is in the form of a Pan-Tilt board to be used as a voltage supply for the two servo motors where the servo motor used requires a voltage of 5 volts to work, and the HC-05 Bluetooth module where the pin of the HC-05 Bluetooth module requires adjustment to be connected to laptops.

The Pan-Tilt board layout design on the Atmega8 was made using the EAGLE software. In the following, we will explain the schematic of the Pan-Tilt board made using the EAGLE software.

The power supply circuit is used as a voltage source for electronic circuits in the Ps3 eye camera Pan-Tilt movement system. The voltage distribution for the electronic circuit in the Ps3 eye camera Pan-Tilt movement system module, as shown in the schematic below, explains that there are several important parts. The 9 VDC 100 Ah voltage from the Accu is used as input for the power supply circuit. The power supply circuit uses a regulator to regulate the 9V input voltage to 5V. This voltage will be the power supply for the two servo motors and the hc-05 Bluetooth module. The voltage regulator used is the LM7805 regulator IC chip to produce a stable voltage of 5 VDC.

The Pan Tilt schematic is shown in figure 9.

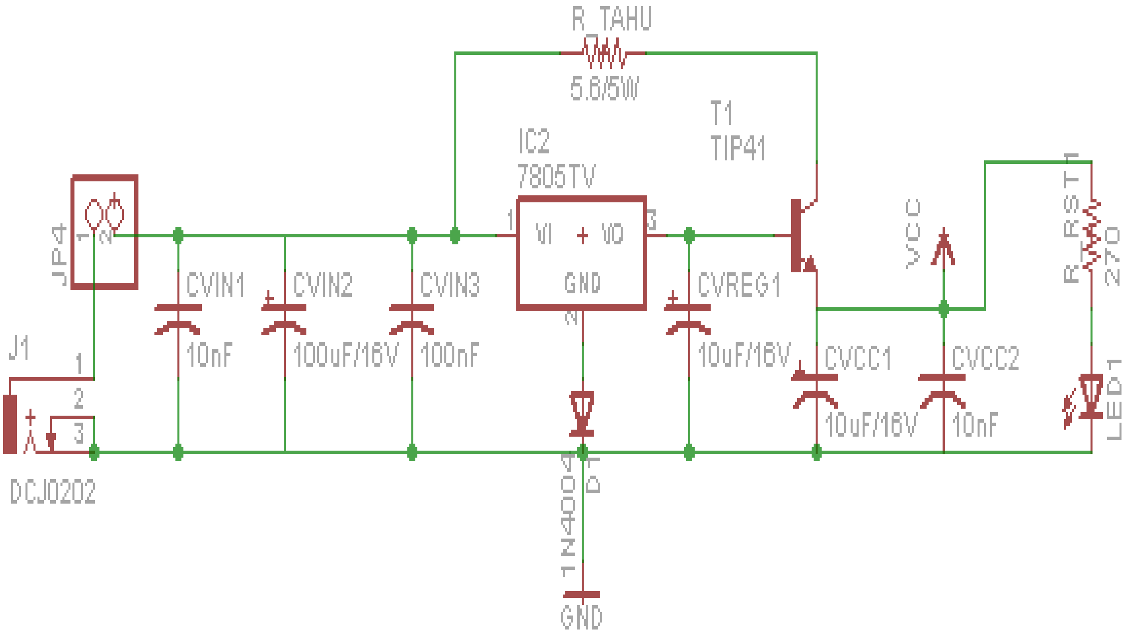

Figure 9 Pan Tilt schematic

F. Atmega8 Minimum System Mechanical Device

This research uses the microcontroller used is ATmega8. Atmega8 is a microcontroller from Atmel Corporation. This type of microcontroller is included in the AVR (Alf and Vegard's RISC processor) type. The AVR microcontroller has an 8-bit RISC architecture, where all instructions are packaged in 16-bit code and most of the instructions are executed in one clock cycle, unlike the MCS51 instruction which requires 12 clock cycles to execute one command. Atmega8 microcontroller minimum system on the Ps3 eye camera Pan-Tilt system. ATmega8 Microcontroller Circuit as shown in figure 10.

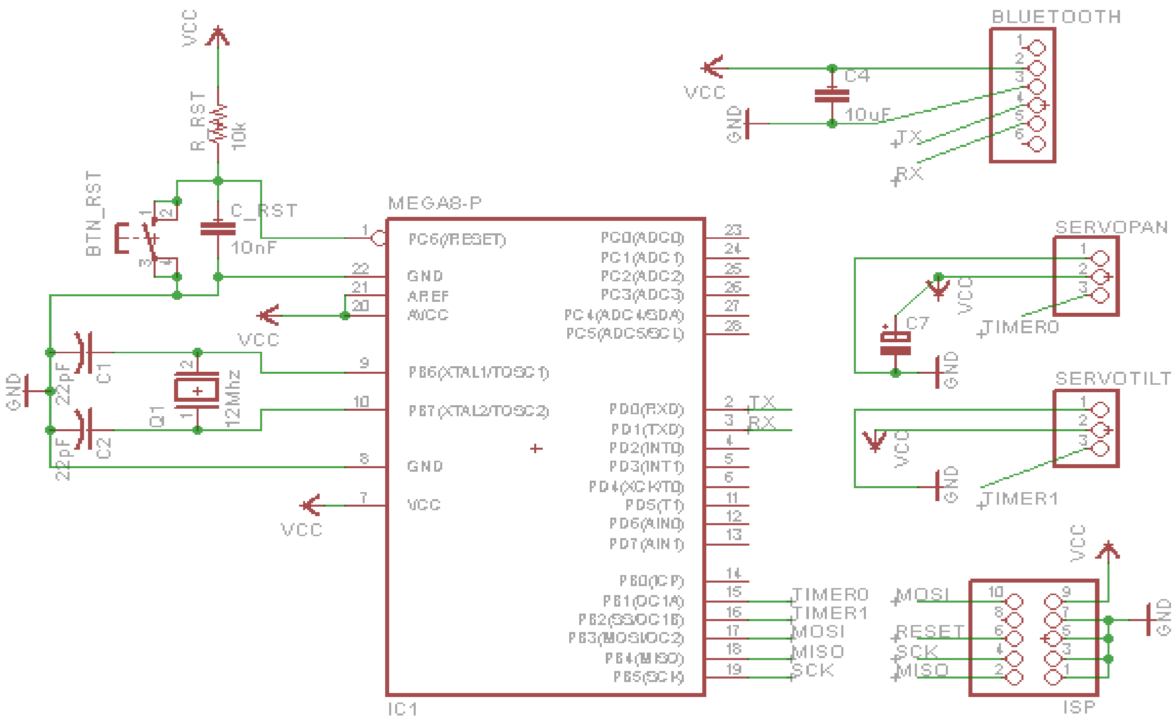

Figure 10 Atmega8 Microcontroller Circuit

This research uses a minimum system to communicate serially with a laptop, besides that the minimum system.

The proportional control signal is sent by the laptop serially then the signal is received and processed by the minimum system. After the Proportional control signal is received, at least the system will send the Proportional control signal to the PWM signal source.

G. Software Design

The software to be designed consists of software for Atmega8 which functions to receive data from a laptop to drive servo motors, and Delphi programming language software which functions as the main processor for the controller and is also used to determine the angular position of the motor shaft and the PWM signal source. Checking permissions is done to access the Bluetooth hardware on the laptop. Next, a search is made for the HC-05 Bluetooth module which will then establish a bond with the laptop so that it can communicate, then access the Virtual Serial Port Emulator software as a bond link with the Visual Studio software. After the process was executed, the Pan-Tilt can already be used. In detail from the explanation above, after Bluetooth and Virtual Serial Port Emulator are bound to each other, data transmission can be carried out.

Through the initial stages, starting with initializing the position of the servo motor so that the position of the Ps3 eye camera is facing an angle of 90˚, the software created obtaining a target image whose position has previously been tracked using an object detector. Objects will be continuously detected by the camera and searched for their center position using both pan and tilt servo motors with the help of a Proportional controller, whose control action sends data to the Atmega8 board to drive the servo motor. After the detected target is right in the middle of the camera's point of view, the software will then take an image of the target detected by the camera.

The essence of the program line above is the movement of the pan servo motor when the position of the face is to the right of the setpoint, the servo will also move to the right when the target is to the left of the setpoint, the servo motor will move to the left, and when the object or target is within the setpoint range, then the servo motor will stop. This applies the same as the servo motor on the tilt axis where when the target position is above the setpoint, the tilt servo motor will move up, when the target position is below the setpoint, the tilt servo motor will move downwards, and when the target is within the setpoint range specified, the servo motor on the tilt axis will stop.Servo controller monitoring form can be seen in Figure 11, which in the form consists of a display of all data issued by the sensor to monitor the joystick handle which is equipped with manual and automatic modes when moving to look for targets, and also a display of the target angle to determine the set point .

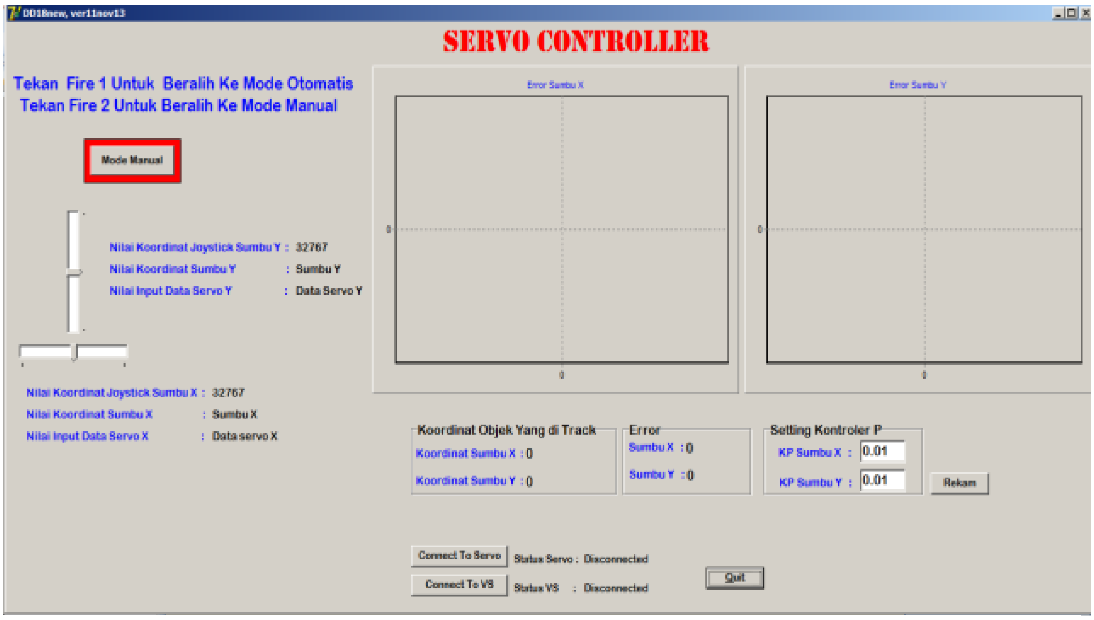

Figure 11 Monitoring Servo Controller

This research uses a control system with a proportional controller method. The movement of the camera holder is based on visual information, namely changes in facial movement using visual studio 2010 software with Open CV. The Ps3 eye camera which is used as a sensor connected to a computer is used to capture images to obtain facial images which are processed to obtain facial positions.

H. Testing Using Proportional Control

In this test, testing is carried out using proportional control, the test is intended to obtain a response value for the movement of the camera holder. Testing is carried out by changing the constant value of the proportional control and giving the system a certain error so that the performance of the controller can be seen whether it can reach the set point or not, and what the optimal proportional value can be used for this servo mounting system. Testing is divided into 2 parts, namely testing the Pan controller and the Tilt controller. By changing the manual tuning value of the proportional controller, the value of Kp = 0.012 is obtained as a test result.

The tuning of the proportional control is carried out at the target speed at t = 3 s/m and also uses the average fps of the tests that have been carried out at a value of 60 FPS. Pan and tilt proportional control tuning tests is shown in table 1.

TABLE 1.
PAN AND TILT PROPORTIONAL CONTROL TUNING TESTS

No	**Proportional Control**	**Result**
1.	0.001	Not successful
2.	0.003	Late Response
3.	0.006	Late Response
4.	0.009	Late Response
5.	0.01	Succeed
6.	0.011	Succeed
7.	0.012	Succeed
8.	0.013	Succeed
9.	0.017	Succeed
10.	0.018	Succeed
11.	0.019	Hunt Motor
12.	0.02	Hunt Motor

I. System Speed Test Reaches Set Point.

The test results at a distance of 1 meter is shown in table 2.

TABLE 2.
TESTING THE MOVEMENT SPEED OF THE SYSTEM TO FOLLOW THE TARGET OF THE REMOTE CAR ON THE X-AXIS AT A DISTANCE OF 1 METRE FROM THE CAMERA POSITION

No	Distance traveled	Time	Velocity		Result
	meters	second	m/s	deg/sec	
1.	1	10	0.1	5.3	Succeed
2.	1	5	0.2	10.6	Succeed
3.	1	3	0.3	15.4	Succeed
4.	1	1	1	20.7	Not Succeed

The test results at a distance of 1 meter are shown in table 3.

TABLE 3.
TESTING THE MOVEMENT SPEED OF THE SYSTEM TO FOLLOW THE TARGET OF THE REMOTE CAR ON THE X-AXIS AT A DISTANCE OF 2 METRES FROM THE CAMERA POSITION

No	Distance traveled	Time	Velocity		Result
	meters	second	m/s	deg/sec	
1.	2	10	0.1	4.3	Succeed
2.	2	7	0.142	6.4	Succeed
3.	2	5	0.21	9.6	Succeed
4.	2	4	0.25	11.7	Succeed
5.	2	3	0.35	12.5	Succeed
6.	2	2	0.53	17.8	Succeed
7.	2	1	1	22.8	Not Succeed

Based on the test results in the table, it was found that the movement speed of the pan-tilt system on the camera mount to follow a moving target from the setpoint to the one meter point on the X axis is a maximum of 0.8 m/s and the maximum speed on the Y axis is 1.7 m/s, so the average maximum speed on the X axis and Y axis is 3.2 m/s.

IV. Conclusion

Based on the data from the results of system design and testing that has been carried out, the following conclusions can be drawn:

a. The proportional controller is designed to be able to control the servo motor to drive the camera towards the target at the elevation and bearing angles but there is still an overshoot
b. Atmega8 microcontroller as a support in the movement of servo motors with wireless data communication, using the hc-05 Bluetooth module as a data receiver from a laptop with a baud rate of 9600.
c. Based on testing the servo motor using the Atmega8 microcontroller support, the reading of the angle direction of the servo motor is displayed in the Delphi software. Based on observations there is a difference between mathematical calculations and measurements using an arc ruler. With mathematical calculations, there is a difference with a value of 1.06 ˚ per 1˚. For future research, it is recommended to use a camera that has a higher fps so that a better sampling rate is obtained it can improve the performance of the controller so that it can track air targets. Development and improvement of control software capabilities to produce position control with a faster response time and smaller steady-state error. In the future target detection research uses continuous cameras so that later it can be applied to patrol boats that do not yet have target detection using cameras

Acknowledgments

The authors gratefully acknowledge Sekolah Staf dan Komando TNI Angkatan Laut, Cipulir, Jakarta, Indonesia, and Sekolah Tinggi Teknologi Angkatan Laut, Surabaya Indonesia for their advice and facilities.

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