Coil-gun Turret Control System by Using Digital Compass on Helmet

Mukhammad Syifa’us , Didik Setyo Purnomo, Indra Adji Sulistijono.

Department of Mechatronics Engineering, Electronics Engineering Polytechnic Institute of Surabaya (EEPIS)
EEPIS Campus Sukolilo, Surabaya 60111, Indonesia.
Tel: +62-31-594-7280 ext. 4186; Fax: +62-31-594-6114;
Email: {didiksp,indra}@eepis-its.edu, {muh,emink}@student.eepi-its.edu

Abstract — ***In this project designed and constructed based Auto Tracking Turret Movement Helm. This final project is inspired from the target tracking system used on aircraft today is Helmet Mounted Sight (HMS). Then the technology was combined with artillery. As we know anti-air attack of conventional artillery shells fired at high speed and fired at random to shoot down the target. Not only for the defense of air attacks, this system can also be mounted on ground combat vehicles such as tanks and also can be mounted on aircraft or helicopter, or on ships. This system uses the IMU (Inertial Measurement Unit) for sensing movement of the head, and use the motor dc as aktuatornya. To obtain the response and accuracy, required synchronization sensor with a precise actuator. Every movement that captured the sensor must be able to be translated into motor movements to obtain the appropriate accuracy. It is expected that the turret can be controlled using the CMPS10based to measure head movement and has a good accuracy.***

Keywords* : *HMS (Helmet Mounted Sight), Artillery, Turret, IMU (Inertial Measurement Unit).

I. INTRODUCTION

Needs equipment upgrades will support the State's defense continues to increase. With increasing technological digunkan other countries, then we must also do development so as not to compete with other countries. Therefore, defense technology used another State is confidential, inevitably we must develop its own defense, especially in supporting the heavy weaponry (Artillery). Control technology heavy weapons can be categorized into two, namely the use of manual control and automatic control. The purpose of the manual control is controlled by a human turret directly is to use existing lever on the turret, or a remote that controls the turret without touching them directly or using a tool bantu.Turret is a platform that allows the weapon he was carrying to perform the movement. For example on the Common Remotely Operated Weapon Station (Crows) (wikipedia.org, 2010) mounted on the cars American army Humvees. The automatic control is to use artificial intelligence to control the movement of the turret.Examples of its use in LOARA an antiaircraft system manufactured by RADWAR Corp..LOARA (radwar.com.pl, 2010) using a variety of sensors such as: radar, camera to detect the target. Each of the above technologies have their respective shortcomings in controlling the turret, such as the remote system either manually or directly by hand in controlling the turret it is harmful because the operator must keep an eye on the target at the same time moving the turret. While the automated system uses a relatively limited artificial intelligence in action.

Control the turret at the end of this assignment using the operator's head movements.Operators use a special helmet in which there is an accelerometer sensor. The accelerometer sensor is used as motion sensing. Then the data is processed using a microcontroller to drive the motor on the turret.

Therefore, in this project developed a turret control system using head movement with this technique which can cover the lack of manual control systems and automatic control systems.

II. CONSTRUCTION

A. Mechanical Construction

Mechanical construction is one of very important factor in this study because if the design is appropriate and whether the results will be good as well and in accordance with the original purpose of submitting this paper. Gun turret is where the dome-shaped weapon that can protect the crew or the mechanism of the weapon and at the same time allow the weapon to shoot in different directions. This picture below is real design of gun turret of USS Iowa 16inch gun turret. Based on this design we can create our own design for coil-gun. **Figure 1** as follows.

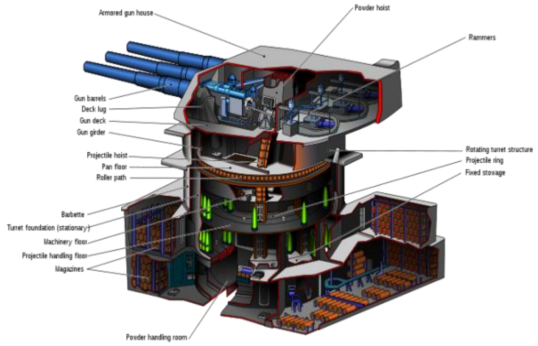


Figure 1. Design of gun turret in USS Iowa[1]

Now we'll show coil-gun turret mechanical design and construction in **Figure 2** and **Figure 3** as follows.

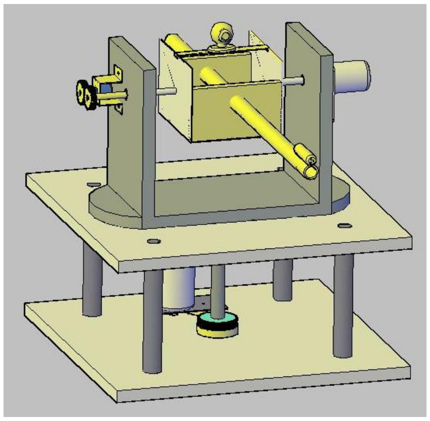


Figure 2. coil-gun turret's mechanical design using software Autocad

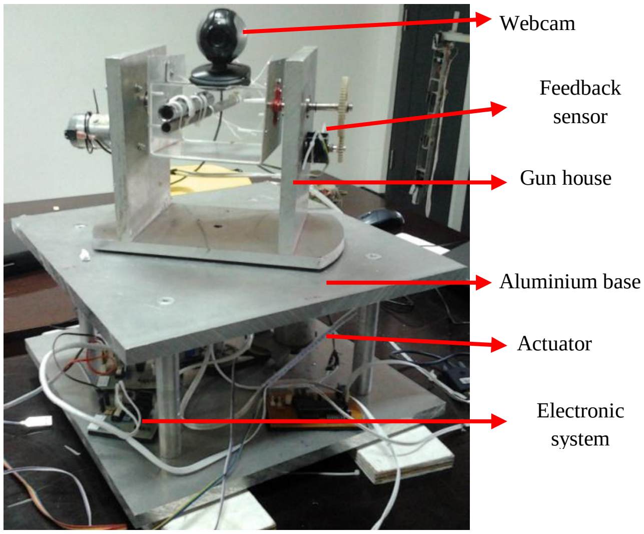


Figure 3. Coil-gun turret implementation

This system consists of two main parts, namely the base and the turret. Base sectionserves as a buffer from moving parts so that the system rigid and sturdy. Base as wellas mounting a motor for rotational yaw motion. This section is made of two squarealuminum plates were then given 4 as penyagga are also made of aluminum. Base40cm x 40cm has dimensions x 19.2 cm. Dc motor to drive the turret connected to thedrive shaft using a timing belt. In order not to shake the drive shaft and smooth whenrotated so the top and bottom mounted bearing that rests on the base.

Here is a helmet that is used to control the movement of the turret. In this hel CMPS10 mounted sensors that are placed behind the aluminum plate for mounting the sensor should be in this position in order to work properly. On the ujunga helmet mounted laser pointer is used to determine the target.

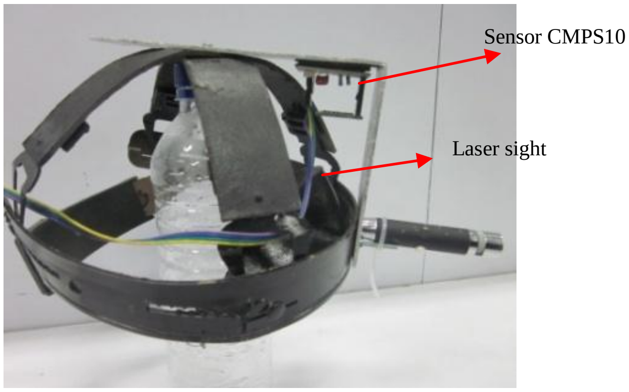


Figure 4. Helmet Mounted Sight

B. System design

The system will be comprised of mechanical, hardware, and system control. Mechanics consists of two parts, namely the base and the turret. Where the base is where the turret is attached. Turret can move the rotation axis pitch and yaw. Hardware consists of sensors, actuators, and controllers. Where is the IMU sensors used consisting of a digital compass and potentiometer. While the actuator consists of the motor. For the control system is divided into two, namely the control of slow-targeting using targeting fast image processing and use control of the operator directly.
Here is how the system as a whole. Where the marked is the focus of this project.

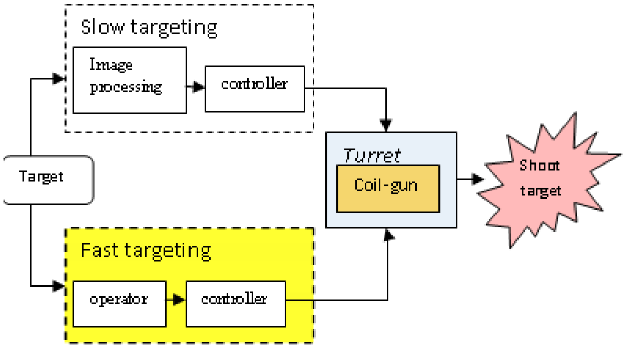


Figure 5. system design

C. Head movement model

the movement of every object in three dimensional space, the movement of the head has three degrees of rotational freedom and three translational degrees of freedom. Figure 2.2 shows the schematic of the movement. Grakan maximum speed of rotation of the head will determine the limits that must be met by tracking head movements. Some literature mentions a maximum rotational speed of 360o / s, List (1984) up to 2000o / s, Aliaga (1997).

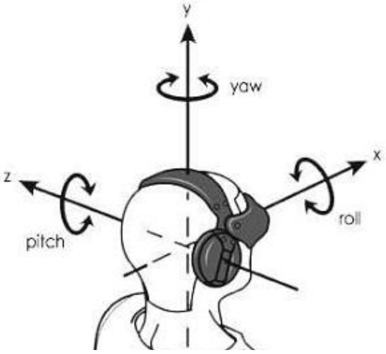


Figure 5. *Head motion*, 6 degree of freedom. (Keir, M. S. 2008)

The detection of head movement is highly dependent on the application being made. For example, a fighter pilot would target space will be very different from doctors who were conducting operations on patients. Head movement is also complex, irregular at a given time and can be very messy at the moment, it makes predictions difficult or unpredictable.

D. Hardware design

The controller is designed based sensors and actuators are mounted on mechanical systems. The sensors consist of three-axis digital compass (pitch, roll and yaw) is installed on your helmet, then potentiometer mounted on the turret to determine the actual position of the turret. As for the actuator consists of motor dcyang first inserted into the driver circuit. The circuit uses minimum system ATmega32. Here is the design of electronic hardware.

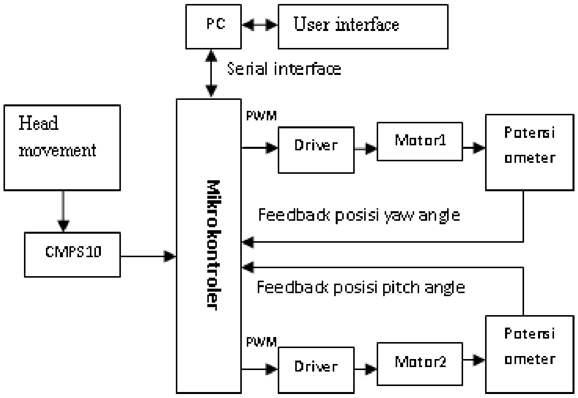


Figure 6. hardware design

CMPS10 sensor using I2C interface is mounted on PORTB.0 and PORTB.1. SDA pin into PORTB.0 while the SCL pin is connected to PORTB.1. For the potentiometer connected to PORTA which is input to existing internal ADC in ATmega32. To provide a PWM signal to the driver using PORTC. The driver uses a 24v power supply to drive the two dc motors as aktuator

E. Control design

The control system design that is built consists of several sensors and actuators which support the proposed methodology, in this case PID. The sensors used are digital compass as head movement sensor, potensiometer as position sensor. The actuator is two DC motor for pitch and yaw mechanism. The PID formulation is a classic controller typically represented by the following figure

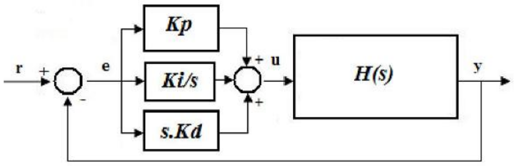


Figure 7. PID Control model

$$u = Kp.\varepsilon + Ki\int e(t)dt + Kd\frac{\Delta e}{\Delta t}$$

In the program, equation will be translated the following program:

$$PID = P_{term} + I_{term} + D_{term}$$

$$P\_term = kP * error$$

$$I\_term = kI * error + I\_term\_old$$

$$D\_termx = (error - error\_old) * kD$$

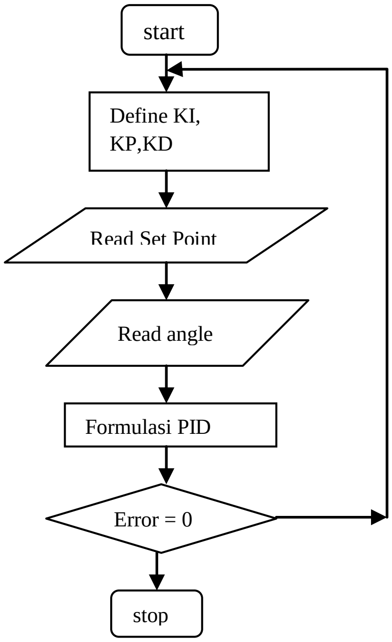


Figure 8. flowchart of controller programming

E. Ziegler-nichols tuning method

PID control has the constants Kp, Ki, Kd which can be searched using the Ziegler-Nichols rules. In 1942 Ziegler and Nichols describes a simple mathematical methods are each used for tuning PID control. This method is performed using the experiment with the assumption that the model of the plant is unknown. This method uses the output of the closed loop system oscillates periodically using only proportional control just like in figure 2.10.

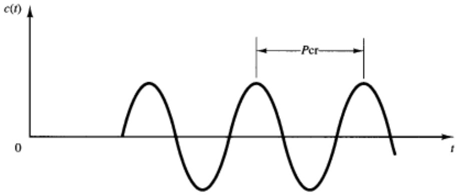


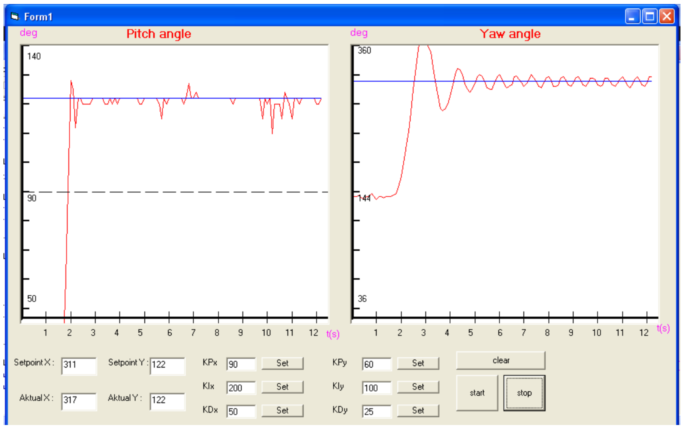
Figure 9. periodic osilasion graph

Table 2.3 ziegler-nichols tuning

Tipe kontrol	Kp	Ti	Td
P	0,5 Kcr	~	0
PI	0,45 Kcr	Pcr/1,2	0
PID	0,6 Kcr	0,5 Pcr	0,125 Pcr

F. Result And Discussion

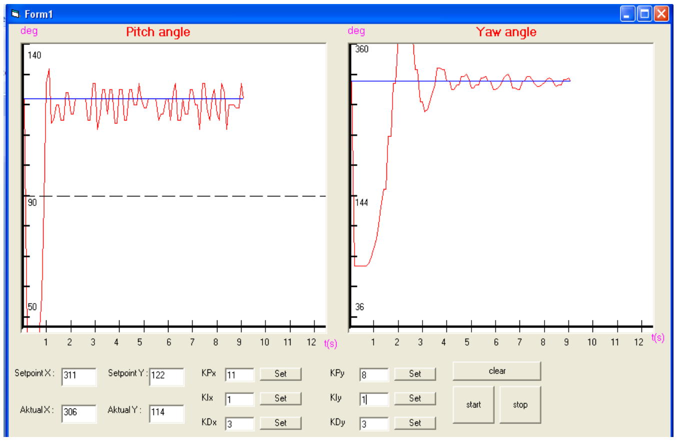
This part will report the result of experiment on the plant based on control system design. The program for controller is in accordance with the proposed control method. This experiment has a purpose to know the robustness of the system. The first experiment is done using PID control by tuning the Kp, Ki, and Kd at first. Tuning method using Ziegler-nichols rule. The result of calculation and output graphic of setpoint and actual reading.



Setpoint X : 311
Setpoint Y : 122
Aktual X : 317
Aktual Y : 122
KPx 90
KIx 200
KDx 50
KPy 60
KIy 100
KDy 25

Figure 10. GUI for experiment turret coil-gun

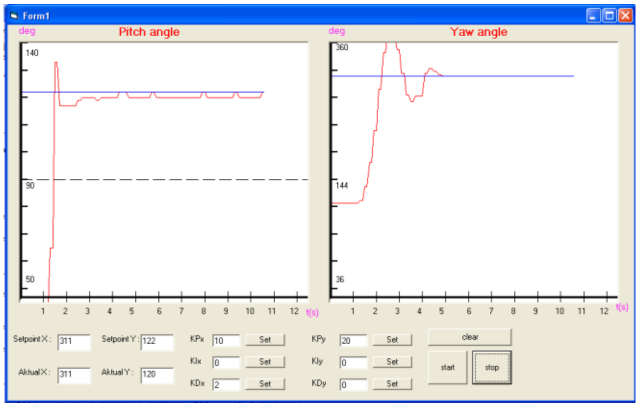
Pitch angle Kp:8 Ki:1 Kd:3Yaw angle Kp:11 Ki:1 Kd:3. The result shows in figure 11



Setpoint X : 311
Setpoint Y : 122
Aktual X : 306
Aktual Y : 114
KPx 11
KIx 1
KDx 3
KPy 8
KIy 1
KDy 3

Figure 11. GUI for experiment 1

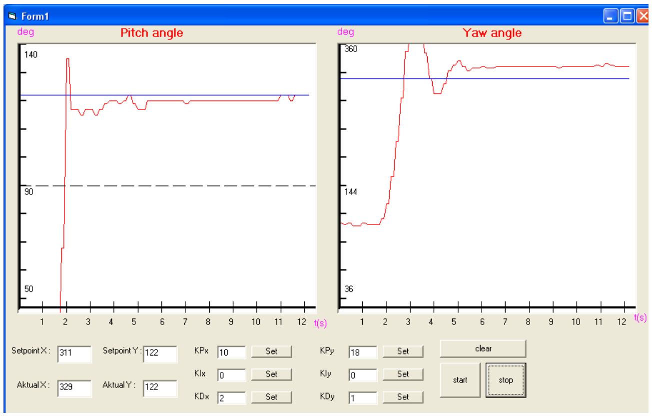
Pitch angle Kp:20 Ki:0 Kd:0Yaw angle Kp:10 Ki:0 Kd:2. The result shows in figure 12



Setpoint X : 311
Setpoint Y : 122
Aktual X : 311
Aktual Y : 120
KPx 10
KIx 0
KDx 2
KPy 20
KIy 0
KDy 0

Figure 12. GUI for experiment 2

Pitch angle Kp:18 Ki:0 Kd:1Yaw angle Kp:10 Ki:0 Kd:2. The result shows in figure 13



Setpoint X : 311
Setpoint Y : 122
Aktual X : 329
Aktual Y : 122
KPx 10
KIx 0
KDx 2
KPy 18
KIy 0
KDy 1

Figure 13. GUI for experiment 3

In the first experiment the system can not be stable and ongoing oscillations. So also in the second experiment. This occurs because the Ki value 1. Integral control can indeed reduce the steady state error but Dapa cause overshoot or even oscillation. In the fifth trial Ki value was eliminated and the system can be stable but with a large steady state error. If the sampling data on the GUI is 100ms then the time required to reach 3.9 seconds for the yaw angle, while for the pitch angle requires a longer time that is 5.4 seconds. Steady state error for the yaw angle measured 6.4% while for the pitch angle reaches 20%

H. CMPS10 reading experiment

In this test is to measure the accuracy of the data readout on CMPS10 yaw. This output data in the form of angles 0-360 degrees, where the value of 0 indicates the north of the earth. Setting this test using a protractor as a reference in the reading corner.

Table 2. result of CMPS10 reading

experiment	yaw angle(^{o})	CMPS read	error(%)
1	40	38	5
2		39	2.5
3		39	2.5
1	90	92	2.22
2		92	2.22
3		92	2.22
1	130	127	2.307
2		128	1.538
3		128	1.538
1	150	153	2
2		153	2
3		154	2.667
1	180	184	2.22
2		184	2.22
3		185	2.78

G. Response system experiment

In this test obtained from the sensor setpoint CMPS10. Setpoint is changed by the operator's head movements. Thus, the turret will follow the operator's head movements. Pause movement between the movement and turret operator will be acuuan how fast the response of this system. The result shows in table1

Table 1. result of response system experiment

Setpoint		Actual		Respon (s)	Error (yaw) %	Error (pitch)%
Yaw (^{o})	Pitch (^{o})	Yaw (^{o})	Pitch (^{o})			
224	96	224	96	2	0	0
132	117	130	117	2.7	1.5	0
230	83	230	83	2.9	0	0
165	133	167	127	2.4	1.2	4.5
237	120	237	119	2.7	0	0.8
117	68	121	70	2.8	3.4	2.9
53	128	53	127	1.8	0	0.7
236	127	237	125	1	0.4	1.5
84	127	88	122	2.5	4.7	3.9
243	52	243	50	2.2	0	3.8

$$\% \, error = \left|\frac{\text{Target} - \text{ActPos}}{\text{Target}}\right| \text{x}100\%$$

$$\overline{e\ yaw} = \frac{\Sigma error}{10} = \frac{11.2}{10} = 1.12\%$$

$$\overline{e\ pitch} = \frac{\Sigma error}{10} = \frac{18.1}{10} = 1.81\%$$

The larger errors indicate less precise tuning of PID and also the slower the response, indicating the value of PID is still not quite right. To speed up the response required the addition of the value of KP's but if too large will cause overshoot. With an average error for the yaw 1.12% and 1.81% for the pitch then it can be deduced. The average error of the pitch and yaw movement is quite small this shows is fine tuning PID

G. Conclusion

Based on the results of experiments and analysis it can be concluded that:

- Response KPx turret with a value of 10, Kix 0, KDx 2, KPy 20, KIy 0, KDy 0 which is 1 second fastest was 2.9 seconds too late. With an average response reaches 2.34 seconds
- Application of the value of Kp, Ki, and Kd using Ziegler-Nichols tuning method makes the system can not be stable and constant oscillation occurs.
- Setting the value of Kp, Ki and Kd is best KPx 10, KIx 0, KDx 2, KPy 20, KIy 0, KDy 0
- Digital compass readings CMPS10 data quite well with an average error value of 2.45%

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