E-ISSN: 3025-0994
Halaman 206-217
Volume 2 Nomor 2 Tahun 2024

Four Wheel Omni Trajectory with Gyrodometry Method in the Indonesia 2022 Ash Robot Contest

Imam Sutrisno[1], Daffa Alifian Harlinanda[1], Zindhu Maulana Ahmad[1], Projek Priyonggo[1], Aprinaldi Jasa Mantau[2], Ari Wibawa Budi Santosa[3], Muhammad Khalil[4], Fahmi Umasangadji[5]

[1]Politeknik Perkapalan Negeri Surabaya
[2]Kyushu Institute of Technoogy, Japan
[3]Universitas Diponegoro Semarang
[4]Politeknik Negeri Tanah Laut, Indonesia
[5]Sekolah Tinggi Ilmu Pelayaran Jakarta
e-mail: imams3jpg@yahoo.com

Abstract

The National Achievement Center (Puspresnas) and the Ministry of Education and Culture of the Republic of Indonesia proudly present the Indonesian Ash Robot Contest (KRAI), a yearly student robotics competition where teams tackle ash-related challenges with their robot creations. At KRAI 2021, it was shown that many robots were controlled using joysticks and resulted in a lack of effectiveness in robotic motion. The use of a joystick makes the movement of the robot take longer. This is because the robot is controlled by humans and the robot has not been able to pinpoint the robot's location. Gyrodometry is a method to map the robot's position using a inner ear and compass of the machine. In this research, Gyrodometry is used to map the position based on the readings of the gyroscope sensor and rotary encoder so that the robot can move automatically. In this research, the KRAI hitter robot can map positions and move in an accurate direction and can move automatically and effectively so that it can save more time and can increase the possibility of strategy in the match. From the results of this study, it was found that without using gyrodometry the error of X reached 11.825 cm and Y reached 35.1325 cm and also the angle error reached 13.7 degrees. and by using gyrodometry error X reaches 4.25 cm and Y reaches 5.775 cm and angle error 2.01 degrees. From these results, it was found that using gyrodometry was better than without using gyrodometry. The addition of waypoints to the robot only produces an average error of 8.2 cm X and Y error of -7.8 cm and the angle error reaches 10.2 degrees.

Keywords: *Robot Contest, Gyrodometry, Four Wheel Omni Trajectory*

INTRODUCTION

Gear up for the Indonesian Robot Contest (KRI), a premier design and engineering showdown for university students in Indonesia. Organized by the Center for National Achievement under the Ministry of Education and Culture, KRI is your chance to showcase your skills and creativity in the exciting world of robotics.

Lagori is a traditional game originating from India. In this game there are two robots, namely throwing robots and building robots, in each game there are two games and in two games each team gets the roles of seeker and hitter in turn. When the first game acts as a seeker, the throwing robot has the task of throwing a ball that aims to drop the Lagori and the compiler robot will pick up the Lagori that fell in the Lagori area and arrange them to form a pyramid. A ball will be placed on top of the seeker robot when compiling Lagori. When the second game acts as a hitter robot. The composing robot goes to the ball area to pick up the ball. The throwing robot throws the ball that is above the opponent's building robot to thwart its mission. (Asia-Pacific Broadcasting Union, 2021)

In general, the robot motion system, such as the speed of a car, is only able to move forward, backward, turn left, and turn right, whether it has four wheels or only two wheels. Robot movement like this is considered very limited and inefficient. Therefore, many researchers carry out further development of the movement of the robot. This is done so that the robot is able to perform movements that are more accurate and precise. In addition, image of a robot flawlessly adapting its movements to any environment, such as diagonal movements, rotating 360 degrees, etc. One of the wheels capable of performing these movements is the omni wheel.

Omni wheels have small wheels on each side that are attached to each of the main wheels, this serves so that the wheels can continue to rotate even though the movement of the robot is not in the direction of the rotation of the wheels. If you look more closely, you will see that the small wheels are designed with a certain distance from each small wheel attached to the main wheel, this is so that the wheels still have a 'circular' nature, so that the movement of the robot can remain smooth. (Pradito, 2015)

Science and technology are evolving at breakneck speed, reshaping every aspect of our lives, including how we learn and create in the scientific realm. From cutting-edge laboratories brimming with robotic assistants (image of a futuristic lab with robots analyzing samples) to immersive virtual reality simulations dissecting the human body (image of a student wearing a VR headset exploring a 3D model of the brain), technology is fueling scientific discovery and exploration like never before. The boundaries between research and reality are blurring, paving the way for a future where innovation knows no limits. One of them is robotics technology. More and more robotic innovations are being created both in terms of saving energy sources and being time efficient. A robot can be said to be perfect when it can reach all directions without having to turn or turn around. However, Moving mountains with robots. One of the biggest challenges in robotics is getting these amazing machines to navigate diverse environments with ease. Whether it's scaling mountains, crossing rivers, or squeezing

through tight spaces, robot mobility is a complex puzzle begging to be solved.. (Fahmizal, 2019)

The 2021 ABU Robot Contest wasn't just about speed; it was a showcase of robotic engineering ingenuity. Teams had to design and build robots where every gear, motor, and sensor worked in perfect harmony to ensure flawless wheel movement. From perfectly calibrated encoders to robust suspension systems, the contest pushed the boundaries of what's possible in achieving wheel accuracy that's out of this world. Inaccuracy or failure of the robot in moving in the direction of its motion can be caused by the absence of sensors in detecting the direction and position of the robot, and also the uneven surface area. Imagine robots moving with such graceful efficiency and pinpoint accuracy, they could put professional dancers to shame. That's the ultimate goal of optimal robot movement. It's about finding the perfect balance between swiftness and control, where every step is calculated and executed with laser-like precision (Sutrisno, 2014)

METHODOLOGY

2.1 Odometry

While odometry is a powerful tool, it's important to remember that it's not perfect. Factors like wheel slippage or sensor errors can cause inaccuracies over time. That's why robots often use other sensors, like cameras or ultrasound, to correct and refine their positioning estimates. (Rahmawan, 2017). Imagine a map unfolding behind your robot, meticulously drawn with every click of the encoder. That's how the robot tracks its position in the world. By counting the pulses and converting them to millimeters, the robot builds a digital roadmap of its journey, constantly updating its location. This equation determines the number of pulses generated:

$K_{roda} = 2\pi r$ (1)

$Pulse_{per_mm} =$ (2)

With:
K_{roda} = circumference of omni wheel
$Pulse_{per_mm}$ = convert the number of pulses to millimeters

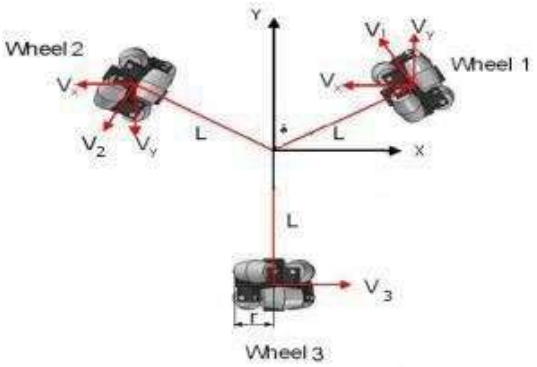


Figure 1 Rotary Encoder Placement Representation (Achmad Yani, Koko Joni, 2018)

Based on Figure 1 the X coordinates and Y coordinates of the three-wheeled Omni-directional robot can be obtained by changing the speed of each wheel from the kinematic system of the three-wheeled Omni-directional robot based on the individual wheel circumferences. Based on the results of these calculations obtained the equation:

$$V_x = -S_3 + S_1\cos(\theta) + S_2\cos(\theta) \quad (3)$$

$$V_y = S_1\sin(\theta) - S_2\sin(\theta) \quad (4)$$

Where :
Si (1,2,3) = circumferential motion of each wheel
θ = angular displacement of the omni wheel from the Y axis (60º)

2.2 Gyroscope

Gyroscope is a wheel that rotates at a central point or axis which is useful for measuring or maintaining the orientation of an object. The wheel axle is connected to a circle around the wheel or is called a gimbal. The gimbals are connected to each other at the base of the slab. This causes the gyroscope to rotate steadily. The ability of the gyroscope to maintain position due to the absence of interference from external forces. This is in accordance with Newton's first law described by Isaac Newton where the net force on an object is zero if the object is at rest or in a state of equilibrium. The basic principle of a gyroscope in measuring orientation is in the form of angular momentum which has a high sensitivity to rotational rates about the x-, y-, and z-axes. The three principal axes will form a change in angle, namely the x-axis as the phi angle (roll), the y-axis as the theta angle (pitch), and the z-axis as the psi (yaw) angle.

The gyroscope produces an angle at a time which is called the angular velocity. This is the output of the gyroscope. The resulting angular velocity value will be processed by integration with time which is useful for measuring the orientation angle.

RESULTS AND DISCUSSION

3.*1 Performance Assessment of Robot Position Estimation via Odometry*

Picture a scientist peering through a microscope, but instead of cells, they're examining lines of code. This test zooms in on the algorithm responsible for the robot's sense of direction, ensuring it maps its movements accurately. This algorithm is based on the pulse value generated by the installed Rotary encoder sensor. So from this test it can be seen the error value between the actual displacement achieved by the robot and the robot displacement value read by the sensor.

$$\text{Error}\,(\%) = \frac{Aktual - Hasil\ Pengujian}{\text{Aktual}}\ x\ 100\% \qquad (3.1)$$

Percentage Error can be calculated by the equation:

Table 1 Testing Data for Robot Position Change in Right Direction

No	Aktual (mm)	Testing Result (mm)	Error (%)
1	1000	978	2%
2	2000	1978	1%
3	3000	2951	2%
4	4000	3938	2%
5	5000	4927	1%
Mean of Error			2%

Table 2 Testing Data for Robot Position Changes to the Left

No	Aktual (mm)	Testing Result (mm)	Error (%)
1	1000	0988	1%
2	2000	1979	1%
3	3000	2975	1%
4	4000	3960	1%
5	5000	4951	1%
Mean of Error			1%

Table 3 Testing Data for Changes in Robot Position in the Forward Direction

No	Aktual (mm)	Testing Result (mm)	Error %)
1	1000	991	1%
2	2000	1970	2%
3	3000	2964	1%
4	4000	3957	1%
5	5000	4949	1%
Mean of Error			1%

Table 4 Testing Data for Changes in Robot Position in the Backward Direction

No	Aktual (mm)	Testing Result (mm)	Error (%)
1	1000	982	2%

2	2000	1960	2%
3	3000	2960	1%
4	4000	3940	2%
5	5000	4926	1%
Mean of Error			2%

The data presented in Tables 1–4 indicate a lack of error uniformity., namely the right, left, front, back directions. The error obtained was due to the uneven surface of the test field. The table is the result of testing the robot's position change manually without using an actuator then the calculation of the average error of testing from all directions Further analysis in table 3.5 reveals the error directionality diverges even more.
Table 3.5 presents a statistical summary of error values in the form of a mean error., it can be calculated by the equation:

$$\text{Mean of error} = \sum Error \quad (2)$$

With :
n = Total number of data
= Sum of all data (percent error direction)

Table 5 Data Percentage of Error Testing Manual Rotary Robot

No	Robot Position Error (Motion Direction)	Percentage of Error (%)
1	Right	2%
2	Left	1%
3	Forward	1%
4	Backward	2%
5	Mean of Error Odometry	1,4%

From Table 1 to Table 4, the data obtained from the test results are then entered into Table 5 and it can be seen that the movement of the robot using odometry has an average error of 1%. The error is caused by rotary readings because there is a slight slip on each rotary encoder sensor and from an uneven surface.

3.2 Rotary Encoder Sensor Test
The positioning of the robot in this study relies on data from a rotary sensor. Rotary sensor readings are also used in gyrodometry methods. The accuracy of the rotary sensor will be validated by comparing its measurements to the actual robot movement controlled by the stepper motor.. Validation of rotary sensor data through comparison with stepper motor movement is shown in Table 3.6.



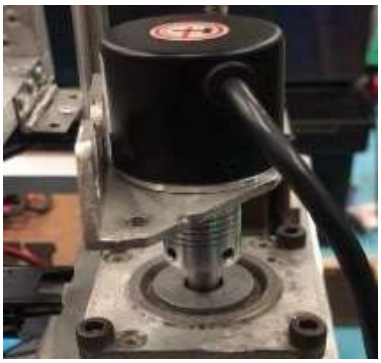


Figure 1 compares the measurement results with a stepper motor

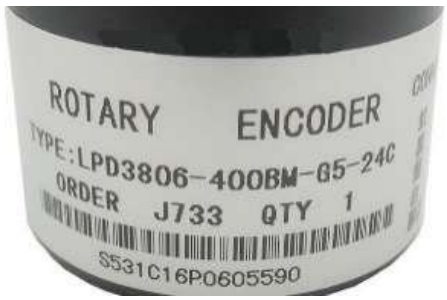


Figure 2 Type Rotary Encoder

In Figure 2 it can be seen that the type of rotary encoder used is LPD3806 – 400BM. The number 400 in this type indicates the number of pulses generated in one rotary rotation (PPR). Then refer to equation 3.4, namely PPR = 400.
PPR or Pulse per Rotation is the number of rotary pulses in one rotation. Inside the rotary encoder sensor, it can be seen through the rotary specifications, in this case the rotary encoder used has 400 pulses in one rotation. Actual Credit is the result of manual calculations obtained.

Table 6 Table of rotary and stepper motor measurement results

No	Angle	Actual (Step)	Result (PPR)	Percentage of Error (%)
1	45	50	49	2 %
2	90	100	99	1 %
3	135	150	149	1 %
4	180	200	199	1 %
5	225	250	247	1 %
6	270	300	297	1 %
7	315	350	347	1 %

8	360	400	397	1 %
Mean of Error				1 %

In Table 3.6 there is an Actual column with step units which means that the actual data (steps) is data from the stepper motor. The stepper motor used has 400 steps the same as the rotary encoder sensor which has 400 pulses in one rotation. Then, a stepper motor that has 400 steps is converted to an angle (360 degrees) with the equation:

$$\text{Step} = \frac{Derajat\ x\ PPR}{360} \qquad (3.6)$$

With:
Step = Number of Steps on the stepper motor
PPR = Number of pulses in one rotation of the rotary encoder

Based on the experimental data in Table 3.6, the value between the rotary encoder reading and the datasheet has an error percentage of 1%. It can be concluded that the Rotary Encoder sensor can work well. (Sutrisno, 2012)

3.3 Gyro Testing

Table 7 Table of measurement results for GY25 robot

No	Actual(°)	Gy25(°)	Error
1	0	0	0%
2	15	13	1%
3	30	27	1%
4	45	41	1%
5	60	55	1%
6	75	68	2%
7	90	82	2%
8	105	96	3%
9	120	110	3%
10	135	122	4%
11	150	134	4%
12	165	146	5%
13	180	159	6%
14	195	172	6%
15	210	187	6%
16	225	199	7%
17	240	211	8%
18	255	235	6%

19	270	248	6%
20	285	261	7%
21	300	275	7%
22	315	288	8%
23	330	302	8%
24	345	314	9%
25	360	328	9%
Total Average			5%

Based on the observed measurements, the GY25 sensor demonstrates an average deviation that has been installed in the robot is relatively small, namely 5% and the highest error is 9% or reaches 32 degrees.

3.4 Gyro Testing on Robot

This test aims to obtain a comparison using gyrodometry with an odometry robot without a gyro sensor.

Table 8 Table of X and Y measurements of robots without gyrodometry.

No	Setpoint			Result without Method			Error		
1	x (cm)	Y (cm)	angle (°)	X (cm)	Y (cm)	angle (°)	X (cm)	Y (cm)	angle (°)
2	100	0	0	95	3,5	12	5	3,5	12
3	200	0	0	210	41,5	21	10	41,5	21
4	300	0	0	307	5,65	20	7	5,65	20
5	400	0	0	392	138	20	8	138	20
6	500	0	0	471	201	40	29	201	40
7	0	100	0	2	95	3	2	5	3
8	0	200	0	2	202	5	2	2	5
9	0	300	0	1,5	302	4	1,5	2	4
10	0	400	0	-20	395	14	20	5	14
11	0	500	0	-42	498	15	42	2	15
12	-100	0	0	-88	-5	17	12	5	17
13	-200	0	0	-210	20	14	10	20	14
14	-300	0	0	-310	55	23	10	55	23
15	-400	0	0	-402	100	29	2	100	29
16	-500	0	0	-506	99	26	6	99	26
17	0	-100	0	-10	89	2	10	11	2
18	0	-200	0	-20	198	1	20	2	1
19	0	-300	0	-20	300	0	20	0	0
20	0	-400	0	-10	405	3	10	5	3
21	0	-500	0	-10	500	5	10	0	5
Mean of error							11,825	35,1325	13,7

This test aims to obtain a comparison using gyrodometry with an odometry robot without a gyro sensor. Table 8 Table of X and Y measurements of robots without gyrodometry From the results of the X and Y test data in Table 3.8 it can be seen that the error obtained without using gyrodometry is relatively larger, namely Error X of 11.825 cm and error Y of 35.1325 cm and angle error reaching 13.7 degrees.

Table 9 Table of X and Y measurement results for robots with gyrodometry

No	Setpoint			Result with Method			Error		
1	X (cm)	Y (cm)	Angle (°)	X (cm)	Y (cm)	Angle (°)	X (cm)	Y (cm)	Angle (°)
2	100	0	0	98,5	5	5,2	1,5	5	5,2
3	200	0	0	203	2,5	0	3	2,5	0
4	300	0	0	306	10	1	6	10	1
5	400	0	0	406	19	1	6	19	1
6	500	0	0	506	19	1	6	19	1
7	0	100	0	0	98	5	0	2	5
8	0	200	0	-3	202	2	3	2	2
9	0	300	0	0	304	2	0	4	2
10	0	400	0	-9,5	403	4	9,5	3	4
11	0	500	0	-13	507	3	13	7	3
12	-100	0	0	95	0	1	5	0	1
13	-200	0	0	195	5	2	5	5	2
14	-300	0	0	300	1	1	0	1	1
15	-400	0	0	400	5	0	0	5	0
16	-500	0	0	500	5	2	0	5	2
17	0	-100	0	0	95	2	0	5	2
18	0	-200	0	10	200	2	10	0	2
19	0	-300	0	10	305	4	10	5	4
20	0	-400	0	5	408	2	5	8	2
21	0	-500	0	2	508	0	2	8	0
Mean of error							4,25	5,775	2,01

From the results of the X and Y test data in Table 3.9, it can be seen that the error obtained using gyrodometry is relatively small, namely Error X of 4.25 cm and error Y of 5.775 cm and angle error reaching 2.01 degrees. From the data analysis in table 3.8 and table 3.9, it can be seen that using gyrodometry is better than without using gyrodometry. (Jamiin, 2014)

3.5 Gyrodometry Equations

This test is carried out based on the robot displacement formula which is based on a rotary encoder sensor placed at the bottom of the robot to help the robot know the

position and also a gyroscope sensor which functions to determine the direction of the robot.

$K_{roda} = 2\pi r$ (3.7)

$Pulse_{per_mm} = PPR/\pi r$ (3.8)

With :
K_{roda} = circumference of omni wheel
$Pulse_{per_mm}$ = convert the number of pulses to millimeters
$Resolusi_{enc}$ = obtained from the rotary specifications (400ppr)
$Pulse_{per_rotation}$ = the number of pulses generated in 1 rotation of the Rotary Encoder sensor

3.6 Gyro Testing Robot

This test aims to determine the gyrodometry mapping on the robot by running the robot automatically moving to several points simultaneously. (Sutrisno, 2014)

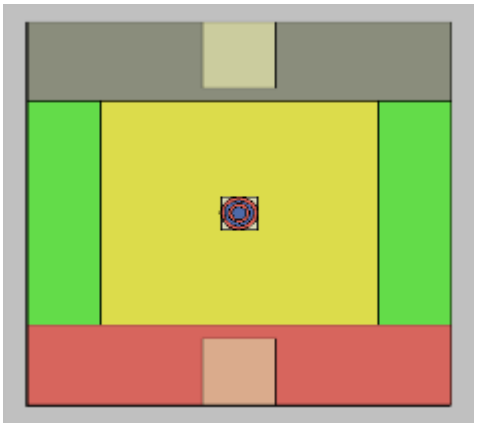


Figure 3 Illustration of Field Testing Equipment Design

Figure 3.3 is a field illustration design for gyrodometry testing purposes (Sutrisno, 2019).

Table 10 Table of waypoint test results

No	Setpoint			Experiment Result			Error		
1	X (cm)	Y (cm)	Angle (°)	X (cm)	Y (cm)	Angle (°)	X (cm)	Y (cm)	Angle (°)
2	240	0	0	229	8	-14	11	-8	14
3	240	0	0	235	10	-9	5	-10	9
4	240	0	0	232	5	-10	8	-5	10
5	240	0	0	233	7	-6	7	-7	6
6	240	0	0	230	9	-12	10	-9	12

Mean of error	8,2	-7,8	10,2

From the waypoint results in Table 3.10, we observe an average error of 8.2 cm and The mean absolute error (MAE) for Y is -7.8 cm, and the MAE for the angle is 10.2 degrees. (Sutrisno, 2014).

CONCLUSION

From the tests that have been carried out, The data presented in this research point to the conclusion that the application of gyrodometry on the robot for better performance in mapping positions and waypoints works well with an average error of X of 8.2 cm and an average error of Y of -7.8 cm and also an average error of angle of 10.2 degrees. The application of the gyroscope sensor on the robot to determine the direction towards the robot works well with an average error of 5% or 18 degrees.

REFERENCES

Asia-Pacific Broadcasting Union. (2021). ABU Asia-Pacific Robot Contest 2022 Theme and Rules. New Delhi: Asia-Pacific Broadcasting Union.

Pradito, D. S. (2015). Prinsip Kerja dan Sistem Gerak Roda Omni. Palembang: Politeknik Negeri Sriwijaya.

Achmad Yani, Koko Joni, R. A. (2018) 'Sinkronisasi Pergerakan Robot Sepak Bola Beroda Menggunakan Metode PID dan Odometry 6', in The 6th Indonesia Symposium on Robotic Systems and Control, pp. 38–42.

Andra Bramanta, A. V. (2017). Control System Implementation and Analysis for Omniwheel Vehicle. IEEE 2017 International Conference on Control, Electronics, Renewable Energy and Communications (ICCREC), 265-270.

Ashady, M. I. (2021). Kendali Posisi Robot Pengumpan dan Penerima Bola dengan Metode Gyrodometry dan Trigonometri pada Robot Sepak Bola Beroda. Skripsi, Politeknik Perkapalan Negeri Surabaya.

Fahmizal, D. U. (2019). Trajectory Tracking pada Robot Omni dengan Metode Odometry. Jurnal Nasional Teknik Elektro dan Teknologi Informasi, 35-44.

Pradana, K. A., & Indriani, D. E. Rampant pork products are flooding Indonesia, how can the cleric council explain?: A medical quantum review.

Sutrisno, Imam (2014). Modified fuzzy adaptive controller applied to nonlinear systems modeled under quasi-ARX neural network. Artificial Life and Robotics.

Sutrisno, Imam (2012). Neural predictive controller of nonlinear systems based on quasi-ARX neural network, ICAC 12 - 18th International Conference on Automation and Computing.

Jami'in M.A., Sutrisno I. (2014). An adaptive predictive control based on a quasi-ARX neural network model, 2014 13th International Conference on Control Automation Robotics and Vision, ICARCV 2014.

Sutrisno, Imam (2014). An improved adaptive switching control based on quasi-ARX neural network for nonlinear systems. Artificial Life and Robotics.