Implementation of Swerve Drive for Straight Motion Movement Stability of Robots

Rifqi Amalya Fatekha [1] , Qolbun Latief Dzikrullah [1] , Adli Samudera Alfaresi [1*]

[1] Department of Electrical Engineering , Batam State Polytechnic , Batam, Indonesia

[*] Email: qolbunlatief@gmail.com

***Abstrak*— Teknologi robot beroda saat ini sudah sangat berkembang terutama pada jenis penggerak roda, model yang ditawarkan sangat beragam tergantung dari fungsi pemakaian. Saat ini ada beberapa jenis roda yang dipergunakan pada pergerakan robot beroda seperti *Diferensial Wheels, Omniwheels, Mechanumwheels* menjadi paling sering digunakan. Dalam penerapan penggerak roda dapat berbeda-beda kontrol yang digunakan, karena perhitungan pergerakan sangat bergantung pada model yang digunakan. Penelitian ini bertujuan untuk mengevaluasi dampak implementasi sistem *Swerve Drive* terhadap kestabilan pergerakan pada robot beroda. Metode implementasi melibatkan kontroler yang memanfaatkan sensor posisi dan sudut untuk mengatur setiap roda secara individual, memungkinkan robot untuk berputar atau bergerak *omnidirectional* dengan kemampuan *manuver* tinggi. Eksperimen lapangan dilakukan dalam beberapa pembagian, terdiri dari pengujian *steering* motor dengan melakukan percobaan dengan input arah 45^O,90^O,135^O,180^O dengan setiap input dilakukan sebanyak 3 kali percobaan dengan rata – rata nilai error sebesar 8.78 %, dan pengujian pergerakan robot gerak lurus dilakukan dengan jarak tujuan 5 meter pada arah bergerak maju, kekiri, mundur, dan kekanan. Sehingga pergerakan robot diasumsikan sebanyak 4 kali pergerakan dengan hasil akhir robot dapat bergerak lurus sesuai dengan setpoint yang diberikan dengan nilai error sebesar 49.23 % akan tetapi semakin jauh jarak tempuh robot maka semakin besar nilai error yang terjadi.**

Kata Kunci: Swerve Drive, Pergerakan Stabil, Kontrol Posisi, Steering

***Abstract*— Wheeled robot technology is currently very developed, especially in the type of wheel drive, the models offered are very diverse depending on the function of use. Currently there are several types of wheels used in the movement of wheeled robots such as Differential Wheels, Omniwheels , Mechanumwheels are the most commonly used. In the application of wheel drive, different controls can be used, because the calculation of movement is very dependent on the model used. This research aims to evaluate the impact of the implementation of the Swerve Drive system on the stability of movement in wheeled robots. The implementation method involves a controller that utilizes position and angle sensors to regulate each wheel individually, allowing the robot to rotate or move omnidirectionally with high maneuverability. Fields**

experiments were conducted in several divisions, consisting of testing the steering motor by conducting experiments with direction inputs of 45^O,90^O,135^O,180^O with each input conducted 3 times.with each input conducted 3 times with an average error value of 8.78%, and testing the movement of a straight robot is done with a goal distance of 5 meters in the direction of moving forward, left, backward, and right. So that the movement of the robot is assumed to be 4 times the movement with the final result that the robot can move straight according to the setpoint given with an error value of 49.23% but the further the distance the robot travels, the greater the value .

Keywords: Swerve Drive, Movement Stability, Control Position, Steering

I. INTRODUCTION

Wheeled robot has become a distributed platform wide in research and industry , because can replace mobility power Work humans in various field , like a wheeled robot that has function climb cliff [1], cleaning robot automatic [2], carrier robot patient [3]. In implementation technology robotics , especially wheeled robots that can turn with ability wheel move so that can changed position , many wheel models are used in various form and method in its implementation [4]. Amount The wheels used on robots can also be used vary depends from implementation [5]and robot capabilities in the required areas . Until moment This Already There is a number of type wheels used in the movement of wheeled robots like *Differential Wheels* [6], *Omniwheels* [7], *MechanumWheels*[8] to be most frequent used . In implementation wheel These are also different mechanism controls used , because calculation kinematics movement really depends on the model used [9].

System *swerve drive* is A breakthrough revolutionary in wheeled [10]–[12]robot design and control , which presents ability unique For combine maneuverability tall with optimal speed and accuracy . *Swerve Drive* differentiates self from the wheel system differential conventional with possible every wheel For turn independently . [13]Every wheel can move and turn without sacrifice speed or robot stability overall . So that give ability For do extraordinary maneuver normal and changing direction of Movement with high precision , allowing [14]the robot to respond with fast to change in environment or tactics game[15]

Superiority from use The application of this system is a wheeled robot can achieve multidirectional movement [16] with corner sharp turn . With movement capable *steering* turn up to 360 degrees in a way independent [9], robot can move forward , backward , turn , and spin without need change robot orientation overall as well as capable robots move omnidirectionally without must change direction face the robot [6], [17]. This matter allows robots to overcome obstacle with easy , use it narrow gaps , and exploring difficult [18]areas reachable with use a wheel system conventional . Implementation *Swerve Drive* also improves robot flexibility in respond change tactics or fast situation changed [9], [16], [18], [19], [20], [21]. With ability For with fast adapt direction and position wheels , the robot can optimize game strategy or respond challenge new with efficient [13], [14]. Flexibility become very valuable in context robot competition , which Where adaptability and capability For innovate can become key success . With objective study This expected give contribution to the development of mobility robots tall especially in robot contests with focus on stability movement in the system *Swerve* Drive requires mobility and maneuverability tall without change direction face the robot[18]

II. METHOD

A. *System Block Diagram*

Representation graphic from a system that uses blocks For describe components - components main connected For make A device complex in a system [22]. A system block diagram is used in a way wide in systems and control engineering for modeling and communicating structure and function a system.

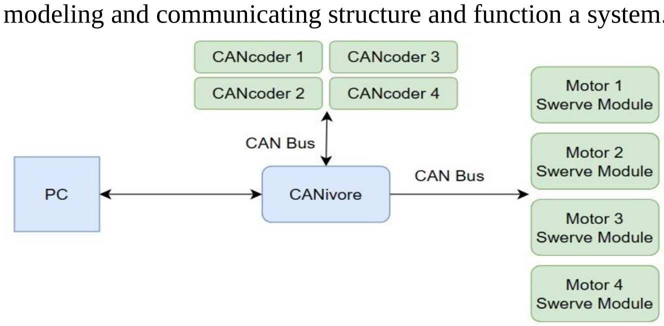
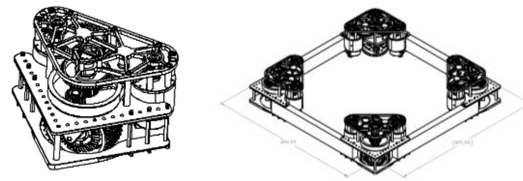


Figure 1Swerve Drive System Block Diagram

block diagram shown in Figure 1 shows that on research *swerve drive* , has device of the system , namely 4 *swerve modules* , each of which has 2 motors and 4 CANcoders works For count round direction motion wheel Then sent through CAN Bus communication to devices CANivore will processed on the computer and become command input For towards the forward moving motor wheel .



(a) (b)

Figure 2. Mechanical Swerve Design (a) Swerve Module (b) Base Swerve Drive

The use of *a swerve drive* system has various type form like case use *swerve drive* 3 wheels [18], will but on research This uses 4 wheels that have function stability more Good compared to with uses 3 wheels [2], Because own more Lots point contact with surface . So that make more robots can reliable For bring burden heavy on point the middle [14]. Implementation use of 4 wheels provide level good *maneuverability* , and also robot capable move linearly with stable at speed tall compared to uses 3 wheels .

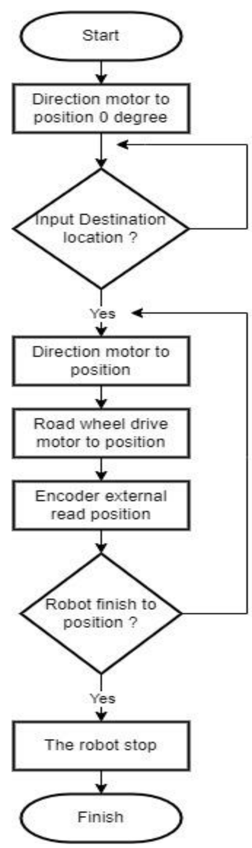


Figure 3Flowchart of Swerve Drive Movement

In the movement that has been done designed in Figure 3 The robot will start with give command the motor *degree* to position 0 º For every the wheel , after the robot gets zero position , the robot will move in accordance with orders given For going to target goal , the robot will stop in a way automatic[23] when target position Already achieved .

B. *PID Position*

Control method used For arrange mark position of the motorbike used For get set point value so that need principle from PID [19]control with another name *for Proportional Integral Derivative,* is control that will react to error value (*Kp , Ki, Kd)* given by the sensor, so can give mark improvements or *feedback* to mark the output .

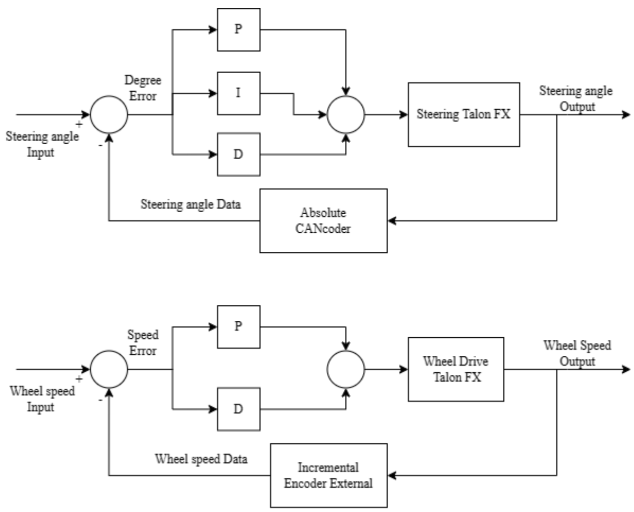
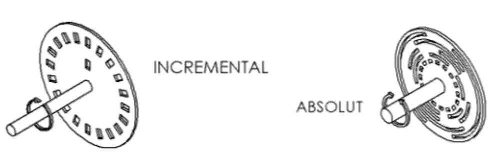


Figure 4PID block diagram

C. *Rotary Encoder*

Rotary encoder is type of sensor used For measure a round or change angle on the axis , when shaft turn *encoder* will transmit data ie form *pulse.* Every moving rotation can measured with count amount *pulse* produced . *Encoder* type *incremental* consists from encoder position double or single and two sensors are also called channels A and B. When the shaft spinning , he transmit *pulse* data every time channel with comparable frequency with speed round temporary , relationship between channels A and B determine direction round [20]. Rotation can measured with count amount *pulse* generated at resolution plate .



(a) (b)

Figure 5 Example encoder types (a) *Incremental encoder* (b) *Absolute encoder*

On the other hand there is type *encoder absolute* that has form different with *encoder* type *incremental* that can be seen on . *Encoder* type This give information direct from position *ablosute* the axis , which is normal output in the form of binary code or gray code, in the experiment use direction face the robot, try this time using the existing *CANCoder absolute* sensor integrated through network *CAN Bus.*

D. *Gyroscope*

Gyroscope or often called as a gyro sensor or facing sensor , is sensor device used For measure or monitor change orientation or angle rotation a object . Gyroscope operate based on principle of angular momentum angle , which states that moment corner a object will still constant If No there is a working torque , so A rotating object will maintain its orientation connection with axis the rotation[9], [21]

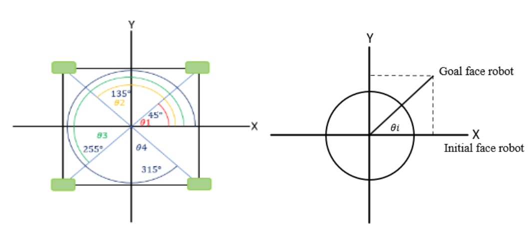
Gyroscopes are often used together with accelerometer and magnetometer inside known packages as *Inertial Measurement Unit* (IMU). Combination these three sensors can give information complete about movement and orientation a object in room three dimensions.characteristics gyroscope That Alone is precession . Precession is movement tilt or turn around axis gyroscopic from style implemented [7]. Equality following show gyroscope characteristics for measure moment corner τ:

$$\tau = \frac{d(I\omega)}{dt} = \frac{dL}{dt} = I\alpha \quad (1)$$

From Eq characteristics gyroscopic , where τ is torque, L is angular momentum , I is style inertia Which produced , ω is speed corner from gyroscope , And α is acceleration corner . Censorship gyro works based on principle this is what illustrates connection between moment angle acting on a object , momentum of inertia object the , and acceleration resulting angle . In the context of a gyroscope, acceleration corner reflect how much fast a object can turn . Speed value corner Then integrated with from time to time For count corner orientation . Mark corner orientation can known use equality following :

$$Vx - \theta_0 \quad (2)$$

From Eq For get robot orientation is required distribution of each θi which is corner wheel to x axis as in Figure 6. (a) θ is corner steering wheel when this and calculations This assumed if zero steering angle each the wheels one way with Vx which is direction motion orientation from robots. With help IMU usage , then direction orientation from the robot will reduced with IMU value is placed flat inside the robot



(a) (b)

Figure 6 IMU diagram (a) Mapping diagram wheel IMU value , (b)

III. RESULTS AND DISCUSSION

In chap This will discussed related results from testing carried out and discussion from The method used is experimental done in a number of division consisting from testing *steering* motor, and testing movement of mobile robots straight *linear* .

A. *Motor steering testing*

On testing This done test with uses 1 module *swerve drive* , experiment done when the robot is placed on field and given order For move with 4 different positions namely 45 ^{o} ,90 ^{o} ,135 ^{o} ,180 ^{o} . After move desired position then the motor from mover *steering* stop . Swerve Drive has 6 parts important For support effectiveness use in testing This done with uses 2 drive motors that is For move wheels and for move direction wheel (*Steering)* , will but For get results test direction wheel , then needed tuning results from each motor as following :

$$\theta i = atan\left(\frac{y}{x}\right) * \frac{180}{3{,}14} \tag{3}$$

From Eq This θ that is corner of each steering wheel , y is the direction the robot is facing with the y and x axes are facing the robot with x- axis , which is then every wheel can determined direction he hoped in the form of input degrees in position *steering* wheel .

And also testing done see chart response you have against the system with formula mark as following :

$$Tr = t_{90\%} - t_{10\%} \tag{4}$$

Rime time (Tr) is measured as the time required by the system to reached 90% of initial set point value , and $t_{90\%}$ is time when the output reaches 90%, and $t_{10\%}$ is time When output reaches 10%.

$$OS = \frac{(Mout - Sp)}{Sp}\ x\ 100\% \tag{5}$$

Overshoot (OS) is measured as percentage maximum exceeded mark from setpoint, Mout is mark maximum output and Sp is mark from setpoint.

$$Ts = t_{s2\%} - t_0 \tag{6}$$

Settling Time (Ts) is measured value as the time required by the system to is at the tolerance limit certain from setpoint value , which is generally the tolerance limit used is ± 2%, Where $t_{s2\%}$ is output time on is at the limit, and t_0 is time beginning test . Then from results the experiment like following :

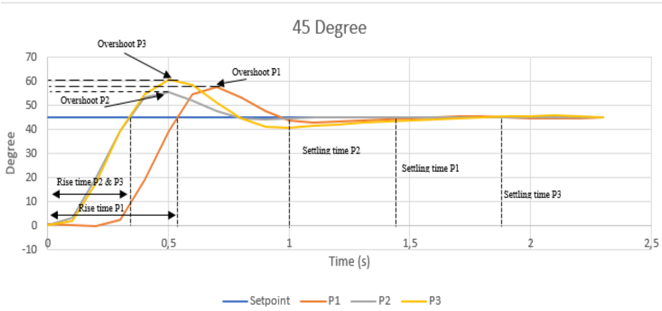


Figure 7 Chart test angle 45 ^{o}

On trial position 45 ^{o} was carried out 3 times as in Figure 7, you can seen that's it summation mark from chart according to equation (4,5,6) as following :

Experiment 1

Rise time = 0.52 s

Overshoot = $\frac{57{,}6-45}{45}\ x\ 100\% = 28\%$

Settling time = 1.4 s

In experiment 1, the time required For reaching the set point has longer time in comparison with the rise time in experiments 2 and 3, it will but it has overshoot No more big compared to the 3rd experiment and the time required For is at the tolerance limit The set point value is 1.4 seconds .

Experiment 2

Rise time = 0.3 s

Overshoot = $\frac{55{,}3-45}{45}\ x\ 100\% = 22.9\%$

Settling time = 1 s

In experiment 2, the time required For reaching the set point has more time fast compared to experiment 1, and also the overshoot value more small compared to with trials 1 and 3 and the time required For is at the tolerance limit the set point value is also higher small compared to Experiments 1 and 3 are 1 second .

Experiment 3

Rise time = 0.3 s

Overshoot = $\frac{60{,}6-45}{45}\ x\ 100\% = 34.6\%$

Settling time = 1.7 s

In experiment 3, the time required For reaching the set point has the same time in experiment 2 , will but the largest overshoot value compared to with experiments 1 and 2, so that time required For is at the tolerance limit The set point value also takes a long time to compare with Experiments 1 and 2 are 1.7 seconds .

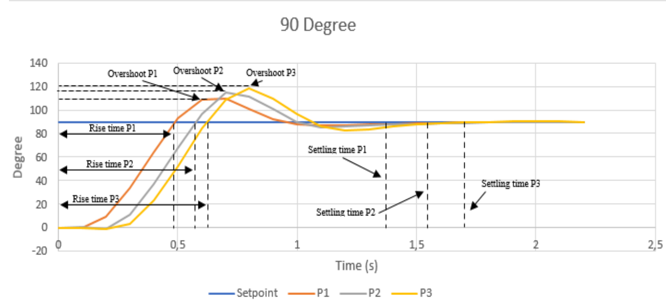


Figure 8 Chart test 90 ^{o} angle

On trial in the 90 ^{o} position , 3 trials were carried out as in Figure 8 can be seen that's it summation mark from chart according to equation (4,5,6) as following :

Experiment 1

Rise time = 0.48 s

Overshoot = $\frac{109{,}4-90}{90}\ x\ 100\% = 21{,}5\%$

Settling time = 1.45 s

In experiment 1, the time required For reaching the set point has more time fast compared to with the rise time in experiments 2 and 3, and also the overshoot more small compared to experiments 2 and 3, the time required For is at the tolerance limit The set point value is 1.45 seconds more fast compared to with experiments 2 and 3.

Experiment 2

Rise time = 0.56 s

Overshoot = $\frac{114,4-90}{90}\ x\ 100\% = 27,1\%$

Settling time = 1.52 s

In experiment 2, the time required For reaching the set point has more time fast compared to experiment 3, and also the overshoot value more small compared to with experiment 3 will but more big compared to with experiment 1 and the time required For is at the tolerance limit the set point value is also higher small compared to experiment 3 namely 1.52 seconds .

Experiment 3

Rise time = 0.64 s

Overshoot = $\frac{118,4-90}{90}\ x\ 100\% = 31,5\%$

Settling time = 1.58 s

In experiment 3, the time required For reaching the set point has time longer in comparison experiments 1 and 2, and also the overshoot value is the largest compared to with experiments 1 and 2, so that time required For is at the tolerance limit the set point value is also longer in comparison with Experiments 1 and 2 are 1.58 seconds .

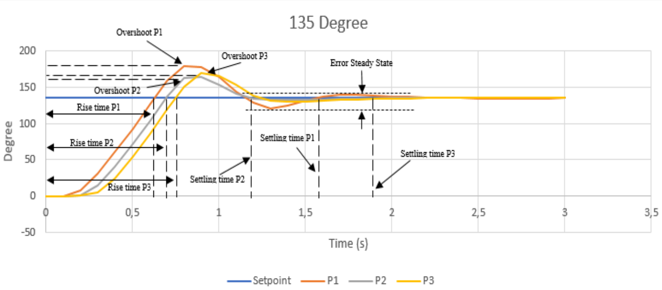


Figure 9 Chart trial 135 ^{o}

On trial At position 135 ^{o,} 3 trials were carried out as in Figure 9 can be seen that's it summation mark from chart according to equation (4,5,6) as following :

Experiment 1

Rise time = 0.6 s

Overshoot = $\frac{179,12-135}{135}\ x\ 100\% = 32,6\%$

Settling time = 1.56 s

In experiment 1, the time required For reaching the set point has more time fast compared to with the rise time in experiments 2 and 3, it will but the overshoot is the largest compared to experiments 2 and 3, the time required For is at the tolerance limit The set point value is 1.56 seconds more fast compared to with trials 3 and longer were compared with experiment 2.

Experiment 2

Rise time = 0.66 s

Overshoot = $\frac{163,65-135}{135}\ x\ 100\% = 21,2\%$

Settling time = 1.4 s

In experiment 2, the time required For reaching the set point has more time fast compared to experiment 3, and also the overshoot value more small compared to with trials 1 and 3 and the time required For is at the tolerance limit the set point value is also higher small compared to Experiments 1 and 3 are 1.4 seconds .

Experiment 3

Rise time = 0.78 s

Overshoot = $\frac{169,8-135}{135}\ x\ 100\% = 25,7\%$

Settling time = 1.7 s

In experiment 3, the time required For reaching the set point has time longer in comparison experiments 1 and 2, and also the overshoot value more big compared to with experiment 2 , so time required For is at the tolerance limit the set point value is also longer in comparison with Experiments 1 and 2 are 1.7 seconds .

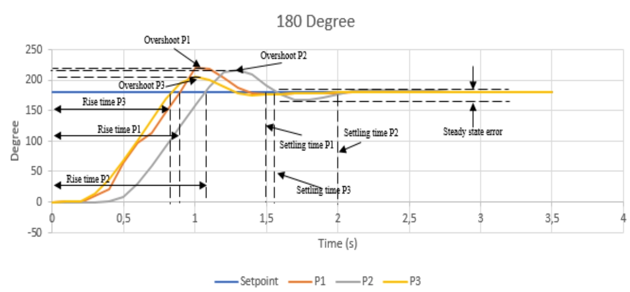


Figure 10 Chart trial 180 ^{o}

On trial in the 180 ^{o} position , 3 trials were carried out as in Figure 10 can be seen that's it summation mark from chart according to equation (4,5,6) as following :

Experiment 1

Rise time = 0.9 s

Overshoot = $\frac{219,64-180}{180}\ x\ 100\% = 22.02\%$

Settling time = 1.5 s

In experiment 1, the time required For reaching the set point has fast time compared to with the rise time in experiment 2 will be but A little longer in comparison with experiment 3, will but the overshoot is the largest compared to experiments 2 and 3, the time required For is at the tolerance limit The set point value is 1.56 seconds become more fast compared to with experiments 2 and 3.

Experiment 2

Rise time = 1.1 s

Overshoot = $\frac{215,86-180}{180}\ x\ 100\% = 19.9\%$

Settling time = 2 s

In experiment 2, the time required For reaching the set point has more time fast compared to experiment 1 will but own longer time compared to experiment 3 , and also the overshoot value more small compared to with experiment 1 and the time required For is at the tolerance limit the set point value is longer compared Experiments 1 and 3 are 2 seconds .

Experiment 3

Rise time = 0.86 s

Overshoot = $\frac{205,93-180}{180}\ x\ 100\% = 14.4\%$
Settling time = 1.6 s

In experiment 3, the time required For reaching the set point has time more fast compared to experiments 1 and 2, and also the overshoot value more small compared to with experiments 1 and 3, though time required For is at the tolerance limit The set point value is 1.6 seconds .

On the fourth test This so obtained the resulting output from given set point position namely 45 °,90 °,135 °,180 °. Which every the input given 3 trials like following :

TABLE I
MOTOR POSITION EXPERIMENT

Actual Position (°)	**Set Point (°)**	**Output Degree**			**Average Error (%)**
		P1 (°)	**P2(°)**	**P3(°)**	
0	45	44,912	45,087	45,087	8.8 %
0	90	89,912	89,912	90	17.6 %
0	135	135	135	135,087	8.7 %
0	180	180,087	180,087	180,087	0 %
		Average			8.78 %

On trial motor position as in Table 1 shows Position steering experiments were carried out 3 tries with setpoint experiment ie 45 °,90 °,135 °,180 °, each the experiment done with position it started from 0 °. So that results the test in Table 1 was obtained that the average error value of steering motor experiment , namely 8.78%.

B. Testing robot movement

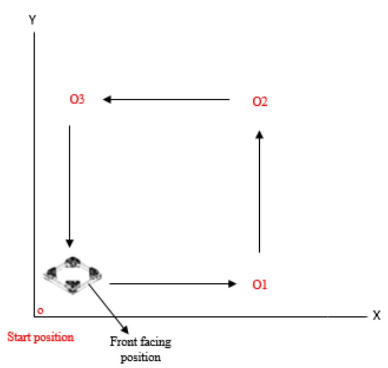


Figure 11 Illustration test *robot movements*

Testing done in position a flat field , then testing carried out on a moving robot as in Figure 11, experiment done with distance aim 5 meters in the same direction , so robot movement is assumed 4 movements . Move move forward 5 meters, then the robot is positioned to position 01 and the robot moves left 5 meters long , then the robot is positioned to position 02 and the robot moves back 5 meters, then the robot is positioned to position 03 and the robot moves right 5 meters long with speed 0.2 or 20% of the maximum speed of the Falcon motorbike , namely 6380 .

$$\omega = (\sin\ (\theta + \theta 1) * \frac{3,14}{180} * \left(\sin(\theta 2 - \theta 3) * \frac{3,14}{180}\right) \quad (7)$$

From Eq on obtained that ω is speed corner in unit , θi is corner wheel to each x axis his motorbike own x- axis varies , θ is corner steering wheel when this and calculations This assumed if corner *zero-steering* every the wheels one way with vx which is direction motion orientation from robots. With help IMU usage , then direction orientation from the robot will reduced with IMU value is placed evenly inside robot .On the results achieved are carried out test as much four times with every test done 2 times, so produce like following :

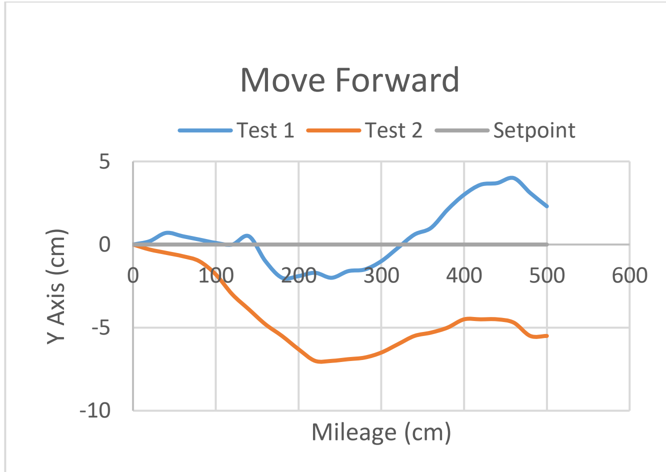


Figure 12 Chart mobile robot experiment proceed with distance 5 meters

In the experiment motion proceed in accordance with graph in Figure 12, results show that in experiment 1, the robot was able move straight on the track with distance travel 120 cm. However , at range distance 140–320 cm, the robot experiences A little shift towards right , and on range distance 340–500 cm, the robot experiences shift left . This matter cause point end robot movement is not in accordance with desired setpoint path . In experiment 1, the robot moves proceed has an average error rate of 49.23%. While on trial motion forward second , robot, start from distance travel 0 to reach point end objective as far as 500 cm, experience shift towards right , as a result , the robot does not reach desired setpoint position .

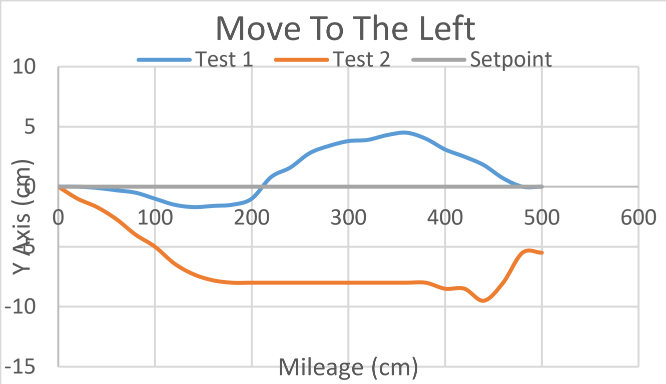


Figure 13 Chart mobile robot experiment left with distance 5 meters

In the experiment motion left in accordance with graph in Figure 13, results show that in experiment 1, the robot was able move straight on the track with distance travel 80 cm. However , at range distance of 100 –200 cm, the robot experiences A little shift towards right , and on range distance 220–440 cm, the robot experiences shift left . But at a distance travel 460 cm until point final 500 cm robot moves going to towards the path setpoint straight . While on trial motion second right , robot, start from distance travel 0 to reach point end objective as far as 500 cm, experience shift towards right . As a result , robots do not reach desired setpoint position .

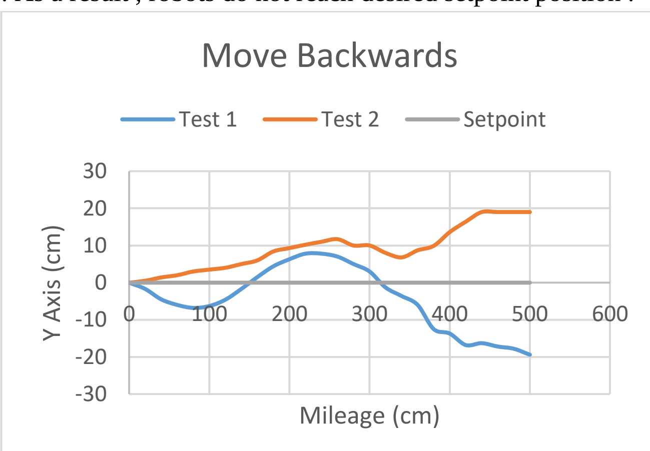


Figure 14 Chart mobile robot experiment back off with distance 5 meters

In the experiment motion back off in accordance with graph in Figure 14, results show that in experiment 1, the robot moved with No accurate will but at a distance travel 150 cm the robot moves to the setpoint and moves back to the setpoint at a distance travel 310 cm and point end the purpose of the robot's movement No is on point end of desired setpoint . While on trial motion Second left , robot, start from distance travel 0 to reach point end objective as far as 500 cm, experience shift towards right . As a result , robots do not reach desired setpoint position .

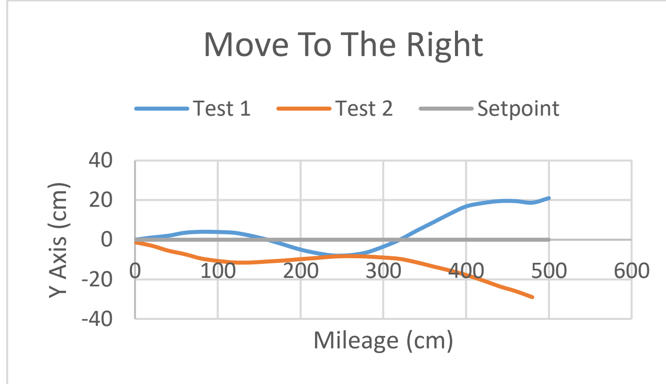


Figure 15 Chart mobile robot experiment right with distance 5 meters

After done test 2 times each its movement with give marker on the part front of the robot (if move forward), and provide marker on the part adjacent left of the robot (when the robot moves to the left), gives marker on the part behind the robot (when the robot moves backwards), and provide marker on the part right of the robot (when the robot moves Kenan). Then from results test obtained that the more Far distance take the robot then the more big error value that makes the robot not move straight in accordance with the given setpoint with the average error value is 49.23%.

IV. CONCLUSION

Based on results testing carried out with using a movement system *Swerve Drive* , got it concluded that robots can move without change direction face wheel with speed movement of 0.2 or 20% of the maximum falcon motor speed , namely 6380 pwm . And research This do testing as following

1. Testing experimental *steering* done via 4 corner inputs position that is 45 ^{o} .90 ^{o} .135 ^{o} .180 ^{o} and every testing done 3 times with an average error rate that is amounting to 8.78%.
2. Testing move straight test done with distance aim 5 meters on direction move forward , left, backward , and right, so robot movement is assumed 4 movements with movement results the end of the robot is not can move straight in accordance with the given setpoint with the error value is 49.23%.

In terms of change direction without change direction face the robot with use stability point motion straight at the IMU. Implementation from system *Swerve Drive* on the robot has level different error values from experiments carried out . Study This expected give contribution to the development of mobility robots tall with focus on stability movement in the system *Swerve Drive* promising wide application in various fields , including exploration robots , vehicles autonomy , and applications industries that need it mobility and maneuverability tall without change direction face the robot . However , in research This need improved Again movement motion straight that is done to make it more accurate from facet movement motion straight .

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