ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

IMPLEMENTATION OF WALL FOLLOWING METHOD BASED ON KINECT FOR ROBOT MOBILE

NOVEM ARDAN ROHMADIN, RONNY MARDIYANTO , RUDY DIKAIRONO
Electrical Engineering Department, Institut Teknologi Sepuluh Nopember

Manuscript Info

Manuscript History:

Received: 18 August 2015
Final Accepted: 26 September 2015
Published Online: October 2015

Key words:

Kinect, mobile robot, navigation

Corresponding Author

NOVEM ARDAN

Abstract

The paper presents implementation of wall following method based on kinect sensor for robot mobile navigation. The objective of this research is how the robot can perform autonomous navigation from start point to the desired one. The method implemented in mobile robot for taking the dangerous object. Wall-following method is a method in mobile robot mobile navigation by moving based on the distance from the wall next to the robot. The key issue here is how to develop good hardware setup in order to create accurate mobile robot navigation. The system utilizes kinect camera as the main sensor, rotary encoders, and compas. We use the depth aquired from the kinect sensor for estimating the distance to the wall and use it to navigate the mobile robot. We conducted experiments by the robot explore the room. In automatic mode, robot continues to explore the room by taking reference wall to the left until the user stops the movement of the robot using remote control. The experimental data shows that the system has an average error of 7, 33% against the robot's ability to enter the sections of the room. The gap width of the room becomes a factor in the failure of a robot entered the room.

INTRODUCTION

Currently mobile robot has been widely applied in human life. Robots have been applied in the field of entertainment, cleanliness, searching for dangerous objects, to searching for survivors in the disaster. The ability of mobile robot will always be developed to meet human needs. Some of themobile robot capabilities developed is a robot's ability to move automatically. The ability of the mobile robot like this is applied to a robot whose task is to explore a place that hasn't been recognized, such as dangerous objects searching robot. The method which can be used by robot for navigate in the unrecognized room is wall following method. By knowing the distance between robot with the walls of the room, the movement of the robot can be set. The robot will move along the wall of the room so the robot is able to enter and explore the room.

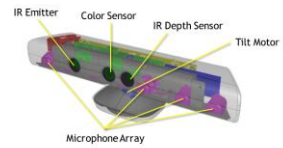
The use of mobile robots in the searching for dangerous objects mission, once used by DENSUS 88. Morolipi is the name of the robot. Morolipi used during the terrorist arrest mission, Noordin M Top. Robot with tank-like shapes used to identify the situation in the room where Noordin M Top was hiding. The Robot had a task to detect whether there are dangerous objects such as bombs that could endanger officers. The robot movement controlled manually by the operator from a distance. The navigation process of robot, which is the movement of the mobile robot to explore the room while looking for dangerous objects, can be developed into an automated system.

Mobile robot with the task to explore an unfamiliar environment often use 3-dimensional distance sensor as an input to control the movement of the robot or just even for the data retrieval. LIDAR (Light Detecting and Ranging) is one of the sensors which are often used as input in mapping and navigation of robot. But the price of LIDAR system is too expensive for several robotic developer, so not all robotics developer can develop a system using LIDAR.

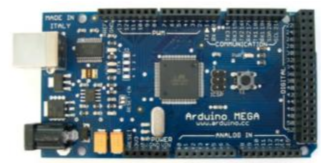
In this case, kinect can be a solution for the problem above. Kinect is a 3-dimensional distance sensor which is equipped with an RGB camera. Microsoft's sensor has a cheaper price compared with LIDAR. Kinect can replace the function of LIDAR in the process of mobile robot navigation and mapping.

Therefore, this research proposal is referred to the hope that it would implement wall following method based on kinect for mobile robot so that the robot will be able to explore the room automatically.

LITERATURE REVIEW



Picture 2. 1KinectCamera [1]



Picture 2. 2Arduino Mega [2]

A. Kamera Kinect

Kinect is a device which is used as a motion detector that was originally used as Xbox game controller. Kinect software is built on technology that was established by Rare, Microsoft Game Studios. Kinect sensor developed by a company from Israel, PrimeSense. Kinect camera can provide RGB-Depth data with a maximum speed of 30 Hz and resolution to 640 x 480 pixels. Kinect camera has a viewing angle of 57 degrees on the horizontal plane and 43 degrees in the vertical plane. Optimal distance measurement when used is 1, 2 - 3, 5 meters. If the distance is used exceeds or less than the optimal distance, then the object will not be caught by the camera. At the bottom of kinect, there are kinect multi-array mics used for recording or voice input. Kinect is also equipped with a motorized tilt to adjust the camera angle, so that the area that can be captured by the camera can be set. To adjust the angle of the camera can use a particular program, with a coverage angle of approximately 27 degrees.

B. Measurement of Robot Positiont

In robot navigation and mapping, the robot must know the actual position and direction of the robot in the Cartesian field. The base concept to determine the position and direction of robot are by reading the distance traveled each of wheel robot. For robots with differential mechanical style, which control the movement of the robot based on the movement of two wheels. Equation 2.1, 2.2, 2.3, 2.4, and 2.5 are used to calculate the position and direction of the robot.

$$\Delta S = \frac{\Delta S_r + \Delta S_l}{2} \quad (2.1)$$

$$\Delta\theta = \frac{\Delta S_r - \Delta S_l}{B} \quad (2.2)$$

$$X = X + \Delta S \cos\theta \quad (2.3)$$

$$Y = Y + \Delta S \sin\theta \quad (2.4)$$

$$\theta = \theta + \Delta\theta \quad (2.5)$$

Description:

ΔS = Total of recent distance traveled by robot
ΔS_r = Recent distance traveled by right wheel
ΔS_l = Recent distance traveled by left wheel
$\Delta\theta$ = Recent angle changes
B = Distance between right wheel and left wheel
X = Position of the robot in the x field
Y = Position of the robot in the y field
θ = Robot angle direction

C. Arduino Mircokontroler

Arduino is an open source physical computing platform. Arduino is not just a microcontroller module.

Picture3. 1Size and Placement of Robot Component

Arduino is a combination of hardware, programming language, and Integrated Development Environment (IDE). IDE is a software to write a program, compile it into binary code and upload it to the microcontroller memory. There are many projects and tools developed by academics and professionals to use Arduino. Now, there are a lot of of support modules (sensors, display, drive, etc.) made by another party to be connected to the Arduino.

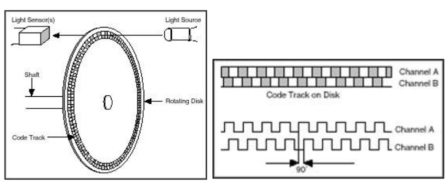
D. Wall Following

Wall following is a method of robot navigation system that is famous among researchers, especially in the field of reactive robot. By using distance sensor, when the robot is too close to the wall, the robot will move away from the wall and when the robot is too far to the wall, the robot will move closer to the wall. Following the wall following implementation is capable of using simple movement such as forward, turn right or left, or using additional control systems.

E. Rotary Encoder

Rotary encoders is electromechanical device that can monitor the movement and position. Rotary encoder generally uses an optical sensor to generate a pulse signal which can be interpreted into position.

Rotary encoder composed of a thin disk which has holes in the circular section of disk. LED is placed on one side of the disk so that the light will go through to the holes of the disk. On the other hand photo-transistor



Picture 2. 3Rotary Encoder [3]

is placed so it can detect light from the LED from the opposite. If the light from LED can reach the photo-transistor through the existing holes, then the photo-transistor will experience saturation and will produce a square wave pulse. The more the pulse generated determine the more accuracy of the rotary encoder.

F. Compass Sensor

Compass is a tool that serves to indicate the direction of an object[4]. Compass is an important part of the reading position and direction, as sensors that can estimate the direction toward the robot. In the field of robot navigation, the direction of mobile robot is an important part. In the compass sensor, there is a processing of the value from two magnet poles inside the sensor that each exposed to a different direction by central processing unit, so that the direction toward the sensor can be known..

G. Mapping Process using Kinect

The making process of 2-dimensial map, while the robot move to explore the room, needs distance data around mobile robot, position and direction of mobile robot in the Cartesian field [5]. Distance data obtained using kinect sensor while the mobile robot position and direction data obtained using a rotary encoder and a compass.

H. Electronic Speed Controller

Picture 2. 5Electronic Speed Controller

ESC (Electronic Speed Control) is device that functions to adjust motor speed using PWM signal with specific frequency and duty cycle. ESC is usually used by radio-controlled vehicles. ESC uses a square signal with a frequency of 50 Hz and pulse width between 1ms to 2ms. The duty cycle of inputsignal in the ESC will affect motor speed and direction of motor rotation. PWM signal with a pulse width between 1ms and less than 1,5ms would result the motor rotates counter-clockwise. PWM signal with a pulse width of 1,5ms would result the motor become silent. PWM signal with a pulse width between 1,5ms and less than 2ms will result the motor rotates clockwise.

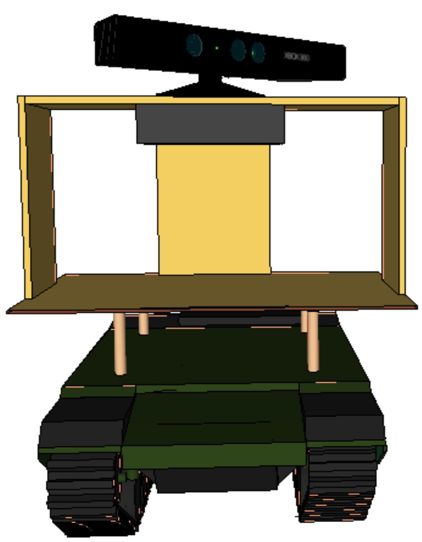
SYSTEM DESIGN

A. Robot Design and Component Robot Placement

Description:

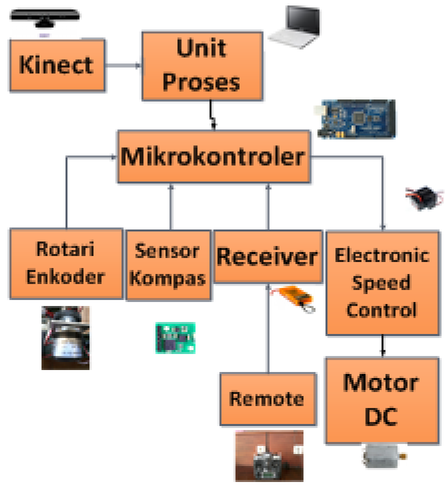
1. Arduino Mega
2. *Receiver*
3. On/Off Button
4. Rotary Encoder : (a) left, (b) right
5. ESC (*Electronic Speed Controller*) : (a) left, (b) right
6. Motor DC : (a) left, (b) right
7. Compass Sensor
8. Kinect
9. Processing Unit

The design of Mobile robot has a basic shape like tank with 2 pieces of track wheels connected by a dc motor as prime mover. Kinect is placed at the top of the robot so that the robot is able to read wall distance and obstacle distance in front of the robot. Kinect is positioned 45 degrees to the left, so the kinect can read the distance from the wall. Reading of distance on the floor is considered necessary that the robot knows the difference between whether there is an obstacle in front of the robot or not.



Picture 3. 2Robot Design

Mobile robot is controlled by user using radio control. The signal from the remote control will be received by



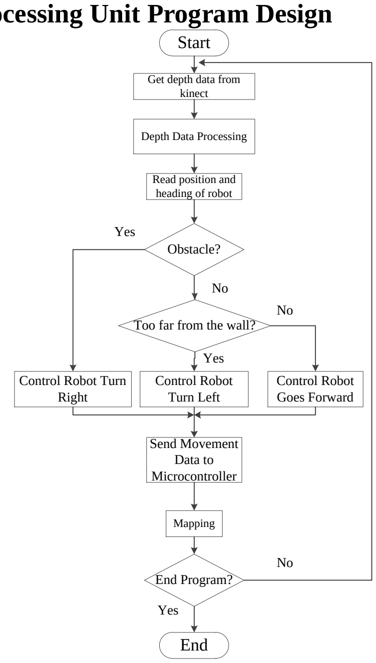
Picture3. 3Diagram Block System of Robot

the receiver. Robot will read signals from the receiver. Based on the signals read by the receiver, robot motion mode will be determined. There are two modes, namely manual and automatic mode. When auto mode is activated, the movement of the robot is controlled entirely by the unit process. Users select the mode via the switch on the remote. Rotary encoder and compass reading robot conditions, both position and direction. Position and direction data is sent to the process unit. Kinect read environmental conditions such as the distance of objects in front of the robot. Kinect distance data captured and processed by the unit process. The first time the robot moves, the robot will trace left wall. Process units will move forward following the left wall and further examine whether there is an obstacle in front of the robot. If there is an obstacle in front of the robot, the robot will avoid the obstacle, if not then the robot will move forward again in the previous direction.

During the of the robot moves, the process unit will generate a 2-dimensional map based on the distance of objects in front of the robot, the position and direction of of the robot. Map shows the environmental conditions around of the robot in two dimensions. This map is an additional feature for the mobile of the robot. Results provisions of the robot movement generated by the process unit will be sent to the microcontroller. The robot will continue to move in accordance with the instruction from process unit. Robot will move automatically until there are instructions back to the manual mode of the user through radio control.

When the manual mode is activated, the movement of the robot is controlled entirely by the user via a remote joystick. Remote control will be set so that the movement forward, backward, turn right and turn left of the robot will be controlled using remote joystick control. Users will control the robot from a distance. The use of remote control of the robot aims to be able to be controlled from a safe distance from the location of use of the robot.

B. Processing Unit Program Design

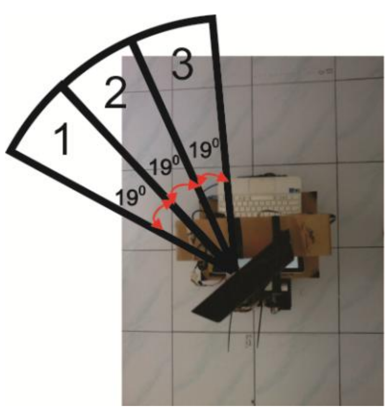


Picture3. 4Flowchart in Unit Process

At the picture above, shown a flowchart of the main movement of the robot. Explanation flowchart described above through the following points:

1. First, robot will initially take the data depth of kinect camera. This depth of data will be saved with form 640x1 matrix.
2. Data depth of kinect will be processed and divided into several regions. The value of the average depth data per region will be compared to determine whether the robot encountered obstacles, find a gap to the left of robot, or road ahead of robot is empty, or the the robot too close to the walll.
3. If the road ahead of robot is empty and a robot near the wall, then the robot will be controlled to move forward.
4. If there is a wall on the left of the robot, the robot will be controlled to move forward. If there is no wall, the robot will move to the left.
5. If there is an obstacle in front of the robot, the robot will be controlled to immediately turn to the right. This action will stop if the robot to meet the characteristics of the sequence number 3 and 4.
6. While mobile robot moving, the robot will simultaneously draw a map of the environment around him.
7. The robot will come out of the automatic mode and return to manual mode if the user stops the movement of the robot using the remote control.

C. Depth Data Processing



Picture3. 5Electronic Speed Controller

Depth data in navigation system was used by robot to determine the environmental condition that exist in front of the robot. System will determine if there is an obstacle in front of the robot or not. In this research, the system utilizes the depth data captured by the camera kinect. The data will be used as a reference movement of the robot.

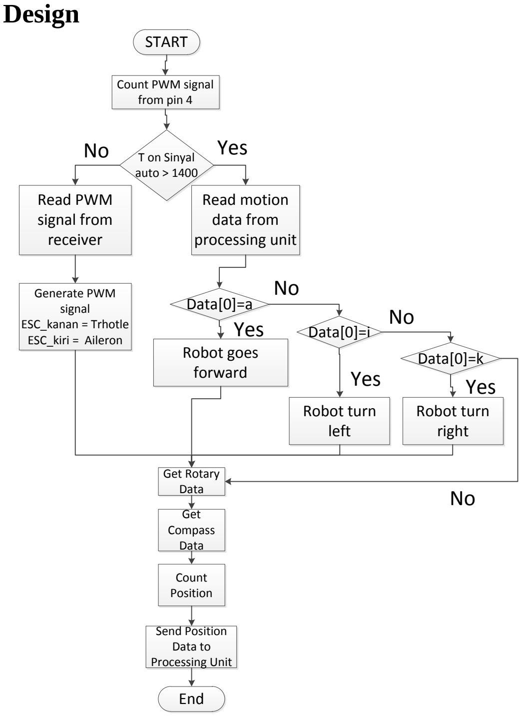
In the designed system, the frame depth data is divided into several regions. Frame depth is divided vertically into three regions, namely region 1 (left), region 2 (middle), and region 3 (right). Each region has a width of 213 pixels vertically. In the vertical plane, region 1 on pixels 0 to 212, region 2 at 213 to 415 pixels, and the pixel region at 3 to 639m pixels. This region will be used in determining the movement of the robot. Region 1,2 and 3 in the program in a variable called jarak_region_1, jarak_region_2, and jarak_region_3.

Furthermore, the depth data of each region 1, 2, and 3 is calculated the average value of the depth data that has been taken. Region 1 is captured distance data from the left side of the robot. Region 2 is captured distance data from the front left of the robot. Region 3 is captured distance data from in front of the robot.

Kinect depth data processing is to determine whether there is a gap to the left of the robot, there is an obstacle in front of the robot, or both so that the robot can be straight forward.

1. Depth data is retrieved from kinect using USB communication through the process unit.
2. Depth data has a form of a matrix of 640 x 480 in 1 channel. This matrix contains the depth of the object that is in front of the camera kinect. The frame is divided into three sections of equal size, namely region 1, region 2, and region 3.
3. The value of the distance data in each region calculated the average value. The average value is stored in the variable jarak_region_1, jarak_region_2, and jarak_region_3.
4. Jarak_region_3 represents the area in front of the robot. If the value of the variable is less than 1000, it indicates that there is an obstacle so the robot needs to transform his movement into a right turn.
5. Jarak_region_1 represents the area on the left of the robot. If the difference jarak_region_3 and jarak_region_1 less than 100, then there is no no wall to the left of robot. The robot needs to transform his movement into a left turn.
6. If the conditions in points 5 and 6 points don't met means the robot position is close to the left wall and in front of the robot there are no obstacles so that the robot only needs to move straight away.

D. Microcontroller Program Design

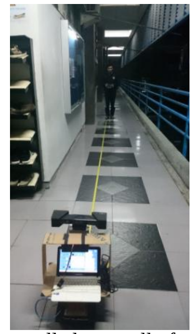


Picture3. 5Flowchart in Arduino

Automatic or manual mode selection is done by reading the PWM signal which is generated by aux pin in the receiver. Aux pin will produce a signal with a frequency of 50 Hz and Ton between 1ms and 2ms.

Auto mode is a mode which all of robot motion was controlled by process unit. The movement of of the robot in accordance with the received data by microcontroller. Data 'a' means that the robot will go forward with a certain speed. Data 'k' means that the robot will turn to the right. And data 'i' means that the robot will turn to the left.

In the manual mode, microcontroller needs to read pwm signals from the receiver. In accordance with the hardware configuration, trho pin generates a signal for the right motor, and aile pin generates a signal for the left motor. Microcontroller will generate pwm signal with the same characteristics with pwm signal input.



Picture4. 2Robot was controlled manually from distance

When each motor moves forward or backward, rotary encoder will generate pulse signals. The faster the motor moves, the signal frequency will be faster. Motor rotation and movement of robot track are comparable. When the track moves, then the rotary encoder will generate pwm signals. Signals from the rotary encoder will be calculated by microcontroller so the distance traveled by the robot will be known. Microcontroller Arduino using external interrupt to read signals from the rotary encoder.

The retrieval data from compass is done using I2C communication between the microcontroller and sensor CMPS11 compass. By calculating the incoming signal from the rotary encoder, the distance traveled by the robot can be known. By using the distance traveled (ΔS) by the right wheel and the left wheel and the direction data of the robot are from compass sensor. System can determine the position and direction of robot.

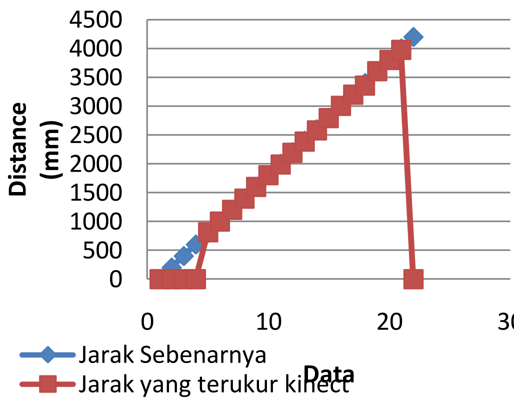
EXPERIMENTS

A. Measuring Distance Experiments with Kinect

The Test on this section is to determine the characteristics of the reading distance estimation made by kinect. Testing is done by recording the reading distance to the object by kinect at the center of the frame depth. Recording is done at a distance of 20 cm to 4200 cm from the camera kinect with interval of 20 cm. Here is the testing that has been done:

From the test data, it can be seen that the accuracy of distance measurement by kinect at a distance of less than 80 cm and more than 4 meters, it has an average error of 100%. Meanwhile at a distance of between more than 80 cm to less than 4 meters, the accuracy has an average error of 0,197%. From this test, it can be seen that the distance measurement using kinect camera is good for distances in the range of 80 cm to 4 meters.

Graph of Actual Distance Measurement with Distance Measurement using Kinect



Picture4. 1Graph of Actual Distance Measurement using Kinect

B. Measuring Distance Robot Control Experiment using Remote Control

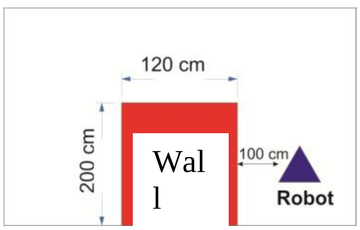
Mobile robot which was designed to be used by the user from a distance. The use of remote control intended that user is at safe location from the search location. This test was conducted to determine the distance between the user's ability with robot to use remote control robots. Testing is done by controlling the robot manually at certain distances and note whether the robot can still be controlled or not.

Table 4.1 Distance test and the success rate to control robot manually

Distance (Meter)	Control Robot Manually
7	Success
14	Success
21	Success
28	Success
35	Success
42	Success
49	Success

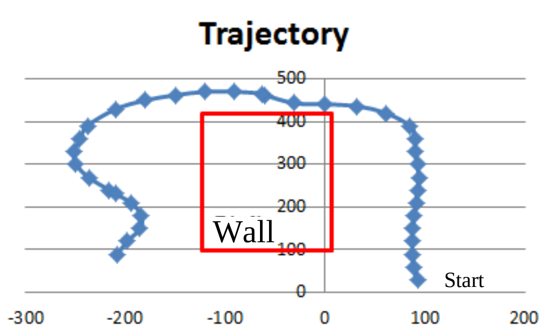
According to the NCTC (The National Counter Terrorism Center), safe distance for personnel concerned when dealing with hazardous materials such as explosives is 21 meters for pipe bombs, 34 meters to a vest bomb, and 46 meters to the suitcase bomb. In accordance with the results of the test, the robot is able to be controlled by the user from a safe distance from the location of the robot.

C. Measuring Robot Capabilities for Wall Following



Picture4. 3Design room for robot to follow the wall

One of the basic theory used in this system is a wall following. Because of that the measurement of the distance from the wall with robot when the robot in automatic running condition was done. This measurement is intended to determine the ability of the robot motion in accordance with the theory used. Testing was done by running the robot automatically to follow the wall.

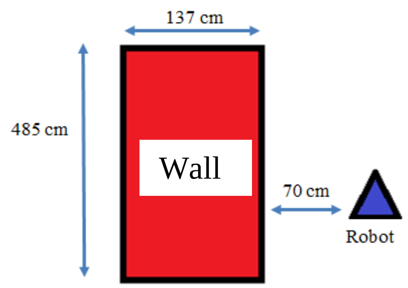


Picture4. 4Robot trajectory

Robots will follow the wall on the left of robot. Robot distance from the wall is measured using a ruler so we can know the actual distance from the wall.

Robots have always kept distance from the wall. When the robot estimates that there is no wall on the left of robot, then the robot will immediately change its movement to turn left. With a set point distance from the wall 108 cm, the robot will keep a distance from the wall with average distance of 80, 36 cm. The RMS error of robot to follow the wall is 35, 88%.

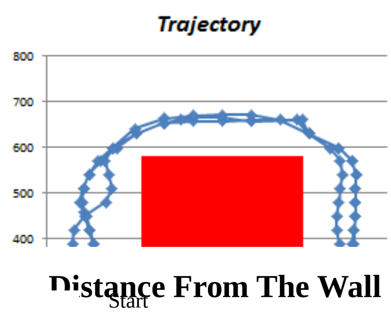
In this test, the robot will follow the wall on the left of robot so the robot will continue to move around the room with reference to the wall on the left. The robot will continue to move along the wall until stopped by the user. Robot trajectory was shown during following the wall. The robot continues to follow to the wall. In this

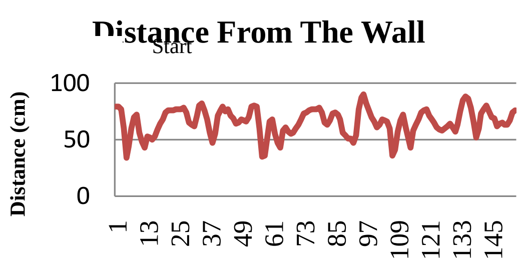


Picture4. 5Design for robot testing

test, robot moved around the walls as much as 3 times, then the robot is stopped using remote control.

In this test, the robot moves along the wall on the left of robot. When there is no wall on the left, then the robot quickly moves to turn left. When the robot is too close to the wall, then the robot will immediately move away from the wall. Setpoint distance in this test is 85 cm. At the moment the robot explore the wall on the





Pi

Picture4. 7 Distance between robot and the wall

left, the robot maintain the distance from the wall with a distance average of 65.73 cm. Robot has an average error of 26.3%. From both these tests was known that the precentage of average error for robot to keep a distance with the wall is 31.09%.

D. Measuring Robot Capabilities for Navigation in the room

The goal of this system in this project is the robot be able to explore the room automically. So it is necessary to test the ability of the robot to explore the room. The room will be divided into several section. The division of the amount of section is done using a separator. Robot will be allowed to run automatically and will note the time it takes the robot to enter each piece of section.

Tabel4.1 Table of Ability for Robot to Explore the Room

Room	Section	Time Per Section	Success Rate for Entering Room Section (%)

		(detik)	
1	1	0	100
2	1	0	100
	2	22	
3	1	0	100
	2	16	
	3	33	
4	1	0	100
	2	15	
	3	27	
	4	54	
5	1	0	80
	2	14	
	3	22	
	4	47	
	5	-	
6	1	0	83.33
	2	13	
	3	19	
	4	40	
	5	62	
	6	-	

During the test, the robot tried to follow the wall to the left of robot. Furthermore, we analyze the explore capabilities of robot. Robot explore capability shows the percentage of successful for robot to tracing the existing section. From these data, it can be seen the relationship between the amount of section with the time it takes the robot to explore the entire room. At room conditions consisting of 1 section to 4 section, the system is able to trace all the sections. But in the room with five sections, the percentage robot to explore the robot dropped to 80%. Percentage of success for robot to enter the sections of the room to 83.33% in a room with 6 division.

Every room needs a different time to enter all the sections. Room 1 takes 0 seconds, room 2 takes 22 seconds, room 3 takes 33 seconds, and the space 4 takes 54 seconds to enter all sections of the room. While the rooms 5 and 6, the robot can not enter all the sections. In the room 5, the robot takes 57 seconds to enter the four sections of the room. And in the room 6, the robot takes 62 seconds to enter the 5 sections of the room.

V.CONCLUSION

1. While robot explore the room, the robot maintain a distance with the wall to the left of robot with the average distance from the wall with set point 108 cm was 80.36 cm. The average error of system is 35.88%. While the set point 85 cm, the robot follow the wall to the left of robot with the average distance from the wall 65.73 cm. The average error is 26.3%. From these data it is known that the average error of robots to keep a distance from the left wall of 31.09% based on set point distance used.
2. Based on testing using test chamber, the average success for robot to explore the sections of the room is 92.67%.
3. 7.33% of error is caused by the inability of robot to enter some sections of the room because the gap between sections were too small for the reaction of robot. On the condition of the room as it is, the system will assume the gap as an obstacle so that the robot would anticipate in a way to distance themselves from it.
4. Addition of the sections of the room without adding the size of the room will further reduce the ability of robot to explore the room. This was caused by the distance reading ability by kinect within the limited between 80 cm to 4 meters.

REFERENCES

[1] Microsoft Developer Network Library. “Kinect for Windows Sensor Components and Specifications”. <URL: http://msdn.microsoft.com/en-us/library/jj131033.aspx>Desember, 2010.

[2] “__”. “Arduino Mega”. http://www.arduino.cc/en/Main/ arduinoBoardMegadiakses 14 Mei 2015.

[3] “__”,”*Encoder Measurements: How-To Guide*”. National Instrument. 2013.

[4] Purnomo, DidikSetyo et al. “*Navigation and Control System of Quadrotor Helicopter*". Electronics Engineering Polytechnic Institute of Surabaya (EEPIS): Indonesia. “__”.

[5] Anggoro D.A., Janu et al. “PerancanganSistemPemetaanOtomatisPada Mobile Robot Menggunakan Sensor Kinect danRotari Encoder”.InstitutTeknologiSepuluhNopember: Surabaya. 2012.