The Prototype of A Forklift Robot Based on AGV System and Android Wireless Controlled for Stacked Shelves

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ABSTRACT

The paper aims to build a prototype of an automatic forklift robot that can collect and place goods in the stacking shelves, that are monitored remotely using an Android-based device. The method used is AGV (Automated Guided Vehicle) on this forklift robot prototype to adjust its positions, by following a line that preset trajectory for stacking shelf positions, where this forklift robot can collect and place goods. The robot navigation system uses a photodiode for the line follower system, and for storage of goods, it uses the proximity sensors detecting the presence of goods on miniature stacking goods and decide where it can store a good or not on that designated cell of the stacking shelf. The miniature of stacking shelves is two by three cells. The control of the robot has two input controllers. One is on a robot itself. The other was on handheld based on Android operating systems, which control remotely using the wireless system with Bluetooth protocol. The results of the discussion on paper, the forklift robot could manage the task given as the predefined line to a followed parameter of stacking shelves with two by three-stack configuration for collect and place goods into their positions, the average time for the robot to collecting and placing goods on stacking from standing still position to stacking shelf then back to the robot origin position. It resulted in the shortest processing time around 43 seconds and the longest time around 45,3 seconds from the start position to stacking shelf position.

Keyword: Automated Guided Vehicle, Forklift Robotic, Android, Line Follower, Bluetooth

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I. INTRODUCTION

The rapid growth of the logistics industry is related to changes in human lifestyles, also triggering aspects of improvement and improvement in the process of storing goods to be able to offset the need for logistics availability of the goods. So a storage system that can be easily accessed anywhere by the user, it easy to find goods, meets safety and security standards, and an automated system with a minimum of human labor is needed. One effort that can be used is to use a forklift clamp robot to automatically put and retrieve goods using the line follower navigation system (AGV) and can be controlled (pick-up and put) of goods manually, or remotely using a Bluetooth-based handheld based on Android operating system.

Robots can have many advantages that cannot be owned by humans, which can produce the same quality if doing a job repeatedly - so it can function for several different tasks [3]. This can be felt so efficiently in particular in the industry. This can also be due to the accuracy that is so high, and the level of production costs and production times are so very low and fast.

This forklift clamp robot was developed by using an embedded system of AT Mega16 for controlling the robot movement and reading optical sensors for navigation, based on manual onboard input instruction and remote control using an android operating system-based handheld via wireless Bluetooth protocol. Operators operate the forklift [4] clamp robot by entering the stacking shelf code by pressing the push button. After the instruction is received, it is adjusted to the data that has been stored in ATMega16 to be executed in the location of the search rack stacking according to the instructions, whether on the lower level rack or the top-level rack, then the system controls the DC motor as a robot to move to the specified location using a guide from the line the navigation guide goes to the stacking shelf, either to pick up or put things after the forklift clamp robot are finished, it will return to its original position through the guideline that has been made.

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Robots can produce the same In the previous work, by [1], using a method of AGV[5] navigation using ATMEGA 328 controllers for controlling and coordinating all the peripherals as the PID control is used to regulate [9] wheel speed control. The motion of AGV is obtained with a 4-servo motor, driven by two motor drivers, the AGV controlled with Bluetooth module. As the Result of multiple path algorithms that are used for path preplanning in case of an obstacle present in the path of AGV.

The purpose of this study is to resolve forklift clamp robot to pick up and put goods on two by three stacking shelves using manual control on the robot forklift unit and remote control using Bluetooth on an android-based handheld, that the captured object can be lifted and taken to its destination and using a line follower for the robot navigation.

II. METHOD

A. System Design

Operation instructions are entered in two ways, as in fig.1 via the keypad on the robot and through the Android via the Bluetooth HC-05 module. If the stacking shelf code has been entered, the robot will move along with TRCT5000 guide input, the black line to where the item will be stored, and store the goods it carries on the rack with helped by proximity sensor to guide placement object on the stacking shelves. After the goods are stored according to the stacking code that has been inputted, the robot will return to the place of origin. Servo motor clamp serves to clamp the goods during the process and release it when it reaches its destination, while the DC motor serves to move the robot to the destination location that gets the voltage output from the motor driver, where information on the destination stacking rack and the operation status is displayed through the Alphanumeric LCD mounted on the robot.

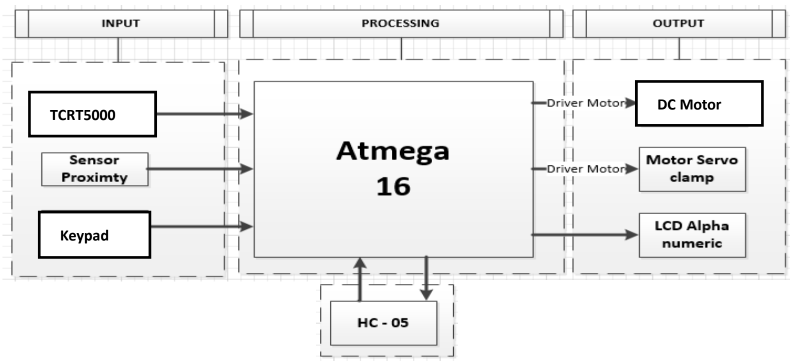

Fig.1. Design System of Robot Forklift

B. System Description

The design on a robot forklift clamp with navigation AGV system in this paper using the system description as follows. Namely using ATMEL® AVR® AT Mega 16® as the main controller of the robot and the inputs of its sensors with 8-bit CMOS architecture as in fig.2, the ATMega16 microcontroller consists of ALU functional units (Arithmetic and Logic Units), a set of working registers, instruction registers and decoders, and timers. 16-bit counter with the separate presale, comparison mode, and capture mode, Real-time countered with its oscillator, Four PWM channels and Analog comparator interface, eight channels with 10 ADC bits. At which Port A (PA0 until PA7), this is a bidirectional I/O (Input-Output) pin and can be programmed as an ADC input pin. Port A can function as an analog input on the A/D (Analog to Digital) converter. Port A is also a two-way bidirectional I / O port if the A/D converter not used.

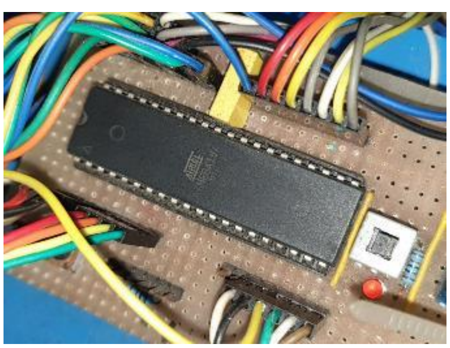

Fig.2.ATMEL®AVR®ATMega16 As Main Controlling Board System for Robot Forklift

The TCRT5000 Infrared Sensor module is to detect the presence of lines. This module will operate at 5V voltage. This sensor will produce logic 1 when hit by a white line and will produce logic 0 when the sensor is placed on a black surface. In this tool, 5 x TCRT5000 modules are placed in front of the robot to guide the robot's journey during operation. This module has a lens to focus the sending and receiving of infrared signals so that this module can be used to detect distance up to 80 cm. This sensor can be

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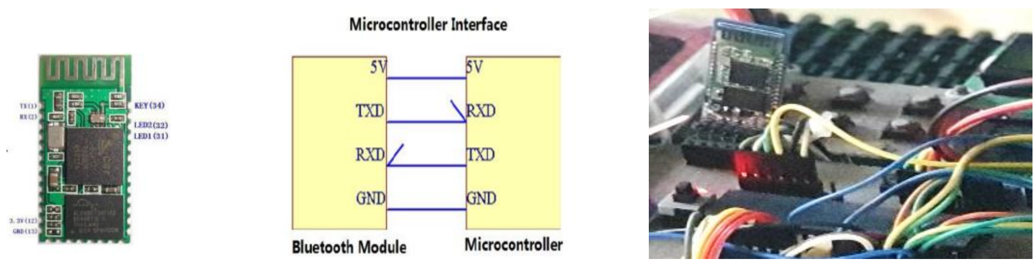
changed as needed by rotating the trimmer. The calibration of the placement sensor is required to acquire the precision of line reading to guide the robot to its location. As shown in Fig.3, where the module placement on the bottom from of the robot for better line color reading being used to navigate, on the upper-side, there is a potentiometer to adjust the sensitivity of the module.

(a) *(b)*

Fig.3. (a) The TCRT5000 Modules Infrared Sensor; **(b)**Placement of 5 Modules TCRT5000 Sensors at The Bottom of The Forklift Robot

Bluetooth HC — 05 Modules is a wireless communication protocol that works at 2.4 GHz radio frequency to exchange data on cellular devices such as PDAs, laptops, cellphones, etc. Bluetooth Module HC-05 with a supply voltage of 3.3 V to pin 12 of the Bluetooth modules as VCC. Pin 1 on the Bluetooth module as a transmitter. Then pin two on Bluetooth as a receiver. Fig.4 (a) is the hardware, Fig.4 (b) is how to connect with the microcontroller I/O with 5Volt (V_{cc}), Fig.4 (c) is how the module placement near microcontroller chip.



(a) *(b)* *(c)*

Fig.4. (a) Bluetooth HC - 05 Module[8]; **(b)** Interfacing Bluetooth module with I/O AT Mega16; **(c)** Placement of HC - 05 Module on Robot

Keypad and Liquid Crystal Display (LCD) alphanumeric in fig.5 are used to display various matters related to status activities or as monitoring from a microcontroller, by displaying text consisting of letters and numbers. While the keypad is used to enter the destination code of the stacking shelf consisting of numbers 1 through 6, with configurations of numbers, 1 to 3 are the lower-level shelves, while 4 to 6 are the upper-level shelves.

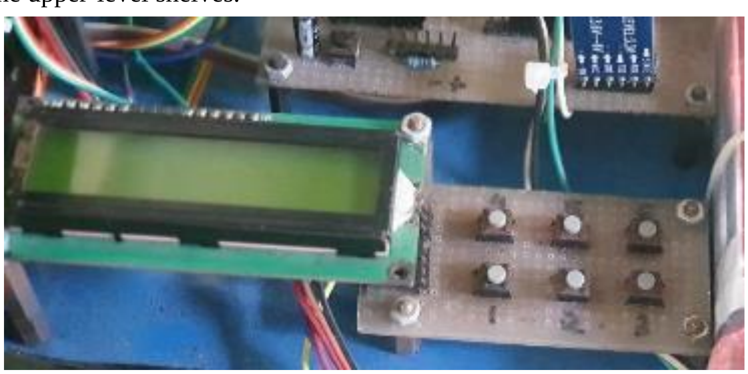


Fig.5. The layout of Keypad and Liquid Crystal Display (LCD) Alphanumeric

Motor Drivers using the L293D module as in fig.6(a). There are two power pins for this IC. One is Vss (Vcc1), which provides voltage for the IC to work. It must be connected to 5V. The other is Vs. (Vcc2) which provides voltage for the motor to work. According to the motor specifications, it can connect this pin anywhere between 4.5 V to 12V, and here it has connected it to 12V. All ground pins must be grounded. The activation pins (Activate 1.2 and Activate 3.4) are used to activate each input pin for motor one and motor two as in fig.6(b). As in fig.6(c), in most cases, we will use both motors; both pins remain high by default when

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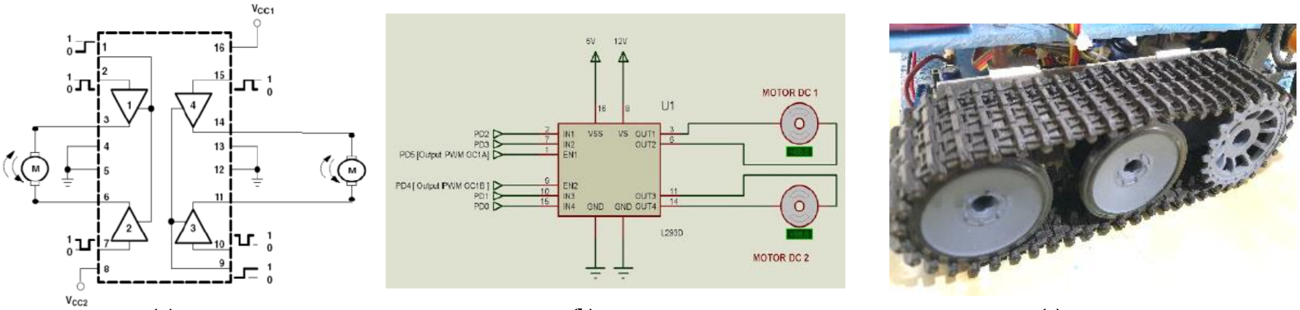
connected to 5V supply. Input pin 1.2 is used to control motor one and input pin 3 and 4 are used to control motor 2. The input pin is connected to any digital circuit or microcontroller to control the speed and direction of the motor.



(a) ***(b)*** ***(c)***

Fig.6. ***(a)*** The L293D module pinou[7]t; ***(b)*** Interfacing L293D module with DC motor[6]; ***(c)*** The DC motor with a drivetrain

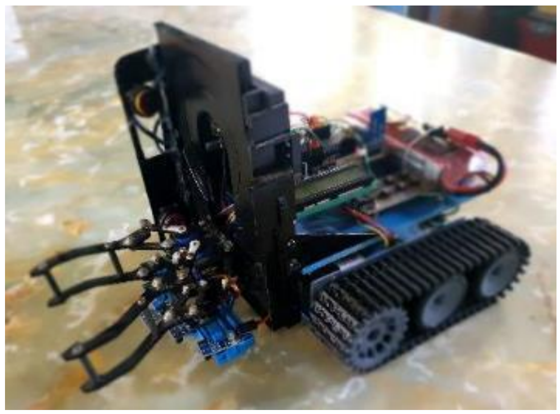


Fig.7. The overall system of the forklift clamp robot

This system powered by 14.4 Volt with 3300mAh lithium-ion battery for supporting its operation, for task pick up and put goods on 2 x 3 stacking shelves, that the captured object can be lifted and taken to its destination and using line follower for the robot navigation as in fig.7.

C. Path and Navigation

As mentioned above, this robot runs following a predetermined path through a starting guideline to the stacking rack location and returns to its original position as follows Fig.8.

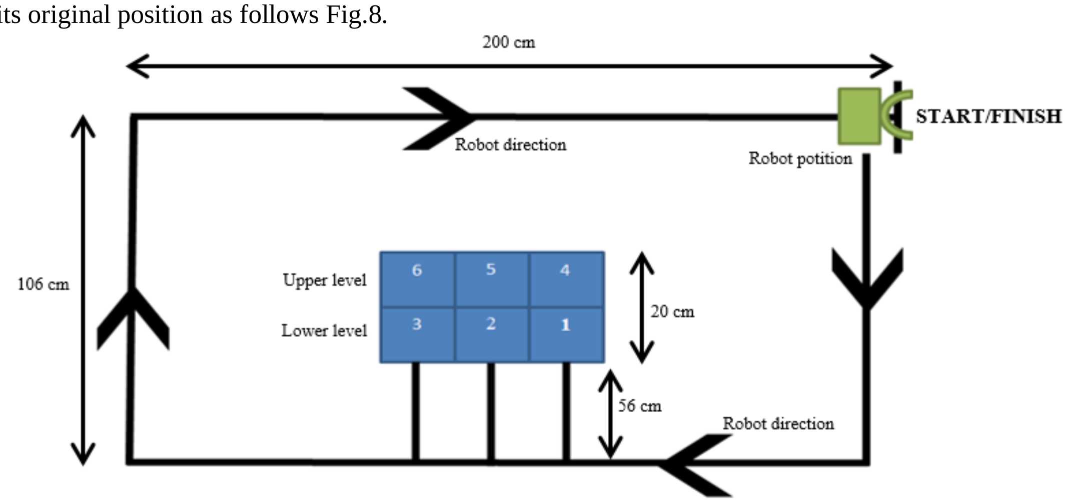


Fig.8. The trajectory of forklift clamp robot task

TCRT5000 sensor readings are forwarded to the microcontroller with parameters that have been previously set, where certain logic values to the DC motor driver to be able to move both ways, i.e., clockwise (Clock Wise = CW) and move counterclockwise (Contra Clock Wise = CCW). The combination of the rotation motors of the right motor and left motor based on the logic table 1

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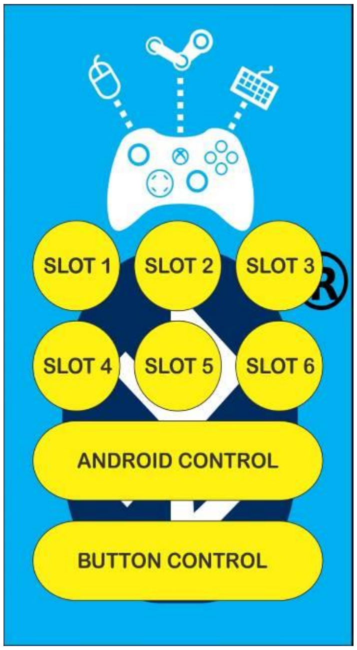
obtained, so that it can make the robot move forward, and turn right or left. The speed of movement from the direction of the robot by the DC motor we use the PWM method settings based on equations (1).

$$\text{Average Voltage} = (\text{Duty Cycle} \div 256) \times 5 \text{ volts} \tag{1}$$

The Pulse-width modulation (PWM) allows the basic Stamp or (a purely digital device) to generate an analog voltage to convert PWM into an analog voltage we need to filter out the pulses and store the average voltage.

D. Android Wireless Control

The remote-control system uses Android, which was built using Android Studio, with Bluetooth protocol where this system can also be selected manually or control using Android in the options menu, as in fig.9(a), and fig.9(b).



(a)

```java
import android.bluetooth.BluetoothSocket;
import android.os.Bundle;
import android.view.View;
import android.widget.Button;
import android.widget.Toast;
import java.io.IOException;
public class Activity_2 extends AppCompatActivity {
    private Button Slot1, Slot2, Slot3, Slot4, Slot5, Slot6, Android, Tombol;
    private BluetoothSocket mBTSocket = null;
    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_2);
        Slot1 = (Button) findViewById(R.id.button5);
        Slot2 = (Button) findViewById(R.id.button11);
        Slot3 = (Button) findViewById(R.id.button10);
        Slot4 = (Button) findViewById(R.id.button7);
        Slot5 = (Button) findViewById(R.id.button9);
        Slot6 = (Button) findViewById(R.id.button8);
        Android = (Button) findViewById(R.id.button12);
        Tombol = (Button) findViewById(R.id.button13);
        Slot1.setOnClickListener(new View.OnClickListener() {
                @Override
                public void onClick(View v) {
                    if (Slot1.isClickable()) {
                        sendData("1");
                    }
                }
            });
            Slot2.setOnClickListener(new View.OnClickListener() {
                @Override
                public void onClick(View v) {
                    if (Slot2.isClickable()) {
                        sendData("2");
                    }
                }
            });
            Slot3.setOnClickListener(new View.OnClickListener() {
                @Override
                public void onClick(View v) {
                    if (Slot3.isClickable()) {
                        sendData("3");
                    }
```

(b)

Fig.9. ***(a)*** Android Bluetooth control UI layout; ***(b)*** Example of Bluetooth control instructions

In control using a Bluetooth connection we use the command character characters in the form of letters or numbers which will later be translated into the ATMega16 language into a control language, for example, we use numbers 1 to 6 to control the robot command to place items on the stacked shelves according to the command numbers. We use letters such as "AA" and "BB" commands to switch controls from "Android Control" or "Button Control", and vice versa.

III. RESULT AND DISCUSSION

The first phase of testing is carried out to get the parameter values, determine the direction of motion of the robot, where the value is taken from 5 TCRT5000 module units mounted on the front of the robot to detect straight lines and turn lines. The following table I. Reads the results of the sensor and the determination of the direction parameters of the robot.

TABLE I
Comparing TCRT5000 State Reading and Motor DC Driving Action

Sensor TCRT5000					Motor DC driving Action	
Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Right Motor DC	Right Motor DC
True	True	True	True	True	Stop	Stop
True	False	False	False	True	CW	CW
False	True	False	False	False	Stop	CW
False	False	False	True	False	CCW	CCW
True	True	True	False	False	CCW	Stop

From the results of testing the robot movement based on table 1. Of 5 piece sensor TCRT5000, where each sensor output is in binary digit 0 or 1, on another word the state 1 equal to "True", and 0 equal to "False", that state drove the L293D module can be analyzed as follows: Binary logic 11111 will cause the left motor to stop and the right motor to stop. 10001 binary logic will cause the left motor clockwise (CW) and the right motor clockwise (CW). Binary logic 01000 will cause the left motor to rotate clockwise

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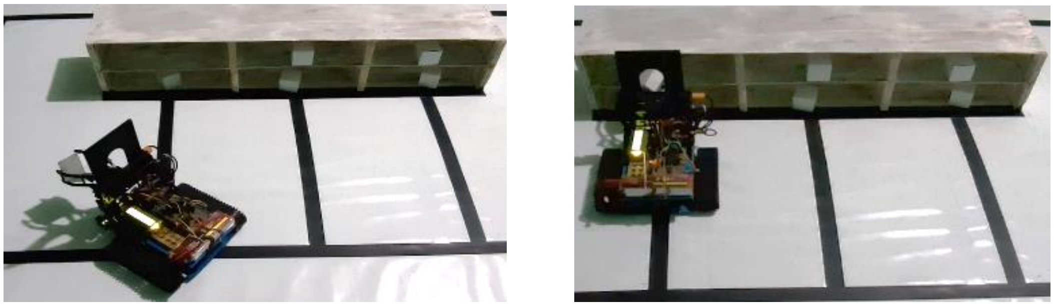
(CW) and the right motor stop. Binary logic 00010 will cause the left motor to rotate the counter-clockwise (CCW), and the right motor rotates the counter-clockwise (CCW). Binary logic 11100 will cause the motor to stop and the right motor to rotate counter-clockwise. If we make a pin output high, the voltage at that pin will be close to 5 Volt, and the output low is close to 0 Volt. If that pin switched the pin rapidly change between high and low so that it was high half the time and low half the time. The average voltage over time would be halfway between 0 and 5 Volt (or its around 2.5 Volt). The average voltage for controlling DC motor speed by modulation of PMW from motor driver L293D module output as in Fig.10.



(a) (b)

Fig.10. ***(a)***Robot turn in to stacked shelves; ***(b)***Robot using it forklift clamp to put goods on the upper level

To get the speed of the motor that we want to follow the direction of movement we conducted a series of trials to get the reaction speed of the movement of the robot in the navigation system following a predetermined guideline, on the other hand, it still requires accurate reading of the guideline, so that the robot does not move out of the guideline predetermined.

Table II
PMW Duty Cycle and Average Voltage

Duty Cycle of PWM	Right Motor Average Voltage(volt)	Left Motor Average Voltage (volt)
75	1,39	1,44
90	1,67	1,72
125	2,43	2,41
160	2,95	2,87
210	3,87	3,98
255	4,97	4,88

If we look at Table II, there is an average voltage difference between the right DC motor and the left DC motor from the PWM output reading. Where for the right DC motor, has an average difference of about 0.1 Volts, in some PWM duty cycle tests, this can be due to either mechanical load or unbalanced weight distribution borne on the DC motor differing between the right and the parts left, but this is still within reasonable limits.

The second phase of testing, namely by running the robot with a load of goods, and see the overall system performance after the system through the first trial is the calibration of the direction of the robot and the speed of the robot. Wherein this second phase of testing the robot carries the load and then moves along the guideline, towards the intended stacked shelves (according to the code pressed on the keypad) both for the lower level shelves (shelves no. 1, 2, 3) and the top-level shelves (shelves no. 4, 5, 6), after placing or taking items the robot will reverse direction to follow the guideline again until it arrives at its original position. At this stage of testing, we carry out testing records for the length of time the process is carried out by the robot, and whether the robot can perform the commands given to it and carried out successfully or failed.

TABLE III
The Overall Robot Response Time of Putting Object on The Stacked Shelves

	Time (seconds)		
	Exp. 1	Exp. 2	Exp. 3
Shelves 1	58	29	33
Shelves 2	40	42	45
Shelves 3	42	47	51
Shelves 4	38	48	42
Shelves 5	41	47	44
Shelves 6	46	49	53

From the data in table III, we can graph the relationship between the response times of the forklift robot from the start position to the position of placing the goods on a stacked rack, where “Exp.” Stand for “experiment”, as follows Fig.11.

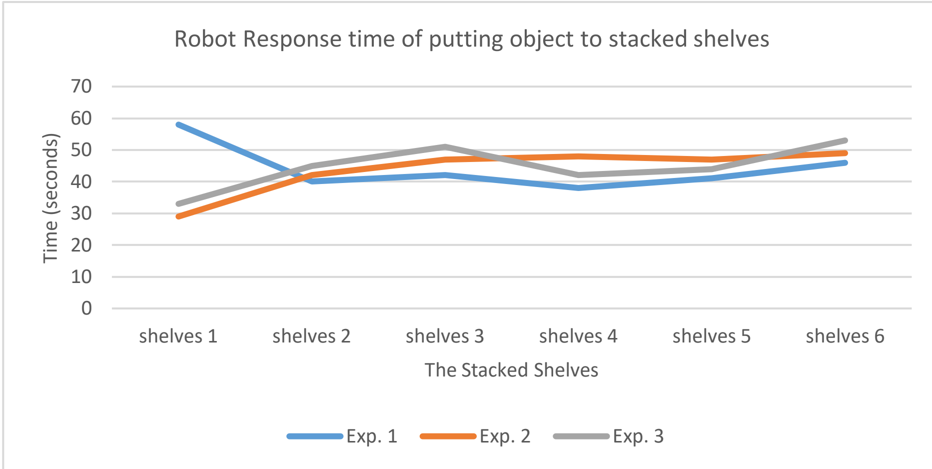


Fig.11. Robot Response Time by stacked shelves

The data obtained from several experiments (Exp. 1 to Exp. 3), as in Fig.11, obtained interesting results. Namely, the total experiment was 18 times, where out of 18 experiments, there were 14 attempts of robots succeeded in placing items on a stacked shelf, and returned to their original place, and four attempts of robots failed to place items on the stacked shelves, due to the position of the robot or forklift clamp which was not well-positioned, and this only happened to the top-tiered shelves in Exp. 2, so that the goods fall and before Exp.3 we charge the battery first, and the results are better, considering that at Exp.3 the stacking rack distance is further from the starting position, when compared to Exp.1 and Exp.2, of the data with the percentage of success of a total of 18 trials was 78%.

As we notice on table 3, from 18 of these experiments, we can take the average speed of the forklift robot response from Exp.1 to Exp.3 at the lower level (shelves no.1 to shelves no.3) is 43 seconds and at the upper level (shelves no.4 to shelves no.6) is 45.3 seconds, where the overall response time is only 45.3 - 43 seconds adrift is 2.3 seconds, so the average response time difference between the lower level and the level The top is 2.3 seconds.

IV. **CONCLUSION**

Based on forklift clamp robot testing, it was found that the robot can move objects on the stacked shelves resulting in the shortest processing time around 46.25 seconds and the longest time around 43.89 seconds from starting position to stacking shelf position. Take or put goods from the start position to the stacking shelf position and the success rate of order execution by 78%. This is caused by a decrease in battery capacity, (because in this study we did not take measurements usage of battery energy) thereby affecting the performance and accuracy of the robot and the speed of the robot movement also one of the inhibiting factors is the power of the battery capacity that can be increased to get optimal robot performance, for further development.

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