DEVELOPMENT OF IOT BASED MONITORING AND CONTROL SYSTEM IN INDUSTRIAL MACHINE

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electronic Engineering Technology (Industrial Electronics) with Honours

by

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960305-11-5801

FACULTY OF ELECTRICAL AND ELECTRONIC ENGINEERING TECHNOLOGY

2020

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Tajuk: DEVELOPMENT OF IOT BASED MONITORING AND CONTROL SYSTEM IN INDUSTRIAL MACHINE

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APPROVAL

This report is submitted to the Faculty of Electrical and Electronic Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering Technology (Industrial Electronics) with Honours. The member of the supervisory is as follow:

Signature: ………………………………………………………

Supervisor: Ts Ahmad Nizam Bin Mohd Jahari @ Mohd Johari

ABSTRAK

Revolusi Perindustrian 4.0 telah memberi perubahan kepada industri pembuatan dalam melibatkan sistem mereka dalam teknologi rangkaian *"Internet of Things"* (IoT). Projek ini mensasarkan keadaan yang berlaku dalam industri sebenar dimana permasalah yang timbul apabila sistem yang sedia ada tidak mempunyai ciri-ciri IoT. Proses menyusun sepertimana yang ada dalam industri sebenar dibangun dalam platform kilang maya menggunakan perisian Factory I/O agar memastikan sistem lebih selamat dan cekap sebelum diaplikasikan dalam industri. Proses dikawal dengan menggunakan mikrokontroler Arduino Mega 2560 menggantikan fungsi *"Programmable Logic Controller"* (PLC) dalam operasi. Program dibangunkan mengikut arahan urutan sepertimana penggunaan PLC dan Modbus TCP/IP digunakan sebagai jalan komunikasi antara perisian dan Arduino. Ianya bergantung kepada 4 keadaan kemasukan barang ke dalam proses. Sementara itu, ESP32 melaksanakan kawalan dan pemantauan terhadap sistem melalui pelayan web sebagai aplikasi IoT. Sistem ini secara amnya boleh dipantau melalui rangkaian internet akan kemaskini perubahan yang berlaku pada urutan proses menyusun dalam masa nyata. Selain itu, terdapat ciri tambahan seperti pembilang bagi setiap barang yang telah dihasilkan dan penggera bagi kondisi tidak biasa semasa proses berlaku.

ABSTRACT

Industrial Revolution 4.0 has changed the manufacturing industry in involving their systems in Internet of Things (IoT) network technology. This project targets the situation in the real industry where problems arise when the existing system does not have IoT features. The sorting process as in the real industry is built in a virtual factory platform using Factory I/O software to ensure the system is more secure and efficient before being applied in the operation. The process is controlled using the Arduino Mega 2560 microcontroller replacing the programmable logic controller (PLC) function in the industry. The program is developed according to the sequence instructions as the use of PLC and Modbus TCP / IP is used as a communication path between Software and Arduino. It depends on the 4 conditions of item entry into the process. Meanwhile, ESP32 implements control and monitoring of the system via a web server as an IoT application. This system can generally be monitored through the internet network will update the changes that occur in the sequence of the sorting process in real time. In addition, there are additional features such as a counter for each item that has been generated and an alarm for abnormal conditions during the process.

ACKNOWLEDGEMENTS

I want to express my deepest thanks to Allah S.W.T for His blessings and greatness guided me to work on right path. First of all, I am grateful to all those people who have been directly and indirectly interested in providing support and assistance in all that I have done. I 'd never be able to work successfully without these. Secondly, I would like to convey my special appreciation to my final year project supervisor, Ts Ahmad Nizam Bin Mohd Jahari @ Mohd Johari for providing guidance and advices through my bachelor's degree project. In addition, my co-supervisor, Ts. Nadzrie Bin Mohamood who assisted me in technical advice. I would also like to take this opportunity to sincerely thanks to all the lecturers Faculty of Electrical and Electronic Engineering Technology (FTKEE) for all the efforts and knowledge gained throughout my degree years. These invaluable knowledge of the field of electronic industry engineering can be implements and enhance skills for my next journey. I do not have any worthwhile words to express how thankful I am to all of them for all the time I have been there.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

The development of technology today in the industrial world has accelerated especially in the manufacturing industry. The success of this fourth revolution or known as IR4.0 empowered by the Internet of Things (IoT) in the application industry to increase productivity and improve operations through real-time data access. This technology leverages production machine communication to the cloud allowing data flow to be transferred. In addition, it provides the ability to monitor and control the process remotely which allows production to be changed quickly in real time when it is needed. This is done by controlling and monitoring the machine remotely based on real data obtained from various parts of the factory even throughout the factory.

This smart factory is simulated using 3D virtual factory which adopted to the real system. It enables to build a virtual process such as sorting process and assembler process in the actual manufacturing industry. Equivalent systems that have been designed with virtual factories allow IoT development to be significantly analysed before the system is applied. Furthermore, virtual factory assembling subsystem using a library of industrial component including sensors, conveyors, and many others. The virtual factory-based PLC training platform also interfacing controller physically by using microcontroller, SoftPC, TCP / IP and other technologies. Hence, IoT-based systems developed through virtual processes enables production machines to be controlled and monitored remotely with connections from internet.

1.2 Problem Statement

Industrial companies face problems with indirect data collection in real time where machines are only visually monitored by manual due to non-IoT-based manufacturing equipment. Companies may be afraid to replace old devices that still work well even those are 20 years or more old. Consequently, it requires the development of a new system, a lot of cost investment and replace an assembly-line equipment which disrupts production. The actual factory process is simulated using virtual factory software requires human intervention either to control or monitor it. The upgrade virtual process with IoT features can implement control systems and monitoring over the internet.

1.3 Objective

The aims of this project are based on problem statement above:

1) To design and develop machine using virtual factory platform.

2) To develop control on virtual factory system using microcontroller.

3) To develop internet-based monitoring and control system.

1.4 Scope

This project focuses primarily on the use of virtual process in control and monitoring systems through the implementation of IoT. This 3D virtual factory simulation designs and develops system into an actual sorting process in industrial manufacturing. The system develops by Arduino as a controller assisted by Arduino Ethernet Shield capable to control the virtual factory process through Modbus TCP/IP communication. The virtual process factory also can be control and monitor via the web server. Moreover, the features such as a counter will be added monitors the value of production for maintenance to ensure quality of productivity.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter focuses on term of IoT relates to control and monitor the industrial machine application by simulation process. Review of audit and centralize various research articles on tests that have been successfully conducted by analysts or experts who are significantly different in the field of study. It also relates to identify and review existing critiques within the topic to justify this research by uncovering gaps in current research. This review adds even better understand the project development and provide a basic idea of how it can help current project development.

2.2 Related

Research on journals or sources related to the subject field will be presented in this section. The purpose of the literature review is to collect valuable knowledge, as well as to gather relevant details that might be useful in this study.

2.2.1 Control and Monitor Automatic PLC System for Packaging Industry

A Human Machine Interface (HMI) implemented for a Programmable Logic Controller (PLC) based automation in packaging process which may be remotely monitored and controlled by mobile application(Mofidul et al. 2019). An IR sensor used to detect objects and provide feedback to the Arduino Uno to move the relay. All the conditions for relays are taken as PLC input. An HMI is designed to create a communication channel between PLC-based operators and factories through android applications and microcontroller.

Model considers one conveyor belts for items to be transport to the destined box and another conveyor belts to transport unfilled boxes and filled boxes. The PLC acts as a controller for high-speed DC motor that rotates the conveyor belt. The interface designed to control and monitor the processes depending on Bluetooth module, Arduino uno and android platform.

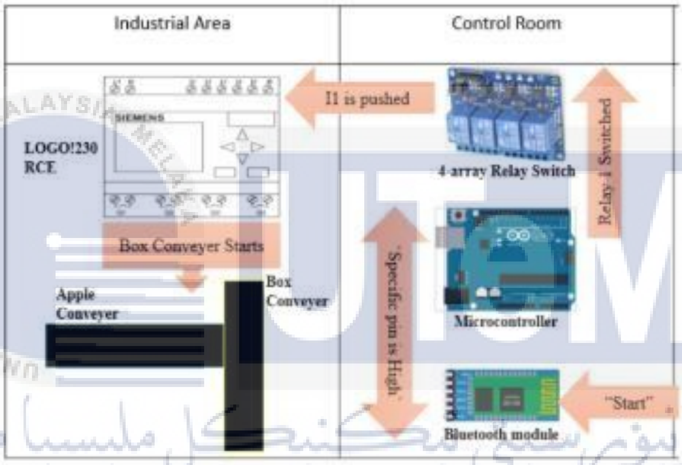

Figure 2.1: Procedure of the system

The implementation of the Software includes the PLC ladder diagram built android application and configured programs as remote control and monitoring system for Arduino. It is also applied utilizing LOGO! Soft V8 in programming and operation of the introduced model. For a quicker, straightforward, and space-saving solution, LOGO! is an ideal selection. LOGO! Soft Comfort minimizes wiring with easier installation.

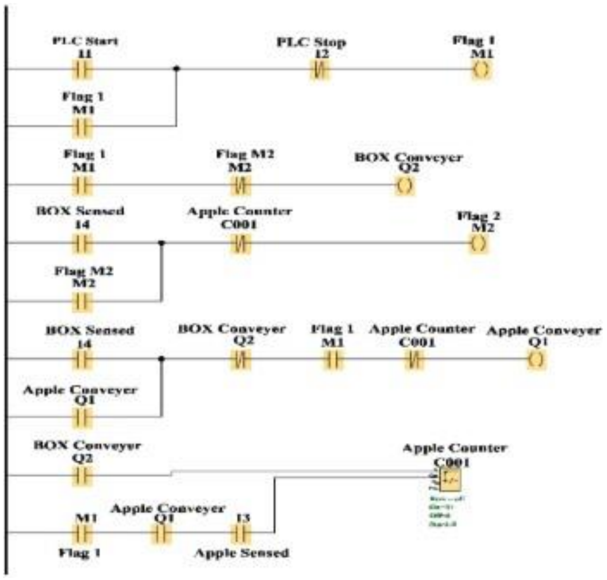

Figure 2.2: The automatic packaging system ladder diagram

Input				Output	
I1	I2	I3	I4	Q1	Q2
PLC starts	PLC stops	Apple or sample sensed	Box sensed	Apple or sample conveyor belt	Box conveyor belt
Relays				Counter	
M1		M2		C001	
Relay contacts		Relay contacts		Apple Counter	

Figure 2.3: Inputs, outputs, and configuration of PLC relay

Android Studio (emulator) is used to develop Android-based PLC monitors application as a remote control. This application provides for remote observation with a single row display and three control buttons.

Table 2.1: Summary Table regarding to 2.2.1

Author(s)	Description	Method
Mofidul et al. (2019)	This PLC with implementation of an HMI that can be controlled and monitored for a prototype of automated packaging process applications through mobile phones. Operators and factories communicate same path to minimize the overall cost of using SCADA.	Android Studio is used in sending command signals and receiving status by the Arduino Uno via Bluetooth. The Switching Relay operates in this process to provide plc input from Arduino as control mode. Arduino receives output from PLC as monitoring mode. Ladder diagram of PLC develops by LOGO! Soft V8.

2.2.2 Automation Industry Simulation Software

According to Sciences (2018) in his thesis aims to create a 3D model of the robotics laboratory which to be used with the KUKASim together with finding a suitable method for transferring code to the actual robots. KUKASim, a simulation software in which the user can make an environment and the robot programming simulation. It permits the offline programming of the robot and since a real environment can be designed, the software is helpful to attempt the program before downloading it to the robot. That could be useful so as to evade impacts and to advance the program. The software gives the chance to have a real time connection with the KUKA's virtual controller, the office lite. There are several advantages of using Office lite, one being that it tends to be utilized in more than one PC and is simpler to move.

Figure 2.4: KUKA Office Lite

The method of controlling the robot is with Office Lite, which makes the control of the robot as it was being controlled with the smartPad. So as to control it and to get the code, the robot has to be connected to the Office Lite. The Office Lite software is installed on a VMware program, so it has to be opened with this software by selecting Office Lite version to run in the machine.

To connect Office Lite controller to a robot in KUKASim, several steps need to be made. KUKASim software must be opened with the desired environment. In KUKASim's "Program" tab switch to the "Controller Map", which is in the left corner at the bottom. Select the VRC and in VRC Host field, write the VMwares computers name, which can be found in "Control panel/All control panel items/System". Then click the button "Connect" on the toolbar of KUKASim. From that point onward, it is important to choose the design for the robots, as indicated by the robot that is needed to be reproduced.It was found that KUKA.OfficeLite combined with KUKASim could be a decent tool for the student to figure out how to utilize the controller of the robot, the smartPAD, yet without the need of being on the labaratory.

As a conclusion, KUKASim improves of the undertaking has included a few issues in regard to establishments, licenses and connections. Regardless of whether a portion of these have just been sifted through, there are still a few perspectives that require further exertion. Disregarding this, KUKASim programming is not only a learning tool yet in addition a product that can be utilized in the manufacturing industry, so it gives student a contact with a real application of the studies.

Table 2.2: Summary Table regarding to 2.2.2

Author(s)	Description	Method
Sciences (2018)	KUKASim software created 3D models of robotics laboratories that will be used and transfer code to real robots. It improves of the undertaking has included a few issues regarding establishments, licenses, and connections that gives benefit to students.	This project uses KUKASim and SketchUp as external software. It also along with the latest Software that is 3D modelling. Office Lite software that controls the robot and installed on a VMware program.

2.2.3 Programmable Logic Controller for Wireless Control and Monitoring

A control device Programmable Logic Controllers (PLC) that is exceptionally particular and advanced to deal with control occasions continuously and it is generally applied in industrial automation control. Nowadays, in response to market demands, numerous highlights and capacities are acquainted with PLC. The present PLCs are now profiting by different new innovations, and built-in wireless is among advancing features that have not been broadly adopted at this point. However, it gets crucial to implement the most appropriate wireless protocol according to application to be specific Bluetooth, Wi-Fi, ZigBee, and others.

ZigBee protocol can possibly be utilized for tending to remote PLC current confinements through the structure and usage of an ongoing remote control and monitoring system(Moallim et al. 2017). In term of its networking capability, ZigBee protocol gives a few kinds of system topologies going from point to point, star, to mesh topology. Network mesh capability of the ZigBee protocol is an amazing method to course information. Data allowed to jump node to node by expanding the range and reliability is improves the ability to build alternative paths when a connection is lost, or one node fails.

After Wi-Fi and Bluetooth, ZigBee was presented and designed specifically to convey modest quantities of data over a short distance while using less power, which means once you set it up, it can keep going for quite a long time. Instead of Wi-Fi, it is a mesh networking standard, meaning each node in the network is connected to each other. A Zigbee based wireless unit is implemented employing Arduino Uno that provides network control flexibility and simple system reconfiguration.

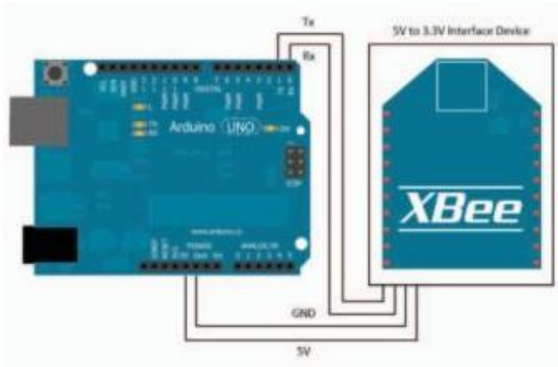

Figure 2.5: Wireless unit connections

Arduino boards can read and write electrical inputs - sensors, push buttons, or serial data and make it into an output – actuating the motors, turn on the LEDs, and others. Arduino works with Arduino Software IDE Wiring-based programming language. As the wireless unit Arduino device reads an updated data in the system, it will convert it into a serial data packet and send it to the XBee RF module to be transmitted wirelessly. The serial data packet is one byte (8bits) developed.

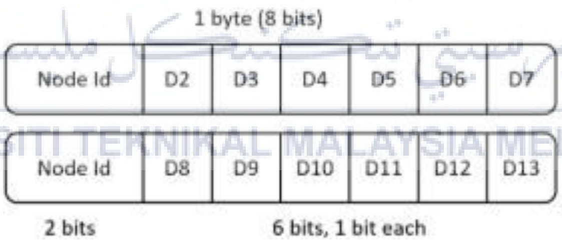

Figure 2.6: Serial data packet structure

The design prototype uses 2 bits for the receiving node Id and 6 bits for carrying data because of the used PLC device's specification that only has six digital inputs and six digital outputs. If another PLC device uses more digital inputs/outputs, the serial data packet may consist of two or three bytes, and others. However, the system prototype may be implemented using Arduino Mega to make up for the additional PLC's inputs/outputs.

Table 2.3: Summary Table regarding to 2.2.3

Author(s)	Description	Method
Moallim et al. (2017)	The ZigBee protocol used to overcome the limitations of wireless PLCs through this design and implementation of monitoring systems and real-time wireless control. This design is a standard network connection where every node in the network is connected over Wi-Fi. It also brings small amounts of data over a short distance with less power usage.	Addressing the wireless PLC using ZigBee wireless protocol. Zigbee implements the use of the Arduino Uno-based wireless unit. Data read from Arduino converts it to a serial data packet and send it to the XBee RF module for transmission. This design prototype depends on PLC type and specification for carrying data.

2.2.4 Arduino Mega Microcontroller IoT-based Warehouse Automation System

Devices can be operated via smartphones between devices that are remotely connected and communicate live using internet by implementing The Internet of Things (IoT). With this system, equipment is easily monitored and controlled.

(Kurnia and Sie 2019) did one subject of research by directing exploratory tests to improve security's, detection monitoring and programmed control in warehouse supervision. The Arduino Mega 2560 based ATMega2560 Chipset is used as a hardware in the control system. I / O pin selection depends on the application used in the warehouses to support the operational activities and the ESP8266 module is used as a tool for IoT communication using the Blynk smartphone application. in case of internet connection failure while accessing the room, the RFID Mifare RC522 module is used.

With Internet of Things, it aims to control and monitor components of sensor and actuator if the device is on an internet connection. If the device is not connected to the Internet, users can access the room by the Radio Frequency Identification method, which requires identification with tags or labels mounted on objects.Panel Control system is connected to the Mifare MC522 and Arduino Mega 2560 to Enable the RFID mode. To ensure the device is connected, various buttons are used for manual operation in case of obstruction of internet connection.

Figure 2.7: Panel Control System

There is a way to create and design mobile application in minutes by Blynk software, one the Internet of Things (IoT) platform. Drag and drop mobile application builders from prototype platforms such as Arduino, Raspberry Pi to industrial classes ESP8266, Sierra Wireless, and several other hardware devices on a variety of hardware applications. The Blynk platform's three main components include the Blynk Libraries, Blynk App and Blynk Server.

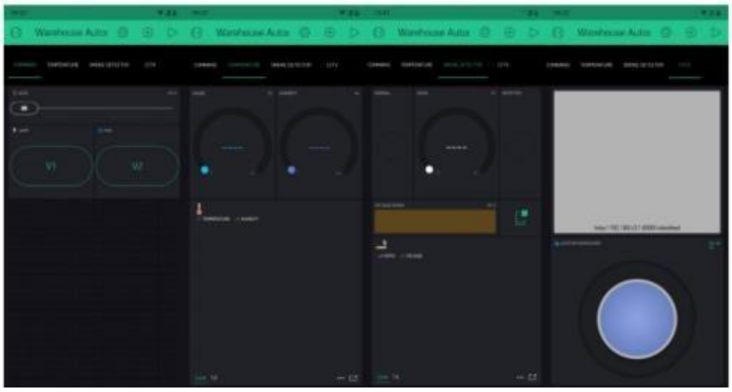

Figure 2.8: Blynk App

The ESP8266, a full TCP/IP stack also known as cheap Wi-Fi microchip have microcontroller capability. ESP-01 can offer access to Wi-Fi networks through microcontroller and able to either hosting an application. It can basically be attached to an Arduino device and get the Wi-Fi capabilities as offered by the Wi-Fi Shield as programmed with the AT command firmware. This module has efficient on-board processing and storage capabilities that enables it to integrate with other sensors and application devices through its GPIO. APSD for VoIP applications Module supports Bluetooth interface. It contains customized RF that enables it to operate under every working environment and does not require external RF parts.

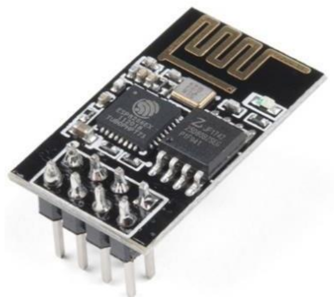

Figure 2.9: ESP8266

Table 2.4: Summary Table regarding to 2.2.4

Author(s)	Description	Method
Kurnia and Sie (2019)	The experiment tests on warehouse to improve security along detection coverage based automatic control and monitoring system. All operating activities in the general warehouse will be supported by instruments that require hardware design to be further developed.	The Arduino Mega 2560 is a control system used by hardware. IoT communication uses Smartphone devices with the Blynk application based of ESP8266 module dan RFID Mifare RC522 module as a backup as failure of internet connection to access the room.

2.2.5 Smart Power Output Device Using ESP8266-based Wi-Fi Module

This study aims to engage in research, modelling and implementation of an integrated technology that will blend WiFi development board modules built on ESP8266 based modules, microcontrollers, and elements of Internet of Things to form an intelligent environment(Martillano 2018).

The concept of Smart Power is applied by allowing light switching and real sources of power controlled and monitored over the internet. it can also operate over a network of local wireless areas using standard IoT elements such as mobile, application protocols and web communications. The circuit controller performed the control and triggered by Microcontroller Unit which is the Arduino MCU. Altogether, hardware setup as a Device Controller combining industrial relay circuits and MCUs in mobile devices. WEMOS D1 Mini Wi-Fi board is used for the communication. Arduino Mega Microcontroller was used for actual control of power outlet switches.

Figure 2.10: D1 Mini Wi-Fi board built on ESP8266 chip

Wi-Fi Board is configured to Arduino Mega by connection of Tx Pin of D1 Mini to the Rx Pin of Arduino. Next, Rx Pin of D1 Mini connected to the Tx Pin to continue the data transmission to the D1 Mini that communicated to the Server using Wi-Fi. The study aims that connection of Arduino and D1 Mini can continue to connect to cloud server by providing locally hosted setup to help situations where the internet is inaccessible but only a Wi-Fi connection is available. These settings can also provide system control that is visible through web applications accessible within the institution.

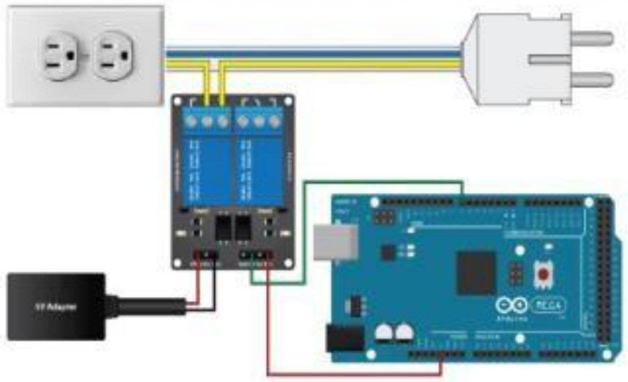

Figure 2.11: Circuit diagram of industrial relay controller to Arduino Mega

The Hypertext Transmission Protocol (HTTP) class is used to transmit data to the cloud server on request for android applications. On the mobile device, power outlets are managed by simply choosing the machine (in a specified room) to turn on or off in-computer picture series. A configured WEMOS Wi-Fi Module that is connected to Arduino Mega receives the data wirelessly. Data converted to digital signals inside the Arduino Microcontroller value in the microcontroller's output pins. Industrial Relays have turned into high or low state values which control the power outlets of the device in a specific laboratory computer room.

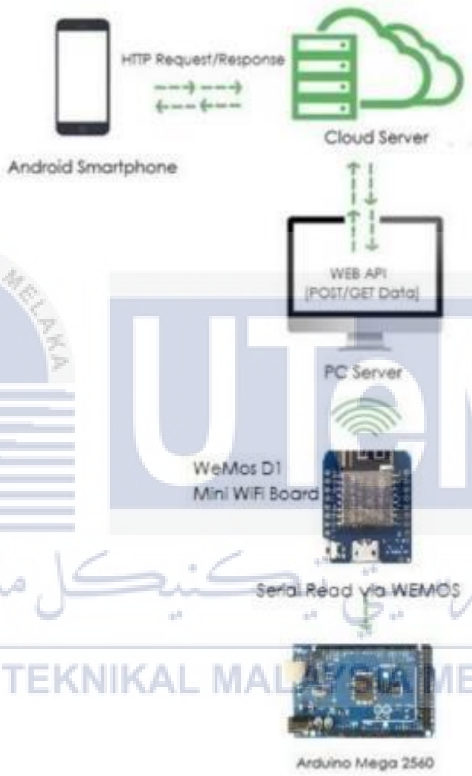

Figure 2.12: Software communication set-up

Table 2.5: Summary Table regarding to 2.2.5

Author(s)	Description	Method
Martillano (2018)	This study on modelling and implementation of a Wi-Fi module, controller, and Internet of Things elements to create a smart environment. The real source of power supply and light transitions are handled in the Internet or local wireless network monitoring smartly which based IoT elements.	This circuit is controlled and triggered by the Arduino Mega 2560 controller. Connection of Arduino and WEMOS D1 Mini can keep on connecting to the cloud server by providing locally hosted setup to help situations where the internet is inaccessible but only a Wi-Fi connection is available

2.2.6 Lighting Control and Monitoring System Using Cayenne Web Server

Total consumption of electrical energy in building especially for lighting contributes to 20-60% of usage. People tend to neglect turning off the switch leaves the room which resulted in energy and cost wastage as the lamps it was used not for need. A concept of internet of things in Lighting control system is designed to conquer this issue so that the lights can be controlled and monitored remotely. Arduino Mega 2560, relays, electric breakers voltage lamp and motion lamp used as microcontroller, connectors and also switch that will turn off lights when nobody in the room. This system also uses the application and web server which helps to manage and control from any distance in real time. The control system circuit design and schematics as shown in the figure below.

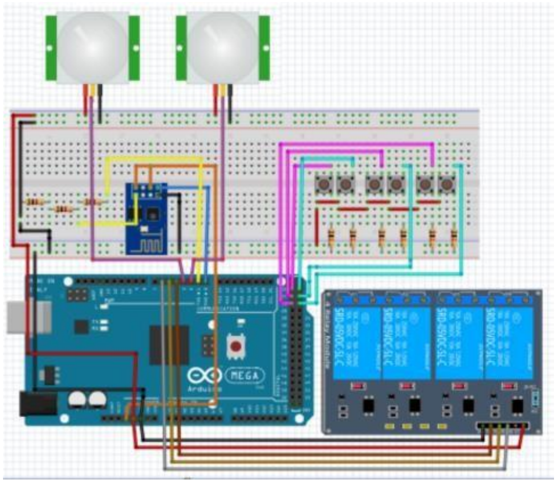

Figure 2.13: Schematic installation

This system is composed of two hardware and software parts. Smartphone / personal computer, Arduino Mega 2560, ESP 8266 wifi module, Motion Sensor (HC-SR501),Pushbutton, Lamp, Relay Module, and other hardware support components are used. The software used is Arduino IDE, web server cayenne, and Cayenne Smartphone Application for acomputer user. This control system using pushbutton and sensor acts as an digital input I / O signal to Arduino.Digital signal is received by Arduino for the relay to turn on or off light. In that time, the data will be transferred to the app or web server cayenne by Arduino Mega 2560 using a wifi module to monitor it. Cayenne app and web server also for automatic or manual remote control.

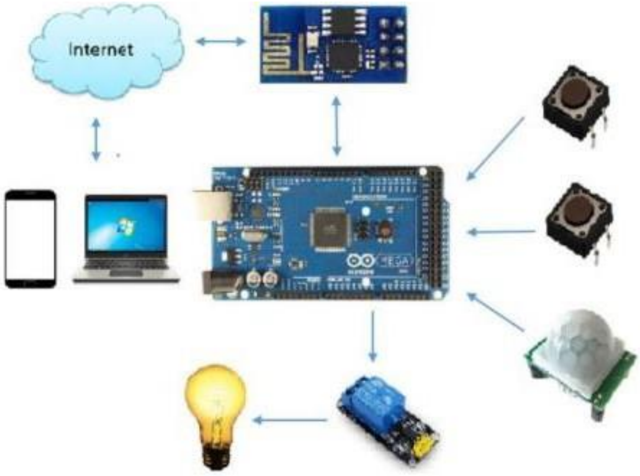

Figure 2.14: Architecture of smart lighting system

Based on the prototype, when the ON pushbutton is pressed, the light turns on so the relay is in close position and the OFF pushbutton is pressed, the lamp goes off. By pressing the Light icon on the web server or mobile app, the light can be switched on or off. The PIR sensor will provide information to ESP826 when there is an existing room. On the web server and mobile application it can be seen in the form of a motion icon. This sensor acts as an automatic switch that switches the lights off when there is no motion in the room.

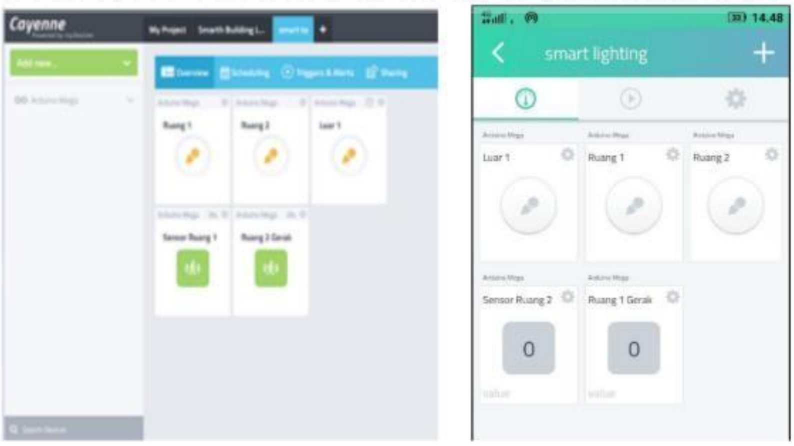

Figure 2.15: Display on the web dashboard and Cayenne apps

This prototype has some differences between the objectives with the outcomes accomplished. These imperatives include slow data exchange between the hardware and the web server or the application. Sometimes because ESP8266 is not steady and the sensor used has a problem with sensitivity, hardware cannot be connected to the Internet network. However, every one of these issues can be improved and upgraded by doing research to the most suitable and efficient equipment that can be used.

Table 2.6: Summary Table regarding to 2.2.6

Author(s)	Description	Method
Firdaus and Mulyana (2018)	The project is to address the inefficiency of energy and high cost generated by creating a lighting control system that can be monitored and remotely controlled through the IoT implementation. The system controls the lighting using application and web server cayenne as prototype of the building.	This system is controlled using Arduino Mega 2560 as a microcontroller, electric breakers for lamp, relay contactors to the motion sensor as a switch that turns off the light in the absence of people in the room. The ESP 8266 Wi-Fi module is used to transfer information to a Cayenne app and web server that can be real-time controlled and monitored.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This section covers on specific methods to be used in the implementation of this project. The method will achieve the desired results based on the objectives of the project. Research have been made related to this field through other journals and technical papers to take advantage and improvement. Furthermore, this development involves of hardware and software. It also consists block diagram, flowchart, and process flow of this project. The project approach based on 3 main phases which is presented in below.

Figure 3.1: Major steps in Methodology

3.2 Planning

The flowchart as shown at Figure 3.2.1.1 as project process flow. This project starts with a description of the problem that is the complexity of applying IoT to Factory I/O simulation as a replaces the actual usage of PLC. Further, searching for related papers and journals, reviewing the literature is done to understand in depth about this case, and all valuable information is gathered for application in project design. This process implements hardware and software combination to integrate the system.

3.2.1 Flowchart of general flow of PSM

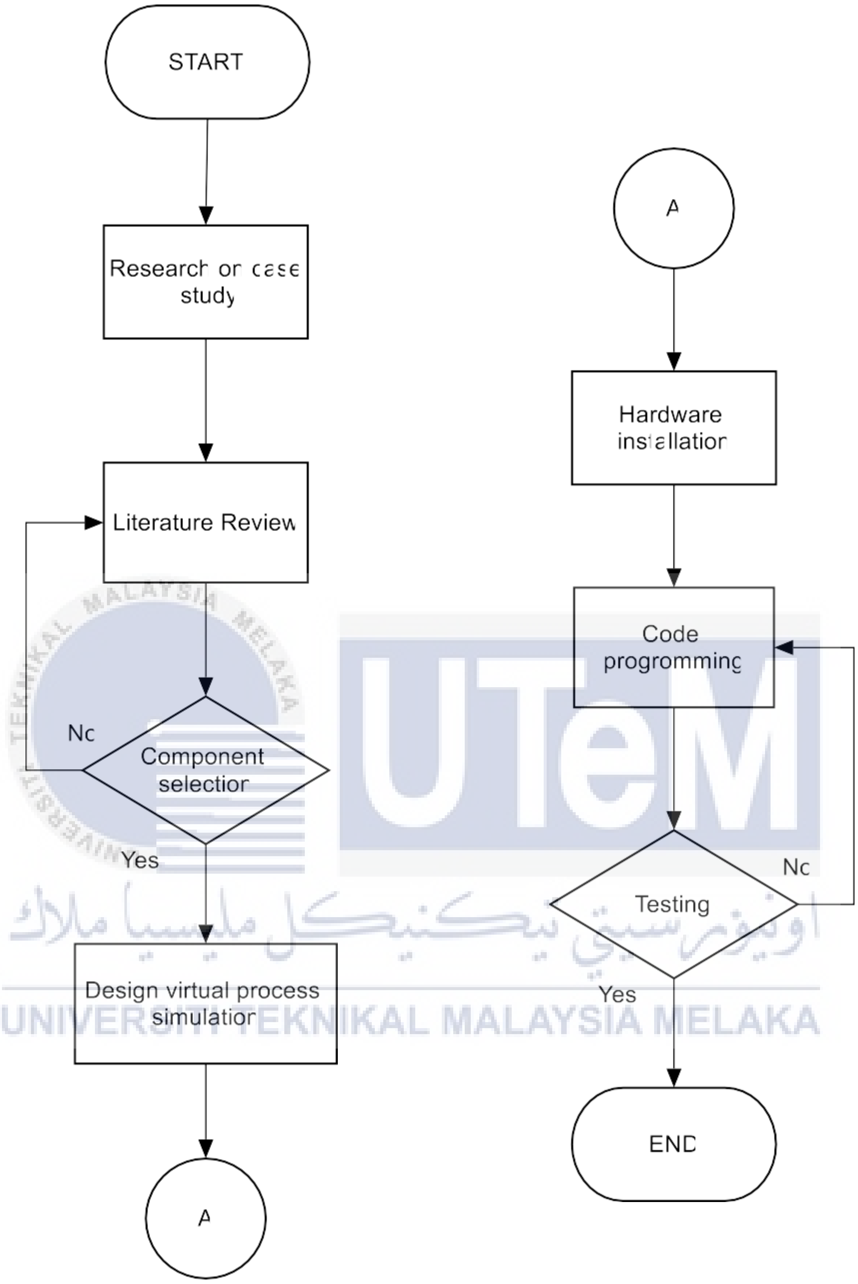

Figure 3.2: Flowchart of general flow PSM

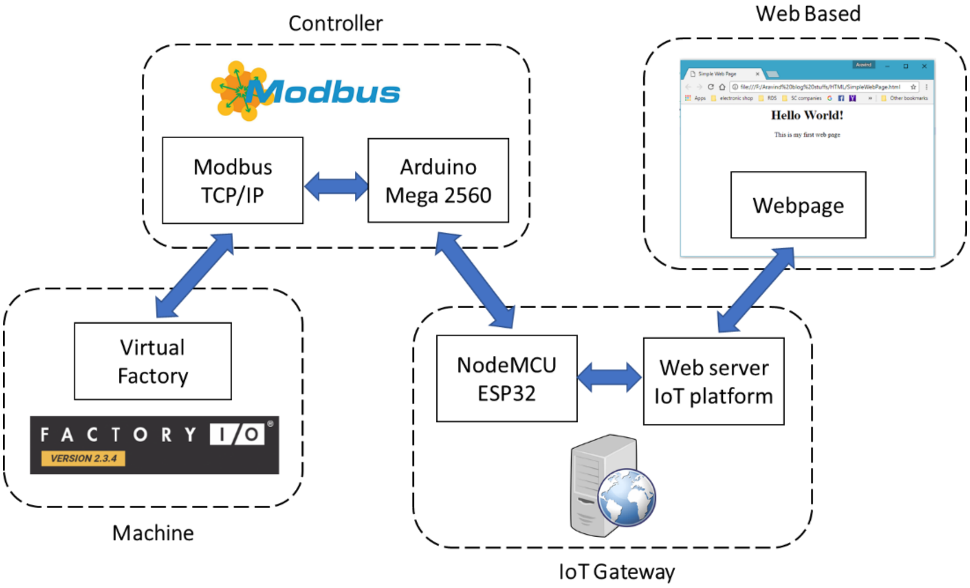

Figure 3.3: Proposed monitoring and control system

Table 3.1: Gantt Progress Chart

PROJECT PLANNING																																						
Listdown the main activity for the project proposal. State the time frame needed for each activity.																																						
	2020																																					
Project Activity	FEB		MAC				APR				MAY					JUN		J	A	SEP				OCT				NOV				DEC					J	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	X	X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Literature review	BP Briefing							Mid Term Break								Study Week	Final Semester Examination		Semester Break									Mid Term Break								Study Week	Final Semester Examination	
Project Planning																																						
Proposal Preparation																																						
Study of Arduino Mega 2560 and Ethernet Shield																																						
Study of Factory I/O																																						
Study of Web server																																						
Construct assembler process simulation																																						
Built Arduino and Web server coding																																						
Simulation the Arduino circuit																																						
Simulation the Factory I/O																																						
Simulation Web server																																						
Perform Analysis																																						
Report preparation																																						

3.2.2 Gantt Chart

The plan is a guide from Gantt's chart that needs to be followed. It relates on work is to be carried out and an implementation schedule. This is to ensure the project runs smoothly within the specified time given. It is also to anticipate the time-consuming to prepare the project as a whole and achieve the expected results.

3.3 Design

3.3.1 Block Diagram of IoT Based Industrial Monitoring and Control System in Industrial Machine

The block diagram shows a schematic illustration of the general sequence of sections for this system as Figure 3.3 shows. The Block diagram shows the router at the middle acts as a communication bridge between Factory I/O, Arduino and web server. The Arduino MEGA 2560 as the main microcontroller communicates with Factory I /O and NodeMCU ESP32 as the main microcontroller communicates through an IoT gateway. This allows the user to control and monitoring the process on Factory I/O from the web server platform.

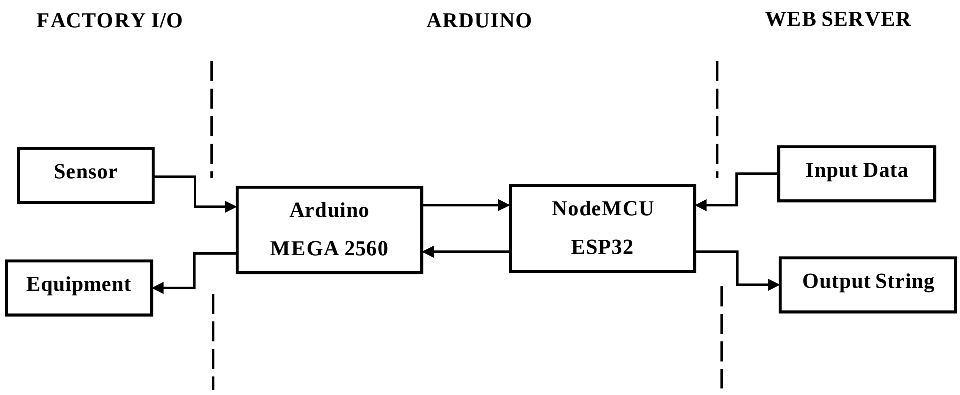

Figure 3.4: Block diagram of the system

3.3.2 Flowchart Process

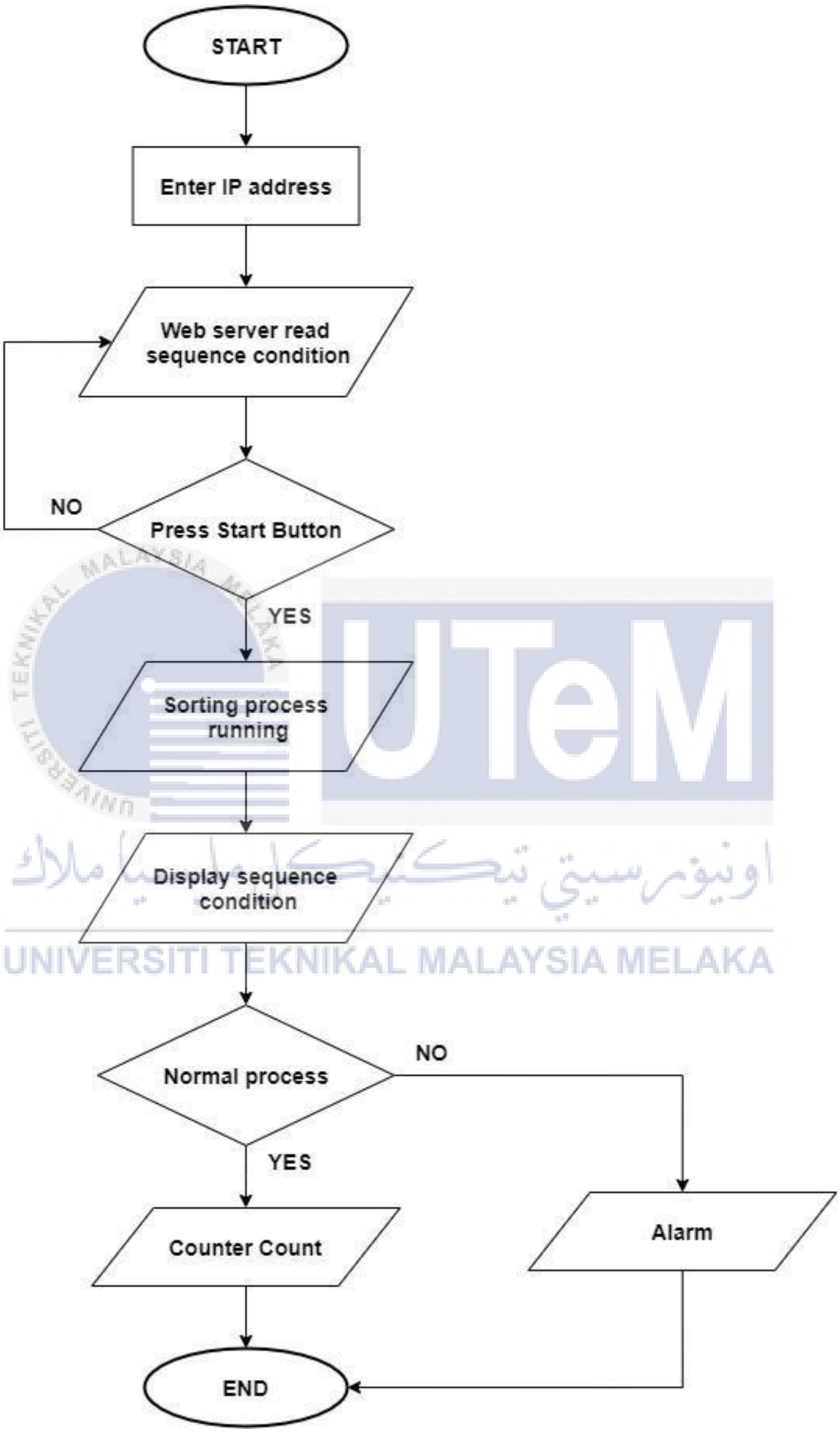

Figure 3.5: Flowchart of the proposed system

3.4 Software Implementation

3.4.1 Factory I/O

Factory I/O is simulation of a factory in 3D and is also used as a learning platform in automation technology. It is easy to design as well as build a virtual factory using many parts choices are inspired by the most common industrial equipment. By placing and assembling these parts together will create a virtual factory according to the desired process. Virtual factory creates using a library of industrial components including conveyors, sensors, and many more. PLC are a common component used as controllers in the industry. Therefore, Factory I/O is often associated with PLC as PLC training or PLC simulator. However, it can also be used with other technologies such as microcontroller, SoftPLC and Modbus. Factory I/O can be integrating with an Arduino Mega 2560 through Modbus TCP (Server and Client) which is industrial machine control master / slave networks.

Figure 3.6: Factory I/O Software

3.4.2 Arduino IDE

Arduino IDE is an open-source software primarily used to compile and write code into Arduino modules. Open-source Arduino Software IDE makes coding so easy that anyone who has never learned it to write and upload code to board. The various Arduino modules are available include, Arduino Mega, Arduino Uno, Arduino Micro, Arduino Leonardo, and more. Each contains a programmed microcontroller on the board and receives information in form of code. The code is also called a sketch that was created based IDE platform will eventually generates Hex Files that are next transferred and upload into Arduino module. Arduino IDE allows users to write and upload code in real-time work environments.

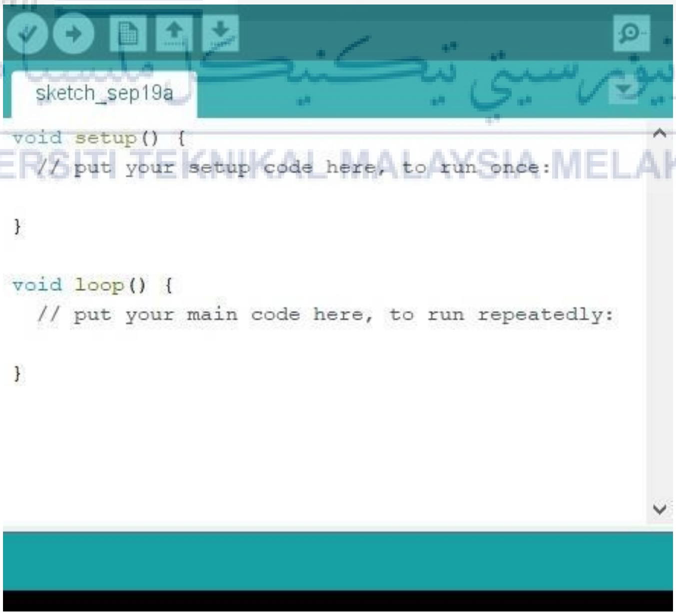

Figure 3.7: Arduino sketch

3.5 Hardware Implementation

3.5.1 Arduino Mega 2560

The Arduino Mega 2560 is an ATmega2560 chipset-based microcontroller board. It contains all necessary to support a microcontroller. Started from a computer with a USB cable and does not require additional components to be attached or powered by an AC to DC adapter or a battery. This device readily available which is everything is already built function in the board. The Arduino Mega 2560 programs by using Arduino Software IDE that can be running both online and offline. Another important feature of this Arduino board is the Arduino shield. The board with preassemble PCBs interface can be connected directly into headers gives incredible capabilities in a condensed package. The specification of this board on Table 3.5.1.1.

Figure 3.8: Arduino MEGA 2560 board

Table 3.2: Arduino MEGA 2560 Specification

Microcontroller	AT mega 2560
Power Supply	7V - 12V
I/O Digital Pins	54
I/O Analog Pins	16
Total I/O Digital	70
Clock Speed	16 MHz
Flash Memory	128 KB
Timer	2 timer (8bit) and 4 timer (16bit)
PWM	12
ADC	16
USART	4
Pin Interrupt	24

3.5.2 Arduino Ethernet Shield

Arduino Ethernet Shield enables Arduino to connect to the internet easily. This shield can get host webpages and scour the Internet by connect to a Wi-Fi router. Pugging header pin from the shield to the Arduino is an easy way to set up. It comes with an Ethernet library to write Internet-connected sketches. It also provides a network (IP) stack with UDP and TCP capability. There are several other features that come with it including the onboard micro-SD card slot that saving files to be served over the network. To ensure the module is reset appropriately during power-up, the Shield also comes with a reset controller. It helps because the Shield has been found to be incompatible with Mega.

Besides, it comes with a standard RJ45 ethernet jack. However, Arduino Mega is preferred over Arduino Uno for Ethernet shield use as it may cause some crashes.

Figure 3.9: Arduino Ethernet Shield module

3.5.3 NodeMCU ESP32

ESP32 is packed with many new features and multiple functions from 30pins. This chip microcontrollers is a low-cost and low-power consumption system was created by Espressif Systems. ESP32 it combines Wi-Fi wireless capability and dual-mode Bluetooth connectivity for various applications. This series uses the Tensilica Xtensa LX6 microprocessor. Its also comes with features power amplifier, built-in antenna switches, low-noise receive amplifier, and power-management modules.

Figure 3.10: NodeMCU ESP32

3.6 Conclusion

In conclusion, this chapter discusses the methods and processes to be used in develop IoT based industrial monitoring and control system in industrial machine. The methodology is very important in developing a system that is well planned and organized in order to complete it in a given time. The main components that have been selected for this system are Arduino Mega 2560 and NodeMCU ESP32. It is powered by Factory I/O software as a virtual factory simulation and Arduino IDE.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter discusses the results of this project and the analysis that has been carried out. The implementation of the software and hardware are presented in detail to verify its functionality in achieving the desired objective. This system should work successfully and any problems that arise will be discussed.

4.2 Software Implementation

4.2.1 Programming Development

In order to ensure that this system works properly, the Arduino Mega 2560 and NodeMCU ESP32 have been used as microcontrollers to control the entire process. The programs that have been developed for the two microcontrollers are different in line with their functions. The Arduino board plays a role in controlling the entire sorting process in Factory I/O software while ESP32 sends and receives data from it to be displayed on the webpage by using Wi-Fi technology. The program is produced through the Arduino IDE Software platform and uploaded to th both Arduino board. Arduino Mega 2560 communicates TCP/IP communications with the addition of the MgsModbus.h library in the sketch which works with Factory I/O and manipulates data. In addition, extra webserver.h library also included in the sketch of the ESP32 board program to serve IoT applications.

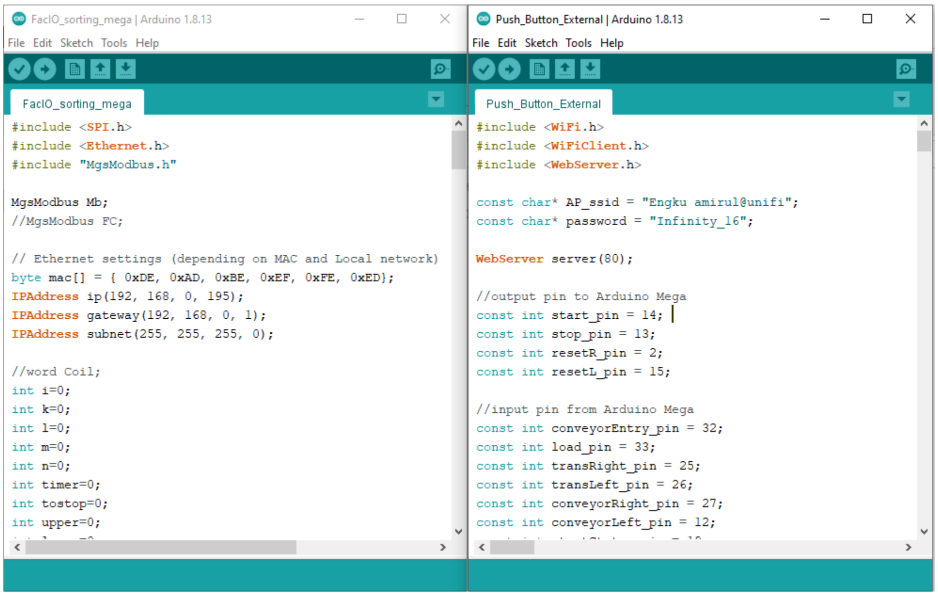

Figure 4.1: Arduino IDE software layout

4.2.2 Sorting by Height Process Scene

Based on the diagram below shows the design for 3D virtual factory simulation. It is a simulation of the sorting process that has been build using the Factory I/O software. This sorting process involves the use of industrial equipment parts such as conveyors, sensors, switches, actuators and more. All operations that occur in the process are controlled and monitored by the operator virtually through the Electrical Switch Board as the power supplier to the entire equipment. Electrical Switch Board is equipped with start button, stop button, reset counter button and digital display for counter reading values on item passing through both left and right conveyor. Sorting process performs a sort box by its specific height. Conveyor entry produces 2 types of boxes with pallets that have been set output randomly from the Emitter while the left and right conveyor receives the box with the pallet to the Remover.

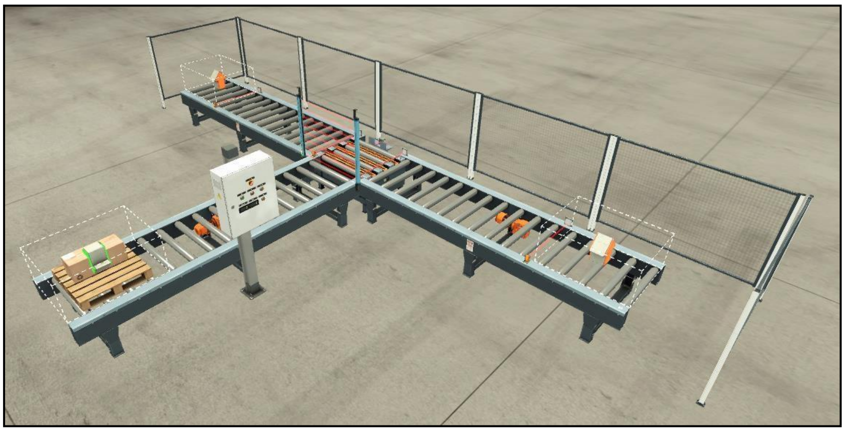

Figure 4.2: Virtual simulation scene of sorting process

4.3 Hardware Implementation

As illustrated in the figure below, it consists of two parts microcontrollers which are Arduino Mega 2560 and NodeMCU ESP32. Programs to control processes in a virtual factory were developed in the Arduino Mega 2560 and assisted by Ethernet Shield. The Ethernet shield module is attached to the Arduino board connecting it to the network with an RJ45 cable. Meanwhile, both devices are interfacing each other through the GPIO that send or receive the data from virtual factory to the web server.

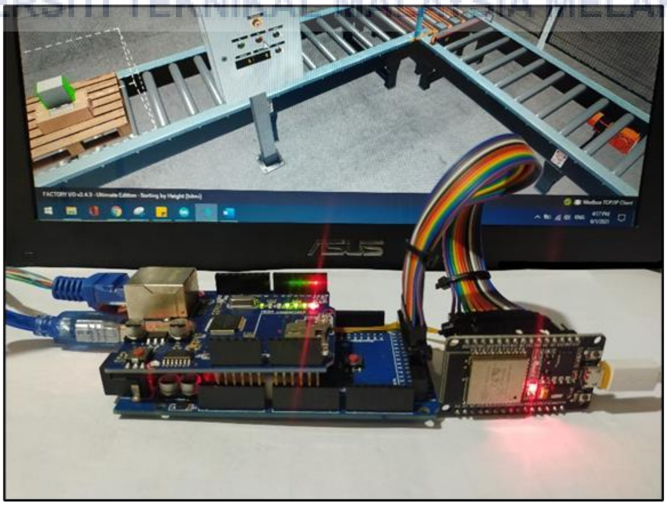

Figure 4.3: Hardware connection

4.4 Result

4.4.1 Sorting Process

This real-time system is controlled by the Arduino Mega 2560 where all sequence instruction is developed in a written program similar to the use of PLCs in the industrial environment. This sorting process runs smoothly even though there are time intervals due to the lack of Wi-Fi speed to transfer data to the server, but it still does not cause the sequence of this process to be interrupted. For an indefinite period, this process will run continuously as a loop. The process runs by pressing the start button at the Electrical Switch Board on the virtual simulation and stops immediately if the stop button is pressed. A box with pallet will enter randomly through the entry conveyor and are separated to the left or right of the conveyor according to the height specified. The counter counts after at exit sensor detecting the object passing through it and displays the current counter reading value on the digital display and can be reset when the reset button is pressed. Any abnormalities that occur during the running process will stop the entire process and turn on the alarm as a warning sign. The alarm will remain ON as long as the abnormal is not removed and needs to be reset by pressing the stop button. For this system movement has been set with 4 conditions related to item entry type from Emitter. Figure 4.2 show the sorting process while running.

Figure 4.4: Running sorting process

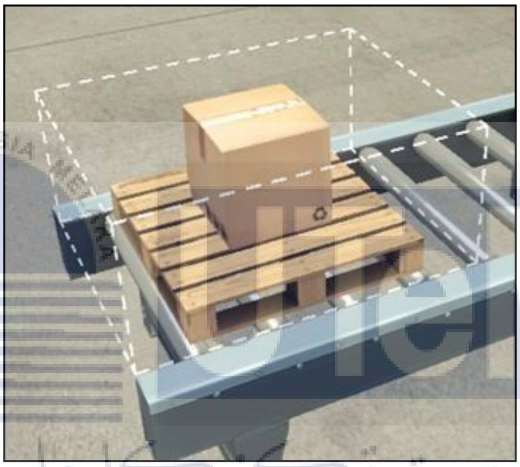

Figure 4.5: Condition 1

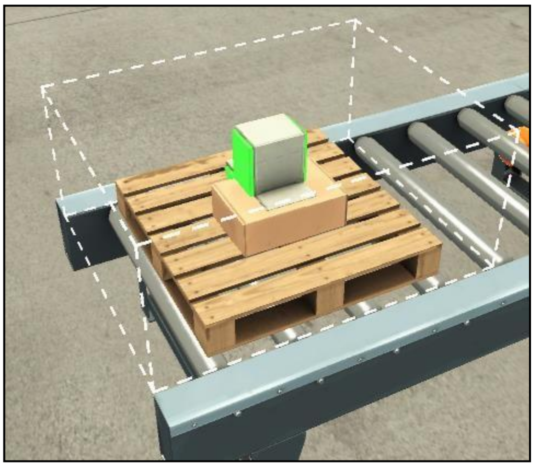

Figure 4.6: Condition 2

Based on the figure above, condition 1 and condition 2 are normal input from the Emitter into this process where the box is equipped with a pallet. Condition 1 is imported with a box with size L while the condition for 2 boxes with size S has a difference from the height angle. For condition 1, the box and pallet passing through the Light Array Receiver and Transmitter will be detected by the pallet sensor, sensor lower and sensor upper then be sorted to the right conveyor. While the condition 2, box and pallet will be sorted to the left conveyor when the pallet sensor and lower sensor are detected.

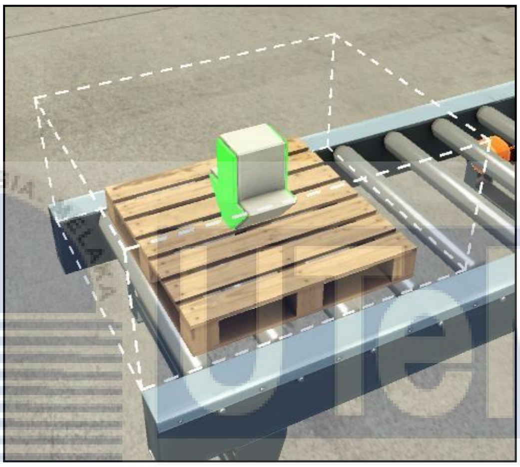

Figure 4.7: Condition 3

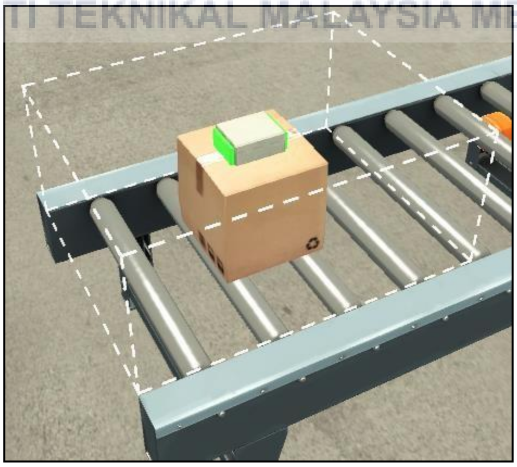

Figure 4.8: Condition 4

Abnormal processes are from condition 3 and condition 4 that have incomplete items. Condition 3, the pallet came without a box applies the use of a timer where the pallet sensor will check the situation if only the pallet passes through the Light Array Receiver and Transmitter for 450 milliseconds without detecting any box from the lower sensor and upper sensor. Meanwhile, Condition 4 detected a box without a pallet by the load sensor and the pallet sensor after the box continue to rotate on the conveyor until carried by the previous pallet up to the loading area.

4.4.2 Factory I/O communicate using IoT application

This section will explain the process that has gone through for the purpose of obtaining the results to be recorded. Among the main achievements of this project objective is about monitoring and control of the internet-based virtual sorting system. Based on the diagram below shows the webpage that has been developed. Entering the URL from the IP address generated by the device in the web browser successfully creates communication between the client and server via the HTTP protocol. Web server monitors the display of condition data received and controlled by NodeMCU ESP32 from Arduino Mega 2560 which controls the sorting process in Factory I/O. The function display on the webpage is almost the same as the Electrical Switch Board which in the virtual simulation process only has additions to the conditions for each equipment either ON / OFF. The response from the data sent or received on the web server is fast in the update. But sometimes the counter value displayed on the webpage is a bit runny and not the same as in the virtual simulation process after so long operating due to time intervals where the data received is inconsistent.

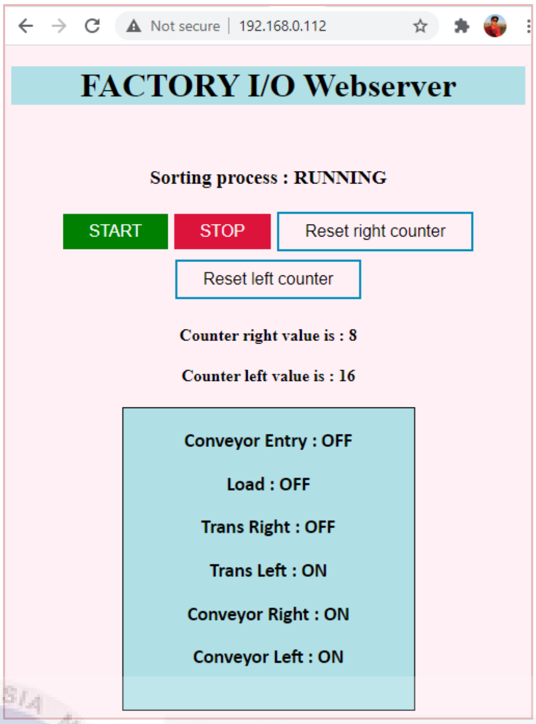

Figure 4.9: Factory I/O webpage

4.5 Data Analysis

4.5.1 Analysis Occurrence Condition

Analysis shows that the output produced by the process runs in the correct sequences. Data is obtained from the serial monitor NodeMCU ESP32 as the data receiver from the virtual sorting process that sent to the web server. The data is plotted in the form of a segment line between two axes connecting between groups of data points obtained to show the change of trend over time. This result is obtained after the start button is pressed on the virtual simulation or web server. The 4 conditions have been recorded and plotted to the X-axis line representing as Time taken in seconds while the Y-axis line represents the ON / OFF condition.

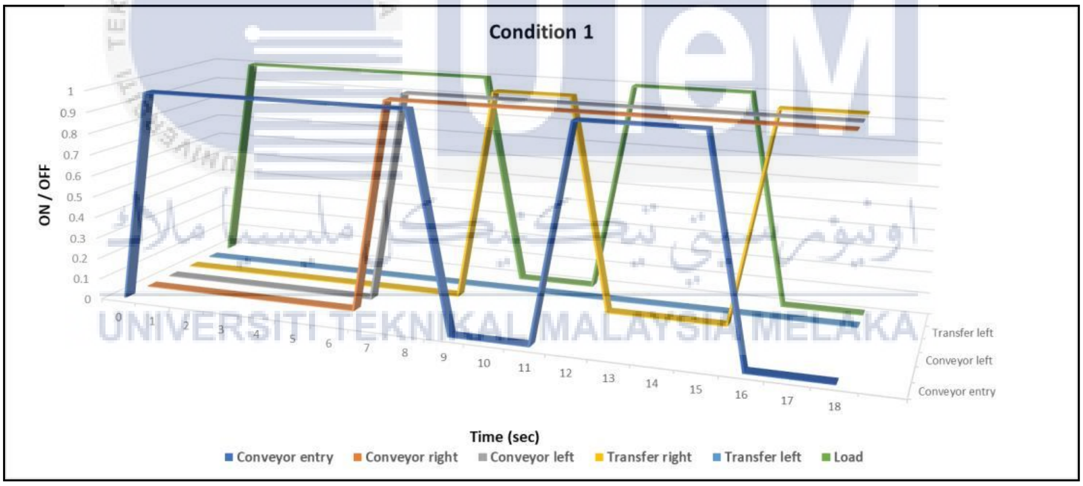

Figure 4.10: Graph for condition 1

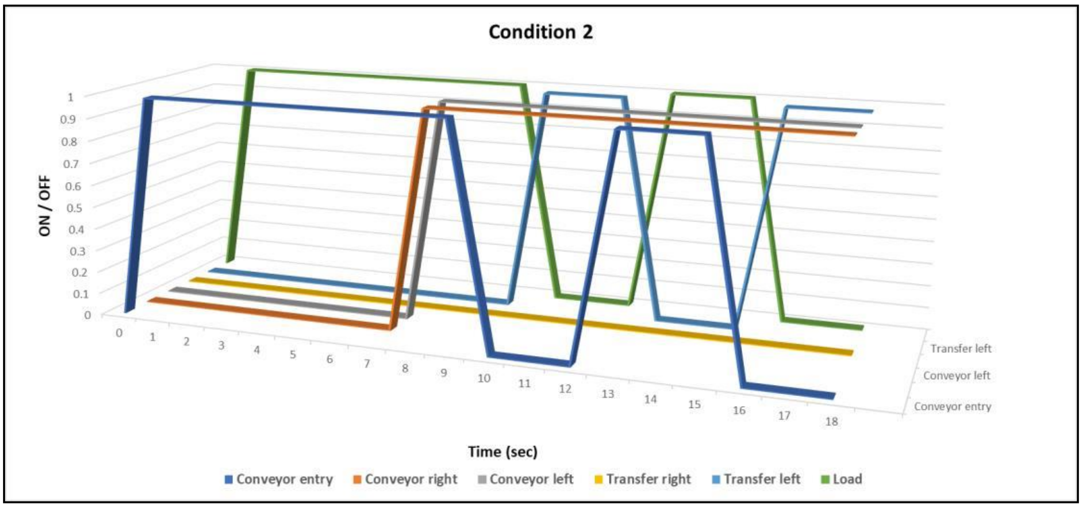

Figure 4.11: Graph for condition 2

The data taken for both of these conditions represents a complete cycle of sorting a process that runs normally until the item is received by Remover. The graph shows condition 1 and condition 2 have approximately same pattern generated by the data obtained.

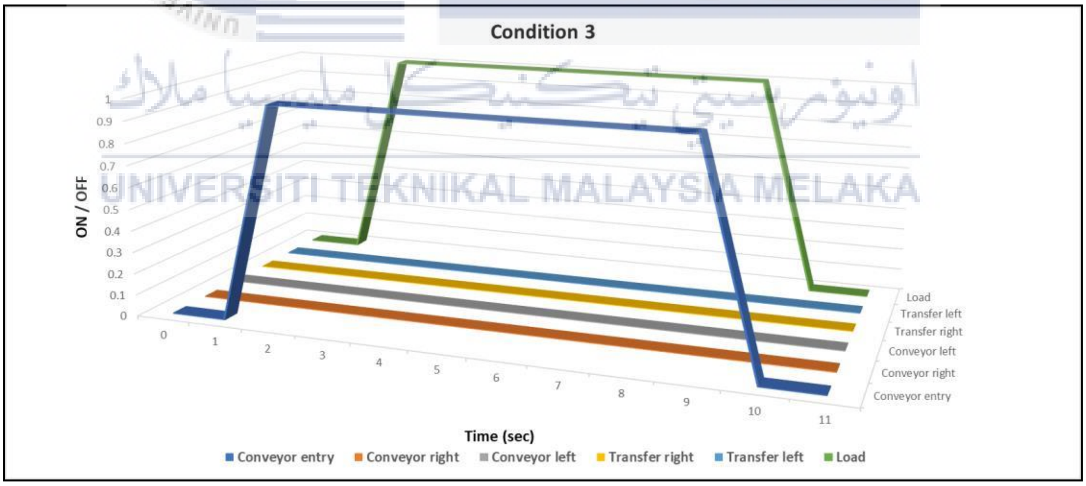

Figure 4.12: Graph for condition 3

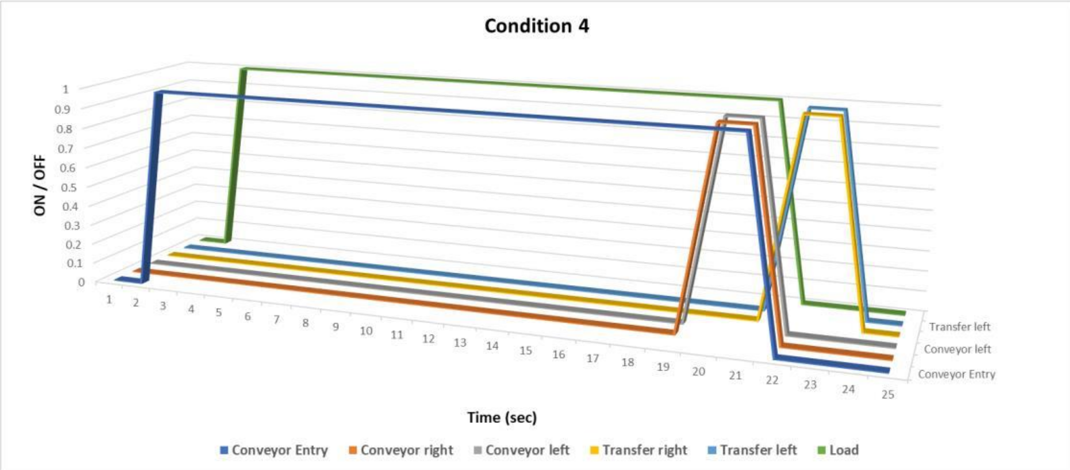

Figure 4.13: Graph for condition 4

Condition 3 and condition 4 represent abnormal processes and data are taken from the beginning of the running process until the process stops completely. The graph above shows that the patterns for the two conditions are different. Condition 3 takes less time for the pallet sensor to detect a pallet that does not have a box. Meanwhile, condition 4 detects the absence of the pallet after taking a long time waiting for the box to be pushed by the previous entry of the pallet. The graph shows the delay sorting process to stop because there is a time interval for the system manipulates data to be sent to server.

4.5.2 Timing Diagram

The time diagram shows a change of state within and between the living lines along the linear time axis. The time diagram is a sequential diagram of this process in a special form. The input and output timing diagram shown below clearly shows the status of the input or output in the system's specific time frame. This time diagram helps to find a way out to solve the problem more easily by directly pointing the event or time frame at conflict system.

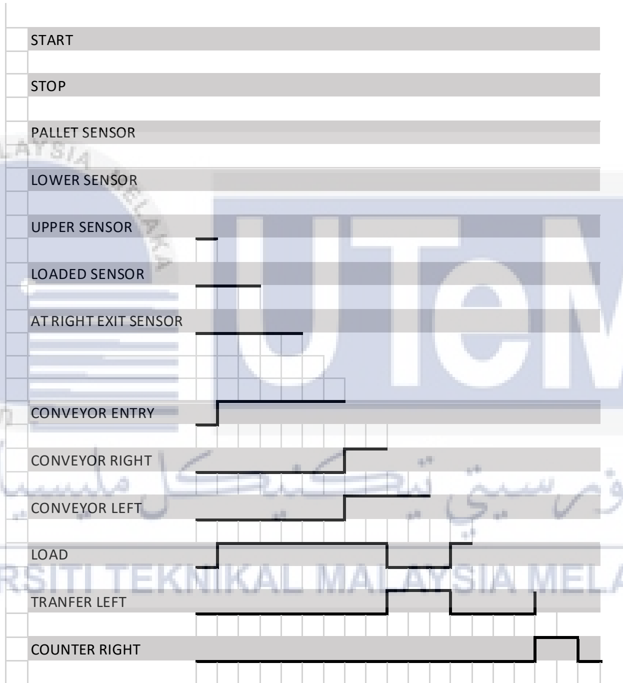

Figure 4.14: Timing diagram for condition 1

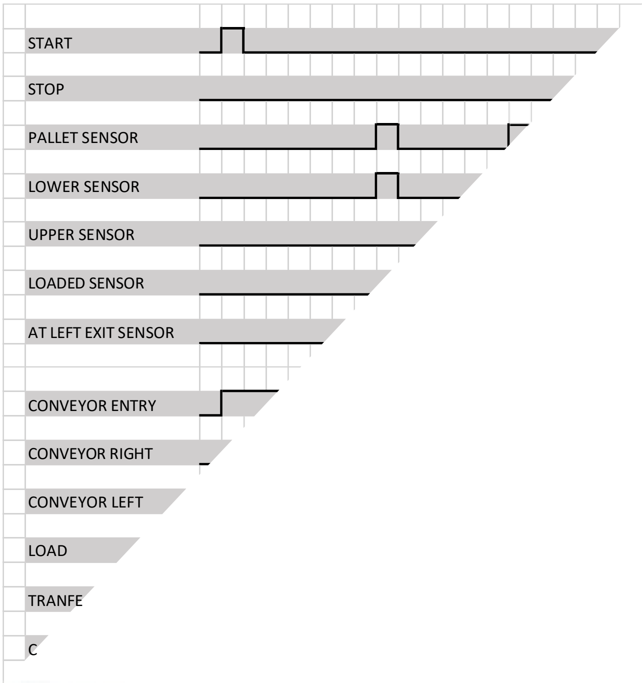

Figure 4.15: Timing diagram for condition 2

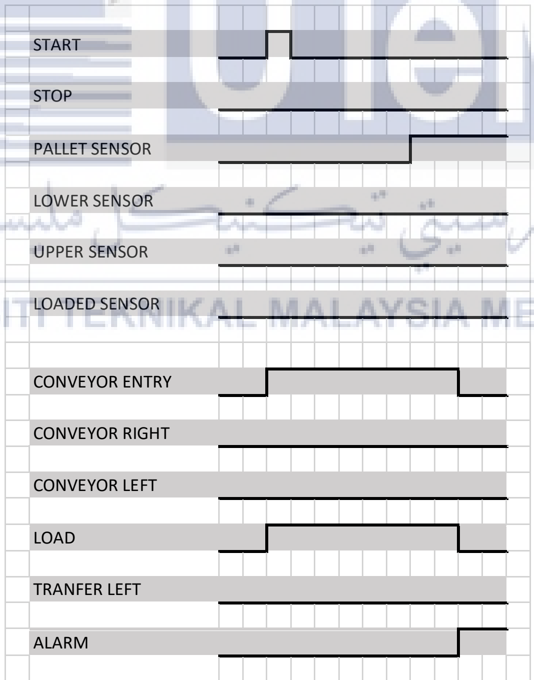

Figure 4.16: Timing diagram for condition 3

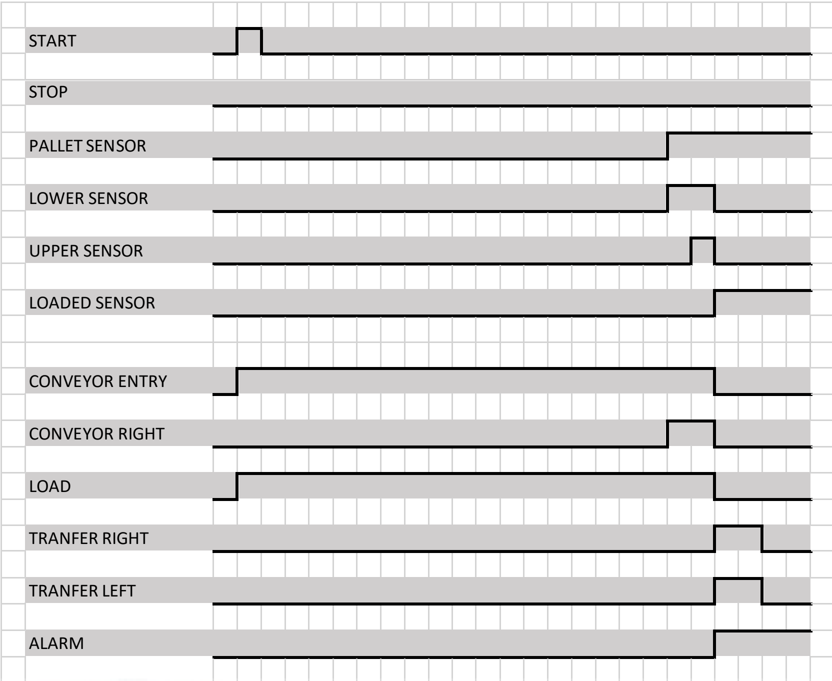

Figure 4.17: Timing diagram for condition 4

Based on the timing diagram, the process sequence is shown more clearly when the sensor detects and responds to the next movement in the process that will occur after the start button is pressed and data has been recorded. Condition 1 and condition 2 do not have much time interval shown by the timing diagram but a slight time difference occurs when the time that has been set by Emitter is random with a minimum item entry of 2 seconds to a maximum of 3 seconds. In addition, the time indicated for the alarm to be triggered for condition 3 and condition 4 is precisely after a certain sensor is detected. Condition 4 does not stop as soon as the pallet sensor, upper sensor and lower sensor are detected due to the time interval that occurs compared to condition 3 which stops as soon as the pallet sensor is detected.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the sorting process in Factory I/O is a real industrial machine that has been successfully developed based on IoT applications in controlling and monitoring the system as a whole. It achieves among the main objective which is to design and develop machine using the virtual factory platform. The entire system has been fully developed using a microcontroller to control the process in Factory I/O. The process that takes place in Factory I/O runs smoothly without any interruption problems during the operating process. Apart from that, system assisted by NodeMCU ESP32 microcontroller has successfully applied the use of the Internet of Things. Web servers become a medium for this IoT application where virtual simulation processes have been controlled and monitored over a network. However, there is no denying this system also has some limitations on the speed of data transmission to the web server. This does not cause the time interval to be too long for the data to update the display on the webpage, but the response received is almost perfect and smooth.

5.2 Recommendation

Based on discussions with supervisors, this project has the potential for future innovations where some things still need to be improved. The microcontroller considered to be upgrades is Raspberry pi as this project has 2 microcontrollers with different uses for communication. Therefore, it can optimize its function in a device that is capable of performing multiple tasks and communications such as a computer. The Raspberry Pi comes with a built in ethernet port enabling implementation for control and monitoring of the virtual simulation process from the web server more smoothly and 40 times faster than Arduino.

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APPENDIX

Appendix 1 Overview Factory I/O Webserver