

CHAPTER 5 – CONCLUSIONS AND RECOMMENDATIONS

This chapter will cover the conclusion after the thesis is done and several recommendations for further research purposes.

5.1 Conclusions

- The source of the bottleneck in the handover process that causes queues is the FIFO implementation based on the courier arrival instead of package availability due to the courier's patience. These issues could be solved by the implementation of the smart locker system by digitalized the queue.
- The unique behaviour of the handover area workload peaks up in early opening hours only due to the initial queues occurs in early opening hours resulting in the smart locker solutions is more cost-effective compared to adding more manpower due to the scalability of the smart locker system usage.
- Based on the simulation, the number of the queue could be drastically reduced from maximum 29 to 3 person per counter and maximum waiting time until handover done from around 60 to 4.5 minutes by implementing 88 smart locker system doors replacing 12 human-based counters and reducing the handover processing time from 2 to 1 minutes. Furthermore, PT. XYZ plan to deploy 400 doors of the Smart Locker system eliminates the queue and waiting time.
- The smart locker system could help to reduce online courier delivery waiting time in PT. XYZ warehouse by significantly help to reduce the processing time to 1 minute from 2 minutes where the package claiming process itself takes in average 18.18 seconds with a standard deviation of 4.12 seconds giving more times for the driver to find the assigned locker and warehouse operator to load the package in the 1-minute time window.
- The smart locker system has 100% repeatability, robustness, and accuracy. With the average recovery time after power failure of 2.7 seconds with a standard deviation of 0.59 seconds.

- The smart locker system provides high level of securities where the QR codes are uniquely generated by the backend of the system so that it could be dynamically updated.

5.2 Recommendations for Future Improvement

- To improve the package claiming process, the web-apps should be deployed in cloud with public IP access so that the user does not needs to connect to a dedicated local network. By doing so, it removes one step in the process and one possible source of error where the users' mobile phone could automatically change the network connection based on the strongest internet signal strength. Having a public IP access for the web-apps make it accessible from any network as long as internet connection established.
- To speed up the scanning process, optimize the QR Code version and payload. Use the lowest possible QR Code version for faster scanning time.
- From the warehouse operations point of view, as an addition of the smart locker system a human-based counter still needed to do the handover of big products that could presents sometimes that could not be covered by the locker sizes. Furthermore, the presence of a human-based counter could also help to handle some errors or problem that might occurs.
- To increase the level of security, the QR Code could be refreshed periodically.

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CURRICULUM VITAE



Michael Jonathan

IOT ENGINEER / ROS2 DEVELOPER

Profile

Experienced full-stack Internet of Things Engineer with proven track records in developing various end to end Internet of Things and Automation applications. Persistent, self-driven, and keen to achieve target. Able to work independently and lead team of engineers. Used to work with various framework for micro-controllers, IoT, and full-stack web development.

Employment History

Process Improvement and Reengineering Officer, PT. Global Digital Niaga (Blibli.com), Jakarta

JANUARY 2023 — PRESENT

- Responsible to implement and evaluate various Automation project in warehouses.
- Initiate IoT implementation in warehouses and offices and with taking account cybersecurity aspects:
 - Warehouse Building Monitoring System.
 - Smart locker system for handover process.
- Initiate robotics development and implementation in warehouses:
 - Build a ROS2 based Indoor Autonomous Mobile Robot with 1000 kg payload from scratch.
 - Responsible in the electrical and software system development.
- Tech stack: **ROS2, C++, Vue.js, Node.js, MQTT, Docker, Arduino IDE, ESP8266, ESP32, GIT, PostgreSQL.**

Software / Electrical Engineer, Mlight Asia Pacific, Jakarta

NOVEMBER 2022 — JANUARY 2023

- Responsible to lead team of software and electrical engineer to evaluate current product root cause of problem.
- Tech stack: **Python, Zigbee, MySQL.**

IoT Engineer, Kawan Lama Sejahtera, Jakarta

AUGUST 2022 — DECEMBER 2022

- Responsible to develop customized IoT solutions and supporting pre-sales technical requirement. Work closely with sales and supports customer from the technical side.
- Success Stories:
 - Knitting machine IoT monitoring system.
 - RS-232 to Bluetooth keyboard converter for digitalization.
 - Customized Excel Macro for checksheet digitalization.
- Tech stack: **React.js, C#, Arduino IDE, ESP8266, ESP32, PostgreSQL, MySQL.**

Freelance Python Programmer, iGarment Ltd., Remote

JULY 2021 — SEPTEMBER 2021

- Responsible to create production simulation.
- Responsible to create analytical process resulting in presentable chart.
- Tech Stack: **Python, Kivy, Vue.js.**

Details

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Links

[Linkedin](#)
[Github](#)

Skills

Time Management
Adaptability
Critical Thinking
Problem Solving
Peer Leadership

Languages

English
Indonesian
German

Automation Engineer, Self Employed, Jakarta

AUGUST 2018 — PRESENT

- PLC and Industrial robot programming for various special purpose machine.
- Micro-controllers design and programming for various IoT and automation applications.
- Tech stack: PLC (IEC 61131-3), Epson Robot, Nachi Robot, Arduino IDE, ESP8266, ESP32.

Education

Master of Mechanical Engineering (Mechatronics), Swiss German University, Tangerang

SEPTEMBER 2022 — PRESENT

Bachelor of Mechanical Engineering (Mechatronics), Swiss German University, Tangerang

AUGUST 2018 — JULY 2022

- Join degree with South Westphalia University of Applied Sciences Soest, Germany.
- Best Graduate for Academic and non Academic.
- Thesis works building ROS2 based indoor logistic Autonomous Mobile Robot.

Internships

Teaching Assistant at Swiss German University, Tangerang

MARCH 2022 — JULY 2022

- Responsible to support Lecturers conducting laboratory experiments:
 - Electrical Engineering Lab
 - Pneumatic Lab
 - Introduction to Mechatronics Lab
- Supporting Lecturers to prepare for faculty accreditation process.

Intern at SMS group GmbH, Moenchengladbach, Germany

MARCH 2021 — JULY 2021

- Responsible to support inspection checklist form digitalization process using mybusiness.ai platform.
- Responsible to create Excel macro to convert old checklist form into the platform via JSON file.
- Responsible to evaluate and improve hydraulic system diagram.

APPENDIX

A. Microcontrollers Source Code

The microcontrollers source code divided in four different files for easier code maintenance and reusability.

- master-thesis.ino

```
#include "config.h"
#include "pinout.h"
#include <qrcodeoled.h>
#include <SSD1306.h>
SSD1306 disp(0x3C, PIN_SDA, PIN_SCL);
QRcodeOled qr(&disp);
String qrValue = "idle";
bool pingLamp = false;
unsigned long prevPingLamp;
bool openDoor = false;
unsigned long prevOpenDoor;
bool isActive = false;
bool doorIsOpen = false;
unsigned long prevStatusUpdate;
#include "mqtt.h"
int count = 1;
void setup() {
    Serial.begin(9600);
    pinout__setup();
    mqtt__setup_wifi();
    mqtt__client.setServer(mqtt_server, 1883);
    mqtt__client.setCallback(mqtt__callback);
    prevStatusUpdate = millis();
    qr.init();
}
void loop() {
    if (!mqtt__client.connected()) {
        mqtt__reconnect();
    }
    mqtt__client.loop();
    if (pingLamp) {
        if ((millis() - prevPingLamp) > PING_LAMP_DURATION) {
            pingLamp = false;
        }
    }
}
```

```
    digitalWrite(PIN_OUT_LAMP, HIGH);
  }
}
if (openDoor) {
  if ((millis() - prevOpenDoor) > DOOR_COMMAND_DURATION) {
    digitalWrite(PIN_OUT_SOLENOID, LOW);
    openDoor = false;
  }
}
if (!isActive) {
  digitalWrite(PIN_OUT_SOLENOID, LOW);
}
if (isActive) {
  if (doorIsOpen) {
    if (digitalRead(PIN_IN_DOOR)) {
      mqtt_client.publish(MQTT_TOPIC_TRANSACTION_DONE, "1");
      doorIsOpen = false;
      isActive = false;
    }
  } else {
    if (!digitalRead(PIN_IN_DOOR)) {
      doorIsOpen = true;
    }
  }
}
if ((millis() - prevStatusUpdate) > 1000) {
  mqtt_client.publish(MQTT_TOPIC_DOOR_STATUS,
String(digitalRead(PIN_IN_DOOR)).c_str());
  mqtt_client.publish(MQTT_TOPIC_SIGNAL_STRENGTH,
String(WiFi.RSSI()).c_str());
  prevStatusUpdate = millis();
}
}
```

- pinout.h

```
#define PIN_SDA 14
#define PIN_SCL 15
#define PIN_IN_DOOR 2
#define PIN_OUT_SOLENOID 13
#define PIN_OUT_LAMP 12
void pinout__setup(){
  pinMode(PIN_IN_DOOR, INPUT_PULLUP);
  pinMode(PIN_OUT_SOLENOID, OUTPUT);
  pinMode(PIN_OUT_LAMP, OUTPUT);
  digitalWrite(PIN_OUT_SOLENOID, LOW);
}
```

- mqtt.h

```
#include <WiFi.h>
#include <PubSubClient.h>
WiFiClient espClient;
PubSubClient mqtt__client(espClient);
void mqtt__setup_wifi() {
    delay(10);
    Serial.println();
    Serial.print("Connecting to ");
    Serial.println(ssid);
    WiFi.begin(ssid, password);
    int count = 0;
    while (WiFi.status() != WL_CONNECTED) {
        delay(100);
        Serial.print(".");
        digitalWrite(PIN_OUT_LAMP, !digitalRead(PIN_OUT_LAMP));
        count++;
        if (count > 50) {
            ESP.restart();
        }
    }
    digitalWrite(PIN_OUT_LAMP, LOW);
    Serial.println("");
    Serial.println("WiFi connected");
    Serial.println("IP address: ");
    Serial.println(WiFi.localIP());
}
void mqtt__callback(char* topic, byte* message, unsigned int length) {
    Serial.print("Message arrived on topic: ");
    Serial.print(topic);
    Serial.print(". Message: ");
    String messageTemp;
    for (int i = 0; i < length; i++) {
        Serial.print((char)message[i]);
        messageTemp += (char)message[i];
    }
    Serial.println();
    if (String(topic) == MQTT_TOPIC_QR_VALUE) {
        if (messageTemp == "idle") {
            qr.init();
            digitalWrite(PIN_OUT_LAMP, LOW);
            isActive = false;
        } else {
            qr.create(messageTemp);
            digitalWrite(PIN_OUT_LAMP, HIGH);
            isActive = true;
            doorIsOpen = false;
        }
    }
}
if (String(topic) == MQTT_TOPIC_LAMP_PING) {
```

```
    if ((messageTemp == "PING") && (isActive)) {
        digitalWrite(PIN_OUT_LAMP, LOW);
        pingLamp = true;
        prevPingLamp = millis();
    }
}
if (String(topic) == MQTT_TOPIC_DOOR_COMMAND) {
    if ((messageTemp == "OPEN") && (isActive)) {
        digitalWrite(PIN_OUT_SOLENOID, HIGH);
        openDoor = true;
        prevOpenDoor = millis();
    }
}
}
void mqtt__reconnect() {
    while (!mqtt__client.connected()) {
        Serial.print("Attempting MQTT connection...");
        if (mqtt__client.connect(CLIENT_ID)) {
            Serial.println("connected");
            mqtt__client.subscribe(MQTT_TOPIC_QR_VALUE);
            mqtt__client.subscribe(MQTT_TOPIC_DOOR_COMMAND);
            mqtt__client.subscribe(MQTT_TOPIC_LAMP_PING);
        } else {
            Serial.print("failed, rc=");
            Serial.print(mqtt__client.state());
            Serial.println(" try again in 5 seconds");
            delay(5000);
        }
    }
}
```

- config.h

```
#define LOCKER_ID "AAA"
#define BOX_ID "003"
const char* ssid = "LockerMME";
const char* password = "sguMME16";
const char* mqtt_server = "192.168.0.100";
#define CLIENT_ID String(\
    String(LOCKER_ID) + \
    "-" + \
    String(BOX_ID) \
).c_str()
#define MQTT_TOPIC_QR_VALUE String(\
    String(LOCKER_ID) + \
    "/" + \
    String(BOX_ID) + \
    "/" + \
```

```
        "qr" \
        ).c_str()
#define MQTT_TOPIC_DOOR_STATUS String( \
        String(LOCKER_ID) + \
        "/" + \
        String(BOX_ID) + \
        "/" + \
        "door_feedback" \
        ).c_str()
#define MQTT_TOPIC_DOOR_COMMAND String( \
        String(LOCKER_ID) + \
        "/" + \
        String(BOX_ID) + \
        "/" + \
        "door_command" \
        ).c_str()
#define MQTT_TOPIC_LAMP_PING String( \
        String(LOCKER_ID) + \
        "/" + \
        String(BOX_ID) + \
        "/" + \
        "lamp_ping" \
        ).c_str()
#define MQTT_TOPIC_SIGNAL_STRENGTH String( \
        String(LOCKER_ID) + \
        "/" + \
        String(BOX_ID) + \
        "/" + \
        "rssi" \
        ).c_str()
#define MQTT_TOPIC_TRANSACTION_DONE String( \
        String(LOCKER_ID) + \
        "/" + \
        String(BOX_ID) + \
        "/" + \
        "transaction_done" \
        ).c_str()
#define PING_LAMP_DURATION 1000
#define DOOR_COMMAND_DURATION 2000
```