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IMPLEMENTATION INTERNET OF THINGS USING LINEAR REGRESSION METHOD FOR SUPPLY CHAIN MANAGEMENT SYSTEM

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Abstract

The Indonesian ministry of the industry stated that the development of industry must be a formidable industrial country in the world by 2025 and has carbon neutrality by 2060. This goal must be considered related to the distance of the supplier location from the industrial and it increases the gas emissions in the air. In this research, the proposed a solution for optimizing the delivery of material supplies from suppliers to the industry. The protocol communication uses the MQTT protocol to connect the device with a broker. This system will collect the information from sensors such as DHT 11, MQ-05, RFID, and other sensors to record the data, track the location, and validate the person accessing the goods and the data in a document. The data can be used as decision-making material using the regression linear method specifically at humidity and temperature. This device will connect to the user's smartphone by using an application that is connected by an online MQTT broker and see the condition of the goods, track the location of the delivery, and control the device from anywhere. The experiment result shows that the device can monitor temperature, humidity, CO2, LPG gas, and smoke gas. It also used the linear regression method used for determine the impact of the correlation between temperature and humidity at supply storage. The model summary states that the slope (B1) value is -1.8637 with a constant (B0) of 110.1554. B1 has a negative value. So, it can be concluded that the temperature variable negatively correlates with humidity. This method will be useful for the system to do some action to stabilize the condition inside the supply room such as giving a notification to the driver or turning on several pieces of equipment automatically to recover the condition. The proposed system is an IoT system using the openHAB platform as a UI that will be used in this system with a linear regression method to find the relationship between system parameters.

Keywords: Linear Regression, MQTT Protocol, Internet of Things, Sensors, Supply Chain Management.

Introduction

The vision of the National Industrial department as stated in the Presidential Regulation for Indonesia to become a resilient industrial country in 2025 (Ainul et al., 2022). The Indonesian industrial sector must be able to have several criteria, including

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Having a role and high contribution to the National economy, KM has a balanced ability with large industries, a solid industrial structure (complete and deep industrial tree), technology has become the spearhead of market development and creation, already has industrial services that support the competitiveness of international industries, and the competitiveness that can face full liberalization with APEC countries (Bekti, 2022).

IoT will be one of the backbones in helping the industry in the SCMS to simplify the supply distribution process (Banerjee, 2018). Due to its enhanced power, the Industry envisions the Internet of Things as a foundation for cyber-physical systems. The "smart factory" concept relies on its capacity to utilize it (Monostori et al., 2016). The supply chains compete with one another, having one that is digitally synchronized improves visibility in a longer supply chain (Kamble et al., 2022). Due to the rising IoT's potential, accessibility, and disruptive nature, key ICT infrastructure must be built by incorporating its enhanced digital capabilities which are characterized by autonomous, sensor-based, knowledge-based manufacturing systems that regulate themselves (Bibri, 2018).

The Internet of Things (IoT) is described as an information exchange between machines and people and between humans and machines and machines in heterogeneous environments (Sicari et al., 2015). Although this paradigm has been predicted to occur soon, IoT digitalization and automation in the context of supply chains already use for quite some time (Holmes et al., 2021). The best answer for businesses experiencing problems related to increasing product movement and a lack of information flow for quick decision-making is digitalization (Preindl et al., 2020). Emerging technologies are essential for a "smart" supply chain that helps get over the present challenges of real-time data collection and exchange, such as IoT deployment at the first until end points (De Vass et al., 2021). Global supply chain networks are facing unprecedented challenges and change, thus they are increasingly looking to Industry 4.0 technology, particularly Internet of Things (IoT) technology, for answers.

IoT devices are being used by forward-thinking businesses to turn intricate supply chains into fully functional networks. Real-time asset tracking, monitoring, and alarms may be provided via these devices' sensor data and Radio Frequency Identification (RFID), which can assist to simplify processes and minimize disturbance. IoT enables supply chain managers to link up machines, cars, and other items for real-time work status information. This can present a complete image of the supply chain, from the manufacturer to the client via the warehouse. Managers now receive the exact position of the vehicle rather than a job status of "in transit". This enables them to take prompt action to maintain the efficient movement of commodities (Pender et al., 2014). We propose an IoT system using the openHAB platform as a UI that will be used in this system with a linear regression method to find the relationship between system parameters.

Research Method

The proposes system is to build supply chain management systems for the industry. The system is designed to monitor temperature, humidity, carbon gas emissions, cigarette gas, and the location of the delivery of supply goods from suppliers. Some of the sensors and other components used are the DHT sensor which is used to get data on the temperature and humidity of goods, and the MQ-05 sensor which is used to get carbon data, gas emissions, and detect gas smoke. GPS sensor which is used to get the location of the driver. The system is also installed with an RFID reader to determine the identity of the accessor of the goods and the microcontroller will validate the person who accesses the goods. The full system can be seen in fig.1.

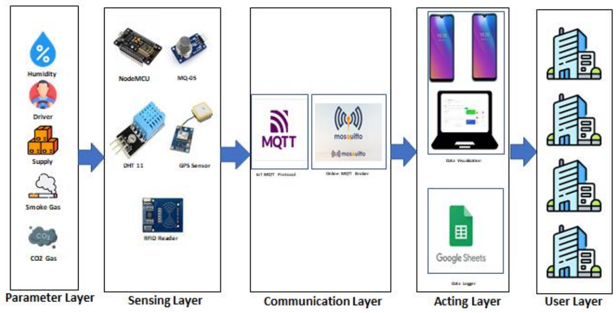

Fig.1. System Architecture

At fig.1 is the several layers of our research. The first layer is the parameter layer which contains several items that will be used to get the data. The second layer is the sensing layer which contains several sensors that will be used to get and send the data to the broker. The third layer is the communication layer which contains the MQTT protocol to send the data and MQTT online broker for sending the data to several devices in the system. The fourth layer is the acting layer which contains several devices to visualize and save the data. The last layer is the user layer which contains all of the users who integrate the system into supply chain management. The temperature and humidity values of the supply items will be linked and data collected in real-time. Data will be submitted in 2 ways, namely in the form of a .csv report that is connected to a spreadsheet and visualized using an application on a smartphone and PC (Brunette et al., 2013). This is done to determine whether the goods are in a normal temperature and humidity state or not. If the temperature is too hot, the driver will receive a notification and open the vent on the hood. Our device is equipped with a gas sensor that can detect the gas content in the car compartment/hood. This is done to measure the level of gas usage in the driver and to secure flammable items (Morgan & Gilman, 2013).

A. Hardware Architecture

Fig. 2 shows the hardware architecture which includes a NodeMcu DHT 11 Temperature Sensor, RFID Reader, MQ-05 Gas Sensor, WiFi Modem, and Battery.

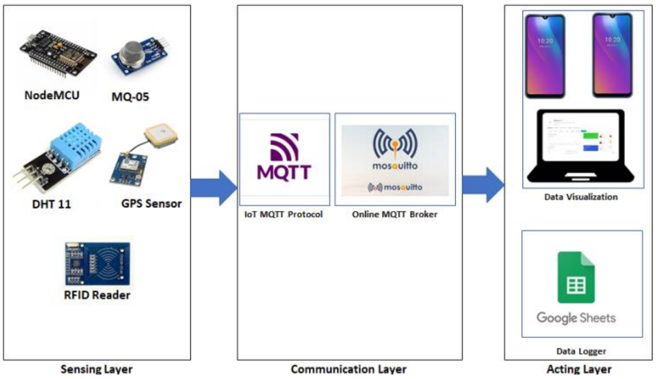

Fig.2. Hardware Architecture

There are 3 layers in our architecture. The sensing layer will be the first layer for getting the data from the supply. The second layer is the communication layer for connecting the sensor with the cloud and data logger. The acting layer is the interface for the user. So, when the system begins the sensor will get several data from the supply. DHT 11 will get the data from the temperature and humidity in the supply box carried by the driver. The data from the sensors will process and validate using the regression linear method (Bisquert et al., 2016). In addition, there is an MQ-05 gas sensor that can measure the level of CO2, LPG gas, and cigarette smoke to secure a flammable supply. If the driver does things that can endanger the supply such as smoking or lighting a match then the sensor will send a warning to the driver to put out the cigarette or fire. The recorded data will be connected to the MQTT protocol to send data to the online broker MQTT and the data will be recorded in the spreadsheet. The users also can watch and stream data by application on smartphones and computers using the MQTT dashboard application.

B. Software Architecture

It includes an Android, MQTT gateway, MQTT broker, Wi-Fi Direct, Blynk cloud, and Spreadsheet data logger as shown in fig.3.

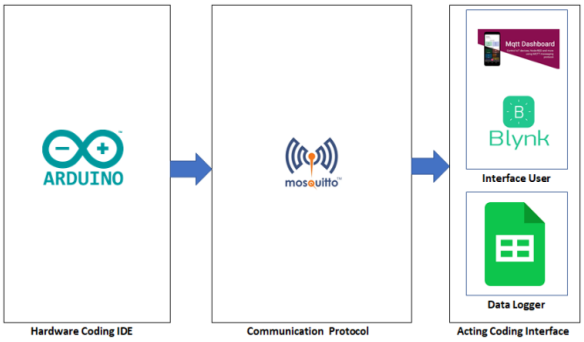

Fig.3. Software Architecture

In the software architecture shown in fig. 3. There are 3 layers. The first layer is the hardware coding ide layer which is used as a software to write programs on the hardware to read the sensor. To code the program on the hardware, we use the Arduino

IDE to write a program on the MCU node in C language so that it can read the parameter values in the system. The second layer is a communication layer that uses the mqtt protocol as a liaison between the broker and the hardware. The mosquitto broker is the online broker which can be connected to many devices. The third layer is a layer on data visualization and data logger. In the third layer the blynk cloud as a data storage and opehHAB will be use for data visualization. The spreadsheet will record all measurement data on the system for backup the data measurement (Hackett et al., 2019).

Hasil dan Pembahasan

A. Data Collection

The data in this study were collected in the room. The data were collected from 15.35 WIB to 16.31 WIB or for 56 minutes, so theoretically, the data collected was 56 * 60 / 5 = 672 rows. However, from the experiments, only 342 data were obtained in the spreadsheet. It could be due to network constraints and packet loss. Figure 4 shows the sensor data in the time domain.

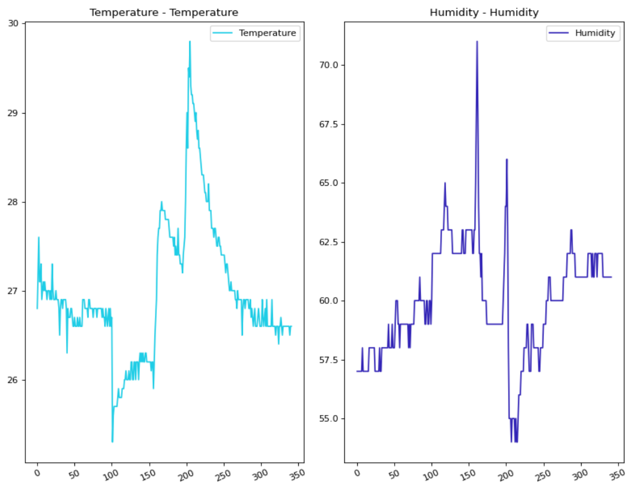

Fig.4 Sensor Data in Time Domain

B. Data Cleaning

Before modeling the data using linear regression, we made observations with scatter plots and histograms to determine the distribution of the data. Fig. 5 is the graph that shows the data distribution.

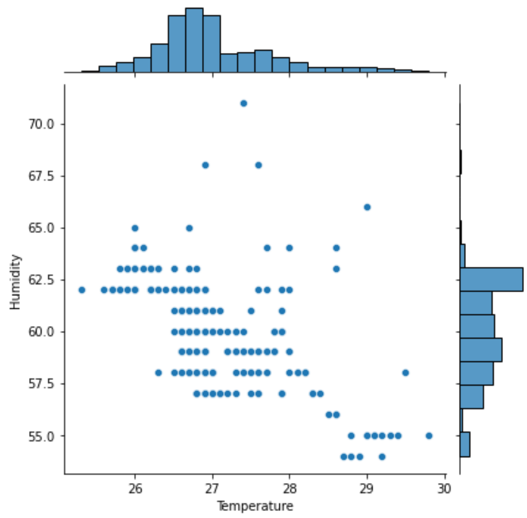

Fig.5. Scatter Plot and Histogram Before Removing Outliers

From the scatter plot and histogram in Fig. 6, it can be observed that there are some outliers. This study handled outlier data on the dependent variable (humidity). Outliers were cleaned by determining the upper threshold of data based on 90 percentile data, where the upper limit is obtained at 65.59, while the lower limit is determined based on first percentile data, where the lower limit is 54.37. After cleaning the outliers, the total cleaned data is 334 rows, where as many as eight outlier data are discarded.

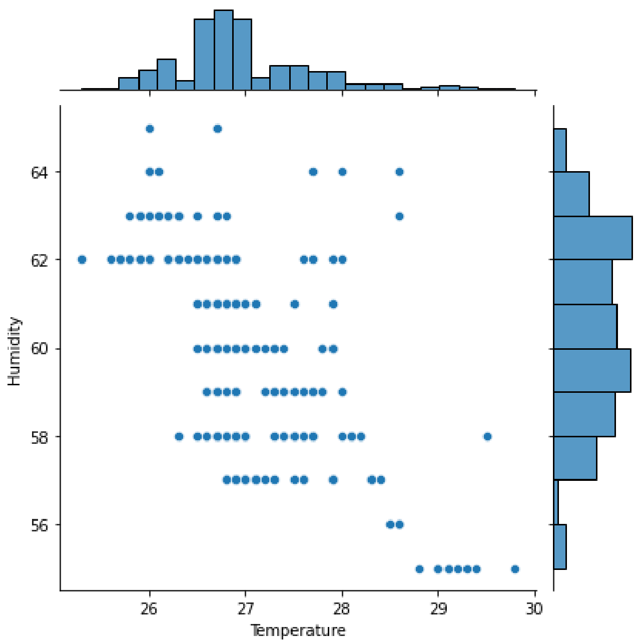

Fig.6. Scatter Plot and Histogram After Removing Outliers

C. *Linear Regression Modeling*

After pre-processing the data, the next step is modeling using linear regression with the independent variable temperature and the dependent variable humidity. In this study, the look for the relationship between these two variables. Modeling results can be seen in figure 7. A summary model is obtained as follows.

```
                            OLS Regression Results
==============================================================================
Dep. Variable:               Humidity   R-squared:                       0.407
Model:                            OLS   Adj. R-squared:                  0.405
Method:                 Least Squares   F-statistic:                     228.0
Date:                Sun, 11 Sep 2022   Prob (F-statistic):           1.38e-39
Time:                        03:54:57   Log-Likelihood:                -634.89
No. Observations:                 334   AIC:                             1274.
Df Residuals:                     332   BIC:                             1281.
Df Model:                           1
Covariance Type:            nonrobust
===============================================================================
                  coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------
const         110.1554      3.328     33.104      0.000     103.610     116.701
Temperature    -1.8637      0.123    -15.101      0.000      -2.107      -1.621
==============================================================================
Omnibus:                       30.351   Durbin-Watson:                   0.158
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               55.710
Skew:                           0.532   Prob(JB):                     7.99e-13
Kurtosis:                       4.694   Cond. No.                     1.01e+03
==============================================================================
```

Fig.7. Model Summary of Linear Regression

From the summary model, it can be observed that the p-value is shallow (close to zero), so it can be analyzed that the temperature variable has a statistically significant to the humidity value. A variable can be said to have a statistically significant value when the p-value is less than 5% or 0.05. The linear regression equation can be written in (1) from linear regression modeling with one attribute.

$$Y = B_1X + B_0 \quad (1)$$

The value of B_1 is the gradient or slope of the line, while the value of B_0 is a constant. From the summary model, it can be analyzed that the value of slope (B_1) is -1.8637 with a constant (B_0) of 110.1554. B_1 has a negative value, so it can be analyzed that the temperature variable negatively correlates with humidity. In a study, the R-squared is said to be good when the value is more significant than 0.7, while the R-squared is less than 0.4, indicating that the variable has a low correlation. From the modeling stage, it can be seen that the model has an R-squared of 0.407 and an adjusted R-squared of 0.405. This relatively low R-squared could be due to the lack of data for modeling, and it could also be due to the presence of much noise data, so it is necessary to do more in-depth data cleaning, such as using the Fast Fourier Transform (FFT) filter or other methods. The model can be described in the graph in Fig. 8.

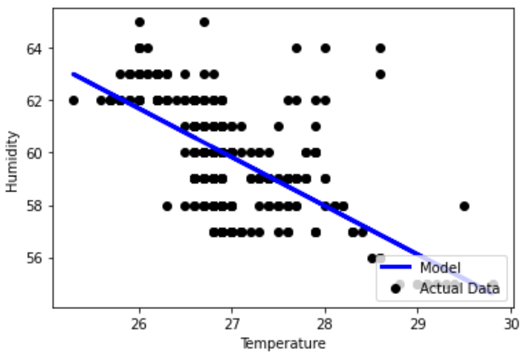

Fig.8. Predicted Data and Actual Data

The following UI display of sensor data that integrated using OPENHAB can be seen in Fig 9.

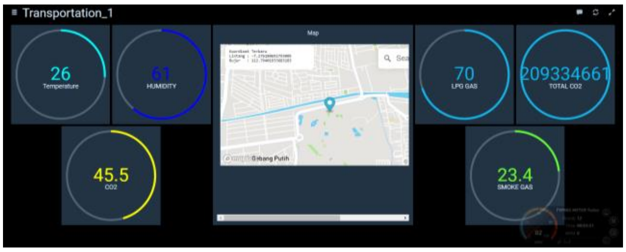

Fig.9. User Interface System

The fig.9 shows some of the parameters measured using the sensor. the measurement process is carried out in real time and can be seen through the panel in the openHAB framework. from the panel there is a colored indicator that will change based on sensor readings in real time. In addition, there are maps that we designed to make it easier for drivers to drive and get the location of the fastest route that can be used on the openHAB panel.

Kesimpulan

The proposed research uses several sensors to measure temperature, humidity, and gas in a supply environment. The microcontroller used is NodeMCU ESP8266. The data is sent by NodeMCU ESP8266 to the MQTT broker for monitoring purposes through the MQTT dashboard application. At the same time, the data is also sent to a spreadsheet to be collected and stored in CSV format for data analysis using the linear regression method. The linear regression method used for determine the impact of the correlation between temperature and humidity at supply storage. The model summary states that the slope (B1) value is -1.8637 with a constant (B0) of 110.1554. B1 has a negative value. So, it can be concluded that the temperature variable negatively correlates with humidity and this method will be useful for the system to do some action for stabilizing the condition inside the supply room such as giving a notification to the driver or turning on several equipment automatically to recover the condition.

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