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Smart Prototype Design of Rice Storage System Based On Internet of Things

By

Budi Suhendro
Departement of Electronics Instrumentation, Indonesian Nuclear Technology Polytechnic, Yogyakarta, 55281, Indonesia

M. Fadhil Nur Hidayat
Departement of Electronics Instrumentation, Indonesian Nuclear Technology Polytechnic, Yogyakarta, 55281, Indonesia

Halim Hamadi
Departement of Electronics Instrumentation, Indonesian Nuclear Technology Polytechnic, Yogyakarta, 55281, Indonesia

Djiwo Harsono
Departement of Electronics Instrumentation, Indonesian Nuclear Technology Polytechnic, Yogyakarta, 55281, Indonesia

Abstract

Temperature and humidity are environmental factors that need to be considered in storing, especially rice. This factor will affect the growth of fungi, the appearance of lice, and insects which can reduce the quality of rice. Therefore, the purpose of this research is to create a prototype smart system for rice storage space based on the Internet of Things (IoT) which can display about conditions temperature, and humidity of the room with User Interface (UI) Node-RED and control it, to achieve optimal storage conditions. The prototype is designed using a Raspberry Pi 3 model B as a microcontroller to control the cooling fan, exhaust fan, and servo motor which is controlled automatically according to the temperature and humidity values that are set based on the results of the DHT-22 sensor measurements. The servo motor is used to drive the ventilation window to open and close. The stepper motor can be controlled using Node-RED UI to open and close the door. Based on the test results, the room conditioning automation system can work well. Information on temperature, humidity, as well as the condition of cooling fans, exhausts, ventilation windows, and doors, can also be displayed on the Node-RED interface with an average delay is 0.5 seconds and a 0% data delivered error percentage. The results of the temperature and humidity measurement of the DHT-22 sensor have an average difference in temperature measurement of 0.91 % and humidity of 1.07 % with the Taffware Temperature-Humidity Meter. In the tests carried out, it took about 5.41 minutes to reduce the temperature from 40 ^{0}C to 30-31 ^{0}C, and to reduce the humidity from 75 % to 64 % took about 1.46 minutes.

Keywords: automation, internet of things, prototype, rice storage, temperature and humidity

Introduction

The main staple food consumed by more than half of the population of Asia especially Indonesia is rice, which is a food source of carbohydrates to meet daily nutritional needs [1, 2]. In order to keep up with global population growth and demand, rice production must increase by at least 25% by 2030 [3].

The quality of rice is not only determined by the quality of the rice planted, but also the way it is stored. Storage is one of the postharvest handling processes of rice which is an important stage in the production process of processing rice for consumption [4, 5]. Rice storage is carried out after the rice plants have been harvested and processed for packaging. There are several factors that need to be considered in rice storage, including environmental factors (temperature, relative humidity of the storage space), chemical factors (water activity, chemical composition of seeds, oxidation process), physiological factors (respiration, transpiration), biological factors (pests, insects, mice, etc.) and packaging factors [6].

In Asia, approximately 3% of the total PHL (storage losses) are caused by insects and fungi, which is half of the 6% of storage losses that are caused by inadequate storage facilities [7, 8]. In traditional storage process, farmers cannot condition and monitor the temperature and humidity of the storage area, which are environmental factors that need to be considered. Errors in storing rice can result in respiration, fungal growth, insect attacks, rodents and rice lice which can reduce the quality of rice. Therefore, control of environmental factors that play a role in storage as well as agents that can cause harm and shorten shelf life is absolutely necessary [9, 10]. High temperature can stimulate the separation of fat, inhibit the enzyme activity of catalase, and cause an uneven surface of rice endosperm during storage, resulting in increased fatty acids and lipid oxidation [11]. The humidity in the storage room must be kept as low as possible (less than 65%) at a temperature about 30°C to reduce the absorption of moisture from the air into the rice. In addition, low humidity can reduce microbiological and fungal activity [12].

Previous Researches

In previous research, conducted by Karim, et al. In 2018, the basic objective of their research is to mitigate the man monitoring and to develop an internet based real time monitoring of temperature and humidity using the very available DHT-11 sensor and ESP-8266 NodeMCU module [13].

In 2019, research conducted by Junizan, et al. About manufacture of an automatic fan system that can change the speed level due to changes in environmental temperature using pulse width modulation techniques and temperature sensors, namely LM35 with Arduino Uno microcontroller. The fan is used to lower the room temperature to a certain level [14].

In 2020, research conducted by Panigrahi, et al. Designed smart sensor agriculture stick for live temperature and humidity monitoring with Arduino technology, breadboard and mixed with different various sensors and live data feed can be obtained online through mobile phone to help farmers increase their overall yield and quality of products [15].

In 2021, research conducted by A. Devi, et al. Designed food grain wastage monitoring and controlling system for warehouse to monitors the atmospheric conditions, rodent and insects activities inside the warehouse, simultaneously takes the necessary controlling actions and sends the notification regarding the performed controlling action to the warehouse owner/manager [16].

Then in 2021, research conducted by Aradwad, et al. Development of microcontroller-based data logger for real-time monitoring of drying and storage of food grains to improve the level of post-harvest processing and reduce losses using temperature and relative humidity sensor DHT-22, LCD, SD Card, motor control driver, and RTC 3231 for real-time monitoring and data recording of temperature and humidity [17].

Based on the problems and previous research, this study aims to create a prototype smart system for rice storage rooms based on the Internet of Things that can condition the temperature and humidity of the room to achieve optimal storage conditions, and allow remote monitoring using the User Interface (UI) dashboard Node-RED. The results of this study are expected to be developed so that it can be applied to actual conditions to improve the quality and extend the shelf life of rice.

Method

The process of designing a monitoring and control system for temperature and humidity can be divided into 3 stages, hardware design, control system design, and user interface design.

Hardware Design

Hardware design is done by combining each component used. The hardware design used is shown in Figure 1.

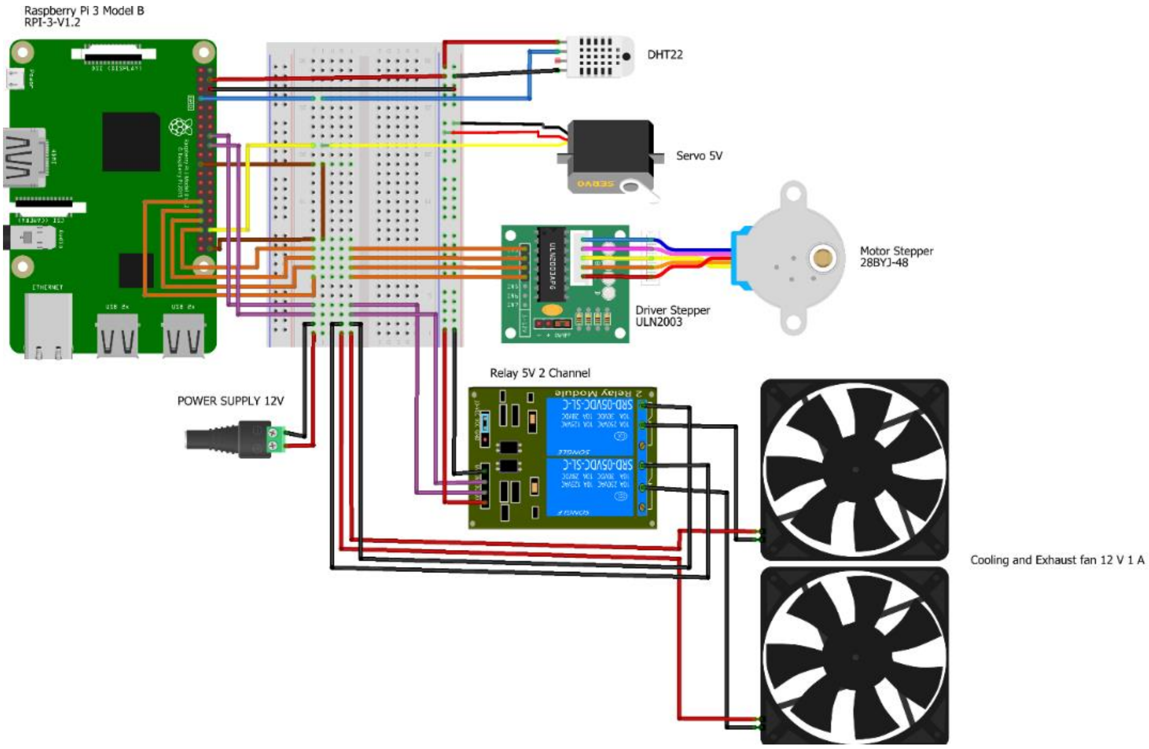

Figure 1. *Hardware Design*

Based on hardware design in Figure 1 there are several components used, including the DHT-22 sensor, to measure the temperature and humidity values of the storage room air which will be the reference values for the actuator drive [18]. MG996R 5V servo motor, as a driver for opening and closing the ventilation window [19]. Mini 12V 1A fan, as an exhaust fan and air conditioning fan. Relay 5V dual channel, as a switch on / off the exhaust fan and cooling fan. 28BYJ-48 5V stepper motor and 2003 ULN driver, for door opening and closing [20,21]. All of these components are connected to their respective GPIO pins on the Raspberry Pi 3 model B as microcontroller [22, 23].

Control System Design

The control system used is a 2-value control system (ON-OFF) in this case, the driver can produce a variable value (quantity) that is controlled in a state of full power or no power at all. Accuracy is a limitation of this control system when high accuracy control is required because the system's controlled variable is always oscillating [24, 25].

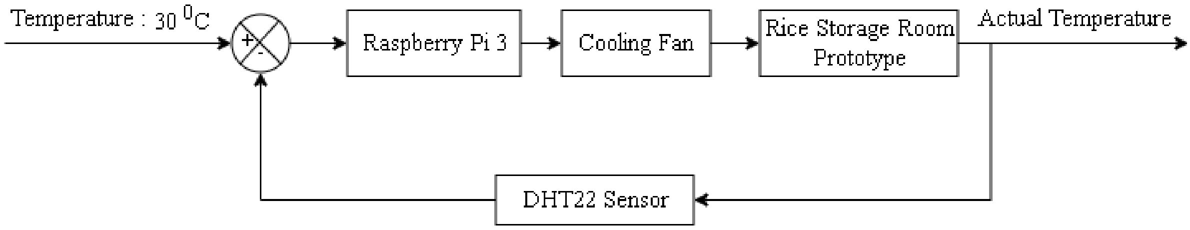

Figure 2. *Control System Diagram: Temperature*

Based on Figure 2 a control system diagram describes the temperature control process, which in this process the Raspberry Pi 3 is used as a microcontroller that will control the cooling fan to reduce the temperature of the storage room. In the close loop process, the actual temperature of the storage space will be measured by the DHT-22 sensor and fed back to the set point so that the error value will be obtained which is used by the control function to achieve the desired set point value. In this process, it is expected that the room temperature can be maintained at a temperature of 30^0C.

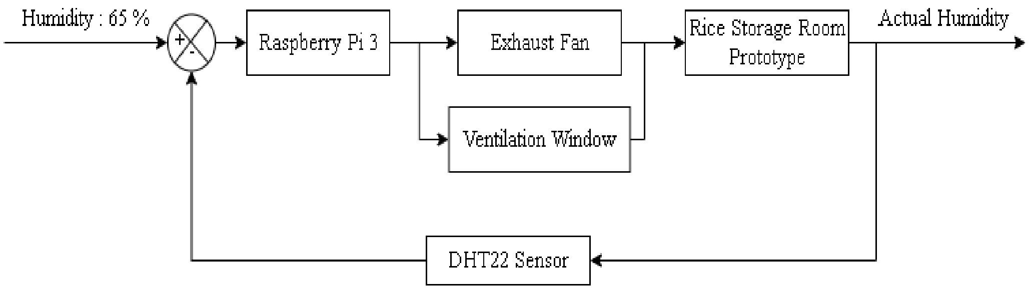

Figure 3. *Control System Diagram: Humidity*

Based on Figure 3 a control system diagram that describes the humidity control process, in which the Raspberry Pi 3 is used as a microcontroller which will control the exhaust fan and ventilation window to reduce the humidity of the storage room. In the close-loop process, the actual humidity of the storage space will be measured by the DHT-22 sensor and fed back to the set point so that the error value used by the control function will be obtained to achieve the desired set point value. In this process, it is expected that the humidity of the room can be maintained at 65% humidity.

Figure 4. *Control System Diagram: Door*

Based on Figure 4 a control system diagram that describes the process of controlling the door opening and closing, which in this process the Raspberry Pi 3 is used as a microcontroller to control the stepper motor. In the open loop process, when the Node-RED UI door button is pressed, the Raspberry Pi 3 will control the stepper motor to move clockwise to open the door, and move in the opposite direction to close the door again.

User Inteface Design

Node-RED is used as a software to design the user interface that will be used. The user interface design used is shown in Figure 5.

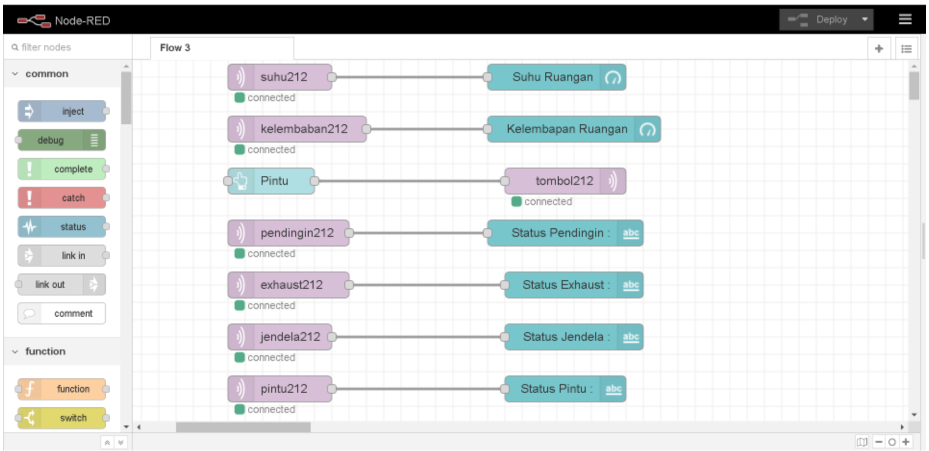

Figure 5. *User Interface Design*

Based on user interface design in Figure 5 there are several nodes are used. MQTT In nodes are used to receive or retrieve data sent from the microcontroller. MQTT Out nodes are used to send data to the microcontroller. Gauge nodes are used to display the results of temperature and humidity measurements. Then, Text nodes are used to display information on the condition and state of the cooling fan, exhaust fan, ventilation window, and door [26].

Result and Discussion

Physical Shape of Rice Storage Room Prototype Model

The prototype model of this rice storage room, clear acrylic material with a thickness of 5 mm was used. The model room is made with a length of 30 cm, a height of 30 cm and a width of 60 cm. The results of making the room model are shown in Figure 6.

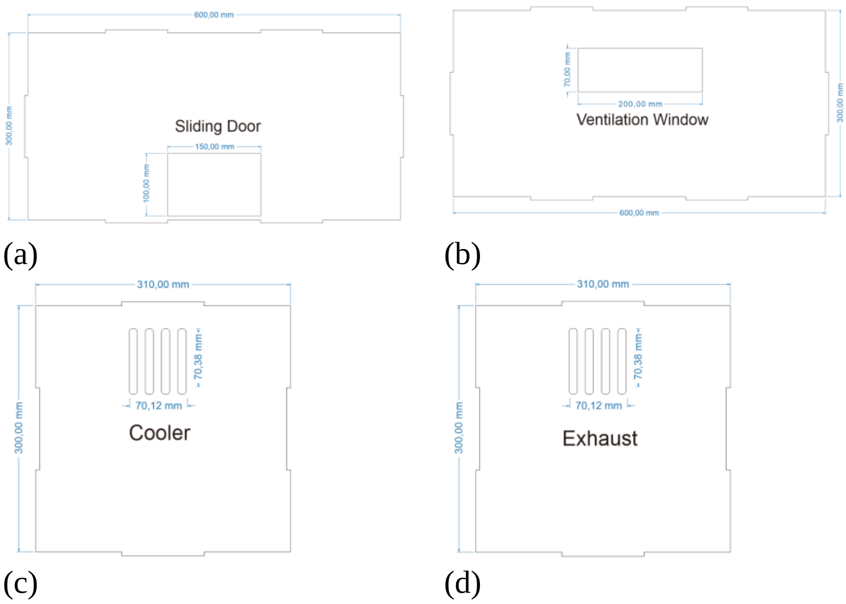

Figure 6. *Prototype Model Result (a) Front Side (b) Back Side (c) Right Side (d) Left Side*

In this prototype model of the rice storage room in Figure 6, there are 2 air holes on the left and right sides as shown in Figure 6 in the hole on the right side is installed a fan that sucks air from the outside in as a cooler. In the hole on the left side there is a fan that sucks air from the inside out as an exhaust. On the side of the back wall, there is a ventilation window that can be opened or closed by a servo motor. And on the front side there is a sliding door that is pulled using a stepper motor and belt. The door can be controlled via the User Interface (UI) of the Node-RED dashboard. In addition, in the prototype room there are miniature wooden cots and rice sacks.

Temperature and Humidity Measurement Test Results

The data was collected by 20 data, but in table 1 only 10 data are shown. The humidity and temperature measured on both sensors were recorded every minute for 20 minutes. The data from the results of the tests carried out are as shown in Table 1.

Table 1. *Comparison of Temperature and Humidity Measurement Results*

Data	Temperature (^{0}C)		Measurement	Humidity (%)		Measurement
	DHT 22	Taffware	Difference (%)	DHT 22	Taffware	Difference (%)
1	27,3	27,1	0,73	58,4	58	0,68
2	27,7	27,1	2,21	59,5	58	2,58
3	27,8	27,1	2,58	59,8	59	1,35
4	27,5	27,3	0,73	60	59	1,69
5	27,3	27,2	0,36	61	60	1,66
6	27,3	27,2	0,36	60,8	60	1,33
7	27,1	27,3	0,73	60,7	60	1,16
8	27,1	27,3	0,73	60,7	60	1,16
9	27,4	27,3	0,36	61,2	61	0,32
10	27,4	27,3	0,36	61,2	61	0,32
Average Temperature Measurement Difference (%)			0,91	Average Humidity Measurement Difference (%)		1,07

Based on the results of the tests obtained in Table 1, the average difference in temperature and humidity between the DHT-22 sensor and Taffware is 0.91% for temperature and 1.07% for humidity.

Automation System Test Result

This test is carried out to ensure that the smart system on the prototype made runs well. To find out the cooling fan, exhaust fan and ventilation window can turn on/off automatically, the temperature and humidity need to be set to 30^{0}C or < 30^{0}C using a hairdryer and for humidity 65% or < 65% using a water diffuser. The results of the tests that have been carried out are shown in Table 2.

Table 2. *Automation System Test Result*

Component	Humidity		Temperature	
	≥ 65%	< 65%	≥ 30^{0}C	< 30^{0}C
Cooler			On	Off
Exhaust	On	Off		
Ventilation Window	Open	Closed		

Table 2 shows that the cooling fan turns on when the temperature is 30^{0}C and will turn off when the temperature is < 30^{0}C. When the measured humidity is 65% the exhaust fan will turn on and the ventilation window will open, otherwise when the humidity is < 65% the exhaust fan will turn off and the ventilation window will close. Based on the results of the tests carried out, it is known that the automation system works well.

Node-RED Dashboard User Interface (UI) Test Results

This test is carried out to ensure that the User Interface (UI) of the Node-RED dashboard can display the latest appropriate data. Currently the Node-RED User Interface display can only be run on the local host network. The UI display for the Node-RED dashboard that has been created is shown in Figure 7.

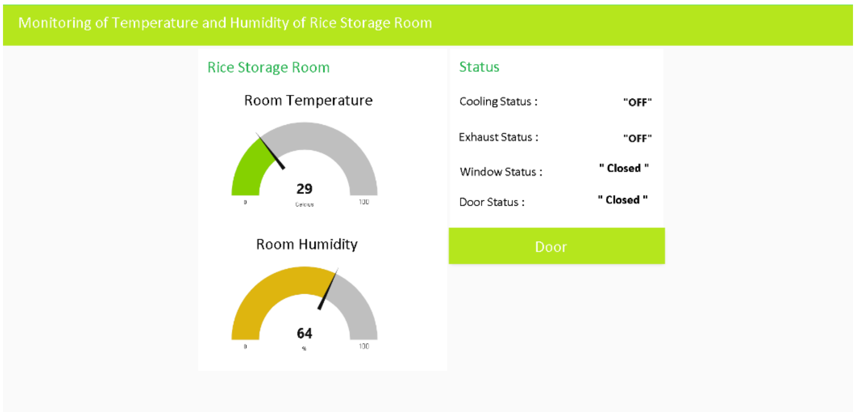

Figure 7. *User Interface (UI) Node-RED dashboard*

Then a test is carried out to see the delay in the DHT-22 sensor measurement data displayed on the Node-RED dashboard UI. The test is done by looking at the time difference between the data displayed on the Raspberry Pi and the data displayed on the Node-RED dashboard UI. The example data from the delay test results can be seen in Table 3.

Table 3. *Data Delivery Delay Test: Temperature*

Data	Raspberry Pi Measurement Results (Temperature)	Raspberry Pi Time (GMT+7)	UI Node-RED Displayed (Temperature)	UI Node-RED Time (GMT+7)	Delay (Second)
1	27,5^{0}C	17.03.15	27,5^{0}C	17.03.16	1
2	27,4^{0}C	17.04.13	27,4^{0}C	17.04.14	1
3	27,5^{0}C	17.06.01	27,5^{0}C	17.06.01	0
4	27,6^{0}C	17.07.49	27,6^{0}C	17.07.49	0
5	27,5^{0}C	17.09.08	27,5^{0}C	17.09.08	0
6	27,5^{0}C	17.10.14	27,5^{0}C	17.10.15	1
7	27,5^{0}C	17.11.08	27,5^{0}C	17.11.08	0
8	27,4^{0}C	17.12.45	27,4^{0}C	17.12.46	1
9	27,5^{0}C	17.13.17	27,5^{0}C	17.13.18	1
10	27,6^{0}C	17.16.23	27,6^{0}C	17.16.23	0
Average Delay (Second)					0,5

Based on the test results in Table 3, the average data delay before being displayed on the Node-RED dashboard User Interface (UI) is about 0.5 seconds. It can be concluded that temperature and humidity data can be displayed properly in realtime on the Node-RED dashboard UI.

Then testing is carried out to ensure that the Node-RED UI can display the latest data, and data errors displayed on the Node-RED UI. Testing is obtained by turning off the server for 5, 10, 15, 20, 25 and 30 minutes, then the server is turned on again. The results of the last reading before the server shuts down and after the server is turned on are recorded.

Table 4. *Node-RED Server On-Off Testing*

Time Server Off (Minute)	Before Node-RED Server Off		After Node-RED Server On	
	Sent by Raspberry Pi	Received Node-RED	Sent by Raspberry Pi	Received Node-RED
5	Temperature: 27^0C Humidity: 62,2%	Temperature: 27^0C Humidity: 62,2%	Temperature: $27{,}2^0$C Humidity: 61,4%	Temperature: $27{,}2^0$C Humidity: 61,4%
10	Temperature: $27{,}4^0$C Humidity: 62%	Temperature: $27{,}4^0$C Humidity: 62%	Temperature: $27{,}7^0$C Humidity: 62,2%	Temperature: $27{,}7^0$C Humidity: 62,2%
15	Temperature: $27{,}2^0$C Humidity: 61,8%	Temperature: $27{,}2^0$C Humidity: 61,8%	Temperature: $27{,}4^0$C Humidity: 63%	Temperature: $27{,}4^0$C Humidity: 63%
20	Temperature: $27{,}3^0$C Humidity: 62,8%	Temperature: $27{,}3^0$C Humidity: 62,8%	Temperature: $27{,}4^0$C Humidity: 62,5%	Temperature: $27{,}4^0$C Humidity: 62,5%
25	Temperature: $27{,}3^0$C Humidity: 62,4%	Temperature: $27{,}3^0$C Humidity: 62,4%	Temperature: 27^0C Humidity: 63,3%	Temperature: 27^0C Humidity: 63,3%
30	Temperature: $27{,}1^0$C Humidity: 63%	Temperature: $27{,}1^0$C Humidity: 63%	Temperature: $27{,}4^0$C Humidity: 62,7%	Temperature: $27{,}4^0$C Humidity: 62,7%
Error Data				0
Data Error Percentage (%)				0

Based on the results of the tests carried out in Table 4, it is known that the Node-RED UI can display the latest data from the measurement results of the DHT-22 temperature and humidity sensor after the Node-RED server is turned on again, with a data error percentage of 0% which means that all measured data has been successfully sent and displayed on the UI Node-RED dashboard.

Room Conditioning System Test Results

The temperature conditioning test was carried out in an open area with a temperature of 31 ^{0}C. The test is carried out by increasing the temperature of the prototype storage room using a hairdryer to a temperature of 40^0C then the hairdryer is turned off, then the cooling fan is turned on and the time is recorded until the prototype room temperature is equal to or less than the outdoor temperature.

Table 5. *Temperature Conditioning Test*

Number of Tests	Temperature (^{0}C)		Time To Reach Outdoor Temperature (seconds)
	Before	After	
1	40	31	337
2	40	31	343
3	40	30	346
4	40	30	331
5	40	31	352

Based on the results of the tests carried out in Table 5, the average time required for the prototype room to reduce the temperature from 40^0C to 30% is about 338 seconds and to 31% is around 344 seconds or about 5.6 minutes.

Humidity conditioning tests were also carried out in an open area with 68% humidity. The test is carried out by increasing the humidity of the prototype storage room using a water diffuser to 75% humidity then the water diffuser is turned off, then the exhaust fan is turned on and the time is recorded until the humidity of the prototype room is equal to or less than the outdoor humidity.

Table 6. *Humidity Conditioning Test*

Number of Tests	Humidity (%) Before	Humidity (%) After	Time To Reach Outdoor Humidity (seconds)
1	75	64	97
2	75	64	102
3	75	65	98
4	75	64	115
5	75	64	118

Based on the results of the tests carried out in Table 6, the average time required for the prototype room to reduce the humidity from 75% to 64% is about 108 seconds and to 65% is about 98 seconds or about 1.4 minutes.

Conclusion

In the research that has been done, it can be concluded that the prototype smart system for rice storage space based on the Internet of Things (IoT) has been successfully design and built using a Raspberry Pi 3 Model B microcontroller, Mosquitto MQTT broker, Node-RED software, and a DHT-22 sensor. Cooling fan, exhaust and ventilation windows are controlled automatically according to the temperature and humidity values that are set based on the results of the DHT-22 sensor measurements. The cooling fan will turn on when the measured room temperature is 30^0C and the exhaust fan will turn on and the ventilation window will open when the measured room humidity is 65%.

In testing the results of temperature and humidity measurements, the DHT22 sensor has an average difference in temperature measurement of 0.91% and humidity of 1.07% with the Taffware Temperature-Humidity Meter sensor. In the tests carried out, it took about 5.41 minutes to reduce the temperature from 40^0C to 30^0C - 31^0C and to reduce the humidity from 75% to 64% it took about 1.46 minutes. Temperature and humidity can be monitored via the User Interface (UI) of the Node-RED. The door opening and closing of the prototype room can be controlled via the Node-RED UI. Node-RED UI can display the latest data from the measurement results of the DHT-22 temperature and humidity sensor, with average data delay is about 0.5 seconds and a data error percentage of 0%.

References

Schneider, P., and Asch, F. 2020. Rice Production And Food Security In Asian Mega Deltas—A Review On Characteristics, Vulnerabilities And Agricultural Adaptation Options To Cope With Climate Change. J Agro Crop Sci. 2020; 206: 491– 503. https://doi.org/10.1111/jac.12415.

Global Rice Science Partnership (GRiSP). 2013. Rice Almanac. International Rice Research Institute. Retrieved from https://doi.org/10.1093/aob/mcg189.

Seck, P. A., Diagne, A., Mohanty, S., and Wopereis, M. C. S. 2012. Crops That Feed The World 7: Rice. Food Security, 4(1), 7–24. https://doi.org/10.1007/s12571-012-0168-1.

Banga, Km., Kotwaliwale, Nachiket., Mohapatra, Debabandya., and Giri, Saroj. 2018. Techniques For Insect Detection In Stored Food Grains: An Overview. Food Control. 94. 10.1016/j.foodcont.2018.07.008.

Kumar, S., Mohapatra, D., Kotwaliwale, N., and Singh, K. K. 2017. Vacuum Hermetic Fumigation: A Review. Journal of Stored Products Research, 71, 47–56.

Septianingrum, Elis and Kusbiantoro, Bram. 2016. Efforts to Extend the Shelf Life of Grain or Rice Through Control of Storage Factors and Storage Methods. Center for Rice Research. Proceedings of the 2015 Rice Technology Meeting. ISBN 978-979-540-108-0.

Sharon, M., Abirami, C. V., and Alagusundaram, K. 2014. Grain Storage Management In India. Journal of Post-Harvest Technology, 2(1), 12–24.

Sarwar, M. 2013. Development And Boosting Of Integrated Insect Pests Management In Stored Grains. Research Review: Journal Agricultural Allied Science, 2(4), 16–20.

Mubashar bdul., Khan M.Saleem,, Ahmad Khalil., and Saeed Yousaf. 2011. Autonomous Environment Control System using Fuzzy Logic. International Journal of Scientific and Engineering Research. 2. 278-283.

L K Hema et al. 2020. IoT Based Real-Time Control and Monitoring System for Food Grain Procurement and Storage. IOP Conf. Ser.: Mater. Sci. Eng. 993 012079. DOI 10.1088/1757-899X/993/1/012079.

Qingyu Zhao., Hui Guo., Dianzhi Hou., Yousaf Laraib., Yong Xue., and Qun Shen. 2021. Influence Of Temperature On Storage Characteristics Of Different Rice Varieties. Cereal Chemistry Volume 98, Issue4, Pages 935-945. https://doi.org/10.1002/cche.10435.

Ratnawatia, and Djaeni, Mohamad, and Damin, Hartono. 2013. Changes in Rice Quality During Storage. Department of Chemical Engineering, Faculty of Engineering, University of Dipenogoro.

Karim, Asif Bin and Hassan, Md. Zahid and Akanda MM and Avijit, Mallik. 2018. Monitoring food storage humidity and temperature data using IoT. MOJ Food Process Technol. 2018;6(4):400-404. DOI: 10.15406/mojfpt.2018.06.00194.

Junizan, Nur Afiqah and Abdul Razak, Amirrudin and Balakrisnan, Bohendiran and Othman, W.A.F.W. 2019. Design and Implementation of Automatic Room Temperature Controlled Fan using Arduino Uno and LM35 Heat Sensor. International Journal of Engineering Creativity and Innovation, 2019, 1 (2), 8-14. Available online: http://technical-journals.org/index.php/IJECI/.

Panigrahi, Shreedhar and Rathod, Nirav and Pinjarkar, Vijaya. 2020. Smart Farming IoT Based Smart Sensor Agriculture Stick For Live Temperature And Humidity Monitoring. Available at SSRN: https://ssrn.com/abstract=3651933 or http://dx.doi.org/10.2139/ssrn.3651933. DOI : 10.17577/IJERTV9IS070175.

A. Devi and M. Julie Therese and P. Dharanyadevi and K. Pravinkumar. 2021. IoT Based Food Grain Wastage Monitoring and Controlling System for Warehouse. 2021 International Conference on System, Computation, Automation and Networking (ICSCAN), 2021, pp. 1-5, doi: 10.1109/ICSCAN53069.2021.9526400.

Aradwad, Pramod and Kumar, Arun and Dubey, Abhinav and Mani, Indra. 2021. Development of Microcontroller-based Data Logger For Real-time Monitoring of Drying and Storage of Food Grains. Agricultural Engineering. 45. 10. 10.52151/aet2021451.1528.

DHT-22 Datasheets. https://www.alldatasheet.com/datasheet-pdf/pdf/1132459/ETC2/DHT22.html.

MG996R Servo Motor Datasheets. https://www.alldatasheet.com/datasheet-pdf/pdf/1131873/ETC2/MG996R.html.

28BYJ-48 5V Stepper Motor Datasheets. https://www.alldatasheet.com/datasheet-pdf/pdf/1245086/ETC1/28BYJ48.html.

2003 ULN Driver Datasheets. https://www.alldatasheet.com/datasheet-pdf/pdf/25575/STMICROELECTRONICS/ULN2003.html.

Colin, Dow. 2018. Internet of Things Programming Projects: Build modern IoT solutions with the Raspberry Pi 3 and Python. Packt Publishing. ISBN: 1789134803, 978-1789134803.

Gondchawar, N., and Kawitkar, R. S. 2016. Iot Based Smart Agriculture. International Journal of Advanced Research in Computer and Communication Engineering, 5(6), 838–842. doi:10.17148/IJARCCE.2016.56188.

Katsuhiko, Ogata. 2010. Modern Control Engineering. Fifth Edition. New Jersey: Pearson Education, Inc., Prentice Hall. 1-10.

Hidayat, Darmawan and Rahmatika, Meutia and Suhendi Syafei, Nendi and Tumbelaka, Bernard Y. 2018. Simulation of On/Off Controller on Feedback Control System with Electronic Physical Model. TELKA, Vol.4, No.1, May 2018, pp. 43~53. ISSN(e): 2540-9123.

Taiji, Hagino. 2021. Practical Node-RED Programming: Learn powerful visual programming techniques and best practices for the web and IoT. Packt Publishing. ISBN: 9781800201590.