Utilization of the Internet of Things for Monitoring Salt Houses with Fuzzy Logic Rule-Based Model

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Abstract. Salt is a crystalline substance that is important and needed in human life. However, salt production still needs to overcome various obstacles, such as the dependence on sunlight, the low quality and presentation of salt, and instability during the manufacturing process. Therefore, a better monitoring system is needed to increase and stabilize the temperature in salt production. To find an effective solution to salt production and quality problems using the Internet of Things through a salt house monitoring system that uses fuzzy logic rule-based model to automatically control the temperature by adjusting the brightness level of the light as a heat source. A monitoring website displays the news, which users can access from a laptop or cellphone connected to the Internet via a network. In the test scenario, the IoT salt house prototype could convert seawater into salt within six days by setting a temperature of 25.50°C-53.10°C and humidity of 25.50RH-96.00RH. Using an IoT-based salt house prototype increased the efficiency and speed of making salt from seawater.

1 Introduction
Salt is a crystalline substance formed by the evaporation of seawater and plays an essential role in human survival because it contains important minerals such as sodium, magnesium, zinc, and others [1]. However, in Indonesia, dependence on salt imports is influenced by factors such as high production costs due to traditional methods and seasonal land. Salt production also depends on uncertain weather conditions, so production results are often unstable [2]. Rapid technological developments have brought significant progress, especially in the Internet of Things (IoT) concept, where various devices connect to the Internet to collect and share data automatically. IoT has great potential to improve production efficiency and quality, including in the salt industry. Internet of Things-based devices have been designed to monitor temperature, salinity, and humidity when making salt [3]. We must know the importance of tracking the salt production process to prevent defects or errors. A monitoring system with real-time data display is necessary to obtain accurate information within a certain period [4].

Implementing IoT-based innovations is also necessary to improve salt production quality and quantity. For example, researcher succeeded in designing an IoT-based monitoring and control system to measure salinity, temperature, and humidity during the salt-making process [5]. In addition, research by Annisa has implemented IoT monitoring on heating ducts to increase production efficiency, although at the cost of using higher electrical power [6].

Based on background and previous research, this research aims to develop a better monitoring system to increase and stabilize temperatures during salt-making. Monitor room temperature and humidity, water temperature, water level, and the status of lights in the salt-making house to design this system. The collected data will be accessible through a website. This research uses the DHT22 sensor, DS18B20 sensor, Ultrasonic HC-SR04 sensor, and NodeMCU ESP8266 as the control unit. Each sensor will send a signal to the Node MCU ESP8266, determining an action or result based on the data received. This tool can also turn on the lights when the temperature and humidity reach specific values. This research aims to optimize the monitoring system by utilizing Internet of Things technology in the context of "Using the Internet of Things for Monitoring Salt Houses" in Indonesia.

2 Methods
This research aims to design a system that ensures smooth operations and meets expectations. This research includes IoT system design, microcontroller system design, system architecture, and system flowcharts.

2.1 IoT System design
The design of the IoT system in this research aims to monitor the salt house using various sensors and NodeMCU ESP8266 as the main module, which acts as a data collection centre and sends data to the cloud.
database (Firebase). Using an IoT system, real-time conditions via a web interface can access information about room temperature and humidity, making it easier for users to monitor the shape of the salt house without being physically at the location, as in Fig. 1.

Fig. 1. IoT design plan.

Fig. 1 is this research's IoT system design for the salt house monitoring system. The hardware consists of sensors and NodeMCU ESP8266 as the module. The module collects data captured by sensors and sends it to a cloud database as a data storage place. Firebase saves data in real-time, and it keeps saving even if sensor data changes. The monitoring website, built in Visual Studio Code, is a user interface that makes monitoring easy. The website was created using Firebase and requires a browser to go to the Firebase website. So, to find out data on the salt house easily, users only need to open a website connected to real-time data in Firebase without refreshing the website to update the latest real-time data.

2.2 Microcontroller system design

System design is designing a system before making an IoT tool. The tool created runs well, does not experience problems, and is as expected. Fig. 2 represents the system design plan, including the microcontroller system design IPO system architecture (Input, Process, Output).

2.3 System Architecture.

System Architecture describes the components used in the system. Fig. 3 represents a salt house monitoring system with IoT, which consists of Input, process and output. It is Input required by the design and production resulting from Input processed or processed in this system.

2.3.1 Inputs

The input component in this system architecture consists of a DHT22 sensor, which measures the temperature and humidity of the room in the salt house. The NodeMCU ESP8266, a data processor, is coupled to the DHT22 sensor. The DHT22 sensor periodically detects room temperature and humidity, and then the data obtained is sent to the NodeMCU ESP8266. Using the DHT22 sensor as an input ensures that the system has access to the temperature and humidity information necessary to monitor the condition of the salt house room.

2.3.2 Process

The processes in this system architecture include processing fuzzy data and sending data to Firebase. NodeMCU ESP8266 uses temperature and humidity data from the DHT22 sensor to perform fuzzy logic. The lights' brightness can be changed using the undefined values produced after processing this Input. Next, NodeMCU ESP8266 sends temperature and humidity data and fuzzy values to the Firebase database as a real-time data storage place. Firebase stores the latest data and will be updated if data changes occur on the sensor side.

2.3.3 Outputs

The output component in this system is controlling the lights with an AC light dimmer. NodeMCU ESP8266 uses fuzzy values generated from the previous process to control the AC light dimmer. The AC light diffuser regulates the brightness of the lights in the salt house. According to the detected environmental conditions, these fuzzy values adjust the lights into three brightness categories: off, dim, and bright. Using the AC light dimmer as an output allows the system to optimize the lighting of the salt house according to the room temperature and humidity detected by the DHT22 sensor.
2.4 System flowchart

Fig. 4 represents the complete flow of the system, consisting of stages from start to finish. To run this system, start by connecting the device to electricity. Following the Node MCU ESP8266 activation, the mobile device's Wi-Fi or hotspot is enabled. The software will launch immediately following the Node MCU ESP8266 internet network connection.

2.5 Implementation of fuzzy logic

This system uses fuzzy logic to transform temperature and humidity data from the DHT22 sensor into indeterminate values, which are then used by the AC light diffuser to regulate the brightness of the lights [8]. Implementing fuzzy logic involves membership functions for temperature and humidity and IF-THEN rules to determine the brightness level of lights based on a combination of undefined values, the distribution of fuzzy sets in Table 1.

<table>
<thead>
<tr>
<th>Function</th>
<th>Variable</th>
<th>Fuzzy set</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>Temperature</td>
<td>Cold</td>
<td>20 - 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal</td>
<td>25 - 35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hot</td>
<td>30 - 35</td>
</tr>
<tr>
<td></td>
<td>Humidity</td>
<td>Dry</td>
<td>40 - 60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Normal</td>
<td>60 - 70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moisture</td>
<td>70 - 80</td>
</tr>
<tr>
<td>Output</td>
<td>Light</td>
<td>off</td>
<td>0 - 20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dim</td>
<td>10 - 40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bright</td>
<td>30 - 60</td>
</tr>
</tbody>
</table>

Based on the data listed in Table 1, the following shows rule-based Table 2:

<table>
<thead>
<tr>
<th>Rule</th>
<th>Temperature</th>
<th>Humidity</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>[R1]</td>
<td>cold AND dry</td>
<td>THEN off</td>
<td></td>
</tr>
<tr>
<td>[R2]</td>
<td>cold AND Normal</td>
<td>THEN Dim</td>
<td></td>
</tr>
<tr>
<td>[R3]</td>
<td>cold AND humid</td>
<td>THEN Dim</td>
<td></td>
</tr>
<tr>
<td>[R4]</td>
<td>Normal AND dry</td>
<td>THEN Dim</td>
<td></td>
</tr>
<tr>
<td>[R5]</td>
<td>Normal AND Normal</td>
<td>THEN Bright</td>
<td></td>
</tr>
<tr>
<td>[R6]</td>
<td>Normal AND humid</td>
<td>THEN Bright</td>
<td></td>
</tr>
<tr>
<td>[R7]</td>
<td>hot AND dry</td>
<td>THEN Dim</td>
<td></td>
</tr>
<tr>
<td>[R8]</td>
<td>hot AND Normal</td>
<td>THEN Bright</td>
<td></td>
</tr>
<tr>
<td>[R9]</td>
<td>hot AND humid</td>
<td>THEN Bright</td>
<td></td>
</tr>
</tbody>
</table>

Like humans, fuzzification is a process that can make decisions. The fuzzy logic parameters processed with IF-THEN in the image below are room temperature conditions, which have three parts: cold, normal, and hot and three parts of room humidity, namely dry, normal, and humid. Fig. 5 and 6 show this fuzzification. The Fig. 5 and 6 show this fuzzification.
3 Results

3.1 System Design Results

It successfully developed a system design that monitors the salt house via the Internet of Things. Fig. 7 displays the system's implementation prototype. In this Fig. 8, there is an explanation of the arrangement and use of every input-output pin utilized in the circuit. The D4 GPIO2 pin is an input for the NodeMCU ESP8266, representing the DHT22 sensor to retrieve the room temperature and humidity data. NodeMCU ESP8266 processes data from these sensors to produce output. Next, GPIO5 pin D1 functions as Input for the NodeMCU ESP8266, representing the DS18B20 sensor to retrieve water temperature data and then process it to produce output. Then, GPIO12 pin D6 and GPIO14 pin D5 function as Input for NodeMCU ESP8266, representing the HC-SR04 Ultrasonic sensor to take water level data and process them as output. There is also GPIO12 pin D6 and GPIO13 pin D7, which function as output from the NodeMCU ESP8266, which is connected to the AC Light Dimmer to control the lights automatically based on commands from the NodeMCU ESP8266. Moreover, the NodeMCU ESP8266, which is attached to the LCD Display to display data from each sensor, produces the GPIO4 pin D2 and the GPIO2 pin D4.

3.2 IoT prototype testing

With two scenarios, prototype testing looked at how long it took to produce salt from saltwater. The first scenario uses a salt house prototype created with IoT, while the second uses traditional methods without a salt house prototype. The first scenario aims to prove that the salt house prototype can speed up the process of making salt from seawater. The second scenario shows that traditional methods require longer to produce salt. Fig. 8 displays an image of the test setting.

3.2.1 Test Results in Both Test Scenarios

Additionally, Table 3 displays the test results for the two test situations.

<table>
<thead>
<tr>
<th>No.</th>
<th>Testing Scenarios</th>
<th>Expected results</th>
<th>Test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>We were making salt using a salt-house prototype.</td>
<td>It takes a long time for seawater to become salt.</td>
<td>6 days</td>
</tr>
<tr>
<td>2</td>
<td>We were making salt without using a prototype (the traditional method).</td>
<td>It takes a long time for seawater to become salt.</td>
<td>&gt;14 days</td>
</tr>
</tbody>
</table>

The test results show that the first test scenario achieved the expected results. With the exact size of the water storage container and the same amount of water, namely 9 litres in six days, the IoT salt house prototype can convert seawater into salt by stabilizing the temperature at 25.50°C to 53.10°C and the humidity at 25.50RH - 96.00RH. Meanwhile, in the second test scenario, making salt without a prototype took more than 14 days to produce salt. Comparing the salt house
prototype and the Internet of Things to conventional methods demonstrates how they can accelerate the process of making salt from saltwater.

![Graph of time to make salt.](image)

**Fig. 9.** Graph of time to make salt.

### 3.2.2 Test Results for Website Monitoring

The following test subjects were the homepage and website data monitoring page. The test results on both pages were successful and in line with expectations. The home page successfully displays the website page menu correctly. In contrast, as expected, the Data Monitoring page successfully shows data on temperature and humidity, water temperature, water level, and light status (off, dim, and bright). It is possible to conclude that the website has successfully passed the test and has shown the anticipated functionality on the two tested pages based on the results of the black-box testing. As seen in Fig. 10 and 11, it is visible.

![Website display in a laptop browser.](image)

**Fig. 10.** Website display in a laptop browser.

![Website display in smartphone browser.](image)

**Fig. 11.** Website display in smartphone browser.

### 4 Discussion

This research successfully designed and implemented an innovative system that utilizes the Internet of Things (IoT) to monitor salt houses. This system combines various sensors, such as DHT22, DS18B20, and Ultrasonic HC-SR04, as Input to measure temperature, room humidity, and water level around the salt house. Data from these sensors is sent to the Node MCU ESP8266 device to be processed and output in light brightness control via AC light dimming. The system can automatically modify the brightness of the lights to suit various environmental conditions since it uses fuzzy logic to provide adaptive capabilities in decision-making based on identified environmental factors. The results of the prototype tests show the success of the IoT salt house system in speeding up the process of making salt from seawater compared to traditional methods. The application of IoT technology to this system provides significant benefits in optimizing the salt manufacturing process and providing accurate monitoring of the salt house environment in real time. The website also successfully passed the Black Box test and displayed the expected functionality, including accurately displaying data on temperature, humidity, water temperature, water level, and light status according to the desired results. This system may still be enhanced in a few areas even if it has achieved its objectives. For example, it adds other sensors to expand monitoring and control to other aspects of the salt house.

Furthermore, by further integrating IoT technology, customers can benefit from remote control and more significant data access. Further development and improvement of this system will significantly impact salt house monitoring and power and the possible use of IoT technology in other domains. Overall, this research shows IoT technology's potential and benefits in optimizing the salt house monitoring system efficiently and effectively.
5 Conclusions

Based on the results of the research previously explained, several things can be concluded, namely as follows: In the test scenario, using a salt house prototype. It converted seawater into salt within six days, stabilizing the temperature at 25.50°C-53.10°C and humidity at 25.50RH - 96.00RH, while the traditional method in the test scenario took more than 14 days. The Internet of Things-created salt-house prototype has raised the productivity and efficiency of salt production from seawater. The Internet of Things can be an effective solution in increasing salt productivity in Indonesia and helping to meet the increasing need for salt.

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