The Development of Smart Farming System for Sea Lettuce Cultured Process

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***Abstract*—Smart farming represents an advanced approach that integrates information and communication technology into machinery, equipment, and sensors for high-tech farm management. Central to this development is the Internet of Things (IoT), which enables remote connectivity and control. This paper proposes transforming seaweed farming into an intelligent system with IoT-based water oxygen control and environmental monitoring. Utilizing Node-RED, an IoT gateway facilitates device connectivity and provides real-time graphical data through a Node-RED Dashboard. Experiments demonstrate that the oxygen control system, managed by two valves, operates effectively through a web application and Node-RED. The system maintains measurement accuracy with a percentage error of less than 5% for water temperature, air temperature, and humidity. The Node-RED Dashboard offers real-time data on valve control status, water temperature, air temperature, humidity, and oxygen valve switches, transmitted wirelessly based on IoT principles.**

***Index Terms*—Environmental Monitoring, Internet of Things, Node-RED Dashboard, Smart Farming, Water Oxygen Control**

I. Introduction

The Phetchaburi Province area is a model area for strategies and strategic plans for seaweed development. It offers unique opportunities to create careers and significantly increase income for farmers, particularly in the cultivation of grape seaweed in the Ban Laem District. The project is not only supported by the Fisheries Department but also serves as a prototype province in strategy and a strategic plan for developing seaweed. It is not just poised to become one of the model provinces under the “Phetchaburi Model” guidelines. However, it is also on the verge of becoming a prototype model for driving the seaweed project. With its excellent potential, Phetchaburi Province is a beacon of inspiration for the future of seaweed development. The field survey of seaweed cultivation data in Phetchaburi province found that seaweed cultivation is both in soil ponds. Cement ponds and fiberglass tanks affect algae growth, including season, light, temperature, nutrients in seawater, water turbidity, the amount of oxygen in the water, pH, and salinity of the water. The temperature of the water used in raising seaweed is in the range of 25 to 33 degrees Celsius. The air temperature in the rising area Algae is in the range of 25 to 34 degrees Celsius. The salinity of the water is in the range of 21.0 to 33.0 parts per thousand. The pH value has changed from 7.9 to 8.4, and the oxygen value in the water (DO) ranges from 2.73 to 8.25 milligrams per liter. Algae growth rates are higher in April to July. The concentration of nutrients in the seawater used to grow algae is relatively high, including ammonia, nitrite, nitrate, and orthophosphate. Algae can take up these nutrients and use them for growth. In addition, from May to July, there will be a relatively high level of oxygen in the water (DO), resulting in a higher growth rate of algae during this period because algae need to use oxygen to breathe to grow.

Therefore, the researcher has a crucial proposal to develop an intelligent farm system prototype for the sea lettuce cultured process in the closed system. This proposal is vital as it aims to control factors that affect growth, enabling the cultivation of seaweed every season and increasing productivity. The widespread practice of growing sea lettuce algae in cement ponds or plastic tanks is a testament to its convenience and durability. It can be easily cultivated and raised in various ways, such as allowing it to float freely in the water or raising it with aquatic animals. Factors that affect the growth of sea lettuce seaweed include the number of nutrients, light intensity, water salinity, and temperature [1]. The above information supports the researcher’s innovative idea of using the agricultural Internet of Things (IoT) has brought new changes to agricultural production. It not only increases agricultural output but can also effectively improve the quality of agricultural products, reduce labor costs, increase farmers’ income, and truly realize agricultural modernization and intelligence [2], [3].

The Internet of Things is a network of devices for communicating machine to machine based on wired and wireless Internet. IoT in agriculture is a revolutionary technology that can be applied to agricultural production year-round [4]. The growth of the global population of coupled with a decline in natural resources, farmland, and the increase in unpredictable environmental conditions. These problems are motivators that are driving the agricultural industry to transition to smart agriculture with the application of the Internet of Things [5]. An IoT technology set applied to the acquisition of agricultural data using open-source solutions such as FIWARE and LoRaWAN, which allow extensive customization and integration with advanced weather forecasting, Machine Learning, and real-time dashboard services [6]. This new technology allows devices to connect remotely, paving the way for smart farming [7]-[10]. The development of IoT technologies has played a significant role throughout the farming sector [11], [12], mainly through its communication infrastructure. This includes connecting smart objects, remote data acquisition, using vehicles and sensors through mobile devices and the Internet, cloud-based intelligent analysis [13], [14], interfacing, decision formation, and the automation of agricultural operations [15], [16].

The proposed intelligent farming system for the sea lettuce cultured process is a transformative solution. It is designed to elevate the process into a more efficient and sustainable system. Comprising a control system for adding oxygen to the water and a control system for various environmental factors, it operates on the principle of sensor devices measuring various values and sending the readings to the microcontroller. The system then collects and processes this information, sending the data to Node-RED via the Internet. The results are displayed in real-time with Node-RED Dashboard in Graphic format, heralding a shift from traditional to modern agriculture. This system not only creates competitive opportunities and emphasizes self-reliance but also promotes the application of digital technology, benefiting the economy, society, and community and contributing to the sustainability of the agricultural sector.

II. Materials and Methods

This paper aims to develop the seaweed farming process into an intelligent farm system with water oxygen control and environmental monitoring using Internet of Things technology. The IoT gateway is built with Node-RED to connect devices through APIs (Application Programming Interface) with Node-RED Dashboard in graphical format. Adopting Internet of Things technology to help manage and develop the sea lettuce cultured process into an intelligent farming system. It consists of 3 parts: 1) The valve controls the oxygen supply to the water, 2) The environmental factor measurement system, and 3) The data display system. In designing the system, the system's functionality can connect multiple sets of environmental measurement devices.

Moreover, uses data communication methods according to the IEEE 802.11 wireless communication standard to transmit measurement data to a small data processing and storage device with Raspberry Pi and create a data display system on a web browser. Whose working principle is that the sensor device measures various values and sends the readings to the microcontroller. The system will receive information from sensor devices. Connected via microcontroller to collect information and process information received from sensors. Then, send the data to Node-RED via the internet network with the MQTT protocol and record it in an online database. The MQTT uses the publish/subscribe model and design for devices with low data transmission speeds or low bandwidth; most of the time, the IoT devices look like that. The purpose of MQTT is to make our systems send and receive data more efficiently, including making the device use less energy. In the IOT system, we want to send real-time data and want our devices to use only a little energy unnecessarily. MQTT has a broker (server) and clients (publisher/subscriber). We will call sending data in MQTT publish. The data will be sent to which Topic and receiving information is called subscribe, which means receiving information but will only receive information from the Topic. A broker is an intermediary that will receive all information from Clients (Publishers), no matter what the Topics are, and then manage to send it. Information Clients (Subscribers) who have subscribed to the Topic received can find a Global Broker or a Cloud MQTT Broker on many websites. It can be created within the network using Mosquito Broker, which can be installed on the Raspberry Pi. The MQTT Operation is shown in Fig. 1. Display results on the information system in real-time with the Node-RED Dashboard in graphic form, as shown in Fig. 2.

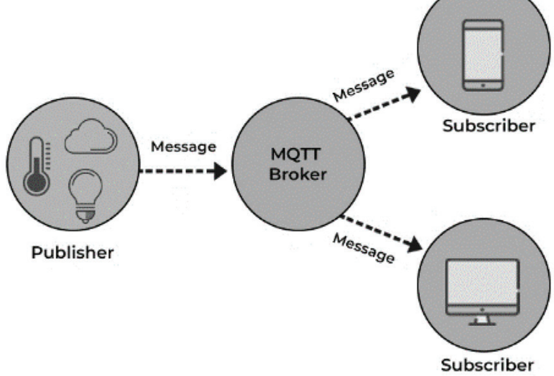

Fig. 1. The MQTT operation

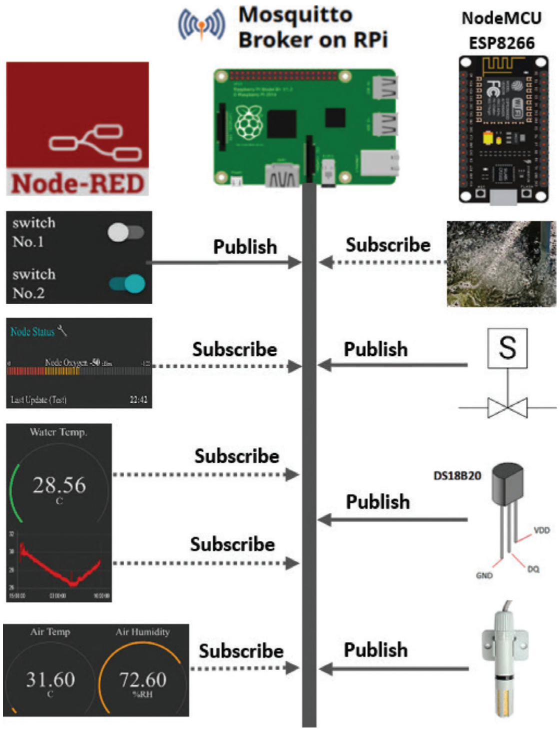

Fig. 2. The design of the proposed embedded system for a smart farm with a Node-RED dashboard

A. The Valve Controls the Oxygen Supply to the Water for Sea Lettuce Cultured Process

The valve control system, a pivotal element of our cutting-edge farm, is designed for optimal efficiency. It comprises a valve control kit that precisely regulates the water oxygen levels. This valve can be conveniently controlled online via a web server using a device such as a solenoid valve or a magnetic controller. The solenoid valve, a YCWS3 type with an orifice of 2.5 mm and a pressure range of 0 to 0.7 Mpa operates on a DC 12 V power supply, as depicted in Fig. 3 to Fig. 5.

Fig. 3. The solenoid valve controls system

Fig. 4. The design of the valve controls the oxygen supply to the water for sea lettuce cultured process

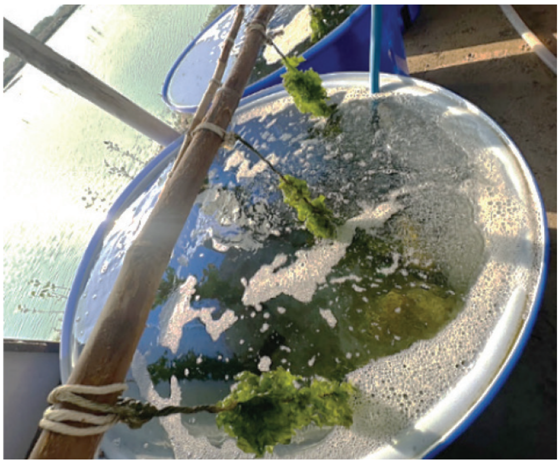

Fig. 5. Addition of oxygen to the water for the sea lettuce cultured process

B. The Environmental Factor Measurement System

The environmental factor measurement system is shown in Fig. 6. There is a principle of considering equipment selection from factors related to algae growth and the appropriate usage characteristics for the actual use environment.

Fig. 6. The design of measuring environmental factors system

The equipment used in this study includes:

1. NodeMCU V2 is an IoT experimental board with ESP8266 chips that provide convenient Wi-Fi and wireless Internet access. The ESP8266 chips control devices and receive data over wireless networks efficiently.
2. Temperature Sensor is DS18B02 Model; Probe waterproof sealed with stainless steel; Input voltage DC 3.0 to 5.5 V; Temperature range from -55°C to 125°C; temperature accuracy ±0.5°C from -10°C to 85°C.
3. Temperature and Humidity Sensor is AM2305 Model; Input voltage DC 3.5 to 5.5 V; temperature range from -40°C to 125°C; humidity range from 0 to 99.9%RH; Temperature accuracy ±0.3°C; Humidity accuracy ±2%RH; temperature resolution 0.1°C; humidity resolution 0.1%RH.

Environmental factors measuring instruments the data from the above sensors must be transmitted to the processing equipment to write a measurement result interpretation program and compare it to a standard measurement instrument. In this study, the defined error was ±1°C for the water temperature measurement, the error was ±1°C for the air temperature measurement, and the humidity measurement error was ±3%RH.

C. The Data Display System

Currently, communication on a computer network has selected a tiny Raspberry PI as the central processing device of the system. Using Linux as the network operating system, as well as using all open-source programs. In this study, our system incorporates an IoT gateway with Node-RED for device connection via APIs (Application Programming Interface). This gateway is a standout feature of our system, excelling in real-time data processing. It receives data from sensor devices, connects them through microcontrollers, processes the data from the sensor, then sends it to Node-RED over the internet using the MQTT protocol and saves it to an online database. The Gateway IoT with Node-RED, as shown in Fig. 7.

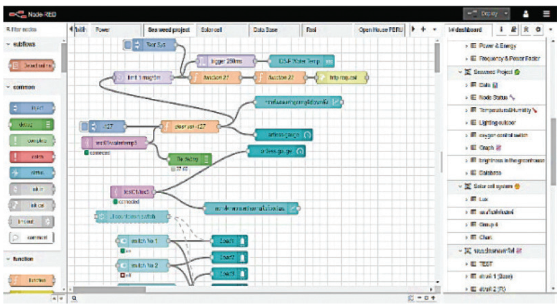

Fig. 7. The Gateway IoT with Node-RED

III. Results and Discussion

This section presents the results obtained from the proposed embedded system in the sea lettuce process for smart farms, including (1) The water oxygen control system, (2) The monitoring environmental factors system, and (3) The data display system

A. The Results of the Oxygen Control System

Fig. 8 shows that the oxygen control system can be operated using two valves, switch No. 1 and No. 2, controlled through a web application, Node-RED, using IoT technology and internet network connectivity. Communication is supported through the MQTT protocol, so the control valve device can be connected to a server or web service that provides web application services. Users can access web browsers on devices that require control, such as computers, smartphones, etc. The user can control the operation of oxygen supply valves, such as on/off and adjust fill levels, through web applications quickly and easily without direct access to the device.

The Web application control can provide several benefits: (1) Users can quickly and easily control the oxygen supply in water through a web browser without technical knowledge. (2) Remote access allows users to control their systems wherever they have an Internet connection, not necessarily near the system they want to control. (3) Users can check the real-time status of their oxygen-in-water filling system without having to be near the system. Therefore, using web applications is a convenient and effective way to control the oxygen-in-water filling system in IoT systems without direct access to equipment in potentially risky or inconvenient locations.

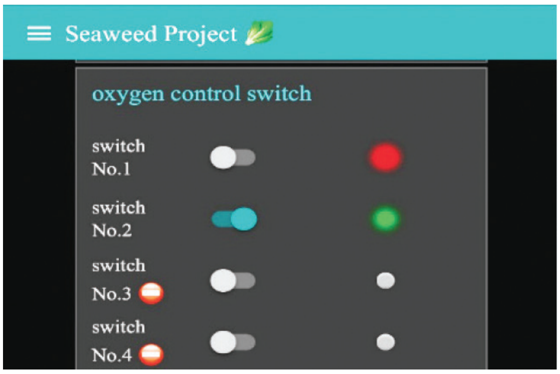

Fig. 8. The switch for the valve controls oxygen

B. The Results of the Environmental Factor Measurement System

The environmental factor measurement system, driven by IoT devices, is a testament to precision. It meticulously measures water temperature, air temperature, and humidity in the greenhouse's seaweed culture process. The defined error for water temperature was ±1°C, for air temperature was ±1°C, and for humidity was ±3%RH. This level of accuracy instills confidence in the system's performance, ensuring reliable and consistent results.

Table I measured water temperature measurements compared to the AZ8371 Instrument Salinity/Temp

Meter; Temperature range from 0°C to 50.0°C; Temperature accuracy ±0.5°C; temperature resolution 0.1°C; Normalization temperature fixed at 25°C. An error range, which represents the difference between the measured value and the true value, is found to be between 0.1-0.4 °C. This means that our measurements are consistently within this range of the true value, indicating a high level of precision.

TABLE I
COMPARISON OF WATER TEMPERATURE MEASUREMENT

Day Time	Experiment (°C)	Measurement (°C)	Error (°C)
15/02/2024 07:30 a.m.	26.3	26.1	0.2
18/02/2024 10:05 a.m.	26.8	26.4	0.4
21/02/2024 1:20 p.m.	28.8	28.5	0.3
24/02/2024 11:00 a.m.	27.4	27.1	0.3
27/02/2024 09:15 a.m.	26.2	26.1	0.1
1/03/2024 12:30 p.m.	28.1	27.8	0.3
4/03/2024 3:40 p.m.	29.5	29.3	0.2
7/03/2024 08:45 a.m.	26.7	26.5	0.2
10/03/2024 10:15 a.m.	26.7	26.4	0.3
13/03/2024 2:50 p.m.	28.6	28.2	0.4
16/03/2024 1:00 p.m.	28.1	28.0	0.1
19/03/2024 1:30 p.m.	28.9	28.5	0.4
22/03/2024 11:00 a.m.	26.5	26.3	0.2
25/03/2024 12:45 p.m.	28.6	28.5	0.1

Table II and Table III compare the temperature and humidity measurements in the greenhouse with the standard AS808 Hygrometer. The temperature range was -40°C to 70°C, and the humidity ranged from 20%RH to 90%RH. The temperature resolution was 0.1°C (0.1°F), and the humidity resolution was 1%RH. The temperature accuracy was ±1°C (1.8°F), and the humidity accuracy was ±5%RH. The error range was between 0.1-0.6 °C and 0.9 - 2.8-% RH. These results reaffirm the effectiveness and accuracy of the IoT devices developed in this study, providing the audience with a sense of reassurance about the system's capabilities.

TABLE II
COMPARISON OF AIR TEMPERATURE MEASUREMENT

Day Time	Experiment (°C)	Measurement (°C)	Error (°C)
15/02/2024 07:30 a.m.	25.3	24.8	0.5
18/02/2024 10:05 a.m.	28.7	28.4	0.3
21/02/2024 1:20 p.m.	32.1	31.7	0.4
24/02/2024 11:00 a.m.	29.8	29.5	0.3
27/02/2024 09:15 a.m.	27.4	26.8	0.6
1/03/2024 12:30 p.m.	31.2	30.8	0.4
4/03/2024 3:40 p.m.	32.3	32.1	0.2
7/03/2024 08:45 a.m.	26.8	26.2	0.6
10/03/2024 10:15 a.m.	28.5	28.2	0.3
13/03/2024 14:50 p.m.	32.4	32.2	0.2
16/03/2024 13:00 p.m.	31.1	31.0	0.1
19/03/2024 13:30 p.m.	32.5	31.9	0.4
22/03/2024 11:00 a.m.	30.8	30.5	0.3
25/03/2024 12:45 p.m.	31.6	31.2	0.4

TABLE III
THE DISPLAY OF THE REAL-TIME DATA ON THE NODE-RED DASHBOARD

Day Time	Experiment (%RH)	Measurement (%RH)	Error (%RH)
15/02/2024 07:30 a.m.	87.3	85.1	2.2
18/02/2024 10:05 a.m.	80.5	78.5	2.0
21/02/2024 1:20 p.m.	65.8	64.3	1.5
24/02/2024 11:00 a.m.	75.4	74.5	0.9
27/02/2024 09:15 a.m.	82.3	81.2	1.1
1/03/2024 12:30 p.m.	72.6	70.5	2.1
4/03/2024 3:40 p.m.	62.7	60.9	1.8
7/03/2024 08:45 a.m.	84.8	82.5	2.3
10/03/2024 10:15 a.m.	79.5	78.2	1.3
13/03/2024 2:50 p.m.	63.5	60.8	2.7
16/03/2024 1:00 p.m.	68.9	66.1	2.8
19/03/2024 1:30 p.m.	64.5	63.5	1.0
22/03/2024 11:00 a.m.	78.3	74.8	3.5
25/03/2024 12:45 p.m.	70.6	68.9	1.7

C. The Display of the Real-Time Data on the Node-RED Dashboard

The software ensures precise data storage and display with the cloud server on Raspberry Pi, powered by Node-RED. The real-time measurement data, with its high level of accuracy, is transmitted via a wireless system of devices, all based on the IoT concept, which involves interconnected devices exchanging data. This reliable system allows for the display of real-time data on the Node-RED dashboard, providing an exact view of node status including valve control oxygen, water temperature, air temperature, humidity, lighting, and the switch of the valves control oxygen, as depicted in Fig. 9.

Fig. 9. The display of the real-time data on Node-RED

D. The Comparison of the Percentage Error

In the experiment, fault tolerance is configured as not exceeding 5 percent for the water temperature, the air temperature, and the humidity measurement. The calculation of the error was done between a measurement from a highly calibrated instrument and the experiment system, which is a replica of the real-time data display system. The results were displayed and compared to determine the percentage difference, as in equation (1).

$$\text{Error} = \left| \frac{\text{Measuring}_{Real} - \text{Measuring}_{Exp}}{\text{Measuring}_{Real}} \right| \times 100 \qquad (1)$$

TABLE IV
COMPARISON OF PERCENTAGE ERROR

Day Time	$TEMP_W$ (%)	$TEMP_A$ (%)	Humidity (%)
15/02/2024 07:30 a.m.	0.77	2.02	2.59
18/02/2024 10:05 a.m.	1.52	1.06	2.55
21/02/2024 1:20 p.m.	1.05	1.26	2.33
24/02/2024 11:00 a.m.	1.11	1.02	1.21
27/02/2024 09:15 a.m.	0.38	2.24	1.35
1/03/2024 12:30 p.m.	1.08	1.30	2.98
4/03/2024 3:40 p.m.	0.68	0.62	2.96
7/03/2024 08:45 a.m.	0.75	2.29	2.79
10/03/2024 10:15 a.m.	1.14	1.06	1.66
13/03/2024 2:50 p.m.	1.42	0.62	4.44
16/03/2024 1:00 p.m.	0.36	0.32	4.24
19/03/2024 1:30 p.m.	1.40	1.88	1.57
22/03/2024 11:00 a.m.	0.76	0.98	4.68
25/03/2024 12:45 p.m.	0.35	1.28	2.47

From the experiment, the Table IV Comparison of percentage error, it was found that the water temperature measurement on 18/02/2024 at 10:05 a.m. had the maximum error value, equal to 1.52%. The date 25/03/2024 at 12:45 p.m. had a minor error value equal to 0.35%, measuring the air temperature in the greenhouse on 07/03/2024 at 08:45 a.m. has a maximum error equal to 2.29%, and on 16/03/2024 at 1:00 p.m. has the most negligible error value is equal to 0.32%, the humidity measurement in the greenhouse on 22/03/2024 at 11:00 a.m. has the maximum error value equal to 4.68% and the date 24/02/2024 at 11:00 a.m. has the most negligible error value is equal to 1.21%.

IV. CONCLUSION

This paper delves into the tools and equipment used in applications of wireless sensors in IoT agriculture, highlighting the anticipated challenges faced when merging technology with conventional farming activities. The environmental measurements obtained from this system boast an impressive accuracy of at most 5%. Data transmission between the measuring node and the central processor via a wireless network is not just efficient, but remarkably easy, allowing for seamless measurement and recording. The system can be viewed backward when connected to the Internet, providing a comprehensive overview at a low cost. The embedded systems measure the environment for smart farms, and this design can measure and report various environmental values, which is still needed. Further development of other environmental sensors to provide flexibility in use as appropriate. However, the system has been designed to support data communication according to international standards, which can connect this system to other systems, instilling confidence in the accuracy and efficiency of IoT devices in environmental monitoring.

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