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The Use of Internet of Things technology to develop a smart farm prototype for pig farming

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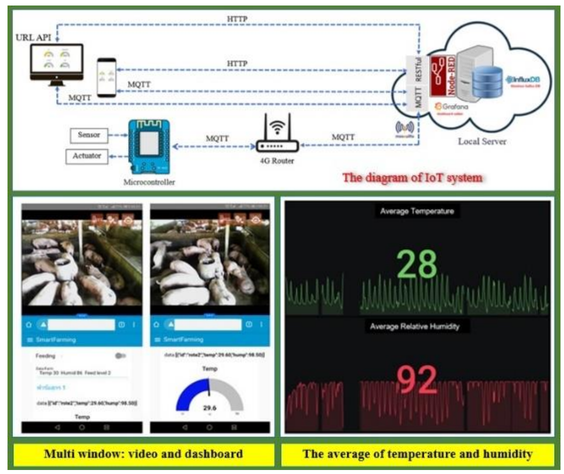
Abstract



This research aims to develop a smart farm prototype using Internet of Things (IoT) technology. The objectives are 1) to design and construct environment monitor and control systems of the housing and 2) to design and build an IoT feeding control system. The development is under the system development process at the pig farms in Nakhon Si Thammarat province, Thailand, using open-source hardware and software. This system utilizes a ESP8266 Wi-Fi microcontroller, which functions to connect different sensors data to server and control the actuators. The MQTT protocol for data transferred over a secure wireless local network. Node-RED for designing the flow of data is stored on the server using a NoSQL database such as InFluxDB. In this research, it was found that the measured temperature was an average of 28 °C ranging from 24.43 °C to 34.34 °C. The humidity was an average of 92%. The feeding control system is following the instructions 100% of the time. Users can access data and control the system via a web application with a smartphone or a computer in real-time. Additionally, the collected information is processed and analyzed as big data for forecasting or studying climate change around the study point in the future. The overall system performance evaluation was at the highest level achieving on average 4.50 out of 5 with a standard deviation of 0.47 from the users. Therefore, the developed IoT system could be used as a prototype and expanded to a larger farm or other kinds of farms.

Keywords: Smart farm; Internet of Things; Node-RED; NoSQL database; MQTT protocol

1. Introduction

Internet of Things (IoT) has started touching people everywhere and from the point of normal user. IoT applications are developed to automated inspection, control, management, and maintenance, and much more. The advance of numerous technologies including sensors, actuators, embedded computing and cloud computing, and the emergence of a new generation of cheaper, smaller wireless devices, many objects, or things in our daily lives are becoming wirelessly interoperable with attached miniature and low-powered or passive wireless devices [1]. These novel sensors and actuators also need evolved automation node potentially acting as IoT gateways [2]. Message Queue Telemetry Transport; MQTT protocol runs over Transmission Control Protocol/Internet Protocol (TCP/IP) that provides ordered lossless connections [3]. Currently, the most popular TSDB is InfluxDB [4]. Node-RED as a programming tool for wiring together hardware devices [5]. The IoT system, cloud computing, big data and other technologies, the demand for agricultural modernization has been brought into deep application research.

The problems of farmers in Muang district, Nakhon Si Thammarat province after raising their pigs to earn extra income are frequent heavy rains and strong sun. Sometimes farmers are unable to cope with the weather problems which cause illness in pigs. Since farmers raise pigs just to earn extra income, they do not have the time to feed them according to the required feeding guidelines. According to a survey, farmers wanted to apply technology on their farms whether with their animal housing. Therefore, what will help target farmers is temperature and humidity control in the pig farm because pigs need to accelerate their growth. If the pigs are raised in an unsuitable environment, it will result in sickness or disease. They will grow slowly, take more time to raise, result in higher costs wasted. The findings can be applied for further business farming purposes.

2. Materials and Methods

This research, we design IoT technology to support small pig farms. The population of this study was taken from SMCE (Small and Micro Community Enterprise) farms in Nakhon Si Thammarat province. The sample of this research was Mr. Viroj Poonpipat's farm. It is located in No. 14/3, Moo 6, Tha Ngio Sub-district, Mueang district, Nakhon Si Thammarat. A pig farm was built with a raised roof for ventilation raising 120 finisher and stage pigs divided into 4 pens as shown in Fig. 1. A farmer's daily duty is to pour food into a rotating mechanical feed hopper once a day. The pig pens are cleaned and observed how they interact. In the evening, the farmer observes whether the pigs have enough food to eat. The farmer has to pour more food sometimes in case it is not enough for the pigs. Moreover, the farmer has to record the amount of food the pigs eat per day. In addition, the farmer will observe the pigs. On a hot day, the farmer sprays water into the pens avoiding Heat Stroke on pigs. On the other hand, the farmer will turn on the lights to give them warmth on cold or rainy days.

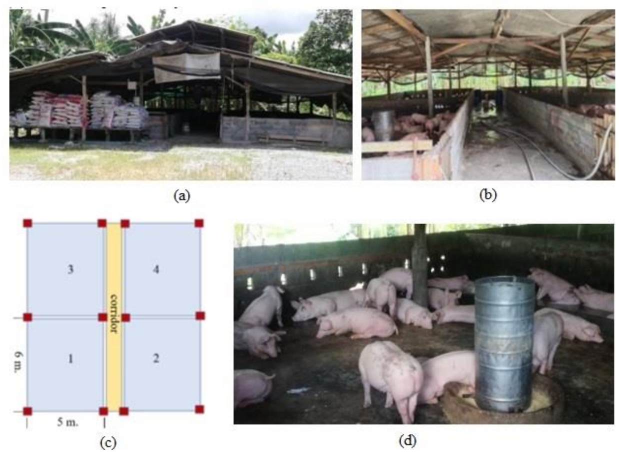


Fig. 1 A characteristics of the pig farm (a) Outside of the pig farm (b) Inside of the pig farm (c) Pig pen layout (d) Subject that is being studied are pigs.

We designed IoT for monitoring temperature, humidity, feed level, and feeding control. We use open-source hardware and software to measure and control through a wireless access point. The device is also used to provide mobile Internet access to Wi-Fi-enabled peripheral devices [6]. The development of the system will be explained in three phases, which are Hardware Design, Software Design, and Implementation Testing. The block diagram in Fig. 2. illustrates the general architecture of the proposed system. A practical design for the prototype by building an IoT platform on a local server uses a NoSQL database as a database for large-scale applications and get data collected from a JSON-style IoT node with InfluxDB that enables massive database scalability, high availability, write fast and read faster. Node-RED is a programming tool provided browser-based (website or API) editor makes easy wiring together flows using the wide range of nodes.

MQTT protocol is used to transfer data from microcontroller (MQTT client) to Node-RED server, whereas, personal devices (MQTT clients) can be used to subscribe topics to visualize data on Node-RED server. This work presents the "Data Storage", "Permanent Data Visualization" and "Real-time Monitorization" [7]. The developed solution covers the connections between server and database.

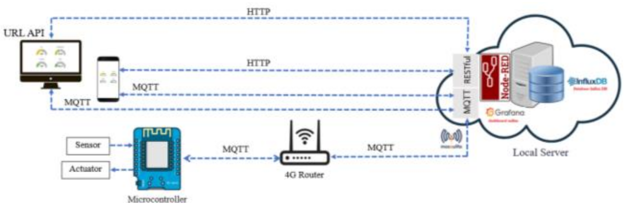


Fig. 2 The block diagram of the proposed system.

Hardware Design

The selection of the hardware part of the system is discussed in this section. A description of the major components used in the research as follows: The WEMOS D1 Mini (ESP8266) is built on the ESP8266EX 32-bit RISC microcontroller running at 80 MHz. It has a full Wi-Fi transceiver, 64 KB of instruction RAM, 96 KB of data RAM and 4 MB flash memory. DHT11 is temperature and humidity sensor module can detect surrounding environment of the humidity and temperature. Humidity measurement range is 20% ~90%, Humidity measurement error is ± 5%, Temperature measurement range is 0~60 °C, Temperature measurement error is ± 2. Ultrasonic module (HC-SR04) is distance measuring transducer sensor, which working frequency is 40 kHz. The reverberation to calculate the distance, accurate at 2 – 400 cm. Relay module is used for controlling the fan, the illumination circuits and the gear motor.

The Fig. 3 shows the overall system architecture overview of smart farm prototype, monitoring and controlling system. IoT node 1 (MCU 1) is an ESP8266 to process temperature and humidity values from DHT11 sensor sent to server. If the temperature is below or equal to 24 °C, the MCU 1 controls the relay to operate to turn on the light. On the other hand, if the temperature is above or equal to 35 °C, the MCU 1 controls the relay to operate to turn on the fan. The IoT can control the temperature as specified. The IoT node 2 (MCU 2) is an ESP8266 that controls the relay to operate to the gear motor to turn on-off the feeding on request via a web application. With a rotating screw feeding mechanism pellets with a diameter of 4.50 cm, it can be released in an amount of 1 kg. per 30 seconds. The ultrasonic sensor (HC-SR04) measures the level of feed remaining in the feed hopper.

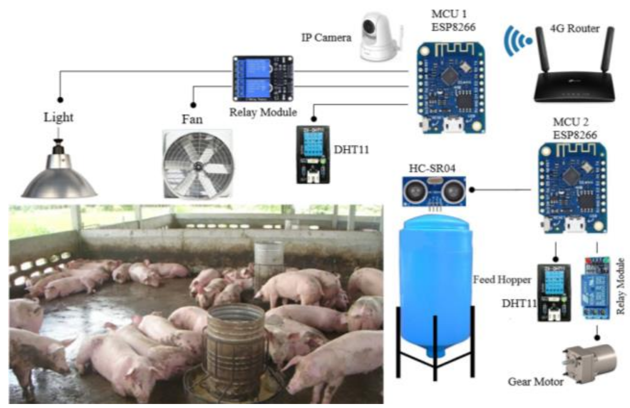
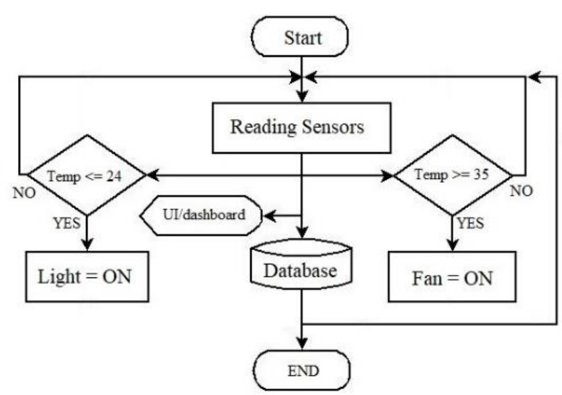


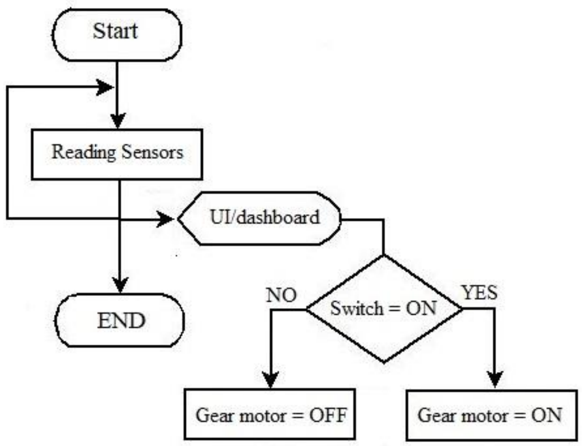
Fig. 3 The diagram of the IoT nodes.

Software Design

The system software operates according to the flowchart as shown in Fig. 4(a). Environment monitoring and temperature control is described in the hardware design section, and sensors data are stored in database. In Fig. 4(b) is feed level monitoring and feeding control, this sensors data is not stored in the database.



(a)



(b)

Fig. 4 The flowchart of system software (a) Data monitoring and temperature control (b) Feed level monitoring and feeding control.

The Fig. 5(a) is the http request node, sending and receiving JSON data from MCU 1 to a website. All the data collected is sent to the database where users can watch the information on temperature, humidity, time, among others. This information is displayed using the Node-RED Dashboard package. The Fig. 5(b) is the MQTT client that subscribes to MQTT broker on the topic that the device publishes. The flow is to manage and handle data from device's three sensors (Temperature/Humidity sensor and Ultrasonic sensor) via topic in Node-RED. The button sends an on-string message when it's on and sends an off-string message when it's off. This node will publish the feeding topic. MCU 2 will then be subscribed to this topic to receive its messages.

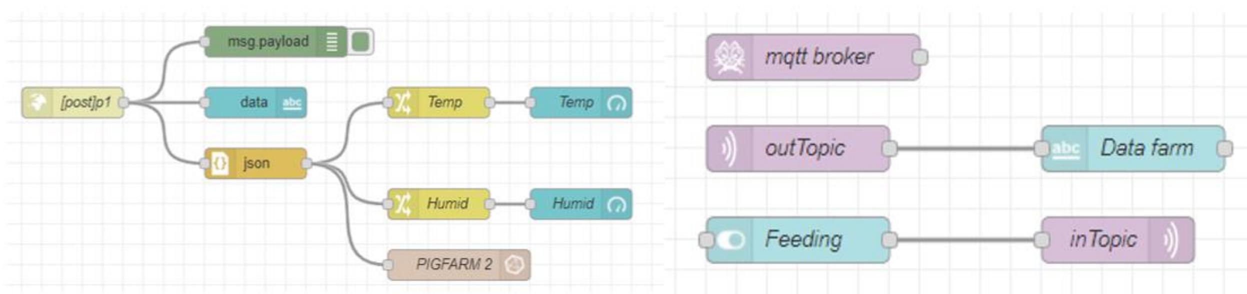


Fig. 5 The Node-RED management page (a) NoSQL databased flow and (b) MQTT protocol.

Implementation Testing

In this part, we present implementation of the system. The installation in the pig farm is shown in Fig 6. software, hardware and the results of the experiments are web application UI dashboard. Fig. 7(a) is feeding control gear motor, (1) which displays data environment in the pig farm and feed level and (2) displays data JSON format. Fig. 7(b) displays multi window: video and dashboard working on computer or smart phone. A video is for observing the eating, health, and behavior of pigs in the farm.

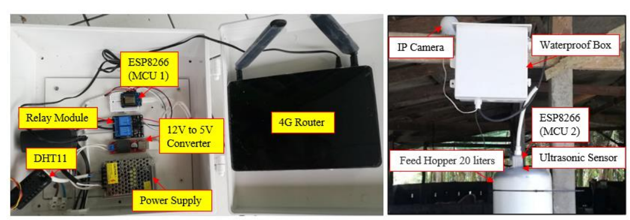
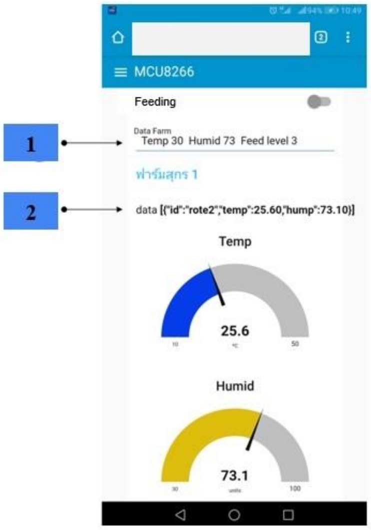
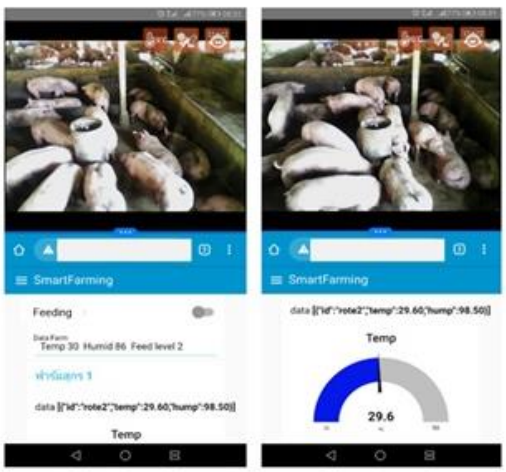


Fig. 6 Installation the IoT nodes in the pig farm.



(a)



(b)

Fig. 7 Web application UI dashboard (a) Feeding control and data environment and (b) Multi window: video and dashboard.

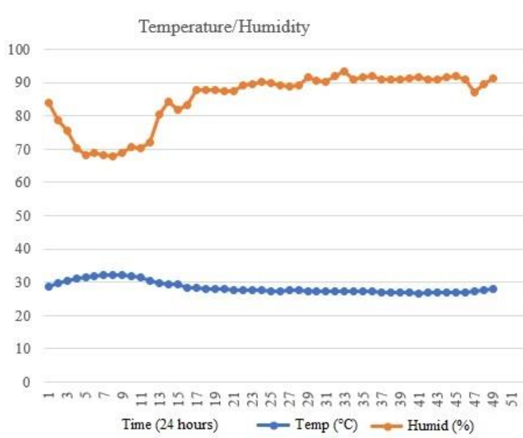
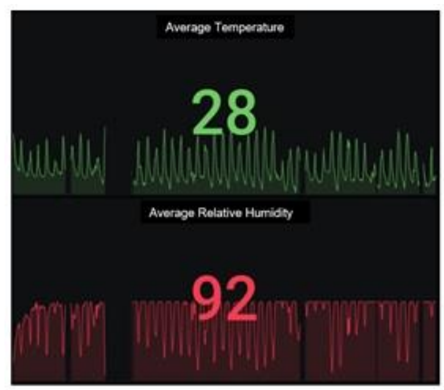
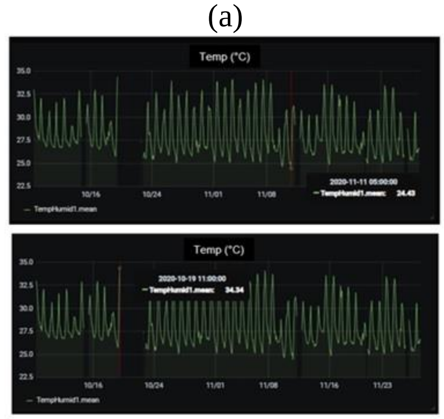


Fig. 8 The chart of temperature and humidity in 24 hours.

The statistics used were mean and standard deviation for analyzing the results of the system performance evaluation. The data were analyzed using Grafana to import data sources from a wide range of database engines. The system to create a database is InfluxDB, which is installed on the server. Grafana is used to visualize the graphs data since we can create and edit dashboards that cover many different types of chart formats. Grafana integrates the dashboard for data analytics and visualization, in which different data sets can be analyzed [8]. Dashboards are created for visualization of the sensors values and feeding controller by the farmer. The pig farm view shows average temperature and average humidity data form 8th October 2020 to 30th November 2020 as shown in Fig. 9(a). The obtained real-time monitoring for a process value temperature, the monitoring dashboard is summarized lowest and highest as shown in Fig. 9(b).



(a)



(b)

Fig. 9 Visualization of the data (a) The average of temperature and humidity (b) Lowest temperature and Highest temperature.

Analyzing the IoT efficiency assessment that evaluates by users, consists of 3 experts, 3 farmers, 4 generals interested using statistical methods (Table 1). The evaluation result was an average of 4.50 with a standard deviation of 0.47, a very high level. The stability of the prototype system was at a high level of evaluation.

Table 1 The results of the evaluation of questionnaires

Assessment details	Mean	Standard Deviation	Evaluation
Prototype design	4.90	0.32	Very high level
Accuracy in operating the prototype system	4.40	0.52	Very high level
Ease of use of the prototype system	4.60	0.52	Very high level
Stability of the prototype system	4.00	0.47	High level
Overall functionality of the prototype system	4.60	0.52	Very high level
Average	**4.50**	**0.47**	**Very high level**

3. Results and Discussion

The findings are consistent with the research objectives, that is, we design and construct environment monitoring and control based on IoT, and design and build an IoT based feeding control. Locally installed Node-RED server is used to monitor and control [9]. After collecting the sensor data ESP8266 transmits data to Node-RED server using HTTP, GET, REQUEST, and MQTT protocol which is responsible for monitoring temperature, humidity, feed level and control of relay module to operate feeding. MQTT protocol is called broker, and client is a device that connects devices to each other. A client subscribes to that topic, stores the received measurements in a NoSQL database. Grafana is widely used in industry to monitor a wide range of objects including infrastructure and applications, it can be used for the visualization and plotting of data in various graphical formats [10]. Users or farmers will the On and Off button to operate feeding and monitoring sensor data on web application in real-time. The information stored in the database can be processed and analyzed. The environment is quite good, the temperature and humidity are measured throughout the research had no effect on the health of the pigs. Environmental data collected over a continuous period of time are processed and analyzed as big data for future forecasts or studies of climate change in study area.

4. Conclusion

For this research, we design and implementation of an environmental measurement and control of the pig farm based on IoT technology. Real-time data are obtained with socket programming and stored in the InfluxDB using Node-RED, monitored and analyzed on the remote desktop with Grafana. Throughout the research period that measured the temperature, it was an average of 28 °C ranging from 24.43 °C to 34.34 °C and the humidity was an average of 92%. Therefore, the temperature control will not work throughout the study period. Due to the temperature not exceeding the specified range. The feeding control is following the instructions 100% of the time. The overall system performance evaluation was at the very high level achieving on average 4.50 out of 5 with a standard deviation of 0.47 from the users. IoT technology allows farmers to monitoring their animal's health and growth rate, helps farmers to take care of their farms more comfortably and reduces working time on the farm. Therefore, the developed IoT could be used as a prototype and expanded to a larger farm or other kinds of farms.

5. Suggestions

This research is a design and development for smart farm prototypes by using low-cost materials and devices. When used in large farms and high cost to build a standardized system, the prototype must be produced in large quantities. Therefore, the number of interested farmers must be sufficient for investment. In the future, it will be developed as an application on smart phone or other mobile devices. A power outage, internet signal lost, or the server crashes will be a problem causing the system to stop working and data collecting will not continue.

6. Acknowledgement

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