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Smart Control and Monitoring System for Closed Poultry House based on IoT

Surateno[1], Syamsiar Kautsar[2*], Risse Entikaria Rachmanita[2], Aan Anwaludin[3], M. Adhiyatma[3], Rosa Tri Hertawamati[3], Budi Hariono[4], Fendik Eko Purnomo[2], and Sryang Tera Sarena[5]

[1]*Department of Information Technology, Politeknik Negeri Jember, Jember 164, Indonesia*
[2] *Department of Engineering, Politeknik Negeri Jember, Jember 164, Indonesia*
[3]*Department of Animal Science, Politeknik Negeri Jember, Jember 164, Indonesia*
[4]*Department of Agricultural Technology, Politeknik Negeri Jember, Jember 164, Indonesia*
[5]*Department of Electrical and Electronic Engineering, University of Nottingham, United Kingdom*
[*]*Corresponding Author: syamsiar_kautsar@polije.ac.id*

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Abstract

The application of technology in the livestock sector has been carried out to increase the productivity of the livestock business. Closed chicken coops are one of the applications of technology in the livestock sector by utilizing a microcontroller that can control the temperature and ammonia levels in the coop under optimal conditions for fattening chickens. When the temperature rises (hot), the system set on the microcontroller will make the fan turn on automatically. This study aims to improve the offline and semi-manual fan control system in closed chicken coops to become automatic. By utilizing Internet of Things (IoT)-based technology, monitoring the condition of the chicken coop can be more easily accessed remotely. The method uses the if-then rule to regulate fan performance based on variable temperature and ammonia levels. The fan work set-point value can be set through the Android application online. Based on test results, the use of the IoT system can work well with an average delay of around 3,3 seconds. A consumer satisfaction survey was conducted on breeders with satisfactory results to ensure its suitability as a commercial product with a satisfaction level of 87.55 (very good).

Keywords: broiler, closed-house, IoT, microcontroller,

1 Introduction

The application of technology to increase the productivity of a business has been widely carried out. It has become a mandatory thing that must be done in modern times like today, including the application of technology in animal husbandry. One application of technology in animal husbandry is the application of technology that can intervene in the environment in the cage to be suitable for optimizing livestock growth. Technological interventions to make the environment in the cage suitable for these needs are often called microclimates.

The technology to create a microclimate in this cage by utilizing a temperature and humidity sensor connected to a microcontroller makes it possible to automatically adjust the temperature and humidity in the cage according to the needs [1, 2]. One example of a tool used in the field is the Temptron which is the primary tool for controlling temperature and humidity in closed-house chicken coops. Temptron has a microcontroller connected to the temperature and humidity sensor in the enclosure so that the microcontroller will turn on the fan when the temperature increases from the expected standard.

Temptron as a microclimate controller in closed-house chicken coops, is still offline, which means that temperature and humidity data can only be accessed on Temptron, with the coops looking directly at the data presented on Temptron. This can be done routinely by cage children in charge of raising livestock daily. However, of course, it is impossible to be done by supervisors responsible for several cages with cage locations that may be far apart or even in different areas.

This research was conducted to design and prototype a tool or platform that allows Temptron to be accessed online using the Internet of Things (IoT) [3, 4]. This will benefit the cage supervisor to monitor and evaluate the microclimate of several closed-house chicken coops without always having to come directly to the cage.

The cage is one of the most critical factors in the maintenance of chickens because the comfort of the cage dramatically affects the productivity that will be produced. The cage system for raising chickens is divided into two: the open-house system and the closed-house system. Open-house cages have microclimate characteristics depending on the climatic conditions of the surrounding environment. In contrast, closed-house cages have microclimate characteristics that can be adjusted with a tool according to the required conditions [5]. Environmental factors influence productivity in chicken rearing during maintenance, including the internal environment in the cage. Farmers need help regulating the temperature and humidity in the open house system, so it does not have an optimal effect on achieving chicken productivity. The cage has another function as a place for chickens to move in addition to protection, so a comfortable cage is needed during maintenance [6].

A closed house is a cage design with a closed system so that environmental conditions can be adjusted according to needs. A system is also designed to remove excess heat and gases (such as CO2) and ammonia. This closed system cage is a solution for raising chickens susceptible to heat stress [7]. Chickens quickly experience heat stress at high environmental temperatures because chickens belong to warm-blooded animals (homeothermic), which have skin without sweat glands, and most of their bodies are covered with feathers. This causes chickens to have difficulty dissipating excess heat in the body.

Meanwhile, if there is a decrease in environmental temperature, the chicken tries to produce heat by moving and eating less, which will interfere with chicken productivity [8]. The closed cage has two working systems, a tunnel and an evaporative cooling system (ECS), controlled by a microcontroller chip. These systems utilize wind flow to remove residual gas, heat, and water vapor and provide oxygen to the cage. Especially the ECS system for controlling air circulation in the cage is also accompanied by flowing water in the fibrous field [9].

The industrial revolution 4.0 "forces" and provides space for every field of business to improve quality in facing global challenges, including the livestock sector. One of the current applications of industrial technology is the development of systems that assist humans in controlling an electronic system with an Internet of Things (IoT)-based program. The development of technology in the field of animal husbandry by utilizing the IoT system is expected to be able to help increase livestock productivity [10]. IoT is a computing and communication technology that adds sensors, microcontrollers, and media for sending information on an object to be accepted and even controlled by a particular application/platform by utilizing the internet network. The system can be used in everyday life with unique markers of objects with a platform to send and receive data over a network without direct human intervention [11].

2 Material and Methods

The IoT-based control system in the Closed House consists of 3 panels: the sensor panel, the main panel, and the contactor panel. The sensor panel is mounted in the center of the cage. This panel contains an integrated sensor to read the condition of the Closed house and send the data to the controller on the main panel serially. The sensor and main panels are connected via a 25-meter DB9 serial cable. The central panel consists of a controller, LCD, AC load driver, and wifi devices to send data to the cloud database via the Internet. The contactor panel consists of a 3-phase contactor, a thermal overload relay, and an MCB as a 'bridge' to control the 3-phase exhausting fan in the Closed House.

Integrated sensor [12] consists of ammonia, temperature, and humidity sensors. The Ammonia sensor used is the MQ137 type. In comparison, the humidity and temperature sensors use the AM2315 sensor. The MQ137 sensor outputs analog data, which is then read by the ADC pin on the microcontroller. In contrast, the AM2315 sensor uses I2C data communication. ATMega328 microcontroller is used as a controller on the integrated sensor. Fig. 1 is a picture of the installation and block diagram of the integrated sensor system installed in the closed house.

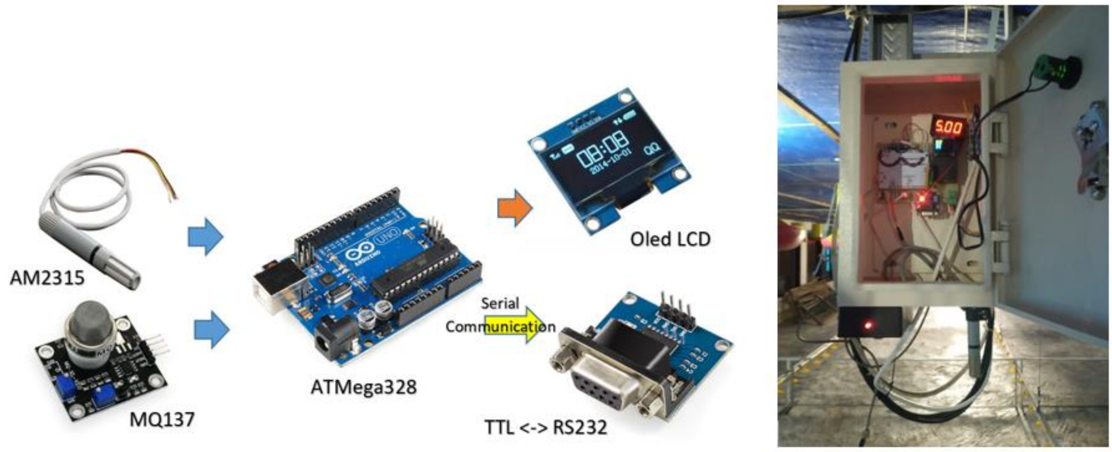

Figure 1. System block diagram of sensor unit

The central panel is located outside the cage, next to the entrance. This facilitates offline data monitoring by the operator without entering the cage. The controller on the main panel uses an ATMega2560 + ESP8266 microcontroller. The ATMega2560 microcontroller is tasked with reading serial data from the sensor panel and processing the data to control the Exhaust Fan. The ATMega2560 also forwards serial data received from the sensor panel to the ESP8266. When connected to the internet, the ESP8266 will send temperature, humidity, and ammonia data to the cloud database [4, 13]. Fig. 2 is an installation photo and a system block diagram of the main panel.

The contactor panel is located inside the enclosure, near the exhaust fan. Exhaust fans used in closed houses use 3-phase electricity. For this reason, the contactor panel is equipped with a 3-phase 18A contactor plus a thermal overload relay. The coil to activate the contactor is connected to the Solid-State Relay on the main panel. Solid-state relays are electronic components that control AC loads with a 5-volt DC trigger input. When the microcontroller provides logic 1 (5volt), the SSR is active, so the 3-phase contactor is also active. When the 3phase contactor is active, the exhaust fan will turn on. Fig. 3 is a photo of the installation of the contactor panel circuit.

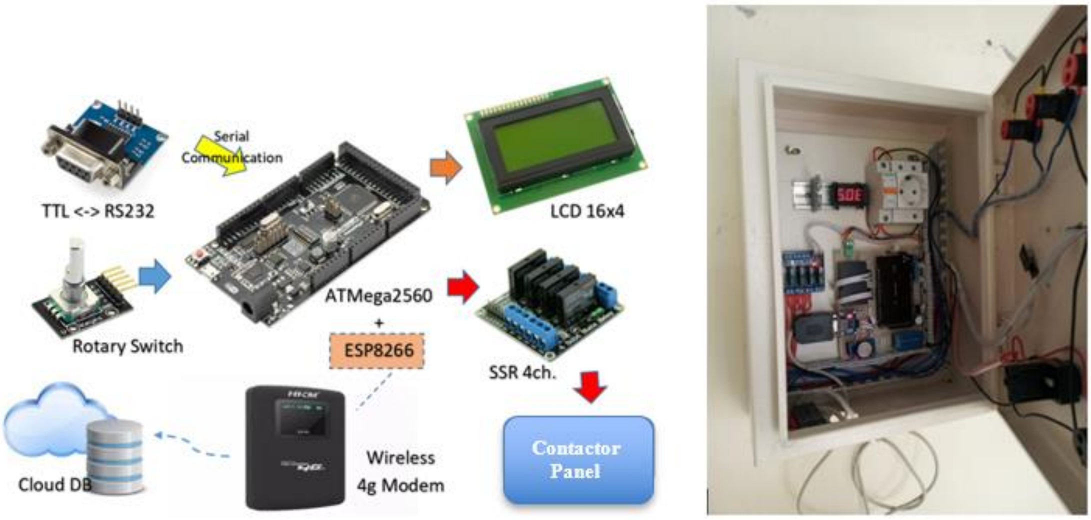

Figure 2. System block diagram of controller unit

Figure 3. Contactor panel unit.

ATMega328 microcontroller will read sensor data MQ137 and AM2315. The data is combined into 1 data protocol with the format shown in Fig. 4. The data is sent to the ATMega2560 microcontroller via a serial cable. The TTL to serial RS232 serial converter module is used to send data using a long cable. RS232 serial communication allows data cables with a maximum length of 100 meters. Where 'xxx' is the temperature value, 'yyy' is the humidity value, and 'zzz' is the value of NH_3 content.

The central panel has an ESP8266, which reads and sends data to the cloud database. The data sent to the cloud is on temperature, humidity, and ammonia gas levels. While the data read from the cloud is data set point temperature, humidity and ammonia gas levels, and manual fan setting data. These data can also be accessed through the Android application on a smartphone. Fig. 5 illustrates data communication between the ATMega328, ATMega2560, and ESP8266 Microcontrollers.

xxx+A+yyy+B+zzz

Figure 4. Protocol data format.

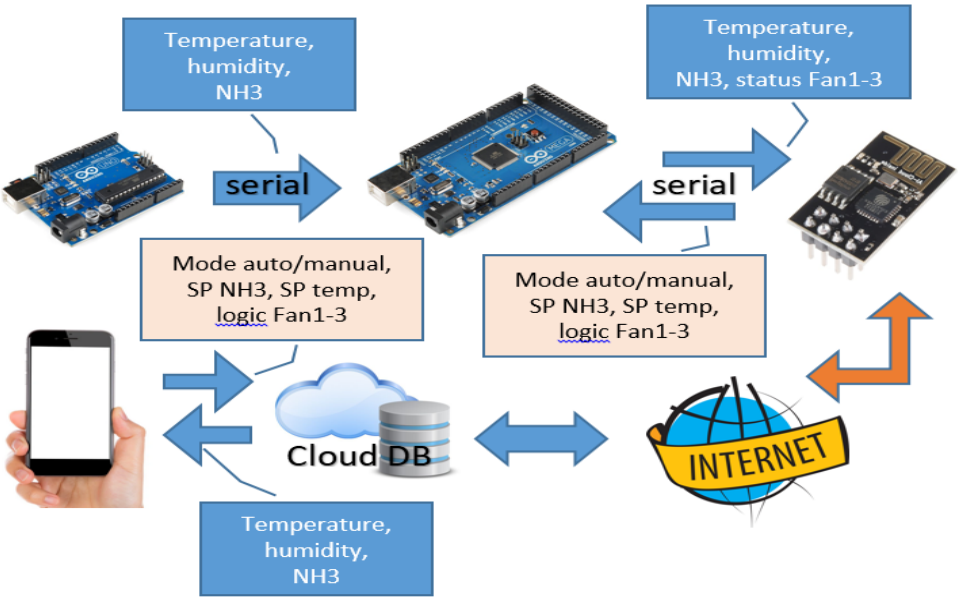

Figure 5. Data communication process.

On the central controller, there are two modes: automatic mode and manual mode [1, 14]. The exhaust fan can be activated via a smartphone by entering manual mode. The three exhaust fans will be activated by entering automatic mode based on the parameters stored in the cloud database. There are 12 parameters for the activation of the three fans. Fan1 NH_3 low level, Fan1 NH_3 High level, Fan2 NH_3 low level, Fan2 NH_3 high level, Fan3 NH_3 low level, Fan3 NH_3 High level, Fan1 temperature low level, Fan1 temperature high level, Fan2 temperature low level, Fan2 temperature high level, Fan3 temperature low level, and Fan3 temperature high level. The ATMega2560 controller for the exhaust fan control system works like the flowchart in Fig. 6. Humidity is limited to monitoring in this system. In the cage for this study, a humidifier was not used to regulate the humidity of the cage. When the fan is active when the temperature or ammonia is at a certain level, the humidity will also naturally adjust to the outside environment of the cage.

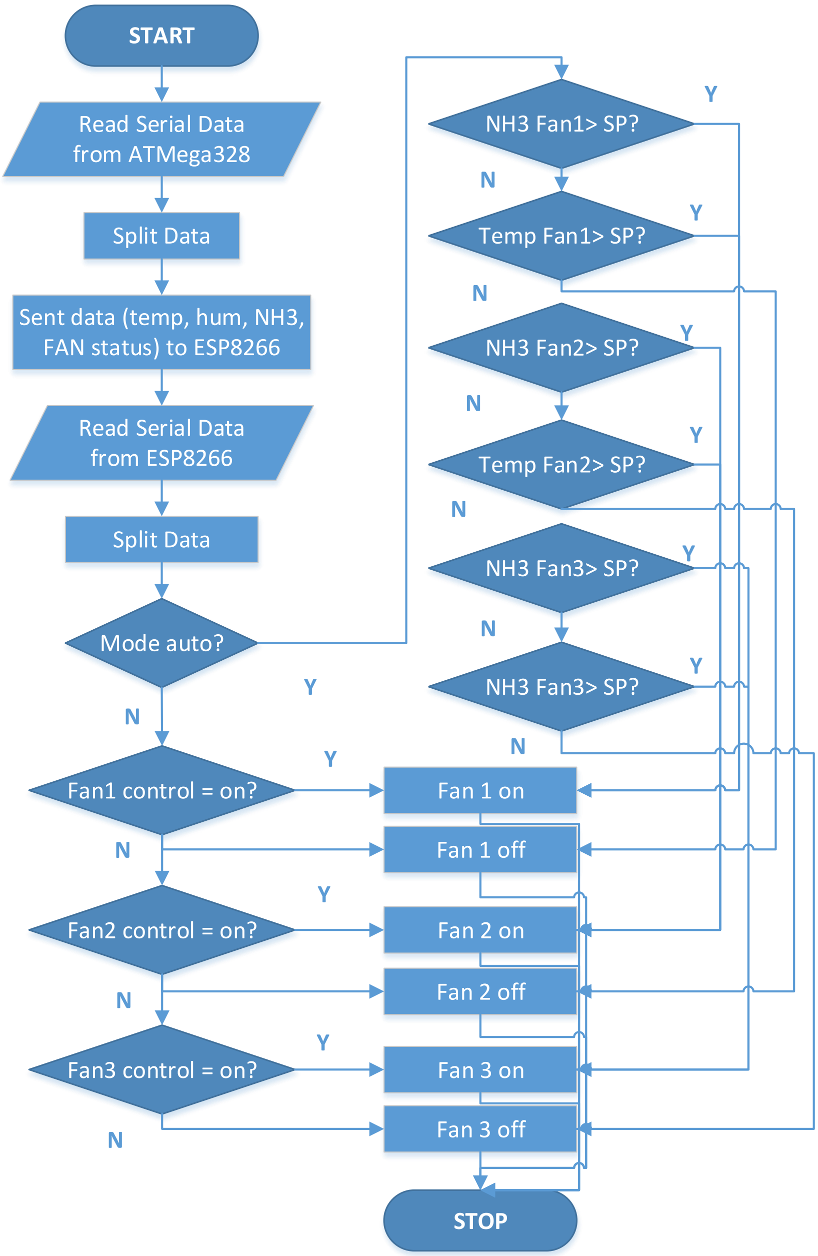

Figure 6. Flowchart system.

3 Results and Discussions

The exhaust fan can be activated via a smartphone by entering manual mode. At this stage, the overall features of the Smart Closed House system are tested. The first step is to validate the sensor used. This is to find out whether the data read by the sensor is following the actual conditions. The MQ137 sensor was validated using an Ammonia Gas

Detector Smart Sensor type AR8500, while the AM2315 sensor was validated using a UT333 Digital Temperature & Humidity Meter. Data is taken as much as five every minute at the exact location. Table 1 is sensor validation data with digital measuring instruments. From the measurement results, the sensor measurement results are obtained, which are not much different from the manufacturer's measuring instrument values.

The next test is to check the data communication between the sensor and the control panel. Checked the data accessed from the sensor and displayed it on the LCD on the main panel. Table 2 is the result of testing data communication between the ATMega328 microcontroller and the ATMega2560. A sampling of data was carried out every 10 minute 10 times a day. Based on the test results, the data can be sent 100%.

Next, check the data from ATMega2560 with the data displayed on the smartphone. As discussed in the previous subchapter, data sampling was done every 10 minutes a day. The delay in sending data to the cloud database is also measured. Based on the test results, data can be sent 100% with an average IoT-based data communication time of 3,3 seconds (Table 3). Fig. 7 is an example of data displayed on a smartphone with internet speed, as listed. Information on the application is made in Bahasa, to make it easier for users to use.

Table 1. Sensor validation

	Minutes	Sensor	Digital	**Δ**
NH_3 PPM	1	7,1	7,2	0,1
	2	7,1	7,2	0,1
	3	7,1	7,3	0,2
	4	7,2	7,3	0,1
	5	7,2	7,3	0,1
			average	*0,12*
Temperature ^{o}C	1	32	32,4	0,4
	2	32	32,4	0,4
	3	32	32,4	0,4
	4	32	32,4	0,4
	5	32	32,4	0,4
			average	*0,4*
Humidity (%)	1	74	74,2	0,2
	2	74	74,2	0,2
	3	74	74,2	0,2
	4	74	74,2	0,2
	5	74	74,2	0,2
			average	*0,2*

Table 2. Serial communication data test

Data	Sensor (NH_3, temperature, Humidity) ATMega328	Sensor (NH_3, temperature, humidity) ATMega2560	Error
1	0, 30, 82	0, 30, 82	0%
2	0, 31, 82	0, 31, 82	0%
3	0, 30, 85	0, 30, 85	0%
4	0, 30, 82	0, 30, 82	0%
5	0, 30, 82	0, 30, 82	0%
6	0, 31, 82	0, 31, 82	0%
7	0, 31, 85	0, 31, 85	0%
8	0, 30, 82	0, 30, 82	0%
9	0, 30, 85	0, 30, 85	0%
10	0, 30, 82	0, 30, 82	0%

Table 3. On-line Communication Data Test.

Data	Sensor (NH_3, temperature, Humidity) ATMega2560	Sensor (NH_3, temperature, Humidity) Smartphone	Error	Delay (second)
1	0, 27, 87	0, 27, 87	0%	3
2	0, 27, 87	0, 27, 87	0%	2
3	0, 27 87	0, 27 87	0%	3
4	0, 28, 87	0, 28, 87	0%	4
5	0, 28, 83	0, 28, 83	0%	3
6	0, 29, 83	0, 29, 83	0%	3
7	0, 29, 85	0, 29, 85	0%	4
8	0, 29, 83	0, 29, 83	0%	5
9	0, 28, 85	0, 28, 85	0%	3
10	0, 29, 85	0, 29, 85	0%	3

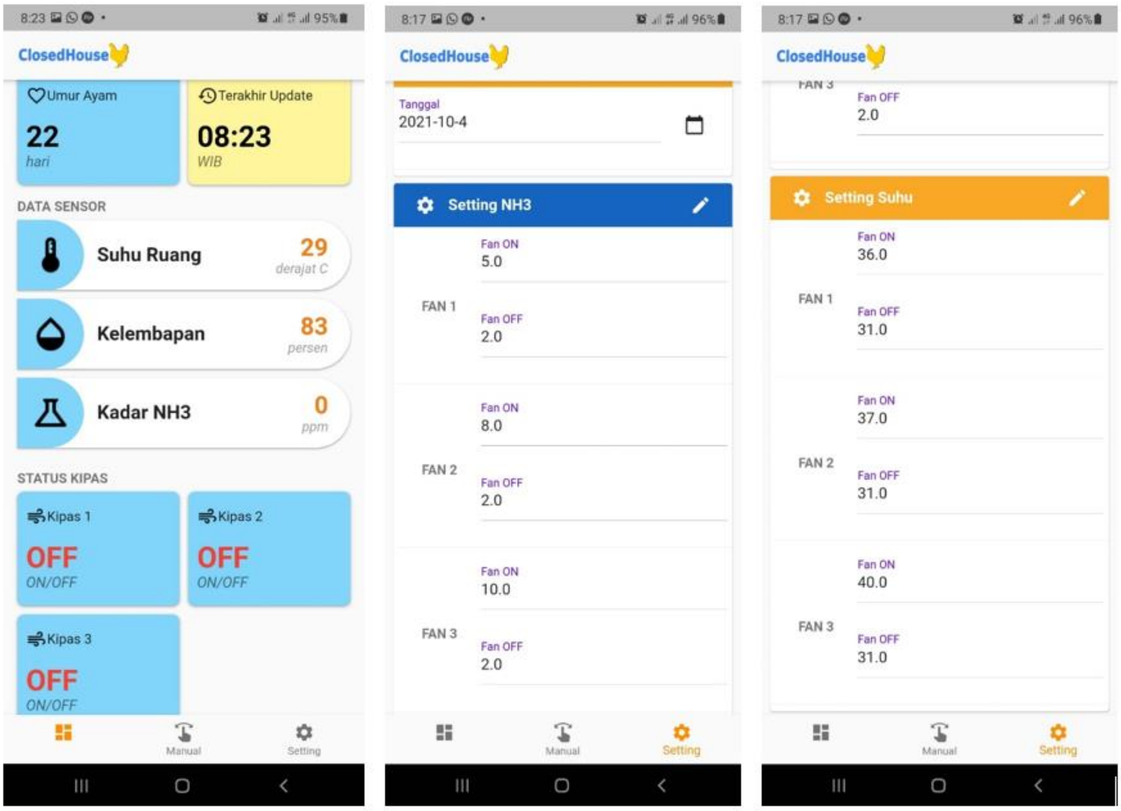

Figure 7. Application display.

In the next stage, a manual control trial was conducted using the Android application. Testing is done by setting the on-off fan through the application. The system response delay was also measured using a stopwatch. Table 4 is the result of testing the conditions of the three exhaust fans in the closed house. At the same time, Fig. 3 is an example of the condition of the application settings and fan response.

Table 4. Actuator Response Test.

Data ke-	Data Fan (1, 2, 3) Mobile App.	Data fan (1, 2, 3) Closed House	Error	Delay
1	off, off, off	Off, off, off	0%	3
2	on, off, off	on, off, off	0%	2
3	off, on, off	Off, on, off	0%	3
4	off, off, on	Off, off, on	0%	4
5	on, on, off	on, on, off	0%	3
6	off, on, on	Off, on, on	0%	3
7	on, on, on	On, on, on	0%	4

Finally, the automatic mode test was carried out. For the controller's performance testing, the sensor is conditioned to meet the work criteria in the flowchart in Fig. 6. For the AM2315 sensor; a heater is used to increase the temperature read by the sensor. For the MQ137 sensor, liquid ammonia is used, which is brought closer to the AM2315 sensor. Table 3 is the result of testing the automatic mode on the Smart Closed House system. The test with the sensor set point value is shown in Fig. 7.

Satisfaction of application users or customers as end users is another important factor that needs to be considered in application development. Application development will be built by looking at the assessment of customers (application users). If there are deficiencies or customer input, it will help improve an application. Customer satisfaction is a condition and post-purchase reaction, or after using a product (service), related to the buyer's negative or positive emotions [15]. The assessment of the sampling of application users is needed to see the reactions of application users to assess an application that is built will certainly provide benefits for evaluating an application or getting an overview of the use value obtained by users with the application. The method used is a poll (survey), which is information collected from respondents through a questionnaire whose questionnaire contains the parameters of customer satisfaction, including the ease of use of the application, the completeness of the application features, the effectiveness of the application's usefulness, and the quality of application design. A survey is one of the research methods to collect data by taking samples from a population and using a questionnaire to collect data [16]. The sample data taken involved 100 respondents who were involved in animal husbandry, including students and breeders. The assessment of each parameter is 1 - 100, with a score range of 0 – 20 is very poor; 21 – 40 is poor; 41 – 60 is sufficient; 61 – 80 is good; and 81 – 100 is very good. The results of the survey (questionnaire) obtained on the parameters of the ease of use of the application obtained an average value of 87.55 or very good, the parameter of completeness of the application features obtained an average value of 83.20 or very good, the parameter of the effectiveness of the usefulness of the application obtained an average value of 90, 87 or very good, and the application design quality parameters obtained an average value of 89.28 or very good.

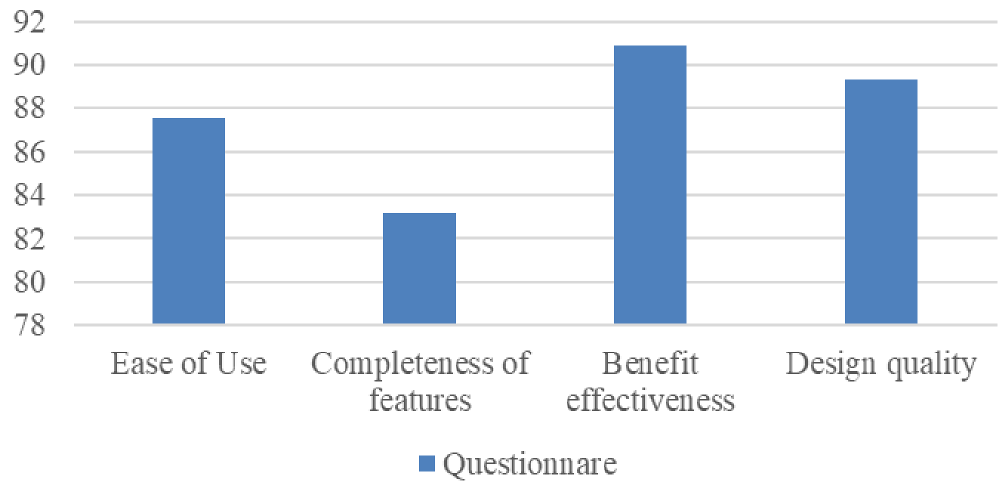

Figure 8. Application user satisfaction survey results.

The survey value of respondents on the parameters of the ease of use of the application obtained an average value of 87.55 (very good). This application is designed with simple principles and optimal function, so users are expected to understand and operate efficiently. The ease of use offered in an application will make it easier for an application product to be accepted by the user community, who is the target of building an application in this case. These people are engaged in livestock, especially Closed Houses. There are four indicators of convenience: ease of identification, ease of navigation, ease of gathering information, and ease of purchase [17] as shown in Fig. 8.

4 Conclusions

The Smart Closed House system can work well based on the test results. Serial communication between microcontrollers can work entirely with a transmission distance of 25 meters. HTTP requests for reading and sending data to and from cloud computing also work well. Data reading speed depends on internet speed. Based on the trial in the first month, the consumption of the data package needed for the IoT system is not more than 2GB. The Smart Closed House system can also use energy efficiency for closed houses. If the closed house is activated using a timer, the fan will still work according to the specified time without considering environmental conditions. System settings can also be done online to provide more flexibility to Closed House operators. The survey results from respondents on the parameters of the effectiveness of the application's usefulness obtained an average value of 87.55 or very good. From these results, it can be described that the respondents assessed that the built Closed house application provided additional benefits to them in managing a Closed House enclosure.

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