Estrus Cycle Monitoring System in Cow Based on IoT

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Abstract— **The orientation of local cattle farms generally only aims to take cow's milk, so local farmers do not have bulls and only have female cows to milk them. If a cow gives birth to a bull, the bull will be sold. This creates a separate problem for these farms because without a bull, the female cows cannot be fertilized naturally and can only be fertilized through artificial insemination so that the number of cows on the farm does not decrease and run out. However, this artificial insemination can only be given when a cow is in heat and cannot be done at any time. However, there are many ordinary dairy farmers in Indonesia who often lack knowledge about the signs of cow lust, making them run out of time for cow lust. Therefore, a device is made that can monitor the heat condition of cows on farms by using an infrared temperature sensor that is connected via the internet network and can be accessed via a smartphone, which can be monitored anytime and anywhere to help cattle breeders. The results of the implementation show that the performance of the infrared temperature sensor is very good because the measurement results are quite accurate because the accuracy level reaches 99.529 percent. The performance of the color sensor is also very good because it can detect colors accurately. The average delay obtained is 1.0175975 seconds. Meanwhile, the packet loss value obtained during the test was 16.11%.**

***Keywords*— *Color Sensor, Cow Insemination, Mlx90614 Sensor*.**

I. INTRODUCTION

Currently, data from the Ministry of Agriculture states that the total national beef production throughout 2018 is estimated to reach around 403,668 tons with a total demand of 663,290 tons. Then, the beef needs of the society are only 60.9% which can be met by local cow breeders. The orientation of local cow farms generally only aims to take cow's milk, so local farmers do not have bulls and only have female cows for milking. If a cow gives birth a bull, the bull will be sold. This created a special problem for this farm because, without the presence of bulls, female cows cannot be fertilized naturally and can only be fertilized through artificial insemination so that the number of cows on the farm is not reduced and exhausted. However, this artificial insemination can only be given when the female cow is in heat, and cannot be done all the time. However, there are many ordinary dairy farmers in Indonesia who still often lack knowledge about the signs of cow lust, making them spend time on cow lust [1].

Therefore, the observation or detection of the estrus cycle needs to be mastered by breeders so that natural mating is successful. The estrus cycle in a cow can be characterized by characteristics such as restless cows, increased temperature which is generally marked by a reddish color of the cow's vulva, thickening of the vagina, decreased appetite, and even loss of appetite. As well as the behavior of riding other cows and mucus discharge from the genitals (vulva). From these signs, the most appropriate guideline for breeders is to be ready to mate their cows when the cows have secreted quite a lot of mucus from their genitals [2]. Many cases occur, regardless of the discharge from the vulva, but breeders have married it. Even just because the cow was 'screaming'. Even though not all cows show this sign, many are silent.

In addition to looking at these characteristics, the officer who checks the estrus cycle of the cows also performs a rectal examination to ensure that the cow is really in the estrus cycle. Rectal exploration is a method of diagnosing the estrus cycle that can be performed on large livestock such as cows, by palpating the uterus through the rectal wall to feel the enlargement that occurs in the uterus and fetus. The detection of the correct estrus cycle in cows is the main key to the success of a marriage in addition to the accuracy and speed of mating, an effective examination of the estrus cycle in cows requires complete knowledge of the behavior of cows when the estrus cycle is normal or not. The detection of the estrus cycle can generally be done by looking at the behavior of livestock and the state of the vulva.

This problem inspired the researcher to make a final project about it. The researcher wants to make a device that can monitor the estrus condition of female cows on farms by monitoring using infrared temperature sensors that are connected via the internet and can be accessed via smartphones that can be monitored anytime and anywhere to help cow farmers.

There was a study entitled "Visual Observation of the Vulva and Changes in Behavior of Estrus Cows in Breeding at the Breeder Level [3]. In this study, seven Ongole Crossbreed cows were investigated to find out the appearance of the vulva and changes in behavior when the cow was estrus at the society farm level of the Mergo Andhini Makmur Livestock Group, Sleman, Yogyakarta. A vaginal smear examination was done every three days as an indicator of the cow being in estrus. Visual observations of the appearance of the vulva (mucus discharge, more reddish color, swelling, temperature) and behavior (aggressiveness, moaning, frequency and duration of eating, rumination, standing, lying down, consumption of food and drink, urination, defecation) were done 24 hours a day. This study concluded that the detection of estrus is visible with the discharge of mucus from the vulva, and there is an increase in anxiety as indicated by the lower frequency of eating, duration of eating, frequency of rumination, and duration of rumination compared to when, not estrus. This study only conducted direct observations not using IoT (Internet of Things) technology [4].

The next research was about The Detection of the Estrus Cycle of Cows Through Analysis of Cow Vulva Image Using Adaptive Neuro Fuzzy Inference System [5]. This research produced an application to detect the estrus cycle using digital image processing and temperature measurement using a thermometer. The results of image observations and temperature measurements are then processed using the Adaptive Neuro-Fuzzy Inference System. This research also does not use the Internet of Things.

Based on previous research, researchers will create an application system that will facilitate monitoring of the estrus cycle in cows using the Internet of Things. Where researchers can make observations from anywhere and anytime. So that our system can be useful for cattle breeders and artificial insemination workers.

II. METHODOLOGY

A. Types of Research

The type of this research was a research and development. The aim and objective of this research with a developmental nature are to expand and deepen existing knowledge. In the research that will be done to design an "Estrus Cycle Monitoring System in Cow Based on IoT". The development done in this study used the ESP-32 microcontroller, the tcs3200 sensor because it detects the level of redness of the cow's vulva when entering the estrus cycle, and the addition of the GY-906 Infrared Temperature sensor to find out the temperature of the cow's vulva when entering the estrus cycle, and an infrared sensor was added to detect objects that will be measured.

B. Research Design

The design of this study was a detailed plan made to conduct research in the manufacture of devices so that the results are obtained in sequence. According to (Rahmat, 2014) the flow of research and development (Research & Development) consists of 10 steps : The first stage is potential and problems. Potential is everything that when utilized will have added value. Problems are deviations between what is expected and what happened (Rahmat, 2014). The Estrus Cycle Monitoring System in Cow Based on IoT is a potential that can be researched and developed where the system can assist farmers in knowing the condition of their cows. The problem experienced by farmers is the inaccuracy in assessing the signs of the estrus cycle in cows in detail. Breeders know the signs of the habit of caring for cows so the results obtained are not detailed. The second stage is data/information collection, the process of collecting data or information is done factually by coming directly to cow farmers and doctors or animal health experts (Mantri), especially cows. In addition, previous research data related to the estrus cycle of the cow are used as reference material in the development or manufacture of this system. The third stage is product design, product design, or the resulting development model, namely the creation of an estrus cycle monitoring system in the cow. The system combines a tool used to monitor the condition of cows and an android-based application to see the results of monitoring the cow's estrus cycle. The tool used utilizes an infrared temperature sensor and a TCS 3200 color temperature sensor which is connected to the NodeMCU ESP 8266 microcontroller. The fourth stage is product design validation, product design validation is an activity to assess whether the product design is more effective or not, the product in this case is the estrus cycle monitoring system in the cow. Validation is done by consulting with experts or experts about the state of the cow. The results of the validation are supported by an analysis of several theories regarding the quality assessment of a tool. The fifth stage is product testing, this test is intended to see if the system that has been developed can provide quality results. It is also used to test the variables that have been find outd above in determining whether the results obtained are following the experts. The sixth stage is data analysis, data analysis is the stage in concluding the results that have been obtained from the monitoring system and then compared with the state of the cow itself. The results of data analysis that have been obtained can be useful information for researchers and cow breeders in knowing the characteristics of the estrus cycle in the cow. The last stage is reporting, this stage is the last, namely documentation or report generation.

C. Tool/System Design

The block diagram of the "IoT-based bovine estrus cycle monitoring system" is shown in Figure 1. This block diagram of the system describes the system planning in the study with the title "IoT-based bovine estrus cycle monitoring system". The microcontroller used in this tool uses ESP8266 which uses power bank resources. Then, the power bank is first connected to the ESP8266 module which requires a voltage of 5V.

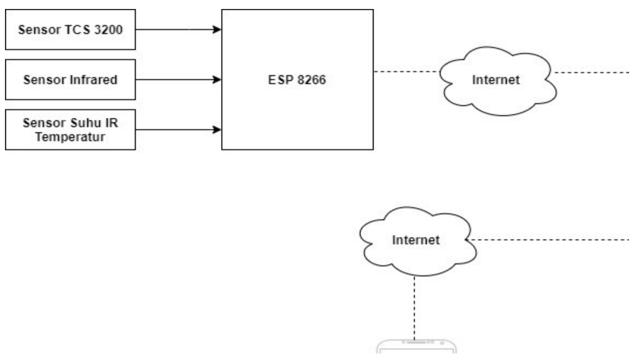


Figure 1. System Block Diagram

Based on Figure 1 shows how the entire system is built. Infrared sensors are used to find out the presence or absence of detected objects. After the ESP8266 gets data from the infrared sensor when an object is detected, the ESP8266 will give a command to the IR temperature sensor to detect the temperature at the vulva, the temperature value used as a marker for cows in estrus is 38 degrees Celsius. At the same time, ESP8266 also gives orders to the TCS 3200 sensor to detect the color of the cow's vulva, the color value used as a reference for cows in estrus is Red>225; Green>100; Blue>100. Data that has been successfully entered on the ESP8266 will be sent to the firebase database to be accommodated via internet data transmission by the wi-fi feature, then the android application requests data from the firebase database using Java functions. Then the data that has been successfully sent is displayed on the android application in the form of notification to notify the user of the condition of the detected cow.

D. Preparation of Tools and Materials

The tools in the research that will be done are shown in Tables I and II.

TABLE I
RESEARCH TOOLS

No	Tool's name	Information
1	NodeMCU 8266	A hardware to control the system
2	Infrared sensor	A sensor as a detector of an object to be measured
3	Sensor Infrared Temperatur	A sensor for detecting the temperature of the cow's vulva
4	Sensor TCS3200	The sensor used to detect color in a cow's vulva
5	Smartphone	Hardware as output to display measurement results

TABLE II
RESEARCH MATERIAL

No	Material Name	Information
1	*Arduino IDE*	As a coding software for the tool as a whole
2.	Android Studio	As software to create applications on smartphones.

E. Determination of Procedures and Parameters

This section will define the system workflow of the "Estrus Cycle Monitoring System in Cow Based on IoT".

Figure 2 is a diagram of the software system design starting from the initialization of infrared, temperature, and RGB. Infrared, temperature, and color sensors will read the cow's vulva object, and the results from the sensor are sent to the NodeMCU and the temperature and RGB value data will be uploaded to android.

The parameters that are used as benchmarks in this study are the success rate in sensor readings, the accuracy of the temperature sensor values, and RGB values.

1) Parameters used

In this study, parameters were find out based on the system that had been created and used for testing parameters in the system. The following parameters are used in this study:

1. Bound Variable: Delay, Packet Loss
2. Controlled Variable: Temperature value, RGB Value
3. Independent Variable: Cow Vulva

2) Data Collection Planning

In this study, the data to be taken include data retrieval of cow vulva temperature values, retrieval of RGB value data, and sending data to android (delay, packet loss).

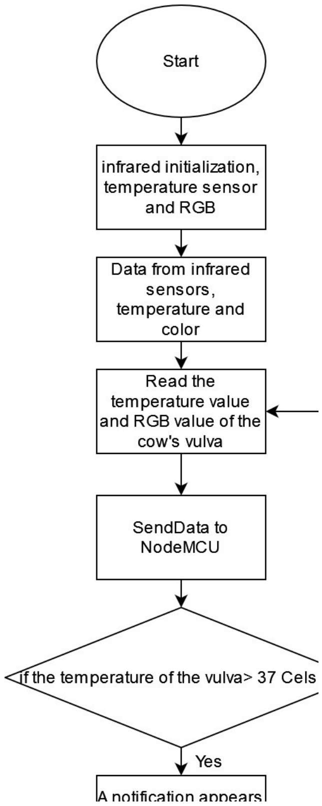


Figure 2. Flowchart of System Procedure Determination

F. Implementation

1) Tool Implementation

In this tool, all sensor components will be connected to the NodeMCU 8266 microcontroller. The following is a schematic drawing of the tool circuit shown in Figure 3.

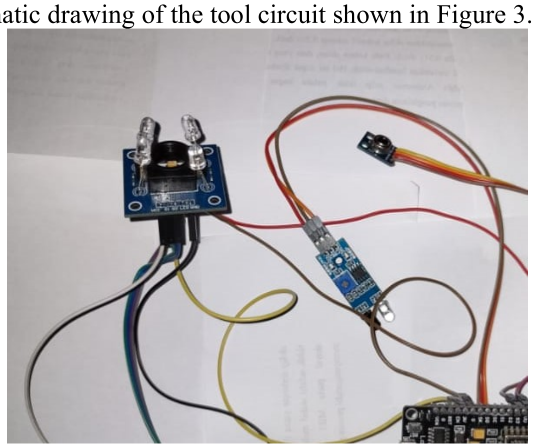


Figure 3. Toolkit

The placement and connection of sensor components with NodeMCU 8266 as a microcontroller on each sensor node in Figure 4 will be explained in Table III.

TABLE III
PIN PLACEMENT BETWEEN COMPONENTS ON NODEMCU

NodeMCU	**TCS3200**	***Infrared***	**IR MLX90614**
GND	GND	GND	GND
VV			VIN
3V	VCC	VCC	-
D8	OUT	-	-
D7	S3	-	-
D6	S2	-	-
D5	S1	-	-
D4	S0	-	-
D3	-	OUT	-
D2	-	-	SDA
D1	-	-	SCL

2) Application Implementation

At the application stage of reading the results of monitoring the temperature of the cow's vulva, located on the temperature and RGB color menu, values and notifications appear on the Android smartphone application indicating whether the cow is ready for artificial insemination or not. The firebase used, can be created by following a few steps. Before researcher start, researcher first need to create a Firebase project before starting to code in Flutter, if you don't have a Google account, please create an account first, let's say you have created a Google account. To create a firebase project, first, open the official firebase website. On the menu select Go to Console, and create a new project.

Then after that select or input, the name of the project according to your wishes. After this process just follows some of the steps that you have to follow. Don't forget, if you want to enable an analysis of our app usage, then switch on Enable Google Analytics for this project. So far, the process of creating a firebase project has been successful. The next step is to add the app to our project.

G. Device Trial

Sensor accuracy testing is done to find out how the quality of the sensor, and whether the sensor works well or not. The testing step starts from NodeMCU as a microcontroller or control center of the entire system to detect an object.

1. Infrared temperature sensor testing, where the infrared temperature sensor detects the temperature of the cow's vulva and gets the temperature value in degrees Celsius from the cow's vulva.
2. And also color sensor testing, where the color sensor detects the color of the cow's vulva and gets the RGB color value of the cow's vulva.
3. Calibration of the infrared temperature sensor for reference to temperature data in degrees Celsius from the cow's vulva.

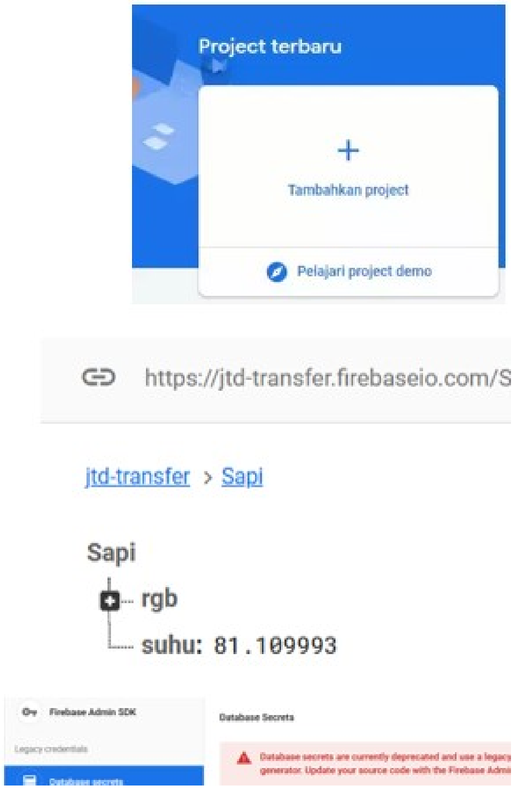


Figure 4. Adding a Project to NodeMCU

TABLE IV
CALIBRATION OF VULVA TEMPERATURE VALUE OF COWS ENTERING THE ESTROUS CYCLE

Rated Temperature (C°)
38.17
38.33

TABLE V
CALIBRATION OF THE VULVA TEMPERATURE VALUE OF COWS NOT YET IN THE ESTRUS CYCLE

Rated Temperature (C°)
36.17
34.33

4. Calibration of the color sensor to reference the RGB color data of the cow vulva.

TABLE VI
CALIBRATION OF THE RGB VULVA VALUE OF COWS ENTERING THE ESTROUS CYCLE

RGB Value		
Red (R)	Green (G)	Blue (B)
102	101	226
110	101	226

TABLE VII
CALIBRATION OF THE RGB VULVA VALUE OF COWS NOT YET IN THE ESTRUS CYCLE

RGB Value		
Red (R)	Green (G)	Blue (B)
88	99	201
43	95	216

The tests that have been done, it is listed in Table 6. and Table 7. above is a comparison between the temperature readings on the vulva of cows entering the estrus cycle which have been read by the infrared temperature sensor MLX90614, the temperature reading here is to find out the required standardization, namely the temperature of the vulva of cows that have entered the estrus cycle and those who have not entered the estrus cycle.

H. Data analysis

1) Delay when the latest data changes

In this study, the delay calculation was done for how long the data changes displayed on the android display were to see whether the communication was going well or not. After that, the values obtained are compared to the delay table located in chapter 2 to ensure that the quality of communication falls into the category of very good, good, adequate, bad, or very bad conditions.

2) Data Delivery Success Rate

In this study, data transmission will be analyzed that how many times the system has failed in communicating. Then the data is averaged so that it can be stated whether the system is running well or not. Here are the results of the calculations using the following equation (1) method:

$$Success\ Rate = \left(\frac{Number\ of\ Trials - Number\ of\ Fails}{Number\ of\ Trials}\right) x100\% \quad (1)$$

3) Calibration Test on Color Sensor

In this section, the Sensor Accuracy test is done to find out whether the sensor can work properly. Initial testing includes NodeMCU as the control center of all systems to detect objects. Color sensor testing, where the color sensor will detect the sample to get the RGB value on the sample Color Sensor Calibration As a reference for RGB color data Samples and trial error literacy. The test in Figure 5 above is a comparison between green readings on good samples and bad samples that are read by the TCS3200 color sensor, green readings are done to find out the standard required for good green and bad green and a trial error occurs when the value is obtained. the same as the previous value.

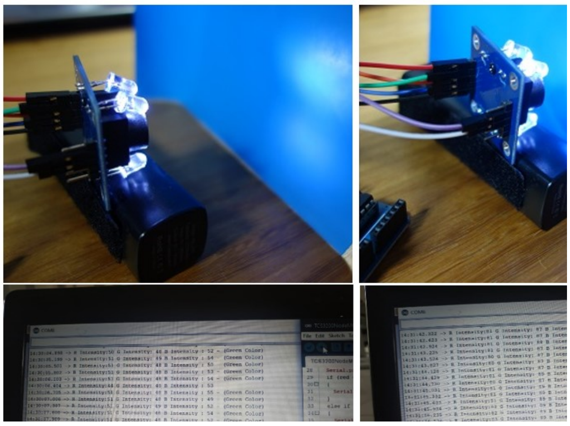


Figure 5. Color Calibration

TABLE VIII
THE SENSOR CALIBRATION TEST IS DIFFICULT TO ENTER

Sample no	RGB Value Distance 3 cm			Trial Error RGB	RGB Value Distance 10 cm		
	Red (R)	Green (G)	Blue (B)		Red (R)	Green (G)	Blue (B)
Sample 1	51	49	54	Success	62	68	50
Sample 2	51	49	54	Error	50	71	64
Sample 3	51	48	50	Success	46	70	65
Sample 4	51	48	55	Success	71	69	55
Sample 5	52	50	49	Success	81	87	93
Sample 6	50	48	52	Success	80	87	91
Sample 7	50	48	52	Error	82	87	92
Sample 8	51	48	54	Success	83	87	88
Sample 9	51	48	54	Error	81	87	91

Sample no	RGB Value Distance 3 cm			Trial Error RGB	RGB Value Distance 10 cm		
	Red (R)	Green (G)	Blue (B)		Red (R)	Green (G)	Blue (B)
Sample 10	51	59	52	Success	80	89	93
Sample 11	52	60	57	Success	82	89	89
Sample 12	53	46	58	Success	83	89	95
Sample 13	53	46	58	Error	80	89	94
Sample 14	45	50	43	Success	80	89	91
Sample 15	51	49	56	Success	81	87	93
Sample 16	43	51	46	Success	38	78	56
Sample 17	44	52	48	Success	41	66	82
Sample 18	44	52	48	Error	44	79	65
Sample 19	55	39	58	Success	59	70	59
Sample 20	51	57	58	Success	39	68	61

4) Calibration Test on Temperature Sensor

Temperature sensor testing is done to ensure that the temperature sensor can produce an accurate temperature value. In this plan, the output from the sensor is displayed through the application. Testing this sensor was done by calibrating the temperature sensor. The results were obtained using the following equation (2) and (3):

$$PocentageError = \left(\frac{Sensor\ Value - Hygrometer\ Value}{Hygrometer\ Value}\right) x100\% \quad (2)$$

$$Average\ Error = \left(\frac{Number\ of\ Data\ Errors}{Number\ of\ Variables}\right) \quad (3)$$

Figure 6. Temperature Sensor Testing

TABLE IX
CALIBRATION OF IR TEMPERATURE

No Trial	Time	Temperature (°C)		Error (%)
		Sensor Value (°C)	Hygrometer Value (°C)	
1	15.10	28.71	28.70	0.00034
2	15.16	28.73	28.72	0.00034
3	15.22	28.71	28.71	0
4	15.28	28.71	28.69	0.00069
5	15.34	28.75	28.74	0.00034
6	15.40	28.73	38.72	0.00034
Error Average Difference				0.00034

III. RESULTS AND DISCUSSION

In this fourth chapter, the overall results from planning to making hardware and software that have been designed will be described as well as answering the formulation of the problem. The objective of system testing is to find out the quality of the system that has been designed to function and work according to the plan. In this discussion, the communication system for reading infrared sensors, infrared temperature MLX90614, and the TCS3200 sensor are explained. The results of the measurement result information data can be accessed via smartphone devices with the android operating system.

A. System Implementation Results

1) Hardware Implementation Results

Based on the system design, data collection will then be done at Pagerwojo Tulungagung cow farmers. The results of Hardware Implementation are shown in Figure 7.

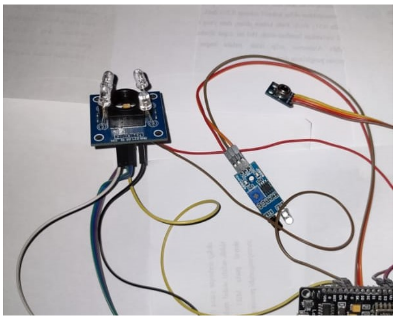


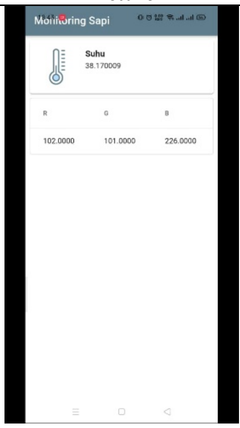
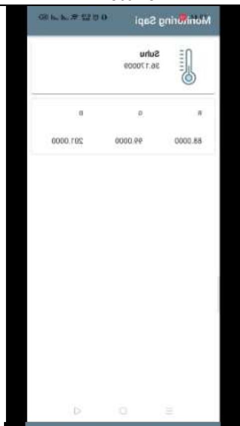
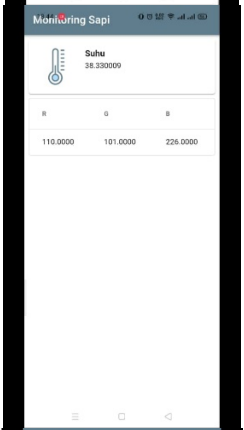
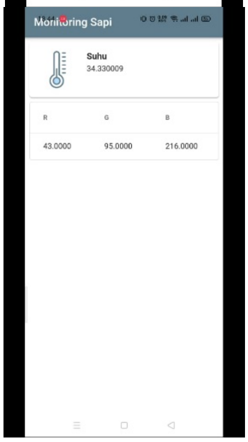
Figure 7. Hardware Implementation Results

The workings of the results of the hardware implementation, namely the infrared sensor are used to find out the presence or absence of the detected object. After the ESP8266 gets data from the infrared sensor when an object is detected, the ESP8266 will give a command to the IR temperature sensor to detect the temperature at the vulva, the temperature value used as a marker for the cow in estrus is 38 degrees Celsius. At the same time, the ESP8266 also gives orders to the TCS 3200 sensor to detect the color of the cow's vulva. Data that has been successfully entered on the ESP8266 will be sent to firebase, then displayed on the android application in the form of notification to notify the user of the detected condition of the cow. The data taken is the distance of the detected object, the temperature measured by the IR temperature sensor, and the RGB value.

2) Software Implementation Results

Based on the system design, data collection will then be done at Pagerwojo Tulungagung cow farmers. The results of the software implementation are shown in Table X.

TABLE X
RESULTS OF SOFTWARE IMPLEMENTATION

Information	**Picture**
Monitoring results in cow A. The temperature display shows the results of temperature measurements on the body of cow A. While the display R, G, and B shows the results of the color sensor readings in detecting the color of the vulva of cow A	
The results of monitoring in cow B. The temperature display shows the results of temperature measurements on the body of cow B. While the display R, G, and B shows the results of the color sensor readings in detecting the color of the vulva of cow B	
Monitoring results in cow C. The temperature display shows the results of temperature measurements on the cow's body C. While the displays R, G, and B show the results of the color sensor readings in detecting the color of the vulva of cow C.	
Monitoring results in cow D. The temperature display shows the results of temperature measurements on the cow's body D. While the R, G, and B displays show the results of the color sensor readings in detecting the color of cow D's vulva.	

B. *Temperature Sensor Test Results*

Testing of the temperature sensor done by the examiner, namely, testing of tools and systems with the results displayed on the application. The objective of this test is to find out the level of accuracy of body temperature results from cows. The measuring parameter of the temperature sensor accuracy is a digital thermometer.

TABLE XI
TEMPERATURE SENSOR TEST RESULTS

No Sample	Temperature Thermo-meter (°C)	Test Sensor 1 (°C)	Test Sensor 2 (°C)	Test Sensor 3 (°C)	Percentage Error (%)
1	32,7	32,8	32,7	33,1	0,30
2	33,5	33,6	33,7	33,9	0,59
3	32,9	32,7	32,6	32,5	0,91
4	32,3	32,6	32,7	32,5	0,92
5	32,1	32,5	32,9	32,6	0,01
6	34,7	34,6	34,7	34,8	0
7	35,1	35,8	35,5	35,2	1,13
8	34,1	34,1	34,2	34,5	0,29
Average					0,471

Thus, the percentage of accuracy in the measurement is as follows:

Accuracy = 100% - % error

Accuracy = 100% - 0.471% = 99.529%

The resulting measurement is quite accurate because it has a fairly high % Accuracy value, which is 99.529%, or almost close to 100%.

C. *Color Sensor Test Results for Cow Objects*

The color sensor test results are shown in Table XII.

TABLE XII
COLOR SENSOR TEST RESULTS

Cow Name	RGB Value			Information
	Red (R)	Green (G)	Blue (B)	
Cow A	102	101	226	Cow A is ready to mate
Cow B	88	99	201	Cow B is not ready to mate
Cow C	110	101	226	Cow C ready to mate
Cow D	43	95	216	Cow D is not ready to mate

Based on the data above, cows A and C are ready to mate because the R-value is above 100. Meanwhile, cows B and D are not ready to mate because the R-value is below 100.

D. *Delay Test Results*

Delay testing is needed to see if the communication system in this final project is running well or not. Wireshark can display several packets when doing live streaming because the protocol used is TCP, therefore it must be filtered first. Do a filter according to the IP used. Figure 9 how to see the IP used by esp8266 on the access point used.

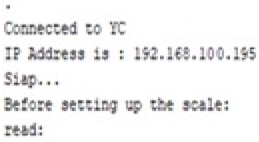


Figure 9. IP used by ESP8266 on the access point

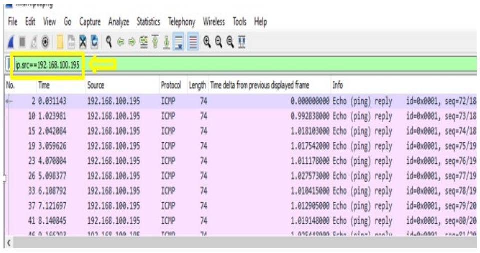


Figure 8. Delay Test Results on Wireshark

Furthermore, the data from Wireshark is converted into CSV format to be processed in Microsoft Excel. Next, researcher find the average delay of a sample of 20 packets. From the calculation of the data packets sent, the average delay obtained is 1.0175975 seconds. The smaller the delay, the better the quality of data transmission because there will be no delay in information.

E. *Packet Loss Test Results*

Testing for packet loss using Wireshark software with the same steps as the delay testing procedure. Packet loss testing is done to find out the amount of data that was not successfully sent to the server. The packet loss value can be seen in the interface description.

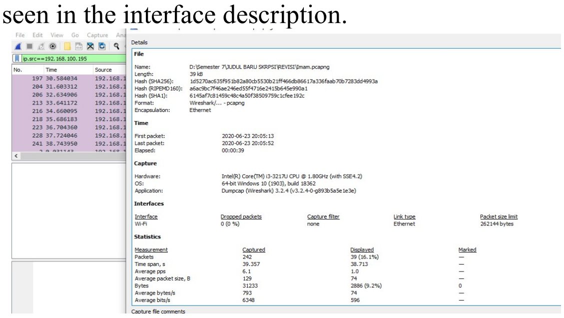


Figure 9. Packet Loss Test Results on Wireshark

From the data displayed by Wireshark, 242 packets were successfully sent. For packets that were not successfully received by the server, there were 39 packets. Then the packets that were successfully received by the server were 203 data packets. From the data obtained, it is calculated using the following equation:

$$Packet\ Loss = \frac{(\text{Data Package Sent} - \text{Package Received})}{Data\ Packet\ Sent}\ x\ 100\%$$

= ((242- 203) / 242) x100%

= 0.161157025x100%

= 16.1157025 %

From the results of the calculations that have been done, the packet loss value obtained when testing is 16.11%. With this value, the packet loss value obtained has a high value. The value of 16.11% falls into the range of poor reliability values.

IV. CONCLUSIONS

The implementation of the estrus cycle monitoring system in cows based on the Internet of Things uses an infrared temperature sensor and an android application color sensor to detect body temperature and the color of the cow's vulva. The sensor readings are processed by NodeMCU for further data sent to the firebase server and displayed on the android application. The performance of the infrared temperature sensor is very good because the measurement results are quite accurate. After all, the level of accuracy reaches 99.529%. The performance of the color sensor is also very good because it can detect colors accurately. Based on the results of the study, the average delay obtained was 1.0175975 seconds. As for the packet loss value obtained when testing is 16.11%.

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