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Early Detection of Livestock Fever, Estrus, and Parturition Using Wearable Tail Sensor

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***Abstract* - The advancement of technology paved the way for the wearable tail sensor to be developed as livestock owners depend on analog measurements for detecting fever, estrus, and parturition. Hence, these advancements help farm and livestock management. This study aimed to design and develop a wearable tail sensor that integrates heat, motion, and pulse sensors for the early detection of livestock fever, estrus, and parturition. This study utilized a Research and Development (R&D) design employing the 4D Model of device development, which encompasses four distinct phases: define, design, develop, and disseminate. The study successfully designed and developed a device that integrates four sensors to detect fever, estrus, and parturition in livestock. The results revealed that the device has a high level of acceptability and adaptability. Statistical analysis also showed that there is no significant difference between the measurements of the analog instruments and the wearable tail sensor in terms of temperature and pulse rate for both cattle and pigs. The researchers successfully constructed a wearable device integrating four sensors to detect fever, estrus, and parturition in livestock that transmits real-time data over the web server and accurate measurements of temperature, pulse, and motion of livestock. This advancement benefits the livestock owners by making it less difficult to track the livestock's fever, estrus, and parturition.**

Keywords: Temperature, pulse, motion, cattle, pigs, health monitoring, agriculture, technology.

I. INTRODUCTION

Livestock diseases exert a detrimental impact on the animal agricultural sector, giving rise to substantial economic repercussions. Notably, Dixon *et al.* (2019) highlighted the threat posed by diseases like African Swine Fever (ASF) to the global animal industry and food security (SDG 2). Their research emphasized the imperative for swine stakeholders to proactively equip pig farmers with training in disease monitoring and surveillance, thereby enhancing bio security practices. In a parallel vein, Santman-Berends *et al.* (2019) revealed that 8.5% of perinatal calves succumb to natural abortions, stillbirths, and parturition complications annually, incurring elevated economic costs and compromising animal well-being. In addition, most developing countries are facing food security issues due to livestock diseases, particularly foot-and-mouth diseases (FMD). FMD causes detrimental impacts on countries that are already struggling with limited food production. According to Tonsor and Schulz (2020), it was estimated that 77% of the global livestock population is affected by FMD. Moreover, in poor countries, FMD negatively affects the herd's fertility and overall health and leads to direct livestock losses. Consequently, this leads to food security issues and causes malnutrition.

Diwan *et. al.*, (2021) under scored the limitations of conventional, unaided monitoring during livestock parturition, labeling it as costly, time-consuming, and ineffective for extensive farming. Recognizing the evolving landscape of technology, the integration of wearable devices into animals emerges as a pivotal solution to monitor their health status (Neethirajan, 2020). Building on this, studies by Gattani *et al.* (2019) and Neethirajan *et al.* (2017) advocated the efficacy of biosensor technologies in real-time tracking and recording of farm animals' physiology, behavior, and living conditions. These advancements prove instrumental in critical aspects of farm management, such as accurate milking, estrus monitoring, epidemic disease alerts, and precise feeding. Tail sensors provide a non-invasive monitoring solution for physiological parameters, optimizing herd reproductive performances and reducing farm labor. They monitor cow activity, body temperature, and rumination behavior, alerting cattle farmers about individual animals needing special care (Saint-Dizier & Chastant-Maillard, 2018). Tail sensors have shown a promising impact in detecting early signs of fever, estrus, and impending calving, providing farmers with valuable insights into their livestock's health and reproductive status (Herlin, 2021).

In light of these technological strides, it is essential to acknowledge the need for a comprehensive evaluation of the effectiveness of a monitoring device across diverse livestock species, specifically cows and pigs. Thus, it is imperative to underscore the existing gap in local studies and innovations within the livestock health technology domain. Consequently, this research aimed to design and develop a wearable tail sensor that integrates heat, motion, and pulse sensors for the early detection of fever, estrus, and parturition.

Specifically, the research (a) designed a wearable tail sensor; (b) developed program logic for the prototype; (c) tested the functionality of the components; (d) tested the accuracy of the measurements; and (e) evaluated the level of acceptability and adaptability of the developed wearable tail sensor. The development and implementation of this tail sensor held the promise of bridging crucial gaps in estrus and parturition monitoring and revolutionizing fever detection. By enhancing the precision of livestock management, this innovation has the potential to transform the entire livestock industry. Moreover, the benefits extend beyond individual farms, providing the broader farming community with an invaluable instrument to elevate livestock management techniques, ensure the sustained productivity and health of their animals, as well as addressing food security issues (SDG 2).

II. MATERIALS AND METHODS

2.1 Materials

This research project aimed to develop a wearable tail sensor using a variety of materials that ensured functionality and reliability. This project utilized key sensors including the MAX30102 Pulse Oximeter for pulse detection, the MPU605O Accelerometer and SW-420 Vibration sensor for movement detection, and the DS18B20 Temperature sensor for temperature detection. Other essential materials include an ESP 32 microcontroller board for data processing, a 1200 mAh Li-Po battery to power up the tail sensor, and a TP4056 Battery Charging board (C type) for charging the battery. The assembly is supported by the Printed Circuit Board (PCB) and soldering lead is used to connect the components. Furthermore, an LED is incorporated for visual feedback of the device.

2.2 Research Design

The study utilized Research and Development (R&D) design based on the 4D model of device development consisting of four phases: define, design, develop, and disseminate (Semmel *et al.*, 1974). During the defining phase, the researchers identified basic problems in livestock, which provided basic knowledge for designing a livestock wearable device. The criteria for the developed innovation could be seen from functionality, accuracy, and practicality which were tested in the development phase (Akker *et al.*, 2013). The functionality was tested on various parameters; accuracy can be seen in the performance of innovation in the field test; and practicality is based on the evaluation questionnaire on the acceptability and adaptability of the innovation. After acquiring the innovation with functional, accurate, and practical criteria, development proceeded to the dissemination phase. In this phase, the developed innovation was pilot-tested to a limited number of engineers, veterinarians, and livestock raisers, with the goal of receiving responses and feedback about the innovation.

2.3 Procedure

The procedures employed in making the Wearable Tail Sensor involved the discussion and application of its design, development, efficiency, functionality, and acceptability and adaptability. In the designing stage, the researchers focused on conceptualizing and prototyping the Wearable Tail Sensor to visualize its dimensions and assemble the materials. It was then followed by the development stage wherein program logic was made for accurate data capture and motion, temperature, and pulse detection, ensuring a consistent and smooth wireless transfer of data by the Microcontroller to a web server using Wi-Fi. Consequently, the testing of the efficiency and functionality of the Wearable Tail Sensor included a meticulous inspection of the prototype's performance, confirming that it effectively detected early signs of fever, estrus, and parturition in livestock, while sending accurate data for instantaneous monitoring. Ultimately, the functionality of the prototype was critically assessed against certain criteria that could identify any areas of improvement, evaluating the acceptability and adaptability of the Wearable Tail Sensor and enhancing it for maximum efficacy and flexibility.

2.3.1 Designing the Wearable Tail Sensor

Initially, the researchers started by planning the needed materials for the wearable tail sensor. Subsequently, a prototype design was developed using Tinker cad. The wearable tail sensor consists of key sensors, including a pulse oximeter, accelerometer, vibration sensor, and temperature sensor. Specifically, this study utilized the MAX30102 Pulse Oximeter, MPU605O Accelerometer, SW-420 Vibration sensor, and TS18B20 Temperature sensor, which were powered up by a 1200 mAh Li-Po battery. An insulator was inserted between the power source and the sensors to prevent interference with the readings of each component. After that, the components were enclosed in a casing. Furthermore, the tail sensor was fastened to the ventral tail base of the livestock using elastic medical bandages and a surrounding hook-and-loop fastener to ensure its stability.

(a) Back view **(b) Front view**

Figure 1: Prototype Design

The ESP32 microcontroller, powered by the power supply, serves as the transmitter of the data collected from the temperature, pulse, and motion sensors. With the use of Wi-Fi, the ESP32 Microcontroller can wirelessly send the data to a web server that can monitor the status conditions of the livestock, enabling the farmer to access the data collected from the system.

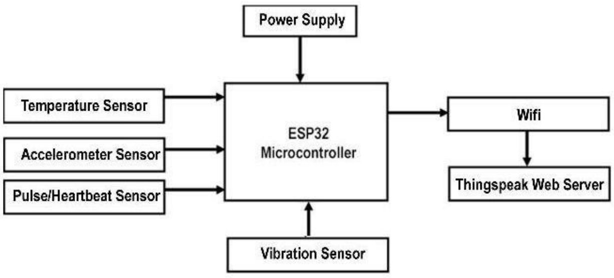


Figure 2: Block Diagram

The circuit connection of the wearable tail sensor is illustrated in Figure 3. The ESP32 microcontroller is powered by a 3.7V Li-Po Battery connected to a TP4056 Charging Board, allowing the device to be rechargeable. The microcontroller transmits data gathered by the MPU6050 Accelerometer and SW-420 Vibration sensor, which measures motion, the TS18B20 Temperature sensor which measures temperature, and the MAX30102 Pulse Oximeter, which measures the pulse. Furthermore, through Wi-Fi connectivity, the microcontroller can wirelessly transmit data to a web server. This allows the user to access the data collected from the system, and detect signs of fever, estrus, and parturition.

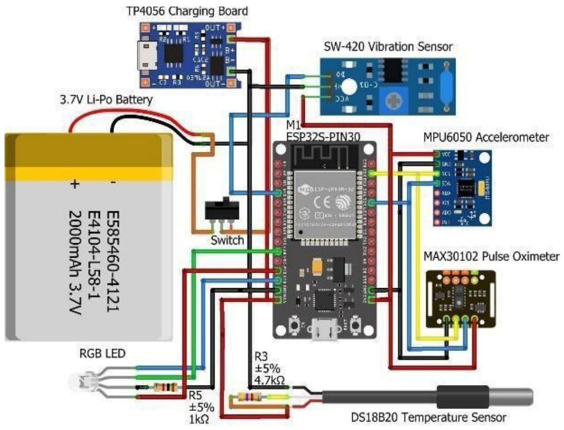


Figure 3: Circuit Connection

2.3.2 Develop a program logic for the prototype

In programming the device, this study employed C++ as its main programming language due to its low development costs by allowing code reuse and providing programs with a clear structure. Applications written in C++ can be tailored to run on a variety of platforms because the language is portable.

The system flow of the program is depicted in Figure 4. Initially, the program starts and begins its execution. If the microcontroller is connected to a WiFi network, the program will initialize the accelerometer and vibration sensor for movement to start measuring data regarding movement. This involves setting up necessary parameters and configurations to enable the sensor to accurately collect data regarding movement.

Similar to the accelerometer sensor, the program also initialized the pulse sensor and temperature sensor for it to proceed with capturing data related to the pulse rate and temperature. Once the sensors are initialized, the collected data from the sensors are then read by the program. Subsequently, the data would communicate to the microcontroller web server, allowing the data to be displayed in real time to the user.

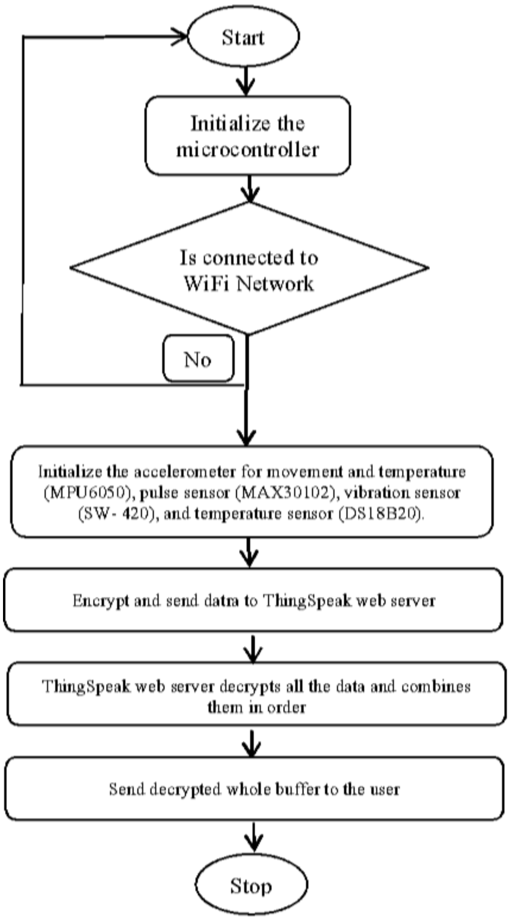


Figure 4: System Flow

2.3.3 Functionality test of the components

The functionality of the sensor was tested by observing the Light Emitting Diode (LED). If the device is connected to the internet, not connected to the internet, and transferring data from the device to the web server a green light, red light, and a blinking blue light will turn on, respectively. The data measured will be uploaded to the web server, ThingSpeak, indicating that the device is fully functional.

2.3.4 Accuracy Test of the Measurements

To test the accuracy of the measurements, the measured values of the wearable tail sensors were compared to values measured manually. In terms of temperature, the measurements of the sensor were compared to measurements obtained by placing the thermometer in the ventral tail of the livestock animals (Sellier *et al.*, 2015). In measuring the logarithmic contraction of an artery, the pulse will be manually measured using a stethoscope (Team, 2022). To determine the accuracy of the measurement of the device, a two-sample t-test assuming equal variances was used.

2.3.5 Evaluation of the level of acceptability and adaptability of the developed wearable tail sensor

Evaluating the acceptability and adaptability of the developed wearable tail sensor is essential for ensuring accurate and reliable information collection. A survey questionnaire was utilized to gather feedback from engineers on the reliability and adaptability of the tail sensor.

2.3.5.1 Respondents and Sampling Technique

The respondents of the study are experts selected via purposive sampling. An evaluator should be:

(a) a degree holder of any engineering course (preferably electronics and communication engineering); (b) employed and practicing the profession for at least 3 years; and (c) residing in Region XII, Philippines.

2.3.5.2 Research Instrument

The questionnaire was developed and pilot- tested. Cronbach's alpha was computed to test the internal validity of the items. A 5-point Likert scale survey will evaluate the acceptability and adaptability of the wearable tail sensor developed in this study.

2.4 Data Analysis

For accuracy testing, the wearable tail sensor's measurements were compared to analog measurements using the t-test for two independent samples. For the level of acceptability and adaptability of the prototype, the weighted mean of the responses of the evaluators was computed. Furthermore, Microsoft Excel was utilized to analyze the data. The table below is used for the interpretation of the weighted mean.

Table 1: Table of Interpretation for Levels of Acceptability and Adaptability

Range	Description	Interpretation
4.50-5.00	Strongly Agree	Very High Level
3.50-4.49	Agree	High Level
2.59-3.49	Neutral	Moderate Level
1.50-2.49	Disagree	Low Level
1.00-1.49	Strongly Disagree	Very Low Level

2.5 Ethical Consideration

The researchers first sought the permission of the school to conduct the said study focused on making a wearable tail sensor and the researchers then asked for the consent of the livestock owners for the participation of their livestock in the study. Acquiring consent from livestock owners to use their animals in research is the initial step in the process. It is crucial to clearly explain the device's function, operating methods, and potential effects on the animals so that owners are fully aware. Owners were informed of their right to withdraw their livestock from the study at any stage, which was sincerely respected by the researchers.

The study set the utmost priority on the well- being of the animals, prioritizing their protection from harm, stress, or discomfort. Adherence to governmental regulations concerning the use of animals in research was strictly followed. When the study was over, confidential information was handled with the utmost confidentiality and was immediately destroyed. Furthermore, this research paper was also free from plagiarism.

III. RESULTS AND DISCUSSION

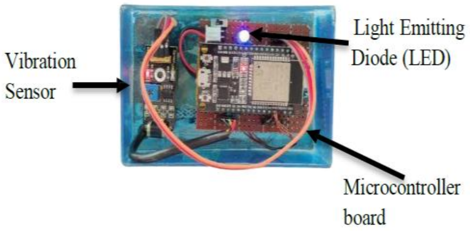
This section presents the gathered data and interpretation of the tail sensor. This includes the results regarding the developed tail sensor, functionality, accuracy, and the level of acceptability and adaptability.

3.1 Wearable Tail Sensor

The researchers successfully designed and developed a Wearable Tail Sensor. To complete the device, the researchers first planned the layout of the sensors in the circuit board. The researchers considered the placements of each component while ensuring that the connection was efficient and well-organized. After which, the researchers assembled the microcontroller board by soldering the sensors onto the circuit board. Subsequently, they wired each sensor to the appropriate pins on the circuit board according to the sensors' specifications.

After the device was assembled, the researchers wrote the code to read data from each sensor using the microcontroller. Moreover, the researchers enclosed the device in a casing made of Polycarbonate to ensure its safety and stability.

(a) top view **(b) bottom view**



(c) interior view

Figure 5: Wearable Tail Sensor Prototype

3.2 Program Logic

Once the device is turned on, its boot sequence starts. The device then attempts to connect to the internet as soon as it starts up. Sensors, including the accelerometer (MPU6050), vibration sensor (SW-420) for movement detection, pulse sensor (MAX30102), and temperature sensor (DS18B20) initialize and indicate readiness by turning green. The LED indicator turns into a static blue light, signaling that the device is connected to the internet and thus, automatically collects information, once blinking, it is already transmitting data to the web server. The microcontroller then processes the data gathered by the sensors and transmits the data to the web server. When the web server receives the data, it reads, processes, and interprets the measurements through separate graphs that correspond to a specific variable. The web server then arranges and displays the gathered data for the user’s use.

3.3 Functionality Tests

To test the functionality of the tail sensor, the researchers conducted tests to assess its ability to accurately initialize and transfer data to the web server when the device is connected to the internet. The results of these experiments are presented in the tables below:

Table 2: The functionality of the Light Emitting Diode (LED) and Wi-Fi Module in its offline, online, and data transmission stage, and the device is turned on simultaneously

NODE	Initial		CONDITION	FINAL	
	Indicator	OUTPUT		Indicator	OUTPUT
1(LED)	Gray	Off	Turned On	Red	On
	Gray	Off	Turned on and Connected to the Internet	Green	On
	Gray	Off	Turned on and Transferring Data	Blinking Blue	On

The table above shows the result of the functionality test of the Light Emitting Diode (LED). The results indicated that when the LED is turned on and is red, it means that the device is offline thus, it is not transmitting any data. However, if the light turns green, it means that the device is on and is ready to transmit data. Lastly, if the light turns into a blinking blue light, it means that the device is transmitting data to the web server.

Table 3: The functionality of the Temperature Sensor and Wi-Fi Module in its offline, online, and data transmission stage, and the device is turned on simultaneously

NODE	Initial		CONDITION	FINAL	
	Indicator	OUTPUT		Indicator	OUTPUT
1 (Temperature Sensor)	Gray	Off	Turned on, connected to the internet, and transferring data.	Red	On

Table 3 shows the result of the functionality test of the temperature sensor. Initially, the LED is gray, indicating that the device is turned off. When the sensor’s LED turns red, this means that it was turned on, connected to the internet, and transferring data to the web server. This implies that the temperature sensor was fully functional.

Table 4: The functionality of the Vibration Sensor and Wi-Fi Module in its offline, online, and data transmission stage, and the device is turned on simultaneously

NODE	Initial		CONDITION	FINAL	
	Indicator	OUTPUT		Indicator	OUTPUT
1 (Vibration Sensor)	Gray	Off	Turned on, connected to the internet, and transferring data.	Red	On

Table 4 shows the result of the functionality test of the vibration sensor. The vibration sensor has a small LED that turns red when the device is turned on. This indicates that the vibration sensor is on and functioning, automatically transmitting data to the web server ThingSpeak.

Table 5: The functionality of the Pulse Sensor and Wi-Fi Module in its offline, online, and data transmission stage, and the device is turned on simultaneously

NODE	Initial		CONDITION	FINAL	
	Indicator	OUTPUT		Indicator	OUTPUT
1(Pulse Sensor)	Gray	Off	Turned on	Red	On

Table 5 presents the result of the functionality of the pulse sensor. Once the device is turned on, the pulse sensor has a small LED that turns into red indicating that the pulse sensor is on and is functioning. Once the pulse sensor is on, it automatically sends data to the web server.

Table 6: The functionality of the Accelerometer and Wi-Fi Module in its offline, online, and data transmission stage, and the device is turned on simultaneously

NODE	Initial		CONDITION	FINAL	
	Indicator	OUTPUT		Indicator	OUTPUT
1(Accelerometer)	Gray	Off	Turned on	Red	On

Table 6 shows the result of the functionality test of the accelerometer. Once the device is turned on, the accelerometer has a small red LED light that indicates that the accelerometer is on and functioning. Once the pulse sensor is on, it automatically sends data to the web server.

3.4 Accuracy Tests

The accuracy of the prototype was determined by comparing the temperature of normal livestock and livestock with fever; the temperature, pulse rate, and movement of normal livestock and livestock near labor; and the temperature, pulse rate, and movement of normal livestock and livestock in heat.

3.4.1 Accuracy in determining fever

Table 7: Result of test of difference for Temperatures of Normal Livestock and Livestock with Fever

	TailSensor		Thermometer		t	p	Cohen's d
	M	**SD**	**M**	**SD**			
Normal Cow	37.08	1.69	37.07	1.70	0.008	0.994	0.006
Cow with Fever	40.46	0.44	40.47	0.46	-0.022	0.983	0.022
Normal Pig	31.64	0.37	31.63	0.38	0.027	0.980	0.027
Pig with Fever	40.35	0.11	40.37	0.12	-0.167	0.875	0.174

Table 7 presents the results of a comparison between the data gathered by the tail sensor and the data gathered using a thermometer. The mean for normal cows using the thermometer was 37.07 (SD = 1.70) while the data collected by the tail sensor had a 37.08 mean (SD=1.69) (t = 0.008, p = 0.994, Cohen's d = 0.006). The cow with a fever has a mean temperature of 40.47 (SD=0.47). The tail sensor measures 40.46 as mean (SD=0.44) (t = -0.022, p= 0.983, Cohen's d = 0.022). The data for the normal pig had a mean of 31.63 (SD=0.38) using a thermometer while 31.64 mean (SD=0.37) for the tail sensor (t = 0.027, p = 0.980, Cohen's d = 0.027). The pig with fever, on the other hand, had a temperature of 40.37 (SD=0.12) using a thermometer while in using the tail sensor, it had a mean of 40.35 (SD=0.11) (t= -1.67, p= 0.875. Cohen's d=0.174). This indicates that there is no significant difference between analog measurements and tail sensor measurements. These results align with the study conducted by Zhang *et al.* (2019) and Burfeind *et al.* (2013) in which their findings suggest that body temperature rising from 40 degrees Celsius and above shows clinical signs of both pigs and cows having fever and in worst case, hyperthermia. Statistics reveal that 80% of cases during the breeding process are mainly fever and some bacterial hyperthermia. This suggests that the data gathered using the device results in accurate and precise data in terms of measuring temperature.

3.4.2 Accuracy in determining estrus

Table 8: Result of test of difference for Temperatures of Normal Livestock and Livestock in heat

		Normal Livestock		Livestock in heat		t	p	Cohen's d
		M	**SD**	**M**	**SD**			
Temperature (in Celsius)	Cow	37.08	1.69	40.41	0.36	-2.727	0.026	1.217
	Pig	31.64	0.37	33.75	0.93	-2.961	0.041	2.981

Table 8 shows the results and data of the difference of the temperatures between normal livestock and livestock in heat. The findings suggest that there is a significant difference between them. Consequently, several studies align with these results. According to Wrenn *et. al* (2013), temperatures fluctuate with the estrus cycle, ranging from low before heat to high on heat days.

Randi et al. (2018) also made similar observations in pigs, finding that a significant increase in surface temperature is associated with the onset of estrus. This implies that the tail sensor is reliable in producing accurate and precise measurements regarding livestock temperature.

Table 9: Result of test of difference for the movements of Normal Livestock and Livestock in heat

		Normal Livestock		Livestock in heat		t	p	Cohen's d
		M	SD	M	SD			
Vibration (in k)	Cow	388.33	225.81	170,798	59,175.63	-4.067	0.015	4.073
	Pig	601.67	274.40	338,635.33	74,518.67	-6.419	0.003	6.415

Table 9 shows the results recorded by the researchers, which used a two-tailed t-test comparing the movements of normal livestock and livestock in heat in terms of the vibration sensor. These findings suggest that there is a significant difference between the movement of normal livestock and livestock in heat. As stated in an article, increased movement and restlessness indicate signs of estrus in both cattle and pigs (Sterry & Schlesser, 2018). A study from Reith and Hoy (2018) also said that symptoms of estrus include mounting, activity, aggressive, and agonistic behaviors. These findings set apart the measurements that indicate estrus in livestock from normal livestock therefore the data transmitted the device is accurate and reliable.

3.4.3 Accuracy in determining parturition

Table 10: Result of test of difference for Temperatures of Normal Livestock and Livestock during Parturition

		Normal Livestock		Livestock during		t	p	Cohen's d
		M	SD	M	SD			
Temperature (in Celsius)	Cow	37.08	1.69	31.60	1.84	3.095	0.036	3.102
	Pig	31.64	0.37	33.44	0.18	-6.130	0.003	6.187

Table 10 shows the results and data of the difference of the temperatures between normal livestock and livestock during parturition. The results indicate that there is a significant difference between the two. These findings align with the study of Miwa *et. al.* (2019) who reported that surface temperature decreased about 30 hours before parturition in cattle, which corresponded to the time of the decrease in ventral temperature and earlier than the increase of behavioral indices. Furthermore, the findings of Littledike *et al.* (2015) show that an increase in body temperature was associated with parturition in sow the increase in body temperature began about 12 hours before the first pig was born and peaked 1-2 hours after the last pig was delivered. These further suggest that the tail sensor device has accurate and precise measurements in detecting temperature to detect parturition.

Table 11: Result of test of difference for Pulse Rates of Normal Livestock and Livestock during Parturition

		Normal Livestock		Livestock during		t	p	Cohen's d
		M	SD	M	SD			
Temperature (in Celsius)	Cow	83.00	18.55	131.33	10.33	-3.219	0.049	3.219
	Pig	91.33	3.68	102.33	2.05	-3.689	0.035	3.693

Table 11 shows the results recorded by the researchers, which used a two-tailed t-test comparing the pulse rate measurements normal livestock and livestock during parturition. The results indicate that there is a significant difference between the two. These findings align with the study of Trenk *et al.* (2015), who also reported an increase in heart rate in cows during late gestation. Similarly, Marchant-Forde and Marchant- Forde (2004) observed an increase in mean heart rate during pregnancy in pigs. These findings provide further evidence for the physiological changes associated with parturition, including an increase in heart rate. This further indicates that the data transmitted by the device is accurate and reliable.

Table 12: Result of test of difference for the movements of Normal Livestock and Livestock during Parturition

		Normal Livestock		Livestock during Parturition		t	p	Cohen's d
		M	SD	M	SD			
Vibration (in k)	Cow	388.33	225.81	1,477	112.04	-6.108	0.004	6.108
	Pig	Pig	601.67	274.40	5,786.33	1,495.62	-4.822	0.009

Table 12 shows the results recorded by the researchers, which used a two-tailed t-Test comparing the movements of normal livestock and livestock during parturition in terms of the vibration sensor. These findings suggest a significant difference between the movements of normal livestock and livestock during parturition. According to the study of Marchand *et al.* (2021), the detection of parturition was much improved when movement metrics by the mother were monitored. During parturition, the sows and cow become restless and their movements are increased than normal (Neary, 2016). The results indicate a difference of movement between normal livestock and livestock during parturition. Furthermore, the findings reveal that cattle and pigs undergoing parturition exhibit increased movement, yet their movement remains lower than those in estrus.

3.5 Level of Acceptability and Adaptability

The validity of the questionnaire is assessed in this study employing Cronbach's alpha. The researchers utilized a self-made 5-point Likert scale questionnaire with two parts on acceptability and adaptability with a total of 17 items. To guarantee the validity and reliability of the instrument, experts performed pilot testing. Furthermore, the results of the pilot tests revealed that the level of acceptability yielded a Cronbach's alpha of 0.75 and the level of adaptability yielded a Cronbach's alpha of 0.63. The high Cronbach's alpha indicates that the questionnaire is indeed reliable and applicable for evaluating the level of acceptability and adaptability of the prototype.

Table 13: Level of Acceptability of the Prototype

Statement	Mean	Descriptor	Interpretation
1) Understanding the functionality of the prototype was easy.	3.66	Agree	High Level of Acceptability
2) I am satisfied with the performance of the prototype.	3.5	Agree	High Level of Acceptability
3) I am likely to recommend this prototype to others.	3.66	Agree	High Level of Acceptability
The prototype was intuitive and easy to use.	3.83	Agree	High Level of Acceptability
The prototype design/layout is intricate and well-thought out.	4	Agree	High Level of Acceptability
The wire management of the prototype is satisfactory.	4	Agree	High Level of Acceptability
The features of the prototype are relevant to its purpose.	4.5	Strongly Agree	Very High Level of Acceptability
The different parts of the prototype are easy to navigate.	4.5	Strongly Agree	Very High Level of Acceptability
Overall, I am satisfied with the prototype.	4.5	Strongly Agree	Very High Level of Acceptability
Weighted mean	**4.02**		**High Level of Acceptability**

The table above shows the acceptability ratings for the wearable tail sensor. Overall, with a mean rating of 4.02, the evaluators strongly agreed on the relevance of the prototype's features to its purpose. This implies that the components of the device are effective and suitable for its intended function. Stated by Fischbein *et al.* (1981), high levels of intuitive acceptance in this context refer to situations with high percentages of correct solutions and high levels of confidence in the solution. Also, with a mean rating of 4.50, evaluators strongly concurred on the ease of navigating the different parts of the prototype, underscoring the user-friendly feature of the device. Additionally, having also a mean rating of 4.02, evaluators strongly agreed on their overall satisfaction with the prototype, indicating a high level of contentment with its overall design, function, and performance. However, despite receiving the lowest mean rating of 3.50, evaluators still expressed satisfaction with the device's performance, suggesting a potential area for improvement. The overall level of acceptability of the device garnered a weighted mean of 4.02, signaling a high level of acceptability. This indicates that the high level of acceptability in this research refers to benefits such as timely management decisions, reduced posting errors, and ease of use, among others (Sasadeeong, 2023). Hence, the device can be used in real-world applications, especially in agricultural farms, and can be effortlessly used by the local community.

Table 14: Level of Adaptability of the Prototype

Statement	Mean	Descriptor	Interpretation
The prototype can easily be adjusted to fit different user needs.	3.17	Neutral	Moderate Level of Adaptability
It is easy to add new features or functions to the prototype.	3.3	Neutral	Moderate Level of Adaptability
Users can change settings or how the prototype works without trouble.	3.66	Agree	High Level of Adaptability
The prototype can keep up with new trends or technology changes.	4.3	Agree	High Level of Adaptability

Users can make the prototype fit different places or conditions.	3.66	Agree	High Level of Adaptability
Putting together or taking apart the prototype is simple and doesn't need special tools.	4.17	Agree	High Level of Adaptability
The prototype's materials are strong and can handle different kinds of weather.	3.83	Agree	High Level of Adaptability
Storing, moving, and using the prototype in different places is easy.	4.67	Strongly Agree	Very High Level of Adaptability
Weighted mean	**3.85**		**High Level of Adaptability**

Table 14 indicates the ratings of the level of adaptability of the wearable tail sensor. Overall, with the highest mean rating of 4.67, the evaluators strongly agreed that it is easy to store, move, and use the prototype in different places, which suggests that the prototype is portable. With the use of optimal decision rules and applications in data fusion and data mining, a network of sensors can identify and classify signals with efficiency (Tenney *et. al*, 1980). Conversely, with the lowest mean rating of 3.17, the evaluators were neutral regarding the ease of adjusting the prototype to accommodate different user needs, implying the necessity for further enhancements to meet a broader range of user requirements. The overall result of the level of adaptability of the prototype received a weighted mean of 3.85, implying a high level of adaptability. This suggests that the prototype demonstrates promising versatility, suggesting its potential suitability for various applications.

IV. CONCLUSIONS

In conclusion, the researchers successfully developed a device integrating four sensors to detect fever, parturition, and estrus in livestock. This study shows a functional program that transmits real-time data to a web server, integrating different colors to indicate different motions. Additionally, the functionality of the device was assessed by observing the LED as it represents different interpretations and conditions, revealing that all components are functional. The accuracy test of the developed prototype implied that the measurements between the analog and developed prototype has no significant difference. Moreover, the study reveals that there is a high level of acceptability and adaptability. These findings suggest and show that the potential of this device as a monitoring device for livestock health and conditions contributes to the community and is well-researched. Overall, the study achieved and reinforced ideas that highlight the importance of exploring and progressively enhancing agricultural technology and innovations.

V. RECOMMENDATIONS

Based on the findings and emerging data of the study, several recommendations have emerged to enhance the utilization and increase the device's functionality. Design-wise, to optimize usability and durability, priority should be given to redesigning the casing for improved water resistance and reinforcing the strap for secure livestock attachment while ensuring ventral tail comfort and seamless integration. While there is no problem with the device's programming, constant improvement of the program plays a key role in unlocking the device's full potential. Concerning the functionality of the device, it is imperative to incorporate a low battery indicator to alert users when the device requires charging, mitigating risks of unexpected power loss, data corruption, and operational disruptions. While the device shows accurate measurements in comparison to analogue readings, constant monitoring over time must be done to check if the sensors are reading data properly. Having a high level of accuracy and adaptability, the device must be subject to updates to better its establishment as a key innovation in the agricultural sector. Furthermore, it is strongly advised to prioritize continuous improvement and periodic assessments of the device's performance and capabilities. This proactive approach ensures that the device remains an impactful and invaluable tool within the agricultural sector, consistently meeting the evolving needs and challenges faced by industry stakeholders. Through diligent refinement and adaptation, the device can maintain its relevance, efficacy, and utility, thereby solidifying its position as an indispensable asset in the field of agriculture.

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