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Wearable Sensor-Based Birth Prediction System for Indigenous Cattle Breeds

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Abstract: ***Calving is a critical stage in dairy cattle management, and delayed identification of labor can lead to calf mortality, maternal health complications, and economic loss. In many traditional farming systems, calving is monitored manually, requiring constant observation by farmers, which is time-consuming and often unreliable. Therefore, the early prediction of calving is essential to ensure timely assistance during parturition, improve calf survival rates, and enhance overall herd-management. However, conventional monitoring practices primarily rely on visual observation of behavioral changes, making early detection difficult and inefficient in large-scale dairy operations. To address these challenges, this study proposes the development of a wearable sensor-based birth prediction system for indigenous cattle breeds that enables continuous monitoring of physiological and behavioral indicators associated with imminent calving. The proposed device integrates a DS18B20 digital temperature sensor to monitor tail-base temperature variations and an MPU6050 accelerometer sensor to detect tail movement and activity patterns,which typically increase before labor. The sensor data were processed using an ESP32 microcontroller, which analyzed temperature drops and abnormal movement patterns that indicated the onset of the calving. When these indicators exceed the predefined threshold values, the system automatically activates a SIM800L GSM module to send instant SMS alerts to the farmer, enabling timely intervention and assistance. The system is designed as a compact, tail-mounted wearable device powered by a rechargeable lithium-ion battery, making it suitable for continuous monitoring in farm environments. Field observations indicated noticeable changes in temperature and tail activity before calving, validating the effectiveness of these physiological indicators. The developed prototype provides a low-cost, reliable, and farmer-friendly solution for predicting calving. This technology has the potential to reduce manual monitoring, improve reproductive management, enhance animal welfare, and support the advancement of smart livestock farming practices.***

Keywords: Calving Prediction, Wearable Sensor System, Indigenous Cattle Monitoring, ESP32 Microcontroller, Accelerometer Sensor, GSM Alert System, Livestock IoT, Smart Dairy Farming

I. INTRODUCTION

Dairy farming plays a vital role in global agriculture by providing milk and dairy products that contribute significantly to food security and rural livelihoods. Efficient reproductive management in dairy cattle is essential for maintaining consistent milk production and ensuring sustainability in dairy farming. Among the various reproductive events in dairy animals, calving is one of the most critical stages that require close monitoring by farmers. Delayed identification of labor can lead to complications such as calf mortality, maternal health issues, and economic losses for farmers. Therefore,the early prediction of calving is essential to ensure timely assistance during delivery and improve both calf survival rates and animal welfare. Traditional methods of predicting calving rely mainly on manual observation of behavioral and physical changes in cattle. Farmers typically monitor signs such as restlessness, increased tail movement, reduced feed intake, and isolation from the herd to detect estrus in cows. Although these indicators provide useful information, they often require continuous observation by farmers and may not always accurately predict the exact onset of labor in cows. In many dairy farms, particularly small- and medium-scale operations, constant monitoring of animals is difficult because of labor limitations and time constraints. Consequently, calving events are sometimes detected late, increasing the risk of delivery complications and economic loss. Recent advancements in sensor technology and embedded systems have created opportunities for developing smart livestock monitoring systems that assist farmers in efficiently managing animal health and reproduction events. Wearable sensor-based monitoring devices can continuously track the physiological and behavioral parameters associated with calving. Parameters such as tail-base temperature and tail movement activity often change significantly before the onset of labor. By monitoring these indicators using sensors, it is possible to detect the early signs of calving without relying on manual observation. Therefore, this study focuses on the development of a wearable sensor-based birth prediction system for indigenous cattle breeds that monitors temperature and movement patterns using integrated sensors and a microcontroller-based monitoring system to provide early alerts to farmers.

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II. LITERATURE REVIEW

Calving prediction is an important aspect of dairy farm management because delayed detection of labor can lead to calf mortality, maternal health complications, and economic losses. Several studies have focused on identifying reliable physiological and behavioral indicators to predict the calving onset. Saint-Dizier and Chastant-Maillard (2015) reported that significant behavioral changes, such as increased tail activity, restlessness, and isolation from the herd, occur shortly before parturition in dairy cattle. Their findings highlighted that monitoring behavioral patterns can provide early indications of the approaching calving process and assist farmers in preparing for timely intervention.

Body temperature monitoring has also been widely studied as a reliable indicator of calving time. Burfeind et al. (2011) observed that cows experience a noticeable drop in body temperature several hours before calving due to hormonal and metabolic changes associated with the onset of labor. Similarly, Suthar et al. (2012) demonstrated that continuous temperature monitoring using digital sensors effectively identified pre-calving thermal variations. These studies confirmed that temperature measurements provide valuable information for predicting calving and can be used in automated monitoring.

Animal movement and behavioral activities have also been investigated using accelerometer sensors. Ouellet et al. (2016) showed that tail movement and overall activity levels increase significantly in the hours preceding calving. Their research demonstrated that accelerometer-based monitoring systems can capture these behavioral patterns and provide early warning signals. Similarly, Lind et al. (2017) reported that wearable motion sensors can detect changes in cattle behavior related to stress and discomfort before parturition, making them useful for automated livestock monitoring.

Recent research has explored the integration of wearable sensors and communication technologies to improve the accuracy of calving prediction. Rutten et al. (2018) developed a livestock monitoring system that combined temperature and motion sensors with microcontroller-based data processing to identify calving-related indicators in dairy cows. Neethirajan (2020) highlighted the potential of Internet of Things (IoT) technologies in smart livestock farming, where sensor data can be transmitted to farmers through wireless communication systems for real-time monitoring of livestock health. These studies demonstrate that combining multiple sensing techniques with embedded systems can significantly enhance the reliability of calving predictions and improve dairy farm management.

III. EXISTING SYSTEM

Existing calving monitoring systems used in dairy farms are mainly based on traditional observation methods and manual supervision. These methods are commonly used by farmers to identify the onset of labor by observing behavioral and physiological changes in animals. Although these approaches provide useful information on the calving process, they require continuous monitoring and considerable experience,making early prediction of calving difficult for farmers, particularly in small-scale dairy farms, where constant observation of animals is not always possible.

A. Traditional Calving Observation Methods

Traditional calving prediction methods include the observation of behavioral signs such as restlessness, increased tail movement, isolation from the herd, and reduced feed intake. Farmers also monitor physical changes, such as udder enlargement, pelvic ligament relaxation, and vulvar swelling,to identify the approach of labor. Although these indicators provide general information about the calving process, they rely heavily on human observation and may vary between animals. In many cases, these signs appear only a few hours before delivery, which may not provide sufficient time for farmers to prepare for assistance.

B. Conventional Monitoring Techniques

In many dairy farms, calving detection depends on periodic manual inspection of animals by farmers or farmworkers. This method requires frequent checking of cattle, particularly during the expected calving period. However, continuous monitoring is difficult on farms with a large number of animals or limited labor availability.Consequently, calving may occur without timely assistance, increasing the risk of complications such as dystocia, calf mortality, and maternal health problems.

C. Limitations of Existing Systems

Existing calving monitoring systems have several limitations, including dependence on manual observation, lack of continuous monitoring, and delayed detection signs of labor. Traditional methods cannot always detect the subtle physiological changes that occur before calving. Furthermore, most farms lack automated systems that can provide real-time alerts to farmers. These limitations highlight the need for a wearable, low-cost, sensor-based birth prediction system that can continuously monitor physiological and behavioral indicators and provide early warnings to farmers for effective livestock management.

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IV. PROPOSED SYSTEM

The proposed system focuses on the development of a wearable sensor-based birth prediction device designed to detect early signs of calving in dairy cattle using physiological and behavioral indicators. Unlike traditional monitoring methods that depend on manual observation and continuous supervision by farmers, the proposed system provides automated and real-time monitoring by integrating temperature sensing and motion detection capabilities. The system processes the collected data using a microcontroller and sends alert notifications to farmers when signs of imminent calving are detected, thereby enabling timely intervention and improved livestock management.

A. Multi-Parameter Monitoring

The proposed system uses multiple indicators to improve the reliability of the calving prediction. A DS18B20 digital temperature sensor was used to measure the tail-base temperature of the cow to identify temperature variations that occurred before the onset of labor. In addition, an MPU6050 accelerometer sensor was used to monitors tail movement and activity levels,which typically increase during the pre-calving stage. Combining these physiological and behavioral parameters provides a more reliable prediction than monitoring a single indicator.

B. Real-Time Monitoring and Alert System

The system was designed to provide continuous real-time monitoring of the measured parameters. The sensors were connected to an ESP32 microcontroller, which continuously read and processed the sensor data according to predefined threshold values. When abnormal temperature drops and increased tail activity patterns indicating possible labor are detected, the system automatically activates a SIM800L GSM module to send an SMS alert to the farmer. This notification allows farmers to monitor animals remotely and prepare for timely assistance during parturition.

C. Wearable and Low-Cost Design

The proposed device is designed as a compact tail-mounted wearable unit that can be easily attached to the cattle without causing discomfort. All hardware components, including the sensors, microcontroller, GSM communication module, and power supply, were integrated into a protective enclosure. The device is powered by a rechargeable lithium-ion battery, making it suitable for continuous monitoring in farm environments. The use of low-cost electronic components ensures that the system is affordable and accessible to farmers.

D. Early Prediction and Livestock Management

By enabling the early prediction of calving, the proposed system helps farmers take timely action to assist animals during labor. Early detection reduces the risk of complications, such as calf mortality and maternal health issues. It also minimizes the need for constant manual monitoring. Therefore, the system supports improved reproductive management, enhances animal welfare, and contributes to efficient and smart dairy-farm management.

V. METHODOLOGY

The methodology of the proposed system focuses on the development of a wearable sensor-based device for the early prediction of calving in dairy cattle. The system integrates temperature and motion sensors with a microcontroller to continuously monitor the physiological and behavioral changes associated with the onset of labor. The methodology follows a structured process, including requirement analysis, component selection, sensor integration, system assembly, and experimental validation, to ensure reliable calving prediction under real farm conditions.

A. Requirement Analysis

The first step in system development is to identify the biological and behavioral parameters associated with the calving process. Prior to calving, cows exhibit noticeable physiological and behavioral changes, such as a decrease in tail-base temperature and an increase in tail movement activity. These parameters were selected as the primary indicators for early prediction of birth. The system requirements were defined based on practical dairy farm conditions, including low cost, portability, ease of installation on cattle, and the ability to provide early alerts to farmers without the need for continuous manual monitoring.

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B. Component Selection

The system uses an ESP32 microcontroller as the central processing unit because of its high processing capability and built-in communication features. A DS18B20 digital temperature sensor was used to measure the tail base temperature of the cows. An MPU6050 accelerometer and gyroscope sensor were used to detect tail movement and activity patterns that increased before the onset of labor.

A SIM800L GSM module was selected to transmit alert messages to the farmer when abnormal conditions were detected. The system was powered using a rechargeable 18650 lithium-ion battery, and a TP4056 charging module was used for battery management.

C. Microcontroller and Sensor Integration

All the sensors were connected to an ESP32 microcontroller for continuous data acquisition and processing. The DS18B20 sensor communicates with the microcontroller using the One-Wire protocol to provide accurate digital temperature readings of the water. The MPU6050 accelerometer communicates through the I²C interface to measure the motion and orientation data. The ESP32 continuously read the sensor values and compared them with predefined threshold conditions that indicated the possibility of imminent calving.

When a both temperature drop and increased movement activity are detected simultaneously, the system identifies the event as a potential pre-calving condition.

D. Communication and Alert System

A communication interface was implemented to notify farmers of the calving conditions. The SIM800L GSM module connected to the ESP32 sends SMS alert messages when the system detects abnormal sensor readings, indicating the onset of labor. This alert allows farmers to take timely action and provide assistance during deliveries. The automated notification system reduces the need for constant manual monitoring and improves the response time during critical calving periods.

E. Hardware Assembly and Validation

The complete system was assembled as a wearable tail-mounted device suitable for use in farm environments. All components, including the ESP32 microcontroller, sensors, GSM module, battery, and charging unit were integrated into a compact protective enclosure.

The device is attached to the tail region of the cattle to continuously monitor temperature and movement. The system was tested under farm conditions to observe temperature variations and tail activity before calving. The collected data were analyzed to verify the reliability of the selected indicators for predicting the onset of labor, ensuring that the system functions effectively as an early birth prediction device for dairy cattle.

VI. SYSTEM ARCHITECTURE

The system architecture of the Wearable Sensor-Based Birth Prediction System for Indigenous Cattle Breeds was designed as a modular and integrated framework that enabled continuous monitoring, data processing, and automated alert generation. The Sensing Module collects physiological and behavioral parameters using sensors such as the DS18B20 temperature sensor and MPU6050 accelerometer sensor**.**

These sensors monitor tail-base temperature and tail movement activity, which are important indicators of the onset of calving. The Processing Module (ESP32 microcontroller) analyzes the sensor data, performs filtering and threshold comparison, and identifies abnormal patterns indicating possible pre-calving conditions.

The Communication Module uses a SIM800L GSM module to transmit SMS alerts to the farmer when the system detects significant temperature drops and increased motion activity. A Power Management Module consisting of a rechargeable lithium-ion battery and charging circuit ensures the continuous operation of the wearable device. A continuous monitoring loop allows the system to repeatedly collect and analyze data, ensuring reliable real-time detection and timely notification to farmers without the need for constant manual observations.

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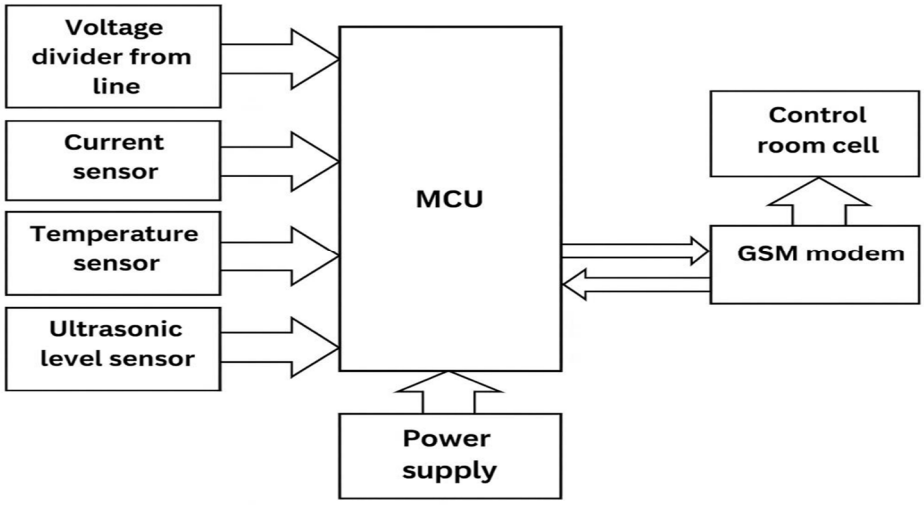


Figure 1. Wearable Birth Prediction System Architecture

VII. ADVANTAGES OF DEVICE

The wearable birth prediction device offers several advantages over conventional calving monitoring methods. Its sensor-based, automated, and farmer-friendly design makes it suitable for continuous monitoring in dairy farm environments.

1) *Rapid Early Prediction:* The device provides early alerts regarding possible calving conditions by continuously monitoring the temperature and movement patterns. This enables farmers to prepare for delivery and provide timely assistance during the labor process.
2) *Non-Invasive and Animal-Friendly:* The system uses wearable sensors to monitor tail-base temperature and tail movement without causing pain or stress to the animal. The tail-mounted design ensures comfortable and safe operation for cattle.
3) *Cost-Effective Solution:* The use of low-cost electronic components, such as ESP32, DS18B20, and MPU6050 sensors, makes the system affordable for small- and medium-scale dairy farmers, reducing the need for expensive monitoring systems.
4) *Automated Monitoring and Alert System:* The system automatically monitors cattle behavior and physiological conditions without the need for continuous human observation. When abnormal conditions indicating calving are detected, the GSM module sends an SMS alert to the farmer, allowing for remote monitoring and a quick response.
5) *Improved Livestock Management:* By providing an early prediction of calving, the system helps farmers reduce complications during delivery, improve calf survival rates, and enhance overall reproductive management on dairy farms.

VIII. RESULT

The Wearable Sensor-Based Birth Prediction System for Indigenous Cattle Breeds was tested on dairy cattle to evaluate its performance in predicting the onset of calving in the latter. The results demonstrated the effectiveness and reliability of the device as follows:

1) Temperature Monitoring: The DS18B20 temperature sensor accurately measured tail-base temperature variations, detecting the gradual temperature drop that occured before the onset of calving.
2) Tail Movement Detection: The MPU6050 accelerometer successfully monitored tail movement and activity levels, identifying increased motion patterns associated with pre-calving behavior.
3) Real-Time Monitoring: The system continuously collects sensor data and processes them using the ESP32 microcontroller, enabling real-time monitoring of physiological and behavioral changes.
4) SMS Alert Notification: The SIM800L GSM module successfully transmitted SMS alerts to the farmer when predefined threshold conditions indicating possible calving were detected.
5) Accuracy and Reliability: The system effectively identified combined indicators, such as a decrease in temperature and an increase in tail activity, demonstrating a reliable prediction of potential calving events.
6) User-Friendly Operation: The wearable device was easy to install on the cattle tail and operated continuously with minimal farmer intervention, making it suitable for practical farm conditions.

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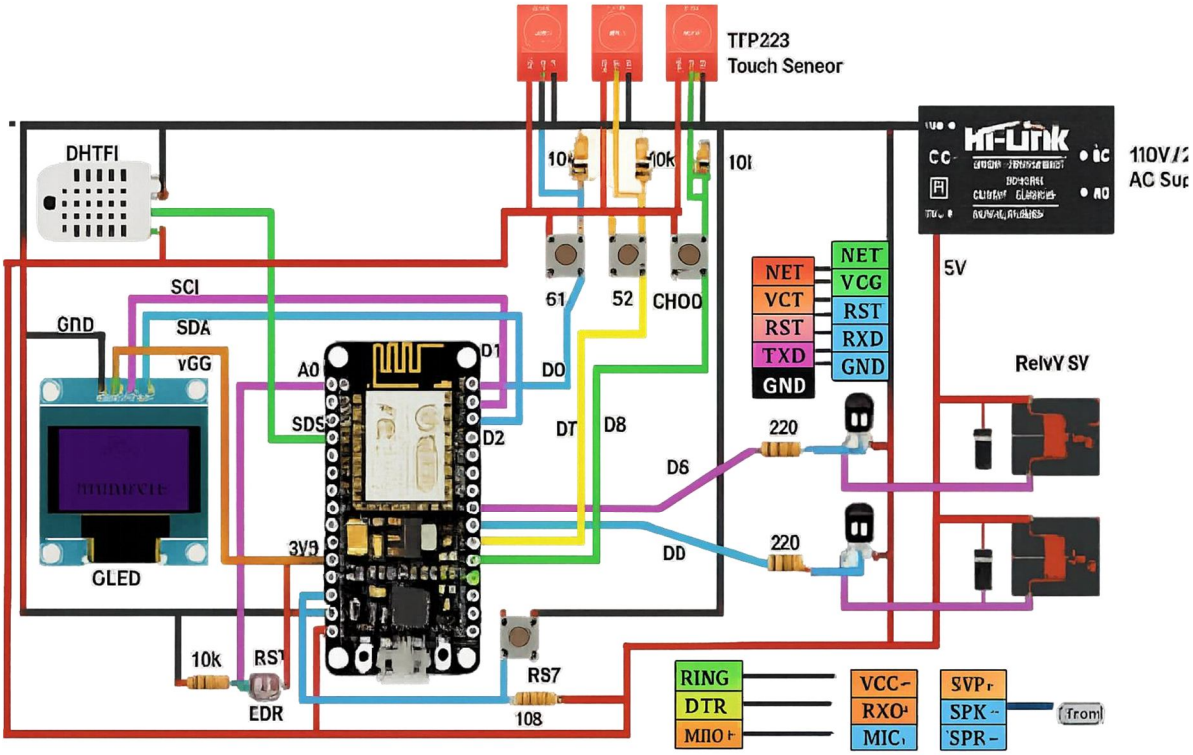


Figure 2. Circuit Diagram

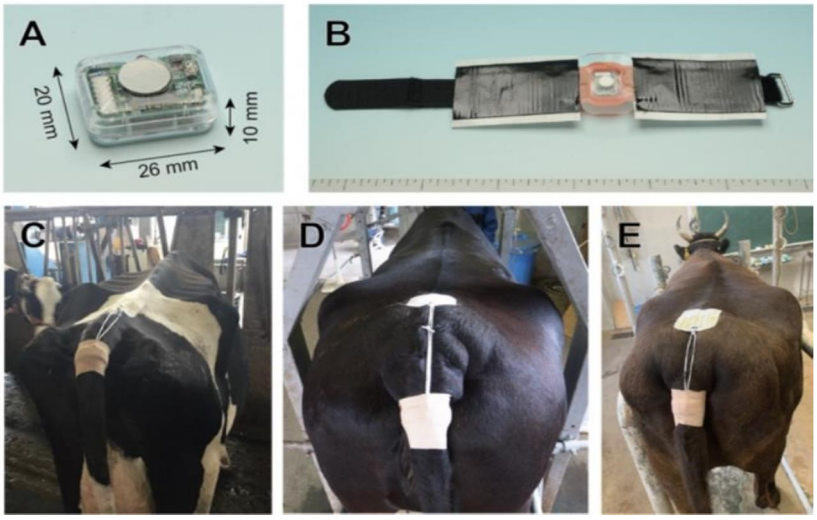


Figure 3. Device Installation on Cattle

Day	Month stage	Temperature (°c)	Motion value	Observation
Day 1	8th Month	38.6	12000	Normal
Day 3	8th Month	38.6	12500	Normal
Day 5	8th Month	38.5	11800	Normal
Day 7	8th Month	38.6	12200	Normal

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Day 9	8th Month	38.5	13000	Normal
Day 11	8th Month	38.5	12800	Normal
Day 13	8th Month	38.6	13500	Normal
Day 15	8th Month	38.5	13200	Normal
Day 17	8.5 Month	38.4	14000	Slight activity increase
Day 19	8.5 Month	38.4	15000	Restlessness observed
Day 21	8.5 Month	38.4	16500	Increased movement
Day 23	8.5 Month	38.3	18000	Tail flicking increased
Day 25	9th Month	38.3	19500	Behavioural change visible
Day 27	9th Month	38.2	21000	Frequent movement
Day 29	9th Month	38.2	22500	Restlessness
Day 31	9th Month	38.1	24000	Abnormal activity
Day 33	9th Month	38.1	26000	Labour signs approaching
Day 35	9th Month	38.0	28500	Pre-calving stage
Day 36	Calving Day	37.9	32000	Alert triggered – Birth occurred

Figure 4. Temperature and Motion Monitoring during Late Gestation.

IX. CONCLUSION

The development of the Wearable Sensor-Based Birth Prediction System for Indigenous Cattle Breeds successfully demonstrated an efficient, reliable, and affordable approach for the early prediction of calving in dairy cattle. By integrating a DS18B20 temperature sensor, MPU6050 accelerometer sensor, GSM communication module, and ESP32 microcontroller-based processing unit**,** the device enables continuous monitoring and real-time analysis of the physiological and behavioral indicators associated with the onset of labor. The automated alert system sends SMS notifications to farmers when abnormal conditions are detected, allowing for timely intervention and reducing risks during the calving process.

The wearable and noninvasive design of the device ensures animal comfort while providing consistent and reliable monitoring results under practical farm conditions. Its compact structure, ease of installation, and low-cost components make it highly suitable for small- and medium-scale dairy farms, where continuous manual monitoring of cattle is difficult. Furthermore, the modular architecture of the system allows for future improvements, such as integration with mobile applications, cloud-based monitoring, and advanced data analysis techniques, to enhance livestock management efficiency.

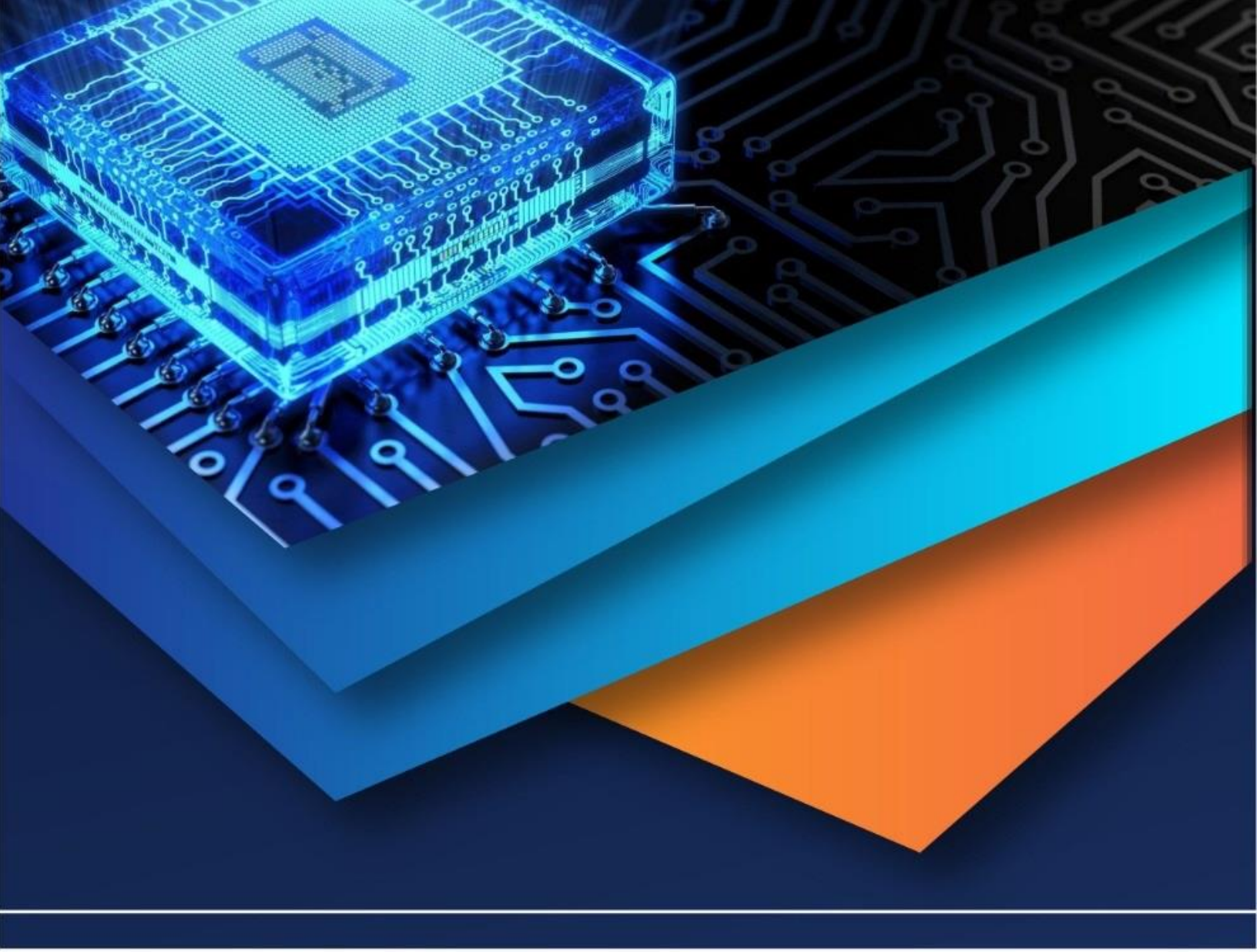
Overall, this project highlights the potential of sensor-based smart livestock monitoring systems for improving reproductive management in dairy farming. The successful implementation of this wearable device demonstrates a practical approach to modernizing traditional calving monitoring practices, enhancing animal welfare, reducing calf mortality, and supporting sustainable and productive dairy farm management.

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