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Advances in Animal Health Monitoring: Internet Of Things (IoT)- Driven Precision Livestock Farming

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Abstract: The Internet of Things (IoT) is an advanced technology that is restructuring the contemporary agriculture practices, transforming the traditional farming into smarter and more effective methods. Considering the crucial role animals play in supplying dairy and meat products for human consumption, the implication of IoT becomes especially apparent in the monitoring and management of cattle health. Contemporary technology simplifies the continuous monitoring of vital health indicators such as their mobility, food and fluid intake and body condition score, shifting to reactive responses to disease outbreaks. Farmers are now able to proactively recognize, anticipate, and avert disease outbreaks by harnessing the capabilities of artificial intelligence and machine learning. This technology simplifies more informed decision-making and more rapid treatments. Through the employment of the Internet of Things, farmers can closely monitor the health of their animals in real time, enhancing the welfare of animals and enhancing productivity.

Keywords--Internet of Things, Machine Learning, and Precision Livestock Farming (PLF)

I INTRODUCTION

The primary sources of livelihood in rural India are agriculture and practice of dairy farming. Increased food and dairy production is critically needed in the future, as the expanding population highlights. The majority of India's historical livestock farming regions have followed traditional practices, with farmers making decisions based only on their own personal experience. There has, nevertheless, been a noticeable departure from these conventional methods. With the current pace, dairy producers are being guided towards the field of precision livestock farming via precision dairy technology. Access to current, quantitative data is essential for making well-informed decisions about livestock management. Information and communication technology (ICT), control systems, machine learning (ML), and data analysis are employed in the gathering and examination of this data (Banhazi et al., 2012).

Prioritising the animal welfare is essential because of the crucial role they play in providing dairy products to people. Forecasting the health and illnesses of cattle in advance is essential, particularly in light of the possibility of animal-to-human disease transfer (Chaudhry et al., 2020). However, it can be challenging to ensure a high quality of life for every individual cow because of fragmented approach to various aspects of dairy farming, such as feeding, milking, reproduction, and health, which are often treated as separate entities. Dairy farmers now have a unique opportunity because to modern technology like sensor-based devices, big data, and application of machine learning. These technologies allow for continuous monitoring of vital signs of animal health, such as movement, temperature, pulse rate, and humidity, rather than responding to illnesses only when they manifest.

Though research has advanced significantly, these technologies have not yet been fully fully utilised in practice possible. There are now several obstacles for livestock farmers to successfully monitor the health of their cattle because veterinary practitioners typically use manual methods to evaluate the physical well-being of animals. The necessity to close the knowledge gap between theory and the creation of useful, real-world systems has been emphasised.

Farmers are now able to proactively identify, anticipate, and prevent cattle diseases before they spread to other areas and cause major losses. Collection of data continuously, enabled by sensors and the predictive competences of machine learning make agriculture and dairy farming feasible. This technology not only reduces the cost of production by enabling a smaller number of farmers to efficiently manage a higher number of animals but also provides farmers with early alerts regarding certain diseases (Neethirajan et al., 2020).

II CONCEPTUAL OVERVIEW OF PRECISION LIVESTOCK FARMING

Precision Livestock Farming (PLF) offers a practical approach to achieve sustainable livestock production. Cross-disciplinary collaboration is vital to translate technological innovations into practical returns for farmers (Vranken et al., 2017). Bigger animals such as dairy cows and beef cattle have been the main targets of PLF implementation because the financial reimbursements balance the cost of the monitoring tags (Halachmi et al., 2019). Enhancement of production and animal welfare are the major benefits of Precision Livestock Farming (PLF) According to Berckmans et al. (2017), this dual

benefit has the potential to significantly advance the field while improving the welfare of the animals.

The benefit of PLF technology to stakeholders, especially dairy farmers, is becoming more and more apparent as it gets more reasonable It enables progress in various areas associated with livestock production, including environmental impact, animal welfare, health, and efficiency (Schillings et al., 2021). Through the integration of smart software with hardware, PLF systems have become capable of extracting useful information from a diversity of data sources. This enables farmers to improve yields and improve animal health (Berckmans et al., 2014). To prioritise the animal welfare is one of the main purposes of precision livestock production (Pomar et al., 2011). Therefore, PLF technologies present a special opportunity to improve productivity and identify health problems in cattle early on.

State-of-the-art "smart technologies" developed in order to help livestock farmers to monitor animal welfare has drawn a lot of consideration from researchers. Several countries have already dedicated considerable funds to the advancement of these technologies, with the goal of shifting to animal farming methods that are more environmentally friendly. This synchronized effort is a big step in animal husbandry that is both more eco-friendly and technological sophistication.

III IMPORTANCE OF MACHINE LEARNING FOR PRECISION LIVESTOCK FARMING

Machine learning has emerged as a very promising approach in dairy research, which offers the potential to revolutionize change the way farmers make decisions regarding their livestock. With machine learning algorithms, comprehensive analyses of integrated datasets can be conducted, leading to a more holistic approach to managing livestock. This is especially significant in the realm of cattle farming, where cows are involved (Cockburn et al., 2020). Envisioning the future, using machine learning to forecast animals' typical behaviour, and triggering alerts when observed behaviour diverges from predetermined thresholds.

Machine learning has been recognized to be useful in the field of cattle farming to predict a range of outcomes. These include the timing of calving, reproductive outcomes and high somatic cell counts. Furthermore, there has been a perceptible change in the way that "big data" has been used into farm animal medicine, with an emphasis on "smart data." This conversion empowers the best possible use of the data resources that are already available. Veterinarians spend a considerable amount of time evaluating and interpreting data to make clinical diagnosis. On the other side, a machine learning system can quickly identify conditions like mastitis by thorough analysis of all relevant data, whereas a human would need to spend 30-60 minutes in doing so. More rapid and reliable diagnostic results can result from the frequent application of this modest and fast diagnostic approach (Hyde et al., 2020).

Machine learning algorithms are capable of handling categorical data and analysis of large datasets that are difficult for standard statistical techniques to manage. Because machine learning algorithms learn directly from the data, they frequently produce better results than traditional analysis techniques, which may be impacted by the researcher's initial hypotheses. (Cockburn et al., 2020).

Machine Learning has proved to be an influential tool in the field of precision livestock husbandry. It can help farmers by offering timely, data-driven perceptions and predictions that will ensure the welfare and well-being of their animals. To summarize, this technological development has the potential to completely transform the way of managing cattle, which will eventually be beneficial for both farmers and the animals they raise.

IV LITERATURE REVIEW

Cattle Farming is an important part of the agriculture sector as it produces necessities like dairy and meat. But, because they are susceptible to to a variety of ailments, cattle can produce lower quality products, if these illnesses are not addressed. To avoid financial losses and to protect the health of their animals, it is essential for the dairy farmers to facilitate prompt and precise diagnosis of these diseases . Conventional disease diagnosis techniques depend on the manual evaluation by specialists, which can be a labour- and time-intensive procedure. Moreover, because various experts may perceive the symptoms differently, these evaluations could be open to subjectivity and mistake. This emphasises the need for more effective and impartial methods of detecting diseases in cattle.

The use of leading-edge technology in precision livestock farming (PLF) and animal healthcare, such as the Internet of Things (IoT) and machine learning, is becoming more prevalent as a means of addressing this problem. By automating data gathering and analysis, these technologies have the potential to completely transform the procedures involved in identifying diseases by lowering the need for human expertise. Automated cattle health monitoring systems have become more and more common in modern agriculture to improve herd management, support animal welfare, and increase the productivity of cattle farming. These technologies provide real-time perceptions into the health and welfare of individual cattle by utilising sensors, the Internet of Things (IoT), and advanced data processing techniques.

This section is an overview of the literature that explores the relationship between machine learning and the Internet of Things (IoT) particularly in the context of cattle farming. This thorough analysis aims to investigate the current state of the field, emphasising the developments

and uses within this field. The main objective is to emphasise how crucial IoT and machine learning are to enhancing livestock management in several areas, such as productivity increase and health monitoring.

Haladjian et al., 2018 created a wearable sensor system that used limb-mounted sensors to track variables such limb movement and weight distribution to evaluate the problem of lameness in dairy calves. Data processing systems were able to distinguish between healthy and lame calves based on the information collected. The findings demonstrated that the average accuracy for detecting cases of irregular stride was 91.1%.

The use of sensors, such as leg- and neck-mounted accelerometers and a localization sensor, to predict calving and estrus episodes in dairy cow was investigated by (Benaissa et al., 2020). Predictive systems were developed using machine learning models, showcasing the potential of multi-sensor integration for thorough dairy cattle monitoring. The results of the study demonstrated how well the system identified calving and estrus periods, providing dairy farmers with useful tools for reproductive management.

Borchers et al. (2017) studied the effectiveness of machine-learning techniques for calving prediction, including random forests, neural networks, and linear discriminant analysis. A combination of activity, rumination time, and lying behaviour factors were examined using neural network techniques, resulting in the creation of sensitive and accurate alerts.

Cowton et al. (2018) developed a unique method for the early detection of respiratory diseases in pigs. They combined deep learning methods with information from environmental sensors to identify disease signs using a Gated Recurrent Unit (GRU) and autoencoder. The temperature, humidity, ammonia levels, and pig activity were all recorded with the help of sensors. Their methodology beat conventional statistical techniques by providing advantages including decreased antibiotic use, better pig welfare, and improved farm management through early intervention.

An outline of research studies on the use of IoT technology for cattle health monitoring is given in Table 1.

The experiment conducted by Sturm et al. (2020) focused on the early detection of subclinical ketosis in dairy cows, a metabolic disorder that affects the cows' health and milk output. In addition to blood metabolite analysis and clinical examinations, they recommended a system that combined sensor data with health monitoring, including rumen pH and temperature sensors. Comparing the approach to conventional methods, field experiments showed how successful it was in detecting subclinical ketosis early on. Improved cow welfare, lower treatment costs, and increased milk output were among the advantages of this strategy.

Swain et al., 2017 introduced a cattle health monitoring system that utilized LabVIEW and Arduino for early disease detection. This system empowered farmers to monitor and compare the body humidity, heart rate, temperature, rumination, and other health indicators of their cattle against predetermined reference values. This allowed for the accurate, timely identification of any health problems in the cattle with an accuracy rate of 72–75%.

Using specialised sensors to measure vital signs such body temperature, ambient temperature, heart rate, and body movement, (Priya et al., 2019) summarized the deployment of a wireless sensor network for cow health monitoring. After the acquired data was processed by an RL78 microcontroller, it was sent over GSM or Zigbee technologies. Health issue indicators were unified into the system, and they were activated when the designated thresholds were exceeded.

Wagner et al., 2020 investigated the use of machine learning in continuous monitoring to detect abnormal behaviour. They measured pH and predicted Subacute Ruminal Acidosis (SARA) in cows by using a ruminal bolus. They used machine learning techniques such as long short-term memory (LSTM), K-Nearest Neighbours for Regression (KNNR), Multilayer Perceptron (MLP), and Decision Tree for Regression (DTR). According to the findings, KNNR performed best, by identifying 83% of SARA events.

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Table 1 IOT APPLICATIONS FOR LIVESTOCK HEALTH SURVEILLANCE

Reference	Objective of the Study	Method/Technology Used	Findings/Results
[1]	Wireless sensor network for intelligent animal monitoring	WSN and IoT platform for real-time data on animal health, behavior, and ambient factors	Implementation of real-time monitoring, data-driven decision-making, and early detection of diseases through a wireless sensor network tailored particularly for cattle health monitoring.
[2]	Non-invasive wearable sensors for dairy calves	Sensors for temperature, accelerometer, microphone	Detected hypothermia, activity, and distress noises for forecasting cattle health and aiding disease identification
[4]	Predicting calving and estrus events in dairy cattle	Neck-mounted and leg-mounted accelerometers, localization sensor	Machine learning models demonstrated potential for comprehensive dairy cattle monitoring
[10]	Early diagnosis of respiratory problems in pigs	Deep learning techniques with ambient sensor data	Model outperformed traditional approaches, reducing antibiotic use, improving pig welfare, and enhancing farm management
[12]	Lameness diagnosis in dairy calves	Limb-mounted sensors for limb movement, weight distribution	Differentiated healthy and lame cows (91.1% accuracy) with challenges in sensor placement, data accuracy, battery life, and durability
[14]	Use of Internet of Things in Healthcare of Animals	Sensor technologies, communication networks, data analytics	Early disease identification, efficient resource utilization, with addressed issues in sensor accuracy, data security, interoperability, and scalability
[16]	Internet-based data repository and smart collar for dairy cows	Sensors for respiration rate, humidity, rumination, controlled by Arduino Uno controller	Monitored health of dairy cows with an internet-based data repository and a smart collar
[17]	Cattle health monitoring system for large farms	Smart collar, local server base station, web application, machine learning	High accuracy in classifying health conditions and cow behaviors.
[18]	Wireless sensor network for monitoring of cattle health	Specialized sensors, RL78 microcontroller, Zigbee, GSM	Health issue indicators triggered when thresholds exceeded.
[19]	Smart wearable collar devices for livestock	Wearable collars with Bluetooth and Wi-Fi	Real-time wireless information access for animal management.
[21]	Automated Body Condition Scoring (BCS)	Sensors and computer vision for feeding pattern changes	Optimized herd health and nutrition management with quick detection of health issues
[22]	Cattle health monitoring system utilizing Arduino and LabVIEW	Arduino and LabVIEW for early disease detection	Allowed tracking and comparison of cattle's health indicators against established reference values with an accuracy rate of around 72-75%
[23]	Early diagnosis of subclinical ketosis in dairy cows	Integrated sensor data and health monitoring	Effectively detected subclinical ketosis, improving cow welfare, reducing treatment costs, and optimizing milk production

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The above table presents a comprehensive evaluation of various research endeavors focusing on Internet of Things-based cattle health monitoring systems. It highlights the wide array of research methodologies to present the significance of IoT technology in modern livestock management. From these insights, our comprehension of IoT applications in cattle health is enriched, laying the foundation for further in-depth investigations in this dynamically evolving domain.

V RESEARCH GAPS

The examination of existing literature has pinpointed several notable research gaps within the current systems:

A. *Integrating Automated Disease Detection in Farming*: While ongoing research endeavours focus on creating algorithms and models for the automated identification of diseases using sensor data, there exists a disconnect between the promising potential of these technologies and their actual deployment in real-world agricultural settings. Specifically, farmers often lack timely notifications about changes in cattle health, which can hinder their ability to administer prompt treatment.

B. *Necessity for Comprehensive Data Sets*: A noteworthy research gap pertains to the need for extensive datasets. The efficacy of machine learning techniques in forecasting various aspects of dairy farming hinges on the availability of comprehensive and integrated datasets. Scrutinizing substantial, all-encompassing datasets has the potential to bolster decision support systems for farmers, thereby empowering them to enhance the well-being and productivity of their livestock.

C. *Enhancing Machine Learning Algorithm Performance for Precision Livestock Farming:* A significant research gap is evident in the imperative to enhance the accuracy and overall performance of machine learning algorithms. Although commercially available sensors capable of monitoring dairy cow health and physiology are in existence, there remains uncertainty surrounding the effectiveness of decision support derived from these sensors due to limited research on the algorithms' efficiency. This underscores the challenge of refining and predicting algorithm categorization performance within the domain of Precision Livestock Farming. While researchers acknowledge the potential of machine learning, it is crucial to establish collaborative partnerships with the dairy industry and the data scientists to gain a comprehensive understanding of their significance and harness their capabilities effectively.

VI COMPARATIVE ANALYSIS OF EXISTING SYSTEMS

Within the domain of IoT-based cattle health monitoring systems, a diverse range of research studies have emerged, each contributing distinctive insights and advancements. To distil this wealth of knowledge and furnish a structured evaluation of these studies, a comprehensive comparative analysis is presented in Table 2. The goal of this analysis is to provide a methodical overview of pivotal research papers, shedding light on their specific strengths and limitations in the pursuit of enhancing cattle health through IoT technology. The goal is to synthesize these findings to acquire a deeper comprehension of the evolving landscape of IoT-enabled cattle health monitoring, and to pinpoint promising directions for future research and development. Below, tabular summary of these research endeavours is provided for the convenience of reference and evaluation, facilitating an efficient review of the diverse studies and their contributions to the field.

Table 2 COMPARATIVE EVALUATION OF RESEARCH PAPERS ON IOT-BASED LIVESTOCK HEALTH MONITORING SYSTEMS

Reference	Strengths	Weaknesses
[1]	Real-time monitoring for animal health, behavior, and ambient factors	Addressed deployment processes, design considerations, power management, and data security
[7]	Impressive sensitivity and specificity in predicting calving using neural network analysis.	Challenges with manufacturer-specific sensor systems.
[12]	Effective lameness diagnosis (91.1% accuracy)	Challenges in sensor placement, data accuracy, battery life, and durability
[14]	Comprehensive IoT framework for animal healthcare	Addressed issues in sensor accuracy, data security, interoperability, and scalability
[25]	Detection of abnormal behavior in dairy cows using machine learning.	Lack of specificity and recommendation of larger datasets for improvement.

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VII DIRECTIONS FOR FUTURE RESEARCH

After conducting an extensive review of existing literature, it becomes clear that there is substantial potential within the domain of IoT-based cattle health monitoring systems. This analysis does, however, also highlight certain areas that need more research and creativity. Following are some of the directions for future research on IoT-based cow health monitoring systems:

A. Development in the Integration of Sensor Technology: Using cutting-edge sensors and technology is a potential field for further research. By taking this step, the accuracy and scope of data collecting about the health of cattle would be improved. Exploration of wearable technology like smart collars, neck tags and sensors enable a profound understanding of each animal's health.

B. Predictive Analytics and Machine learning: It is important to design and implement machine learning algorithms to perform predictive analysis in monitoring the health status of cattle. From the historical data, these algorithms can forecast possible health problems, allowing for proactive intervention. But there is still much work need to be done to increase the flexibility and accuracy of these models for different variety of cattle breeds and environmental conditions.

C. Cost-Effectiveness and Scalability: For small-scale farmers, cost and scalability continues to be a major challenge. Future studies must concentrate on pinpointing the economical solutions that are effortlessly applicable to varied agricultural activities. This could involve searching for more reasonably priced sensors, implementation of effective communication protocols, or employing cloud-based solutions that can adapt to resource limitations.

D. Effective and Easy to Use User Interfaces and Mobile Applications: The efficacy of IoT-based cattle health monitoring systems depends deeply on user interest and commitment. Hence, improving the user interfaces and developing mobile applications that make data management and remote monitoring easier should be the top primacies for research efforts. The goal of these projects is to improve the system's usability and accessibility for veterinary professionals as well as farmers.

VIII CONCLUSION

Several important findings are revealed following a thorough analysis of the literature on disease detection in livestock. First and foremost, it's clear that cattle are prone to a variety of illnesses, which can provide serious difficulties for farmers. One major problem is that abnormal variations in cattle's health are not promptly reported. Due to treatment delays brought on by this ignorance, the severity of these illnesses may worsen and financial losses may result.

When the current dairy farming situation is examined more closely, it becomes clear that machine learning approaches show promise for predictive skills in several areas, including disease identification. But these machine learning techniques are only as good as the quality and quantity of large, comprehensive datasets covering every aspect of cow health. In the end, this improves the welfare and general effectiveness of livestock management practices, demonstrating the possibility for farmers to greatly improve their use of decision support systems for analysing large datasets.

Although there are commercial sensors made especially to keep track of the vital health parameters of dairy cows, there is not enough information available in the literature to determine how well these sensors would support decisions. This information gap highlights one of the field's major challenges: predicting and improving the efficacy of the algorithms employed in precision livestock farming.

It is critical to stress the value of teamwork in light of the general acknowledgement of machine learning's promise in cattle health monitoring. To fully realise the benefits of these cutting-edge strategies, dairy farmers, data scientists, and other stakeholders should collaborate on these initiatives. Realising the entire range of advantages that these cutting-edge technologies may provide in terms of enhancing cattle health, productivity, and the sustainability of livestock production depends on our joint effort.

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