Enhancing Dairy Farming: An Analysis of IoT, Sensors, and GPS-Based Technologies for Disease Detection and Health Monitoring

Dr.J.V.Anchitaalagammai, Professor/CSE
Velammal College of Engineering and Technology,
Madurai, India.
jva@vcet.ac.in

Dr.S.Kavitha, AssistantProfessor/CSE
Velammal College of Engineering and Technology,
Madurai , India.
skt@vcet.ac.in

Mr.S.Murali, Assistant Professor/CSE
Velammal College of Engineering and Technology,
Madurai, India.
smu@vcet.ac.in

S.Velunachiyar, PG Student/CSE
Velammal College of Engineering and Technology.
Madurai, India
velunachiyars@gmail.com

Abstract*— Advancements in smart farming technologies have enabled significant improvements in dairy health management, with a particular focus on the early detection and management of diseases such as mastitis, a leading cause of reduced productivity and economic losses in dairy farming. This literature review explores the application of Internet of Things (IoT) devices, sensors, and GPS technologies in modern dairy systems. Wearable sensors monitor physiological parameters such as body temperature, milk conductivity, and rumination patterns to enable the early detection of mastitis, reducing the reliance on manual diagnosis and minimizing treatment delays. Additionally, environmental and behavioral data collected through GPS tracking provide insights into grazing patterns, activity levels, and deviations in movement, which are often early indicators of health issues. IoT frameworks integrate these datasets into centralized platforms, enabling real-time health alerts and predictive diagnostics. Despite their potential, challenges such as sensor accuracy, data integration, and scalability persist. This review highlights the transformative role of these technologies in improving herd productivity, mitigating economic losses from diseases like mastitis, and paving the way for sustainable, precision dairy farming practices.

Keywords*— Mastitis detection, IoT in the Dairy Farming, Wearable sensors, GPS Tracking for livestock, Precision Dairy Health Management.

I. INTRODUCTION

Dairy farming has undergone significant advancements with the integration of cutting-edge technologies aimed at improving herd health, optimizing productivity, and ensuring milk quality. The detection and diagnosis of mastitis, one of the most prevalent and costly diseases in dairy cattle, have become more efficient through the use of sensor and IoT-based dairy health monitoring systems. Early detection of mastitis, along with other health issues such as lameness and mobility problems, can significantly reduce veterinary costs, minimize animal suffering, and improve overall milk yield. The use of machine learning (ML) and artificial intelligence (AI) in veterinary applications has further enhanced diagnostic accuracy, enabling the prediction of diseases such as mastitis and lameness with high precision. Sensor technologies, including wearable devices, accelerometers, and thermal cameras, have revolutionized behavioral analysis and mobility monitoring, offering real-time data on animals' physical condition and health. Combined with GPS tracking, these systems allow for comprehensive monitoring of grazing patterns, activity levels, and behavioral changes that may indicate health issues. Additionally, milk quality and adulteration detection technologies are increasingly used to ensure the safety and integrity of dairy products, identifying potential contaminants or substandard milk.

Beyond specific diseases, the broader animal health monitoring ecosystem benefits from the synergy of IoT, sensor networks, and data analytics. These technologies provide insights into various health parameters, ranging from metabolic conditions to environmental stress, and are crucial in promoting sustainable dairy farming practices. As these innovations evolve, the potential for improved productivity, reduced disease incidence, and better animal welfare continues to grow, paving the way for smarter, more efficient dairy farming.

This paper delivers a comprehensive review on Mastitis Detection and Diagnosis, Lameness and Mobility Monitoring, Sensor and IoT-Based Dairy Health Monitoring, Milk Quality and Adulteration Detection, GPS in Health monitoring, Early Prediction of Diseases Beyond Mastitis, Advanced Machine Learning Applications in Dairy Farming.

II. AREAS OF DISCUSSION

Mastitis Detection and Diagnosis: Mastitis, a costly udder inflammation in dairy cattle, requires early detection to prevent milk production losses. Traditional methods like SCC testing are slow, but sensor-based technologies, including infrared thermography and IoT-integrated sensors, enable real-time diagnosis. Machine learning enhances accuracy, allowing timely interventions that improve herd health and reduce financial losses. This study explores the sensitivity, accuracy, and specificity of mastitis detection methods reported in various research papers. CMT scoring systems, infrared thermography, and machine learning models such as SVM and Random Forest, the study highlights the strengths and limitations of each technique. A detailed comparison graph Fig.1, Fig.2 is presented to summarize the findings, focusing on specificity and accuracy. The review emphasizes the importance of reliable detection methods for timely intervention in dairy management, noting variations in performance metrics and the need for improved models to enhance diagnostic accuracy and practical application on farms.

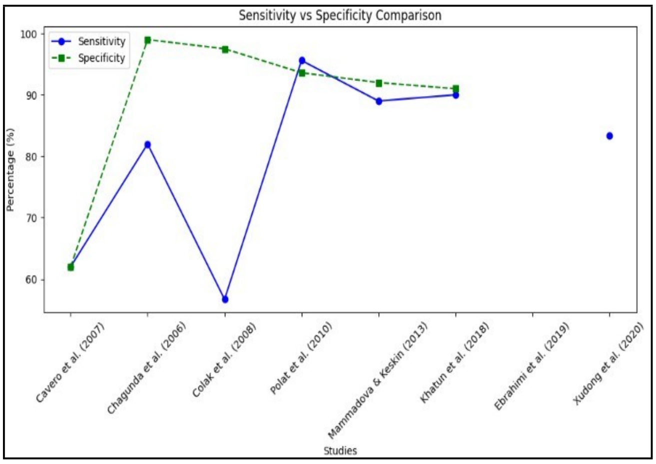

Fig.1 Sensitivity vs Specificity comparison on various studies

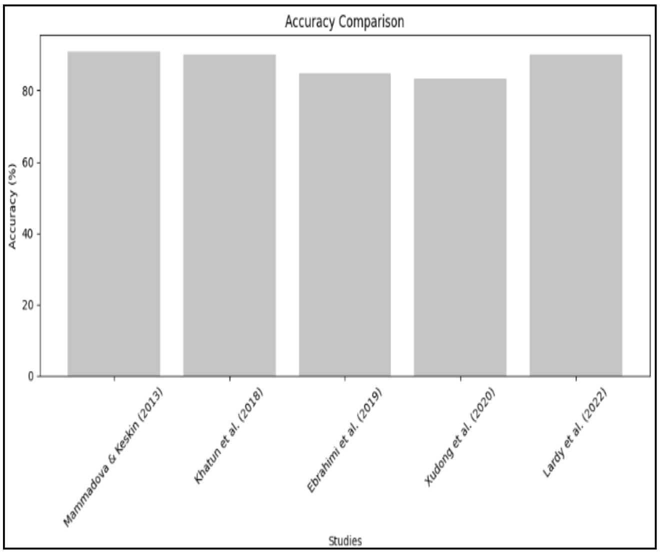

Fig.2 Accuracy Comparison on various studies

Lameness and Mobility Monitoring: Lameness in dairy cattle affects mobility, productivity, and health. Traditional visual detection is subjective, but sensor-based solutions like accelerometers and pressure sensors provide continuous, objective monitoring. Integrated with IoT, real-time data enables early intervention. Machine learning enhances detection by identifying patterns, improving herd health, productivity, and overall animal welfare.

Sensor and IoT-Based Dairy Health Monitoring: Sensor and IoT technologies have transformed dairy health monitoring by tracking vital signs, activity, and location in real time. They detect early signs of illness like mastitis or lameness, enabling remote monitoring via mobile apps. Machine learning enhances predictive insights, improving herd health, productivity, and reducing veterinary costs.

Milk Quality and Adulteration Detection: Sensor technologies ensure high milk quality by monitoring composition, cleanliness, and contaminants in real time. Conductivity and infrared spectroscopy detect abnormalities, while electronic noses and spectroscopic sensors identify adulteration. IoT integration enables continuous monitoring, helping farmers maintain safety standards, improve product quality, and prevent health risks for consumers.

GPS in Health Monitoring: GPS technology enhances livestock health monitoring by tracking movement patterns to detect issues like lameness or illness. Integrated with IoT and wearable sensors, it provides real-time data for early intervention. This improves animal welfare, reduces healthcare costs, and is particularly useful in large-scale farming operations for efficient herd management.

Early Prediction of Diseases Beyond Mastitis: Machine learning and sensor technologies enable early disease prediction in dairy cows by analyzing physiological and behavioral data. This study explores disease detection, including heat stress, Bovine Respiratory Disease, and hypocalcemia risk. Optimized algorithms enhance accuracy, improving cattle health management, reducing suffering, and minimizing financial losses through timely interventions. Fig.3 represents the comparison radar chart on various studies in finding variety of diseases.

Advanced Machine Learning Applications in Dairy Farming: Machine learning is revolutionizing dairy farming by detecting health issues and optimizing herd management. Techniques like neural networks and gradient-boosted trees analyze sensor data to identify infections and behavioral changes. These models enhance real-time monitoring, improving productivity, reducing economic losses, and ensuring better animal welfare in modern dairy operations.

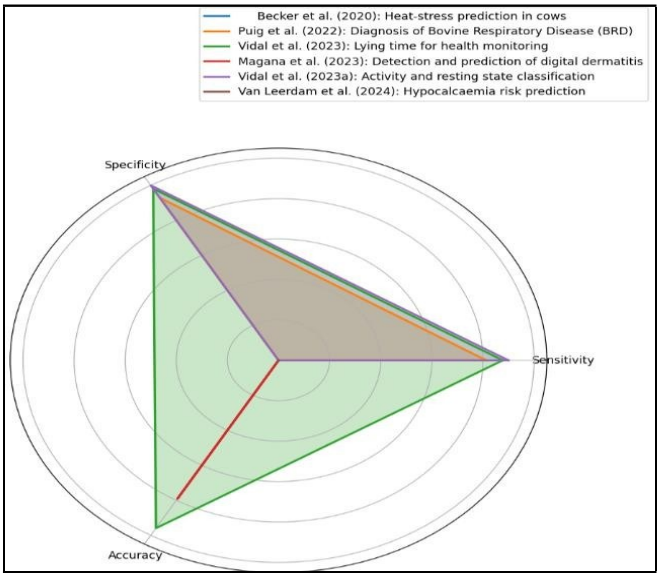

Fig. 3 Comparison Radar chart on various studies

III. A LITERATURE REVIEW

A literature review on Enhancing dairy farming is in comparative format is in the table 1.

S.No	Area Of Discussion	Author(S)	Issues Discussed	Introduced Methodology	Conclusion	Ref. No
1	MASTITIS DETECTION AND DIAGNOSIS	Khatun et al. (2018)	Examines the effectiveness of using automatic milking system (AMS) data to detect clinical mastitis (CM) early	Logistic mixed models were used to analyze electronic data, identifying key measurements for predicting CM in dairy cows	A multivariable model combining EC, MY, MF, and other metrics can predict CM accurately, improving detection and on-farm utility	[1]
2		Ebrahimi et al. (2019)	Investigates the use of machine learning models to predict sub-clinical mastitis from large milking datasets and generalize across farms	Various machine learning models, including Deep Learning (DL) and Gradient-Boosted Trees (GBT), were tested on milking data to predict sub-clinical mastitis, with performance evaluated using ROC and AUC	GBT and DL models effectively predict sub-clinical mastitis with high sensitivity, offering a promising tool for automated farm use, though specificity needs improvement	[2]
3		Dhoble et al. (2019)	Explores a novel machine learning-based cytometric fingerprinting method for accurate, label-free detection of subclinical mastitis in dairy cows	Cytometric fingerprints from milk samples were analyzed using machine learning models to classify pathogens, lactation stages, and infection intensities with high accuracy	The CFML method outperforms traditional testing tools, offering an efficient, high-throughput approach to mastitis typing, potentially improving antibiotic use in dairy farms	[3]
4		Xudong et al. (2020)	Focuses on developing a deep learning-based algorithm (EFMYOLOv3) for automatic detection of mastitis in dairy cows using thermal infrared images	A bilateral filtering enhancement algorithm was used to improve thermal image details, and EFMYOLOv3, based on MobileNetV3 and YOLOv3, was applied to detect cows' eyes and udders	EFMYOLOv3 offers high-speed and accurate detection of mastitis with 83.33% classification accuracy, achieving real-time performance, though accuracy can be improved with additional imaging methods	[4]
5		Fadul-Pacheco et al. (2021)	Evaluates machine learning techniques (Naïve Bayes, Random Forest, Extreme Gradient Boosting) to predict clinical mastitis (CM) onset in dairy cows, integrating multiple data streams	Random Forest was used for predicting CM, with the best performance achieved when integrating genetic, health, and production data, and combining two models for short- and long-term predictions	Random Forest performed well for both overall and daily CM prediction, with integrated data improving prediction accuracy, aiding farmers in timely decision-making to prevent mastitis	[5]
6		Lardy et al. (2022)	Detecting cow health, stress, and reproduction conditions using machine learning on time series data from sensors	Random Forest algorithm was used on 24-hour cow activity data (eating, resting, in alleys) to detect various conditions such as disease, oestrus, and calving	The method achieved over 90% classification accuracy for normal days and successfully discriminated between cow conditions, although sensitivity needs improvement before full implementation on farms for herd management	[6]
7	LAMENESS AND MOBILITY MONITORING	Taneja et al. (2020)	Lameness detection in dairy cattle, data transfer optimization, model accuracy, and the challenge of managing IoT systems efficiently	Hybrid clustering and classification model, activity monitoring via pedometers, fog computing, and early lameness detection using K-NN classification	Custom models for herd groups improve lameness detection accuracy; fog computing reduces data transfer, requiring coordinated edge, fog, cloud resources	[7]
8		Balasso et al. (2021)	Posture and behavior identification in dairy cows, accelerometer data accuracy, machine learning algorithms, and sensor application challenges for commercial farms	Triaxial accelerometer on cows, machine learning algorithms (XGB, Random Forest, KNN, SVM), feature extraction, model training, and testing	Accurate posture detection, but lower accuracy for some behaviors. Sensor application needs improvement, and further studies are needed for commercial use	[8]
9		Biszkup et al. (2024)	Recognizing complex animal movements, improving welfare monitoring, machine learning accuracy, and sensor fusion for behavior and health prediction	RumiWatch sensors and camera observations, using SVC and Random Forest classifiers, to recognize 14 complex movements for animal behavior analysis	The method accurately identifies complex movements, combining sensors enhances accuracy, and further studies can expand the system to recognize more behaviors	[9]

10	SENSOR AND IOT-BASED DAIRY HEALTH MONITORING	Chaudhry et al. (2020)	Technology-based livestock health monitoring, sensor data collection, machine learning for disease prediction, and precision farming for better cattle welfare	IoT-based system with multi-sensor board, mobile/fixed base units, data transmission via LoRa, and machine learning for health prediction	IoT and machine learning can enhance livestock health monitoring, increase milk production, and prevent diseases, benefiting farmers and public health	[10]
11		Neethirajan (2020)	Sensor technologies, big data, AI, and ML in animal farming; improving efficiency, animal welfare, and production while addressing challenges	Explores the role of sensors, AI, and ML in animal farming; reviews applications to enhance health, efficiency, and sustainability	Agriculture 4.0 accelerates AI and sensor adoption in farming; data-driven insights improve performance, but standardization challenges remain globally	[11]
12		Post et al. (2021)	Low-frequency treatments, mastitis, lameness detection, sensor data, classification model applicability, and challenges with false positives and prediction accuracy	Sensor data from dairy farms used with machine learning models; risk groups identified to improve prediction accuracy of mastitis and lameness	Risk group limitation improves prediction accuracy, but low treatment frequency limits model effectiveness; expert knowledge essential alongside sensor data for decision-making	[12]
13	MILK QUALITY AND ADULTERATION DETECTION	Mu et al. (2020)	Milk source identification, estimation of milk fat and protein content, E-nose technology, and machine learning models for quality prediction.	E-nose with metal oxide sensors, PCA and LDA for feature reduction, and machine learning algorithms (SVM, RF, GBDT) for prediction	Fusion of E-nose and DHI features improves milk source identification; RF models accurately estimate fat/protein content, enhancing quality prediction	[13]
14		Sowmya and Ponnusamy (2021)	Milk adulteration detection, expensive lab equipment, long detection time, need for low-cost, real-time, portable, AI-based sensor solutions	Developed multispectral AI-based sensor system with UV, visible, and IR spectrums, IoT integration, and machine learning for adulterant detection	AI-powered system detects milk adulterants with 100% accuracy after optimization, using IoT for real-time results, though with distance limitations	[14]
15	GPS IN HEALTH MONITORING	Bailey et al. (2017)	GPS collars enhance livestock grazing research, but challenges remain in validating genetic markers and remotely detecting welfare issues	GPS tracking, accelerometers, and genetic analysis are combined to study grazing patterns, livestock behavior, and potential health concerns	GPS tracking improves grazing distribution research, and combining it with accelerometers and genomic technologies could advance livestock welfare monitoring	[15]
16		Aswini et al. (2017)	Challenges in cattle health and environmental monitoring, including tracking and timely detection of abnormalities, are addressed through IoT technology	IoT-based system using Arduino, sensors, GSM, and Wi-Fi to monitor cattle health, environmental parameters, and location, with cloud storage	IoT-based system enhances cattle monitoring, detects health issues remotely, improves farm management, and increases milk production by quick intervention	[16]
17		Suresh and Sarath (2019)	Challenge of monitoring cattle health on large farms and detecting diseases early through continuous health parameter tracking	IoT-based system with data gathering and mobile nodes, TDMA for data transmission, cloud analysis, and alerts for abnormal cattle health	The proposed system efficiently monitors cattle health, detects abnormalities, and sends alerts, reducing labor and improving disease management on farms	[17]
18	EARLY PREDICTION OF DISEASES BEYOND MASTITIS	Becker et al. (2020)	Heat stress in dairy cows, negative impact on milk yield, need for accurate prediction of heat stress severity	Used heat stress scoring system and machine learning (logistic regression, Gaussian naïve Bayes, Random Forest) to predict heat stress	Random Forest outperformed other methods in predicting heat stress, with potential for future studies using more data and advanced techniques	[18]
19		Puig et al. (2022)	Conventional methods for diagnosing bovine respiratory disease (BRD) are subjective, time-consuming, and lack sensitivity and specificity	Advances in technology, real-time data analysis, and machine learning improve early diagnosis of BRD by tracking animal behavior and biomarkers	Behavioral analysis sensors (BAS) can enhance BRD detection, but further research is needed to integrate these technologies for farm use	[19]
20		Vidal et al. (2023)	Sensor data can predict metritis in cows, but optimal methods and time windows for prediction models need to be identified	Compared k-NN, RF, and SVM classifiers on sensor data from accelerometers, analyzing time windows and time-lags for metritis prediction	Steps and lying time from TrackaCow data in 3-6 hour windows can predict metritis events using the RF classifier	[20]
21		Magana et al. (2023)	Machine learning models for early detection and prediction of digital dermatitis (DD) in dairy cows based on sensor data	Used TPOT and K-means algorithms to develop models for DD detection and prediction from behavioral sensor data in cows	Machine learning models showed 79% accuracy for DD detection and 64% for prediction, aiding early warning systems for herd management	[21]

22		Vidal et al. (2023a)	Comparison of sensor data preprocessing, classifier performance, and behavioral data for predicting metritis events in dairy cows	Used random forest (RF), k-NN, and SVM classifiers with various time windows, time-lags, and behavioral data for metritis prediction	Optimal metritis prediction achieved using 6- or 12-hour aggregated data with time-lags of 2–3 days, highlighting classifier and data window importance	[22]
23		Van Leerdam et al. (2024)	Prediction of hypocalcaemia in dairy cows using behavioral sensor data and blood calcium concentrations during the transition period	Constructed predictive models (logistic regression, XGBoost, LSTM) using behavioral data and static features to identify cows at risk	Deep learning model (AUC = 0.71) effectively predicts hypocalcaemia risk using behavioral and static features, aiding herd calcium status monitoring	[23]
24		Hyde et al. (2020)	Automated diagnosis of mastitis using machine learning, comparing contagious and environmental transmission, and evaluating model performance with random forest	Random Forest algorithm used to diagnose contagious vs environmental mastitis transmission with high accuracy, predictive value, and cross- validation	Random Forest provided the best performance for mastitis diagnosis, optimizing parameter tuning, variable importance, and predictive thresholds for accuracy	[24]
25		Zhou et al. (2022)	Predicting dairy cow disorders using machine learning algorithms, analyzing multiple variables from automated monitoring and milking systems	Eight machine learning algorithms analyzed data from automatic monitoring systems, using variables like milk yield, rumination time, and conductivity	Rpart algorithm outperformed others, with high accuracy and AUC; future research should focus on integrating AI for accurate management tools	[25]

TABLE 1. A COMPARATIVE REVIEW ON VARIOUS AREAS OF DISCUSSION IN DAIRY FARMING

IV. CONCLUSION

This literature review highlights the application of machine learning (ML) techniques in analyzing sensor data to predict and detect disorders such as mastitis, metritis, hypocalcemia, and digital dermatitis. Behavioral, physiological, and environmental parameters collected through wearables and milking systems have been established as key indicators of disease onset. Models that incorporated static features like parity, lactation stage, and calving season demonstrated improved accuracy, while temporal aggregation of sensor data captured subtle behavioral shifts, enhancing disease detection capabilities.

Automated monitoring and early detection of health disorders in dairy cattle have shown significant potential for improving animal welfare, productivity, and farm management.

Among the ML techniques reviewed, algorithms such as random forests, XGBoost, support vector machines, and deep learning models consistently achieved high predictive performance, with accuracies exceeding 70% for specific disorders. Time-series analysis and ensemble methods further improved robustness by identifying behavioral trends. Innovations like decision threshold optimization and feature selection enhanced sensitivity and specificity, as seen in mastitis and metritis detection. The findings also highlight the importance of contextualizing data, such as excluding early postpartum periods, for more accurate predictions.

Overall, the studies demonstrate the effectiveness of ML models in disease prediction, showcasing their potential to transform herd management practices through reliable and timely health monitoring tools.

V. FUTURE DEVELOPMENTS IN DAIRY FARMING

Advancements in automated detection for mastitis in dairy cattle will focus on integrating diverse data streams, such as milk composition, behavioral patterns, and environmental conditions, with existing sensor data like milk yield and electrical conductivity. Machine learning models, particularly ensemble and deep learning methods, can be optimized to improve the early prediction and differentiation of mastitis types (contagious vs. environmental), aiding in more targeted intervention strategies.

Real-time data processing through wearable sensors and edge computing will enable immediate detection of mastitis symptoms, reducing the time to treatment and mitigating disease progression. Improving model interpretability for mastitis-specific predictions will empower farmers to adopt proactive and effective mastitis management practices.

Furthermore, advancements in farm management software could incorporate mastitis detection tools seamlessly, offering automated alerts and tailored control measures. These innovations aim to enhance productivity, reduce antimicrobial use, and improve cow welfare by minimizing the prevalence and severity of mastitis cases.

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