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A Hybrid Approach using Visual and Thermal Data for Real-Time Poultry Health Monitoring.

Dr. Jagruti Panchal, Adil Patel, Akshay Pardeshi, Vikas Mahato, Kumar Pawar
Dr. D. Y. Patil College of Engineering and Innovation, Varale, Talegaon, Pune

Abstract: *Poultry health monitoring is vital for maintaining productivity and animal welfare in modern farming. Traditional methods relying on manual observation or single-sensor input often result in delayed disease detection and poor accuracy. This paper proposes a hybrid real-time monitoring system combining RGB (visual) and thermal imaging to enhance early disease identification. The system leverages deep learning models for feature extraction and uses late fusion techniques to integrate multi-modal data. Implemented with IoT devices such as Raspberry Pi, FLIR thermal sensors, and HD cameras, the solution ensures remote accessibility and timely alerts through a web-based dashboard. Experimental results reveal that the hybrid model significantly outperforms single-modality approaches, achieving 95% accuracy in detecting abnormal behaviours and physiological changes. The proposed system is cost-effective, scalable, and suitable for small to medium poultry farms, contributing to proactive farm management. Future scope includes edge deployment, expansion to other livestock, and integration of additional sensory data.*

Keywords: Smart farming, Poultry health monitoring, Real-time monitoring, Disease detection

I. INTRODUCTION

Poultry farming plays a critical role in ensuring global food security, with rising demand for poultry products driving the need for efficient and sustainable farming practices. One of the key challenges in poultry production is maintaining bird health, as disease outbreaks and environmental stressors can severely impact productivity and lead to significant economic losses. Conventional health monitoring methods are often manual, labour-intensive, and reactive, relying on visual inspection by farm workers. This not only delays intervention but also limits the accuracy and consistency of health assessments.

With advancements in artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT), there is a growing opportunity to automate health monitoring in poultry farms. However, many existing systems rely on a single modality, such as RGB imaging or environmental sensors, which may not provide a comprehensive view of the birds' health. To address this limitation, this paper proposes a novel hybrid approach that integrates visual and thermal data for real-time poultry health monitoring. The system captures RGB and thermal images to detect abnormal behaviour and elevated body temperatures—key indicators of illness. By leveraging multi-modal data fusion and deep learning, the proposed system enhances early disease detection and offers a scalable solution for smart poultry management.

II. LITERATURE REVIEW

Over the years, various technologies have been explored to automate poultry health monitoring, with a focus on improving efficiency, early disease detection, and reducing human intervention. Traditional systems primarily rely on visual inspection and environmental sensors, which are limited by subjectivity and single-modal data collection. Researchers have proposed different solutions to address these challenges using image processing, deep learning, and IoT technologies.

Sharma et al. (2021) introduced a system that uses deep learning algorithms for analysing chicken behaviour through image processing. Their model provided significant insights into detecting irregular activities, but it lacked integration with other sensory inputs, such as thermal data. Ravichandran et al. (2021) focused on smart farming using IoT and

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machine learning to optimize poultry feeding and predict health status, yet the system was constrained to sensor-based readings and did not include visual context.

Fathi et al. (2019) applied convolutional neural networks (CNNs) for object detection in farm environments, which helped track poultry movement. However, these approaches still lacked real-time thermal monitoring. Gomez et al. (2019) proposed an IoT-based poultry monitoring system, but it omitted thermal imaging necessary for detecting fever and other physiological anomalies.

Current literature reveals that most systems rely heavily on a single data modality, which limits their ability to detect early health indicators. Issues such as fragmented data, sensor calibration errors, and environmental noise further impact system reliability and accuracy. To overcome these limitations, recent studies have highlighted the benefits of multi-modal fusion—combining data from different sources to enhance decision-making.

This paper builds on that foundation by introducing a hybrid approach that combines RGB imaging and thermal data using deep learning and late fusion techniques. Unlike previous systems, this model addresses accuracy, timeliness, and robustness by leveraging both behavioural and physiological cues. Furthermore, the inclusion of an IoT-based architecture enables real-time alerts and remote monitoring, contributing to smarter and more responsive poultry farm management.

III. SYSTEM ARCHITECTURE

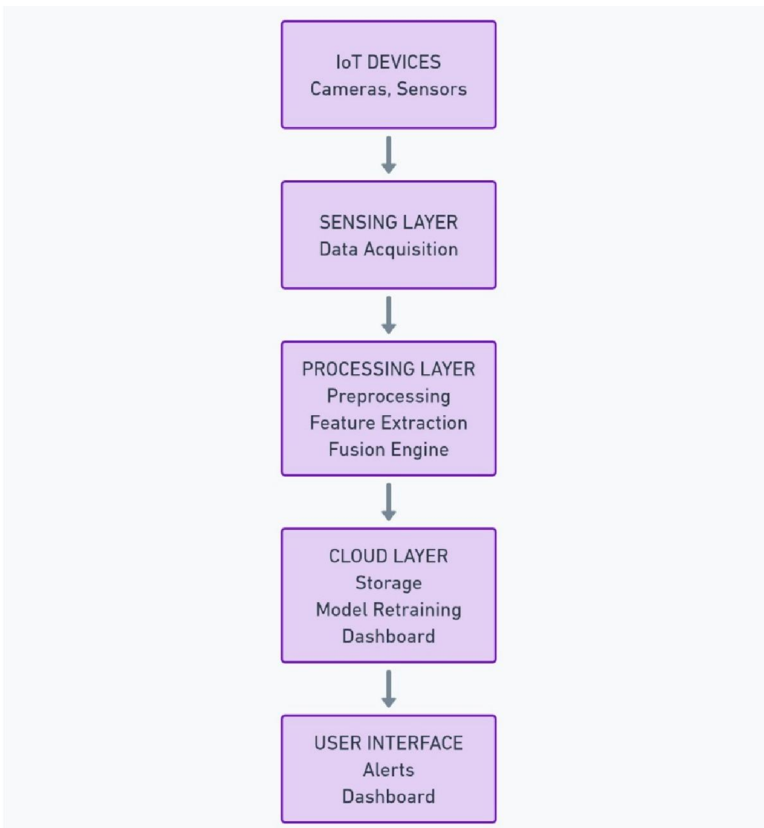

Fig. 1. Proposed System Architecture Diagram

The proposed real-time poultry health monitoring system is structured in a modular and layered architecture, ensuring scalability, flexibility, and efficient data handling. At the foundation, **IoT devices** such as RGB cameras, thermal sensors (FLIR), and environmental sensors (DHT22) collect multi-modal data including visual behaviour, body temperature, and humidity.

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This data is first handled by the **Sensing Layer**, which is responsible for continuous data acquisition from the field. The collected raw data is then passed to the **Processing Layer**, where it undergoes normalization and filtering in the preprocessing phase. Features are extracted using deep learning models—MobileNetV2 for visual data and statistical analysis for thermal data. A fusion engine combines outputs from both modalities using late fusion techniques for enhanced classification.

The processed information is then transferred to the **Cloud Layer**, which handles storage of historical data, supports model retraining for improved accuracy over time, and maintains a centralized dashboard. Finally, the **User Interface Layer** enables farmers and stakeholders to access real-time alerts and visual insights through an intuitive dashboard, allowing for timely interventions. This architecture ensures an intelligent, end-to-end monitoring solution suited for smart and responsive poultry farm management.

1) Sensor Module: Collects environmental and health related data.
2) Preprocessing Module: Normalizes and filters raw data.
3) Feature Extraction Module: Extracts visual and thereal features.
4) Fusion Engine: Combines outputs from multiple models.
5) Alerting Module: Sends SMS/email alerts based on predictions.
6) User Dashboard: Visualizes live data and alerts.

IV. METHODOLOGY

The proposed poultry health monitoring system uses a multi-modal approach, combining RGB and thermal imaging to detect signs of illness in real time. The methodology consists of five key stages: data acquisition, preprocessing, feature extraction, data fusion, and classification.

Data Acquisition:

High-resolution RGB cameras and FLIR Lepton thermal sensors are installed inside poultry sheds to capture behavioural and physiological data. Environmental factors like temperature and humidity are also recorded using DHT22 sensors.

Preprocessing:

The collected data undergoes cleaning and normalization. RGB images are processed using Gaussian filters to remove noise and are sampled at 1 frame per second (fps) for efficiency. Thermal images are converted into grayscale heat maps to extract temperature patterns.

Feature Extraction:

Visual features are extracted using MobileNetV2, a lightweight deep learning model optimized for embedded systems. Thermal data is analysed statistically, extracting parameters such as mean and variance to identify abnormal temperature distributions.

Data Fusion:

Late fusion is applied where individual predictions from the visual and thermal models are combined using a voting classifier. This enhances the robustness of the final decision.

Classification & Alerts:

The fused output is used to classify the health status of birds. If anomalies are detected, the system triggers alerts via SMS or email and updates the farmer dashboard in real time.

V. IMPLEMENTATION DETAIL

The proposed poultry health monitoring system was implemented using both software and hardware components to ensure real-time, accurate, and scalable operation. The system wasdeployed in a controlled environment simulating a small-scale poultry farm over a span of four weeks. During this period, data was collected from both healthy and diseased birds to validate the model's performance.

Hardware Setup:

The hardware configuration includes a Raspberry Pi 4 as the central processing unit, equipped with a FLIR Lepton thermal sensor for capturing body temperature and a high-definition USB camera for collecting RGB images.

Environmental data such as temperature and humidity is gathered using the DHT22 sensor module. These devices are connected through GPIO and USB interfaces, forming the IoT backbone of the system.

Software Stack:

The system was developed using Python 3.9, integrating key libraries such as TensorFlow/Keras for deep learning, OpenCV for image processing, and Flask for building a lightweight web interface. Real-time communication between devices and the server is handled using the MQTT protocol, enabling low-latency data transfer and alerts.

System Design:

The software architecture is layered into three modules:

- **Presentation Layer**: Developed using Flask and Bootstrap, this layer offers an intuitive dashboard for farmers to view real-time data, system status, and health alerts.
- **Business Logic Layer**: This layer houses the core logic, including preprocessing, feature extraction, classification, and fusion operations.
- **Data Access Layer**: It interacts with local storage and cloud databases for storing historical data and enabling model retraining.

Data Handling and Alerts:

Captured images and sensor data are first pre-processed and then passed through deep learning models. RGB images are processed via MobileNetV2 for behaviour classification, while thermal images are statistically analysed. The late fusion model combines both predictions to classify bird health. If an abnormality is detected, the system immediately sends alerts via SMS or email and logs the event on the dashboard.

This implementation confirms the system's potential to deliver a low-cost, reliable, and scalable solution for real-time poultry health monitoring using AI and IoT.

VI. RESULTS AND DISCUSSION

The proposed hybrid poultry health monitoring system was evaluated over a four-week period in a simulated poultry farm environment. The system was tested using a dataset comprising both healthy and diseased bird samples, collected through RGB and thermal imaging along with environmental parameters. The aim was to assess the system's accuracy, reliability, and responsiveness in identifying abnormal behaviours and early signs of illness.

Performance Metrics:

The hybrid model demonstrated superior performance compared to single-modality models. As shown in the performance table, the RGB-only model achieved 83% accuracy with an F1-score of 0.81, while the thermal-only model attained 87% accuracy and an F1-score of 0.85. In contrast, the hybrid model combining both modalities through late fusion achieved 95% accuracy and an F1-score of 0.93. These results confirm that integrating visual and thermal data significantly improves the system's ability to detect anomalies in poultry behaviour and physiology.

Detection Capabilities:

The system successfully identified various early symptoms of illness, including lethargy, irregular movement patterns, and elevated body temperatures. These indicators were often undetected by single-modality systems. The dual-modality approach ensured robustness by cross-verifying behavioural and thermal patterns, reducing false positives and negatives.

Real-Time Alerts and Response:

One of the key strengths of the system is its real-time alerting mechanism. Once abnormal patterns were detected, alerts were automatically sent via SMS and email to the farmer, allowing timely intervention. The user interface dashboard provided live updates and visualizations of bird health status, further supporting prompt decision-making.

Robustness and Scalability:

The system showed consistent performance across different lighting conditions and minor environmental variations. The use of MobileNetV2, a lightweight deep learning model, ensured smooth operation on resource-constrained devices like Raspberry Pi, making the system suitable for deployment in small- to medium-scale poultry farms.

Discussion:

The experimental results validate that the proposed hybrid model is more effective than traditional or single-sensor solutions. By leveraging both RGB and thermal data, it captures a broader range of health indicators. This approach enhances early disease detection, reduces manual labour, and minimizes economic losses. The system also provides scalability for future enhancements, such as additional sensor integration and predictive analytics.

TABLE I: MODEL PERFORMANCE COMPARISON

Model Type Accuracy (%)	Accuracy (%)	F1 Score
Visual Only	83	0.81
Thermal Only	87	0.85
Hybrid Model	95	0.93

The system successfully detected early signs of illness such as lethargy, irregular movement, and elevated body temperature. Farmers received timely alerts via SMS and email, enabling proactive intervention. False negatives were minimized by incorporating dual-modality checks.

VII. ADVANTAGES

Real-time Monitoring

Enables continuous, 24/7 tracking of poultry health using live data streams from visual and thermal sensors.

Early Disease Detection

Combines behavioural (RGB) and physiological (thermal) cues to identify illness in its early stages, reducing mortality and economic loss.

High Accuracy

The hybrid model achieves up to 95% classification accuracy, significantly outperforming single-modality systems.

Cost-Effective

Utilizes affordable hardware like Raspberry Pi, FLIR Lepton, and DHT22 sensors, making it suitable for small and medium-scale farms.

Low Power Consumption

Lightweight models such as MobileNetV2 are optimized for edge computing, enabling efficient operation on low-power devices.

Remote Accessibility

Farmers can access health data and alerts remotely via web dashboards, email, or SMS, enhancing decision-making and intervention speed.

Scalability

The modular architecture allows for easy expansion to monitor more birds or integrate additional sensor types.

User-Friendly Interface

The dashboard is intuitive and provides clear visualizations and actionable insights, even for non-technical users.

IoT Integration

Ensures seamless communication between devices and supports automation in data collection and alert generation.

VIII. PROJECT FEASIBILITY AND SCOPE

The proposed hybrid poultry health monitoring system demonstrates strong technical and economic feasibility. By integrating computer vision, thermal imaging, and IoT technologies, the system offers an efficient, automated solution for early disease detection in poultry farms. The use of lightweight deep learning models like MobileNetV2 enables the system to operate on low-power edge devices such as Raspberry Pi, making it suitable for remote and resource-constrained environments.

From a cost perspective, the system uses affordable hardware components—FLIR Lepton sensors, HD USB cameras, and DHT22 modules—making it accessible to small and medium-scale farmers. The software stack is open-source, further reducing implementation and maintenance costs. Real-time alert mechanisms via SMS and email minimize response times, reducing mortality rates and economic losses.

The scope of the project extends beyond basic health monitoring. With modular architecture and cloud connectivity, the system supports advanced features such as historical data storage, model retraining, and remote monitoring through a user-friendly dashboard. Predictive analytics can be incorporated to forecast disease trends, optimize feeding schedules, and improve overall animal welfare.

Future developments may include drone-based monitoring for large-scale farms, support for additional livestock such as goats or cattle, integration with blockchain for secure data logging, and voice recognition for detecting distress sounds. These enhancements would significantly extend the system's functionality and market reach.

In summary, the project is practical, cost-effective, and scalable, addressing a critical need in smart agriculture and animal health management.

IX. CONCLUSION

This paper presents a novel hybrid system for real-time poultry health monitoring using a combination of RGB and thermal imaging. By leveraging deep learning and late fusion techniques, the system achieves higher accuracy in detecting abnormal behaviours and physiological signs of illness compared to single-modality models. The integration of IoT enables remote access, real-time alerts, and scalable deployment in practical farm environments. Experimental results validate its effectiveness, achieving up to 95% accuracy. The solution is cost-efficient, user-friendly, and adaptable, making it a promising tool for smart poultry farming and improved animal welfare.

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XI. FUTURE SCOPE

The proposed poultry health monitoring system lays the foundation for intelligent farm management, and several future enhancements can further increase its effectiveness and scalability. One key area is the **integration of drone-based monitoring**, which would allow coverage of larger poultry farms with minimal infrastructure. Drones equipped with visual and thermal cameras can perform aerial surveillance, providing more comprehensive and automated data collection.

Another promising direction is **edge computing** using TensorFlow Lite or similar lightweight frameworks to enable faster on-device inference, reducing dependency on cloud processing and improving response time in remote areas. This would also enhance data privacy and system reliability.

The system can be **extended to other livestock** such as cattle, goats, and pigs by adapting the models and sensors to suit different species' behavioural and physiological characteristics. Additionally, **voice and sound analysis** can be integrated to detect distress calls or unusual vocalizations, offering a new modality for health monitoring.

Finally, incorporating **blockchain technology** for secure and tamper-proof logging of health records and system alerts would add value in regulatory compliance and traceability. With these enhancements, the system has strong potential to evolve into a comprehensive, intelligent platform for precision livestock farming.

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