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AI-Based Early Poultry Disease Risk Prediction System Using Real-Time Trend Analysis

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Abstract: Poultry health is closely linked to the environmental conditions maintained inside a poultry shed. Unfavourable conditions and undetected illness can affect bird welfare, increase mortality, and cause financial losses. In many farms, routine observation is still performed manually, which may delay the identification of developing problems. This paper presents an integrated monitoring system with six components: an IoT sensing layer, an ESP32 edge controller, a backend server, an AI analysis layer, a user interface with alerts, and smart support functions for farmers. DHT22, MQ-135, and IR sensors collect temperature, humidity, gas-concentration, and bird-movement readings, while an ESP32-CAM captures images of the poultry environment. The ESP32 transfers sensor readings to a Node.js and Express.js backend over Wi-Fi. The backend checks incoming values against configured thresholds and examines recent readings across sensors. A 75-second hazard-memory window is used to identify abnormal events that occur close together. The AI layer evaluates significant deviations and returns a health score, risk category, possible conditions, evidence, and preventive guidance. Camera images are also assessed to provide visual observations of birds and litter. A live dashboard presents sensor values and analysis results. Multilingual and audio notifications, SMS/WhatsApp communication, and report generation are included to support farmer interaction. If the external AI service cannot be reached, a deterministic rule-based mechanism continues to provide basic risk assessment. By bringing sensor trends and visual observations together, the system is intended to improve awareness of potential health risks, reduce the need for repeated manual checks, and help farmers respond in a timely manner.

I. INTRODUCTION

Poultry production contributes to food supply and agricultural livelihoods, but bird health is strongly influenced by the conditions inside the housing environment. Temperature, relative humidity, air quality, litter moisture, and activity levels can provide useful indications that conditions may be deteriorating. When changes in these factors are noticed late, opportunities for early intervention may be lost. Routine farm inspections are useful, yet checking sheds only at fixed intervals can make continuous observation difficult, particularly on farms that house large flocks. Internet of Things (IoT) technology offers a way to collect environmental readings continuously through connected sensors. Artificial Intelligence (AI) can then examine the collected information for patterns and deviations that may require attention. Combining these capabilities can provide farmers with alerts based on changing farm conditions.

This paper describes the AI-Based Early Poultry Disease Risk Prediction System Using Real-Time Trend Analysis. The sensing unit uses a DHT22 device for temperature and humidity, an MQ-135 sensor for air-quality changes, and an IR sensor to observe bird movement. These devices are connected to an ESP32 controller. An ESP32-CAM captures images of the shed to support visual inspection of birds, litter, and surrounding conditions. Sensor readings are transmitted over Wi-Fi to a backend application implemented with Node.js and Express.js. The backend validates incoming values and compares them with configured safety thresholds. It also retains recent abnormal readings in a 75-second hazard-memory window. Examining events within this interval makes it possible to consider related deviations together rather than treating every reading as an isolated event.

The AI analysis component uses the sensor information to produce a farm health score, a risk category, possible conditions, supporting observations, and preventive suggestions. Images from the ESP32-CAM are grouped into Bird, Litter, or Other categories so that visual observations can complement the environmental readings. A web dashboard displays current sensor values, analysis outputs, and alerts, with WebSocket communication used for live updates. The design also includes regional-language notifications, voice alerts, SMS and WhatsApp messaging, historical reports, and ventilation-control support. A rule-based assessment path is available when the external AI service is unavailable. The overall objective is to combine continuous sensing, temporal trend evaluation, and image-based observations in one monitoring platform that helps farmers recognize potentially unsafe conditions and make informed management decisions.

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1.1. RESEARCH CONTRIBUTION

The system brings together IoT sensing, AI-assisted analysis, and continuous monitoring to help identify conditions that may place poultry health at risk. Environmental readings and bird activity are observed over time, while image-based inspection supplies an additional view of the shed. The principal contributions are summarized below:

A. Integrated IoT-Based Monitoring: Multiple sensors connected to an ESP32 collect temperature, humidity, gas-level, and bird-movement information on an ongoing basis. The ESP32-CAM supplements these readings by capturing images from the poultry shed.

B. Edge-Based Data Collection: The ESP32 serves as the local controller for the sensing devices. It gathers readings, carries out initial handling, and forwards the collected information to the backend over Wi-Fi.

C. Multi-Sensor Trend Detection: The backend retains abnormal readings within a 75-second hazard-memory interval. Evaluating deviations from different sensors during this interval helps reveal combinations of changes that may indicate an unfavourable shed environment.

D. AI-Based Health-Risk Assessment: The AI component examines detected sensor deviations and prepares a structured assessment. Its output includes a health score, risk category, possible conditions, observations supporting the assessment, and preventive guidance for the farmer.

E. Camera-Based Visual Analysis: Images obtained through the ESP32-CAM are processed and assigned to Bird, Litter, or Other categories. The image-analysis output also includes confidence information, observations, status, and recommendations.

F. Real-Time Backend and Dashboard: The Node.js and Express.js server accepts sensor readings through a telemetry API and maintains recent monitoring information. WebSocket messages carry current readings, alerts, and AI assessment results to the dashboard.

G. Hybrid Risk Assessment: A local rule-based assessment is provided as a fallback if the external AI service cannot be accessed. This allows essential risk checks to continue without relying exclusively on that service.

H. Farmer Support and Automated Alerts: The interface is designed to present live alerts, multilingual and voice notifications, SMS/WhatsApp messages, historical reports, and trend charts. Ventilation-control support and feedback-based guidance are also included to help farmers act on identified conditions.

1.2 RELEVANT LITERATURE

Research on poultry health management increasingly considers the use of Artificial Intelligence (AI), Internet of Things (IoT), and continuous monitoring. Previous work has examined sensor-based farm observation, image-assisted disease identification, environmental measurement, and automated surveillance. The studies below form the background for the system presented in this paper.

A. **Paper-1: IoT Enabled Smart Poultry Farming System With Deep Learning, for Chicken Health Detection Instantly (2026)**

Study [1] describes an IoT-supported poultry monitoring arrangement that combines an ESP32 board, environmental sensors, and cameras. Its sensing setup includes DHT22 and MQ135 devices, while an ESP32-CAM collects poultry images. The authors evaluate several deep-learning approaches and report 99.19% testing accuracy and 95.62% validation accuracy for EfficientNet-B0. The work illustrates how environmental sensing and image analysis can be used together in poultry management. Image-based methods, however, depend on suitable visual data and do not by themselves provide continuous evaluation of combined environmental changes. The system described in this paper therefore considers sensor-trend detection, AI-assisted risk assessment, and image analysis as complementary functions.

B. Paper-2: A Hybrid Approach to Real-Time Poultry Disease Surveillance and Intervention (2026)

The study in [2] presents a hybrid poultry-disease surveillance framework that combines deep learning with mathematical epidemiological modelling. DenseNet121 is used for image analysis, while a modified SEIRD model represents disease spread through a poultry population. Differential Evolution is applied to identify intervention strategies. The work demonstrates how image-based learning and disease-spread modelling can contribute to surveillance and planning. Its

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combination of modelling, optimization, and image-processing components may require substantial implementation effort and suitable input data. In contrast, the present work concentrates on integrating live sensor collection, short-term trend detection, AI-supported risk evaluation, and dashboard-based communication.

C.PAPER-3: TRANSFORMING POULTRY HEALTH MANAGEMENT WITH AI-POWERED DISEASE DETECTION (2025)

Eskioglu and Özdemir [3] examined AI methods for poultry health management in the context of Agriculture 4.0 and Precision Livestock Farming. Their review covers techniques such as Support Vector Machines, Support Vector Regression, Convolutional Neural Networks, and Long Short-Term Memory networks. It emphasizes the value of environmental, behavioural, and biological information when assessing poultry health. The review supports the use of intelligent analysis in automated farm management. Translating these methods into a practical installation still requires coordination between sensing hardware, data processing, trend evaluation, and farmer-facing notifications. The system in this paper addresses these implementation needs through a connected IoT and AI monitoring arrangement.

*D.***Paper-4 : How Artificial Intelligence Helps Us Spot Bird Flu Outbreaks A Review (2025)**

Shafi et al. [4] surveyed AI techniques used to identify and monitor avian-influenza outbreaks. The review discusses environmental observation, biosensors, computer vision, and machine-learning approaches to surveillance. It points to the benefit of combining information from more than one source when monitoring potential outbreaks. AI-supported surveillance may help identify warning signs and inform preventive action; however, accessible, continuous monitoring at the level of an individual poultry farm remains a practical concern. The proposed work focuses on farm-level observation using IoT sensors, camera-based analysis, and ongoing risk assessment.

1.3 GAP ANALYSIS

Prior studies have investigated AI, IoT, and deep-learning methods for poultry monitoring, but bringing these capabilities together in a continuously operating and practical farm system remains challenging. The literature reviewed above indicates several areas that require attention.

A. Limitations of Image-Only Early Warning: Sakib et al. [1] use an ESP32-CAM and deep-learning image classification for poultry health detection. Although the reported classification results are promising, images alone may not reveal ongoing changes in temperature, humidity, or air quality. Combining visual observations with continuous environmental and behavioural readings can provide a more complete picture of shed conditions.

B. Implementation Demands of Hybrid Prediction Models: The framework in [2] brings together deep learning, epidemiological simulation, and optimization for surveillance and intervention planning. Its operation depends on several computational elements, data quality, and modelling assumptions. These factors need to be considered when adapting such a framework to farms with different resources and operating conditions.

C. Integration of Continuous Monitoring Functions: Eskioglu and Özdemir [3] discuss a range of learning methods for poultry health management. A further practical requirement is to connect sensor acquisition, time-based trend evaluation, AI assessment, and communication with farmers within one operational system.

D. Data Consistency and Standardization: Shafi et al. [4] describe surveillance methods that draw on several AI techniques and information sources. Differences in data quality, potential bias, and inconsistent implementation can influence the reliability of the resulting assessment. A defined process for collecting, validating, and handling sensor information is therefore important.

E. Joint Evaluation of Time-Series and Visual Information: Sensor readings and camera images describe different aspects of the poultry environment. Analysing them independently can leave useful context unused. Evaluating environmental trends alongside camera observations may provide additional evidence when identifying conditions that require attention.

F. Dependable Alerts and Service Continuity: Detection is useful only when the result reaches the farmer in time. A practical solution should communicate updates promptly and retain essential monitoring capability when an external AI analysis service is temporarily unavailable.

G. Research Gap Addressed by the Proposed System: The proposed design responds to these needs by connecting an ESP32-based sensing unit, environmental and activity sensors, and an ESP32-CAM for image capture. A Node.js and Express.js backend receives the telemetry and stores recent readings. Its 75-second hazard-memory interval brings together abnormal events that occur close in time, supporting assessment of trends rather than isolated measurements.

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The design also includes AI-assisted risk evaluation, camera-image analysis, and a live dashboard updated through WebSocket communication. When the external AI service is unreachable, a deterministic rule-based mechanism continues basic risk assessment. Together, these functions are intended to support continuous observation, earlier awareness of abnormal conditions, and more informed decisions by farmers.

II. PROPOSED SYSTEM DESIGN

The proposed design is an integrated IoT and AI framework intended to identify early signs of poultry-farm health risk. It observes environmental and behavioural conditions, evaluates sensor readings and captured images, and highlights patterns that may be associated with an unhealthy environment.

Six principal modules form the architecture: the Sensing Layer, Edge Controller, Backend Server, AI Analysis Layer, User Interface and Alerts, and Smart Actions and Farmer Support. Information passes between these modules so that farm conditions can be measured, evaluated, and presented to the farmer.

A. Sensing Layer (IoT Hardware)

The IoT sensing layer obtains environmental and activity-related measurements through devices connected to the ESP32. The hardware used in the system includes:

- DHT22 Sensor: Records the temperature and relative humidity within the poultry shed.
- MQ-135 Gas Sensor: Measures changes in gas concentration and air quality, including variations associated with ammonia.
- Litter-Moisture Sensor: Provides readings of moisture present in the poultry litter.
- IR Sensor: Senses movement and activity of birds.
- ESP32-CAM: Takes images of the farm environment for subsequent visual assessment.
- LED and Buzzer: Give an on-site indication when the system detects an abnormal condition.

Together, these devices supply the environmental and activity information required by the processing stages.

B. Edge Controller

The ESP32 is the edge device responsible for collecting readings from the connected sensors at defined intervals. It sends the measurements to the backend using Wi-Fi and the telemetry interface. Image capture is performed separately by the ESP32-CAM. In this way, the edge layer links the physical monitoring devices with the software platform.

C. Backend Server

The server side is implemented with Node.js and Express.js. Sensor measurements arrive from the ESP32 through the /api/telemetry endpoint. The backend carries out the following tasks:

- Accepts incoming measurements and checks their validity.
- Keeps the latest sensor status together with a history of recent telemetry.
- Checks measured values against configured safety thresholds.
- Uses a 75-second hazard-memory interval to group recent abnormal readings.
- Passes relevant sensor information to the AI risk-assessment component.
- Publishes current readings and alert information to the dashboard using WebSocket communication.

The hazard-memory interval retains recent abnormal events for 75 seconds. Considering these events together allows the backend to recognize related changes across sensors rather than making a decision from each measurement in isolation.

D. AI Analysis Layer

The AI analysis module evaluates sensor information and images captured from the poultry shed. It provides three main functions:

1. AI-Based Health-Risk Assessment: After the backend identifies significant sensor deviations, it sends the relevant information to the AI service. The returned assessment contains a health score, a risk category, possible health conditions, observations supporting the result, and suggested preventive measures.

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2. Camera-Based Image Analysis: The ESP32-CAM images are examined and assigned to one of the categories Bird, Litter, or Other. The output includes observations, confidence details, status information, and recommendations, adding visual context to the sensor-based assessment.

3. Rule-Based Fallback Mechanism: If the external AI service is unavailable, the system applies predefined rules and safety thresholds to identify basic risk conditions. This fallback preserves essential monitoring support during a service interruption.

E. User Interface and Alerts

The dashboard gives farmers an overview of the current state of the poultry shed. WebSocket updates are used to display temperature, humidity, gas concentration, litter moisture, bird activity, sensor warnings, AI risk assessments, and image-analysis results. The design also supports multilingual messages, voice notifications, and SMS/WhatsApp communication so that important information can reach farmers through different channels.

F. Smart Actions and Farmer Support

This module is intended to help farmers respond to detected changes. It brings together immediate notifications, past reports, trend visualizations, and preventive guidance. The design also provides for ventilation or fan-control support to help maintain suitable conditions inside the shed and assist day-to-day farm decisions.

G. Overall System Workflow

The main processing sequence is as follows:

1. IoT devices measure temperature, humidity, gas concentration, litter moisture, and bird activity continuously.
2. The ESP32 gathers the sensor measurements and sends them to the backend over Wi-Fi.
3. The Node.js and Express.js server validates each incoming record and checks the configured thresholds.
4. Abnormal events from the recent 75-second interval are considered together to identify possible risk patterns.
5. Sensor information relevant to the detected pattern is submitted to the AI module for assessment.
6. The ESP32-CAM obtains poultry-shed images for visual classification and analysis.
7. The backend distributes sensor values, alerts, and AI assessment outputs to the dashboard through WebSocket messages.
8. Farmers view the current monitoring results and preventive guidance on the dashboard.
9. If the external AI service cannot be contacted, the rule-based fallback supplies a basic indication of risk.

In summary, the architecture links IoT measurement, backend trend processing, AI-supported interpretation, and farmer communication to improve awareness of possible poultry health risks.



III. EXPECTED OUTCOMES AND BENEFITS

The system is intended to strengthen poultry-shed monitoring by combining sensor measurements, AI-assisted evaluation, camera observations, and timely communication. These functions can help bring unusual environmental conditions to the farmer's attention earlier, allowing suitable action to be considered before the situation becomes more serious.

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A. Expected Outcomes

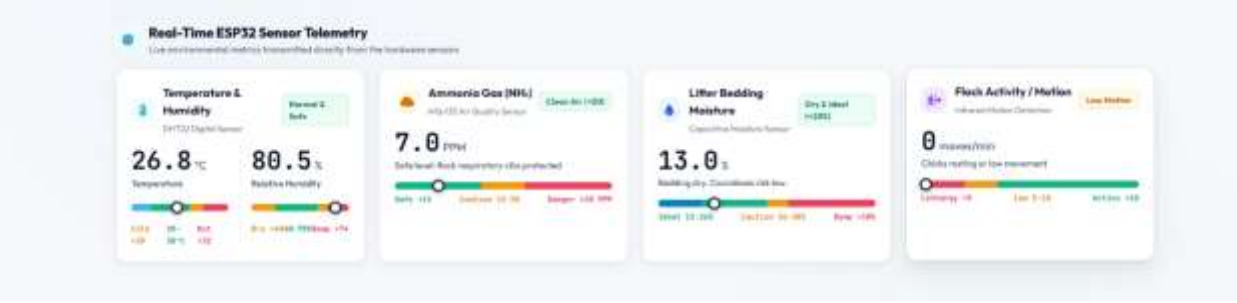
1. Real-Time Monitoring: Continuous readings of temperature, humidity, gas concentration, litter moisture, and bird activity provide an updated view of conditions inside the shed.
2. Early Identification of Abnormal Conditions: Configured thresholds and the 75-second hazard-memory interval help detect and evaluate multiple sensor deviations occurring within a short period.
3. AI-Based Health-Risk Assessment: The AI component evaluates sensor information and produces a health score, risk category, possible conditions, supporting observations, and preventive guidance.
4. Camera-Based Visual Monitoring: Images from the ESP32-CAM are categorized as Bird, Litter, or Other, with associated observations and confidence information.
5. Live Dashboard Information: WebSocket updates make current sensor readings, alerts, AI assessments, and image-analysis results available through the monitoring interface.
6. Continued Basic Assessment: The rule-based fallback provides essential risk indications if the external AI service is not responding.
7. Farmer-Focused Communication: Multilingual and voice notifications, SMS/WhatsApp messages, historical reports, trend charts, and ventilation-control support are included in the system design.

B. Benefits of the Proposed System

1. 1. Reduced Manual Checking: Continuous measurement can reduce the frequency of routine manual checks of environmental conditions in the poultry shed.
2. 2. Earlier Awareness: Prompt notifications can make farmers aware of unfavourable readings sooner and give them an opportunity to respond.
3. 3. Informed Farm Decisions: Risk assessments, sensor measurements, and image observations provide information that can guide preventive action.
4. 4. Broader Condition Monitoring: Using several sensors together with camera analysis covers more aspects of the poultry environment than a single monitoring source.
5. 5. Remote Access to Information: Dashboard and notification functions allow farmers to review important monitoring information without being beside the sensing unit.
6. 6. Improved Record-Based Management: Stored readings and trend charts help reveal changes over time and support more informed management of shed conditions.
7. 7. Potential Cost Avoidance: Recognizing abnormal conditions at an earlier stage may help limit the severity of problems and avoid some preventable losses.

C. Overall Expected Impact

The system aims to move poultry monitoring beyond periodic inspection by providing continuous observation of environmental and behavioural conditions. Sensor trends, AI-assisted assessment, camera analysis, and live alerts are combined to support earlier recognition of potential risks and timely preventive decisions. Testing across different poultry farms and operating environments will be required to determine its practical performance and longer-term value.



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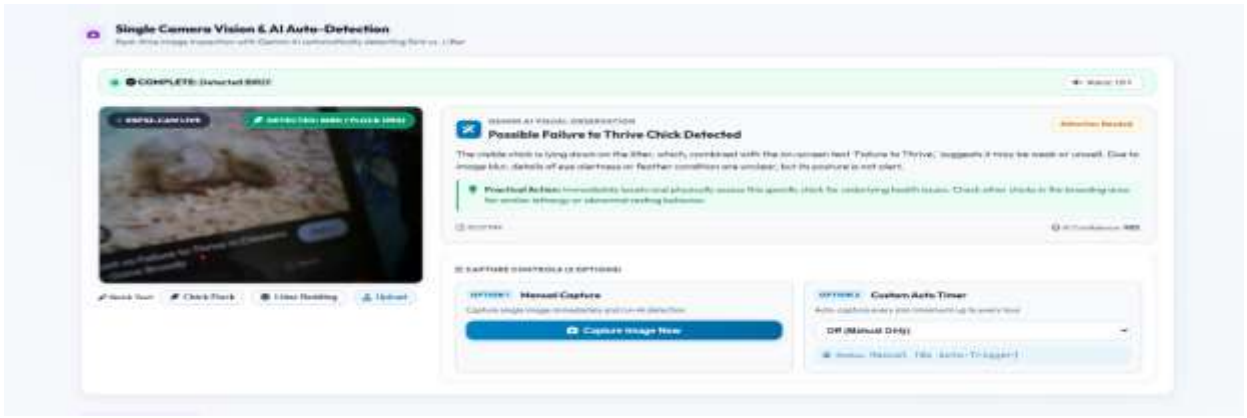

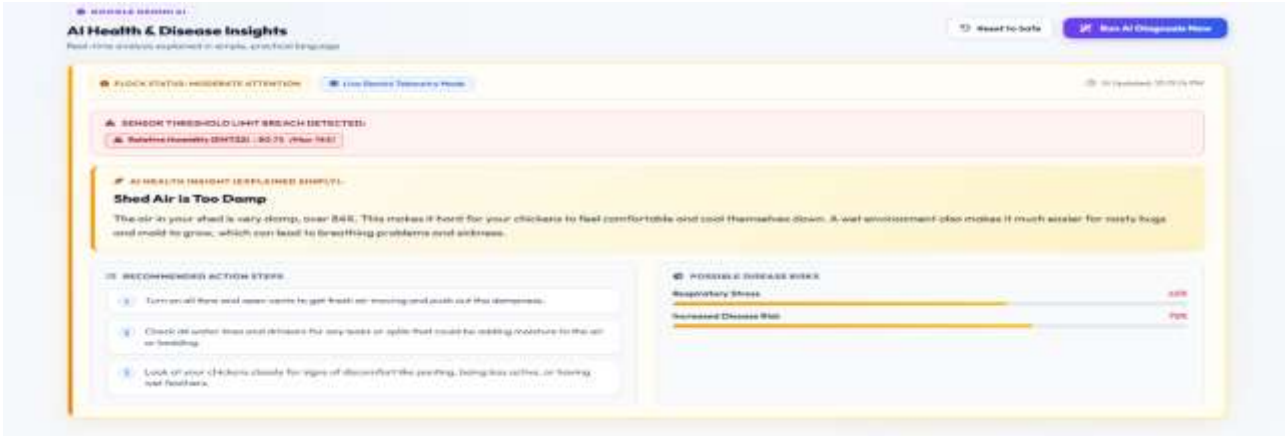

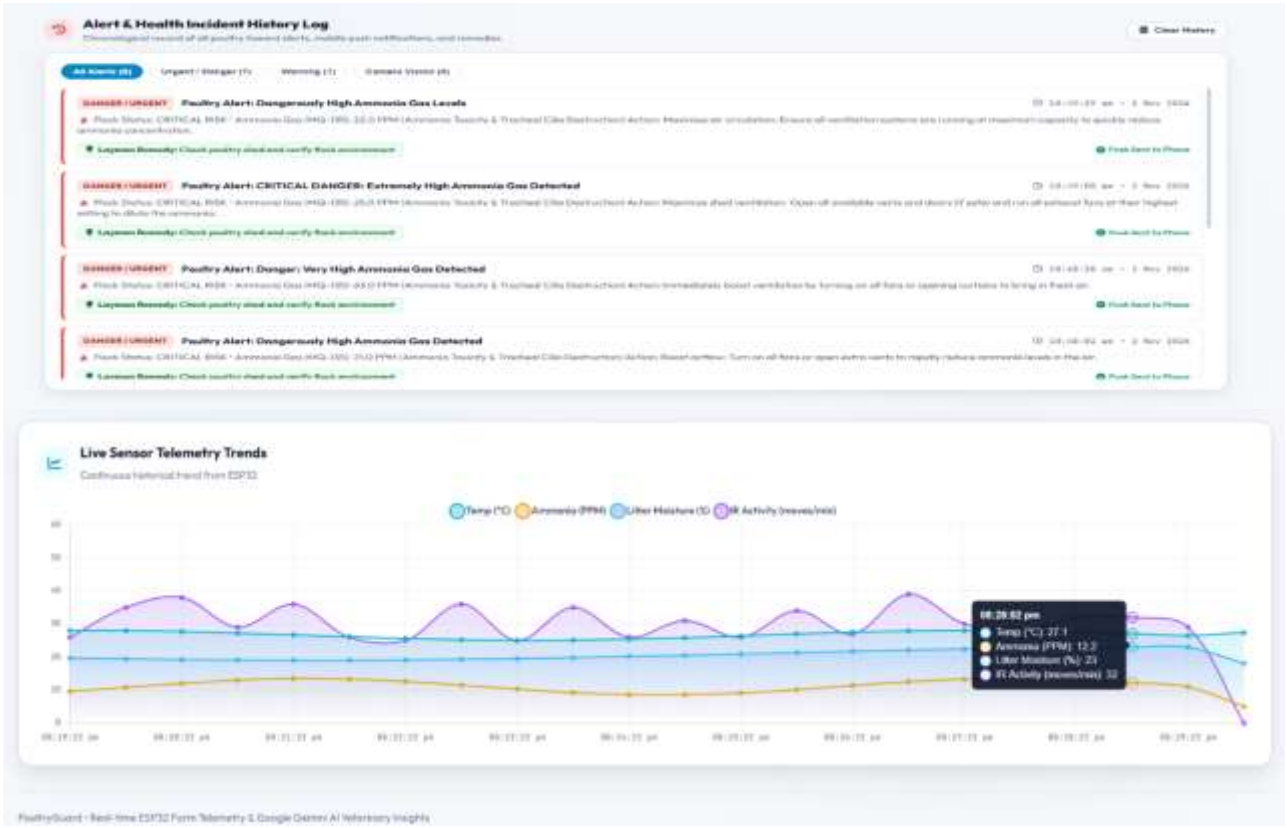

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IV. METHODLOGY

1. Data Collection Using IoT Sensors — Environmental and activity information, including temperature, humidity, gas concentration, litter moisture, and bird movement, is gathered using devices such as the DHT22, MQ-135, and IR sensors connected to the ESP32.

2. Data Preprocessing and Storage — The collected readings are checked, organized, and stored in a structured form, such as a CSV file or database, for subsequent processing and analysis.

3. Machine Learning Model Development — Models such as Decision Tree and Random Forest may be trained to examine patterns in the available input data and estimate disease-risk categories.

4. Trend Analysis for Anomaly Detection — Current measurements are compared with recent observations to identify unusual changes, for example, an increase in temperature or a reduction in bird movement, that may indicate an unfavourable condition.

5. Real-Time Prediction and Risk Classification — The model and incoming sensor information are used to assign a risk category of Low, Medium, or High.

The methodology combines IoT data acquisition, edge-level collection, backend trend evaluation, AI-assisted risk analysis, and camera-based observation. The 75-second hazard-memory interval is used to examine sensor deviations that occur close together. Results are made available through the live dashboard, while a rule-based fallback supports basic assessment if the external AI service is not accessible.

This combined process is intended to maintain ongoing observation of poultry-shed conditions and provide information that can assist timely decisions.

V. RESULT ANALYSIS AND DISCUSSION

The implemented system brings together IoT sensing, backend data handling, time-based trend evaluation, AI-assisted assessment, and camera monitoring. It observes poultry-farm conditions continuously and presents information that may help identify potential health risks.

A. Real-Time Sensor Monitoring
DHT22, MQ-135, litter-moisture, and movement sensors connected to the ESP32 collect environmental measurements and bird-activity readings. The ESP32 forwards this information to the backend, where incoming records are checked and retained for display on the monitoring dashboard.

B. Hazard Detection and Trend Analysis
Configured safety thresholds are applied to incoming sensor values to identify deviations. The backend also uses a 75-second hazard-memory interval to consider recent abnormal readings together, helping reveal related changes in the farm environment.

C. AI-Based Health-Risk Assessment
The AI component evaluates sensor readings and the trends identified by the backend. It returns a health score, risk category, possible conditions, supporting observations, and preventive suggestions. This information is intended to help farmers understand the nature of a potential concern and decide on an appropriate response.

D. Camera-Based Visual Analysis
Images obtained through the ESP32-CAM are analysed and grouped into Bird, Litter, or Other categories. Observations, confidence information, and recommendations from this process provide a visual complement to the sensor measurements.

E. Real-Time Dashboard and Alerts
The dashboard presents current sensor readings, risk-assessment outputs, image-analysis information, and alerts. WebSocket communication is used to deliver updates as new information becomes available.

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F. Rule-Based Fallback Analysis

When the external AI service cannot be reached, the backend uses predefined thresholds and rules to provide a basic assessment of abnormal conditions. This fallback helps preserve essential monitoring functions during service interruptions.

G. Discussion

The system places sensor monitoring, short-term multi-sensor trend analysis, AI-assisted assessment, and image-based observation within a common workflow. The 75-second hazard-memory interval provides a way to consider related deviations, while camera analysis adds visual context to the environmental measurements. Dashboard updates make the results available to farmers and can support timely preventive action.

Further evaluation using data collected from operational poultry farms, together with veterinary review, is needed before conclusions can be drawn about prediction accuracy, reliability, and the system's effect on poultry health.

VI. CONCLUSION AND FUTURE SCOPE

A. Conclusion

The proposed system combines Internet of Things (IoT) sensing, temporal trend analysis, AI-assisted risk assessment, and camera-based observation to support poultry-farm monitoring. An ESP32 controller gathers environmental and activity information from connected devices, including temperature, humidity, air quality, litter moisture, and bird movement.

Measurements are sent to a Node.js and Express.js backend, where they are validated and checked against configured safety limits. The 75-second hazard-memory interval allows the backend to examine multiple abnormal readings that occur within a short time. The AI component prepares a health-risk assessment, and the ESP32-CAM contributes images for visual analysis.

A web dashboard presents sensor information, analysis outputs, and alerts, with WebSocket communication used for live updates. A deterministic rule-based fallback also supplies basic risk information when the external AI analysis service is unavailable.

The system is intended to improve awareness of changing poultry-shed conditions, lessen reliance on repeated manual observation, and provide farmers with information for making timely decisions. It establishes an integrated technical approach to poultry-farm monitoring.

B. Future Scope

Further development of the system may consider the following areas:

1. Larger Dataset Collection: Gathering poultry data from more farms, seasons, and operating conditions would provide a stronger basis for evaluating and improving the risk-assessment process.
2. Advanced Machine Learning Models: Future work may compare suitable machine-learning and deep-learning approaches using poultry datasets with reliable labels and validation.
3. Enhanced Image Analysis: The visual component could be extended to examine a wider range of visible health indicators and unusual bird behaviours.
4. Veterinary Integration: Working with veterinary professionals would help review the risk categories and assess the suitability of the system's recommendations.
5. Mobile Application Development: A dedicated mobile interface could make live readings, alerts, and historical information easier for farmers to access.
6. Multilingual and Voice-Based Alerts: Additional regional-language options and further voice-notification support could make the system more accessible to farmers.
7. Automated Farm Control: Later versions could extend the control functions for fans, ventilation, and other shed equipment using defined operating limits and safety conditions.
8. Long-Term Performance Evaluation: Trials across poultry farms and a range of environmental conditions are needed to assess accuracy, reliability, scalability, and practical usability over an extended period.

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