Acoustic Sensor Based Smart Runway Health Monitoring System

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ABSTRACT

This poster details the development of an Advanced Runway Health Monitoring System (ARHMS) —a prototype that seamlessly integrates cutting-edge acoustic sensor detection and sophisticated machine learning-driven computer vision to provide real-time assessments of runway conditions. The system effectively tackles critical safety challenges in airport infrastructure by enabling continuous monitoring of surface defects, foreign object damage (FOD), and structural integrity that traditional manual inspections often overlook. By leveraging YOLOv8 for precise object detection, OpenCV for image processing, and embedded acoustic sensors, the prototype was trained on over 600 Kaggle dataset images and tested on a scaled physical model simulating real runway environments, demonstrating impressive accuracy in hazard detection.

PROBLEM STATEMENT

Current runway inspections are manual and periodic, making them ineffective at detecting real-time defects and FOD. This heavy reliance on human inspection leads to late identification of cracks and structural damage, causing delayed maintenance, elevated accident risk, and reduced operational reliability. There is a critical need for a continuous, non-intrusive, automated monitoring solution capable of providing real-time hazard detection without runway closures.

INTRODUCTION

Runways are critical aviation infrastructure subjected to heavy structural loads and constant environmental stress. Defects like cracks, surface roughness, and foreign object debris (FOD) can cause serious accidents if left undetected. Traditional inspection methods are manual, periodic, and error-prone. ARHMS introduces a hybrid AI-based solution designed for continuous, real-time monitoring, replacing reactive practices with a proactive, intelligent safety framework.

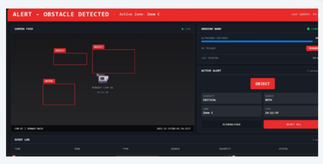
PROPOSED SOLUTION

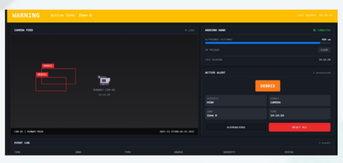
ARHMS combines Piezoelectric and MEMS acoustic sensors to detect subsurface structural defects through vibration signal analysis, with YOLOv8-powered computer vision identifying surface hazards including FOD, cracks, and anomalies. The system performs real-time data processing and generates automated alerts to airport authorities, producing clear runway status outputs — "Runway Ready" or "Runway Not Ready" — enabling rapid, informed decision-making. High-resolution cameras placed at 50-metre intervals with overlapping fields of view ensure complete runway coverage with zero blind spots.

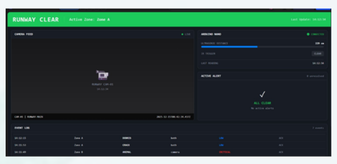
SYSTEM FLOW

Acoustic Sensors & Cameras → Data Capture & Preprocessing → AI / ML Analysis (YOLOv8) → Surface & Subsurface Hazard Detection → Runway Status Alert Generation → Authority Notification & Maintenance

LIVE DASHBOARD — ALERT STATES







The real-time dashboard displays live camera feed, Arduino Nano sensor data (ultrasonic distance & IR trigger), active alert severity, zone, source, and timestamp — with operator acknowledge and reset functions for rapid ground response.

PHYSICAL PROTOTYPE

A scaled physical airport model was built to simulate real runway environments, complete with LED runway lighting, multiple aircraft positions, and integrated sensors to validate system performance.

CONCLUSION

ARHMS demonstrates that a hybrid acoustic and AI vision approach can deliver continuous, reliable runway hazard detection. By automating surface and subsurface monitoring, the system significantly reduces dependence on manual inspection, enables faster maintenance decisions, and enhances overall aviation safety and operational cost-effectiveness. The prototype confirms strong potential for scalable real-world airport implementation.

FUTURE SCOPE

- Integration with Airport Operations and ATC systems for fully automated runway clearance decisions without human intervention.
- Expanded coverage to taxiways, aprons, and helipads for complete airside safety monitoring.
- Predictive maintenance models trained to forecast surface cracks and structural degradation before failure occurs.
- Scalable IoT and cloud-based dashboards enabling simultaneous real-time multi-airport monitoring and analytics.