Predictive Maintenance for HEMM Using Thermal Imaging & Machine Learning

Mine Automation and Data Analytics

Problem Statement

HEMM components such as dump trucks and excavators are prone to overheating due to friction, excessive load, or lubrication failures. HEMM failures cause **production delays & high costs**.

Current maintenance is reactive – failure is detected **after damage is done**. Traditional sensors (e.g., vibration, pressure) may not detect latent heat buildup.

Solution

A predictive maintenance system that detects early warning signs using **thermal imaging** and **sensor data analysis**. Thermal imaging combined with machine learning enables proactive failure detection and maintenance scheduling.

How Our Project Works

Key Components:

1. **Thermal Cameras & IoT Sensors** – Capture real-time machine heat signatures.
2. **AI-based Image Processing** – Classify normal vs. faulty conditions.
3. **Edge & Cloud Deployment** – Real-time decision-making & dashboard monitoring.
4. **Real-Time Monitoring:** Displaying results on a dashboard.

🔍 **Goal:** Identify **early signs of failure** (engine overheating, hydraulic leaks, worn bearings, etc.).

Data Collection and Preprocessing

- **Thermal Imaging (FLIR Cameras)**

- *Infrared cameras detect **temperature variations**.*
- *Faulty parts **heat up abnormally**, indicating failure risk.*

- **Sensor Data (IoT-based Monitoring)**

- ***Temperature, vibration, pressure sensors** continuously track machine health.*
- *Stored in **CSV files** for real-time analysis.*

- **Data Preprocessing Techniques**

✓ ***Image Enhancement** – Apply **colormap (Jet/Hot)** for better fault visibility.*
✓ ***Noise Reduction** – Smooth images to remove sensor inaccuracies.*
✓ ***Data Cleaning** – Handle missing sensor values & outliers.*

AI Model – CNN-Based Fault Detection

Why CNN (Convolutional Neural Networks)?

- Best for **image classification**.
- Learns **heat patterns** and detects **anomalies** automatically.

Model Training Process

📌 **Dataset:**

- *Labeled as **"Normal"** and **"Anomaly"**.*
- *Stored in dataset/normal/ and dataset/anomaly/.*

📌 **CNN Architecture:**

- **Conv2D layers** extract heat features.
- ***Fully connected layers** classify images.*

📌 **Output:**

- □ *Normal Condition*
- 🔴 *Anomaly Detected*

Model Training & Accuracy

Training Steps:

1. *Data Augmentation (rotation, scaling) to improve robustness.*
2. *Training CNN on thermal images.*
3. *Validation on unseen test images.*

Results:

- ***Accuracy: 90-95%** on test images.*
- ***Precision & Recall:** High for anomaly detection.*

Real-Time Deployment (Edge + Cloud + Dashboard)

📡 Edge AI Deployment

- *Model runs on **NVIDIA Jetson** or **Raspberry Pi** near the equipment.*
- ***Low latency** – Faults detected in real time.*

🌐 Cloud Integration (Flask API)

- *Data sent to **central cloud storage**.*
- *API allows real-time access to predictions.*

📊 Streamlit Dashboard

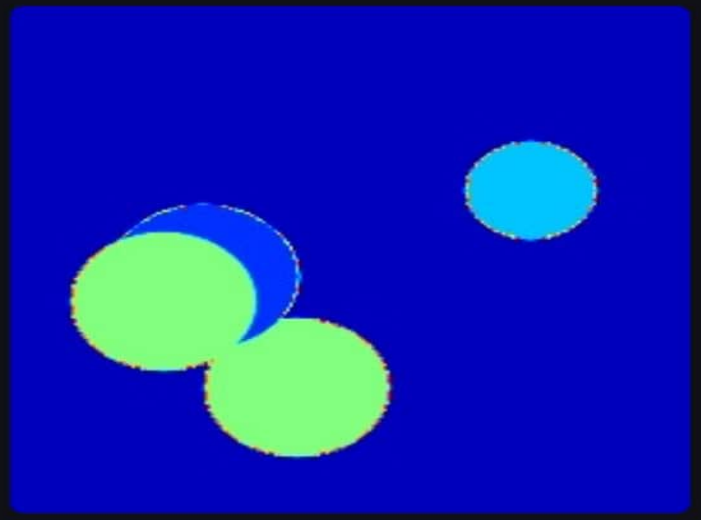
- *Shows **latest thermal images, sensor readings, and fault alerts**.*

DEMO – Streamlit Dashboard Walkthrough

Dashboard

Timestamp	HEMM_ID	Sensor_Location	Temperature	Vibration	Condition	Thumbnail
2025-04-04 01:18:09	HEMM_04	Transmission	73.48	3.20	Anomaly (99.64%)	
2025-04-04 01:18:04	HEMM_04	Brakes	61.34	3.42	Anomaly (99.64%)	
2025-04-04 01:17:59	HEMM_04	Brakes	91.79	3.63	Normal (100.00%)	
2025-04-04 01:17:54	HEMM_04	Cooling System	69.40	1.17	Anomaly (99.64%)	
2025-04-04 01:17:49	HEMM_01	Transmission	67.15	1.31	Anomaly (99.64%)	
2025-04-04 01:17:44	HEMM_03	Transmission	66.50	4.68	Normal (100.00%)	
2025-04-04 01:17:39	HEMM_02	Cooling System	87.36	3.75	Normal (100.00%)	
2025-04-04 01:17:34	HEMM_03	Cooling System	84.25	1.97	Normal (100.00%)	
2025-04-04 01:17:29	HEMM_01	Hydraulics	77.36	1.25	Anomaly (99.64%)	
2025-04-04 01:17:24	HEMM_01	Transmission	97.07	1.53	Normal (100.00%)	

Latest Captured Thermal Image

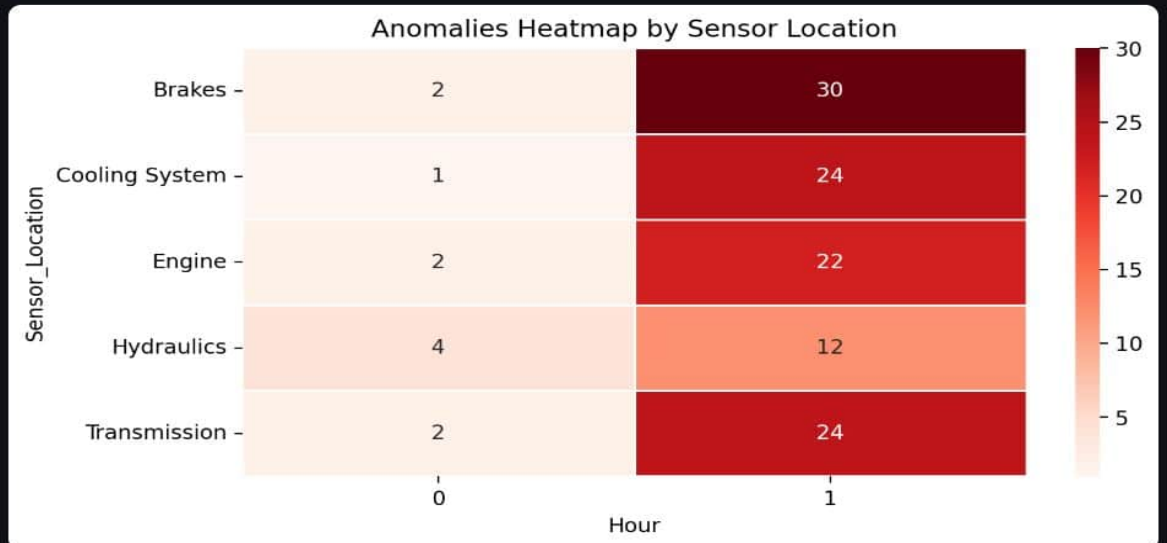


Latest Thermal Image (Colorized)

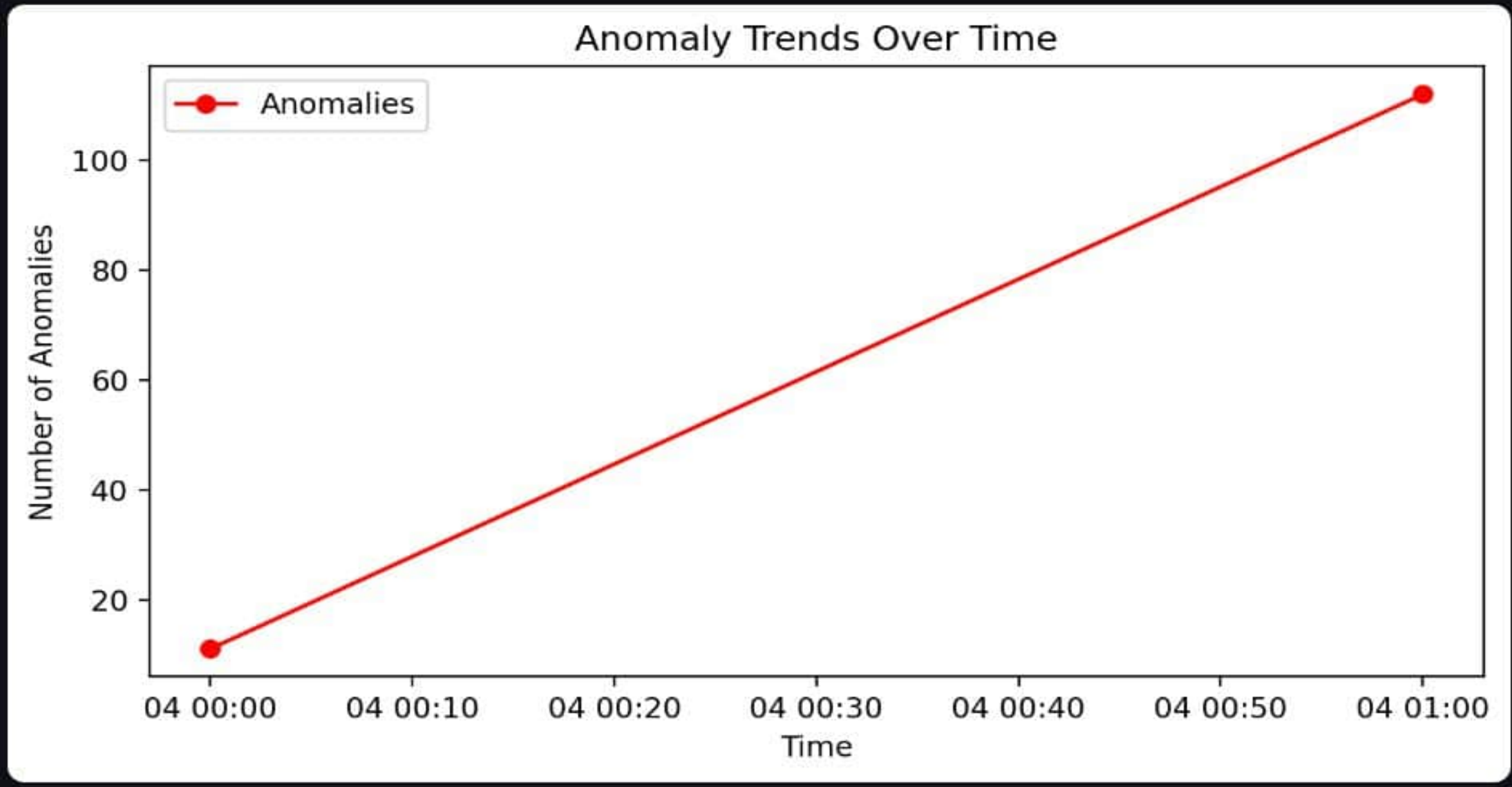
Automatic Classification Result

✅ **Normal Condition** (1.00)

Heatmap of Anomalies by Sensor Location



📈 Fault Prediction Trends



Key Features of the Dashboard

✔ ***Real-Time Thermal Image Processing*** *– Auto-updates every 5 seconds.*

✔ ***Sensor Data Table with Color Highlights*** *–*

- *Normal (Green)*
- *Anomaly (Red)*

✔ *Automatic Fault Classification.*

✔ *Download Sensor Data (CSV Format).*

Future Enhancements

Next Steps:

1. **Live HEMM Tracking** – GPS + thermal data for fleet-wide monitoring.
2. **SCADA/CMMS Integration** – Automated maintenance scheduling.
3. **More Advanced AI Models** – Vision Transformers for better accuracy.

Expected Outcomes

- 20–30% reduction in unplanned downtime.
- Early fault detection (48+ hours before failure).
- Seamless integration with SCADA/CMMS systems.

THANK YOU

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