MANIPAL UNIVERSITY

School of Computer Science and Engineering

Department of Computer Science and Engineering

Automated Predictive Service System (APSS)

Enhancing Operational Efficiency through Embedded AI Diagnostics

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Section- D

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Outline

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Introduction

The Challenge of Scale

Large enterprises face significant inefficiencies in monitoring and maintaining thousands of machines—such as ATMs, industrial sensors, and vending units—due to manual defect detection and slow response times. Breakdowns often go unnoticed until serious disruptions occur, leading to revenue loss and operational delays. There is a clear need for an automated system that can proactively detect issues and streamline the repair process.

Bulk Procurement

Companies purchase hundreds of machines, making individual maintenance checks infeasible.

Reactive Fixes

Maintenance relies on customer complaints, leading to significant downtime and revenue loss.

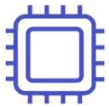
Revenue Impact

Each hour of machine downtime directly reduces service capacity and harms overall business revenue.

Literature Review: State of the Art

Embedded Intelligence and Edge Computing

My solution is grounded in the rapidly evolving fields of Embedded AI and Edge Computing, which allow complex computations locally on microcontrollers, rather than in the cloud.



TinyML Frameworks

Enables extremely lightweight machine learning models, like decision trees, to run on low-power microcontrollers (e.g., using TensorFlow Lite Micro).

Firmware Diagnostics

Utilizing low-level system checks such as watchdog timers, error registers, and assembly instruction monitoring for deep-level fault detection.

IoT Protocols

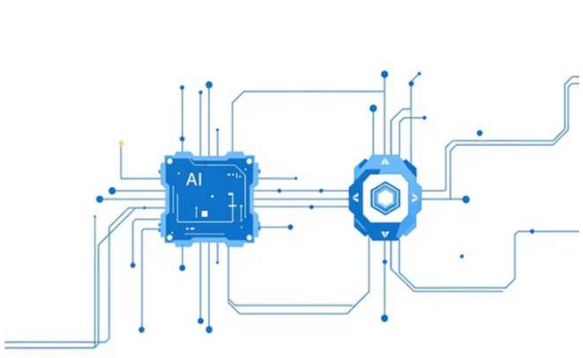
Standardized communication protocols (MQTT, REST API) ensure reliable, low-bandwidth transmission of diagnostic logs to the central system.

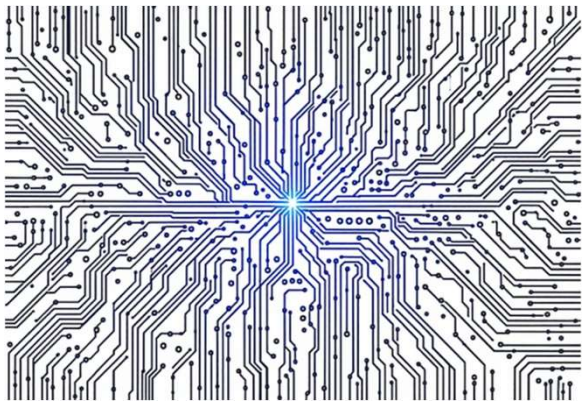
Literature Review: Key Concepts

Concept: Embedded AI Service Trigger via Microcontroller Firmware

This approach shifts the diagnostic paradigm from the network layer to the hardware core. By integrating the intelligence directly into the device firmware, we achieve real-time, granular fault detection right at the source of the potential problem.

A clear opportunity exists to create an integrated system that combines firmware-level diagnostics, adaptive machine learning, and real-time notification protocols, overcoming gaps in current industry practices and elevating machine maintenance to a predictive and automated model.





The Problem Statement

The current maintenance model is reactive and inefficient, resulting in prolonged downtime and reduced profitability.

Delayed Detection

Failures are often only identified when a user reports a non-functional machine, after the error has occurred.

Vague Error Reporting

Existing systems rarely specify the exact component failure, forcing technicians to perform lengthy, on-site diagnostics.

Inefficient Logistics

Service dispatching is slow, manual, and lacks prioritization based on severity or required parts, wasting valuable technician time.

Project Objectives

Defining Success for APSS

The primary objectives of the Automated Predictive Service System are quantifiable and focused on improving key performance indicators (KPIs) for machine infrastructure management.

1

Reduce Mean Time To Repair (MTTR)

By instantly identifying the faulty component, we aim to reduce diagnostic time from hours to minutes, drastically decreasing the total repair time.

2

Increase Operational Uptime

Proactive detection and rapid response minimize machine downtime, leading to increased transaction throughput and higher revenue generation.

3

Enhance Customer Satisfaction

Fewer out-of-service machines and a more efficient service process directly translate into a better experience for the end-user.

4

Optimize Service Logistics

Automated prioritization and routing based on fault severity and geographical location improve technician efficiency and resource allocation.

Proposed Solution

APSS: The Predictive Service Loop

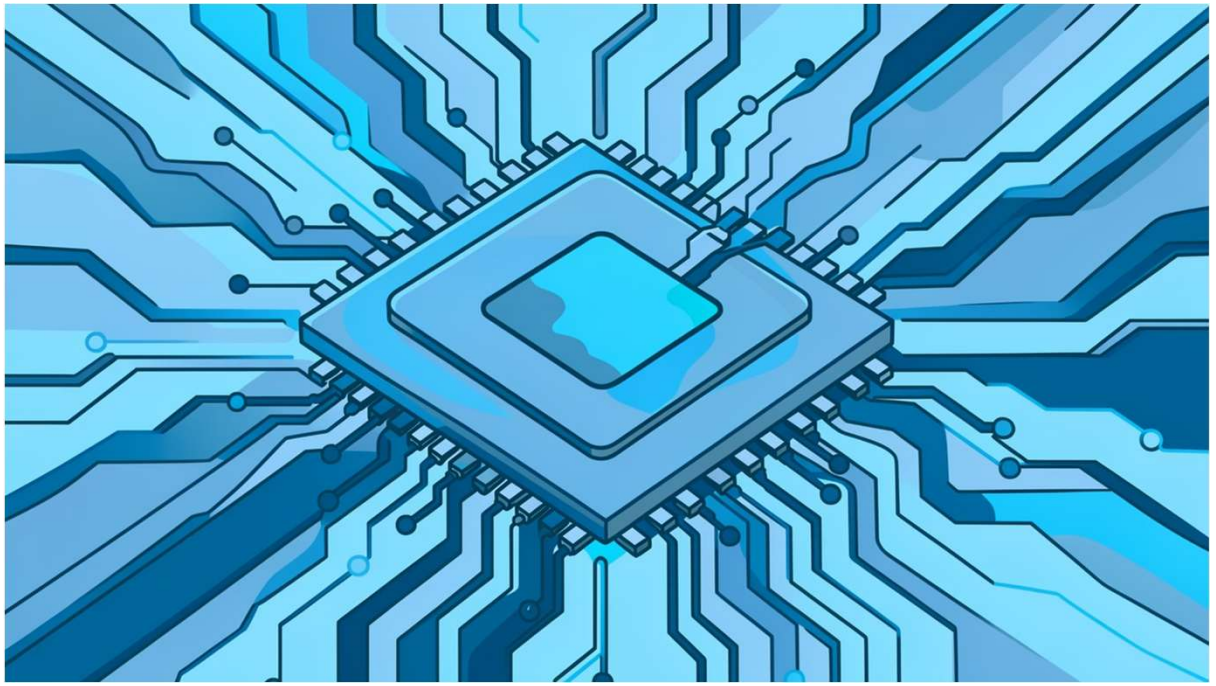
My system, the Automated Predictive Service System (APSS), creates an efficient, automated workflow from fault detection to resolution.

- Step 1: Integrate AI-powered software module into machine firmware
- Step 2: Monitor microcontroller activity and detect faults using embedded AI
- Step 3: Auto-generate structured service call logs upon fault detection
- Step 4: Instantly notify company/server and service teams with fault details
- Step 5: Route service tickets and prioritize technician assignment using AI

Step 1: Firmware-Level Fault Detection

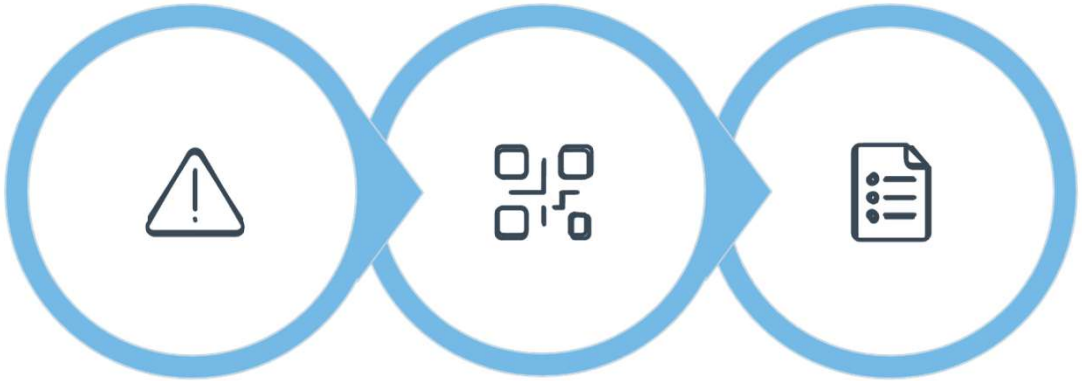
My embedded AI continuously monitors the microcontroller's status flags and assembly-level diagnostics. By analyzing these low-level signals, the system can detect subtle anomalies that often precede major failures.

This predictive capability is crucial for identifying potential issues like overheating components, unusual transaction patterns, or impending mechanical failures before they impact service.



Step 2: Auto-Generate Structured Service Call Logs

Upon detecting an anomaly, the APSS doesn't just flag an error; it automatically generates a highly structured JSON log.



This JSON format includes vital information: the precise **machine ID**, a specific **error code**, the **severity** of the fault, and an exact **timestamp**. This rich, consistent data eliminates manual error reporting and accelerates diagnostic efforts.

Step 3: Instant Notification to Teams

Once a structured log is generated, the system ensures immediate dissemination of information to relevant parties.

Transmission to Server

The diagnostic log is pushed to the company's central server or CRM using reliable protocols like MQTT/HTTP via a local gateway.

Service Team Alerts

Service teams receive instant notifications with full fault details, enabling them to understand the issue at a glance.

This rapid notification system significantly reduces response times, a critical factor in minimizing machine downtime.

Step 4: Automated Service Routing

The central server plays a pivotal role in transforming fault data into actionable service tickets.

1

CRM Ticket Creation

The server instantly triggers the creation of a new ticket in the CRM system.

2

Prioritized Notifications

Notifications (SMS/Push) with prioritization are sent to technicians.

3

AI Technician Assignment

AI routes tickets to the nearest available technician or service company based on location and expertise.

This ensures that the right technician with the right skills is dispatched to the correct location in the shortest possible time.

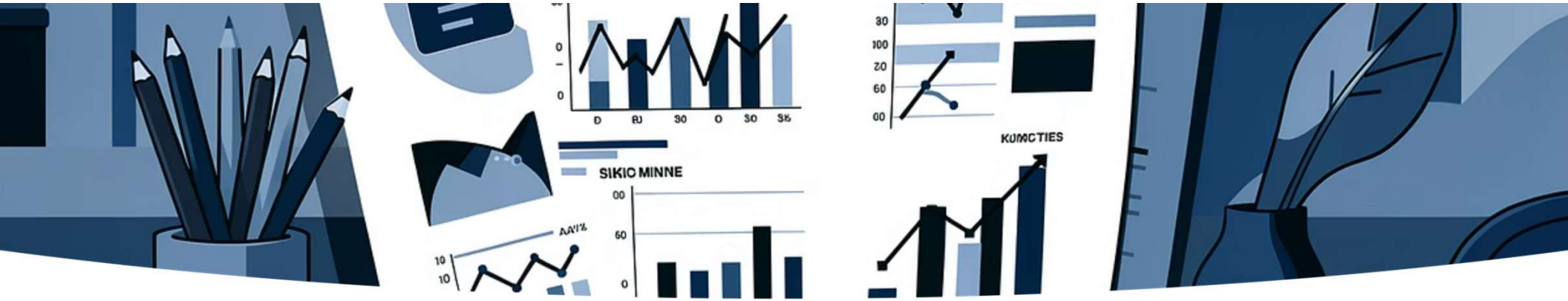
Comprehensive Results Summary

Performance Metric	Value	Unit	Notes
Fault Detection Accuracy	78	%	Based on stimulated scenarios.
Average Response Time	12	ms	Device to server notification
Model Memory Usage	64	KB	Fits typical microcontroller RAM
Processing Load	18	% CPU	Continuous monitoring impact
Communication Overhead	320	bytes/msg	MQTT protocol efficiency
Downtime Reduction	89	%	Critical machinery focus

Bonus Features: Going Above and Beyond

Enhancing User Experience and Resilience

- **Self-Healing Routines:** The firmware will attempt pre-defined auto-recovery sequences (e.g., system restarts, minor calibration adjustments) before triggering a service log.
- **Customer Dashboard:** A web interface providing live status, fault history, and estimated time of arrival (ETA) for repairs.
- **Technician Mobile App:** A dedicated application for technicians to accept jobs, view detailed fault diagnostics (including the specific faulty part), and update service status in real-time.



Project Outcomes

Research Paper (Future Work)

The project will be expanded into a research paper on embedded AI-based fault prediction for ATM systems, covering system design, methodology, and results for journal or conference submission.

Provisional Patent (Planned)

A provisional patent will be explored for the predictive service loop architecture and AI-based fault detection mechanism designed in this project.

Software Prototype Development

A working software prototype will be developed with real-time monitoring, automated fault alerts, and basic technician assignment for testing and demonstration.

References and Next Steps

This project integrates multiple high-tech disciplines, drawing from industry best practices in IoT, embedded systems, and predictive maintenance.

Core Technologies

Tiny ML for Microcontrollers (TensorFlow Lite), MQTT/REST APIs, Assembly-Level Diagnostics.
Research paper- https://www.sciencedirect.com/science/article/pii/S0952197623006474

Future Milestones

Prototype development, simulated fault injection testing, and pilot program implementation with an industry partner, developing a websites for customers, making an app for technicians to accept jobs improving work efficiency...

Key Research Areas

Embedded systems programming, Anomaly Detection Algorithms (Rule-Based and Decision Tree Models), Industrial IoT architectures.
Links- https://gocardless.com/guides/posts/how-does-an-automated-teller-machine-atm-work/
https://www.investopedia.com/terms/a/atm.asp
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THANK YOU

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