Senior Design Project Proposal – Revised Executive Summary

Project Title

Design and Implementation of a Hybrid Handheld and Distributed Intelligent Multi-Modal Leak Detection System

Team Members

Engineering and Computer Information Systems (CIS) student.

Faculty Advisor

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Industry Sponsor (if applicable)

N/A

Problem Statement

Water leaks in residential and commercial buildings are often detected late, resulting in property damage, increased maintenance costs, and wasted resources. Traditional leak detection systems rely on single sensing modalities or localized alarms, which can lead to false positives and limited coverage. This project proposes a hybrid leak detection approach that combines a handheld inspection device with a distributed network of fixed sensors, supported by AI-based sensor fusion, to improve detection reliability, localization, and verification.

Project Objectives

- Design a handheld, multi-modal leak detection device for localized inspection and verification
- Develop distributed fixed sensor nodes for continuous monitoring near plumbing fixtures
- Implement embedded signal processing and feature extraction at the edge
- Transmit sensor data to a central repository using wireless communication
- Apply AI-based data fusion techniques to detect and classify leak events
- Demonstrate the integrated system in a realistic, controlled test environment

System Overview

The proposed system consists of two complementary components: (1) a distributed network of low-power, fixed sensor nodes placed near key plumbing locations (such as sinks, toilets, and water heaters), and (2) a handheld inspection device used for targeted diagnostics and leak verification. Both components collect multi-modal sensor data, including vibration, acoustic, moisture, and temperature measurements. Sensor data from the distributed nodes and handheld device is transmitted to a central repository where AI-based analytics perform sensor fusion, leak detection, and localization.

Technical Approach

The project will follow a modular design methodology encompassing hardware design, embedded firmware development, wireless communication, cloud-based data storage, and machine learning-based data analysis. Feature-level sensor fusion will be employed to combine signals from multiple modalities and multiple locations, enabling improved detection accuracy and reduced false alarms. The handheld device will function as a mobile sensing node that complements the fixed network and provides validation of detected leak events.

Expected Deliverables

- Functional distributed sensor nodes
- Handheld leak detection prototype
- Embedded firmware with edge processing and feature extraction
- Central data repository and cloud-based processing pipeline

- AI-based leak detection and classification model
- Visualization dashboard and alert mechanism
- Final technical report and live system demonstration

Project Timeline (One Semester)

Weeks 1–2: Requirements definition, system architecture design, and literature review
Weeks 3–4: Sensor selection, hardware prototyping, and initial firmware development
Weeks 5–6: Sensor integration and data acquisition testing
Weeks 7–8: Wireless communication setup and central data repository implementation
Weeks 9–10: Feature extraction and AI/ML model development
Weeks 11–12: System integration, testing, and performance evaluation
Weeks 13–14: System refinement, documentation, and demo preparation
Week 15: Final presentation, demonstration, and submission

Evaluation Metrics

- Leak detection accuracy
- False positive and false negative rates
- Detection latency
- System reliability and robustness

Risks and Mitigation

Potential risks include sensor noise, wireless communication reliability, limited training data, and system integration challenges. These risks will be mitigated through multi-modal sensor fusion, robust communication protocols, controlled data collection experiments, and incremental system integration and testing.

Conclusion

This project aims to deliver a practical and scalable hybrid leak detection system that integrates distributed sensing, handheld verification, and AI-based analytics. The proposed multidisciplinary approach reflects real-world engineering practice and provides students with hands-on experience in embedded systems, IoT networking, and intelligent data-driven decision making.