

PROJECT REPORT

LiverGuard

An AI-IoT Multi-Sensor System for Non-Invasive Liver Health Monitoring and Early Disease Detection

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Introduction

LiverGuard is an innovative, AI-IoT-based multi-sensor diagnostic platform designed to provide non-invasive, real-time, and affordable screening of liver health. The device integrates skin colour sensing, thermal pattern analysis, and bio-impedance measurement to detect early physiological indicators of liver dysfunction.

LiverGuard aims to bridge the gap between clinical diagnostics and community healthcare, enabling early detection, remote monitoring, and preventive management of liver diseases without the need for invasive biopsies or expensive imaging modalities.

Problem Statement

Liver diseases such as cirrhosis, hepatitis, and fatty liver progress silently, often detected only after major damage. Traditional diagnostic approaches rely on biopsy, imaging, and biochemical assays, which are invasive, expensive, and unsuitable for continuous monitoring. Patients in rural or low-resource regions lack access to such diagnostics, resulting in delayed detection and poor outcomes.

System Overview

1. Conceptual Design:

LiverGuard captures three complementary bio-signals from the human body surface:

- Skin Colour (RGB Sensor – TCS34725): Detects subtle yellowing associated with bilirubin accumulation, serving as a proxy for jaundice.
- Thermal Imaging (MLX90640): Maps regional thermal asymmetries that may indicate inflammatory or perfusion changes in hepatic tissue.
- Electrical Impedance (GSR Sensor – AD5933): Measures tissue impedance variations over the hepatic region, reflective of fatty infiltration or fibrosis.

2. Architecture:

Sensor data is processed by an ESP32 microcontroller, which transmits data via IoT protocols (Wi-Fi) to a cloud where cloud-hosted ML models analyze the incoming data streams, predict liver condition (Healthy / Unhealthy), and generate health recommendations for the user through an interactive web dashboard.

Software Framework

1. Machine Learning Architecture:

The predictive engine employs a two-layer stacked ensemble model:

- Base Layer Models:
Random Forest, XGBoost, SVM (RBF & Polynomial kernels), Logistic Regression, and CatBoost.
- Meta Layer (Stacking Estimator):
Logistic Regression model integrating predictions from the base layer for optimized generalization.

2. Data Handling and Optimization:

- Dataset Augmentation: Employed hybrid extrapolation using random noise injection, statistical sampling, and SMOTE-like interpolation to enhance the small dataset and prevent overfitting.
- Hyperparameter Optimization: Implemented using Optuna for efficient model tuning.
- Model Performance:
 - Accuracy: 95%; ROC-AUC: 0.987
 - F1-Score: 0.93 (Unhealthy), 0.96 (Healthy)
 - Precision: 0.94 (Unhealthy), 0.95 (Healthy)

3. Web Interface:

A responsive, user-friendly **LiverGuard** Web Portal hosts the predictive models. Users can input real-time sensor readings, view instant diagnostic results, receive lifestyle recommendations, and access educational content including YouTube health tutorials and prototype operation guides.

Dataset

To ensure authenticity and real-world relevance, a custom dataset was curated using the **LiverGuard** prototype on 96 volunteers spanning diverse age, BMI, and gender groups. Faulty or inconsistent samples were removed to maintain data integrity, ensuring that the AI model learned from reliable, physiologically representative measurements.

Hardware Specifications

Component	Model / Description	Function
Microcontroller	ESP32	Data collection and IoT transmission
RGB Sensor	TCS34725	Skin colour analysis for jaundice
IR Sensor	MLX90614	Contactless body temperature sensing
Thermal Camera	MLX90640	Surface temperature pattern mapping
GSR Sensor	AD5933	Bio-impedance measurement
Power Source	Portable Battery	Field usability
Enclosure	Acrylic Case	Protective, ergonomic casing

Features and Advantages

- Completely Non-Invasive: Eliminates need for biopsy or imaging.
- Portable and Affordable: Designed for both clinical and community use.
- Precision: Multi-sensor and AI fusion enhances diagnostic accuracy.
- Cloud-Integration: Enables real-time remote monitoring.
- Preventive Focus: Ideal for early detection and continuous health tracking.

Future Scope

- Expansion of dataset through clinical collaborations.
- Integration with mobile apps for at-home testing.
- Incorporation of deep learning models for advanced pattern recognition.
- Real-time alerting and integration with Electronic Health Records (EHRs).

Conclusion

LiverGuard successfully demonstrates the fusion of AI, IoT, and biomedical sensing into a single, accessible diagnostic platform that can transform liver health management. With its 95% accuracy, cost-effective design, and multi-modal intelligence, LiverGuard is poised to become a vital screening tool in the early detection of liver diseases, empowering communities toward proactive healthcare and reducing global liver disease burden.