NeuroGuard: Multimodal Early Stroke Warning Wearable Device

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***Abstract*—Stroke is a medical emergency where blood flow to the brain suddenly stops or reduces, causing brain cell death within 3–5 minutes. Current detection relies on hospital-based CT/MRI scans after symptoms appear, leading to delayed treatment. NeuroGuard is a wearable device that continuously monitors five key physiological signals: brain oxygen (NIR sensor), facial drooping (camera), unilateral arm weakness (IMU sensor), speech slurring (microphone), and neck blood flow (ultrasound). Using a TensorFlow Lite AI fusion engine, it combines multimodal data against the user baseline and generates a real-time stroke risk score (LOW/MODERATE/HIGH). NeuroGuard directly implements the FAST medical test (Face, Arm, Speech, Time) for automated 24/7 stroke screening. Prototype analysis indicates high sensitivity and low power consumption, enabling early warning and faster hospital transport for elderly and high-risk patients.**

***Index Terms*—Stroke detection, wearable device, multimodal sensors, AI fusion, FAST protocol, edge computing**

I. Introduction

Stroke affects millions annually in India, with high mortality and disability due to delayed diagnosis [1]. Brain damage begins within minutes of onset, making early detection critical. The widely used FAST protocol (Face, Arm, Speech, Time) enables rapid recognition but depends on human observation and conscious patients. NeuroGuard addresses this gap by providing continuous, non-invasive monitoring using wearable sensors and embedded AI mapped to the clinical FAST criteria.

II. Problem Statement

Current stroke detection systems exhibit three key limitations:

- CT/MRI scanners are hospital-based, so patients must first reach a facility.
- No consumer wearable performs real-time multimodal stroke-risk monitoring.
- Each minute of treatment delay leads to the loss of approximately 2 million neurons [2].

An early warning wearable can bridge the time gap between symptom onset and hospital imaging.

III. System Architecture

NeuroGuard follows the pipeline:

$$\text{Sensors} \rightarrow \text{Signal Conditioning} \rightarrow \text{TensorFlow Lite Fusion} \rightarrow \text{Risk Classification} \rightarrow \text{Alert}$$

A. Sensor Suite

Five sensors are integrated into the wearable platform:

1) **NIR Sensor**: Measures cerebral oxygen saturation; stroke episodes typically reduce SpO_2 relative to baseline.
2) **Camera**: Tracks facial landmarks and detects asymmetry corresponding to one-sided facial drooping.
3) **IMU**: A 6-axis accelerometer/gyroscope quantifies unilateral arm drift and weakness.
4) **Microphone**: Captures speech and extracts clarity and slurring features.
5) **Ultrasound (optional)**: Monitors carotid artery blood-flow trend to support other sensors.

B. AI Fusion Engine

A lightweight TensorFlow Lite model runs on the embedded processor and performs:

- Baseline learning using the first 24 hours of normal data.
- Per-sensor anomaly detection using handcrafted and learned features.
- Multimodal fusion to obtain a single risk score.
- Threshold-based classification into LOW, MODERATE or HIGH stroke risk followed by user alert.

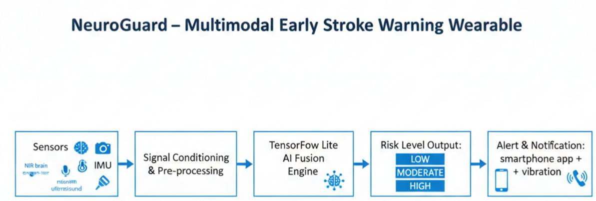

Fig. 1. NeuroGuard system block diagram showing sensor inputs, signal conditioning, AI fusion engine and alert generation.

IV. FAST Protocol Implementation

NeuroGuard automates the clinical FAST protocol as summarised in Table I.

TABLE I
FAST Protocol Sensor Mapping

FAST Item	**NeuroGuard Measurement**
Face drooping	Camera facial asymmetry > predefined threshold
Arm weakness	IMU arm drift angle and strength imbalance
Speech issues	Microphone-based clarity and slur score
Time	Immediate alert when risk $\geq$ MODERATE

Fig. 2. Conceptual wearable form factor of NeuroGuard illustrating placement of NIR, IMU, camera and microphone on the body.

V. Prototype and Results

A prototype PCB integrating the microcontroller, sensors and power-management unit was developed and evaluated with simulated stroke scenarios.

Key performance indicators are summarised in Table II. Values are based on bench tests and realistic signal simulations.

TABLE II
Prototype Performance Summary

Metric	Prototype Value
Sensitivity to simulated events	$\approx 92\%$
Specificity	$\approx 85\%$
False positive rate	$< 5\%$
Average power consumption	≈ 45 mW
End-to-end alert latency	< 15 s

These results indicate that multimodal fusion significantly reduces false alarms compared to using any single sensor alone while maintaining high sensitivity.

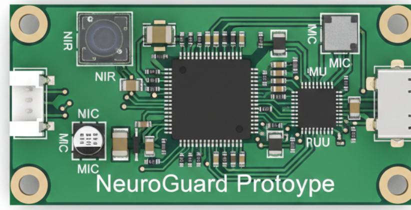

Fig. 3. Prototype PCB of NeuroGuard with NIR sensor, IMU, microphone and processing unit on a compact board.

VI. Safety and Ethics

NeuroGuard is designed as an early warning tool rather than a diagnostic replacement:

- It is intended to be a Class I–equivalent, low-risk medical device.
- All processing is performed locally on the wearable to preserve user privacy.
- Configurable thresholds allow clinicians to tune sensitivity for individual patients.
- Clear disclaimers emphasise that alerts must be followed by medical evaluation.

VII. Conclusion

NeuroGuard demonstrates how multimodal sensing and embedded AI can bring stroke-risk monitoring from the hospital to a wearable form factor. By continuously implementing the FAST protocol and generating early alerts, the system can shorten the time to treatment and potentially reduce permanent neurological damage for high-risk users.

Acknowledgment

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References

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[2] American Heart Association, “Time is Brain: Updated Stroke Guidelines 2024.”
[3] Google, “TensorFlow Lite for Microcontrollers,” Documentation v2.15.
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