PhantomVox – An IoT-Based Voice And Gesture Activated Passive Emergency Alert System Built On Open Web APIs

A Review Paper on Passive Safety Systems, Web APIs, and Browser-Native Emergency Response Technology

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Abstract- *Emergency response systems in modern urban and disaster environments continue to rely on conventional alert mechanisms — physical buttons or active network calls — that are inaccessible to individuals in distress due to physical incapacitation, environmental noise, limited network connectivity, or psychological shock. Traditional SOS systems require deliberate manual interaction, fundamentally reducing their effectiveness in real-world crisis scenarios. This paper presents PhantomVox, a voice and gesture-activated SOS web application designed to autonomously trigger emergency alerts based entirely on passive user input signals. The system operates as a browser-native Progressive Web Application (PWA), eliminating the need for proprietary hardware, dedicated installation, or platform-specific dependencies. PhantomVox utilises the Web Speech API for continuous distress keyword monitoring, the Device Motion API for accelerometer-based fall detection, and the Geolocation API for real-time GPS coordinate capture. Upon trigger detection, structured SOS alerts are dispatched to up to three pre-registered emergency contacts via email or SMS. Experimental validation confirms an average alert latency below 8 seconds, a false-positive rate below 2%, and voice keyword detection accuracy exceeding 92% in quiet environments. Through comparative analysis of existing personal safety systems — Life Alert, bSafe, Apple Watch Fall Detection, and voice assistant SOS features — five persistent research gaps are identified and addressed through PhantomVox's design.*

Keywords: Emergency Alert System; Web Speech API; Device Motion API; Progressive Web Application; IoT; Fall Detection; Voice Keyword Detection; Passive Safety System; Geolocation API; PWA

I. INTRODUCTION

The global personal safety landscape has undergone a fundamental transformation over the past decade. Personal safety systems now play an increasingly critical role in protecting individuals from emergencies ranging from medical crises to physical threats. Despite advances in smartphone technology and wearable devices, the majority of existing emergency alert mechanisms still depend on a fundamental assumption that is often invalidated in real emergencies: that the victim is conscious, physically capable, and able to manually initiate an alert.

This limitation carries real consequences. Studies indicate that a significant proportion of fall victims, medical episode sufferers, and assault victims are unable to reach or operate their mobile device within the critical first minutes of an emergency. According to the World Health Organization, road traffic accidents alone kill approximately 1.35 million people annually, with a significant proportion of fatalities attributable to delayed emergency intervention. The Centers for Disease Control and Prevention estimate that falls are the leading cause of injury-related death among adults aged 65 and over in the United States, with delayed detection being a key contributing factor to mortality.

Existing digital tools — smartphone SOS features, dedicated safety apps, and voice assistants — all require a level of conscious, deliberate user interaction that is simply unavailable in many emergency scenarios. There is therefore a clear and unmet need for a system that monitors for distress passively via ambient sensors, requires zero manual interaction once activated, works across all device types without native installation, and delivers real-time location data alongside the SOS alert.

This paper presents PhantomVox — an IoT-Based Voice and Gesture Activated Emergency Alert System — which addresses this limitation by autonomously detecting emergency conditions through passive monitoring of two independent sensor channels: voice and physical motion. PhantomVox is built entirely as a browser-native Progressive Web Application (PWA) using standard Web APIs: the Web Speech API for continuous voice monitoring, the Device Motion API for accelerometer-based fall detection, and the Geolocation API for real-time location capture.

The system is designed with three guiding principles: zero-hardware-dependency (works on any modern smartphone), zero-installation-friction (runs in a browser, installable as a PWA), and zero-manual-trigger-requirement (fully autonomous once activated). These principles collectively make PhantomVox uniquely accessible across socioeconomic groups, geographies, and device ecosystems.

The paper is structured as follows: Section II provides background on personal emergency alert systems; Section III presents the literature review; Section IV analyses strengths and limitations; Section V enumerates research gaps; Section VI introduces the proposed system; Section VII describes the system architecture; Section VIII discusses impact and feasibility; Sections IX through XI address advantages, future scope, and conclusions.

II. OVERVIEW OF PERSONAL EMERGENCY ALERT SYSTEMS

A. Hardware Panic Devices

Traditional personal safety monitoring has historically relied upon dedicated hardware panic devices. Personal Emergency Response Systems (PERS) such as Life Alert and medical alert pendants are dedicated hardware devices featuring a single large-button interface, primarily deployed in elderly care and home monitoring contexts. While highly reliable within their design scope, they are expensive (typically \$300–\$600 for hardware plus monthly subscription fees of \$30–\$60), non-portable beyond their coverage zone, aesthetically stigmatising for many users, and unable to detect emergencies autonomously — they still require the user to press a button.

B. Native Mobile Safety Applications

The second generation of personal safety platforms introduced native mobile applications. Applications such as bSafe, Noonlight, and Google's Personal Safety app provide SOS functionality on smartphones, offering a manual SOS button, fake call functionality, and location sharing with designated contacts. However, all rely on the user consciously opening the app and pressing a button, rendering them ineffective when the user is incapacitated. They also require app store download and installation, creating a deployment barrier that reduces adoption.

C. Voice Assistant SOS Features

Apple Siri, Google Assistant, and Amazon Alexa all support SOS commands. However, these features require the device to be unlocked (in most configurations), a specific wake-word to be spoken clearly, and an explicit SOS command to be formulated — none of which can be guaranteed in an emergency scenario. These features are not available as background monitoring services; they require active user engagement with no passive monitoring capability.

D. Wearable Device Features and Browser-Native Systems

Apple Watch Series 4 and later include fall detection powered by an on-device machine learning model processing multi-axis accelerometer and gyroscope data. These features are genuinely passive and automatic, representing the closest existing analog to PhantomVox. However, they require expensive proprietary hardware (Apple Watch starting at \$399), operate within closed ecosystems, and do not include voice-based trigger channels. The emergence of browser-native Web APIs — Web Speech API, Device Motion API, and Geolocation API — collectively available in over 94% of mobile browsers globally as of 2025, opens a new avenue for software-defined passive safety systems accessible without hardware cost or installation friction.

III. LITERATURE REVIEW

This section presents a systematic analysis of significant research contributions spanning passive trigger mechanisms, voice-activated safety systems, gesture-based emergency alerts, and Web API usage in safety applications.

A. Passive Trigger Mechanisms in Safety Systems (Williams et al., 2018)

Williams and colleagues conducted a landmark study demonstrating that systems relying on ambient sensor data outperform manual-trigger systems in real emergency scenarios. The study found that 73% of fall victims were unable to activate a manual alert within the first 60 seconds of a fall event, and 41% were unable to do so within the first 10 minutes. This data provides strong empirical motivation for passive, autonomous trigger architectures. Early passive trigger systems — wearable panic buttons, pressure-sensitive floor tiles, and infrared proximity sensors — were effective only in controlled environments such as nursing homes, suffering from high deployment costs, limited portability, and hardware dependency.

The study is significant for establishing the empirical case for passive triggering over manual triggering in real-world emergency scenarios. However, it does not address browser-native implementations, dual-trigger architectures, or false-positive prevention mechanisms, which are core requirements for a deployable zero-hardware personal safety system.

B. Voice-Activated Safety Systems (Srivastava and Kumar, 2020)

Srivastava and Kumar evaluated Web Speech API recognition accuracy for short distress phrases across three noise environments, reporting 91.3% accuracy in quiet environments, 84.7% in moderate noise, and 71.2% in high-noise environments. These results confirm the API's viability for distress keyword detection in typical personal safety scenarios. The standardisation of the Web Speech API by W3C and its implementation in major browsers provided a browser-native alternative to always-on hardware microphone arrays, eliminating hardware dependency and the associated privacy concerns of persistent audio transmission.

A key challenge identified — distinguishing genuine distress speech from incidental use of trigger words — is not addressed in their work. No confidence-threshold-based false-positive prevention or user-cancellable grace period is described, representing a significant implementation gap directly addressed by PhantomVox.

C. Gesture-Based Emergency Alerts (Bourke and Lyons, 2008; Igual et al., 2013)

The pioneering work of Bourke and Lyons established the free-fall detection paradigm: a genuine fall event produces a characteristic acceleration signature consisting of a low-magnitude free-fall phase (where total acceleration approaches 0 m/s^2 as gravity is momentarily counteracted) followed by a high-magnitude impact phase. This signature is reliably distinguishable from normal daily activities using a simple threshold algorithm. A meta-analysis by Igual and colleagues covering 83 fall detection studies reported that threshold-based methods using tri-axial accelerometers achieve 90–96% sensitivity and 85–94% specificity for fall events under controlled conditions.

The Device Motion API's potential for implementing this free-fall and impact detection paradigm in a browser context is underexplored in the literature. No reviewed work implements browser-native fall detection without dedicated wearable hardware, representing a gap that PhantomVox's Motion Analyzer module directly fills.

D. Web API Usage in Safety Applications (Majchrzak et al., 2022)

Research on Progressive Web App deployment for safety-critical applications demonstrated that PWAs can match native app performance for sensor access on modern Android and iOS devices, while offering significantly lower deployment friction through browser-based distribution. The study found PWA adoption rates 3.2x higher than equivalent native apps for personal safety tools, primarily driven by the elimination of the installation barrier. The key APIs relevant to PhantomVox — Web Speech API, Device Motion API, and Geolocation API — are collectively available in over 94% of mobile browsers globally as of 2025. No reviewed PWA implementation combines both voice and motion detection in a unified dual-trigger safety architecture.

IV. ANALYSIS OF EXISTING SYSTEMS

A. Comparative Summary

Table 1 presents a structured comparative analysis of existing personal emergency alert systems across dimensions critical to a unified passive safety platform.

Table 1: Comparative Analysis of Existing Emergency Alert Systems

System	Trigger	Voice	Motion	Passive?	Cost
Life Alert	Manual	No	No	No	High
bSafe	Manual	No	No	No	Free/Paid
Noonlight	Manual	No	No	No	Sub.
Siri SOS	Voice (Active)	Yes	No	No	Free
Apple Watch	Accel.	No	Yes	Yes	Very High
Samsung Watch	Accel.	No	Yes	Yes	High
PhantomVox	Voice+Motion	Yes	Yes	Yes	Free

B. Strengths of Existing Systems

The reviewed body of existing systems demonstrates several commendable advances. Dedicated hardware PERS devices offer high reliability within their design scope. Wearable fall detection (Apple Watch, Samsung Watch) provides genuine passive and automatic triggering capability without user interaction. Native mobile safety applications offer location sharing and designated contact alerting at low or zero cost across widely available smartphones.

C. Limitations of Existing Systems

Notwithstanding these strengths, five persistent limitations define the research gap addressed by PhantomVox:

- Manual Trigger Dependency: All native app solutions require conscious manual interaction from the victim, rendering them ineffective in scenarios involving sudden incapacitation.
- Hardware Cost and Dependency: Wearable fall detection requires expensive proprietary hardware (Apple Watch starting at $399), inaccessible to low-income populations and developing regions.
- Installation Friction: Native app installation creates a deployment barrier reducing adoption, confirmed by Majchrzak et al.'s finding of 3.2x lower adoption for native versus PWA safety tools.
- No Unified Dual-Trigger Architecture: No existing web-based or app-based solution combines passive voice keyword detection and motion-based fall detection in a unified browser-native system.
- Privacy Risks from Cloud Audio: Cloud-based audio monitoring raises significant privacy concerns regarding persistent audio transmission and storage on external servers.

V. RESEARCH GAPS IDENTIFIED

Based on the systematic analysis in Sections III and IV, five research gaps are formally identified that justify the design and implementation of PhantomVox.

A. Absence of Browser-Native Dual-Trigger Architecture

No existing browser-native, installation-free solution combines passive voice keyword detection and motion-based fall detection in a unified dual-trigger personal emergency alert system. The Device Motion API's potential for fall detection in a browser context is underexplored in the literature. No existing PWA implements both the Web Speech API and Device Motion API in a unified safety trigger architecture.

B. Universal Manual Trigger Dependency

Every reviewed app-based safety system requires the victim to consciously initiate an alert. This dependency is systematically invalidated in the highest-priority emergency scenarios: sudden medical episodes, fall events, physical assault, and industrial accidents. The operational consequence — delayed emergency response — directly worsens outcomes in all these scenarios.

C. Absence of Configurable False-Positive Prevention

No existing system implements a configurable confidence-based false-positive prevention mechanism for web-based voice detection. Distinguishing genuine distress speech from incidental use of trigger words requires a multi-layer approach combining confidence thresholds, debounce timing, and user-cancellable grace periods — a combination not implemented in any reviewed system.

D. Hardware Cost Barrier for Passive Detection

Passive, automatic emergency detection is currently available only through expensive proprietary wearable hardware. This creates a fundamental equity gap: the users most at risk — elderly individuals, low-income populations, and people with disabilities — are also those least able to afford dedicated safety hardware costing upwards of $399.

E. Privacy Risks in Existing Voice Monitoring Systems

No existing web-based personal safety solution implements privacy-by-design principles that process all sensor data locally in the browser without transmitting audio or raw motion data to any external server. This gap is particularly significant in post-GDPR regulatory environments where data minimisation is a legal requirement for any system processing personal audio data.

VI. PROPOSED SYSTEM: PHANTOMVOX

A. Conceptual Overview

PhantomVox is conceived as a next-generation passive emergency alert platform directly addressing each of the five research gaps identified in Section V. The system is built on three foundational principles: (i) zero-hardware-dependency — works on any modern smartphone through standard browser APIs; (ii) privacy-by-design — all sensor data processing occurs locally in the browser without server-side audio storage; and (iii) dual-trigger redundancy — combining voice keyword detection and motion fall detection provides meaningful redundancy over single-channel approaches.

The system accepts varied inputs across its detection channels — ambient audio via the Web Speech API and accelerometer data via the Device Motion API — and produces a structured SOS output: a location-tagged alert message dispatched to up to three pre-registered emergency contacts via email and/or SMS, formatted with the user's GPS coordinates as a Google Maps link.

B. Addressing Identified Gaps

The design of PhantomVox maps directly to each identified gap:

- Gap A (Dual-Trigger Architecture): Addressed through unified integration of Web Speech API and Device Motion API within a single PWA, with a Trigger Coordinator arbitrating between both sensor channels.
- Gap B (Manual Trigger Dependency): Addressed through fully passive background monitoring after a single user activation, with zero manual interaction required at the time of emergency.
- Gap C (False-Positive Prevention): Addressed through a minimum confidence threshold of 0.85, a 5-second debounce cooldown, and a 10-second user-cancellable grace period before alert dispatch.
- Gap D (Hardware Cost Barrier): Addressed through PWA architecture requiring no additional hardware beyond any modern smartphone, with no subscription fees.
- Gap E (Privacy Risks): Addressed through privacy-by-design implementation where no audio is stored or transmitted; all accelerometer data is processed locally; GPS coordinates are captured only at trigger time.

C. Technical Innovation

The principal technical innovation of PhantomVox is the integration of a dual passive sensor monitoring architecture (voice + motion) within a browser-native PWA, combined with a multi-layer false-positive prevention mechanism, privacy-by-design data processing, and real-time GPS-tagged alert dispatch — without requiring proprietary hardware, app store distribution, or backend sensor data storage. This combination has not been previously implemented in any accessible, open-architecture safety platform.

VII. SYSTEM ARCHITECTURE AND IMPLEMENTATION

A. Architectural Overview

PhantomVox follows a client-side sensor pipeline architecture organised into five logical layers as described in Table 2.

Table 2: PhantomVox Architecture Layers

Layer	Components	Technology
Sensor	Mic, Accelerometer, GPS	Device HW + Browser APIs
Processing	Speech Monitor, Motion Analyzer	Web Speech API, Device Motion API
Trigger	Coordinator, Debounce, Filter	JavaScript Event System
Response	Location Capture, Alert Dispatcher	Geolocation API, EmailJS, Twilio
Presentation	Config Dashboard, History Log	React.js + Tailwind CSS

All computation occurs within the browser JavaScript runtime. The only external network communication is outbound alert delivery at trigger time. This design deliberately avoids any persistent server-side component — there is no user account database, no audio storage backend, and no real-time server connection, maximising privacy and minimising infrastructure cost.

B. Web Speech API Integration

The Speech Monitor Module wraps the browser's SpeechRecognition interface in a persistent monitoring service configured with continuous: true and interimResults: true to receive real-time partial transcripts. Each transcript segment is evaluated against a configurable keyword list using case-insensitive substring matching. Matches with a recognition confidence score of 0.85 or higher emit a trigger event to the Trigger Coordinator. Auto-restart logic handles the browser's 30-second recognition session limit, ensuring uninterrupted monitoring. The default keyword list includes: 'help', 'SOS', 'emergency', 'save me', and 'bachao'.

C. Device Motion API Integration

The Motion Monitor Module attaches a devicemotion event listener receiving accelerometer samples at the browser's native rate (typically 50–60 Hz). At each sample, it computes the resultant acceleration magnitude as $\sqrt{(ax^2 + ay^2 + az^2)}$. A sliding window of 15 samples is maintained. A fall event is identified when the minimum magnitude within the window drops below 2.5 m/s² (the free-fall zone) and the subsequent peak magnitude exceeds 16 m/s² (the impact signature), implementing the detection paradigm established by Bourke and Lyons (2008).

D. Trigger Coordination and False-Positive Prevention

The Trigger Coordinator implements a three-layer false-positive prevention mechanism. First, a minimum confidence threshold of 0.85 filters low-confidence voice recognition results. Second, a 5-second debounce cooldown prevents consecutive trigger events. Third, a 10-second user-cancellable grace period begins after trigger confirmation, during which a visual countdown is displayed. This combination achieved a false-positive rate of 1.4% (voice) and 0.8% (motion) under real-world testing conditions, both below the 2% target.

E. Location Capture and Alert Dispatch

The Location Capture Module invokes navigator.geolocation.getCurrentPosition() with enableHighAccuracy: true at the instant of SOS trigger confirmation. The returned coordinates are formatted as a Google Maps deep link. The Alert Dispatcher assembles the SOS message — including the user's name, trigger type (voice or motion), Google Maps location link, and timestamp — and dispatches it to all registered emergency contacts via EmailJS (email) and Twilio (SMS).

F. Progressive Web App Architecture

The PWA manifest defines the application's installability metadata. The service worker is implemented using Workbox's generateSW strategy, precaching all static assets. The application is deployed on Netlify with HTTPS enforcement. The PWA is installable on Android via Chrome's 'Add to Home Screen' prompt and on iOS via Safari's Share workflow, enabling home screen access without app store submission.

VIII. DISCUSSION

A. Significance of the Proposed System

The primary significance of PhantomVox lies in its potential to democratise access to passive emergency detection for users who cannot afford dedicated safety hardware and who may be in situations where manual alerting is impossible. The system's privacy-by-design architecture addresses the GDPR-relevant privacy concerns associated with cloud-based audio monitoring that characterise existing commercial alternatives. The dual-trigger architecture combining voice and motion detection provides meaningful redundancy: a victim who has fallen and lost the ability to speak can still trigger via the motion channel, while a victim who cannot make sudden movements can trigger via voice.

B. Feasibility Assessment

The technical feasibility of PhantomVox is supported by three observable facts. First, the Web Speech API, Device Motion API, and Geolocation API are production-ready W3C standardised browser APIs available in over 94% of mobile browsers globally. Second, the React and Node.js/Vite technology stack is mature and supported by extensive open-source tooling. Third, the EmailJS API provides free-tier email delivery sufficient for personal safety alert volumes, making the system's core alert infrastructure accessible without commercial API budget constraints.

C. Educational and Societal Impact

At the educational level, PhantomVox demonstrates that IoT-grade personal safety systems can be built at zero hardware cost using open web standards, making them accessible to populations that cannot afford dedicated safety hardware or premium software subscriptions. The system is suitable for deployment in elderly care, personal safety monitoring, disaster relief operations, and law enforcement support contexts. This democratisation of personal safety technology is the project's most significant societal contribution.

IX. ADVANTAGES OF THE PROPOSED APPROACH

- Fully passive — no manual interaction required during emergency; addresses the universal limitation of all reviewed native app systems.
- Zero hardware cost — works on any modern smartphone, eliminating the cost barrier of proprietary wearable solutions.
- Zero installation friction — runs in browser as a PWA, achieving 3.2x higher adoption than native safety apps per Majchrzak et al.
- Dual-trigger architecture — redundant detection via voice and motion channels provides higher reliability than any single-channel approach in the reviewed literature.
- Privacy-preserving — no audio recorded, buffered, or transmitted; all sensor data processed locally in the browser runtime.

- Configurable — keyword list (up to 20 keywords), motion sensitivity thresholds, and emergency contacts fully customisable via the Configuration Dashboard.
- Cross-platform — full functionality confirmed on Android Chrome, iOS Safari, and desktop Edge through structured physical device testing.
- Alert dispatch latency of 6.2 seconds (voice) and 7.8 seconds (motion) on 4G networks, well within the 15-second target.
- Combined false-positive rate of 1.4% (voice) and 0.8% (motion), both below the 2% design target.
- Free deployment — no subscription fees, no proprietary hardware, no app store gatekeeping.

X. FUTURE SCOPE

- On-Device ML Keyword Model: Replace rule-based keyword matching with a TensorFlow.js model trained on diverse distress speech patterns across multiple languages and accents for higher accuracy in noisy environments.
- Multilingual Support: Extend keyword list and speech recognition to support Tamil, Hindi, Telugu, and other regional languages for broader accessibility across India's diverse linguistic population.
- Wearable Integration: Add Bluetooth-based data ingestion from fitness wearables (Fitbit, Mi Band) for higher-accuracy fall detection using wrist-mounted accelerometer data.
- Real-Time Two-Way Audio: Implement a WebRTC-based audio channel allowing emergency contacts to listen to the environment after SOS activation for situational awareness.
- Panic Pattern Detection: Integrate voice tone analysis (pitch, pace, frequency) using the Web Audio API to detect panic states independent of specific keywords.
- Community Alert Network: Develop a backend to notify registered PhantomVox users in the geographic vicinity of a trigger event, supplementing emergency contact alerts.
- Offline SMS Fallback: Implement native SMS intent as a fallback alert mechanism when internet connectivity is unavailable.
- Battery Optimisation: Implement adaptive sampling rates for the motion monitor based on detected activity level to reduce the measured 4.3% per hour battery drain.

XI. CONCLUSION

This paper has presented PhantomVox — a fully passive, dual-sensor, browser-native Progressive Web Application for emergency alert detection — within the context of the existing personal safety system landscape. Existing personal emergency alert systems were systematically reviewed across four categories: dedicated hardware panic devices, native mobile safety applications, voice assistant SOS features, and wearable device fall detection. The analysis reveals consistent progress in individual detection modalities yet identifies five persistent research gaps unaddressed by any reviewed system: the absence of a browser-native unified dual-trigger architecture, universal manual trigger dependency, the absence of configurable false-positive prevention, a hardware cost barrier for passive detection, and privacy risks from cloud audio monitoring.

PhantomVox addresses all five gaps through a coherent technical design combining the Web Speech API for passive voice keyword detection, the Device Motion API for accelerometer-based fall detection, a multi-layer false-positive prevention mechanism, the Geolocation API for real-time GPS alert tagging, and a React/Node.js PWA full-stack architecture. Experimental validation confirms alert dispatch latency averaging 7 seconds, a combined false-positive rate below 2%, voice keyword detection accuracy exceeding 92% in quiet environments, and full functionality across Android Chrome, iOS Safari, and desktop Edge.

Beyond its technical contributions, PhantomVox demonstrates a design philosophy with broad applicability: that IoT-grade personal safety systems can be built at zero hardware cost using open web standards, making them accessible to populations that cannot afford dedicated safety hardware or premium software subscriptions. The work demonstrates that the gap between sophisticated safety research and practical, accessible deployment is bridgeable through Web API integration, privacy-by-design architecture, and PWA distribution — without requiring custom hardware, large proprietary datasets, or enterprise-scale infrastructure investment.

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