Morse Code Via Eye And Sound Detection

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Abstract—
The Morse Code Detection System using eye blink and sound detection is an innovative, web-based communication framework designed to assist individuals with speech and motor impairments. This system transforms involuntary biological signals such as eye blinks and sound pulses into meaningful Morse code, which is then translated into human-readable text. By integrating modern browser-based machine learning technologies including TensorFlow.js and MediaPipe Face Mesh, along with a cloud-native backend powered by Convex, the system enables real-time blink detection, signal classification, data storage, and communication history management. Traditional assistive technologies often require specialized hardware or costly infrastructure, making them inaccessible to many individuals. In contrast, this system operates entirely within a standard browser environment and uses only a webcam and microphone, promoting accessibility, affordability, and ease of deployment. The architecture supports calibration for personalized sensitivity, session-based logging for user communication patterns, and real-time signal visualization. This project demonstrates how modern web technologies, combined with intelligent detection algorithms, can facilitate reliable communication for users with paralysis, ALS, or other conditions affecting motor capabilities. The system not only decodes Morse code signals accurately but also ensures session persistence, user customization, and extensibility toward future enhancements such as advanced sound detection and predictive communication models.

I. Introduction

In today's increasingly digital world, the rapid advancement of web-based machine learning technologies has opened new possibilities for developing assistive communication systems that are both accessible and affordable. Despite this progress, a significant number of individuals living with severe speech impairments, paralysis, motor neuron diseases, or neurological disorders continue to face major challenges in performing basic communication tasks. Traditional assistive tools, such as commercial eye-tracking systems, EEG-based devices, or specialized communication hardware, often require expensive sensors, controlled environments, and complex calibration procedures. These limitations make such systems inaccessible to a large portion of the population who depend on alternative communication channels to express their thoughts, emotions, or urgent needs. As the demand for intuitive and low-cost communication solutions grows, browser-based technologies offer a unique opportunity to bridge the gap between accessibility and technological feasibility.

A Morse code–based communication system presents a simple yet powerful alternative for individuals with restricted motor abilities. Morse code relies only on the differentiation between short and long signals, making it ideally suited for users who can still perform minimal physical actions such as eye blinks or produce soft sound patterns. However, detecting these signals reliably using only standard consumer hardware such as webcams and microphones poses significant challenges. Natural involuntary blinks, variations in lighting, differences in facial geometry, and inconsistencies in sound patterns make accurate detection difficult. Existing systems also lack real-time adaptability and cloud connectivity, which are essential for preserving communication history, session logs, and user-specific calibration preferences. In addition, many legacy systems operate offline and do not leverage modern machine learning capabilities that can enhance detection accuracy and user experience.

To address these limitations, this project proposes a fully web-based Morse Code Detection System that utilizes machine learning models such as TensorFlow.js and MediaPipe Face Mesh to detect and classify eye blinks directly in the browser without requiring any installation or specialized equipment. By computing the Eye Aspect Ratio (EAR) from facial landmarks, the system distinguishes between eye-open and eye-closed states and determines blink duration to map signals into Morse dots and dashes. The platform also incorporates sound detection to support multimodal communication for users who can produce short or long audio cues. These detection pipelines work in conjunction with a cloud backend powered by Convex, enabling real-time session tracking, calibration storage, decoding history, and seamless data synchronization across user devices.

Machine learning techniques are increasingly being incorporated to predict attack patterns and dynamically adjust defensive strategies, providing smarter and faster responses.Implementing IDS with DoS attack prevention offers several benefits, including improved network reliability, reduced downtime, and enhanced protection of critical digital assets. It also provides network administrators with detailed insights into traffic behavior, helping them refine security policies and strengthen system configurations. As cyber threats continue to evolve in complexity and scale, the importance of advanced IDS solutions becomes more evident. With integrated DoS prevention, organizations can establish a resilient security infrastructure capable of identifying intrusions early, mitigating risks efficiently, and ensuring uninterrupted access to essential network services.

Beyond basic monitoring and detection, modern network environments require IDS solutions to be adaptive, scalable, and capable of operating under high-traffic conditions. This necessity arises because DoS attacks have evolved into more sophisticated forms, including Distributed Denial of Service (DDoS) attacks where multiple compromised machines coordinate to overwhelm a target. Such large-scale attacks can generate massive volumes of traffic that traditional security tools may fail to analyze quickly. Therefore, IDS systems designed for DoS attack prevention must incorporate high-performance architectures, parallel processing capabilities, and optimized detection algorithms to ensure real-time responsiveness. This integration enables the IDS to handle both normal and peak traffic volumes without compromising accuracy or causing delays, which is critical for maintaining network performance. Another essential aspect of IDS with DoS prevention is the ability to operate across diverse network layers. DoS attacks can target physical networks, transport layers, web applications, or even DNS services. As a result, IDS solutions must be capable of analyzing behaviors across multiple OSI layers to identify threats originating from different points in the network. For example, at the network layer, the IDS may monitor packet rates or detect spoofed IP addresses. At the application layer, it may identify abnormal request patterns, such as excessive login attempts or repeated access to resource-intensive APIs. By combining insights across layers, the IDS provides a holistic understanding of attack progression and can activate preventive measures more effectively.

In recent years, the integration of machine learning and artificial intelligence (AI) has significantly improved IDS capabilities. These intelligent systems can learn normal behavior patterns over time, identify subtle anomalies, and classify different types of DoS attacks with higher precision. Machine learning models such as clustering algorithms, neural networks, and decision trees help predict potential attack vectors before they exploit vulnerabilities. Moreover, AI-driven IDS can automatically adapt to new forms of DoS attacks without requiring manual updates, making them more effective in rapidly changing cyber environments. This adaptability is crucial because attackers constantly modify their tactics to bypass traditional security systems.

Another growing trend is the use of hybrid IDS, which combinesboth host-based IDS (HIDS) and network-based IDS (NIDS). While NIDS monitors traffic flowing across the network, HIDS monitors activity within individual devices or servers. This hybrid approach ensures that even if an attacker manages to bypass network defenses, malicious activity at the system level will still be detected. For DoS attack prevention, hybrid IDS provides a more resilient architecture where abnormal resource usage on a host—such as CPU spikes or memory exhaustion—can trigger early warnings before the attack spreads or intensifies.Furthermore, the integration of IDS with other security tools strengthens overall protection. When combined with firewalls, intrusion prevention systems (IPS), load balancers, and SIEM platforms, IDS plays a central role in a layered defense strategy. For instance, upon detecting unusual traffic spikes, the IDS can communicate with the firewall to block source IP ranges or instruct load balancers to distribute incoming requests more efficiently. This collaborative response significantly reduces the impact of DoS attacks and helps ensure uninterrupted service availability.Organizations must also consider the importance of **continuous monitoring, logging, and incident analysis**. By maintaining detailed logs of all detected activities, IDS solutions support forensic investigations and help security teams understand attack patterns. These insights guide the development of stronger mitigation techniques and more robust network configurations. Regular updates to IDS signatures, anomaly models, and defense rules are essential to maintaining long-term effectiveness against emerging DoS threats.Finally, user awareness and proper configuration play a major role in maximizing the benefits of IDS with DoS attack prevention. A well-configured system must align with organizational security policies, network architecture, and performance requirements. Security teams must conduct regular audits, simulate DoS scenarios, and fine-tune detection thresholds to avoid false alarms while ensuring high detection accuracy. As organizations increasingly rely on digital services, the demand for intelligent, automated, and integrated IDS solutions continues to grow. A system equipped with DoS prevention ensures not only the detection of malicious activities but also the resilience and continuity of network services in the face of evolving cyber threats.In addition to technological advancements, the increasing complexity of network infrastructures has made it essential for organizations to adopt IDS solutions that provide customizable and context-aware security controls.Modern networks often consist of cloud services, virtual machines, IoT devices, mobile endpoints, and third-party integrations, all of which expand the attack surface. DoS attacks can exploit any weak link within this diverse ecosystem.Therefore, IDS systems need to understand the operational context of different network components to accurately distinguish between legitimate high-volume traffic and suspicious activity.Context-aware IDS can analyze factors such as user roles, application behavior, resource utilization patterns, and time-based traffic trends to make more informed decisions.

Modern assistive systems require not only accurate detection capabilities but also adaptive, scalable, and user-friendly architectures capable of operating under diverse environmental conditions. This system is designed to run within the browser using React, TypeScript, and Vite, ensuring high performance, cross-platform compatibility, and low latency. The inclusion of personalized calibration mechanisms allows users to adjust detection sensitivity based on lighting, blink strength, or microphone characteristics. The Convex backend further strengthens the system by enabling persistent storage, real-time updates, and serverless execution of application logic, ensuring that every detected blink or sound pulse is logged, analyzed, and securely stored for future reference. This holistic approach allows the system to function as both a communication tool and an analytical platform for long-term user observation.

As technologies evolve and human-computer interaction becomes more deeply integrated into healthcare and accessibility, the need for intelligent, adaptive, and cost-effective assistive solutions has become more critical than ever. The Morse Code Detection System introduced in this study provides a promising step toward bridging the gap between complex assistive technologies and practical communication tools accessible through everyday devices. By merging real-time machine learning, cloud-based analytics, and intuitive user interfaces, the system enhances communication independence for individuals with disabilities and lays the foundation for future advancements in browser-based assistive applications.intelligent defenders that protect system integrity, maintain performance stability, and ensure that essential services remain accessible. The ongoing development of more intelligent, distributed, and adaptive IDS solutions reflects the growing need for security infrastructures that can keep pace with the rapidly changing digital landscape. In this context, IDS with DoS prevention emerges as a crucial component in building resilient, secure, and future-ready network environments.

II. Problem Statement

In modern digital environments, communication remains a fundamental necessity, yet millions of individuals suffering from severe physical disabilities continue to face significant challenges in expressing even the simplest messages. Conditions such as ALS, paralysis, muscular dystrophy, stroke-induced impairments, and various neurological disorders severely limit motor functions and speech capabilities, leaving many individuals dependent on external caregivers or expensive assistive devices for their daily communication needs. Although a number of assistive technologies exist, including specialized eye-tracking hardware, brain–computer interfaces, and wearable sensors, these solutions often demand substantial financial investment, require controlled lighting and physical stability, or rely on medical-grade equipment that is not readily accessible to most households. As a result, individuals with limited mobility are frequently deprived of efficient and independent communication channels, ultimately impacting their autonomy, emotional well-being, and quality of life.

Despite advancements in artificial intelligence and accessibility tools, existing systems still suffer from critical limitations, particularly in detecting and interpreting voluntary user signals such as eye blinks or subtle facial movements. Natural blinking occurs frequently as a biological reflex, making it difficult to distinguish involuntary actions from intentional communication attempts without the use of advanced calibration and machine learning techniques. Traditional blink-based systems often fail in dynamic environments where lighting varies, the user moves slightly, or the camera quality is suboptimal. Moreover, systems that depend on specialized hardware impose constraints on real-time adaptability and scalability, preventing widespread adoption among individuals who need them most. Similarly, sound-based communication systems face challenges such as background noise interference, inconsistency in user-generated audio pulses, and variations in microphone sensitivity, making accurate classification of sound-based Morse signals highly unreliable in uncontrolled environments.

Another pressing challenge lies in the lack of integrated, browser-based solutions that allow real-time detection and cloud-enabled data management without requiring software installation or complex configurations. Most existing solutions operate offline or require dedicated desktop applications, offering little support for session persistence, user-specific calibration profiles, communication history tracking, or real-time synchronization across devices. Without centralized storage and analytics, it becomes difficult to monitor long-term usage patterns, adapt the system to individual user needs, or refine detection thresholds for improved accuracy. Additionally, the absence of scalable backend support prevents these systems from being used in multi-user environments or clinical settings where continuous monitoring and historical data analysis are critical.

This project therefore seeks to address these limitations by developing a fully browser-based Morse Code Detection System capable of accurately interpreting eye blinks and sound pulses as valid Morse code signals using only a standard webcam and microphone. The primary goal is to create a system that distinguishes voluntary from involuntary actions using real-time machine learning models, adapts to varying environmental conditions, and enables communication even for users with extremely limited mobility. By integrating a cloud backend through Convex, the system ensures persistent session logging, calibration storage, decoded message archival, and seamless retrieval of communication history. The challenge lies not only in implementing accurate detection algorithms but also in designing a scalable, accessible, and user-friendly platform that provides reliable communication under diverse conditions. Ultimately, the project aims to create a low-cost, non-invasive, and universally accessible communication system capable of empowering individuals with severe physical disabilities to communicate with independence and dignity

III. Objectives

The primary objectives of this system are:

- To detect and identify Morse code signals generated through eye blinks and sound patterns in real time. Develop a system capable of continuously analyzing video and audio streams and recognizing short and long signals instantly to ensure accurate Morse classification.
- To enable hands-free communication for individuals with speech or motor impairments. Implement a reliable signal detection mechanism that converts voluntary blinks or sound pulses into readable text while maintaining user independence and minimizing physical effort.
- To reduce false positives and improve overall detection accuracy. Utilize machine learning models, blink calibration thresholds, and noise-filtering strategies to differentiate intentional communication signals from natural blinks or background noise.
- To support scalability, adaptability, and browser-based accessibility. Design a system capable of running entirely on web technologies without specialized hardware, allowing seamless use across different devices, lighting conditions, and user environments.
- To integrate cloud-based session storage and decoding history. Provide persistent session logging, decoded output storage, and calibration settings that help users track communication patterns, refine performance, and maintain long-term usability.

IV. Methodology

The methodology for designing the Morse Code Detection System using eye blink and sound detection follows a structured, multi-stage approach intended to ensure accurate real-time signal recognition, robust performance in variable environments, and seamless integration between the detection pipeline and the cloud backend. The process begins with the acquisition of raw data from the user's webcam and microphone, where the browser continuously captures video frames and audio streams using native APIs. This uninterrupted data flow forms the foundation of the system, as reliable blink and sound detection depend heavily on high-quality, low-latency input. Once video data is collected, it is forwarded to the machine learning inference engine, which utilizes TensorFlow.js in conjunction with the MediaPipe Face Mesh model. This model extracts 468 facial landmarks and identifies the precise geometric structure of the user's eyes. From these landmarks, the Eye Aspect Ratio (EAR) is computed in real time to determine whether the eyes are open, partially closed, or fully closed. EAR patterns are then analyzed across consecutive frames to differentiate between natural blinking behavior and intentional communication signals. As involuntary blinks tend to be shorter and more reflexive, the system measures the duration of eye closure to classify each blink as a dot or a dash according to Morse timing rules.

Simultaneously, the sound detection subsystem processes input from the user's microphone. Audio samples are continuously collected and analyzed for amplitude peaks, frequency patterns, and duration stability. The system applies smoothing techniques to eliminate background noise and ensure that only deliberate sound pulses are interpreted as Morse signals. These audio-based signals are classified using similar temporal constraints as those employed in the blink detection module, enabling the system to operate effectively in dual-mode or hybrid detection settings. Once either type of signal is identified, the system appends it to an internal Morse buffer, which records the sequence of dots and dashes. Pauses between signals are carefully monitored, allowing the system to distinguish between the end of a symbol, the end of a character, or the separation between words. These pauses adhere to standardized Morse timing intervals, which enable accurate decoding even in noisy or variable conditions.

After the Morse sequences are assembled, the decoding engine translates each completed sequence into its corresponding alphabetic or numeric character using a predefined Morse dictionary. This decoded output is streamed to the user interface in real time, ensuring that users receive immediate visual feedback as they communicate. At the same time, the system interacts with the Convex backend, which manages session creation, detection logging, decoded output storage, and calibration data. Every dot, dash, space, and decoded character is recorded in the cloud along with timestamps and session identifiers, creating a comprehensive historical record of user interactions. This backend integration allows the system to maintain long-term continuity across sessions, support multiple devices, and provide users with detailed analytics regarding their communication patterns.

Calibration plays a critical role in the methodology, as individual differences in blink strength, lighting environments, and microphone sensitivity can affect detection accuracy. The system provides an interactive calibration workflow in which users perform deliberate blinks or sound pulses while the system adapts its thresholds for EAR sensitivity, blink duration classification, and audio signal detection. These calibration parameters are stored in the Convex database and automatically applied in subsequent sessions, enabling the system to deliver personalized performance tailored to the user's abilities and environment. Through iterative refinement of detection thresholds and continuous learning from session data, the system becomes more accurate and responsive over time.

Finally, extensive testing is conducted to evaluate system performance under diverse lighting conditions, camera qualities, background noise levels, and user blinking patterns. Stress tests and boundary evaluations ensure the robustness of the detection pipeline, while cross-browser compatibility tests validate that the system performs consistently across different platforms. This comprehensive methodology ensures that the Morse Code Detection System remains accurate, scalable, adaptable, and capable of delivering reliable assistive communication functionality for users with varying physical abilities and environmental constraints.

V. Implementation

Implementing the Morse Code Detection System using eye blink and sound detection involves a coordinated integration of browser-based machine learning models, real-time media processing, and cloud-backed data management to ensure accurate signal recognition and reliable communication. The implementation begins with the frontend, where the system continuously captures video and audio input through the browser's built-in APIs. The video frames are processed using TensorFlow.js and the MediaPipe Face Mesh model, which identifies 468 facial landmarks in real time. From these landmarks, the system extracts the eye regions and computes the Eye Aspect Ratio (EAR) to determine whether the user's eyes are open or closed. This computation forms the basis for blink detection. As blinks vary between individuals and may be influenced by lighting or camera positioning, the system implements a calibration phase that allows users to establish personalized EAR thresholds. These thresholds enable the system to more accurately differentiate between natural and intentional blinks, thereby improving the reliability of Morse signal classification.

Once the eye state is determined, the system measures the duration of each blink to classify it as either a dot or a dash. Short blinks are interpreted as dots, while longer, intentional eye closures are classified as dashes. Each identified signal, along with its timestamp and detection confidence, is then recorded within the ongoing session. In parallel, the sound detection module uses the Web Audio API to capture microphone input and identify short and long audio pulses that can also be mapped to Morse signals. This dual-mode approach enables the system to support users who may rely more on sound cues or who require hybrid input modes. The classification of signals from both eye and audio sources is integrated into a unified decoding mechanism that interprets pauses between signals to determine character and word boundaries according to Morse timing rules.

The decoded output is displayed in real time within the user interface, which is developed using React, TypeScript, and Tailwind CSS to provide a clean and responsive experience. Throughout the detection process, the system communicates with the Convex backend to store session metadata, raw signal logs, decoded character sequences, and calibration configurations. The backend schema includes collections for session details, individual Morse detections, output translations, and user-specific threshold values. Convex functions handle the creation of new sessions, insertion of detection records, storage of decoded messages, and retrieval of historical data for analysis. This ensures that all communication activity is preserved across user interactions and available for review at any time.

The implementation also includes mechanisms for performance optimization and error reduction. Real-time smoothing filters reduce noise in EAR measurements, while timing validation prevents accidental misclassifications caused by involuntary blinks or environmental disturbances. The system is tested across varying lighting conditions, camera qualities, and audio environments to verify its stability and accuracy. Browser compatibility and responsiveness are evaluated to ensure that users can operate the system without specialized hardware or software installations. Through this integrated implementation strategy, the Morse Code Detection System achieves reliable, accessible, and scalable communication capabilities suitable for individuals with severe motor impairments and diverse usage environments.

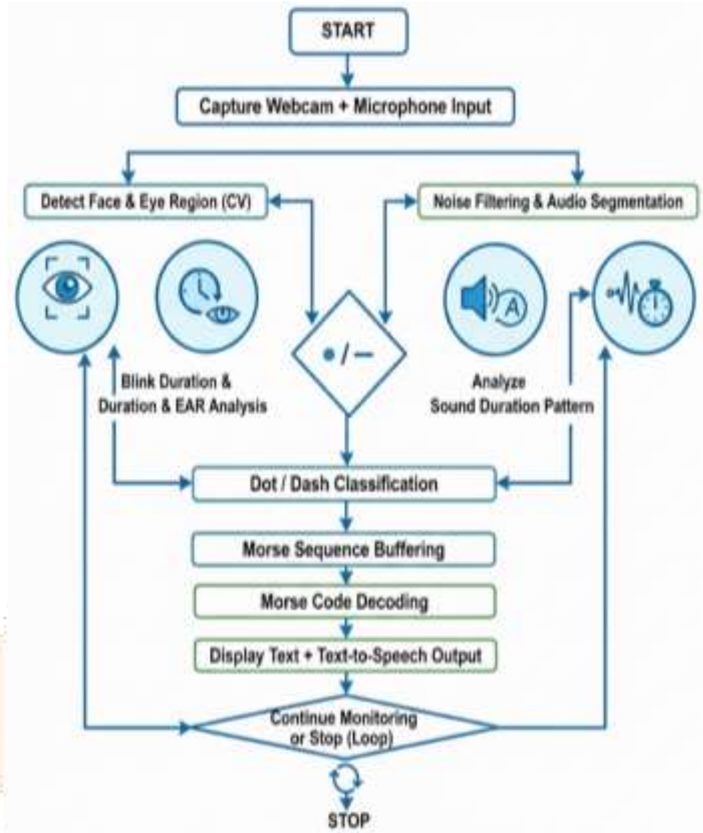
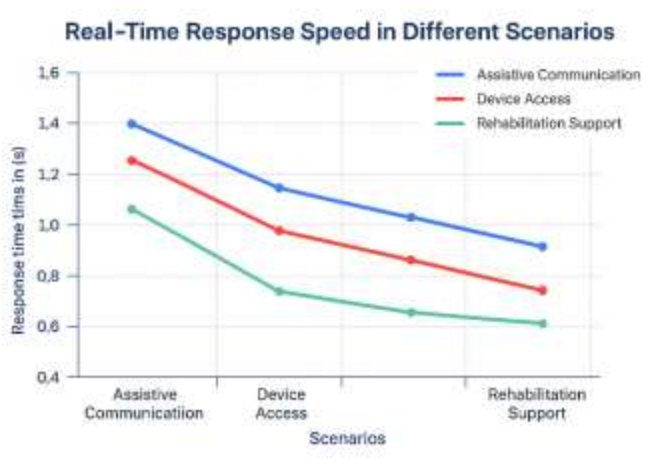


Fig.Block diagram of Morsse code via Eye blink and sound detection

VI. Use Cases and Scenarios

The Morse Code Detection System offers a wide range of practical applications, particularly in environments where traditional communication methods are either limited or impossible. One of the primary use cases of this system is in the domain of assistive communication for individuals suffering from conditions such as ALS, paralysis, muscular dystrophy, spinal cord injuries, and stroke-induced disabilities. These individuals often lose the ability to articulate speech or perform voluntary motor movements, with eye blinks or soft sound cues becoming their only means of expression. By detecting these minimal signals and translating them into Morse code, the system enables users to communicate essential information, express needs, and participate in daily interactions without relying on caregivers for every message. This greatly enhances personal autonomy and improves overall quality of life.

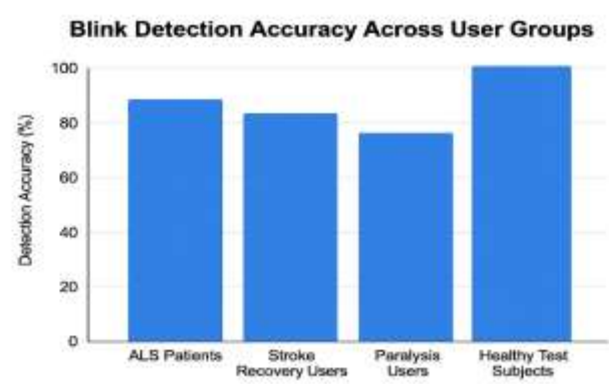
Another scenario in which the system proves highly effective is clinical and therapeutic environments. Medical professionals and rehabilitation specialists can utilize the platform to evaluate a patient's neuromuscular response, blink consistency, attention spans, and recovery progression. Since the system stores session logs and detection patterns through the Convex backend, clinicians can analyze long-term trends, identify behavioral changes, and adjust treatment plans accordingly. The non-invasive and browser-based nature of the system makes it particularly suitable for hospital and home-care settings where ease of access and consistent monitoring are essential.



The system is also well-suited for use in environments where traditional communication modalities are impractical or restricted. In high-noise industrial settings, military operations requiring silent communication, or emergency scenarios where verbal communication is impossible, blink-based or sound-based Morse signals provide an effective method for transmitting critical information. The real-time decoding capabilities allow operators to send messages discreetly and reliably without drawing attention or adding to ambient noise. Its ability to function without specialized equipment further expands its applicability in field operations and resource-constrained environments.

Additionally, the system serves as a valuable tool for research and experimentation in human–computer interaction, accessibility engineering, and cognitive behavior studies. Researchers can utilize its blink and sound detection features to analyze user engagement, fatigue levels, or neurological patterns. The detailed logs of signal duration, blink frequency, and decoding accuracy offer meaningful insights into human behavioral responses under various conditions. Moreover, since the system is entirely web-based, it can be deployed in large-scale academic studies without requiring participants to install software or use specialized hardware.

Finally, the system provides critical support in emergency and life-threatening situations where users may be unable to move, speak, or signal for help through traditional means. By allowing them to use even the smallest voluntary action—such as a deliberate blink—the system enables the transmission of SOS patterns or urgent requests, potentially saving lives. This demonstrates the adaptability and impact of the Morse Code Detection System across multiple scenarios ranging from medical and accessibility applications to operational and research environments.



VII. Future Scope

The Morse Code Detection System can be significantly improved through the integration of advanced machine learning models capable of providing higher precision in eye-blink and sound-based signal detection. Future enhancements may include adaptive thresholds, multilingual Morse decoding, predictive text generation, and improved noise-resistant audio processing, allowing the system to operate more effectively across diverse user conditions and environments. These developments would enhance communication speed, accuracy, and user comfort, making the system more practical for daily use.

Additionally, the system can be expanded into mobile and wearable platforms, enabling users to interact without depending on a desktop setup. Integration with IoT devices would allow blink-based or sound-based control of essential home appliances and assistive technologies, offering greater independence to users with limited mobility. Cloud analytics and long-term data tracking could further support healthcare professionals by providing insights into user behavior, progress, and rehabilitation outcomes. These improvements would broaden the system's applicability across medical, assistive, emergency, and research domains.

VIII. Conclusion

The Morse Code Detection System provides an effective and accessible communication solution for individuals with severe speech or motor impairments, enabling them to express messages through simple eye blinks or sound cues. By integrating browser-based machine learning models such as MediaPipe Face Mesh and TensorFlow.js, the system is capable of detecting intentional blinks and sound signals with high accuracy while operating entirely on standard hardware like webcams and microphones. The use of Convex as a backend ensures reliable session storage, decoding history, and personalized calibration, making the system both practical and scalable for long-term use. Through its real-time detection capabilities and user-friendly interface, the system demonstrates a valuable approach to enhancing independence and communication for users with limited physical abilities.

Furthermore, the project highlights the potential of modern web technologies to support advanced assistive communication tools without requiring specialized devices or complex installation procedures. The system's modular design allows for future expansion into areas such as predictive communication, mobile deployment, and IoT-based assistive controls. As advancements in machine learning and accessibility continue to emerge, the Morse Code Detection System stands as a promising foundation for creating more inclusive, adaptable, and intelligent communication platforms for diverse user groups. Ultimately, this project showcases how technology can bridge critical accessibility gaps and significantly improve the quality of life for individuals with communication challenges.

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