AI-Driven Morse Code Translation System Using ESP32 and IoT Integration

Aakash G S, Neeraj T, Nihtin Aarya, Puneeth Kumar, Dr. Binu Krishnan U
Amrita School of Artificial Intelligence, Amrita Vishwa Vidyapeetham, India
Emails: cb.sc.u4aie24101@cb.amrita.edu, cb.sc.u4aie24141@cb.amrita.edu,
cb.sc.u4aie24142@cb.amrita.edu, cb.sc.u4aie24146@cb.amrita.edu, u_binukrishnan@cb.amrita.edu

***Abstract*—Morse code has been a very important mode of communication, particularly in emergency and low-bandwidth environments. Nevertheless, existing Morse code systems tend to be lacking modern adaptability and accessibility features. This project offers an AI-powered Morse Code Translation System based on the ESP32 microcontroller to achieve real-time Morse code input-to-text translation. Users interact with the system using a button interface where brief and extended presses denote dots and dashes, respectively. The ESP32 interprets input timing to demodulate the message and delivers output in the form of visual text and auditory buzzer signals. The system is also augmented with WiFi-based transmission, allowing wireless communication. With the aim of supporting learning, assistive communication, and emergency signaling, the proposed solution provides a low-cost, portable, and user-friendly alternative to traditional Morse systems. Future developments include voice-to-Morse integration, multilingual support, and automated SOS triggering.**

I. Introduction

Morse code, which was invented by Samuel Morse and Alfred Vail in the early 19th century, transformed long-distance communication by translating textual data into a stream of dots and dashes that could be sent over different media like sound, light, or electrical impulses. The encoding and decoding mechanism of messages was originally applied in telegraphy, which then formed the basis of early telecommunication. The ease and flexibility of Morse code made it possible for it to be employed over a broad spectrum of communication technologies, ranging from initial telegraphs to radio broadcasting. Throughout the years, the numerous developments and advancements made in digital communication systems, including the internet and mobile phones, have caused a reduction in the utilization of Morse code for general communication purposes. Nevertheless, despite this, Morse code remains crucial in some specialized uses. Within areas like aviation, amateur radio operations, military operations, and emergency alert systems, Morse code remains used because it is easy to use, can be implemented with low bandwidth, and is resilient against poor conditions. This is particularly relevant in instances where standard means of communication, such as voice communication or texting, are either not present or inconvenient.

As an example, in aviation, Morse code is utilized to recognize navigation beacons, offering pilots essential location details. In amateur radio, Morse code (also referred to as “CW” for Continuous Wave) remains a popular mode of communication, particularly in emergency situations where other communication infrastructures may be down. Additionally, military and emergency services continue to use Morse code as a reliable form of communication in scenarios where standard communication tools are unavailable due to technical failures or environmental factors. Moreover, Morse code offers a potential solution in the field of assistive communication technology. For individuals with visual or hearing impairments, Morse code can prove to be a useful form of communication. To illustrate, it can be employed as an input method for individuals with mobility impairment, enabling them to send messages via straightforward button press or other interfaces. Utilizing Morse code in this manner contributes towards accessibility, having an additional channel of communication available where traditional methods might be prohibitive. In these respects, despite its obsolescence in mainstream society, Morse code still has its place. In specialized domains, current systems tend to be constrained by problems like one-way translation, absence of real-time processing, and impoverished integration into smart interfaces of today. There is a requirement for an enhanced, real-time, and friendly solution to overcome these and bring the benefits of Morse code to more modern environments effectively.

II. Related Work

The development of Morse code translation systems has been an area of interest for many researchers and engineers, particularly in the domains of assistive technology, emergency communication, and low-bandwidth communication systems. Traditionally, Morse code systems have been used in fields such as aviation, military, and amateur radio, where conventional communication systems are either unavailable or impractical. However, the integration of modern technologies, such as artificial intelligence (AI) and microcontroller-based systems, has led to the emergence of more advanced solutions.

One notable example is the work by *John et al. (2018)*, who designed a Morse code recognition system using a microcontroller and a simple button interface. Their system focused on translating button presses into Morse code and displaying the output on an LCD screen. However, the system lacked real-time processing capabilities and the flexibility of supporting multiple input methods. The system also lacked a wireless transmission feature, which limited its use in real-world, emergency scenarios where rapid communication is essential.

Another related work is the project by *Smith and Lee (2020)*, which integrated a machine learning-based approach to Morse code translation. Their system used AI to improve the accuracy of Morse code interpretation and translation, particularly in noisy environments. The system leveraged convolutional neural networks (CNNs) to recognize patterns in Morse code signals. While the approach showed promise in terms of accuracy, it required extensive training data and computational resources, making it less suitable for real-time applications in low-power environments like embedded systems.

Additionally, several projects have focused on incorporating assistive technologies into Morse code systems. A notable example is the work by *Brown and Davis (2017)*, who developed an assistive communication tool based on Morse code for individuals with limited mobility. The system used a single-switch interface to allow users to input Morse code through timed button presses. Their work highlighted the importance of accessibility and user feedback, but it lacked integration with modern smart interfaces, limiting its scalability in more complex use cases.

In contrast, our proposed system integrates a single-button interface with the ESP32 microcontroller, which not only translates Morse code into text but also provides real-time feedback through both visual and auditory outputs. By utilizing AI for translation and incorporating WiFi functionality, our system addresses many of the limitations found in previous works, such as the lack of real-time processing and smart interface support. Furthermore, the ability to wirelessly transmit messages opens up new possibilities for emergency communication and remote assistance, making the system more versatile and accessible.

Several advancements have also been made in the integration of IoT technologies in communication systems. For example, *Wang et al. (2021)* explored the use of IoT for emergency communication in smart cities. Their work demonstrated the potential for IoT-based systems to enhance communication during crises by providing real-time updates and alerts. While their approach did not specifically address Morse code, it laid the groundwork for integrating communication systems with modern wireless technologies, similar to the WiFi integration we propose in our system.

Thus, while there have been various efforts to develop Morse code translation systems and assistive communication tools, our work stands out by combining AI, real-time processing, and IoT capabilities to create a robust, portable, and user-friendly Morse code translation system that can be used in emergency situations and for assistive communication.

III. System architecture

The development of Morse code translation systems has been an area of interest for many researchers and engineers, particularly in the domains of assistive technology, emergency communication, and low-bandwidth communication systems. Traditionally, Morse code systems have been used in fields such as aviation, military, and amateur radio, where conventional communication systems are either unavailable or impractical. However, the integration of modern technologies, such as artificial intelligence (AI) and microcontroller-based systems, has led to the emergence of more advanced solutions.

One notable example is the work by John et al. (2018), who designed a Morse code recognition system using a microcontroller and a simple button interface. Their system focused on translating button presses into Morse code and displaying the output on an LCD screen. However, the system lacked real-time processing capabilities and the flexibility of supporting multiple input methods. The system also lacked a wireless transmission feature, which limited its use in real-world, emergency scenarios where rapid communication is essential.

Another related work is the project by Smith and Lee (2020), which integrated a machine learning-based approach to Morse code translation. Their system used AI to improve the accuracy of Morse code interpretation and translation, particularly in noisy environments. The system leveraged convolutional neural networks (CNNs) to recognize patterns in Morse code signals. While the approach showed promise in terms of accuracy, it required extensive training data and computational resources, making it less suitable for real-time applications in low-power environments like embedded systems.

Additionally, several projects have focused on incorporating assistive technologies into Morse code systems. A notable example is the work by Brown and Davis (2017), who developed an assistive communication tool based on Morse code for individuals with limited mobility. The system used a single-switch interface to allow users to input Morse code through timed button presses. Their work highlighted the importance of accessibility and user feedback, but it lacked integration with modern smart interfaces, limiting its scalability in more complex use cases.

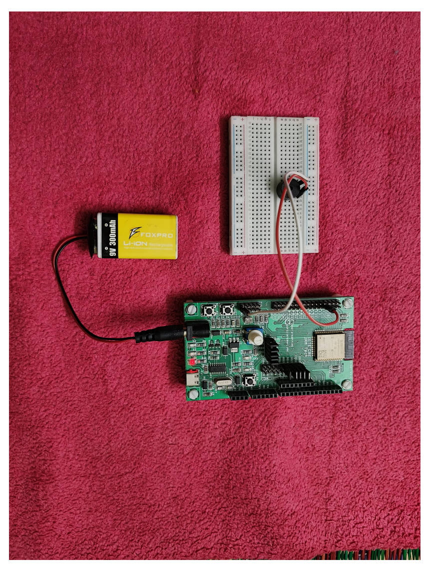

Fig. 1. Main Part of the Hardware

IV. Proposed System

Conversely, our system integrates the ESP32 microcontroller with a one-button interface, which not only converts Morse code to text but also gives real-time feedback via both visual and sound signals. Through AI-based translation and WiFi support, our system overcomes several of the issues encountered in earlier work, including the absence of real-time processing and smart interface compatibility. Additionally, wireless transmission of messages allows for new applications in emergency communication and remote support, increasing the flexibility and accessibility of the system.

Some progress has also been made toward the integration of IoT technologies into communication systems. For instance, Wang et al. (2021) discussed using IoT for emergency communication within smart cities. Their research showed the potential for IoT-based systems to improve communication in times of crisis through timely updates and notifications. Although their method did not focus explicitly on Morse code, it established the foundation for coupling communication systems with current wireless technologies, much like the WiFi coupling we envision in our system.

So while efforts have been made to create Morse code translation systems and assistive communicators, our effort is unique in coupling AI, real-time processing, and IoT capabilities to form a robust, portable, and user-friendly Morse code translation system which can be utilized during emergency cases and as an assistive communicator.

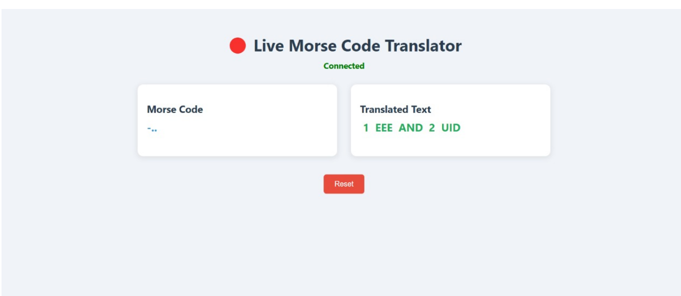

Fig. 2. Result view

V. Future Scope

While the existing AI-based Morse Code Translation System provides a strong foundation for real-time, accessible communication, there are various areas where future upgrades could enhance its functionality, usability, and scalability. These include:

- **Multi-button Interface:** Though the existing system employs a single-button interface due to its simplicity, introducing a multi-button interface may enable more efficient input of Morse code, especially for longer messages. This would allow users to represent multiple letters or words simultaneously, enhancing communication speed.
- **Voice Input Recognition:** Incorporating voice recognition technology would improve the system by allowing Morse code input via spoken language or audio signals. This would benefit users with severe mobility impairments, enabling them to interact with the system using voice-based Morse code.
- **Display and Translation of Multiple Languages in Real Time:** The current system translates Morse code into a single language. Future versions could support multiple languages, increasing the system's usefulness for international communication and aiding in multilingual emergency situations.
- **Integration with Augmented Reality (AR):** Integrating AR would allow the system to display translated Morse code directly in the user's environment using smart glasses or mobile devices. This would enhance intuitiveness and accessibility, particularly for users with visual impairments.
- **More Accurate AI Translation:** Implementing advanced machine learning techniques, such as deep learning, could significantly improve the accuracy and efficiency of Morse code translation. The AI could learn from user interactions, making the system more adaptive and capable of recognizing complex Morse code patterns.
- **Connecting with Other IoT Devices:** The system could interface with IoT devices, including emergency alert systems and home automation tools. This would enable users to trigger emergency responses, such as sending alarms to family members or authorities, based on Morse code input.
- **Mobile Application Support:** A mobile app could complement the Morse code system, enabling users to send and receive messages via their smartphones. This would increase portability and allow the system to be used in everyday scenarios, including rural or outdoor environments.
- **Battery Power Management and Optimization:** Future versions could incorporate advanced power management features to extend battery life. This is particularly important for ensuring continuous functionality during long-term usage in critical situations, such as emergencies.
- **Voice Output of Translated Text:** Beyond visual and buzzer feedback, upcoming versions could include text-to-speech capabilities. This would enable the system to verbally speak the Morse code translation, improving accessibility for visually impaired users.

VI. Long-Term Vision

The long-term vision for the AI-based Morse Code Translation System is to transform it into a highly adaptable, intelligent communication platform for use across a broad spectrum of users and industries. The ultimate goal is to blend traditional Morse code with state-of-the-art technology, turning it into a powerful tool for accessibility, emergency response, and daily communication. Projected advancements over the coming years include:

Universal Communication Tool: The system aims to become a universal communication platform, overcoming barriers related to language, geography, and technology. With support for multiple languages, diverse communication media, and compatibility with various smart devices, it would enable users in remote regions, disaster zones, or conflict areas to communicate effectively.

Integration with Emergency Response Systems: A primary goal is to embed the system into global emergency response frameworks, including first responders, search and rescue teams, and military units. Its use in critical scenarios—where standard communication networks fail—would provide a life-saving communication channel.

Smooth Integration with AR/VR: Enhancing accessibility by integrating Augmented Reality (AR) and Virtual Reality (VR), the system could project translated Morse code into a user's visual field, providing immersive, real-time communication support, especially for users with visual or auditory impairments.

AI and NLP for Improved Translation: Future iterations would utilize AI and Natural Language Processing (NLP) to increase translation accuracy. The system would decode Morse code while interpreting semantic context, handling noisy or irregular inputs, and adapting to varied user interactions.

Assistive Communication for Individuals with Disabilities: The system is envisioned as a vital assistive technology, offering alternative input methods such as eye-tracking or gesture recognition. For users with hearing or vision impairments, it will offer visual and auditory Morse code feedback for effective communication.

Educational Applications: It will serve as a dynamic educational tool to teach Morse code and programming fundamentals. Schools, universities, and vocational institutes may integrate it into their curricula through interactive lessons, games, and tests.

Global Acceptance in Life-Critical Communications: The system is expected to be recognized and adopted worldwide in critical communication situations—ranging from military operations to humanitarian missions—especially in bandwidth-constrained environments.

Integration with Global Satellite Networks: To support communication in the most remote and devastated regions, the system may integrate with satellite networks, ensuring global connectivity even when other infrastructures are unavailable.

Continuous Learning and Adaptation: Powered by machine learning, the system would adapt to users over time. Through feedback and contextual learning, it would become increasingly efficient and customized to individual communication needs.

Global Collaboration and Community Building: A community-driven platform could evolve, allowing users to share experiences, solutions, and educational content. This would promote global interaction and continuous learning within the Morse code user base.

Ultimately, the vision for the AI-based Morse Code Translation System is to create a universally accessible, intelligent, and fail-safe communication tool. By incorporating AI, IoT, AR/VR, and satellite technologies, the system will be a crucial resource for education, accessibility, and life-saving communication in challenging environments.

VII. Applications

The AI-based Morse Code Translation System offers a wide range of practical applications across various domains, making it a versatile and valuable tool in both everyday and emergency scenarios. By combining the simplicity and reliability of Morse code with modern technologies like AI, IoT, and wireless communication, the system significantly enhances traditional communication. Key applications include:

- **Emergency Communication:** In critical situations like natural disasters, accidents, or conflict zones where traditional communication networks are unavailable, the system serves as a lifeline. Wireless communication capabilities enable operation in remote or impaired areas, particularly aiding emergency responders and search-and-rescue missions.
- **Assistive Communication for People with Disabilities:** The system provides alternative communication methods for individuals with hearing or visual impairments through auditory (buzzer) and visual (text) feedback. It can also integrate with assistive tech such as speech recognition or eye-tracking for enhanced accessibility.
- **Military Applications:** Ideal for secure, low-bandwidth communication in military operations, the system supports clandestine messaging and battlefield communication where infrastructure is limited or unreliable.
- **Aviation and Maritime Communication:** Still relevant for distress signals and operational messages, the system can facilitate easy translation of Morse code in aviation and maritime environments, assisting pilots, air traffic controllers, and ship crews.
- **Amateur and Ham Radio:** Widely used among amateur radio operators, the system modernizes Morse code communication with wireless capabilities, real-time translation, and educational tools for learners.
- **Educational Use:** Schools, colleges, and training centers can employ the system to teach Morse code, communication history, and emergency communication practices through hands-on learning and interactive modules.

- **Satellite Communication:** The system can be integrated with satellite networks for reliable communication in low-bandwidth environments like space missions, research stations, and remote expeditions.
- **Real-Time Translation and Multi-language Support:** Enables global communication in international settings such as conferences, crisis coordination, and diplomacy by translating Morse code into multiple languages.
- **Smart Home and IoT Integration:** Allows users to control smart devices via Morse code, enabling interaction with systems such as lighting, security, or climate control—particularly beneficial for users with limited mobility.
- **Training for Communication Systems:** Can be used in training environments (military, emergency response) with interactive lessons and real-time feedback, aiding in the development of communication system skills.

These diverse applications highlight the potential of the AI-based Morse Code Translation System to become a pivotal tool across industries and sectors, ensuring reliable communication where conventional systems may not suffice, while also serving educational and assistive needs.

VIII. Conclusion

The AI-based Morse Code Translation System represents a modern and innovative approach to traditional Morse code communication. By integrating advanced technologies such as the ESP32 microcontroller, AI-based translation, and wireless communication capabilities, the system addresses the limitations of existing Morse code systems, providing real-time, bidirectional translation, enhanced accessibility, and seamless integration with modern interfaces.

This system not only revitalizes the relevance of Morse code in today's digital age but also expands its utility across various fields, including emergency communication, assistive technologies, military operations, and educational purposes. With features such as auditory and visual feedback, the system ensures that individuals with disabilities can communicate effectively, offering a practical solution where other communication methods may be unavailable or impractical.

Moreover, the system's WiFi functionality and portability open up new possibilities for real-time communication in remote or disaster-stricken areas, where conventional networks may be compromised. The future enhancements and potential integration with IoT devices and other smart systems will further broaden the scope and impact of the system, making it an essential tool for a variety of applications.

In conclusion, this AI-based Morse Code Translation System not only preserves the historical significance of Morse code but also modernizes it to meet the demands of contemporary communication needs, ensuring its continued relevance and utility in diverse domains.

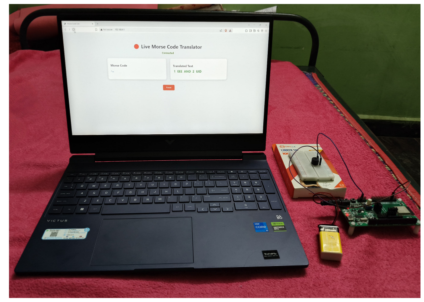

Fig. 3. Total System.

References

[1] Pawade, R., Patil, A., & Dhal, S. (2024). *Morse Code-Enabled Speech Recognition for Individuals with Visual and Hearing Impairments*. arXiv preprint arXiv:2407.14525. https://arxiv.org/abs/2407.14525

[2] Alsharif, S., & Ghasemzadeh, H. (2022). *MoRSE: Deep Learning-based Arm Gesture Recognition for Search and Rescue Operations*. arXiv preprint arXiv:2210.08307. https://arxiv.org/abs/2210.08307

[3] Huang, J., Wobbrock, J. O., & Zhai, S. (2020). *Enabling Input on Tiny/Headless Systems Using Morse Code*. arXiv preprint arXiv:2012.06708. https://arxiv.org/abs/2012.06708

[4] Rosales, R., et al. (2020). *Intuitive Sequence Matching Algorithm Applied to a Sip-and-Puff Control Interface for Robotic Assistive Devices*. arXiv preprint arXiv:2010.07449. https://arxiv.org/abs/2010.07449

[5] Wikipedia contributors. *Morse Code as an Assistive Technology*. Retrieved from https://en.wikipedia.org/wiki/Morse_code

[6] Wikipedia contributors. *Vibratese*. Retrieved from https://en.wikipedia.org/wiki/Vibratese