International Journal of Advanced Trends in Engineering and Management
(ISSN 2583-7052)

pp. 298-303, April

Music Therapy Based on EEG Signals Using IoT

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Abstract: As the level of stress, anxiety and emotional imbalance increases, we need more intelligent systems to provide mental health assistance. Current methods of music therapy and EEG monitoring have problems such as depending upon manual supervision, not providing personalized treatment and lack of real-time adaptability. Because of these limitations, there is a lack of effectiveness with therapy and keeping track of your emotional state while not in the clinic is very difficult. Traditional systems also have limitations because they are bulky and don't have good remote access. The purpose of this study is to create an IoT-based music therapy system that collects EEG signals, preprocesses and analyse to identify the brain state. This system allows real-time brainwave analysis, provide personalized treatment and allow remote monitoring. Experimental data display greater regulation of emotional states, decreasing brainwave activity related to stress and increasing the user comfort level and confirming the effectiveness of EEG based automated music therapy.

Keywords: Music Therapy, EEG Signals, Neurofeedback, Wearable EEG, Real-Time Monitoring, Smart Healthcare, EEG Device, Brain Computer Interface (BCI), Internet of Things (IoT)

1. Introduction

Modern lifestyles, work-life imbalance, and work pressure are main contributors to mental stress and anxiety which leads to physical health problems like sleep disorder, reduced concentration, depression, and cardiovascular problems. As people become more conscious about their mental wellbeing, they need effective, safe, and non-invasive therapies that support the regulation of emotions and stress reduction. While music therapy is an evidence-based non-pharmacological intervention that helps to alleviate stress, improve mood, and promote mental health. Traditional methods do not have personalized music therapy and lack of remote monitoring. It needs manual supervision or therapist intervention to observe continuously, which is not always feasible.

Electroencephalogram signals, which are the electric signal produced by the neurons in the brain, are used to identify the mental or emotional state of an individual. It was identified by four main frequency bands such as alpha, beta, theta and delta waves. It represents the mental state of stress, relaxation, concentration, drowsiness and deep sleep. By analyzing the mental state through brainwave patterns, the automated system is used to regulate the brainwave through music. When EEG is integrated with IoT, it provides real-time monitoring and personalized music therapy. IoT enables the EEG and therapy data to be stored on the cloud for remote monitoring through web or mobile interfaces.

This integrated approach significantly improves the accessibility, personalization, and effectiveness of music therapy. Users can benefit from continuous monitoring and automated therapy without the need for constant expert supervision. The system is cost-effective, scalable, and suitable for applications in healthcare, education, rehabilitation, and home-based wellness environments. The system is cost-effective, scalable, and suitable for applications in healthcare, education, rehabilitation, and home-based wellness environments.

Recent studies have focused on improving personalization and real-time adaptability of EEG-based music therapy systems. Ran et al. proposed an EEG signal-driven real-time emotional music generation system capable of fast calibration for new users [1]. To address the inter-subject variability of EEG signals, the authors employed instance selection and transfer learning techniques for subject-independent emotion recognition. Furthermore, the recognized emotional states were directly integrated into a neural music generation network, enabling the creation of personalized music that closely aligned with the user's real-time emotional expression. The system achieved high recognition accuracy while maintaining low computational latency, making it suitable for practical therapeutic scenarios.

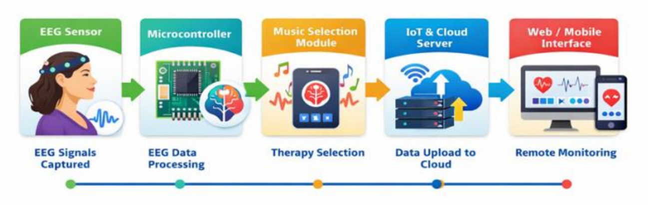
One of the earliest and most influential contributions in this area was presented by Miranda, who introduced the concept of the Brain–Computer Music Interface (BCMI) [2]. In this work, EEG signals were mapped to generative music rules, allowing users to influence musical parameters such as tempo, loudness, and pitch through brain activity alone. This pioneering study demonstrated the feasibility of EEG-driven generative music systems and highlighted their potential for therapeutic and assistive applications, particularly for individuals with physical or neurological impairments.

Expanding BCMI concepts, Hossan and Chowdhury proposed a real-time EEG-based automatic brainwave regulation system using music as a neurofeedback mechanism [3]. Their system analyzed EEG signals across standard frequency bands—delta, theta, alpha, beta, and gamma—and automatically selected suitable music tracks to regulate the user's mental state. Experimental results indicated that relaxation music effectively reduced high-frequency brain activity associated with stress and agitation, confirming the effectiveness of music-based EEG neurofeedback for emotional regulation.

In clinical applications, Lam et al. developed an IoT-enabled EEG headphone system designed for chronic tinnitus assessment and symptom management using customized music interventions [4]. The proposed system integrated EEG sensing, pitch-matched customized music, and cloud-based monitoring to support long-term home-based therapy. Experimental results from a 30-day study showed significant reductions in tinnitus severity scores, accompanied by measurable increases in alpha-band EEG activity. This study demonstrated the effectiveness of EEG-guided customized music therapy and highlighted its potential for scalable and accessible healthcare solutions.

The current literature indicates that music therapy using EEG (electroencephalography) has therapeutic benefits such as emotional regulation and symptom relief from neurological disorders; however, most of these systems are limited by inter-subject variability in EEG signals, a lengthy calibration process before use with participants' EEG data, and the need for pre-defined or third-party generated music. Therefore, researchers have developed integrated, personalized, and real-time frameworks for providing music-based therapies based on the use of reliable EEG-derived emotion recognition and controllable music generation methods.

2. Proposed Methodology



In the proposed system, the EEG sensor captures the EEG signals and the microcontroller processes the Signals from sensors, these signals represent EEG data as Alpha, Beta, Theta, and Delta signals, which is used to determine an individual's Mental State or Mental Activity levels and automatically select suitable music based on the results from the EEG Signal Analysis. The data from this entire analysis system is connected via IoT to the cloud to monitor and analyze in real-time.

2.1 System Architecture

An automated and intelligent music therapy framework that uses EEG signal acquisition, embedded processing, and IoT communication is proposed by this project. The system offers continuous monitoring of brain function, real-time assessments of the user's mental state, and delivery of customized music therapy based upon objective neurologic data. Using objective neurologic data rather than subjective evaluations results in improved effectiveness and accessibility to therapeutic interventions in a variety of settings, including health, home, and education.

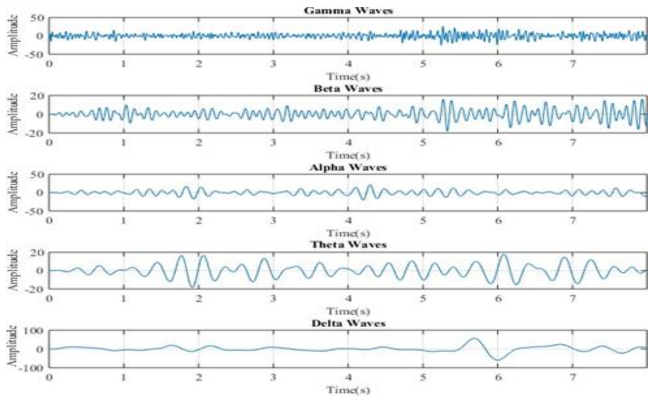
2.2 Data Acquisition and Integration

The EEG signal is collected via non-invasive electrodes that are placed on the scalp. Low-voltage electrical signals from the brain are picked up and can be amplified into high voltage signals through an instrumentation amplifier and filtered to remove noise and unwanted signals. Conditioned signals are digitized through an analog-to-digital converter (ADC) before being sent to a microcontroller, which is the control and processing center of the entire system. There is also an IoT communication module included in the overall design, allowing for interoperability so the EEG can be transmitted directly to a cloud-based platform for storage, monitoring, and analysis.

2.3 Data Preprocessing and Analysis

Using a microcontroller for real time EEG signal analysis, frequency domain features are extracted for each brainwave band, including:

- Delta Waves (0.5-4Hz) represent your state of deep sleep and very little awareness.
- Theta Waves (4-8Hz) relates to you in a state of drowsiness as well as being in a meditative state.
- Alpha Waves (8-13Hz) relate to you being in a relaxed, calm and stress-free state.
- Beta Waves (13-30Hz) represent you being alert, focused, and experiencing high levels of stress.



With frequency analysis, identification of the predominant brainwave band will determine the user's current mental and emotional state. An automated data driven approach using these techniques removes subjective assessments from the process, resulting in increased diagnostic reliability.

2.4 Model Development

A rule-based decision model is implemented to map detected brainwave patterns to appropriate music therapy categories. The music therapy recommendations are broken down by their relationship to the following mental states:

1. Music to provide calmness in response to stress and anxiety.

2. Music to aid in the reduction of tension.

3. Music to help improve focus and concentration.

This model operates in real-time, with the music selections continuously updated based on the user's brainwave input received as an electroencephalogram (EEG) signal. This allows for adaptive therapy based on the user's evolving neurological state.

2.5 Connectivity and User Interface

The IoT module helps the embedded system to talk to the cloud server in time. People who are allowed to, such as users, caregivers and healthcare professionals can see the systems data on a website or mobile app. The interface does a thing like:

- Showing what is going on with someone's mental state right now
- Letting you watch therapy sessions
- Looking at EEG data
- Keeping an eye on the system from far away

This connection makes it easier for people to get to the system and helps with taking care of people from far away. The IoT module and the connection it makes are important for healthcare monitoring. The IoT module is what makes all this possible.

2.6 Analysis and Reporting

The EEG data used in the development of the cloud-based platform can be stored for long periods of time to allow for long-term reporting and analysis to:

- Find trends in mental health
- Assess whether the therapy is effective
- Assess how the individual experiences stress or relaxation
- Modify treatment options based on how the individual experiences stress or relaxation

With the ability to create reports like these on the cloud, individuals will have access to preventative healthcare and long-term improvements in therapy.

2.7 Security and Compliance

To ensure that the sensitive data stored in the proposed applications are kept confidential as well as provide a reliable system for continuous performance of treatment, secure communications and encrypted storage will be implemented throughout the cloud storage system. Users will require various forms of authentication before being granted access to the database where their information resides; therefore, privacy protection will also be implemented for the sensitive neurological as well as for health information, which will allow users to deploy these applications in both personal and clinical settings.

3. Research and Discussion

The objective of this research study is designed to provide a real-time, EEG-based music therapy system that utilizes a novel approach for emotional regulation through the dynamic analysis of EEG signals, rather than a static playlist and emotion recognition through a set of pre-defined rules. This study has developed a closed-loop system that will continuously analyze the EEG signal for the subject to provide feedback and improve individualized treatment/action while addressing the variability of EEG signals between subjects.

The proposed system also provides a more efficient solution to practical usability by implementing low-latency processing as well as user-adaptive calibration. In combination with the features of real-time emotion recognition and adaptive delivery of music improve the robustness and engagement of the system for applications in stress management, mental health and rehabilitation. The outcomes of this study demonstrate the ease of implementation of a system that is based on the integration of EEG and personalized music therapy in the real world.

4. Conclusion

The Music Therapy system based on EEG signals utilizing IoT provides an automated and innovative way to provide mental health and emotional wellbeing support to individuals. The system continuously monitors the EEG signals from the user, allowing for real time (and live) detection of brainwave patterns that are reflections of the user's mental state (stress, relaxation, or concentration).

The In-built signal processing capability of the system allows for accurate analysis of brain signals in the methods of signal alignment, which enables the system to choose appropriate music therapy based on the current neurological state of the user without manual intervention. By using an objective measurement system to deliver all therapy in a data-driven way, meaning each relationship to be personal and based on the user's current neurological condition.

The addition of IoT technology to this system allows for an increased level of functionality and accessibility to the system since there is real time data transmission, remote monitoring and secure access to data from web and mobile platforms. Healthcare providers/professionals, caregivers and users can view real-time therapy progress and analyze historical eeg data for effectiveness analysis and control at any remote location.

By reducing the necessary level of continuous expert supervision and providing a solution that is cost-effective, scalable, the proposed system can be used in all healthcare facilities, wellness centers, academia and home environments. Overall, this system demonstrates the potential of combining EEG technology and IoT to deliver effective, personalized, and modern mental health support solutions.

5. Future scope

In another area, cloud-based data analytics and long-term data storage represent an exciting opportunity for increased growth. The cloud would allow for the secure storage of EEG data so that health care providers could view large aggregates of EEG data over time and evaluate how the trends associated with mental health continue to develop. Health care providers could also evaluate the effectiveness of various therapies, customize treatment plans for patients based upon their EEG readings, and complete research projects. By connecting this type of support system to mobile applications (e.g., for therapy session tracking, alert notifications based upon ECG results, and system settings management), users would have easier access to manage their systems and receive real-time updates.

Furthermore, there could be a multi-user format developed (i.e., wearable EEG technology) that would allow hospitals, rehabilitation centers, and expansive wellness programs to have access to the system as well. From an engineering standpoint, these types of devices could be unified under low-power, portable design utilizing IoT hardware. Future models of the system could also include caregiver alerts regarding stress-related abnormalities; automated recommendations regarding "best-fit" therapy schedules; and the use of automated event notifications/recommendations for other types of functions. By developing the above-mentioned technologies with advanced security features (e.g., multi-factor authentication and encryption), the systems would have the to change into highly secure intelligent deployable solutions for next-generation mental health care and smart wellness environments.

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