International Journal Of Advance Research, Ideas And Innovations In Technology

IJARIIT

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 10, Issue 6 - V10I6-1519)
Available online at: https://www.ijariit.com

Mindsymphony: A Survey of Brain-Computer Interface Applications in Music Therapy Related Applications

Tanishq Zade
tanishqzade3@gmail.com
MIT Art, Design and Technology University, Loni Kalbhor, Maharashtra

Anurag Gutte
anurag.gutte@gmail.com
MIT Art, Design and Technology University, Loni Kalbhor, Maharashtra

Sushrut Wankhade
sushrutwankhade1204@gmail.com
MIT Art, Design and Technology University, Loni Kalbhor, Maharashtra

Rahul Gurbani
gurbanirahul04@gmail.com
MIT Art, Design and Technology University, Loni Kalbhor, Maharashtra

Prof. Dr. Jayashree Prasad
jayashree.prasad@mituniversity.edu.in
MIT Art, Design and Technology University, Loni Kalbhor, Maharashtra

Prof Anuja Gaikwad
anuja.gaikwad@mituniversity.edu.in
MIT Art, Design and Technology University, Loni Kalbhor, Maharashtra

ABSTRACT

MindSymphony is an EEG-based dynamic music therapy system which displays the potential of BCI (brain Computer Interfaces)in regulating emotional states through real-time monitoring of brainwaves and adapting the music accordingly. This survey examines various current BCI applications in personalized music therapy, focusing on key algorithm methodologies, as well as the various challenges in EEG signal processing and emotion detection. This paper categorizes and compares existing approaches, addressing limitations and proposing strategies to enhance reliability and user experience in BCI-driven music therapy applications. It also discusses potential future research directions. This survey aims to provide a comprehensive overview of BCI-based adaptive music therapy and its applications.

Keywords: *BCI, LDA, Linear Discriminant Analysis, Music, Music Therapy, Therapy, Brain-Computer Interfacing*

1. INTRODUCTION

1.1 Background

Brain Computer Interfaces (BCIs) were initially conceptualized in the 1970s and were primarily used for establishing communication channels for individuals with severe disabilities. The initial uses for early systems were to interpret brain signals for simple tasks, they read the user's various brainwaves (Alpha waves, Beta waves, Gamma waves, Delta waves, Theta waves) and used the information inferred to determine the state of the user based on predetermined parameters. These systems/ models were the very framework on which models such as 'Mindsymphony' are built. Mindsymphony works by manipulating the music being played in a way that allows it to achieve its goal state based on the user's current state, which is determined by the live Electro Encephalogram reading taken.

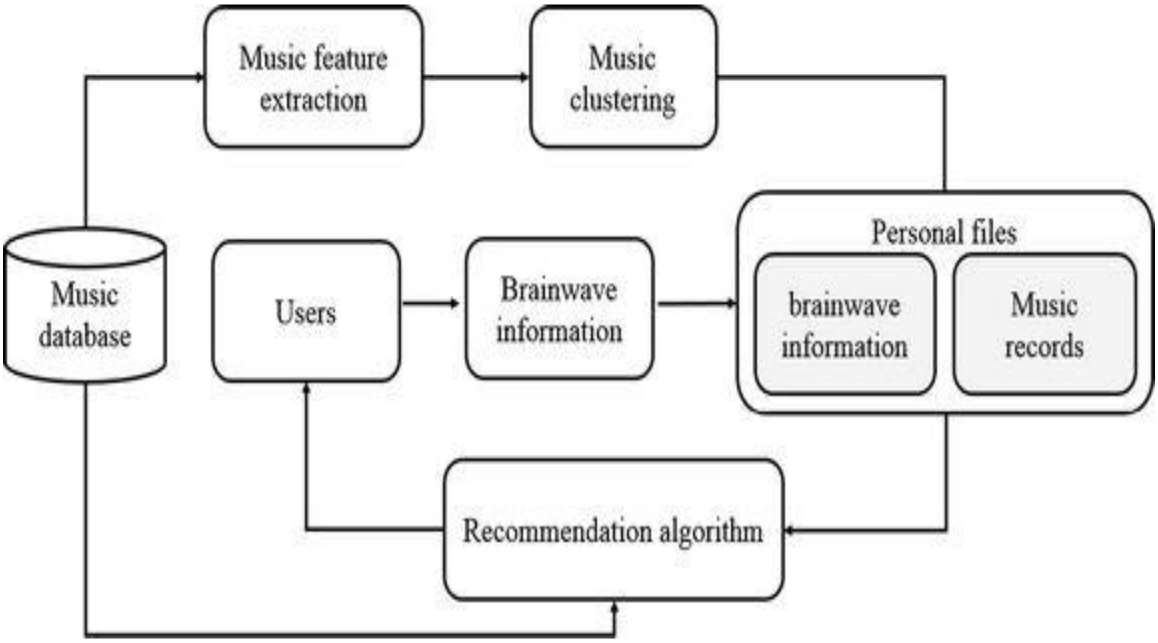
1.2 Importance

Adaptive music therapy offers a significant advantage as compared to traditional music therapy as in traditional music therapy there is a way of knowing the real time state of the individual and usually depends on a predefined set of music compositions. While Music therapy is proven to be an effective tool for emotional rehabilitation, the somewhat rigid nature of traditional music therapy limits its effectiveness. Compared to which adaptive music therapy allows real-time tailoring of the music being played according to the user's current emotional state, ensuring that the music directly resonates with the listener's current requirements and can thus maximize its effectiveness in a far more efficient, specific and a targeted way as compared to the traditional methods.

1.3 Objectives

The primary objective of this paper is to explore Brain computer Interfaces and their integration with music therapy via Electro Encephalogram (EEG) readings and continuously monitoring and adapting the music in real-time based on the EEG readings in such a way that helps achieve the desired goal state, which in the case of Mindsymphony is the real time adaption of music according to the user's current emotional state. It also aims to analyze the various challenges faced in the creation of a seamless adaptive system for an application such as this.

2. BLOCK DIAGRAM



This block diagram illustrates the workflow ofMindsymphony's system. The breakdown of its components is as follows:

Music Database
This serves as a repository of various music tracks with diverse features like tempo, rhythm, and mood.
Music Feature Extraction
Tracks from the music database undergo feature analysis to extract characteristics such as melody, harmony, beats, and emotional attributes. These features help in categorizing and analyzing the suitability of music for therapeutic purposes.
Music Clustering
Based on the extracted features, the music tracks are grouped or clustered into categories. These clusters could represent emotional states or therapeutic goals (e.g., calming, energizing).
Users
Individuals engaging with the system. They provide real-time brainwave information via EEG devices.
Brainwave Information
The system collects the users' brainwave data, which refl ects their emotional and cognitive states.
Personal Files
These store individual user data, including historical brainwave information and previously recommended or listened-to music tracks. This allows the system to build a personalized profi le for each user.
Recommendation Algorithm
This component uses the real-time brainwave data, personal user fi les, and the clustered music information to generate music recommendations tailored to the user's current emotional state.
Feedback Loop
The system continually adapts by using real-time user data and updates personal profi les based on interactions, ensuring dynamic and personalized music therapy.

3. PROPOSED ALGORITHM

The development of the MindSymphony's system relies on a combination of signal processing and machine learning algorithms, which are used for real-time emotional state classifi cation and personalized music recommendation. Some of which are:

Bandpass Filter for Signal Processing
To isolate specifi c brainwave frequency bands, such as beta waves (13-30 Hz) for focus detection, a Butterworth bandpass fi lter is employed. This algorithm removes noise and irrelevant frequencies while preserving the signal components essential for feature extraction.
The fi ltered data enables accurate identifi cation of emotional states.
Key Steps:
Defi ne the lower and upper cutoff frequencies for the bandpass fi lter.
Design the fi lter using the Butterworth method to ensure a smooth frequency response.
Apply the fi lter to the raw EEG data using the fi ltfi lt function for zero-phase distortion.

Feature Extraction

The system computes statistical features from the fi ltered EEG data to represent brainwave activity. Key features include:
Mean Amplitude: Captures the average signal strength over time for each frequency band. Frequency Power: Quantifi es the intensity of specifi c brainwave bands (e.g., alpha, beta,
gamma). These features are crucial for distinguishing emotional states, such as relaxed vs. focused.

Linear Discriminant Analysis (LDA)

Linear discriminant analysis (LDA) is a supervised machine learning algorithm which is used for classifi cation and dimensionality reduction technique that identifi es a linear combination of features that best separates diff erent LDA classes. The application of which in MindSymphony, can be used to classify the emotional and cognitive states of Users based on Electro Encephalogram (EEG) data such as relaxed, tense or focused. This categorization allows for personalized music therapy through the selection of the appropriate music based on the user's current state. Additionally, LDA improves the neural responses through feedback. It provides real-time feedback on brain activities helping users pinpoint their emotional and cognitive states in a more eff ective and effi cient manner. In the case of Mindsymphony LDA is used to classify diff erent emotional states

Data Preparation

Extracted EEG features (alpha, beta, gamma, etc.) from the fi ltered dataset.
Labeled data as 1 (Focused) or 0 (Not Focused) based on beta wave amplitude (>15 Hz).

Dataset Splitting

Divided the dataset into training (80%) and testing (20%* sets using train_test_split.

Model Training

Trained the Linear Discriminant Analysis (LDA) model using the training dataset.

Feature Reduction

LDA computed a linear combination of features to separate classes (focused vs. not focused) and reduced the feature dimensionality for better classifi cation.

Prediction

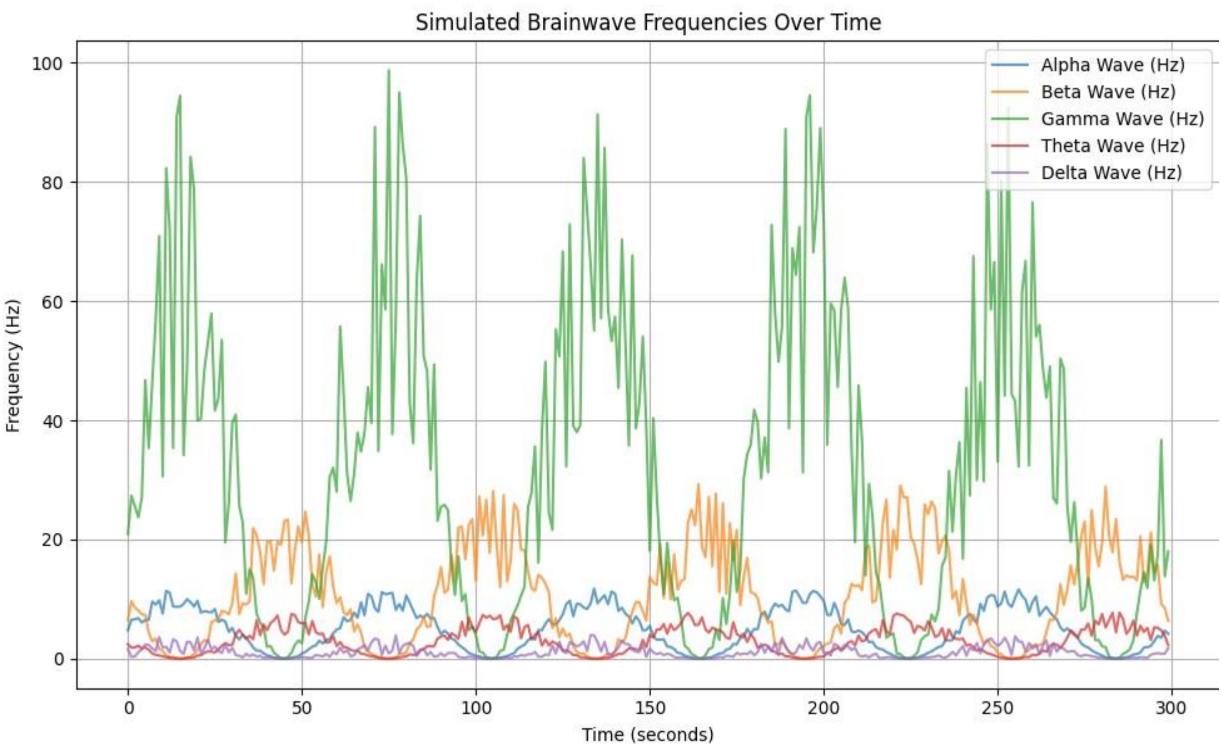
Used the trained LDA model to predict the emotional state for the test dataset and real-time EEG data.

Evaluation

Calculated the model's accuracy using accuracy_score to valuate its performance in classifying focused states.

Integration

Applied the trained LDA



Music Recommendation Logic

The music recommendation system operates based on a decision rule tied to the classifi ed emotional state:
If the user is focused, the system plays low-volume instrumental or ambient music.
If the user is not focused, the system selects calming or motivational tracks from a pre-defi ned music database. The music playback is handled using Pygame, which dynamically adjusts volume and track selection in response to real-time classifi cation.

Real-Time Processing Loop

A continuous processing loop evaluates EEG signals at regular intervals, updating the emotional state and corresponding music recommendations dynamically:
Volume Control: Adjusts the music volume based on the classifi ed state (e.g., reduced during focus, full during relaxation).

Real-Time Classifi cation: Applies the trained LDA model to predict emotional states as new data arrives.
Conclusion
These algorithms collectively enable the MindSymphony system to process EEG data, classify emotional states, and provide tailored music therapy in real time. Their integration ensures a seamless and adaptive user experience, making the system eff ective for emotional regulation and cognitive enhancement.

4. CHALLENGES

Real-Time Data Processing
Achieving the necessary low latencies for EEG signal processing and adaptive music delivery is a signifi cant technical challenge, as any delays can disrupt the therapeutic experience.
Accuracy of the EEG Data
Ensuring that EEG signals are accurately interpreted despite potential noise and artifacts is crucial for eff ective therapy customization.
Data Security and Privacy
Protecting sensitive and confi dential user data, including EEG signals and therapy records, is also a major concern, requiring robust encryption and strict access controls.

5. CONCLUSION

MindSymphony helps incorporate the branches of neuroscience, technology and music therapy designed to enhance and improve emotional as well as cognitive well-being. By using the EEG(Electro Encephalmogram) brainwaves, MindSymphony delivers real-time, personalized music therapy according to individual brain states. This method not only helps in rehabilitation but also aids in conditions like stress, fatigue, anxiety, helping improve overall mental health and focus. With the aim to focus on usability, safety and privacy, MindSymphony provides a solution for improving overall mental well-being and cognitive functions.

6. FUTURE RESEARCH DIRECTIONS

6.1. Improved EEG Signal Processing
Developing more advanced algorithms to enhance the real-time EEG signal processing and accuracy, particularly pertaining to better noise fi ltration and higher accuracy
6.2. Personalized Music Therapy:
Creating more personalized and tailored music selection algorithms based on individual preferences and emotional responses to optimize the outcomes in the most eff ective and effi cient way.
6.3. Long-Term Impact:
Conducting research on the long-term eff ects of music-based neurofeedback, particularly in terms of cognitive improvement and emotional regulation over a prolonged period of time.
6.4. Enhancing The User Experience:
Improving system accessibility and usability, especially for users with disabilities, by developing more intuitive and more usable interfaces as well as adaptive controls.
6.5. Neuroplasticity and Cognitive Rehabilitation:
Exploring the potential of models like Mindsymphony in stimulation of neuroplasticity for cognitive rehabilitation in conditions such as strokes or brain injuries.
6.6. AI-Driven Feedback Systems:
Investigating the use of AI to refi ne the real-time feedback and optimize the music based on the relevant user data.

REFERENCES

[1] K. D. Rajakumar and J. Mohan, "A systematic review on the effect of music intervention on cognitive impairment using EEG, fMRI, and cognitive assessment modalities," Results in Engineering, vol. 22, no. 102224, pp. 1-11, 2024. Available: https://doi.org/10.1016/j.rineng.2024.102224

[2] J. Sun, J. Yang, G. Zhou, Y. Jin, and J. Gong, "Understanding Human-AI Collaboration in Music Therapy Through Co-Design with Therapists," in Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24), Honolulu, HI, USA, May 11–16, 2024, pp. 1–21, doi: 10.1145/3613904.3642764.

[3] L. Xin, "Analysis of the eff ect of music therapy on psychological anxiety relief based on artifi cial intelligence recognition," Applied Mathematics and Nonlinear Sciences, vol. 9, no. 1, pp. 1-14, 2024, doi: 10.2478/amns.2023.2.01517.

[4] D. Williams, V. J. Hodge, and C.-Y. Wu, "On the use of AI for Generation of Functional Music to Improve Mental Health," Frontiers in Artifi cial Intelligence, vol. 3, p. 497864, Nov. 2020. doi: 10.3389/frai.2020.497864.

[5] T. H. Zhou, W. Liang, H. Liu, L. Wang, K. H. Ryu, and K. W. Nam, "EEG Emotion Recognition Applied to the Eff ect Analysis of Music on Emotion Changes in Psychological Healthcare," International Journal of Environmental Research and Public Health, vol. 20, no. 1, p. 378, Dec. 2022. doi: 10.3390/ijerph20010378.

[6] M. Cao and Z. Zhang, "Adjuvant music therapy for patients with hypertension: a meta-analysis and systematic review," BMC Complementary Medicine and Therapies, vol. 23, no. 110, pp. 1–11, Apr. 2023. doi: 10.1186/s12906-023-03929-6.

[7] Eseadi, C., & Ngwu, M. O., "Signifi cance of music therapy in treating depression and anxiety disorders among people with cancer," World J. Clin. Oncol., vol. 14, no. 2, pp. 69–80, Feb. 2023. DOI: 10.5306/wjco.v14.i2.69.

[8] S. Uhlig, A. Jaschke, and E. Scherder, "Eff ects of Music on Emotion Regulation: A Systematic Literature Review," in Proceedings of the 3rd International Conference on Music & Emotion (ICME3), Jyväskylä, Finland, June 11-15, 2013.

[9] J. Peksa and D. Mamchur, "State-of-the-Art on Brain-Computer Interface Technology," Sensors, vol. 23, no. 13, p. 6001, Jun. 2023. DOI: 10.3390/s23136001.

[10] D. Williams, V. J. Hodge, and C.-Y. Wu, "On the use of AI for generation of functional music to improve mental health," Frontiers in Artifi cial Intelligence, vol. 3, Article 497864, pp. 1–6, Nov. 2020. DOI: 10.3389/frai.2020.497864.

[11] T. H. Zhou, W. Liang, H. Liu, L. Wang, K. H. Ryu, and K. W. Nam, "EEG Emotion Recognition Applied to the Eff ect Analysis of Music on Emotion Changes in Psychological Healthcare," International Journal of Environmental Research and Public Health, vol. 20, Article 378, pp. 1–21, Dec. 2022. DOI: 10.3390/ijerph20010378.

[12] A. Kawala-Sterniuk, N. Browarska, A. F. Al-Bakri, M. Pelc, J. Zygarlicki, M. Sidikova, R. Martinek, and E. J. Gorzelanczyk, "Summary of over Fifty Years with Brain-Computer Interfaces—A Review," Brain Sciences, vol. 11, no. 1, p. 43, Jan. 2021. DOI: 10.3390/brainsci11010043.

[13] M. Sun, "Study on Antidepressant Emotion Regulation Based on Feedback Analysis of Music Therapy with Brain-Computer Interface," Computational and Mathematical Methods in Medicine, vol. 2022, Art. no. 7200678, Oct. 2022. DOI: 10.1155/2022/7200678.