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EMI for Therapeutic Gamification in Health care

Dr M Manoj Prabu[1], Ms Shanmugapriya Sridhar[2], Ms Shanmugavalli S[3], Mr Sharan B[4], Mr Sivagiri G[5]

Department of Biomedical Engineering, Sri Shakthi Institute of Engineering and Technology, Coimbatore.
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A B S T R A C T

Stroke recovery is very important for post-stroke treatment, which requires innovative solutions to effectively restore motor function. Our project is a unique way in this area by combining electromyography (EMG) sensors and synthetic machines to cross current treatment models. Using the Arduino Uno microcontroller and the Bio-Amp music control module, we will connect the biological and play areas and create a communication platform for rehabilitation. At the heart of our system is an EMG signal processor that translates simple complex tasks into action commands in a custom Pygame environment. Real-time feedback mechanisms allow users to tailor actions that meet individual recovery needs. By incorporating elements of gamification, our system promotes motivation and adherence to treatment regimens, creating a new and rewarding healing experience. The core of our innovation is the integration of hardware and software components. The Arduino Uno microcontroller acts as the nerve center that coordinates the EMG data flow and game logic. Meanwhile, the Bio-Amp classical music player acts as a watchman, taking care of the complex nature of muscles. Python programming emerges as a way to combine these elements to create a unified and beautiful user interface. Through extensive development and rigorous testing, we have demonstrated the efficacy and usability of our system, which presents a new approach to stroke care. By using EMG signals and synthesizing them together, we are breaking new ground in rehabilitation technology and promising advances in motor function rehabilitation and patient care. Our mission is not only to redefine the boundaries of current treatments, but also to pave the way for future innovations in integrative healing approaches using biofeedback systems.

Keywords: Electromyography, Therapeutic Gamification, Stroke Recovery, Arduino, Bio Amp Muscle Candy, Python programming.

1. Introduction

Stroke is a major public health problem worldwide, causing long-term disability and reduced quality of life for millions of people. Traditional anticonvulsant treatments often do not work and may not adequately address the diverse needs of stroke survivors. Therefore, there is a great need for new and effective rehabilitation methods that can increase motor function recovery and promote long-term independence. In recent years, there has been increased interest in changing stroke rehabilitation care using new technologies such as electromyographic(EMG)signals, Arduino microcontrollers, and gamification. These technologies offer a unique opportunity to create interactive and participatory recovery systems that can be tailored to the unique needs and abilities of individual stroke survivors. The incorporation of EMG signals into rehabilitation therapy holds particular promise. EMG signals reflect the electrical activity of muscles and can provide valuable information about remaining muscle function in stroke survivors. By capturing and analyzing EMG signals, rehabilitation interventions can be developed that target specific muscle groups and movements and promote better recovery of motor function. Additionally, integrating an Arduino microcontroller with a biofeedback sensor such as the Bio Amp Muscle Sensor Candy can create a highly responsive and adaptive rehabilitation system. These systems convert EMG signals into real-time feedback and control commands, allowing stroke survivors to actively participate in therapy in a virtual environment. Gamification adds another dimension to stroke recovery care. By incorporating game elements such as challenges, rewards, and progression, recovery can be made into an exciting and motivating experience. This integrated approach not only improves user engagement, but also promotes adherence to treatment regimens, ultimately leading to improved recovery outcomes.

In this context, the goal of our research is to develop a new EMG-controlled retrieval game using an Arduino Uno machine, a Bio-Amp module, and a Python program. This unique approach combines the latest technological advances with evidence-based rehabilitation principles to create a comprehensive and personalized rehabilitation platform for stroke survivors. Using the power of EMG signals, Arduino technology, and automation, our system provides an efficient solution to problems faced by stroke survivors and medical professionals in rehabilitation centers. Through rigorous testing and evaluation, we aim to demonstrate the effectiveness and efficiency of our unique recovery system and demonstrate its ability to improve motor performance and improve the quality of life.

2. Literature Review

Electromyographic Interface for Therapeutic Gamification in Healthcare In recent years, there has been a growing interest in the integration of electromyographic (EMG) technology with therapeutic gamification in healthcare. This approach has shown promise in enhancing rehabilitation outcomes, particu- larly in stroke rehabilitation and assistive technology control.Stroke rehabilitation is a crucial area where EMG-based ther- apy has been explored extensively. Faisal Amin etal,(2023) emphasized the significance of effective rehabilitation for stroke survivors, noting the potential of EMG-based interven- tions such as robot-aided therapy, virtual reality, and mirror therapy in improving motor control and functional recovery.M.A. van Haaften et al. (2024) explored how simplifying gaming simulations impacts their usefulness for learning and data collection. They found that while it’s crucial to maintain some realism, simplifying the simulations didn’t lessen their value as learning tools. By keeping things straightforward and truthful, simplified simulations can still effectively teach and collect data.Yang Zhou et al. (2023) addressed challenges in processing bioelectrical signals for controlling assistive robots. Their study demonstrated the effectiveness of machine learn- ing algorithms, particularly support vector machine (SVM), in processing EMG signals for motion pattern recognition and real-time control of upper limb exoskeletons. Ruvenaa, Nurul Hashimah Ahamed, et al. (2023) conducted a review on the use of mobile games in neurological rehabilitation. Analyzing 50 studies, they found that mobile games improve various aspects such as cognitive skills, handgrip strength, memory, and more. However, challenges include inconsistent study designs and small sample sizes. Future research should focus on long- term studies with larger samples, standardized protocols, and personalized game experiences based on patient feedback to enhance engagement and effectiveness. Additionally, Peter Smith, Calvin MacDonald, et al. (2023) evaluated the usability and effectiveness of a limb-different accessible video game controller using EMG sensors. Their findings highlighted the positive impact of gamification on rehabilitation outcomes, indicating improved user performance and satisfaction. Ethan Eddy et al. (2023) conducted a comprehensive review of EMG input systems, providing insights into interaction design, model design, system evaluation, and reproducibility. Their framework offers valuable guidance for designing effective EMG-based interfaces for healthcare applications. Finally, Lin et al. (2024) evaluated the usability and effectiveness of MyoGuide, a mobile training platform utilizing EMG technol- ogy for wrist extension training in subacute stroke patients. Their study showed positive results in terms of improving patient performance and satisfaction, while also highlighting challenges related to independent use of the interface.Their study showed positive results in terms of improving patient performance and satisfaction, while also highlighting chal- lenges related to independent use of the interface. Overall, these studies underscore the potential of EMG-based interfaces for therapeutic gamification in healthcare. However, further research is needed to address challenges related to interface usability, system reliability, and patient engagement to fully realize the benefits of EMG-based therapeutic gamification in healthcare

3. System Architecture

This flow chart illustrates a gamified rehabilitation system controlled by Electromyography (EMG) signals.The process starts with initializing Pygame, loading images, and setting up serial communication with an Arduino to read EMG data. Game objects are created, and the main game loop begins, continuously reading and processing EMG signals to detect muscle contractions. When a contraction is detected, the paddle's position in the game is updated. The system handles collision detection, updates the game state, renders the screen, and processes user input. The game loop repeats until an end condition is met, providing an engaging and therapeutic experience for users.

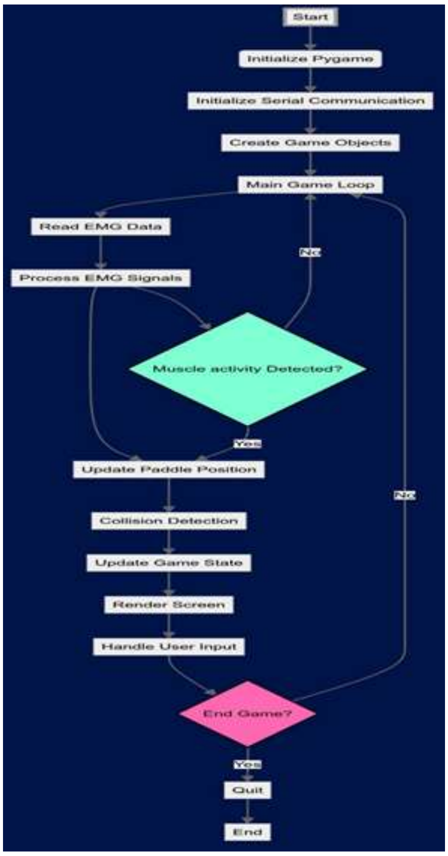

Figure:(1)-flowchart of electro myographic interface with gaming environment

4. System Design

Block Diagram

This block diagram shows a system where muscle signals control a game. The Bio-amp Muscle Candy Sensor detects muscle activity (EMG signals) and sends them to an Arduino Uno, which converts these analog signals into digital data. The PC's game engine processes this data along with traditional joystick and pedal inputs. The game software integrates all inputs, generating control signals for the game. The gaming environment then responds to these control signals, allowing real-time interaction based on the user's muscle activity and other inputs. This creates a seamless integration of muscle-based and traditional controls for gaming.

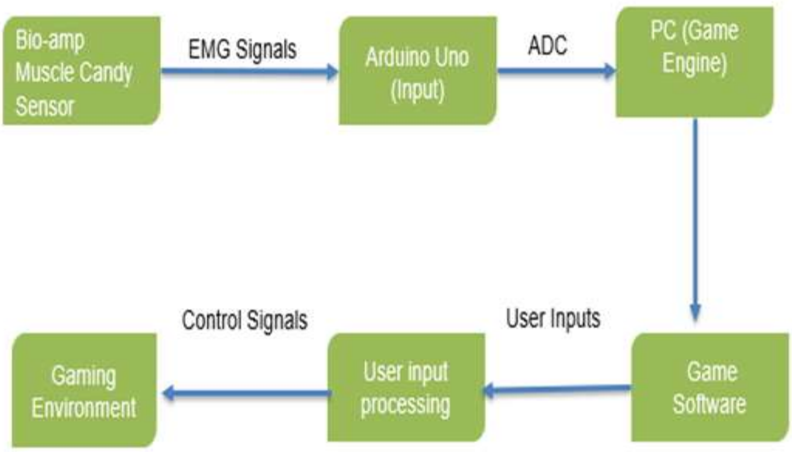

Figure:(2)-Block diagram

5. Circuit Diagram

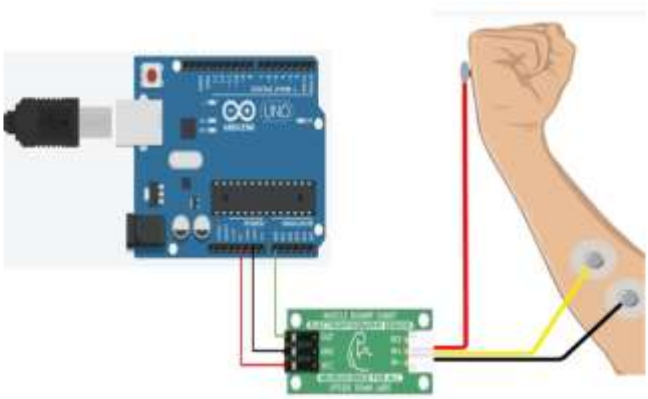

Figure:(3)-Circuit representation

6. Hardware Components

Arduino Uno: Arduino Uno serves as the microcontroller platform for signal processing and communication with the EMG sensor. Bio-amp Muscle Candy Sensor: The Bio-amp Muscle Candy sensor is chosen for electromyographic (EMG) signal acquisition. It detects and measures muscle activity, providing input for the game control system. These hardware components are selected for their compatibility, reliability, and suitability for EMG signal acquisition and processing. The Arduino Uno provides a versatile and accessible platform for interfacing with sensors and implementing signal processing algorithms. The Bio-amp Muscle Candy sensor offers high- quality EMG signal acquisition capabilities, enabling precise and accurate measurement of muscle activity for responsive gameplay control. Together, these components form the foundation of the hardware setup, facilitating the development of an effective and responsive game control system based on EMG signals.

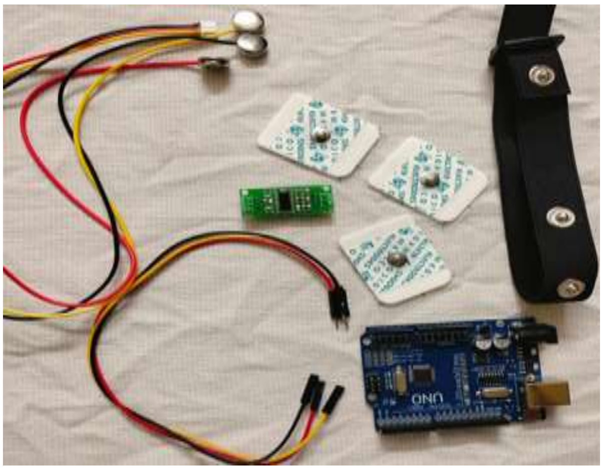

Figure:(4)-Components

7. Software Components

Programming Languages: Python is used to process EMG signals from the Bio-amp Muscle Candy sensor and create the rehabilitation game with Pygame. The process involves signal processing, game development, integration with hardware, testing, and documentation. Python's simplicity and powerful libraries make it ideal for these tasks, ensuring the game responds accurately to user input and provides an effective therapy tool for stroke rehabilitation.

Development Tools: In this project, Visual Studio Code (VS Code) is used as the primary development tool. VS Code provides a user-friendly interface for writing and editing code, with features like syntax highlighting and code completion. It supports extensions for Python, Arduino, and other development tasks, enhancing productivity. With built-in Git integration, developers can manage version control directly within the IDE. VS Code also offers debugging capabilities and an integrated terminal for running commands. Overall, VS Code simplifies the development process and improves workflow efficiency.

Game Development: Pygame is used for game development. Pygame is a Python library that simplifies the creation of 2D games. It handles graphics, user input, game logic, and audio, making it ideal for developing interactive games. With Pygame, developers can create visually appealing games with responsive controls and immersive gameplay experiences.

8. Methodology

In our project, ”Cosmic Paddle,” we harness muscle activity data using an Arduino Uno and the BioAmp Muscle Candy sensor to control a Pygame-based game. The BioAmp Muscle Candy sensor detects EMG signals from the user’s forearm muscles, which are then digitized by the Arduino Uno These digital signals are sent to a computer via serial communication. The game’s core mechanic involves controlling a paddle’s movement based on the EMG data. We implemented a background thread to continuously read and process the serial data from the Arduino. The game logic checks the processed EMG signal against a predefined threshold. If the signal exceeds this threshold, indicating a muscle contraction, the paddle moves to the right; otherwise, it moves to the left. The main game loop in Pygame updates the paddle position according to the EMG input, handles ball and bomb dynamics, checks for collisions, and renders the graphics. Additionally, we included on-screen buttons to pause and resume the game. This innovative approach leverages biofeedback to create an interactive gaming experience, demonstrating potential applications in both gaming and rehabilitation.

a) System Overview

The system is composed of two main components:

Game Application: The game application, ”Cosmic Paddle,” is developed using the Pygame library, a set of Python modules designed for writing video games. Pygame provides function- alities for handling graphics, sound, and user input, allowing for the creation of an interactive and visually engaging game. The game logic includes a paddle controlled by the player, balls that the player must intercept, and bombs that must be avoided. The paddle’s movement is dynamically controlled based on real-time input from the EMG sensor, creating a unique and immersive gaming experience.

EMG Sensor Setup: The EMG sensor setup involves the BioAmp Muscle Candy sensor connected to an Arduino Uno. This sensor detects electrical activity produced by skeletal muscles. The captured EMG signals are amplified and filtered to remove noise, then digitized by the Arduino. The Arduino processes these signals and sends them to the game application via serial communication8vels and translates these into control commands for the game. When the muscle activation exceeds a predefined threshold, it triggers the paddle to move in a specific direction. This setup leverages biofeedback to provide an intuitive and responsive game control mechanism.

b) Hardware setup

EMG Sensor Sensor Placement: The EMG sensor, specifi- cally the BioAmp Muscle Candy sensor, is strategically posi- tioned on the user’s forearm. This location is chosen because it is rich in muscle activity, providing a clear and strong signal for detecting electrical activity produced by muscle contractions. Proper placement ensures accurate measurement of muscle activation levels, which are crucial for controlling the game. Signal Processing Unit: An Arduino Uno board is employed to process the raw EMG signals captured by the sensor. The Arduino reads the analog signal from the sensor and performs initial processing to filter noise and enhance the signal. This involves amplifying the signal and applying filters to remove unwanted frequencies, ensuring that the data is clean and meaningful. The processed data, representing the muscle activity, is then converted into a digital format that the computer can interpret. Serial Communication: The processed EMG data is transmitted from the Arduino to the computer via a serial connection. This is typically achieved using a COM port with a baud rate of 9600, ensuring a reliable and real-time data transfer. The serial communication setup enables the continuous flow of EMG data to the game application, facilitating responsive and accurate control of the game dynamics based on muscle activity.

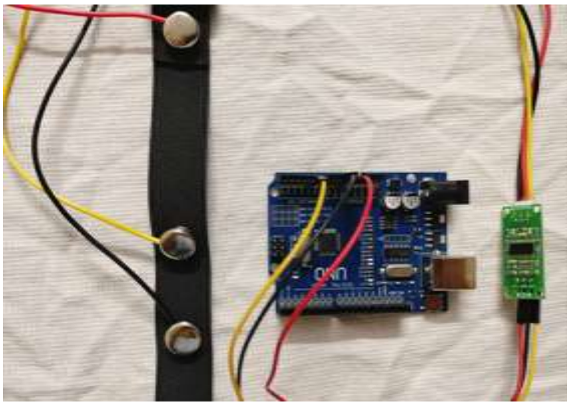

Figure:(5)-connections

System Requirements: The computer setup involves a standard PC equipped with Python and the necessary libraries for game development and serial communication. The key software components include: Python: The programming language used to develop the game application.

Pygame Library: A set of Python modules designed for writing video games. Pygame handles graphics rendering, user input, and sound, providing a robust framework for developing interactive games.

PySerial Library: Used for handling serial communication between the Arduino and the computer. This library allows the game application to receive real-time data from the EMG sensor.

c) Software developement

The software development process for the game applica- tion involved several key stages, each contributing to the creation of an interactive and responsive gaming experience.

Pygame Initialization: The development began with initializing the Pygame library, creating a window with dimensions 800x800 pixels. This provided the canvas for the game's graphics and user interface elements.

Variable Initialization: Crucial game variables such as paddle size, ball speed, and color schemes were defined. Additionally, images for the game's background, paddle, ball, and bomb were loaded and scaled appropriately to fit the game window.

Game Element Design

Paddle Class: Attributes: The Paddle class encapsulated attributes for the paddle's image, size, position, and movement speed. Methods: Methods were implemented to update the paddle's position based on input direction (left or right) and ensure that it remained within the screen bounds. Ball Class: Attributes: Similar to the Paddle class, the Ball class included attributes for the ball's image, size, position, and speed. Methods: Functionality was implemented to update the ball's position, detect collisions with the walls and paddle, and adjust its trajectory accordingly. Bomb Class: Attributes: This class defined attributes for the bomb's image, size, position, and falling speed. Methods: Methods were developed to update the bomb's position as it fell down the screen and remove it from the game if it reached the bottom.

Serial Data Integration Serial Communication Setup: The PySerial library facilitated communication between the Arduino and the game application, enabling the exchange of real-time data. Data Reading Thread: To prevent blocking the main game loop, a separate thread was implemented to continuously read EMG data from the serial port. This ensured that the game remained responsive even during data retrieval.

Signal Processing: The data received from the Arduino was decoded and parsed into signal and envelope values, representing muscle activity. Threshold Detection: The envelope value was compared against a predefined threshold to detect muscle contractions. If the envelope exceeded the threshold, indicating a muscle contraction, corresponding actions were triggered in the game.

User Interface Design Control Buttons: Interactive buttons for pausing and resuming the game were integrated using a custom Button class. These buttons provided user control over the game's state, enhancing the overall gaming experience. Game Loop: The main game loop orchestrated event processing, updated game elements based on user input and EMG data, and rendered the screen at a smooth frame rate of 60 frames per second.

This ensured fluid gameplay and responsiveness to user interactions.

Implementation :The implementation phase encompasses the setup of game elements, real-time data capture, user interaction processing, collision detection, and game state management.

Game Initialization Screen Setup: The Pygame display is initialized, providing the canvas for the game's visuals. Screen dimensions are set, and a caption is applied to the window.

Image Loading: Images for the game's background, paddle, ball, and bomb are loaded and appropriately scaled to fit within the game window.

Object Creation: Instances of the paddle, ball, and bomb classes are instantiated and initialized with their respective attributes, including positions and initial states.

Main Game Loop Event Handling: The game loop continuously processes user events, including quitting the game and clicking on interface buttons. These events are handled to ensure smooth gameplay. Paddle Movement: The position of the paddle is dynamically updated based on real-time EMG data captured by the serial reading thread.a This data indicates the direction of movement, allowing users to control the paddle using muscle contractions.

Collision Detection: Algorithms are implemented to detect collisions between the ball, paddle, and bombs. Upon collision, appropriate actions are taken, such as bouncing the ball off the paddle or removing a bomb from the game.

Screen Rendering: The game's elements, including the paddle, ball, and bombs, are drawn onto the screen during each iteration of the game loop. The display is updated to reflect any changes, ensuring a visually engaging and interactive gaming experience.

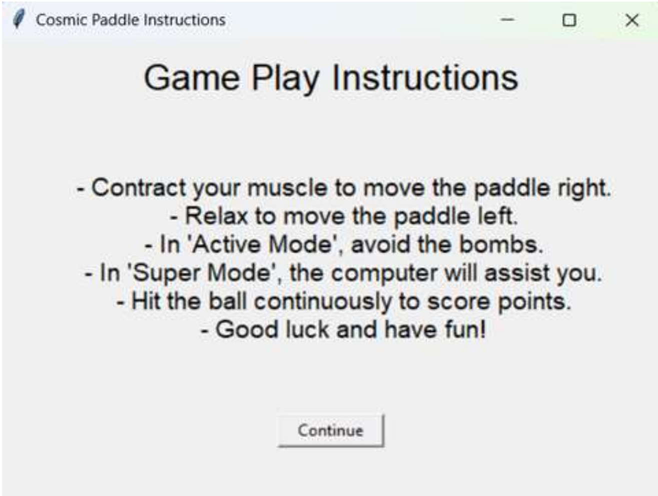

Figure:(6)-Gaming window

Figure:(7)-Instruction page

Figure:(8)-home page

9. Game Development and Integration

Developing a paddle game that responds to muscle contraction and relaxation involves creating an engaging gameplay experience while seamlessly integrating EMG-based control mechanisms.

Paddle Game Concept: The game revolves around a classic paddle-and-ball mechanic, where the player controls a paddle to bounce a ball and prevent it from falling off the screen.

Muscle Control Mechanism:

The paddle's movement is controlled by the user's muscle contraction and relaxation. contraction of specific muscle groups moves the paddle Rightward, while relaxation moves it leftward.

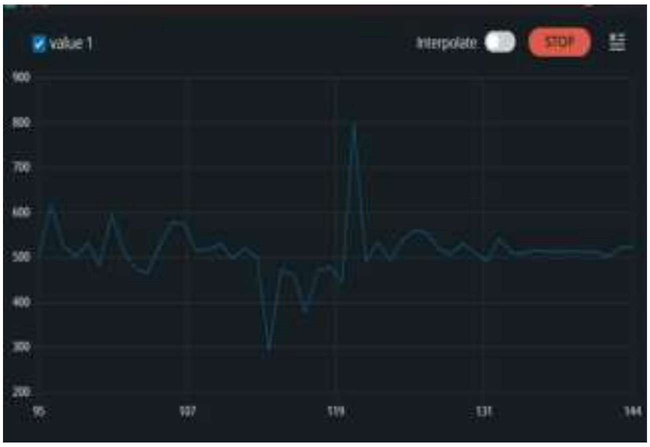

Figure:(9)-EMG wave form

Gameplay Dynamics: The game features dynamic paddle movement, responsive to real-time changes in muscle activity. Different muscle actions can be mapped to various paddle movements, offering a range of control options and gameplay strategies.

Game Development Environment Setup: Use a game development framework like Pygame to create the game environment. Design visually appealing graphics, including the paddle, ball, and background elements. Paddle Control Implementation: Implement functionality to capture and process real-time EMG signals using Python scripts. Map muscle contraction and relaxation levels to paddle movement speed and direction. Ensure smooth and responsive paddle control, with adjustments for sensitivity and calibration.

Gameplay Elements: Develop core gameplay mechanics such as ball physics, collision detection, and scoring mechanisms. Incorporate power-ups, obstacles, and level progression to enhance gameplay depth and replay ability.

Integration with EMG Control EMG Signal Processing: Utilize the preprocessed EMG signals generated by the hardware setup. Apply feature extraction techniques to interpret muscle activity levels and patterns. Mapping EMG Signals to Paddle Control: Establish mapping rules to translate EMG signal characteristics into paddle movements. Define thresholds for muscle activation and relaxation to initiate paddle motion.

Real-time Interaction: Integrate the EMG signal processing pipeline with the game's control system. Ensure real-time responsiveness and synchronization between muscle actions and paddle movements.

10. Result

The project successfully merged electromyography (EMG) signals with gaming mechanics, enabling users to control game elements through muscle contractions. This innovative approach fosters engaging rehabilitation exercises, enhancing motor skill development. The system's real-time feedback mechanism promotes user interaction and motivation. Future enhancements could include expanding game levels and incorporating additional sensors for precise muscle activity tracking. The output image demonstrates the system in action, showcasing the intuitive user interface and EMG-controlled paddle. Overall, the project underscores the potential of gamified biofeedback systems in revolutionizing rehabilitation therapy.

11. Conclusion

This project demonstrates the viability of integrating electromyography (EMG) signals with gaming mechanics to create an interactive rehabilitation tool. By enabling users to control game elements through muscle contractions, the system promotes engaging and effective therapeutic exercises, facilitating motor skill development. The real-time feedback mechanism enhances user interaction and motivation, underscoring the potential of gamified biofeedback systems in revolutionizing rehabilitation therapy. Further enhancements, such as expanding game levels and incorporating additional sensors for precise muscle activity tracking, could augment the system's effectiveness. Overall, the successful fusion of EMG technology with gaming illustrates a promising avenue for enhancing rehabilitation outcomes and improving the quality of care for individuals undergoing stroke rehabilitation.

12. Discussion

The social impact of gaming therapy in stroke rehabilitation extends beyond individual patient outcomes. By transforming rehabilitation into an enjoyable and interactive experience, gaming therapy can reduce the emotional and psychological burden associated with stroke recovery. The increased engagement and motivation observed in patients can lead to more consistent and prolonged therapy sessions, ultimately improving rehabilitation outcomes. Moreover, the accessibility and adaptability of gamified systems can cater to diverse patient needs, promoting inclusivity in stroke rehabilitation.

13. Future Scope

The successful integration of electromyography (EMG) signals with gaming mechanics offers promising prospects for future development. Potential areas for exploration include enhancing game mechanics, introducing multiplayer functionality for social interaction, implementing personalized rehabilitation programs using machine learning, integrating with virtual and augmented reality technologies, and establishing long-term monitoring and assessment systems. These advancements could revolutionize stroke rehabilitation therapy, providing tailored and engaging interventions to improve motor function and overall quality of life for patients. Continued research and innovation in EMG-based gaming hold the key to optimizing rehabilitation outcomes and advancing the field of motor rehabilitation.

Acknowledgements

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