BCI Usage for Virtual Body Control: New Goals and Potential Benefits

BCI (Brain Computer Interface) refers to the interpretation of brain signals and their transfer to computers. This field, still under active development, can be exemplified by prosthetic body control, understanding patients' mental states through brain analysis in psychiatry, and enabling physically impaired individuals to write and communicate. The brain is the central hub and source of all decisions, movements, and emotions of a person; therefore, decoding the brain can mean generating solutions at the deepest level. Such a level of technology and scientific development excites me greatly, as someone passionate about technology since the age of seven, aiming for a more technological world and supporting scientific progress. This technology, which has not yet become widespread and continues to attract investments from a limited number of large companies, holds the potential to open doors to various solutions and advantages. Another possibility in this field is the direct use of technology through thought power.

Examples: Advanced brain analysis developed by pioneering companies such as Neuralink enables physically impaired individuals to use computers, write, communicate, and control robotic arms in many projects. Development in VR (Virtual Reality) and AR (Augmented Reality) sectors; VR allows people to experience a more realistic virtual environment, while AR can be applied in everyday life at any moment.

Biosensors play a role in tracking the interaction between neurons in the brain, generating graphical representations of signal flows, and interpreting patterns. This allows us to monitor a person's movements or the signals that motor neurons hypothetically send to muscles. Movements such as walking or running can be interpreted using devices like EEG as follows:

Concepts and Basic Logic: Brain signals are recorded using EEG (Electroencephalography). Motor cortex activity shows movement patterns like walking or running in specific rhythms (mu: 8–12 Hz, beta: 13–30 Hz). However, EEG is noisy, and a single channel cannot fully determine a movement.

Example Channels: Region A: mu rhythm associated with walking (~10 Hz), Region B: beta rhythm (~30 Hz), Region C: unrelated activity, e.g., daydreaming or irrelevant signals.

Basic Logic: If A and B are active within specific ranges and C is low → the person is classified as "walking." This mapping is initially determined through calibration.

Calibration Process: Instruction and Data Collection: The user is given on-screen instructions: “Walk,” “Stop.” EEG signals are recorded from channels A, B, and C.

Threshold Determination: Average and tolerance ranges are calculated for each channel:

A_thresh = mean(A) ± Δ

B_thresh = mean(B) ± Δ

C_thresh = determined maximum value

Automatic Calibration Logic:

```
if A_thresh_min <= A_signal <= A_thresh_max and
   B_thresh_min <= B_signal <= B_thresh_max and
   C_signal <= C_thresh_max:
       movement = "walking"
else:
       movement = "unknown"
```

Repetition and Different Users: If the user changes or the session is different, calibration is repeated. The interface automatically updates new threshold values as the user follows on-screen instructions.

Results: If these outputs are directly applied to a mechanical arm or prosthesis, it becomes possible to send commands for various applications. For instance, in a VR environment, EEG inputs can directly control a character: when the walking function is active, the character walks; when the jump command is active, the character jumps. Using a VR headset provides the most accurate and reliable feedback.

This approach resolves initial issues such as equipment weight, fatigue, using a joystick for walking, and the need for cameras or sensor-based suits to achieve realistic movements. It allows the user to feel more immersed in their virtual self. This not only opens the way for a new realistic gaming sector but also enables a safe secondary space. In today’s world, where distance and spatial limitations exist, online meetings and interactions, or experiences that cannot be safely tested in real life, can be realistically experienced in this way. Of course, widespread adoption and development require continuous innovation and modification in the sector over time.

Future Perspective and Recommendations: Although BCI technology is still in development, its potential and innovative approach can revolutionize healthcare, education, gaming, and social interaction. The proliferation of this technology will not only enrich individual experiences but also significantly contribute to social interaction and accessibility. In the future, with more comprehensive calibration methods, multi-user support, and extended command sets, BCI systems can reflect human movements and decisions more naturally and intuitively in both virtual and physical worlds. In this context, further work, including prototype development and user-centered testing, can maximize the potential of BCI technology and lead to the creation of safer, more accessible, and effective applications.

Prepared by: Etka Kerem Allis

Date: 07.10.2025