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Operation of a virtual keyboard based on EMG Signals

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ABSTRAC

We demonstrate the operation of a virtual keyboard utilizing electromyography signals derived from finger movements. Initially, we identify human arm surfaces corresponding to specific finger motions, where EMG sensors are subsequently placed. The raw EMG signals obtained from our setup undergo filtration using a custom-made electric circuit. A LabVIEW program is employed to measure and manage these EMG signals. Following the conversion of analog signals to digital format, the data is inputted to an Arduino board, which then displays the corresponding letters from the virtual keyboard onto a computer monitor. The success of this demonstration is contingent upon a training session adhering to the established protocol.

Keyword: Virtual keyboard, EMG, Arduino

INTRODUCTION

Traditional keyboards have been an integral part of human-computer interaction for decades, serving as the primary input method for various computing devices. However, these conventional keyboards have limitations, particularly in terms of portability and convenience. In recent years, there has been growing interest in alternative input methods that offer enhanced mobility and accessibility. One promising approach is the utilization of electromyography (EMG) signals to operate virtual keyboards. EMG technology involves detecting electrical signals generated by muscle contractions, offering a non-invasive and intuitive means of interaction. By capturing EMG signals associated with specific hand movements, it becomes possible to control virtual keyboards without the need for physical keys. (Usakli & Gurkan, 2009)

This paper explores the concept of operating virtual keyboards based on EMG signals, aiming to provide a comprehensive understanding of the underlying principles and implementation strategies. Through a combination of sensor technology, signal processing techniques, and software integration, EMG-based virtual keyboards offer a novel and potentially transformative solution to traditional input methods. In this context, the following sections will delve into the theoretical foundations of EMG signal processing, the design considerations for virtual keyboard interfaces, and the practical implementation of EMG-based control systems. Additionally, potential applications and future directions for research in this field will be discussed, highlighting the significance of EMG-driven interaction paradigms in advancing human-computer interaction.

LITERATURE REVIEW

Electromyography (EMG) is a technology utilized to measure and record electrical signals produced by skeletal muscles. These signals are captured using an electromyography device, which detects the electrical potential generated when muscle cells are electrically activated or stimulated by nerves. Such signals serve various purposes, including the assessment of abnormal muscle activity and the analysis of biomechanics in human or animal behavior. In normal voluntary muscle contractions, the electrical discharge manifests as a complex action potential, characterized by a potential ranging from approximately 10 µV to 10 mV, a duration of 30 ms, and a broad frequency band spanning from 5 to 10,000 Hz. With an electromyography device meeting specific conditions for amplification and recording, both qualitative and quantitative analyses can be conducted. Figure

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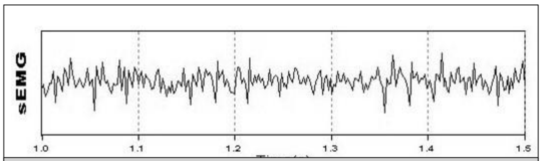
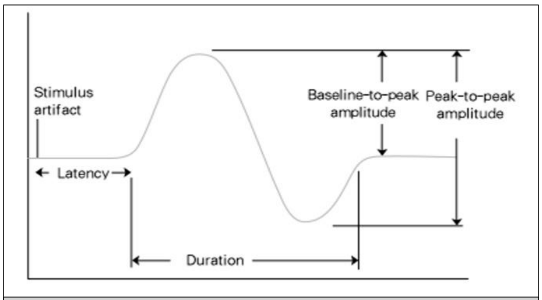
1 illustrates an example of measured EMG data, revealing a signal corresponding to finger motion alongside significant noise interference. Figure 2 presents a schematic diagram elucidating the EMG signal, facilitating the interpretation of finger movement-related parameters such as duration and signal amplitude. (Pourmohammadi & Maleki, 2020)



1. An example of EMG from finger movement

FIGURE 1



2. A typical EMG signal showing amplitude and duration from finger motion response

FIGURE 2

RESEARCH METHODS

Among the existing EMG sensor-based products, one such product is the MYO armband. This device primarily detects broad arm movements and coarse finger gestures, such as clenching or opening the hand. However, its functionality is limited to recognizing simple actions, like instructing a robotic arm to move forward or stop, or performing basic commands such as advancing a video playback. We aim to surpass the capabilities of existing products by employing multiple EMG sensors to recognize finer movements, such as the flexion and extension of individual fingers when typing on a keyboard, and translating those actions into corresponding keystrokes. The objective of this project is to develop a virtual keyboard system. By identifying the muscle groups responsible for the movement of each finger along the inner arm, EMG sensors will be strategically placed. Additionally, the system will include not only standard characters but also arrow keys, numbers, and special characters, mirroring a traditional qwerty keyboard layout. Hand movements for typing will be monitored using an acceleration sensor. This innovative approach eliminates the need for cumbersome physical keyboards, allowing users to type freely without spatial constraints, attaching the product only when needed. (Del Vecchio et al., 2020)

It also provides a solution for individuals with amputated hands who struggle to press keyboard buttons. Human muscles are categorized into voluntary and involuntary muscles. Involuntary muscles, like the heart, cannot be consciously controlled, while voluntary muscles, such as those in the arms and legs, can be moved consciously. The muscles responsible for finger movement fall under the category of voluntary muscles. Despite amputation, the muscles involved in finger flexion and extension remain in the arm, allowing patients to consciously contract or relax them. Even in the absence of fingers, individuals can still generate muscle movements consciously. When a patient with an amputated hand imagines finger movement and contracts the corresponding muscle, the muscle behaves as it did before the amputation, generating an EMG signal that can be detected. Thus, typing becomes feasible even without actual finger movement. (Phinyomark et al., 2020)

Initially, human anatomy is utilized to identify the appropriate placement of the EMG sensor. Subsequently, the EMG signal is detected via the attached sensor using the LabVIEW program and ELVIS equipment. The collected data is then analyzed using MATLAB, with a focus on determining the necessity of notch filter design. The analog signal of the EMG is inputted to the Arduino Leonardo board for digital output. This digital output is linked to the computer to execute keyboard input actions. Figure 3 presents a diagram outlining the operational process of the EMG-based virtual keyboard system.EGO-Swarm encompasses various parameters for generating a smooth path, including the maximum speed and maximum acceleration of the drone. The optimal values for these parameters fluctuate based on the drone's immediate surroundings where the current path is being generated. However, the current EGO-Swarm implementation maintains the initial settings for maximum speed and maximum acceleration without adapting to changes in the

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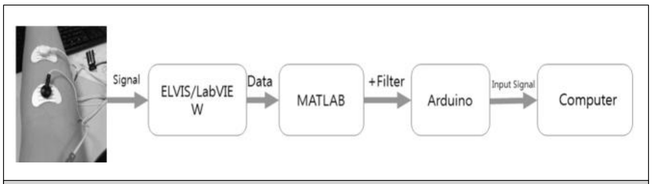
real-time environment. (Lu et al., 2020)

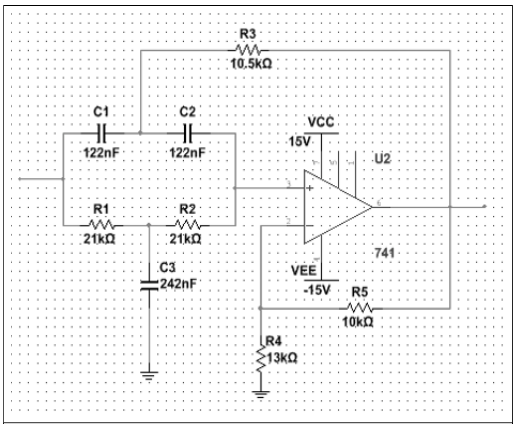


3. Schematic of the virtual keyboard operation procedures

Figure 3

We examined the specialized Arduino filter module provided with the EMG sensor, made adjustments to it, and implemented it accordingly. This filter module comprises a low-pass filter, instrumentation amplifier, 1-pole high-pass filter, and regulator. The low-pass filter is employed to eliminate high-frequency noise. (Mukhopadhyay & Samui, 2020)

Subsequently, we observed a baseline flow phenomenon characterized by slow fluctuations in the waveform's baseline. Due to its low-frequency nature, this baseline flow can be effectively mitigated using a high-pass filter. The instrumentation amplifier proved valuable for its ability to effectively eliminate common noise. However, it was noted that the waveform remained somewhat distorted and contained vibrations attributable to power interference. Such power-related interference is a prevalent issue in biological signal measurements and necessitates mitigation for accurate diagnostics. Given that the interference stems from power frequency or its integer multiples, a notch filter was introduced to attenuate the frequency component within a narrow band around a specific frequency, thereby suppressing the interference signal. As the EMG signal encompasses components ranging from 5Hz to 500Hz, a notch filter with a high Q value (2.17) was designed to preserve components at other frequencies as much as possible. As illustrated in Figure 4, a Schallen-Key second-order notch filter was employed for this purpose. (Li et al., 2023)



4. Details of the notch filter used to cut off known noises

Figure 4

Following the implementation of the notch filter, we conducted signal analysis using Fast Fourier Transform (FFT) to identify the segment of the EMG sensor signal exhibiting the most significant noise. Prior to applying the notch filter, the segment with the most prominent noise corresponded to power interference (0Hz). However, post-application of the power removal notch filter, the power interference noise was notably diminished, indicating its successful mitigation. This observation confirms the effective elimination of signals aligned with the power frequency.

As the EMG sensor was exclusively applied to the four fingers of the right hand, the functionality is limited to utilizing only the 13 keyboard buttons depicted in Figure 5 (u, i, o, p, j, k, l, ;, n, m, ,,

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., <space>). However, there exists a constraint wherein double consonants and capital letters cannot be accommodated. Nevertheless, by attaching sensors to both hands, an additional feature can be integrated to recognize the clenched-fist gesture of the opposite hand, possibly utilizing the Shift key. Mode transition is achievable by altering the angle of the arm. (Clarke et al., 2020)

5. Eleven keyboard letters used in the operation

Figure 5

6. Overall virtual keyboard system mounted on human arm

Figure 6

RESULTS AND DISCUSSION

Any slight adjustment in the placement of the EMG sensor resulted in ground movement or signal distortion. Moreover, repeated movement of the same finger led to muscle fatigue and a subsequent decrease in signal amplitude. Muscle signals varied depending on the subject's physical condition. Although power noise was mitigated, other noise sources remained unresolved. Nevertheless, the EMG sensor proved beneficial in assessing muscle activity levels by capturing surface signals. While direct customization for individual characteristics was unattainable, leveraging a thorough understanding of each user's muscle distribution could greatly enhance the efficacy of a portable keyboard interface device. Further research is warranted in the following areas. (Toledo-Perez et al., 2020)

The first issue concerns a reduction in signal amplitude attributed to muscle fatigue. Muscle stimulation prompts ions in the body to separate and subsequently return to their initial state, a process that takes time. However, repetitive muscle contractions and relaxations lead to a decline in the output size of the EMG signal. To address this challenge, the signal's amplitude change per unit sampling was averaged to minimize fluctuations and retain only relevant signals.

The second issue involves the influence of elbow movements on the signals transmitted to finger muscles. Finger movements are deciphered through muscles in the arm located between the elbow and wrist. Nonetheless, the muscles responsible for elbow flexion and extension are also connected to the arm, affecting the finger muscles via the wrist connection. (Rodr\'\iguez-Tapia et al., 2020)

When finger muscles are engaged, the signal is minimal, whereas arm movement generates a larger EMG signal, detected by multiple EMG sensors affixed to the arm. Although arm movement has been substituted with an acceleration sensor, further consideration and effort are required to filter out the significant signal originating from the arm. The third concern pertains to the impact of minor variations in the placement of the EMG sensor. (Wayahdi et al., 2021)

Similar to a person's fingerprint, face, and voice, the muscle distribution also exhibits subtle variations. While the muscles associated with each finger align with musculoskeletal science to some extent, differences exist. Consequently, even minor shifts in attachment locations can result in either stable or unstable grounding. Furthermore, numerous muscles converge at the wrist, facilitating signal capture, yet slight alterations in attachment positions can alter the shape and magnitude of the signal. Hence, maintaining consistency by marking attachment locations during

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each experiment was crucial. To ensure clear and reliable operation, an algorithm capable of discerning analog signals must be implemented. (Farago et al., 2022)

CONCLUSION

This paper reports the design, production, and implementation process of an EMG-based virtual keyboard generated by finger movement. Although the implementation of basic movements was successful, realistic problems related to EMG signals were also identified. If this is secured, it is expected that it will be able to play a certain role as a device for human-machine communication in virtual reality or virtual-based systems.

In operating a virtual keyboard based on EMG signals, this technology offers significant potential in enhancing accessibility for individuals with motor impairments, such as those who have lost the ability to directly press keyboard keys. By harnessing EMG signals from muscles around the arm, users can control the virtual keyboard without the need for direct physical finger movements. This research has demonstrated that using EMG technology, albeit with some technical limitations, still enables the creation of an effective and comfortable typing experience. However, there are still some technical challenges to overcome, such as muscle fatigue and signal interference from unwanted arm movements. With a better understanding of each individual's muscle distribution and the development of more sophisticated algorithms, it can be expected that this technology will become more reliable and user-friendly in the future. In conclusion, operating a virtual keyboard based on EMG signals promises significant advancements in the field of technology accessibility, which can improve the quality of life for individuals with diverse special needs.

REFERENCE

Clarke, A. K., Atashzar, S. F., Del Vecchio, A., Barsakcioglu, D., Muceli, S., Bentley, P., Urh, F., Holobar, A., & Farina, D. (2020). Deep learning for robust decomposition of high-density surface EMG signals. *IEEE Transactions on Biomedical Engineering*, *68*(2), 526–534.

Del Vecchio, A., Holobar, A., Falla, D., Felici, F., Enoka, R. M., & Farina, D. (2020). Tutorial: Analysis of motor unit discharge characteristics from high-density surface EMG signals. *Journal of Electromyography and Kinesiology*, *53*, 102426.

Farago, E., MacIsaac, D., Suk, M., & Chan, A. D. C. (2022). A review of techniques for surface electromyography signal quality analysis. *IEEE Reviews in Biomedical Engineering*, *16*, 472–486.

Li, G., Bai, D., Jiang, G., Jiang, D., Yun, J., Yang, Z., & Sun, Y. (2023). Continuous dynamic gesture recognition using surface EMG signals based on blockchain-enabled internet of medical things. *Information Sciences*, *646*, 119409.

Lu, L., Mao, J., Wang, W., Ding, G., & Zhang, Z. (2020). A study of personal recognition method based on EMG signal. *IEEE Transactions on Biomedical Circuits and Systems*, *14*(4), 681–691.

Mukhopadhyay, A. K., & Samui, S. (2020). An experimental study on upper limb position invariant EMG signal classification based on deep neural network. *Biomedical Signal Processing and Control*, *55*, 101669.

Phinyomark, A., Campbell, E., & Scheme, E. (2020). Surface electromyography (EMG) signal processing, classification, and practical considerations. *Biomedical Signal Processing: Advances in Theory, Algorithms and Applications*, 3–29.

Pourmohammadi, S., & Maleki, A. (2020). Stress detection using ECG and EMG signals: A comprehensive study. *Computer Methods and Programs in Biomedicine*, *193*, 105482.

Rodr\'\iguez-Tapia, B., Soto, I., Mart\'\inez, D. M., & Arballo, N. C. (2020). Myoelectric interfaces and related applications: current state of EMG signal processing--a systematic review. *IEEE Access*, *8*, 7792–7805.

Toledo-Perez, D. C., Rodriguez-Resendiz, J., & Gomez-Loenzo, R. A. (2020). A study of

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e-ISSN : 2797-3298
p-ISSN : 2089-9424

computing zero crossing methods and an improved proposal for EMG signals. *IEEE Access*, *8*, 8783–8790.

Usakli, A. B., & Gurkan, S. (2009). Design of a novel efficient human--computer interface: An electrooculagram based virtual keyboard. *IEEE Transactions on Instrumentation and Measurement*, *59*(8), 2099–2108.

Wayahdi, M. R., Ginting, S. H. N., & Syahputra, D. (2021). Greedy, A-Star, and Dijkstra's Algorithms in Finding Shortest Path. *International Journal of Advances in Data and Information Systems*, *2*(1), 45–52. https://doi.org/10.25008/ijadis.v2i1.1206

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