

# A Study on the Effectiveness of Interactive Systems Using Electromyography

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**Abstract**—The paper presented an intuitive control system using electromyography (EMG) data that is obtained from the Myo gesture control armband. The aim of this study is to enable users to control multiple devices with a single EMG device in an intuitive way. The presented system shows the ability of EMG-based gestures to control Phillips Hue that allow user to control light bulb by simple hand movements. Moreover, the authors also developed new functionalities, which is according to users' preferences, to register gestures. These functions aim to improve the usability and enhance the naturalness of operations. Additionally, unique gestures, which less common in everyday life, is defined to reduce misrecognition when switching between different devices. Furthermore, to achieve reliable and accurate recognition of multiple gestures, the Support Vector Machine (SVM) models is considered to be a machine learning method for training processed EMG data. The experiment results demonstrate significant improvements in user experience and practical applicability in various interactive scenarios.

**Keywords**—Human Interface; Machine Learning; Human Factors and Human-in-the-Loop

## I. INTRODUCTION

In recent years, rapid advancements in computer technology have led to the widespread integration of various devices such as desktops, laptops, and smartphones into everyday life. These devices are typically operated using physical input devices like keyboard, mouse, and touch panel. With the increase of virtual reality (VR) and augmented reality (AR), the device controller based on intuitive human movements became popular. However, in situations where the risk of infection needs to be avoided, or where external cameras are impractical, new methods of device interaction are needed. Against this background, electromyogram (EMG)

measurement devices are attracting attention. Against this background, electromyography (EMG) measurement devices limited to single-person use have attracted attention. The use of biological information control equipment such as EMG signals has the advantage of intuitive operation and does not require external sensors. In addition, the availability of easily collected physiological data, such as electrocardiograms and pulse waves, expands the possibilities for device controllers to use this information. Research and applications using EMG as user interfaces for computers and devices have garnered interest in areas such as prosthetic control [1], gesture recognition [2], biofeedback [3] and assistive technology for people with disabilities [4]. These studies and applications open up new possibilities in the field of user interfaces and improve the quality of life for individuals with physical disabilities. Although there are benefits to using EMG for device controller, naturalness of movement is a major concern and challenge. If device control using EMG is not seamlessly integrated with natural movement, users may find control operations challenging and may experience increased fatigue due to unnatural movements.

Numerous studies have investigated different gesture recognition techniques using different sensors and machine learning algorithms. Traditional methods often rely on accelerometers and gyroscopes, but EMG can measure muscle activity more directly, allowing for more correct and sensitive gesture recognition. Recent progress has focused on improving the accuracy and robustness of gesture recognition systems through the use of machine learning algorithms such as Support Vector Machines (SVM), Neural Networks, and Random Forests. SVM has been widely adopted due to its effectiveness in processing high-dimensional data and its ability to create complex decision boundaries, making it suitable for distinguishing various gesture patterns based on EMG signals.

Several studies have explored advanced techniques for EMG-based gesture recognition. For example, the study of Chen et al. [5] "Gesture recognition by instantaneous surface EMG images" published in Scientific Reports, proposed a method to use instantaneous surface EMG images for gesture recognition. The method focuses on converting the EMG signal into an image-like representation, which allows for more accurate and robust gesture classification using image processing techniques. Furthermore, in the study "A novel EMG-based hand

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gesture recognition framework based on multivariate variational mode decomposition," Yang et al. [6] developed a framework that utilizes multivariate variational mode decomposition (MVMD) to decompose EMG signals into different modes. This approach improves the extraction of relevant features and increases recognition accuracy. These studies highlight the potential of advanced signal processing techniques and machine learning models, such as SVM, to improve the accuracy and reliability of EMG-based gesture recognition systems.

In modern society, where electronic devices, computers, and smartphones have become indispensable in our lives, innovations in operating methods have the potential to have a significant impact on our daily lives. This article focuses on the operation method using EMG measurement device, clarify its advantages and challenges, and discusses the prospects for novel equipment operation methods.

## II. PROPOSED SYSTEM

This system is intended to implement the operation of a lighting device using an EMG measuring device., estimate gestures from the EMG signals, and make it possible to control lighting device intuitively. The overall system architecture is illustrated in Fig. 1.

### A. EMG Device and Data Collection

The Myo Armband was used for EMG data collection. The Myo Armband is a wearable device that collects EMG signals, which represent the electrical activity of muscles, and transmits this information to a computer system. The device is equipped with eight skin-contact EMG sensors that can be worn on the user's forearm, and directly capture the electrical activity of muscles upon contact. Each sensor corresponds to a specific muscle and records the contraction patterns. The collected EMG data is

processed internally and converted into digital signals. These digital signals are transmitted via Bluetooth to communicate with the computer system. Additionally, the Myo Armband has a built-in gesture recognition algorithm that can identify specific muscle contraction patterns as gestures.

### B. Lighting Device Control

The Philips Hue lighting system was used as a lighting device based on recognized gestures from the EMG device. Philips Hue is a lighting system that is connected via LAN to a lighting management bridge and can be controlled directly from the operating device via the bridge. It is allowed to control the lights on/off, adjust the brightness, or change the color tone. The specific gestures and corresponding actions of Philips Hue are as follows:

- Make a fist gesture to turn on Philips Hue lighting.
- Perform a double-tap gesture with the thumb and index finger to turn off Philips Hue lighting.
- Performing a gesture of bending the arm inward, Philips Hue adds 2000 to the current color number and changes the lighting color.
- Performing a gesture of bending the arm outward, Philips Hue subtracts 2000 from the current color number and change the color of the light.

These gestures enable users to turn Philips Hue lights on/off, adjust the brightness, and change the color of the lights.

### C. User Interface

In order to provide visual feedback to the user, a web-based interactive user interface was designed. This interface displays the current state of the light and reflects real-time actions performed by the user through gestures.

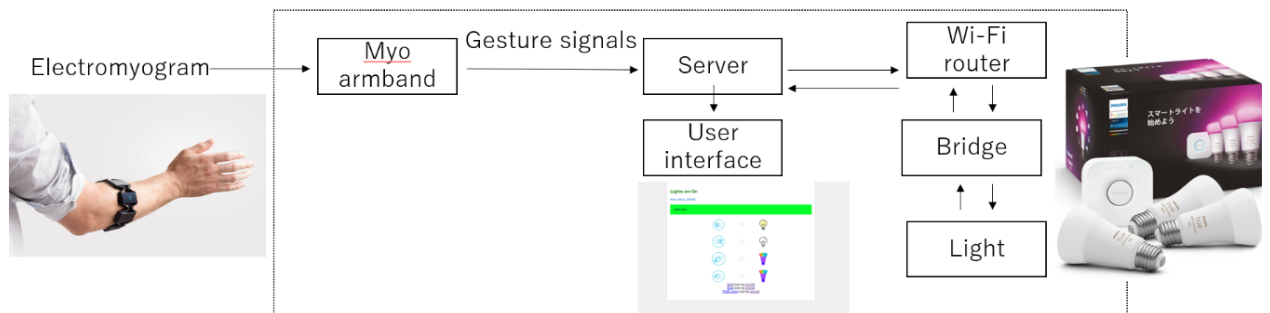


Fig. 1. System architecture

### III. EVALUATION OF OPERATION

#### A. System Evaluation

In this study, considering the efficient interaction design and evaluation of structured user interfaces [7], four elements for evaluating intuitive and interactive systems are set, as shown in TABLE I. These elements were established to facilitate the evaluation of the system.

The system was evaluated by three male adults who were unfamiliar with using the Myo armband. Participants were asked to operate the system without a time limit, performing all gestures without restrictions on the number of repetitions. During this evaluation, participants provided feedback on their experience with the system, and their ratings were used to assess the system's performance in relation to the four evaluation elements. The experimental setup is shown in Fig. 2. The average evaluation results for each element, based on the ratings from all three participants, are presented in Fig. 3.

#### B. Experiment Results and Discussion

According to the evaluation results shown in Fig. 3, the system received a high evaluation in prompting and reducing physical burden. However, there is still room for improvement in its mental models and operational feedback. Possible reasons of these results include errors in the EMG signal measurement process, such as the transmission of unexpected EMG messages and calibration accuracy. Participants who operated the system commented that the system has the potential to be applied to devices other than lighting. For devices that are operated frequently, such as lights and doors, the accuracy of the system operation should be prioritized while allowing for a lag from input to output. Due to the property of EMG, reducing the unintended movements that occur within the system is a significant challenge. By utilizing EMG as a new method of operating devices, there are benefits such as the ability to perform operations in parallel with other tasks and operate devices in any environment without requiring specific body movements. Furthermore, since the system is intuitive to operate, it is not dependent on a specific language, and has the potential to be effective in various countries and regions.

TABLE I: EVALUATION ELEMENTS OF INTUITIVE AND INTERACTIVE SYSTEM

Elements	Description
Clue	Provide information about what the user should do next
Mental Model	Enable predictability of operations by presenting consistent concepts
Reducing Physical Strain	Ensure avoidance of unnatural postures and excessive operational force
Operational Feedback	Ensure a reliable response from the system



Fig. 2. The experiment scene

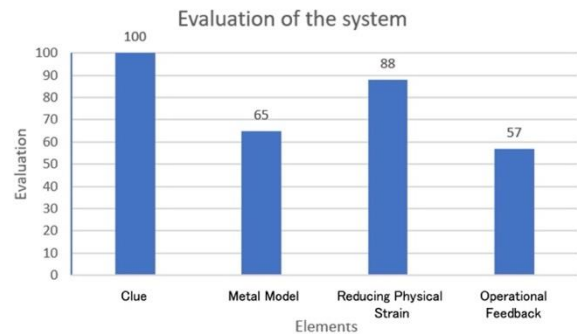


Fig. 3. The evaluation result of the system

### IV. GESTURE ENHANCEMENTS

To evaluate the benefits of using EMG, an intuitive and interactive system using the Myo gesture-controlled armband was developed. The experimental results revealed significant benefits and room for improvement. An important finding was that the user experience of the system was negatively affected because the operation feedback was rated lower than expected. To address this issue, improving the responsiveness and accuracy of the system to ensure smoother interactions has become the focus of this research. One key improvement is the introduction of additional gestures to control devices, such as Philips Hue lights. Allowing users to register their preferred gestures is expected to enhance the naturalness of operations and improve usability. This system relies on the existing gesture recognition of the Myo armband, which detects movements like wrist bending and hand opening/closing. By enabling control through finger movements alone, it is expected to create a system that takes physical limitations and strain into account.

Gesture recognition has been a focus of research for many years, and various methods have been explored to improve accuracy and user experience. Considering the nature of electromyography (EMG) data, which involves multi-channel and high-dimensional time-series data, there are solid reasons for choosing Support Vector Machines (SVM) as a classification method. SVM is particularly suited for processing high-dimensional data, allowing for the creation of complex decision boundaries, making it ideal for distinguishing between different gesture patterns based on EMG signals.

As a preliminary step to improving the system, an experiment was conducted to extend the gesture recognition capabilities of the Myo armband. Although the Myo armband was originally designed to recognize up to five gestures, its recognition capabilities were successfully extended to five different gestures using a Support Vector Machine (SVM) approach, focusing on controlling the system using only finger movements while considering physical constraints and load. The training data used consisted of EMG data collected at 200 frames per second, which was converted into features. The features adopted were maximum value, absolute mean, variance, and kurtosis. Training was performed with 2400 feature vectors per gesture. An RBF kernel was used, with hyperparameters set to cost: 100 and gamma: 0.001. This extension has shown the potential to further improve the system's responsiveness and accuracy. The validation results are shown in TABLE II.

Based on the results of the preliminary study, a broader range of gesture recognition was successfully achieved using the Myo armband. Specifically, the system was improved to accommodate a wider range of gestures by training a Support Vector Machine (SVM) model using 32-dimensional feature vectors derived from 8-channel EMG data from the Myo armband. This approach enables reliable recognition of multiple gestures, thereby broadening the applicability of the system in various interactive environments.

TABLE II: GESTURE ACCURACY

Gesture	Accuracy
Overall	98.53%
Index Finger Raised	98.19%
Middle Finger Raised	96.39%
Pinkey Finger Raised	99.58%
Thumbs Up	99.44%
Rest	99.03%

Furthermore, one of the key challenges identified with the previous system was latency in gesture recognition, which resulted in delayed interactions that negatively

impacted the user experience. The gesture prediction time for this system, as predicted by the SVM, is approximately 0.001 seconds. The system's latency depends on the number of frames required to convert the muscle EMG data features into feature vectors. By leveraging SVM, processing speed was optimized, allowing the system to respond to user input quickly and accurately, reducing the sense of lag and making overall interactions more natural.

The proposed system was tested with an expanded set of gestures, demonstrating its potential to effectively handle a more complex range of inputs. The improved gesture recognition not only enhances the versatility of the system but also contributes to a more seamless and intuitive user experience. Furthermore, the system can be controlled using finger movements alone while taking physical constraints and load into account, which represents a significant improvement over previous iterations.

## V. CONCLUSION

The aim of this study is to explore the effectiveness of EMG in enhancing interactive systems. An intuitive system was developed using the Myo gesture control armband to demonstrate its potential. Through experimental evaluation, the system showed notable advantages in user interaction, but several areas in need of further improvement were identified. Specifically, the need for enhanced operational feedback was identified, leading to recommendations for additional gestures and features that would allow users to customize gestures to their preferences. It is expected that these enhancements will increase the naturalness and usability of the system. Furthermore, defining new and less common gestures can minimize false recognitions, especially during device switching scenarios, ultimately reducing system malfunctions and enriching the overall user experience.

As future work, it is to explore the integration of machine learning techniques beyond SVM to further optimize the performance of the system in real-time applications. The goal is to study the system's adaptability to different user muscle signal patterns, which will enhance its robustness and reliability across different user groups.

In addition, this system is expanded for people with physical disabilities who need rehabilitation, and the scope of daily equipment operation is expanded. This study demonstrates the ability to increase older adults' motivation for recovery and improve their quality of life. Moreover, this system is also expected to analyze cultural body movements, such as those in dining scenes. Considering the different ways of people eating their meals, this system is possible to provide different solutions across different countries. By setting these goals, the research aims to identify social impacts and highlight practical applications.

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