第 28 回日本バーチャルリアリティ学会大会論文集（2023 年 9 月）

Enhancing Social and Physical Interaction of an ALS Patient using extra robotic arms controlled by BMI

周 嵩晨 1), 安藤 良一 1), 川口 碧 1), Mark Armstrong1),
Giulia Barbareschi 1), 荻野 幹人 2), 武藤 将胤 3), 南澤 孝太 1)
Zhou Songchen, Ryoichi Ando, Midori Kawaguchi, Mark Armstrong, Giulia Barbareschi, Mikito Ogino, Masatane Muto, Kouta Minamizawa

1) 慶應義塾大学大学院メディアデザイン研究科
（〒 223-8526 横浜市港北区日吉 4-1-1，zhousongchen，kouta@kmd.keio.ac.jp）
2) 株式会社電通サイエンスジャム
3) 一般社団法人 WITH ALS

概要: Patients with ALS have difficulty expressing themselves through body language, which is the main means of communication during social participation. In this study, we have developed a human augmentation technology for ALS patients to control alternative arms using BMI and a touch sensor to have social interaction with others.
キーワード： Human Augmentation, Disability, Art& Entertainment, Communication

1. Introduction

Communication, both verbal and nonverbal, is crucial for human interaction. However, individuals with Amyotrophic Lateral Sclerosis (ALS) progressively lose their ability to speak and control their body movements[1], greatly affecting their communication abilities. Steven [2] has shown that communication plays a critical role in improving the mental health of ALS patients.

Brain-Machine Interface (BMI) has emerged as an essential communication tool for these individuals, especially when ALS progresses to a state known as total locked-in syndrome (TLS). Notably, many ALS patients hope for BMI to aid in communication and emergency alerting[3].

Several studies[4][5][6] have utilized BMI technology to enhance the communication abilities and control over robotic arms and wheelchairs of ALS patients. However, there is a research gap in addressing the crucial role of body language in communication, highlighted by the 7%-38%-55% rule[7].

In our research, we devised an innovative robotic avatar control system combining BMI and touch sensor to command the movements of a robotic arm, enabling communication through body language for ALS patients. This system offers a viable solution, particularly for patients in the early to mid-stages of ALS, where some degree of finger movement control is still retained.

The integration of touch sensors to initiate mechanical arm movements addresses the issue of the non-real-time nature of BMI signals and the inherent latency in obtaining these signals. This latency presents a challenge for users in accurately timing the robotic arm's actions. Hence, our system emulates the natural progression of human movement, from the brain's conception of action to the neural signals controlling muscle contractions to execute it. In this model, the BMI simulates the brain conceiving an action, while the touch sensors mimic the neural signals triggering muscle contractions to initiate movements.

This design not only enhances the users' sense of agency but also allows more precise control over the mechanical arm's actions. As the disease progresses, the system is capable of adapting to changing needs, transitioning to full BMI control. Thus, our research aims to elevate the quality of life for ALS patients through this novel communication method.

2. Methods

This section describes the overall structure and operational workflow of the system.

2.1 Movements Design

Movements Recording:

Method 1: By recording the trajectory of the top position of the robotic arm and using the humanoid arm

Inverse Kinematics (IK), the entire arm trajectory can be deduced through reverse inference.

Method 2: By utilizing the animation system, the positions and rotation data of the seven joints of the robotic arm are recorded to capture the arm's motion trajectory.

Considering the difficulty of accurately capturing the arm's motion trajectory using IK and ensuring user safety, we adopt the second method.

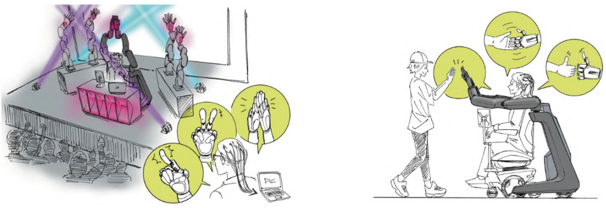

Fig.1: Illustrations of Performance and Daily Life Movements

In this project, taking into account the ALS patient's profession as a DJ, in order to enhance his social interaction, the designed actions include performance gestures such as waving, clapping, and DJ movements. Additionally, everyday actions like handshaking, taking photos gestures, and greeting gestures are also included. (Fig. 1 shows)

2.2 System Components

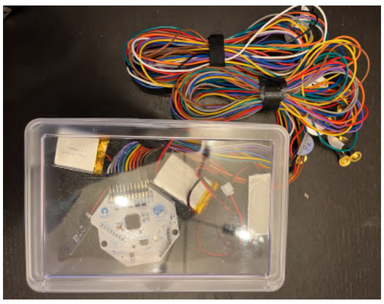

Fig.2: BMI Device

The system utilizes an OpenBCI BMI device (Fig.2 shows), programmed by Dentsu ScienceJam Inc., to enable user to perceive sounds from the left, center, and right directions. During the sound presentation, the user focuses on the left half of the body, the center, and the right half of the body, respectively. The BMI device then outputs signals of 1, 2, and 3, corresponding to the left, center, and right directions.

The system employs the Fusion 4 robotic arm (Fig.3 shows) from avatarin Company, which can be controlled using the Unity animation system. In this project, we utilize Touch Designer to send commands and switch animations in Unity, thereby controlling the robotic arm.

Additionally, the system incorporates the Blackberry Hands robotic arm (Fig.4 shows), which can be connected

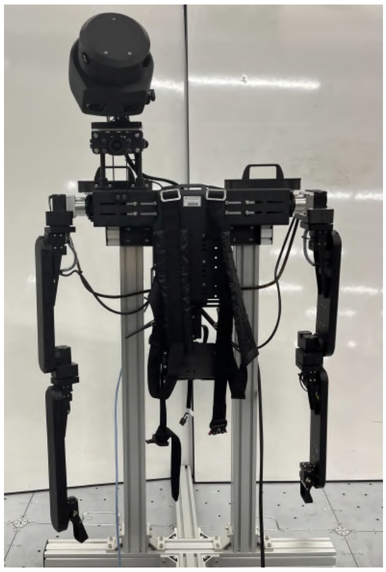

Fig.3: Fusion 4 Robot Arm

Fig.4: Hackberry Robot Hand

to Fusion 4 and controlled using the pins on Fusion 4. In this project, we use Touch Designer to send commands to Unity, and Unity scripts relay the information to the pins of Fusion 4, thereby controlling the hand movements.

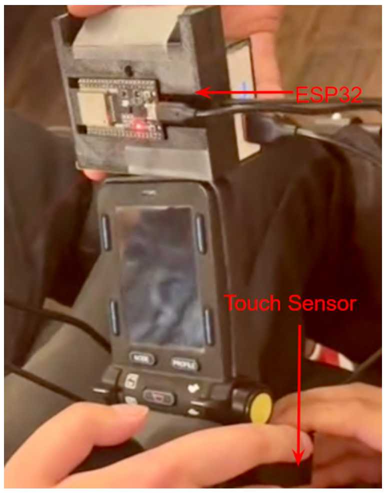

Fig.5: Touch Sensor

To detect touch, an ESP32 Arduino board and a touch sensor are used as a touch system (Fig.5 shows), and it sends information to Touch Designer through the OSC signal. When the user's finger leaves the touch sensor, it triggers the movement of the robotic arm.

2.3 Usage Workflow

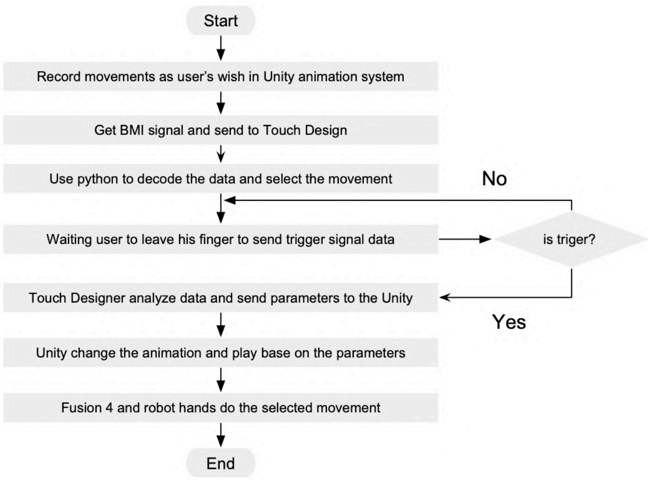

Fig.6: Workflow

Firstly, based on user requirements, a variety of motion trajectories for the robotic arm are designed and recorded, encompassing actions such as waving, clapping, DJ-ing, handshaking, photo-taking gestures, and greeting.

A patient with ALS is selected as the experimental subject, who operates the robotic arm via the BMI device and touch sensor.

When the ALS patient hears sounds from the left, center, or right, they choose the action they want to activate and transmit signals to Touch Designer via the BMI device.

Upon receiving the data, Touch Designer selects the information to be sent to Unity through OSC signal and waits for the activation signal from the touch sensor.

When the user wants to trigger the action, the user removes their finger from the touch sensor. The touch sensor then sends activation information to Touch Designer via the OSC. Touch Designer subsequently transmits the execution information, such as action instructions and execution speed parameters, hands gesture command, to Unity via OSC.

Unity, upon receiving this, switches actions and adjusts the speed of action execution through its animation system, and uses Fusion 4 SDK to send signals to pins to move Hackberry Hands. Therefore, achieving the effect of the user using the BMI to control the robotic arm for nonverbal communication.

The aforementioned process is illustrated in the Fig.6.

3. Result

As of the submission of this paper, due to the underdeveloped state of the Unity animation control system, we did not allow ALS patients to use the system to control the Fusion 4 robot for limb language communication experiments to ensure the safety of the experimenters.

Fig.7: Robot Control Test

However, we utilized the Oculus Rift and controllers, and under controllable safety conditions, we operated the Fusion[8] robot, allowing ALS users to experience enhanced human interaction using the robotic arm (Fig.7 shows). The users found this experience intriguing.

Fig.8: Touch Sensor Test

Furthermore, we also enabled users to utilize a touch sensor (Fig.8 shows). Once an action was selected using BMI signals, a slight removal of the finger from the touch sensor would activate the mini robot arm. This experiment demonstrated the feasibility of the system. Compared to triggering actions without the touch sensor, where the robotic arm would immediately move upon receiving the BMI signal, users reported improved control over the robotic arm.

4. Discussion

We acknowledge several limitations in our research. Firstly, real-time recording of actions is not supported by our system, requiring users to pre-program each gesture in our experiments. This poses a significant challenge, particularly for ALS patients. Secondly, we have not conducted experiments involving user interaction for non-verbal communication with others, limiting our understanding of the system's practical application in social contexts.

To address these limitations and enhance our system, we propose the following improvements:

Developing a customizable K-frame system: We are considering the development of a K-frame system that allows users to customize the motion trajectory and modes of the robotic arm using eye-tracking technology. This customization will enhance the flexibility and personalization of the system, better meeting the individual needs of ALS patients.

Conducting experiment: We plan to involve volunteers in interacting with the robotic arm controlled by users. Through visits, interviews, surveys, and questionnaires, we will evaluate the system's potential to enhance users' communication abilities. We will also analyze the differences between robotic arm non-verbal communication and natural human non-verbal communication from an observer's perspective, seeking ways to improve it.

Making movements based on text and tone: With advancements in AI and eye-tracking technology, patients can now input text using their eyes and generate speech with voice tone and emotions based on AI-trained voice data. However, control over physical gestures is lacking. To address this, we aim to enhance patients' expressive capabilities by integrating text input, selected voice tone, and emotions to control the robotic arm.

Through these improvements, our goal is to enhance the functionality, usability, and practical applicability of our system, ultimately benefiting ALS patients in real-world scenarios.

5. Conclusion

Building upon previous advancements in decoding BMI signals and the Fusion 4 robotic arm, our study incorporated a BMI device to capture users' brainwave signals. These signals were processed using Touch Designer and transmitted to the Unity system to determine the appropriate actions for the robotic arm and hand. Additionally, the system awaited input from a touch sensor, which, upon activation, prompted the robotic arm and hand to perform physical gestures, facilitating bodily interaction with others.

During the experiments, a patient with ALS expressed novelty and anticipation towards this novel form of physical interaction. The patient was able to successfully operate our system, demonstrating its feasibility. Compared to triggering the robotic arm motion immediately upon receiving BMI signals without the touch sensor, users reported a greater sense of control when utilizing the touch sensor.

This system held significant potential in enhancing communication abilities, particularly for individuals afflicted with ALS and similar conditions.

Acknowledgment

This work supported by JST Moonshot R&D Program "Cyberneticbeing" Project. (Grant numberJPMJMS2013)

Reference

[1] Lewis P Rowland and Neil A Shneider. Amyotrophic lateral sclerosis. *New England Journal of Medicine*, 344(22):1688–1700, 2001.

[2] Steven Laureys, Frédéric Pellas, Philippe Van Eeckhout, Sofiane Ghorbel, Caroline Schnakers, Fabien Perrin, Jacques Berre, Marie-Elisabeth Faymonville, Karl-Heinz Pantke, Francois Damas, et al. The locked-in syndrome: what is it like to be conscious but paralyzed and voiceless? *Progress in brain research*, 150:495–611, 2005.

[3] Yu Kageyama, Xin He, Toshio Shimokawa, Jinichi Sawada, Takufumi Yanagisawa, Morris Shayne, Osamu Sakura, Haruhiko Kishima, Hideki Mochizuki, Toshiki Yoshimine, et al. Nationwide survey of 780 japanese patients with amyotrophic lateral sclerosis: their status and expectations from brain–machine interfaces. *Journal of Neurology*, 267:2932–2940, 2020.

[4] Mikito Ogino and Yasue Mitsukura. An eeg-based robot arm control to express human emotions. In *2018 IEEE 15th International Workshop on Advanced Motion Control (AMC)*, pages 322–327. IEEE, 2018.

[5] 加納尚之. 完全閉じ込め症候群 (tls) となった als 患者のコミュニケーション-脳波 (erp) を用いた android スマートフォンアプリの開発. **看護理工学会誌**, 6(2):63–69, 2019.

[6] Sanjaya Mallikarachchi, Dulith Chinthaka, Janith Sandaruwan, Isuru Ruhunage, and Thilina Dulantha Lalitharatne. Motor imagery eeg-eog signals based brain machine interface (bmi) for a mobile robotic assistant (mra). In *2019 IEEE 19th International Conference on Bioinformatics and Bioengineering (BIBE)*, pages 812–816, 2019.

[7] Dipika S Patel. Body language: An effective communication tool. *IUP Journal of English Studies*, 9(2), 2014.

[8] MHD Yamen Saraiji, Tomoya Sasaki, Reo Matsumura, Kouta Minamizawa, and Masahiko Inami. Fusion: full body surrogacy for collaborative communication. In *ACM SIGGRAPH 2018 Emerging Technologies*, pages 1–2. 2018.