Investigation of Accuracy of CNN-Based EEG Classification for Third Hand Control with BMI

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Abstract: Brain Machine Interface (BMI) is a technology that connects the brain to machines. BMI could be used to operate a prosthetic hand for a people without one hand, or a third hand for an able-bodied people to extend their physical capabilities. In this study, we investigate whether CNN can classify the EEG of the third hand and the original hand, and whether the third hand can be controlled by EEG.

Keywords: Third Hand, Brain Machine Interface, EEG, Neural Network

1. Introduction

BMI is a technology that connects the brain to machine. There is a lot of research to read thoughts from the human brain and operate machines. For example, BMI could be used to operate a prosthetic hand for a people without one hand, or a third hand for an able-bodied people to extend their physical capabilities. It is expected that the third hand is used to support the original hand or to perform another task while using the original hand. Advanced Telecommunications Research Institute International (ATR) experimented EEG-based BMI to operate a robotic arm [1]. Experimental participants manipulated a robotic arm positioned to the left of the participant while performing the original two-handed task (Fig. 1). The results of this experiment were clearly divided into two groups: those who could manipulate the arm well (8 participants, average success rate 85.0%) and those who could not (7 participants, average success rate 52.5%). ATR stated that this result might be due to the ability to multitask. This study showed the possibility of using EEG-based BMI to give instructions to the third hand while moving both original hands. However, it has not been shown that a third hand can be used using EEG independently of the original hand. Therefore, we tested whether original and third hands could be classified by EEG. We attempted to classify the EEG with a single task, because participants' ability to multitask could affect the results on the ATR experiment. First, we tested whether EEG classification of both original hands and one third hand was possible. Then, we tested whether EEG classification of one original hand and two third hands, one on the right side and one on the left side of the body, was possible. We also tested whether EEG classification of the original hand, the third hand, and the virtual hand was possible.

2. Experiment 1

The EEG with a single task was classified to verify whether the third hand and the original hand could be individually controlled by the CNN. Experimental participant performed a single task in which they closed one randomly designated hand out of three hands: their original two hands and a third hand. The EEG was measured for 3 seconds at a 128 sampling rate for each hand closing motion, 300 trials each for training and 60 trials each for testing, with an Emotiv Epoc Flex Gel Kit [2]. The participant was instructed on the task as shown in Fig. 2. When the instruction target was a third hand, the participant imagined closeing the third hand in the screen without physical action. Its CG was automatically closed with a slight delay from the instruction. The EEG data for training were cropped with a length of 256 and a step width of 80. The experiment was conducted in two combinations, one with the third hand on the right side and the other on the left side. The results are shown in Table 1. The classification accuracy was high, it was suggested that CNN could classify the original hand and the third hand. The left and right positions of the third hand were found to have no effect on the accuracy of the classification. On the other hand, the classification accuracy of the third hand was clearly higher than that of the original hand, which led to the suspicion that the third hand was just judged to be not the original hand.

Fig. 1 Appearance of experiment by ATR [1]: The participant grabs the tray with both hands and the experimenter passes the object from the right side to the third hand in the center.

3. Experiment 2

To resolve the suspicion, experiment 2 and 3 were conducted under condition that did not produce simple conflicting relationships for the third hand. In experiment 2, there were two third hands, one on the right and one on the left. The EEG was measured and cropped as in experiment 1 for each of the four hand closing motions (Fig. 3), note that 300 trials each for training and 75 trials each for testing. The experiment was conducted in two combinations of 3-class classifications, one with the original hand on the right side and the other on the left side. We examined whether we could classify the original hand and the third hand, and investigated whether the classification ac-

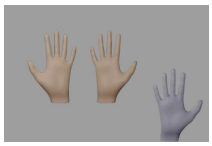

Fig. 2 Screen of experiment 1

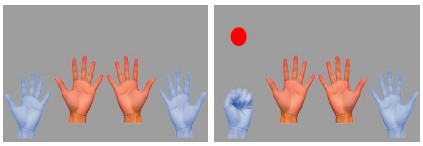

Fig. 3 Screen of experiment 2

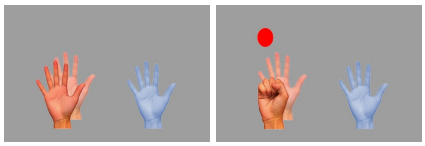

Fig. 4 Screen of experiment 3

Table 1 Classification accuracy for experiment 1

	right original hand	left original hand	third hand
right third hand	78%	79%	91%
left third hand	74%	72%	88%

Table 2 Classification accuracy for experiment 2

	right third hand	left third hand	original hand
right original hand	64%	73%	50%
left original hand	79%	59%	51%

Table 3 Classification accuracy of experiment 3: each individual accuracy from combination (1), and inclusion relationship from combination (2), (3) and (4)

	original hand	virtual hand	third hand
(1)-combination	63%	59%	66%

judge / correct	original hand	virtual hand	third hand
(2): third hand	22%	78%	–
(3): virtual hand	58%	–	42%
(4): original hand	–	79%	21%

curacy was influenced by whether the original hand was right or left (Table 2). The classification accuracy of the third hand, both left and right, was still higher than the original hand. Because the intention to close the third hand may be stronger than when closing the original hand, this may make it easier to classify the EEG. Furthermore, the classification accuracy of the third hand on the opposite side of the original hand was higher than that of the third hand on the same side as the original hand. EEG manipulation would be more suitable for a prosthetic hand, where one original hand is unusable, than for a third hand while using both original hands.

4. Experiment 3

In Experiment 3, there were a right original hand, a right third hands, and a right virtual hand. It is assumed to move their own hand in the metaverse only by imagination. The virtual hand is their own hand in the metaverse and moves as their own original hand, but they do not actually physically move the hand. The EEG was measured and cropped as in experiment 2 for each of the three hand closing motions (Fig. 4). The measured EEG data were trained in the following four combinations.

1. three hands: right original, virtual and third hand
2. two hands: right original and virtual hand
3. two hands: right original and third hand
4. two hands: right virtual and third hand

Each combination was tested with EEG data from all three hands. In combination (1), 3-class classification was tested. In combinations (2), (3) and (4), the similarity of each hand was investigated. The results of combination (1) showed that there was little difference in the classification accuracy of the three hands. It was suggested that a 3-class classification was possible (Table 3). Furthermore, the probability of misclassifying virtual hand when original hand was the correct answer was higher than the probability of misclassifying third hand, and the probability of misclassifying virtual hand when third hand was the correct answer was higher than the probability of misclassifying original hand. The virtual hand may contain characteristics of both the original hand and the third hand. In combinations (2), (3) and (4), the classified class of the hand excluded for training was investigated (Table 3). The probability of classifying original hand as third hand or classifying third hand as original hand was low, it was suggested that there was a difference between the original hand and the third hand. Even if the original hand actually moved while attempting to move the virtual hand only through imagination in the metaverse, it would still be able to move the virtual hand without any problems.

5. Conclusion

We investigated whether the original hands and the third hand could be classified independently using only EEG data. Experiments showed that the probability of correct classifications was higher than the probability of incorrect classifications. It was suggested that the original hands and the third hand could be classified. In the future, we would like to increase the amount of training data to improve classification accuracy.

Acknowledgment

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