A Brain-Controlled Mahjong Game with Artificial Intelligence Augmentation

Chapter · December 2022

DOI: 10.1007/978-3-031-20503-3_47

7 authors, including:

Yu Qi
Zhejiang University

Zhu Xinyun
Zhejiang University

Xu Kedi
Zhejiang University

Junming Zhu
Zhu Foundation

A Brain-controlled Mahjong Game with Artificial Intelligence Augmentation

Xiaodi Wu[1], Yu Qi[2](✉), Xinyun Zhu[1], Kedi Xu[1], Junming Zhu[3], Jianmin Zhang[3], and Yueming Wang[1](✉)

[1] Qiushi Academy for Advanced Studies, Zhejiang University, Hangzhou, China
[2] MOE Frontier Science Center for Brain Science and Brain-machine Integration, and the Affiliated Mental Health Center & Hangzhou Seventh People's Hospital, Zhejiang University School of Medicine, Hangzhou, China
[3] The Second Affiliated Hospital of Zhejiang University School of Medicine, Hangzhou, China

Abstract. Brain-computer interface (BCI) provides a direct pathway from the brain to external devices, which have demonstrated potential in rehabilitation and human-computer interaction. One limitation of current BCI lies in the low precision and stability in control, thus the user scenario and the interaction process play an important role in BCI applications. We propose to leverage the ability of artificial intelligence (AI) to improve the easy-of-use of BCIs. We designed a brain-controlled mahjong game with AI augmentation. As the user plays the game, an AI system continuously monitors the game and suggests several optimal candidate options, and the user directly selects from the candidates rather than from all the mahjong tiles in hand. This design enables the mahjong game with easy control, thus improving the user experience. Our system is evaluated by a human subject with an invasive BCI system. Results demonstrate that the subject can fluently control the system to play the mahjong game.

Keywords: Brain-computer interface · System design · AI augmentation.

1 INTRODUCTION

Brain-computer interface (BCI) establishes a pathway from the brain to external devices such as computers and neuroprosthetics [1–4]. Especially, BCI provides a novel way of human-computer interaction, which gives rise to new applications such as BCI typewriters [5, 6] and BCI games [7, 8].

The challenge of current BCIs lies in the limited bandwidth and low precision in control. In continuous control tasks, the state-of-the-art non-invasive BCIs could mind-control a robotic arm to continuously track and follow a computer cursor [9]. Invasive BCIs demonstrated higher bandwidth compared with non-invasive ones, while the control performance is far behind natural motor controls. Meanwhile, the nonstationary property of neural signals leads to unstable BCI control [10]. With the limitations of BCI systems, the system design and the user interaction process play an important role in leveraging the performance of BCIs. To improve the easy-of-use of BCI systems, efforts have been made. Several studies design special typewriter interfaces to facilitate BCI-based interactions [5, 11]. The Berlin Brain-Computer Interface presents the

⋆ Corresponding authors: Yu Qi (qiyu@zju.edu.cn) and Yueming Wang (ymingwang@zju.edu.cn).
Demo video: https://bcidemo.github.io/BCIMahjongDemo/

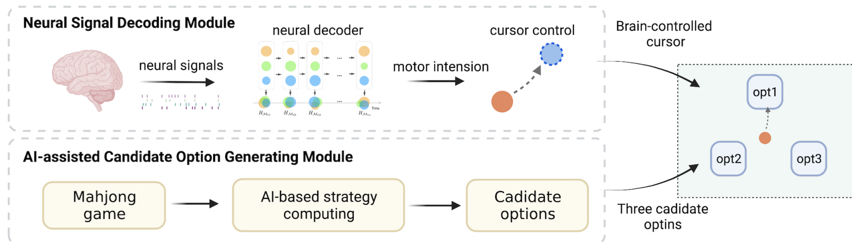

Fig. 1. Framework of the AI-based BCI mahjong system.

novel mental typewriter Hex-o-Spell which uses an appealing visualization based on hexagons, and improves the bandwidth of BCI systems [5]. Some approaches design games specifically tailored to the characteristics of direct brain-to-computer interaction [8, 12, 13]. Besides, a few studies involve AI language model to improve performance of BCI communication system [14].

Inspired by studies mentioned above, this study proposes an artificial intelligence augmentation approach to improve the human-computer interaction with a BCI system. We propose a BCI mahjong game with artificial intelligence assistance to improve the easy-of-use of BCI system. As the user plays the game, an AI system helps suggest optimal candidate options. Instead of directly choosing a tile from the tiles in hand, which usually requires delicate operations, the user can choose from the candidate options. In this way, the difficulty of operation can be highly reduced. A user can play the mahjong game with easy control, such that improves the user experience.

2 THE BCI MAHJONG SYSTEM

The framework of the proposed BCI mahjong system is illustrated in Fig. 1. The system consists of two modules, a neural signal decoding module and an AI-based candidate option generating module. The neural decoding module decodes neural signals to control a computer cursor. The AI-based option generating module computes three optimal candidate options based on the current game situation. A user can control the cursor ball to choose an option from the candidates.

2.1 User Interface

The user interface is illustrated in Fig. 2a. The major part is a control panel where three candidate options generated by the AI system are placed at the top, left and right. The user controls the cursor ball that starts from the middle to reach the three candidate options for selection. The cursor can move within the control panel. When the user moves the cursor ball to an option and holds it for 200ms, an action is performed. For situations of ‘pung’, ‘chow’ and ‘complete’, there are only two options located at the left and the right, as shown in Fig. 2b and Fig. 2c. The mahjong system is a three-player game based on an open-source project [15].

The play process is illustrated in Fig. 2d. Firstly, the user watches and thinks for five seconds, during which the cursor ball does not move. Then the user controls the cursor to select an option. If the user fails to select an option within 20 seconds, the system will randomly select one option from the three candidates.

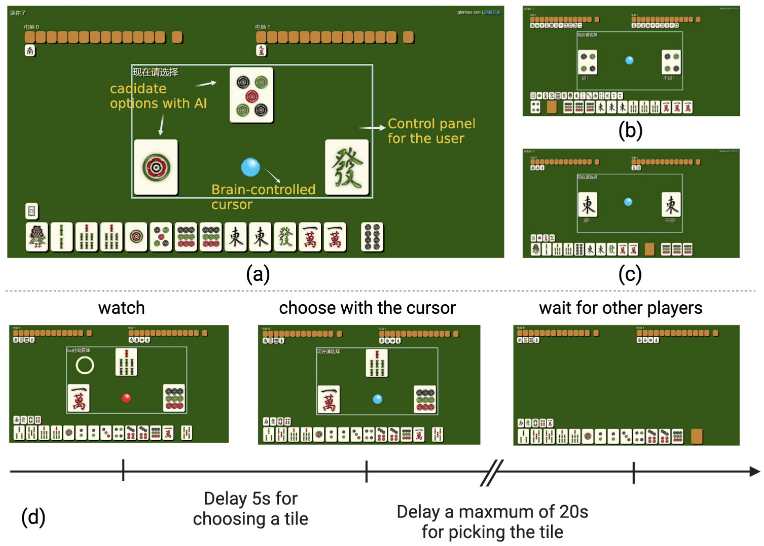

Fig. 2. User interface of the mahjong game.

2.2 The AI Augmentation Algorithm

The goal of mahjong game is to start from current hand to reach ready hand in minimum steps. In the optimal case, we start from current hand and search all paths to find the fastest one. However, the high randomness and a lot of asymmetric information of mahjong bring a vast search space and sampling space to standard search algorithms. In order to obtain feasible solutions in acceptable time, we adopt the shanten-based heuristic evaluation algorithm, which uses the function based on the shanten number as the evaluation function.

We have some definitions as follows. The shanten number is the minimum number of tiles required by current hand before ready hand. The useful tile is the tile that can be drawn at next step that will decrease the shanten number. The improved tile is the tile that can be drawn at next step that will not decrease the shanten number but increase the number of useful tiles. When the player needs to play a tile, we use the evaluation function to evaluate all the actions as follows: $Score_0 = 9 - n_{shanten}, Score_1 =$ number of useful tiles, $Score_2 =$ number of improved tiles. Specifically, the constant 9 guarantees a minimum benchmark 1 of $Score_0$. Every time the player needs to play a tile, we compare the score array $\{Score_n\}$ for all the possible actions in lexicographical order, then the options with the top three score array are presented as candidates for the users to choose from. The pseudocode of the mahjong AI approach is in Algorithm S1.

2.3 The Neural Decoding Algorithm

The neural decoding algorithm is a dynamic ensemble model (DyEnsemble) [16, 17]. The DyEnsemble approach is a Bayesian filter with an assembled measurement function, which can cope with nonstationary neural signals. The model settings and model

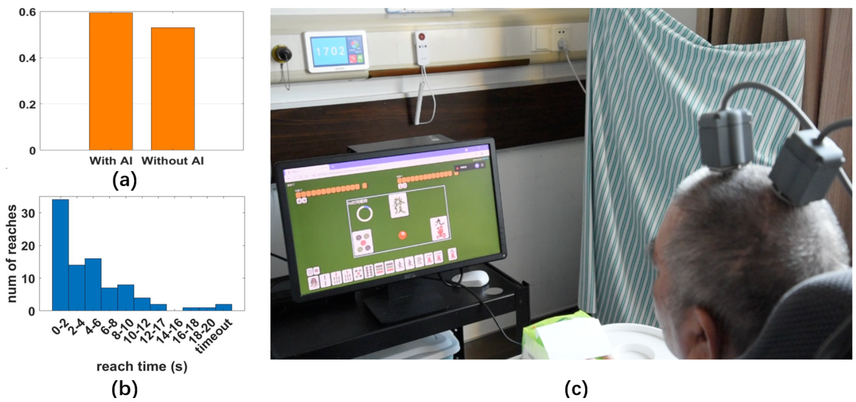

Fig. 3. Performance of the AI-augmented mahjong game.

calibration process is similar to [16]. After model calibration, the user can control a cursor ball with the brain signals.

3 RESULTS

3.1 Evaluation of the AI augmentation

We first evaluate the AI augmentation performance. In this experiment, a total of six participants were involved, and each participant played 10-21 mahjong games both with and without the AI assistance. The results are shown in Fig. 3a. Without the AI assistance, there are 44 winnings out of 83 games, with a winning rate of 53.0%. With the AI assistance, there are a total of 47 winnings out of 79 games, with a winning rate of 59.5%. The AI assistance effectively improves the winning rate by 12.3%.

3.2 Online Performance

The online experiment is carried out with a human participant (Fig. 3c). The participant is a 74-year-old male who suffers from movement disability due to traumatic cervical spine injury at C4 level. Two 96-channel Utah intracortical microelectrode arrays were implanted into the participant's left primary motor cortex for BCI control. The details of the neural signal recording are specified in supplementary materials.

On the experiment day, a total of 5 rounds of mahjong games were played, among which two rounds were won, with a winning rate of 40%. The participant had 89 mahjong playing actions, and the average action time was 4.4 seconds. Among the actions, only two of them failed to act within 20 seconds. The histogram of action time is shown in Fig. 3b. As shown in the figure, 39.5% of actions were completed within 2 seconds, and 71.9% of the actions were completed within 6 seconds. The results indicate that the user can play the mahjong game fluently with the BCI control. The way of improving the user experience of BCI systems using AI assistance is valuable and extendable to other BCI systems.

ACKNOWLEDGMENT

This work was partly supported by the grants from National Key R&D Program of China (2018YFA0701400), Key R&D Program of Zhejiang (2022C03011), Natural Science Foundation of China (61906166, 61925603), the Lingang Laboratory (LG-QS-202202-04), and the Starry Night Science Fund of Zhejiang University Shanghai Institute for Advanced Study (SN-ZJU-SIAS-002).

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