뇌-기계접속 된 동물과 사람사이의 실시간 인터넷게임

A Real time Internet Game Played with a Brain-Computer Interfaced Animal

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Abstract A Many studies have been made on the prediction of human voluntary movement intention in real-time based on invasive or non-invasive methods to help severely motor-disabled persons by offering some abilities of motor controls and communications. In the present study, we have developed an internet game driven by and/or linked to a brain-computer interface (BCI) system. Activities of two single neuronal units recorded from either hippocampus or prefrontal cortex of SD rats were used in real time to control two-dimensional movements of a robot, or a game object.

Keyword : Brain-Computer Interface(BCI), Internet game , Neuron, Hippocampus, Prefrontal cortex

1. Introduction

A brain-computer interface (BCI) is a system that translates its user's brain activity into external device control commands. The effective modulation of two adaptive controllers, the user's brain and the BCI system, is still a major challenge. In this study, we developed a neuron based internet game series called RaviDuel driven by a BCI system as one of the implementations of a virtual reality linked to a general-purpose BCI system, in which we used the BCI system developed in our previous study [1]. RaviDuel consisted of a betting game RaviDuel and a competitive game RaviDuel+. In RaviDuel, players betted on the time taken in completing a mission or on one of the subjects who competed with each other for completing a mission, in which the mission was driven by the BCI system. RaviDuel+ was a player vs. player hitting game, where one of the players was supposed to be a user (a rat, a pet, or a paralyzed person) of the BCI system. The BCI system coded a series of motor functions into prefrontal cortex (PFC), or hippocampal (CA1) region of the brain of the user and generated real-time command signals that controlled game objects of RaviDuel or RaviDuel+.

2. System

Figure 1 shows the schematic diagram of the presented system. The system consists of two parts, the BCI and the internet game systems. In the BCI system, the activities of two of m single neuronal units, $s_j\,(j=1,2,\cdots,m)$ recorded, were used in real-time to control two-dimensional movements of a water disk, a robot, or game objects. A combination of the two neuronal units was assigned to the motor function of selecting a motion direction (left, right, forward, or backward) and another, to the motor function of selecting a motion power (one, two, three, or zero step count).

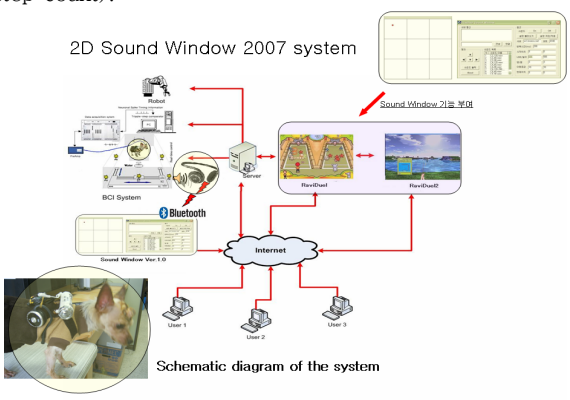

Figure 1. Schematic diagram of the system.

We quantified and coded the firing rate of each of the two neuronal units into four levels to estimate the relative neuronal activity difference and generate a corresponding command signal for a combination of the motion directions and the motion powers[2]. The game system was constructed to be driven by the command signal output of the BCI system.

2.1. The BCI system

Figure 2 shows a block diagram of the BCI system developed in our previous study. The BCI system was composed of data acquisition, feature extraction, source selection, coding, and control units. In the data acquisition unit, neuronal signals recorded from PFC, or CA1 region of the rat brain were amplified, filtered, sorted, and transformed into m spike trains $s_j,\ j=1,2,\cdots,m$ in real-time, where $s_j=(t_1^j,t_2^j,\cdots,t_p^j,\cdots)$ and t_p^j denotes the time of occurrence of the p' th spike emitted by the j' th neuron. Each spike train during a time interval $(0\le T)$ was transformed into time series data $X_j=(x_1^j,\cdots x_i^j,\cdots,x_z^j)$ in the feature extraction unit, where $x_i^j=\rho^j(t_i)-\rho^j(t_{i-1})$ and $z=T/\Delta t$ and $\Delta t=t_i-t_{i-1}$ is the bin size of the time series data. The neuronal response function $\rho^j(t_i)$ was evaluated as sums over spikes from j' th neuron for $0\le t\le i\Delta t$ [4]. The correlation coefficients r_{jk} and the partial correlation coefficients $r_{jk,l}$ of the time series data were then calculated using the equations given in reference [5]. The correlation coefficient r_{jk} measures the correlation between the time series data X_j and X_k. The partial-correlation coefficient $r_{jk,l}$ measures the net correlation between the time series data X_j and X_k after excluding the common influence of (i.e., holding constant) the time series data X_l [6]. The source selection unit classified the time series data X_j into two groups, correlated, and uncorrelated groups, according to the values of the correlation coefficients. Each group was again subdivided into two subgroups based on the values of the partial correlation coefficients of its elements.

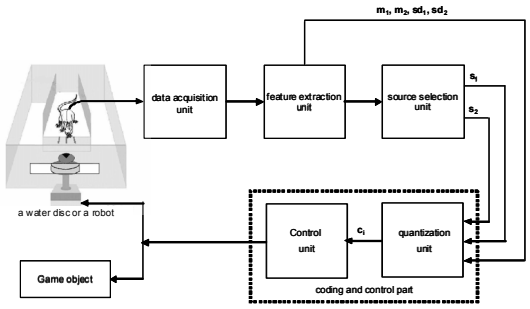

Figure 2. A block diagram of the BCI system developed in our previous study

Two spike-trains s_{j1} and s_{j2} were then selected, where the corresponding time series data X_{j1} and X_{j2} were belong to the uncorrelated group but not in the same subgroup. In result, s_{j1} and s_{j2} were independent each other as well as had large difference in their correlations with other spike trains $s_{j\ne j1,j2}$. The coding unit coded a series of motor functions into the spike train s_{j1} and s_{j2} by an coding function $f(s_{j1},s_{j2})$ and transformed in real-time the relative difference between the neuronal activities of the spike trains s_{j1} and s_{j2} into a command signal corresponding to one of the motor functions. The control unit received the command signal from the coding unit and executed it correspondingly to control a water disk or a robot of the BCI system and a game object of the game system.

2.2. The game system

The internet game system was constructed to be driven by the command signal output of the BCI system. *Figure 3* shows the flowchart of procedures of a game session in the internet game system. Once a series of initialization steps, such as sign up, login, option selection, etc., is set up, a cam server, a game server, and the BCI system are connected to the user system, and a game session starts. The cam server controls and transfers to a game client system real time images captured from a video camera recording the two-dimensional movements of a water disk or a robot and the behavior of a user in the BCI system. The game server controls game procedures and network packet transmissions until a session of

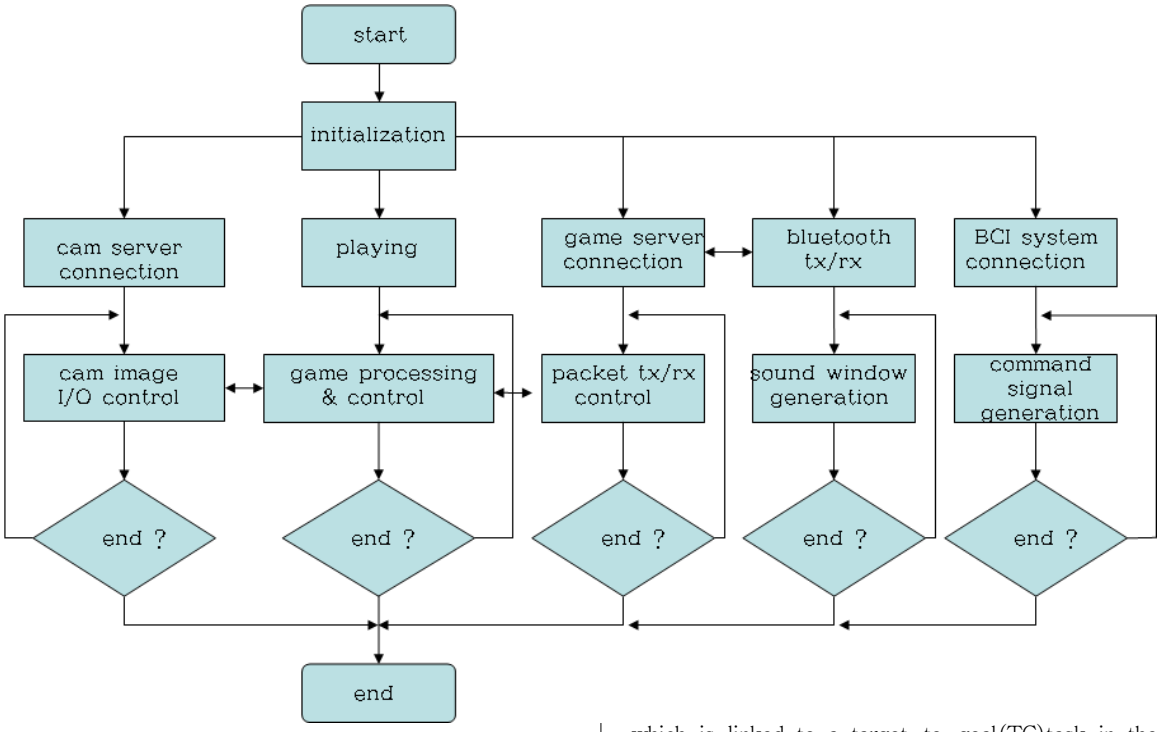

Figure 3. Flowchart of procedure if a game session in the internet game system

a game ends. The game server controls a betting, a competitive, and/or an interactive game.

A betting internet game, RaviDuel, was programmed and simulated. In RaviDuel players bet on the time taken in completing a mission or on one of the subjects who

Figure 4. Windows of a session of the game. RaviDuel, RaviDuel^{+} & RaviDule2

competes with each other for completing a mission. The mission was animated like that a rat finds a water spring, which is linked to a target-to-goal(TG)task in the BCI system. An other competitive internet game, *RaviDuel*$^{+}$, was programmed and tested. *RaviDuel*$^{+}$ is a player vs. player hitting game, where one of the players was supposed to be a user (a rat, a pet, or a paralyzed person) of the BCI system. *Figure 3* shows a window of a session of the game, *RaviDuel, RaviDuel*$^{+}$ *& RaviDule2.*

4. Conclusion

A neuron based internet game series called RaviDuel driven by a BCI system was developed as one of the implementations of a virtual reality linked to a general-purpose BCI system. Activities of two single neuronal units recorded from PFC, or CA1 region of SD rats were used in real time to control two-dimensional movements of a game object. A betting game, named as RaviDuel, and a competitive game, named as RaviDuel+ were programmed and tested. RaviDuel is a betting game, where players bet on the time taken in completing a mission. RaviDuel+ is a player vs. player hitting game, where one of the players is supposed to be a BCI user (a rat, a robot, or a pet). The constructed game system linked to the BCI system was successfully implemented and the games, RaviDuel and RaviDuel+, were operated in real-time. The current development of new online communication system between animal (or paralyzed)

and human showed a promising vision in the fusion technology among neuroscience, robotics and information technologies.

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