Intelligent Adaptive User Interfaces for BCI Based Robotic Control

V. Gandhi[1], G. Prasad[1], T. M. McGinnity[1], D. H. Coyle[1], L. Behera[2]
[1]*Intelligent Systems Research Center, University of Ulster, Derry, UK;* [2]*IIT Kanpur, India*

Correspondence: V. Gandhi, Intelligent Systems Research Center, University of Ulster, UK. E-mail: gandhi-v@email.ulster.ac.uk

Abstract. The inherent lower bandwidth of a two-class BCI is still a major challenge in making BCI practical for day-to-day use. In this paper we present an intelligent adaptive user interface (iAUI) to facilitate enhanced robot control via BCI. The iAUI is a user-centric graphical user interface (GUI) that facilitates multiple controls needed in controlling a powered wheelchair or a robotic device using just a two-class motor imagery (MI) brain-computer interface (BCI). The iAUI offers a continuously updated prioritized list of all the control options (in the form of forward, left, right, backward and start/stop) for selection via a BCI by utilizing the information obtained from the sonar sensors mounted on the robotic device. Results on multiple participants in player-stage simulation as well as the physical robotic arena show that the iAUI addresses to a large extent the inherent lower bandwidth of a BCI for effective control of a robotic device.

Keywords: brain-computer interface (BCI), graphical user interface (GUI), motor imagery (MI), wheelchair, EEG

1. Introduction

There are normally only two output commands in a two-class brain-computer interface (BCI) e.g., left hand vs. a right hand/foot imagery (MI), for every trial. This limited communication bandwidth renders control of assistive devices such as a smart wheelchair or a telepresence mobile robot, which require multiple motion commands, a significant challenge. There are several interfaces available in the literature; some utilizing shared control strategies, however these have not been strictly user-centric in terms of offering true independence while controlling a robotic wheelchair. This paper proposes a GUI using a 2-class MI BCI to perform a multi-task robotic control, and is referred to as an intelligent adaptive user interface (iAUI). The iAUI is implemented by sharing the real-time knowledge from the robotic device (in the form of sonar sensor information) and is effective in suitably controlling the device whilst minimizing the effort required by the user.

2. Method

As shown in Fig. 1, the BCI user is expected to perform 2-class MI (i.e., left or right hand) in accordance with the display of commands through the iAUI and control the device in the robotic arena. The iAUI is composed of four main modules namely the communication module (CM), the information refresh module (IRM), the adaptation module (AM) and the monitor module (MM) (i.e., iAUI front-end). The commands that are offered to the BCI user (e.g., Backward, Forward, Left, Right, Halt and Main) are displayed on the MM such that the most likely command is placed at the top-most location ready for selection at the start of a scan cycle. The two options at the top-most location have the highest probability of being chosen by the BCI user. This prioritization of the options solely depends upon the dynamic situation of the robot with reference to the environment i.e., the obstacles surrounding the robotic device as detected from the sonar sensor readings. These most likely options presented through the iAUI are expected to be the easiest and quickest to access and thereby reduce the decision-making time. The simulated and the physical robotic arena have various obstacles (see Fig. 1). The location of the robot in the arena is displayed as a visual scene on the left side while the corresponding GUI associating the user's mental imagination is displayed on the right side. In Fig. 1, A-A' and B-B' displays a graphical view to understand two of the various adaptive forms of the interface using an example. Assume that the robot begins from a starting position in the robotic arena marked (A') and is to be maneuvered towards the 'Target' position shown by an orange colored marker. At position in (A'), the two most probable choices displayed are 'Forward' and 'Right'. The BCI user performs a left hand MI and issues the command 'Forward'. When the robot begins to move in the forward direction, the left and right hand sides of the robot get blocked and only the front and backward sides remain open (shown in (B')). This information is sent to the interface in the form of sonar sensor values. Thus, the interface adapts immediately after the user's 'Forward' command and alters the first two probable choices as 'Backward' and 'Forward' (shown in (B)). Thus, the user has the opportunity to select the 'Forward' and the 'Backward' choices in the first instance, as these are the most suitably available choices.

3. Results and Discussion

The number of commands needed to reach the specified destination (Room 1, Room 2 and Cupboard (see Fig. 1)) in the simulated arena considering 100% BCI accuracy is detailed in Table 1. If a command is to be selected from the two options on the 2nd (or 3rd) rung of the iAUI (see Fig. 1), then the user is expected to perform no imagination i.e., one (or two) no-control (NC). Forty-two commands are required to reach the three targets through the iAUI and forty-six are needed through the non-adaptive interface. However, only 31 NC commands are required through the iAUI, while 45 NCs are required through the non-adaptive interface. This suggests that the adaptive nature of the iAUI is very valuable in minimizing the time loss through NC i.e., the iAUI prioritizes the commands available to the user so that the user is preferably not required to perform NC and go to the next available choice. The probabilities of the control tasks that are more likely to be expected from the BCI user are adapted and their position accordingly reordered to enhance the otherwise low communication bandwidth. The results are comparable with some of the contemporary designs in the literature by calculating the overall cost using nominal time, mission time, mission time ratio, concentration time and concentration time ratio [Rebsamen et al., 2010]. The average cost in maneuvering the device to the three target locations is 1.98 using the iAUI while it is 2.21 with the non-adaptive interface.

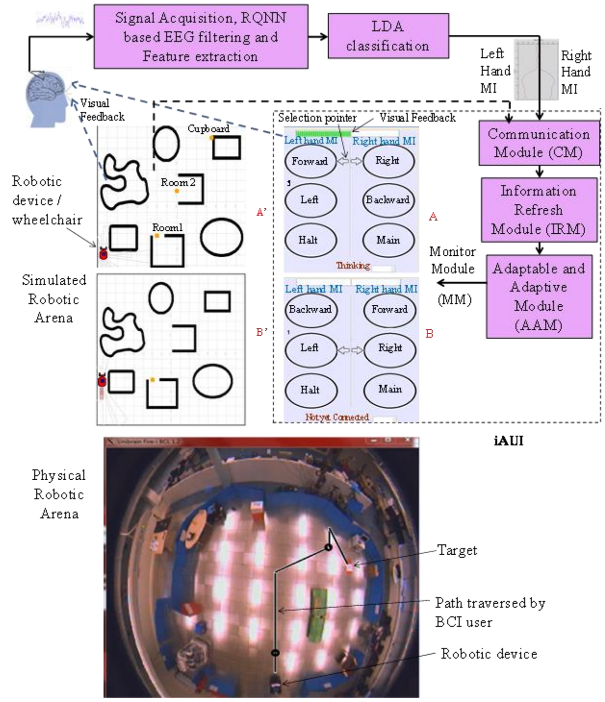

***Figure 1**. iAUI architecture within the complete BCI system.*

The iAUI has been evaluated using five subjects in a player-stage simulation and three subjects in a physical robotic arena (see video isrc.ulster.ac.uk/Staff/VGandhi/VideoRobotControlThroughMI). One session consisting of forty trials was used to train the classifier before beginning the session on any day. The average cost with five subjects maneuvering the device to the three destinations in the simulated arena is 4.42, 8.00, 7.86, 12.47 and 10.16. The average cost with three subjects maneuvering the physical mobile robot to the two target destinations is 3.66, 11.17 and 11.62. The path traversed while maneuvering the robotic device to Target 1 by one of the BCI users is shown in Fig. 1. Most of the subjects reached the targets on the 1st or 2nd attempt and were easily acquainted with the adaptive interface as the sessions progressed. The major advantage with the iAUI is the user-centric display of choices being made available for user selection, which is the novelty of the presented interface. A preliminary and a comprehensive study of the iAUI with a comparative analysis are detailed in [Gandhi et al., 2009; Gandhi, 2012].

***Table 1.** No. of required commands.*

Destination	iAUI	Non-adaptive
Room 1	13 / (07)	13 / (13)
Room 2	09 / (07)	11 / (12)
Cupboard	20 / (17)	22 / (20)

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References

Gandhi V, Prasad G, Coyle D, Behera L, McGinnity TM. A Novel Paradigm for Multiple Target Selection Using a two class Brain-Computer Interface. *Proceedings of the Irish Signals and Systems Conference*, 2009.

Gandhi V. Quantum neural network based EEG filtering and adaptive brain-robot interfaces. *PhD Thesis*, University of Ulster, 2012.

Rebsamen B, Guan C, Zhang H, Wang C, Teo C, Ang MH, Burdet E. A brain controlled wheelchair to navigate in familiar environments. *IEEE Trans Neural Syst Rehab Eng*, 18: 590-598, 2010.