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Vision-Based Shared Control for a BCI Wheelchair

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Abstract. Brain-actuated wheelchairs offer paraplegics the potential to gain a degree of independence in performing activities of daily living. It is not currently possible to achieve precise proportional control of devices using the low resolution output of a brain-computer interface (BCI). Consequently, we have developed a shared control system that interprets such commands, given the context of the surroundings. In this paper we show that a vision system provides sufficiently reliable information to the shared controller, to enable synthesized BCI subjects to drive safely in an office environment. The shared controller reduces both the time and number of commands required to perform a task.

Keywords: Shared Control; Brain Computer Interface; Wheelchairs; Computer Vision

1. Introduction

Current brain computer interface (BCI) technology, based on electroencephalography (EEG), can typically only discriminate between a limited number of classes and make a command decision every 1-2 seconds [Millán and Carmena, 2010]. Therefore, it is difficult to control a powered wheelchair safely and efficiently, using only the outputs of a BCI. Consequently we use shared control [Carlson and Demiris, 2010], such that the wheelchair interprets the high-level BCI commands, given the environmental context. For example, when the user issues a "go left" command, the shared controller determines exactly when and how far left to turn, based upon the presence (or absence) of obstacles. To interpret the surrounding environment, we have developed a reliable vision system that runs on a pair of standard USB webcams. In this paper, we briefly describe the wheelchair control architecture, before showing experimentally that the vision-based shared controller increases safety and efficiency.

2. The Wheelchair Platform

2.1. The Vision System

The obstacle detection algorithm is based on monocular image processing from the webcams, which ran at 10Hz. First we segment the image, using a method based on the watershed algorithm (similar to that proposed by Fazl-Ersi and Tsotsos [2009]). After the segmentation, adjacent regions with a similar average colour are merged. We then assume that large regions in contact with the bottom of the image have high probability of being floor, providing that they do not cross the horizon line. The floor colour is learnt from such regions, which allows us to build a set of floor patches. Regions that do not fall in this set are deemed to be obstacles. Since we know the position of the camera and its lens distortion parameters, we build a local occupancy grid that can be used by the shared controller.

2.2. Shared Control

The default behaviour of the wheelchair is to move forwards and the user can issue one of two commands (turn left or right). The shared controller pro-actively steers away from an object if it is detected to one side of the wheelchair, until sufficient free space is found to continue moving forward [Tonin et al., 2010]. If an object is detected directly in front of the wheelchair, it will stop and await further BCI commands. In this way, it is possible to dock to a desk by approaching it from a perpendicular angle (± 45º) and not delivering any further BCI commands.

3. The Experiment

3.1. Synthetic BCI commands

We controlled the wheelchair using synthetic motor imagery (MI) BCI commands, whereby an expert driver pressed a button on the keyboard to indicate a desired left or right turn. The BCI synthesizer would then probabilistically generate the output of the corresponding classifier for the synthesized subject. This was computed according to the confusion matrix obtained from the offline BCI training sessions of 3 subjects. The rest of the BCI loop remained the same as the standard described by Tonin et al. [2010]. The first synthesized subject was biased to the right and would often fail to deliver a left command whereas subjects 2 and 3 were usually able to deliver correct commands.

3.2. Experimental Task

The goal was to drive the wheelchair from the start point, through one room into another, where the subject should reach a table, then return to the first room and dock to a desk, as shown in Fig. 1. Each subject performed the task twice, under two conditions: with shared control and without shared control (although the wheelchair would stop if a collision was predicted, it would not provide any proactive assistance). We also determined a benchmark performance by manually controlling the wheelchair directly from the keyboard (i.e. without BCI synthesis). Each trial was time-limited to six minutes.

3.3. Results

For the BCI condition, without shared control, subject BCI 1 was unable to navigate through the doorway, due to incorrectly classified or delayed commands and hence could not complete the task within the time limit. With shared control, all subjects required fewer BCI commands to achieve the task more quickly. The shared controller operated as expected, hence no collisions occurred.

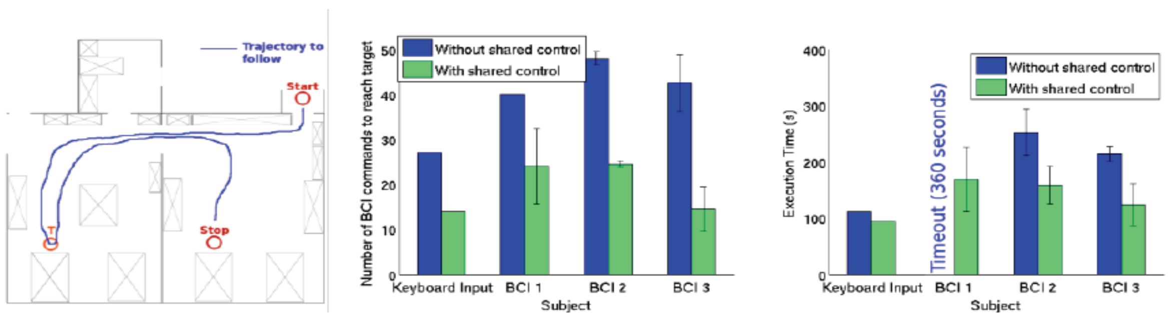

Figure 1. *Number of commands and time required to perform the illustrated task. Note that "Keyboard Input" is a manual control benchmark and subject BCI 1 could not reach the target without shared control.*

4. Discussion

The vision system we developed has provided sufficiently accurate information to the shared controller, which has allowed subjects to navigate safely around an office environment, using synthesized BCI commands. Overall performance improved with the use of shared control. We aim to confirm these results using real participants in the near future.

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