A Scene-Combined Navigation Method Based on Newton's Rings Paradigm for Brain-Actuated Intelligent Wheelchairs

Y. Li[1], G. Xu[1,2], J. Xie[1], J. Wang[1], Q. You[1], F. Zhang[1], S. Zhang[1]
[1]*School of Mechanical Engineering, Xi'an Jiaotong University, Xi'an, China;*
[2]*State Key Laboratory for Manufacturing Systems Engineering, Xi'an Jiaotong University, Xi'an, China*

Correspondence: G. Xu, Xi'an Jiaotong University, 710049, Xi'an, China. E-mail: xugh@mail.xjtu.edu.cn

Abstract. Brain-actuated intelligent wheelchair has become a research hotspot as the elderly and people with disabilities increase year by year. However, these systems suffer from very low information transmission rates (ITR) and low level navigation methods. To overvome these two problems, we firstly adopt the recently proposed Newton's Rings paradigm to improve the ITR and reduce the user's discomfort; then, a new technology called scene-combined navigation method is designed to improve the efficiency of navigation.

Keywords: Intelligent wheelchair, Brain-Computer Interface, Scene-combined, Newton's Rings paradigm, Navigation method

1. Introduction

Many BCI applications have been developed to help people suffering from paraplegia or with other physical impairments to autonomously drive a wheelchair [Luis et al., 2012]. However, several problems lead to their shortages of low efficiency and low robustness.

First and foremost, BCIs provide low information transfer rates and accuracies, and require a concentration effort [Rebsamen et al., 2010], which makes it difficult to control the wheelchair reliably.

Then, usual BCI-wheelchairs based on low-level navigation (e.g., front, back, left, and right) require excessive instructions even in simplistic scenarios [Iturrate et al., 2009].

Aiming at these two problems, we develop a new brain-actuated intelligent wheelchair. On the one hand, a previously proposed paradigm by our team called oscillating Newton's Rings [Jun et al., 2012] is utilized to achieve a relatively high ITR. Then we design an effective and reliable scene-combined navigation method.

2. Material and Methods

2.1. The Newton's Rings paradigm

In a previous study, we utilize a special visual stimulation protocol, called motion reversal, to present a novel steady-state motion visual evoked potential (SSMVEP)-based BCI paradigm that relied on human perception of motions oscillating in two opposite directions. In the present research, the ITR reaches 40.25 ± 8.23 bits/min when we set 9 simulators, which is relatively high as compared to ITRs of P300 BCIs (20-25 bits/min) [Luis et al., 2012].

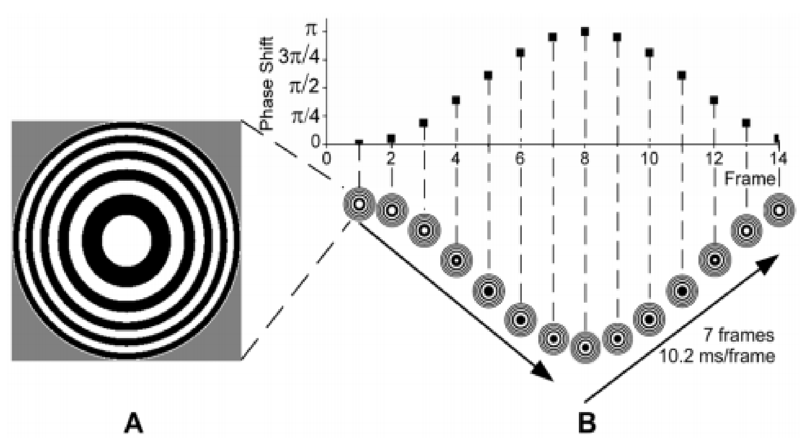

Figure 1. *The Newton's Ring paradigm. (A) A Newton's Ring based stimulator. (B) The motion reversal procedure of the rings. It was illustrated with a 14 Hz motion reversal frequency and each reversal contained 7 frames. The phase of the Newton's ring was modulated by a sinusoid of 7 Hz in [0, π] to produce motion reversals.*

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2.2. Navigation method

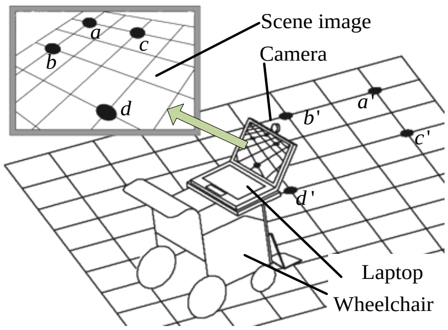

Figure 2. *The scene-combined navigation method. A navigation method which associates the stimulators and the scene is designed to improve the efficiency and robustness of the navigation. A wide-angle camera is mounted on the front of the wheelchair. The stimulators are presented on the scene image captured by the camera. By calibrating the camera, the position of a stimulator (e.g., a, b, c or d in the figure) in the image and the corresponding position on the floor (e.g., a', b', c' or d') are associated. A subject gaze at a stimulator to select his or her desired target position and the computer generates commands to drive the wheelchair there.*

3. Results

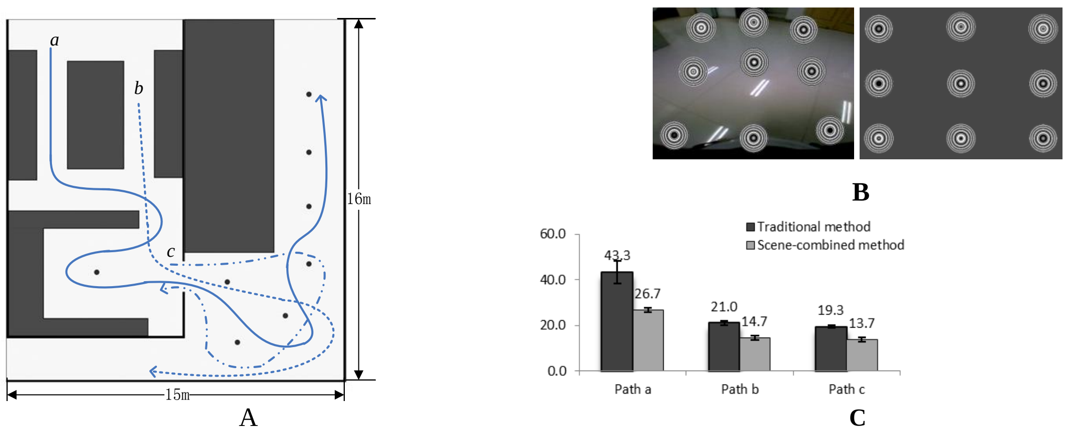

Figure 3. *Experimental validation of the scene-combined navigation method compared to traditional method. (A) Three paths (a, b and c) with different length and complexity are designed to test the new and tradition navigation method. (B) Left: the stimulus pattern of scene-combined method, each stimulator corresponds to a position on the floor; Right: the stimulus pattern of traditional method, each stimulator corresponds to running forward a certain distance or turning a certain angle. (C) The average number of instructions needed for the three paths.*

4. Discussion

Based on the relatively high ITR and accuracy of the Newton's Ring paradigm, we designed an efficient and robust navigation method. The results show that a high-level navigation strategy achieves considerable improvement in efficiency as opposed to a low-level strategy.

Acknowledgements

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References

Iturrate I, Antelis JM, Kübler A, Minguez J. A noninvasive brain-actuated wheelchair based on a P300 neurophysiological protocol and automated navigation. *IEEE Trans Robot*, 3(25): 614-627, 2009.

Luis F, Jaime G. Brain Computer Interfaces: a Review. *Sensors*, 12(2):1211-1279, 2012.

Rebsamen B, Cuntai G, Haihong Z, Chuanchu W, Cheeleong T, Ang MH, Burdet E. A brain controlled wheelchair to navigate in familiar environments. *IEEE Trans Neural Syst Rehabil Eng*, 18:590-598, 2010.

Xie J, Xu F, Wang J, Zhang F, Zhang Y. Steady-State Motion Visual Evoked Potentials Produced by Oscillating Newton's Rings: Implications for Brain-Computer Interfaces. *PloS ONE*, 7(6):e39707, 2012.