ABSTRACT

Brain-Computer Interfacing using the Mirrored Word Reading Paradigm

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Brain-Computer Interface (BCIs) based vehicles are an important development that can allow disabled users to increase independence and mobility. Currently BCI-based vehicles are relatively expensive and hence restrict wider adoption. This research work therefore sought to develop a low cost BCI-based vehicle system for severely disabled users. Previous work has been performed on low cost BCIs however the specific application platform and BCI aspects studied in this work has not been addressed. To this end, the first phase of research involved the determination of specifications, development and validation of a BCI-based vehicle prototype. Comprehensive research was performed which led to the development of a BCI-based vehicle prototype that comprised of the P300 Speller Paradigm, Quanser Qbot and the communication and control systems for effective closed loop device control. The Qbot platform was selected due to its similarity to existing BCI-based wheelchairs and its low cost sensors such as sonar, infrared and vision. Comprehensive evaluation of the developed prototype indicated serious deficiencies in two main areas, namely the BCI paradigm in terms of perceptive and contextual deficiencies and localisation in terms of odometry drift.

The second phase of the research addressed the two key deficiencies of the developed prototype. Extensive research was therefore undertaken to identify and review suitable paradigms which did not have these perceptive and contextual deficiencies. A shortlist was compiled of the most promising paradigms which were then further evaluated and assessed. The Mirrored Word Reading Paradigm (MWRP) was selected as the best option. The MWRP is a specialised tool used in the clinical setting to study linguistic processing in psychology and neuroscience. The MWRP however has never been applied for BCI implementation and is therefore a novel paradigm in the BCI domain making this the seminal study on MWRP for BCI implementation. This paradigm was designed, prototyped and evaluated in both the offline and online settings via comprehensive experimental trials. This investigation found the novel MWRP to be very appropriate for BCI implementation.

The use of low cost instrumentation such as shaft encoders on the Qbot platform generated significant errors leading to unacceptable odometry drift. Therefore, research was also undertaken to identify an accurate low cost approach to vehicle localisation to reduce these errors. The localisation approach utilised the geometrical patterns of floor tiling. This approach is very efficient and was found to perform well using only low cost vision sensors, namely a monocular CCD camera. The localisation system was tested with a programme of trials in a laboratory environment to establish its effectiveness. The assessment found that the developed approach significantly reduced the error in position determination for the vehicle. In particular, the error in position estimation was reduced by 91.75% on average compared to using shaft encoders only for a 7.61m travel distance. The localisation approach was therefore found to be suitable for implementation.

Finally, an online BCI-based vehicle prototype was developed which comprised of the MWRP paradigm, the low cost localisation approach and the necessary communication and control components. This allowed for the testing of the final system. The online MWRP-based BCI was then studied for navigation trials in a laboratory environment using subjects. The assessment yielded an average BCI classification accuracy of 89.38% and a maximum accuracy of 100% whilst retaining the error reduction of the low lost localisation approach. These classification accuracies are comparable to state of the art BCIs. The MWRP however exhibited bit rates of 3bits/min compared to 15bits/min for the P300 Speller. Vehicle commands however took on average 25 seconds to execute. The lowered bit rate was therefore not detrimental for the application context of this work. However, the MWRP has the added benefit of providing an avenue for BCI implementation in situations where the existing BCI paradigms are inappropriate such as for persons with photosensitive epilepsy. This testing therefore validated the novel MWRP for real time vehicle control using the low cost localisation approach.

In conclusion, the novel MWRP provides an avenue for BCI implementation in cases where current BCI paradigms are inappropriate due to perceptive and contextual limitations. Additionally, the low cost localisation approach allows for the retrofitting of existing BCI-based vehicles such as wheelchair systems within restrictive budgets. This work therefore researched, developed and validated a BCI-based vehicle system that could be used for the benefit of disabled individuals. The initial aim and objectives of this work were therefore achieved. Some possibilities for further research include the investigation of the MWRP for the control of other application platforms such as virtual keyboards and mouse based BCIs. Moreover, the low cost localisation approach can be integrated to other control modalities such as joysticks and eye trackers. This research therefore opens numerous potential avenues for further study using the novel MWRP and the low cost localisation approach for BCI-based vehicles.

Keywords: Randy Evin Shane Harnarinesingh, Brain-Computer Interface, Mirrored Word Reading Paradigm, Vehicle Localisation