The Design of a Customised Portable BCI Headset for Home Based Neurorehabilitation

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Abstract— **This project aims to design a new portable Brain Computer Interface (BCI) headset that can be used by non-professionals (patients, caregivers) as part of BCI therapeutic applications in the home environment. The suitability of the design of the new headset under its operating conditions was evaluated through use of mechanical testing in Computer Aided Design (CAD) software and physical prototypes. Extensive use of CAD based design was used to create a novel testbed for future prototypes of BCI headsets. We present a solution for optimised hardware design of the BCI headset which incorporates existing electronic components (dry electrodes, portable amplifier, battery etc.)**

Keywords—headset, EEG, home based, Brain Computer Interface, CAD, design

I. Introduction

There are currently no portable BCI headsets available for home use by Spinal Cord Injury (SCI) and stroke patients for motor rehabilitation. The fidelity of existing consumer BCIs are too poor to use as part of a BCI system and current designs are not intuitive for a lay person to put on their head [1,2]. A user centered approach, described in the ISO 9241-210, was applied to optimise the headset design for SCI patients [3]. Through a study of complex data gathered from the users we have devised a set of guidelines as to how to approach our design strategy. The shape of the headset was optimised in CAD, based on given criteria rather than a priori defining the shape of the headset.

II. Methods

A. User Requirements

User requirements and related technical requirements were based on two usability studies by our group in which we trained more than 30 non experts (patients, their caregiver and therapist) to use the Emotiv (Epoc, USA) headset on their own without help from a specialist. [4,5].

B. Design Process

The user / technical requirements were used to generate various design concepts for BCI headset re-design. Physical prototypes of the portable headset designs were created in order to test both mechanical and electrical components of the headset. CAD modelling, in Solidworks and Autodesk Fusion 360 were 3D printed using rapid prototyping facilities.

The number of channels for the EEG headset was determined by the user requirement of having a headset design that covers the sensory-motor cortex and related areas. Eight channels were chosen, as a larger number of channels would require a larger battery and amplifier, adding extra weight and volume to the headset. The electrodes were positioned at locations C3, C4, T3, T4, F3, F4, P3, P4, suitable for neurorehabilitation of movement. Electrode locations were defined as fixed points of the model.

Autodesk Fusion 360, generative design software was used with the aim of improving structural design, comfort optimising material selection and customisation. Prior to creating a headset, a 3D CAD model of a human head was produced in Autodesk ReCap software, from a series of images taken of a head (Figure 1). This head model was imported into Fusion 360 and defined as the obstacle geometry.

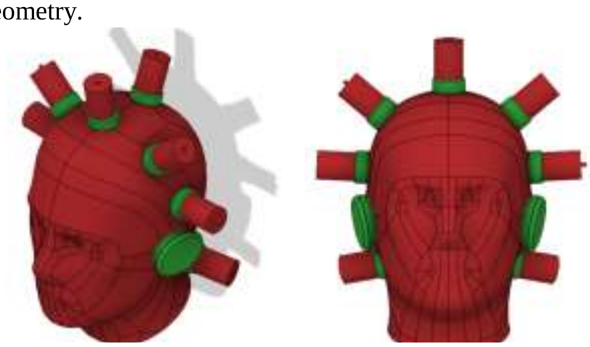

Figure 1. Fusion 360 generative design parameters. Green components indicate construction geometry; red components indicate obstacle geometry.

The Generative designed headset resulted in a frame geometry optimised for any desired head size and shape. Additionally, the electrode locations were precisely mapped on the head model. The generative process involved the construction geometry to be defined, in this case the electrode holders and the battery / amplifier holders, as well as the obstacle geometry to be defined (i.e. the users head). These were based on the existing physical model of a wearable EEG device without the housing, developed at UESTC. Loading conditions for the headset were specified based on the masses of the electronic components.

The physical model has been 3D printed and the EEG electronic components were integrated.

III. Results

A. CAD Modelling

Figure 2 shows an example of the generative process, starting from a single headset band and resulting in an optimised geometry. Varying the headset plastic material resulted in different design solutions shown in Figure 3. All design options can withstand the loading conditions and the chosen design, made from ABS plastic, consisted of the least material mass (Fig 3, option 3). ABS was the plastic material of choice due to its high strength to weight ratio. Additionally, there was an 'unrestricted manufacture' design option 4 also made from ABS, however this wasn't chosen as rapid prototyping was the manufacturing method of choice based on ease and cost of manufacture [6].

Figure 2. CAD model (left) and the initial generative test headset (right).

Figure 3. Generative design solutions. 1: PET plastic (0.22kg, 3D printing), 2: Acrylic (0.17kg, 3D printing), 3: ABS plastic (0.14kg, 3D printing), ABS (0.14kg, unrestricted manufacture).

B. Physical Prototyping

The model was 3D printed in ABS plastic to incorporate the electronic components and test the headset The geometry of the chosen design is shown in Figure 4. These dimensions were based on one individual head but can simply be modified to any head shape dimensions, by re-running the generative software with a different head model.

Figure 4. 3D printed Generative model with electronic components included.

Each electrode is made up of three dry electrodes and PCB (connecting the electrodes together), which is sandwiched between two pieces of plastic as shown in Figure 5. Dry electrodes were chosen over wet electrodes in order to reduce set-up time and to prevent skin irritation from gels.

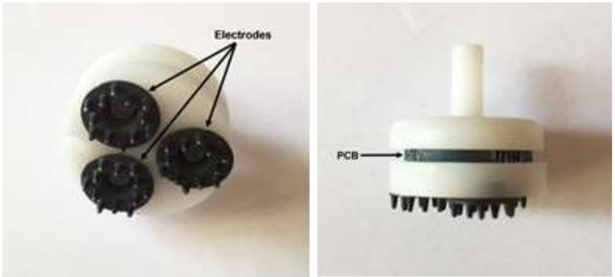

Figure 5. Single off the shell dry/hard electrode consisting of 3 individual electrodes connected to a PCB. Electrode and PCB held together with plastic, designed at UESTC.

IV. Discussion and Conclusions

A BCI headset design was created using novel generative design in CAD software and driven by a set of user requirements from extensive data gathering. The headset represents the optimum geometry and material and was achieved through an iterative process. Given advances in CAD modelling and rapid prototyping a viable solution for home use BCI could be to create personalised headsets. Future work will involve testing of proprietary electrodes and signal processing.

Acknowledgement

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References

[1] Nijboer, Femke & van de Laar, Bram & Gerritsen, Steven & Nijholt, Anton & Poel, Mannes. (2015). Usability of Three Electroencephalogram Headsets for Brain–Computer Interfaces: A Within Subject Comparison. Interacting with Computers. 27. 500-511. 10.1093/iwc/iwv023.

[2] Salisbury, D., Parsons, T., Monden, K., Trost, Z. and Driver, S. (2016). Brain–computer interface for individuals after spinal cord injury. Rehabilitation Psychology, 61(4), pp.435-441.

[3] Schreuder, M., Riccio, A., Risetti, M., Dähne, S., Ramsay, A., Williamson, J., Mattia, D. and Tangermann, M. (2013). User-centered design in brain–computer interfaces—A case study. Artificial Intelligence in Medicine, 59(2), pp.71-80.

[4] Al-Taleb M., Vuckovic ,A., (2016). Home-Based Rehabilitation System Using Portable Brain-Computer Interface and Functional Electrical Stimulation. Proceedings of the 6th International Brain-Computer Interface Meeting, organized by the BCI Society. DOI: 10.3217/978-3-85125-467-9-100.

[5] Petric-Gray, N., Al-Taleb, M., Purcell, M., Fraser, M. and Vuckovic, A. (2018) Patient feedback on self-managed brain computer interface treatment of central neuropathic pain in spinal cord injury: Steps towards service design. 7th International BCI Meeting, Pacific Grove, CA, 21-25 May 2018.

[6] Łagoda, A. and Gabor, R. (2018). Strength parameters of the ABS materials used in 3D printing. AIP Conference Proceedings, 2029. 020036. 10.1063/1.5066498.