MR-Braintap: Increasing Freedom through Mixed Reality-Brain Computer Interface

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Abstract
In this paper we contribute to the exploration of new interaction interface methods for Mixed Reality, by combining a Microsoft HoloLens with a g.tec Brain-Computer Interface. This is motivated toward helping handicapped people overcome some of their limitations to interact more freely with their environment. We provide a design approach to explain how a mixed reality interface could be operated using P300 brain signals. We also provide an example of overlaying a virtual TV remote to control a real TV in the user's environment. This setup shows a practical example of how mixed realty BCI might enhance the user's independence via control of smart home devices. Eligible populations range from children with cerebral palsy to young adults with spinal cord injury to aged persons with disabilities from Parkinson's disease or stroke.

Author Keywords
Mixed Reality; Brain-Computer interface; HoloLens; MR-Braintap; virtual interaction.

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces – Interaction styles.

Figure 1: In this picture, the HoloLens is combined with the g.tec BCI. The Processing of the brain signal is done on the Laptop in the Background. Transmitting the HoloLens input is done with UDP.

Introduction

In our technologically enhanced society, most digital tasks are fulfilled by combining visual perception and tactile hand movement. Whether touching a screen, typing on a keyboard or sliding a mouse, we rely on manual abilities. With ageing, these tasks can get harder or even impossible to accomplish. Sometimes this can happen because of a temporary limitation, like a shoulder joint replacement. In severe cases like Parkinson's disease, there may be a near total loss of function. We propose a novel system that might help overcome such limitation by creating the capacity to visually control a dynamic wearable interface. This brain computer interface (BCI) employs the user's thoughts to control their environment. In the following, we present the MR-Braintap, an approach that combines a Mixed Reality (MR) glass and a BCI.

Conceived as a tool for children with physical limitation due to cerebral palsy (CP), we designed the MR-Braintap as an MR interaction interface device to explore options to increase children's cognitive abilities and independence. The MR-Braintap consists of the Microsoft HoloLens and an EEG-based BCI from g.tec. This technology is simple to use, providing a user-friendly, practical approach for the user to achieve increased environmental control customized to their own personal needs and goals. Figure 1 demonstrates the technical setup.

Incorporating the work of Holzner et al. (2009), who explored a P300-based BCI in the context of smart home applications in Virtual Environments, we propose a dynamic MR interactive interface. We will extend the P300 speller board to project within the HoloLens. Our system will eliminate the problem of having the control board limited to a fixed screen, liberalizing the mobility of the user. It can also help with fulfilling practical daily tasks in their environment. We expect the interaction to be easy to learn and comfortable for those with limited movement.

Mixed Reality and BCI

In order to explain the design process and how the MR-Braintap can be used in older persons with disability, we will first explain the research and technological approaches that serve as the underlying structure of the MR-Braintap.

Mixed Reality

The Microsoft HoloLens is a wearable mixed reality glass, allowing the user to experience the real world with an overlay of computer generated content in real time. By projecting a virtual image onto each glass, the brain automatically forms a 3D image of it. The mapping and placement of virtual objects in the real world is then done by the integrated 3D tracking system of the Microsoft HoloLens.

Although the Microsoft HoloLens is capable of reacting to voice commands through a built in *Cortana* system, these commands need to be learned and can be unreliable in noisy environments or with an unclear voice (which often occurs in persons with disability). Besides voice commands, the interaction through mid-air gestures can also be used. The two simple gestures "air tap" and "bloom" control nearly all the functions of the device. However, the user has to stretch out his arm in front of the camera and use fine finger movements in order to use these gestures. Therefore, using multiple commands can be very tiring or even impossible for those with disability. Both interaction

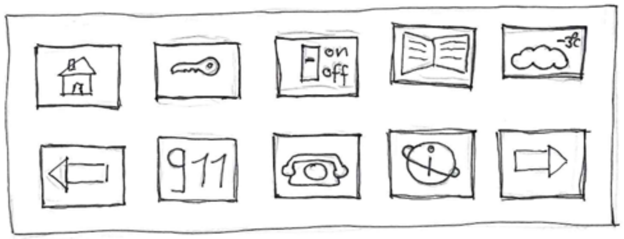

Figure 2: This sketch represents a possible collection of interaction items seen in the Microsoft HoloLens. Each icon can control a virtual or real world application.

options require training, impacting user adoption by increasing frustration. In order to avoid such limiting factors, we began working with the g.tec BCI in order to establish a new interaction form for the Microsoft HoloLens content.

BRAIN-COMPUTER INTERFACE

Electroencephalography (EEG) is a method to measure and record the electrical activity of a brain. By placing electrodes on the scalp of a person, cortical electrical signals are continuously recorded. In an EEG-based BCI, these signals are sent to intelligent computer algorithms capable of detecting thought-related changes in EEG signals. These messages are "decoded" and can then be sent to activate external devices on demand. In order to generate and detect such an event-related potential (ERP) in EEG, the brain needs to be activated by thoughts or by specific external stimuli such as flashing light. Depending on the area of the stimuli, different measurement procedures come into play. The P300 system utilizes specific visual evoked potentials that are detected 300ms following induced events such as a flashing letter. The P300 signal is the most reliable ERP, in the context of smart home applications (Holzner et al., 2009). In order to capture the signal linked to a desired visual target, a control board is used. Figure 2 shows an example. This board consists of different icons which can be selected, depending on the icon the user is focusing on. An algorithm detects the correct icon by flashing the icons in a specific sequence until the icon with the most attention is selected. The breakthrough for this approach came from Farwell & Donchin, (1988). Although this seems to be the most reliable approach, there are shortcomings, related to the selection process and the speed of selection. Both are further discussed and tested by Guger et al., (2009) and Reza Fazel-Rezai & Waqas Ahmad, (2011).

Design of the MR-Braintap

As described above, under "Mixed Reality and BCI", the Microsoft HoloLens extends the real world vision through overlaying virtual content in real time, for example holograms or interfaces. We will use this to place an interface with adjustable functionalities in 3D space. Figure 2 shows a low fidelity design approach of this concept. This design interface consists of 10 icons ranging from those icons which can display virtual content like the weather icon to others which allow interaction with the environment to turn on or off the lights. In order to provide interaction for different real world objects, the interface changes dynamically. This can be achieved by making use of the integrated cameras of the Microsoft HoloLens. The cameras are able to detect markers, which allow the system to identify objects in the environment. Figure 3 and 4 are illustrating this on the example of a living room and a TV. As the user is looking at the TV, it will be recognized by the Microsoft HoloLens and project a virtual remote control interface next to the TV.

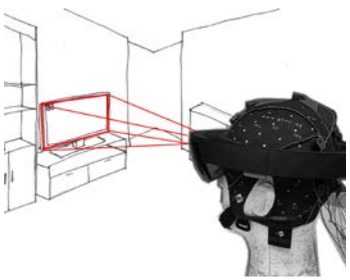

Figure 3: This living room scenario shows the detection of an object, such as a TV. This can be done by placing markers on real world objects.

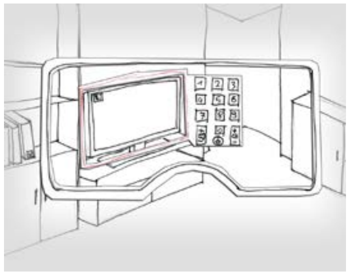

Figure 4: This illustration shows the view from the inside of the HoloLens. After detecting the TV, the HoloLens blends in a remote control layout next to the TV.

After this, a specific interaction can occur. The virtual remote control icons will start to flash until the P300-based approach of the g.tec BCI analyzes and processes the signal on a separate computer. The result will then lead to execution of the desired action, such as turning on the TV.

In a prototype, we have already managed to establish the necessary UDP connection between the Microsoft HoloLens and the g.tec BCI computer. The next step on the interaction is the identification of the brainwave signal.

With machine learning algorithms it would be possible to drive this even further. The system could analyze and track which objects in the environment are most frequently used and setup the fitting interface automatically, when they come in the field of view.

Conclusion and future work

With the MR-Braintap, we attempt to combine a mixed reality glass, with an EEG-based BCI. We propose an MR interactive interface design approach, which supports the wearer to achieve virtual interaction elements in their personal environment. This technology may be especially useful for people living with severe physical disabilities. The user simply looks at the interaction control board in the Microsoft HoloLens and a function, like in a smart home context, is triggered and automatically adjusts to the detected object in the real world.

Future work could explore questions about the comfort of wearing the system, or questions about the details of how to connect it with different smart home devices. Exploring these topics, different assistive devices can be designed, not only for the elderly but for persons of all ages with severe physical disability.

Overall we see it as the first approach to create a supporting device, which can be used by anyone who is restricted in their movement and want to gain greater control of their environment. It might help them to reclaim a bit of their freedom through the advantages of virtual elements in the real world.

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