

Superman-like X-ray Vision: Towards Brain-Computer Interfaces for Medical Augmented Reality

Tobias Blum₁*

Ralf Stauder₁

Ekkehard Euler₂

Nassir Navab₁

₁Computer Aided Medical Procedures & Augmented Reality (CAMP), Technische Universität München, Germany

₂Surgery Department, Klinikum Innenstadt, LMU München, Germany

ABSTRACT

This paper describes first steps towards a Superman-like X-ray vision where a brain-computer interface (BCI) device and a gaze-tracker are used to allow the user controlling the augmented reality (AR) visualization. A BCI device is integrated into two medical AR systems. To assess the potential of this technology first feedback from medical doctors is gathered. While in this pilot study not the full range of available signals but only electromyographic signals are used, the medical doctors provided very positive feedback on the use of BCI for medical AR.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Artificial, augmented, and virtual realities—;

1 INTRODUCTION

One of the visions of medical AR is enabling surgeons to have a Superman-like X-ray vision into patient. The use of display devices such as head-mounted displays (HMD) to augment pre- or intra-operative images onto the patient comes already very close to this idea. Just like Superman, surgeons do not want to use the X-ray vision constantly as often they have to see the skin of the patient, their hands or instruments outside the patient body. To switch between standard and X-ray vision or change parameters of the visualization, surgeons need a user interface (UI). Developing appropriate UIs for such tasks is a major problem for AR, in particular for medical AR where the user has to stay sterile and most surgeries require the surgeon to use both hands. As is commonly known, Superman does not need a traditional UI, but can control the X-ray vision with his mind. This paper presents first steps towards transferring the concept of mind-controlled X-ray vision from comic books to medical AR by using gaze-tracking in combination with BCI devices that measure bioelectric signals.

Augmenting structures inside a human body, while at the same time showing structures outside the patient, is a common problem in medical AR. Most systems use transparency [4] which can lead to bad depth perception and requires an UI to change the transparency. An alternative are virtual windows, a visualization technique that has already been used by one of the very first medical AR systems [1]. While such a visualization improves depth perception, the virtual window hides real objects. In [2] a similar technique was used, where augmented objects do not completely occlude the patient skin, but the visibility of some features is preserved based on surface curvature. For non-medical AR, different solutions to visualize occluded objects have been proposed using e.g. visual saliency [7] to preserve information on the occluding object while showing the occluded object. While such methods can improve the perception, in particular for medical AR it is crucial that the surgeon can control the visualization. Using methods that automatically de-

cide which features of the real and the augmented images should be presented are problematic in medical AR.

BCI devices have been used in combination with AR by [3] and by [9] in steady-state visual evoked potential (SSVEP) BCI systems. SSVEP systems use active stimuli such as flickering lights or patterns and can detect if the user is looking at them. In both systems AR was used to augment active stimuli that allow triggering interactions with real objects.

2 METHODS

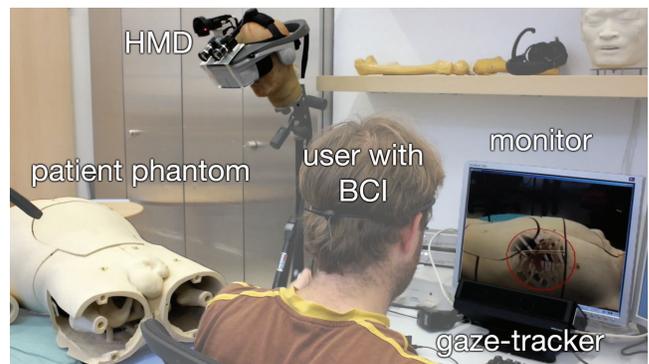


Figure 1: Setup using a HMD, a monitor-based visualization, a gaze-tracker and a BCI.

We integrated a BCI device and a gaze-tracker into two medical AR systems. We used the Neural Impulse Actuator (NIA) by OCZ Technology. The NIA is a head-band that can read bioelectric signals. It can be used to read alpha and beta brain waves, electromyographic (EMG) and electrooculographic signals. The device is marketed for computer games and is based on technology for hands-free computer access for people with disabilities. After initial tests it has shown that learning how to control the alpha and beta waves requires a longer learning phase. The goal of our pilot study was to get first feedback from medical doctors (MD) on the use of BCI. Although alpha and beta waves would allow controlling additional parameters [5] we decided not to use them to avoid the learning phase for the MDs. Using the electrooculographic signals, which are triggered by eye movement, the user has to look to the left or right. Because the gaze position is important, as will be detailed later, the use of eye movement showed to be difficult. For this study we focused on the use of EMG signals as controlling them can be learned within few minutes. EMG signal raise with muscle tension. It has shown that the easiest and most robust way for the user to increase the EMG signal is to raise the eyebrows. As an alternative BCI device we tried the NeuroSky mindset, a similar device, which can detect brainwaves, concentration and eye-blinks. We decided not to use the mindset in this study for different reasons. The mindset was too big to fit under the HMD. Furthermore it was difficult to differentiate between normal eye-blinks and eye-blinks that should trigger an action. The use of the concentration value has shown to

*e-mail: blum@in.tum.de

be difficult, as during a surgery it is difficult for the user to control the concentration. In addition to the BCI a gaze-tracker was used. The gaze-tracker is a Tobii X60, which detects the gaze of the user on a monitor.

The first system where we integrated the BCI and the gaze-tracker is a medical AR system that uses an optical tracking system and a video see-through HMD to augment a volume rendering of a CT on a patient [8]. It uses a focus and context visualization [2] where augmented objects are shown through a focus window. The setup with the BCI is shown in figure 1. We implemented two different methods to use the BCI. In the first method, the focus window and the augmented anatomy is only shown as long as the EMG signal is above a threshold. When using the HMD, the focus window is fixed to the center of the view and can be controlled by moving the head. We also presented the images from the HMD on a screen to the surgeons. In this setup the gaze-tracker is used to control the position of the focus window. In the second method, a peak in the EMG signal is used to switch between three different visualization modes. In the first mode, no augmentation is shown. By an EMG peak the second mode is activated where the position of the focus window is controlled by the gaze. In the next mode the focus window is fixed to the current gaze-position. The next EMG peak will switch off the augmentations again.

The second system we integrated the BCI is CamC [6], a monitor-based medical AR system where an optical camera is mounted next to a mobile X-ray device. Using a mirror construction the optical camera has the same view on the patient as the X-ray device. The X-ray and the video image are overlaid by a one-time calibration. CamC has been used in over 40 real surgeries. The standard visualization method of CamC combines the X-ray and the optical image using simple alpha-blending. A slider on a touch-screen controls the alpha value. Using the touch-screen during a surgery is difficult as the surgeon has to stay sterile and in most OR setups the screen is not within reach of the surgeon. Usually it can only be operated indirect via communication with a nurse. The BCI was integrated similar as in the HMD-setup. Using peaks in the EMG signal the user can switch between three modes, where in the first mode only the X-ray is shown, in the second mode the video is augmented in a circular area around the current gaze-position, and in the third mode, the area where the video is shown is fixed.

The system was shown to 9 medical professionals, 3 of them female, and with an average age of 32.7. 6 of them were last year medical students. We explained the technology to them and familiarized them with the BCI and the gaze-tracker. All participants used the HMD-based setup once wearing the HMD and once using the monitor and the gaze-tracker. The use of the BCI with CamC was illustrated to them. All participants were made familiar with the possibility to capture additional brain waves and use them to control additional parameters. Afterwards they answered several questions on a scale between 1 (I totally disagree) and 5 (I totally agree).

3 RESULTS

For the majority of the participants the BCI was intuitive to use (4.6 ± 0.7). Surprisingly they rated the possible use of BCI for non-AR applications higher (4.0 ± 0.7) than for HMD-based (3.6 ± 1.0) and monitor-based (3.8 ± 0.7) AR. The additional use of gaze-tracking was seen as very valuable (4.7 ± 0.7) and most participants preferred using a peak in the EMG signal to trigger an interaction over using constant muscle activity (4.2 ± 1.0). Most participants could imagine using a BCI for a short time during a surgery (4.6 ± 0.5) while there was no clear tendency on whether the use during a whole surgery is acceptable (2.7 ± 1.2). Most participants stated that the recognition of the BCI events has to be improved (4.1 ± 1.1) and the majority would be willing to spend time to learn how to use brain waves to control additional parameters (4.2 ± 0.7).

4 DISCUSSION

We presented an integration of a BCI device and a gaze-tracking into medical AR systems and a pilot study to assess the potential of the technology. One drawback of the study is that no brain waves but only EMG signals have been used to avoid a learning phase for the MDs. However an important result from the questionnaire was that most participants would be willing to spend time to learn how to interact using brain waves. We encountered some problems with using the BCI device in combination with the HMD. Sometimes the HMD put too much pressure on the sensor which led to problems in obtaining a signal from the user. However BCI devices are interesting in particular for HMD-based AR as they could be integrated into HMDs. For two users the BCI device did not work immediately but we had to change the activation thresholds as their EMG signals were constantly higher as for the other users. Apart from this, both the BCI and the gaze-tracker worked for all participants. While this was only a pilot study to assess the possible use of BCI the results are promising. We only used very simple hardware and a very short training period. Nevertheless the majority of participants was in favor of this new kind of UI and found this Superman-like mind-controlled X-ray vision very intuitive. Using more advanced devices and trained users, it would be possible to control additional parameters. While BCIs could also be beneficial for other AR applications, they are interesting in particular for medical AR, where the use of the hands in an UI is usually not possible.

ACKNOWLEDGEMENTS

This work is supported by the Deutsche Forschungsgemeinschaft (DFG), Research Grant NA-620/8-1.

REFERENCES

- [1] M. Bajura, H. Fuchs, and R. Ohbuchi. Merging virtual objects with the real world: Seeing ultrasound imagery within the patient. In *ACM SIGGRAPH Computer Graphics*, volume 26, pages 203–210. ACM, 1992.
- [2] C. Bichlmeier, F. Wimme, S. Heining, and N. Navab. Contextual anatomic mimesis hybrid in-situ visualization method for improving multi-sensory depth perception in medical augmented reality. In *Mixed and Augmented Reality, 2007. ISMAR 2007. 6th IEEE and ACM International Symposium on*, pages 129–138. IEEE, 2007.
- [3] J. Faller, G. Müller-Putz, D. Schmalstieg, and G. Pfurtscheller. An application framework for controlling an avatar in a desktop-based virtual environment via a software ssvp brain-computer interface. *Presence: Teleoperators and Virtual Environments*, 19(1):25–34, 2010.
- [4] M. Kersten-Oertel, P. Jannin, and D. Collins. Dvv: towards a taxonomy for mixed reality visualization in image guided surgery. *Medical Imaging and Augmented Reality*, pages 334–343, 2010.
- [5] D. McFarland, D. Krusienski, W. Sarnacki, and J. Wolpaw. Emulation of computer mouse control with a noninvasive brain-computer interface. *Journal of neural engineering*, 5:101, 2008.
- [6] N. Navab, S. Heining, and J. Traub. Camera augmented mobile c-arm (came): Calibration, accuracy study, and clinical applications. *Medical Imaging, IEEE Transactions on*, 29(7):1412–1423, 2010.
- [7] C. Sandor, A. Cunningham, A. Dey, and V. Mattila. An augmented reality x-ray system based on visual saliency. In *Mixed and Augmented Reality (ISMAR), 2010 9th IEEE International Symposium on*, pages 27–36. IEEE, 2010.
- [8] T. Sielhorst, M. Feuerstein, J. Traub, O. Kutter, and N. Navab. Campar: A software framework guaranteeing quality for medical augmented reality. *International Journal of Computer Assisted Radiology and Surgery*, 1:29, 2006.
- [9] K. Takano, N. Hata, and K. Kansaku. Towards intelligent environments: an augmented reality-brain-machine interface operated with a see-through head-mount display. *Frontiers in neuroscience*, 5, 2011.