Project Proposal

LOOKING AROUND IN A VIRTUAL WORLD

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Abstract:
The aim of this project is to develop a smart camera for virtual worlds, based on EEG (electroencephalographic) measurements. The influence on the camera could range from a mouse-look alternative, to gently nudging the camera to where the user is attending. Currently, there are two methods that could be used: covert attention, and eye movement. For this project, we will implement these pipelines, evaluate them offline, and design a mapping to camera movement, to culminate in on-line experiments to determine the usability and user experience.

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1. PROJECT OBJECTIVES

So far, most brain-computer interfaces seek to replace traditional input modalities, like mouse or keyboard. However, current EEG(electroencephalography)-based BCIs (brain-computer interfaces) have considerable problems: long training, low detection rates, sensitivity to noise, low speed, cumbersome hardware. These make it difficult to make such BCIs an interesting replacement for able-bodied users.

We want to develop a BCI that could potentially be a valuable addition to walking around in virtual worlds. What happens if we use the direction the user is covertly paying attention to, to modify the camera through which the user sees the virtual environment? This could be done explicitly, as an intuitive alternative to the common mouse-look (without changing the direction of movement), or more implicitly by gently nudging the camera into the direction of attention. Secondly, how does this covert attention paradigm compare to interaction based on overt attention: eye movement (to be measured with EOG, and later maybe just by frontal EEG channels). Can we map the directions derived from these paradigms to camera movement in such a way that it is appreciated by the user? And do these paradigms still work in a more game-like environment, with all the distractions that come with it?

The goals of the project are:

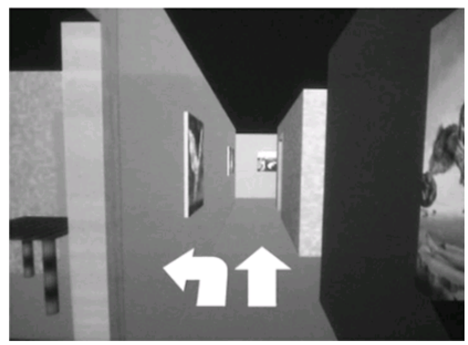
- Offline and online pipelines for detection of covert attention and eye movement, plus evaluation of their performance and speed.
- Online prototypes which use covert attention and eye movement for camera control in a virtual environment, evaluated on the usability and user experience.
- A final prototype using covert attention and/or eye movement for camera control in a realistic game environment.

Participants will gain experience considering the topics: BCI, EEG, EOG, eye movement, signal processing (Python), usability and user experience evaluation, and the development of virtual environments (Unity3D). Additionally, they experience cooperating in a team with a variety of backgrounds, to work on a multidisciplinary research area.

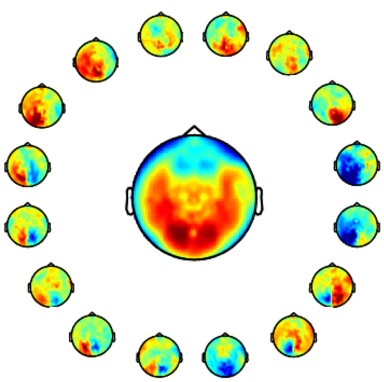
2. BACKGROUND INFORMATION

BCI applications for healthy people are on the rise. However, considering the many issues that come with BCIs, how can we make it a valuable addition to current input modalities, in such a way that this large target group will accept this new modality? This eNTERFACE project is based on the idea that BCI may be more valuable when do not use it to replace traditional input devices. Brain activity provides a wide array of information, which could be used in innovative, new ways (Nijholt, 2009).

Secondly, the experience of the user, the subject, has so far been largely ignored by the BCI community, which has mainly focused on detection accuracy and bitrates. Nonetheless, usability and user experience are very important for user satisfaction and acceptance of this new technology.



It has been proven that BCIs can work in virtual environments, and that this can be very motivating for the subjects (Leeb et al, 2007; see figure). Lécuyer et al. (2008) provides a nice overview of a variety of virtual environments controlled by BCIs in different ways. As they focus mainly on direct control in the form of replacement of traditional input modalities, adjusting the camera point-of-view is not yet one of the mentioned ways for control.



Covert spatial attention is a relatively new BCI paradigm. Posterior alpha activity is modulated by the location of covert spatial attention (see figure left, from the poster by Bahramisharif, SIREN 2009). In an MEG study, four classes (up/down/left/right) were classified with 69% accuracy, based on 2.5s windows (van Gerven & Jensen, 2009; van Gerven et al., 2009). "Covert spatial attention is a promising paradigm for BCI control since it is natural for the subject to orient one's attention to the direction of intended control. Furthermore, little training time is required in order to attain acceptable results. However, at present the paradigm remains relatively unexplored." (van Gerven et al., 2009). Previous work by Kelly et al. (2006) shows a two-class covert spatial attention class achieving a bit rate of 7.5 bits per minute.

Deng et al. (2009) classified eye movements in four directions (up, down, left, right) based on EOG measurements, with very high accuracies. Another group implemented an EOG mouse cursor, and published a paper on solutions for common problems with eye-gaze interfaces (Yagi et al., 2007).

TECHNICAL DESCRIPTION

Technical description

Brain and EOG signals are recorded with an *EEG system*. These signals are analyzed by the *BCI pipeline*, and the results are communicated to the *application* to adjust the camera.

EEG system: At the moment, the only option available would be to use a BioSemi set we can bring. However, an Enobio head set and an Emotiv set have also been ordered. Before the start of the project it will be decided what set would be the best considering signal quality and user experience.

BCI pipeline: Python will be used for signal processing. The golem library will be used for machine learning functions, and psychic for EEG processing. Other relevant libraries are numpy, scipy, matplotlib, and cvxopt. Information about these methods will be provided in advance, and experts are available for advice.

Application: The virtual environment will be developed with Unity3D, a platform-independent game engine. Unity3D can be scripted in a variety of languages – we will probably limit ourselves to JavaScript. This way cameras can be easily adjusted.

Resources needed

Facility: room for 5+ working participants; a quiet room with desk and chair for experiments

Equipment:: a PC for each participant – **bring your own laptops!;** we bring EEG + EOG sensor equipment, plus laptops to run the experiments on.

Software: Unity3D; Python in combination with golem (machine learning library, golemml.googlecode.com) and psychic (EEG signal processing library, psychicml.googlecode.com) – see *technical description* above.

Staff:: See *Profile of Team*

Project management

The *project leader* is responsible for the global project management. After the splitting up in *teams*, one on the team will be appointed as *team leader* for the management within that team. Two times a week there will be a *progress&plans meeting*, during which the schedule can be adjusted and new plans can be made if required by new developments.

3. WORK SCHEDULE

Preparation

Due to the restricted duration of the workshop, there is some preliminary work to be done before the official start. Participants are expected to read recommended literature, and already think about the group they would prefer to be in. The software will also be available in advance, so participants can already try to set it up. Short tutorials will be made available to give everybody an easy start. The protocol and questionnaires for the main experiment will also be developed in advance, as far as possible.

Workshop schedule

	Everybody	*Covert Attention Group*	*Eye Movement Group*	*Game & Task Group*
Week 1	Kick-off meeting: split into groups Setting up computers with the necessary software	CA Pipeline implementation and offline evaluation Report implement-ation and results	EM Pipeline implementation and offline evaluation Report implement-ation and results	Preliminary experiments for evaluation of pipelines Report methods
Week 2		Mapping of CA classification results to camera action + preliminary tests Report mapping	Mapping of MA classification results to camera action + preliminary tests Report mapping	Development of virtual environment and implementation of tasks, questionnaires Report methods
Week 3	Conduct experiments	Analysis of CA	Analysis of EM	Analysis of usability and user experience
Week 4	Demonstrate prototype Review meeting: discuss future work and cooperation	Analysis of CA wrap-up Report CA-part wrap-up	Analysis of EM wrap-up Report EM-part wrap-up	Analysis of usability and UX wrap-up Report wrap-up

4. BENEFITS OF THE RESEARCH

The focus in BCI research is still mainly in the area of performance. This research may contribute in the so-far-ignored fields of usability and user experience. Secondly, it will move two paradigms that have so far been used in more abstract clinical environments into a more game-like environment, testing its applicability in more realistic settings.

Tangible results at the end of this project:

- An evaluated offline and on-line covert-attention pipeline
- An evaluated offline and on-line eye-movement pipeline
- A virtual world application that adjusts the camera based on covert attention and eye movement.
- A demo movie
- A report for the eNTERFACE proceedings

All the developed software will be available on a freely accessible project website.

Besides these direct deliverables, this project will provide its participants with background knowledge, experience, skills, and practice with the paradigms in an online (real-time) game-like setting, and evaluating them based on the usability and user experience.

5. PROFILE OF THE TEAM

Principal Investigator
Danny Plass-Oude Bos, *PhD Candidate (attending the full 4 weeks)*
After expanding her computer science education with some subjects about neurophysiology, she did her internship at the University of Nijmegen in 2007, implementing physiological artifact detection in an online EEG-based BCI system. In 2008 she obtained her master thesis in Computer Science (Human-Computer Interaction specifically) on BrainBasher, looking into the user experience of using BCI for games. At the moment she is working as a PhD student at the University of Twente, still attempting to merge BCI with HCI by researching how BCI can be made a more intuitive means of interaction.

Proposed Staff
Mannes Poel, *Assistant Professor (attending 2 weeks)*
Mannes Poel is assistant professor at the Human Media Interaction group of the department of Computer Science of the University of Twente. He has a background in pure mathematics and theoretical computer science. After working several years on verification of concurrent processes he shifted his interest in Neural Networks, Machine Learning and Artificial Intelligence. At the moment his research focuses on Machine Learning in the context of Human Behavior Computing, including Brain Computer Interfaces (BCI). Currently he supervises several PhD students in these areas. He has published several papers on Machine Learning in Human Media Interaction, some of them also focusing on affective dialogue management. He participates, among other projects in the Dutch project BrainGain and the European project AMIDA.

Bram van de Laar, *PhD Candidate (attending 2 weeks)*
Bram obtained his Bachelor degree in Computer Science (2006) and Master degree in Human Media Interaction (2009). With a broad interest in technology, such as: 3D, video, networking, music, sounds, haptics, brain-computer interfacing and physical exertion, Bram tries to combine different media to create a synergy by exploiting different modalities. User experience and 'added value' play an important role in this philosophy. As a PhD candidate Bram gets the space to explore the possibilities in this area.

Ali Bahramisharif, *PhD Candidate (attending 6 days over 3 weeks)*
Ali Bahramisharif got his bachelor's and master's degree in the field of Electrical and Electronics Engineering from Sharif University of Technology and Tarbiat Modarres University, Tehran, Iran, respectively. Since April 2008, he is working as a PhD student at the Intelligent Systems group of Radboud University Nijmegen, and as of Feb. 2009 he has appointed as a part-time researcher at the Donders Institute for Brain, Cognition and Behaviour, Nijmegen, the Netherlands. Research interest includes brain-computer interfacing (BCI), machine learning and pattern recognition. His recent research focuses on using covert spatial attention for BCI.

Boris Reuderink, *PhD Candidate (pending)*
Boris Reuderink obtained his master degree in 2007, after spending time on different machine learning problems, including OCR of handwritten text on envelopes and the detection of laughter in audio-visual data. Brains and intelligence have always been his guiding interests. These interests can be combined his PhD position at the University of Twente, for which he focuses on making BCI function in real-world settings for healthy users.

Other researchers wanted
For the Covert Attention group, preferably we are searching for a PhD student or researcher with experience in EEG signal analysis; for the eye movement group somebody with signal processing knowledge; and for the game and task development group, experience with usability and user experience evaluation is a pro.

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