Networked Eye-trackers in Shared Multimodal Collaboration

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In this project we will implement a set of low-cost eye-tracking devices, connect them and employ to gain better understanding of communication patterns in face-to-face and distant collaboration and learning.We will develop a shared multimodal environment, consisting of networked eye-trackers and a joint gaze-display, and test it on hands-on data capture and analysis. Given the time constraints, a real-time gaze transfer over distance will be tested in remote educational and problem-solving tasks.

Participants will learn the principles of gaze tracking both on the hardware and software level, the role of gaze in multimodal communication, eye-tracking signal analysis, and methods for gaze transfer.

The project is linked to research projects currently conducted at the University of Eastern Finland related to expertise and engagement in collaborative tasks. Preliminary work has been done in cooperation with EU FP7 project TA2 at the Brno University of Technology (http://medusa.fit.vutbr.cz/TA2/). The team will be lead by Dr. Roman Bednarik (http://cs.uef.fi/~rbednari/) with assistance of his group members.

2. Project objectives

Gaze plays a central role in conversation, communication, and collaboration (Ishii & Nakano, 2010). In everyday social interaction participants use gaze to signal their interest and mutual understanding (Clark & Brennan, 1991). In remote collaborative situations, gaze is either missing completely or it is hard to interpret it from a video stream. With the increasing use of systems for online video mediated conversation, it is however important to gain understanding of the role of gaze in remote collaboration. Gaze-aware intelligent systems could aid communication, could infer various qualities of collaboration, such as estimate the interest or engagement of the participants. If reliable models of gaze could be derived, behavior of embodied humanoids and/or assistive tools could also be improved. Finally, gaze-aware collaborative environments could be developed, such as collaborative natural interaction games.

In this project we will build a multimodal environment consisting of several connected eye-trackers and collect data to gain deeper understanding of the role of gaze in collaboration. We will employ several eye-trackers, either custom built or commercial, and together with video and audio data we will analyze the behaviors of simultaneously interacting participants during problem solving. The project merges computer vision, video analysis, networking and human-computer interaction topics.

The resulting framework will allow:

- gaze tracking on a single head-mounted tracker
- connecting a large number of eye-trackers and tracking of multiple users
- mapping each eye-tracker scene and gaze to the shared work environment
- further improvements, such as mapping the point of gaze of each participant to the content of the environment, resulting eventually into a gaze-aware collaborative tool

Participants will learn the principles, benefits and challenges of eye-tracking both on hardware and on software level.

3. Background information

Browsing the proceedings of ETRA (Eye tracking research and applications) will provide a good introduction to the state-of-the-art of applied eye-tracking. For an

overview of eye tracking research till 2002 see Duchowski(2002), and more recent treatment of the methodology in Holmqvist et al. (2011).

In the project will design and build a head-mounted eye-tracker, similar to the one presented in Li et al. (2006). For processing of the data, we will use some combination of the methods developed in ITU gaze tracker (http://www.gazegroup.org/downloads/23-gazetracker) and those in Haytham project (http://www.itu.dk/research/eye/?page_id=19). Participants are advised to get familiar with them before the beginning of eNTERFACE.

4. Detailed technical description

a. Technical description.

This project consists of three work-packages. The development, implementation and testing of the outcomes will create a prerequisite environment in which further studies and research can be conducted.

At the beginning, we will assemble a wearable eye-tracking glasses (inspiring illustration below) using components, available off-shelf. With available open-source packages, such as OpenCV, ITU and Haytham, we will connect the hardware and start collecting data from the eye-tracker in real time.

Figure 1: Example of a wearable eye-tracking system (Tobii, 2012).

In parallel, we will develop a system able to map the dynamic scene view to with a predefined shared workspace, such as a projector screen. We will employ fiducial markers or/and some other advanced computer vision approach. OpenCV, or a similar system, will be used for tracking of markers.

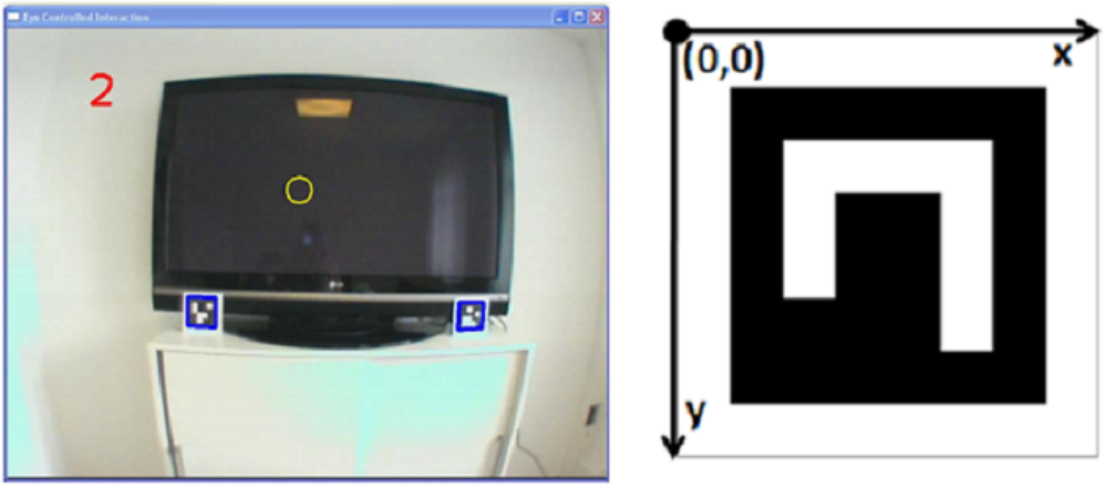

Figure 2: Example of passive marker system (Dikablis - Ergoneers)

Finally, we will build a networked solution that will integrate the data from multiple, yet connected, eye-tracking stations onto the shared workspace.

Figure 3: Smartboard interaction enhanced by real-time gaze. Adopted from http://bit.ly/XPdLNc.

Work-packages

WP	Name	Est. efforts (hours)
1	**Eye tracking system implementation and cloning**	**150**
2	**Integration, mapping and environment setup**	**200**
3	**Use, annotation and analysis**	**100**

Equipment needed

For each participant: A computer with Windows 7/Linux, microphones, two high quality webcam (e.g. Playstation camera) one to be dismantled, one scene camera. Optics - lenses, and IR, resistors. Frames and other tools will be brought to the workshop.

A computer for integration and a network switch, projector, a scene camera.

Personnel/Participants

A team of 6-8 researchers would be an ideal workforce to attack the challenges of this project.

The candidate participants are expected to have good programing skills (C/C++/C# preferred) and be fluent in as many as possible of the following areas:

- HCI and interaction design
- Image processing (OpenCV and similar)
- API and network programming programming
- Collaborative technologies, CSCW

Management

PI will be overlooking the progress of the project, in both local and remote way. Two PI's research group members will be available for supervision, implementation help and integration. Each team member will have distinct responsibilities in the project contingent on the skills and expertise.

5. Work plan and implementation schedule

	Week 1	Week 2	Week 3	Week 4
WP1				
WP2				
WP3				

WP1 Eye tracking system implementation and cloning
In this package, we will build a prototype of the wearable system, test it and then clone to get a set of eye-trackers (devices so each team member should have one to take). We will use off-the-shelf hardware with small modifications and readily-available software to conduct data collection. A state-of-the-art eye-tracker will be available for comparisons of the performance of the custom-developed devices.

WP2 Integration, mapping and environment setup
The eye-tracking systems will be integrated to the form networked collaborative system. The scene, as viewed from each eye-tracker, will be mapped onto the common shared environment (e.g. a projected desktop or a conference video). The environment will be tagged by fiducial markers and those will be tracked from each of the connected eye-trackers. A networked solution will be developed to allow concurrent transmission of the mapped gaze coordinated onto the common shared plane.

The central deliverable will be formed in WP2: an integration and mapping of marker tracking with gaze direction, and networked eye-tracking combining data from connected devices.

WP3 Use, annotation and analysis
Upon the integration, we will study, for example, remote Lego building and other problem-solving tasks such as repair situations, debugging or text processing. The data will be captured for later analysis. Using state-of-the-art methods and tools, we will analyze the captured data for typical patterns and we will attempt to build models that will be able to recognize the quality of behaviors. These models can be later used for building interactive support systems or gaze-aware systems. An example of gaze-aware environment could be built given the progress of the previous two packages and satisfactory mapping of gaze to the environment.

6. Benefits of the research

The central novelty here is the development of networked eye-tracking collaborative system. It will consist of two primary components, both will be made available. Mapping of gaze onto the environment using markers will be adopted from related projects and if possible, added to an existing eye-tracking package. The second component will focus on networked eye tracking.

It is expected the team will collaborate on a scientific publication describing the development process and testing of the system. Guidelines for building similar solutions will be published.

The developed project will be used for future research of gaze-aware collaborative systems. A dataset will also be published for scientific audience.

7. Profile of team

Roman Bednarik (http://cs.uef.fi/~rbednari) is at present (2011-2013) an Academy of Finland principal project investigator. He has been an assistant professor at the University of Eastern Finland (UEF), 2007-2011, and he is a docent of interactive technologies at UEF since 2012. Dr. Bednarik has published over 60 scientific publications in high-quality forums (IJHCS, BRM, JEMR, ETRA, B&IT), focusing on the methodology of eye-tracking, analysis of gaze data and design of intelligent applications. He has also been involved in the development and evaluation of Jeliot 3, an educational tool that received a Premier Award for Excellence in Engineering Education, finalist candidate, 2007. In 2011, Bednarik was a visiting scholar at the School of Information Sciences, University of Pittsburgh, USA. In 2011 - 2013 Bednarik has been a co-organizer of workshops on dual eye-tracking at ECSCW'11 and ACM CSCW'12, and other eye tracking workshops at major international conferences, such as PETMEI'13 at ECEM.

Two eye-tracking researchers from UEF will participate in the development, Mr. Shahram Eivazi (http://cs.uef.fi/~seivazi/) and Ms. Hana Vrzakova (http://cs.uef.fi/~hanav/). Both bring expertise in design and implementation of eye-tracking systems and in advanced analysis methods for eye-tracking data.

Researchers needed

The optimal candidates should have skills in human-computer interaction and development of interactive technologies. Good programming skills will be needed to integrate the developed tools. Previous experience with OpenCV programming will

be of great benefit.

8. References:

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