eyeTS: **eye**-tracking **T**utoring **S**ystems

Towards User-Adaptive Eye-Tracking Educational Technology

eNTERFACE 2012 Project Proposal

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Abstract

The eyeTS project investigates the statistical properties of eye movements to information displayed to a learner by a foreign language learning tutoring system. In an eye-tracking experiment the granularity of the information is manipulated. Two questions are asked in this context: (1) Can learners' actions be predicted based on their allocation of attention to the different types of information? and (2) Can the amount of attention allocation to coarse- vs. fine-grain information be used to predict their learning gain?

Technical implementation of the project involves integration of a Facelab 5 eye-tracker with a foreign language learning platform via Text 2.0, an open-source infrastructure for tracking eye movements to web-based content. The project comprises the technical implementation, conducting an eye-tracking experiment, and eye movement analyses in order to answer the two above-mentioned research questions and to make suggestions on the eye movement regularities which a user-adaptive language learning interface should consider.

1 Objectives

Aiming at cognitively-motivated adaptivity for intelligent tutoring systems (ITS), we propose to use eye-tracking to collect data on learners' gaze behavior during interaction with a tutoring system, in order to predict their learning paths, on the one hand, and their learning success, on the other. Ultimately, eye-tracking data collected in real-time would be fed back to the tutoring system which would adapt to the learner based on a predictive model exploiting eye movement information. Hence **eyeTS**: an ITS which keeps track of the learner's eye movements, in other words, is eye gaze-aware.

In this project we will focus on computer-assisted language learning (CALL) as the tutoring domain while addressing two research questions:

(1) Is learners' gaze behavior while learning with an interactive CALL system predictive of learners' actions?

(2) Are learners' gaze patterns while inspecting a CALL system's feedback of different granularity predictive of learning gains?

More specifically, in (1) we hypothesize that learners' choice of action – e.g., continuing an exercise at the same level, moving to a more difficult level, or returning to an explanation of a

language phenomenon – can be predicted based on the inspection time (and/or number of fixations) allocated to different types of contents displayed by the interface. The granularity of the information displayed to the learner will be manipulated to contain coarse-grained information (e.g., overall score on an activity) or more fine-grained information (e.g., mistakes highlighted and corrected or meta-linguistic explanations). In (2), we ask whether the amount of attention allocation to coarse- vs. fine-grained information can predict learning gains (as measured, for instance, by pre- and posttests).

2 Background

The eyeTS project investigates the statistical properties of eye movements to information displayed to a learner by a foreign language learning platform. Specifically, we are interested in feedback provided by a, so called, open learner model.

A learner model (or student model) is a pedagogical system's internal representation of learner's knowledge. *Open* learner model (OLM) is a general term for learner models which are accessible to the learners, be it just visualized or also interactively maintained and updated by the learners [3, 2, 4].

Bull, Cooke, and Mabbott [1] presented descriptive information on users' inspection of the computer screen during learning process, in particular, during inspection of an open learner model offering multiple alternative views. Even though observation of the eye movements was potentially informative in this study, no statistical analyses of differences between inspections to selected locations (information) were presented. Therefore, the implications of the allocation of visual attention are rather limited.

In the proposed study, we take a more direct approach to modeling the statistical patterns of eye movements to information presented by a learning interface, in particular to the learner model, and use this information to predict learners' actions and learning gain.

3 Project description

In order to answer the research questions posed, we will design and implement an eye-tracking experiment infrastructure and we will conduct an experiment in which learners will interact with a language learning eyeTS, an eye-tracking language tutoring system. Interactive language learning material will be created using an existing web-based platform developed at Saarland University as part of the Allegro project (`http://www.allegro-project.eu`). Learning content will be augmented with eye-tracking-sensitive tags which enable access to information on eye fixations to web-based content. During the experiment, learners' gaze will be traced as they interact with the language learning material and subsequently statistically analyzed. The technical aspects of the project are summarized below.

Implementing the eye-tracking server The first step toward enabling gaze-aware user interaction is to develop an interface for capturing eye-tracking data. In this project, we will use Text 2.0, a light-weight infrastructure which facilitates building gaze-aware web-based applications easily (`http://text20.net`, `http://code.google.com/p/text20/`).

Text 2.0 is a software interface which serves as a link between eye-tracker data and textual data presented on a computer screen, allowing to follow user's looks to the information displayed; for instance, to specific areas of interest in a web application's interface (here: error feedback areas, the OLM views). Text 2.0 works in a client-server mode: an internet browser communicates with an eye-tracking Text 2.0 server to capture gaze behavior from an eye-tracker device. The core technical part of the project consists in programming a Facelab 5-compatible Text 2.0 server which will capture gaze data from the Facelab tracker.

Facelab 5 tracker from Seeing Machines Inc. (`http://www.seeingmachines.com/product/facelab/`) is a remote eye-tracker that can record eye gaze positions against screen, saccades

and head position for each sample. For the current project, only the eye gaze data is of interest. The sampling frequency of the tracker is 60 Hz. The visual accuracy as well as temporal resolution of the Facelab 5 tracker are at the good-enough level in order to be used to identify visual attention to rather large interest areas that are visually distinct from one another. The learning platform's user interface for the experiment will be designed with this in mind.

Developing gaze-aware learning content A gaze-aware learning scenario will be tested using an existing web-based platform for interactive language learning activities. Due to time constraints, the project will focus on only one language phenomenon as a learning target. Team members will adapt existing learning content addressing the phenomenon to make its web presentation gaze-aware. Content here includes: explanations of the language phenomenon, interactive exercises addressing it, pedagogical feedback on errors, and the part of the open learner model which presents the system's knowledge on learner's mastery of the phenomenon.

Statistical analysis Upon data collection, statistical analysis of the eye movements, we will be performed using R, an open source statistics platform (`http://www.r-project.org/`).

4 The Team

Principal Investigators:

Magdalena Wolska, Saarland University
Expertise in computer-assisted language learning, natural language processing for educational applications; Allegro project

Pirita Pyykkönen-Klauck, Saarland University
Expertise in cognitive psychology, multimodal communication, eye-tracking, statistics

Researchers:

To join the project we invite 3-4 students and/or researchers interested in intelligent tutoring systems (especially computer-assisted language learning), human-computer interaction, and eye-tracking methodology.
Technical realization of the project requires fluent Java and C++ programming skills (at least 2 participants). Other technica495(93.23-1.55762(o)5(w)-2.99886(w)-3.00625(n.68762(i))]TJ 28

7. Performing statistical analyses.
8. Writing up.

Time-schedule:

Week 1

- *Getting started:* Learning to work with the hardware and software: Facelab 5 tracker, Facelab 5 API, Text 2.0, language learning platform
- *Implementation-related tasks:* Starting to implement the Text 2.0 Facelab 5 tracking server; Adding eye-tracking data into the learning platform's session logs
- *Experiment-related tasks:* Finalizing the design of the eye-tracking experiment

Week 2

- *Implementation:* Finalizing implementation of the Text 2.0 Facelab 5 server
- *Content development:* Creating Text 2.0 learning content; testing gaze-aware language learning material
- *Experiment:* Testing the eye-tracking experiment; Data collection starts

Week 3

- *Experiment:* Completing eye-tracking data collection
- *Implementation:* Converting experiment session logs into a long data format for statistical analysis in R

Week 4

- *Analysis:* Statistical data analysis
- *Report:* Results presentation; Writing-up the report

6 Expected outcomes

The spread of PCs, laptops, tablets, and smart phones with integrated eye-tracking devices is not any more a question of "whether", but rather a question of "when". Eye-tracking-based adaptivity and user-centered personalization, that is, presentation of content tailored to the given user's predicted preferences or needs, is bound to become a commonplace feature of future applications. The results of this project will contribute to informing the design of user-adaptive interfaces, in particular, of personalized learning technology. The evaluation of the user actions taken based on different feedback types and the effects of these on the final learning score can be fed directly back to the interface, enabling online (real-time) adaptation. The architecture of a user-adaptive learning interface, such as the one we propose, is directly transferable and testable in other learning environments. Inspecting learners' visual attention is therefore expected to bring valuable information for future intelligent educational technologies.

The proposed project can be considered a pilot study on eye-tracking tutoring systems at the time when integrated eye-trackers are not yet common, producing important user experience data from language learning interfaces. Results obtained using light-weight eye-tracking technology chosen for the implementation for this project will give insight into what can be expected of the first products that will start appearing on the market.

Finally, a practical project outcome will the implementation of Text 2.0 server for the Facelab 5 eye-tracker which will be made available at the end of the project. With Text 2.0, an open-source eye-tracking infrastructure, as the core technology, this project will provide a proof-of-concept for open-source gaze-aware educational user interfaces.

References

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[4] J. Xu and S. Bull. Encouraging advanced second language speakers to recognise their language difficulties: a personalised computer-based approach. *Computer Assisted Language Learning*, 23(2):111–127, 2010.