ADAPTIVE KNOWLEDGE TRANSFER IN E-LEARNING SETTINGS ON THE BASIS OF EYE TRACKING AND DYNAMIC BACKGROUND LIBRARY

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Motivation

Based on everyday experience when dealing with computers, we may state that many times users adopt their behaviour to the computer. However, the still existing barrier of many different user groups towards the computer technology indicates a strong need for user centred design of computer applications and hardware. Computer technology evolved over the decades and significant improvements in human-computer interaction have already been made. As observed in [Norman 1998], when new technology matures and has reached the transition point, the change from technology-driven products to customer-driven, human-centered products could and should be made. Possible application domains of user centred applications adaptable to emotions are manifold, for example in many dimensions adaptable e-learning systems, personalised counselling services, technical support, marketing applications, adaptable help systems and many others.

E-learning paradigms and implementations have brought many advantages to technology-based distance education. It is now possible to identify, analyse, track and monitor relevant aspects of instruction, such as different velocities, paths, or strategies of learning. There are also attempts to integrate adaptivity into e-learning based on effective reading speed [Ng, 2003]. According to [ADL 2001], the value of personalised instruction is measurable by means of its effectiveness, e.g. a learner in a classroom setting asks on average 0.1 questions an hour, whereas in an individual tutoring setting, a learner is required to answer about 120 questions an hour. Thus, students' learning performance may be enhanced significantly through individually tutored instruction: statistically over a big number of data a standard deviation of 2 units can be measured (for details see also [Bloom 1984]).

The presented research is focused on a new generation of adaptable knowledge transfer. This new and innovative approach strives to capture dynamically user behaviour based on real-time eye-tracking system. With merging the eye tracking methods with the proper content presentation the goal is to develop methods of how to individually impart knowledge to each single learner. Moreover, the predefined learning content modules should be dynamically linked to a background library providing additional and personalised information on the displayed learning content. Innovative solutions and an improved and more profound understanding are expected in various areas, as follows:

- improved knowledge of the users' behaviour in the field of human-computer interaction in general as well as related to the displayed learning contents
- improved and detailed course-progress tracking
- more detailed recording of the consumed learning content and cognitive processes of the user
- novel possibilities for identifying the most suitable media and content presentation within knowledge transfer environments
- identification of possible user problems and development of correction and adaptation mechanisms
- identification of problematic areas in the content flow and / or content structuring
- identification of the need for detailed additional information related to the learning content, more specific to the paragraphs accessed by the user

- use of collaborative filtering methods based on user behaviours and best practices suggestions in the learning process
- improved realization and presentation of the knowledge modules under consideration of user behaviour
- fine-grained content adaptation to the each particular user

Adaptivity and Personalisation in E-Learning Environments

Tracking the behaviour of users and analysing their learning progress are not new research issues, but were demonstrated in classic systems such as CLASS and PLATO (see [Crowell 1967] and [Modesitt 1974]). There are various technical solutions of adaptable systems, like shadowing [Hothi 1998], hiding links [Brusilovsky 1998] and stretch text among others [Boyle 1998]. There are also systems, like [Sholion Wb+] that foster pedagogically structured learning contents. Modern user modelling techniques are important, as they allow systems to personalise the human-system interaction [Conlan et al. 2002]. Well-defined learner model standards and specifications, like PAPI (Public and Private Information for Learner - IEEE), IMS LIP (IMS Learner Information Package) or GESTALT (Getting Educational Systems Talking Across Leading-Edge Technologies) already exist. This brief introduction of some aspects in context exemplifies - and may also clarify - that adaptivity and personalisation constitute broad research fields with a relatively long history and a large number of significant results. However, much work is still to be done toward existent or emerging issues and challenges.

In this paper we want to strongly emphasise the need for profiling more finely-grained user information and - in agreement with [Conlan et al. 2002] - of structuring fine-grained, standardised, and adaptable learning objects. Current techniques are not able to derive fine-grained information about users' behaviour. Rather, they typically provide larger-grained information such as the monitoring of mouse clicks and mouse movements, and determining how long a user stays on a single page.

Adaptivity through Eye Tracking

AdeLE defines an innovative framework for enhancing adaptive and personalised knowledge transfer processes. This is done by exploding the advantages of merging real-time content tracking and real-time eye tracking technologies at the user's side of the system, and encompassing the functionality of a dynamic background library at the content delivery side. Let us describe which characteristics of eye tracking systems are relevant and useful to support the real-time user profiling mechanisms with the purpose of enhancing personalisation and adaptivity.

Very roughly, eye movements can be divided into two components: fixations and saccades. Fixations are periods of relative stability during which part of the visual scene is focused upon in the centre of the fovea [Jacob 1995]. During fixations, visual information is processed. Saccades are very rapid eye movements, which bring a new part of the visual scene into focus. During saccades, little or no visual processing can be achieved. Fixations last about 200 to 400 ms and exhibit velocities of around 100°/s. Saccades last about 25 to 100 ms and exhibit velocities of around 300°/s [Salvucci and Goldberg 2000]. The smaller eye movements and tremors, which occur during fixations, often have little meaning in higher-level analysis.

The fixation duration is the interval between the end of one saccade and the start of the next saccade. The gaze duration is the time spent on an object. Fixation and gaze duration are not indicative of attention per se, because one can also pay attention to objects, which do not lie in the foveal region. One must differentiate between the users' objective behaviour (eye movements), their latent cognitive operations, and their subjective impression [Galley 2001]. Saccadic velocity, which is closely related to saccadic amplitude and only assessable to eye tracking systems with high temporal resolution, can serve as an indicator for activation in the sense of tiredness or mental effort. Saccadic velocity is said to decrease with increasing tiredness and to increase with increasing task difficulty [Fritz et al. 1992]. Furthermore, blinks are interesting for our purpose. To blink means to close the eyes for a very short period to cover them with a thin film of tears [Galley 2001]. Blink velocity and frequency together with the eyelids' degree of openness can provide information on the user's tiredness level. Increasing tiredness is said to be indicated by increasing blink rate, decreasing blink velocity and decreasing degree of openness [Galley 2001].

In the AdeLE framework, the intention is to observe users' learning behaviour in real time by monitoring characteristics such as objects and areas of focus, time spent on objects, frequency of visits, and sequences in which content is consumed (see also [Preis and Mueller 2003]). It is hoped thus to gain an insight into the strategies which users apply when using an e-learning platform and to be able to detect patterns indicative of disorientation or other suboptimal learning strategies. In the context of user behaviour interpretation, it is very important to not rely exclusively on eye tracking data, but to supplement it with constant user feedback. It should be possible to suggest optimised strategies such as the best time to take a break. The ultimate goal of our approach is to assist users to improve their learning behaviour. The user will always retain the final say over whether to accept or reject the system's suggestions.

Different Eye-Tracking System Solutions and their Suitability for the Project

At present there are two types of eye-tracking systems on the market: outside-in systems and inside-out systems. Within this chapter we'll describe the characteristics of both systems. Advantages and disadvantages related to the requirements of this project will be outlined. More detailed information can be found in Duchowski (2003). See also Jacob (1995) and Galley (2001).

Outside-in systems are characterized by the fact that one or more cameras record the eye of the participant and trace the gaze in a scene through imaging algorithms. The cameras are positioned in front of the participant.

Advantages:

- cheap systems available
- can be integrated into the monitor and therefore basically invisible

Disadvantages:

- the head can't be moved a lot as it is fixed by a sort of head-rests
- small area to be measured
- visible cameras are likely to influence the participant
- calibration of the system is difficult and has to be done regularly

Inside-out systems are characterised by a special device that the participant has to wear on the head. The image of the eye is led into a mini-camera by using mirrors. This mini-camera records the eye and the actual line of vision is found out through imaging algorithms.

Advantages:

- movements of the head are compensated
- the area to be measured is theoretically endless

Disadvantages:

- the device on the head of the participant can influence his/her actions and performance
- expensive

For the purpose of our project outside-in systems seem to be more suitable, especially when considering that the intention is to provide an attentive work place and adaptable contents to a vide range of average users. Evidently, the price plays a decisive role. Survey of the existing systems has shown that the eye-tracking device can be integrated into a standard monitor (http://www.tobii.se). Due to the current trend of rapid technical progress, we expect that in the next few years it would be possible to build a low-cost but high-quality eye-tracking system based on standard hardware components which would be suitable for real-time analysis of eye-tracking information as described on this project.

The AdeLE Framework

The architecture of the AdeLE framework is shown in Figure 1. The core module is the Adaptive Semantic Knowledge Transfer Module (ASKTM). Taking a global view, the ASKTM coordinates all the surrounding modules and sends and requests information to and from them. The ASKTM compiles pieces of content and meta-information for delivery to the students. Separate interfaces are provided for the other two groups of users: content creators and trainers (or tutors). For media and platform-independence, the information is provided in an XML schema and can be transformed into various formats. Content delivery is shown in the upper left and lower left parts of Figure 1; XML-based interfaces for module intercommunication are also important for interoperability.

User-centred modules for advanced user profiling are shown in the upper right part of Figure 1. The core functionality for gaining enhanced and more precise user information is located in the combination of the Eye Tracking Module (ETM) and the Content Tracking Module (CTM). ETM in combination with CTM provides real time fine-grained data regarding the user’s reading and learning behaviour. The ETM also gives the system hints about concentration, excitement, tiredness, and level of knowledge assimilation. The entire set of information of user interaction and behaviour is supplied to the User Information Module (UIM). The Interactive Dialog Module (IDM) allows users to set and change user profile settings actively. Further, the system also can proactively force user interaction. For example, the latter module can be used to verify and if necessary adjust any automatically inferred user information. If tiredness is suspected, IDM also may be used to suggest a short break or provide a relaxation exercise to the user.

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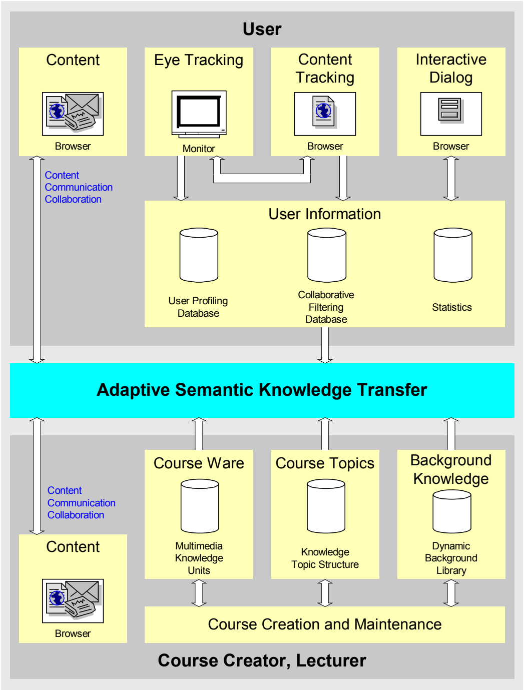

Figure 1: The architecture of the AdeLE framework.

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The UIM encompasses three user information databases of different granularity: the User Profiling Database (UPD), Collaborative Filtering Database (CFD) and Statistics Database (SD). The UPD holds fine-grained information about a wide range of user interactions (e.g. sequences of scanned and viewed pieces of information) and more abstracted values of user behaviour types (e.g. level of gained expertise in certain subtopics). Similar user profiles or user behaviour types are grouped and managed in the CFD. Through collaborative filtering, the system can proactively suggest particular pieces of information in proper media by exploiting the collective knowledge of user groups and their behaviour. Finally, the SD manages abstracted information in a user-independent level. Course creators and administrators may use valuable information (e.g. identified problematic areas of courseware sections) without violating the privacy of individual learners. The learning process will be improved, because the system will create or deliver adapted content by means of tracked statistical data (e.g. by delivering more images/tables for learners that have problems with large and complicated texts).

Lecturer-centred modules for the course creation process are shown in the lower-right section of Figure 1. The Course Creation and Maintenance Module (CCMM) represents the core module for the entire course management and controls the Courseware Module (CM), the Course Topics Module (CTM) and Background Knowledge Module (BKM). Course creators and lecturers can set up and maintain courses as well as request statistics about their courses. The CM manages pieces of information in different media types and an extensive set of metadata. CM can either store pieces of information locally or just manage metadata and include remotely located sources by caching them. On the one hand, the CTM manages course content by just defining subsections using meta-descriptors, i.e. course creators only predefine subtopics and their relations at the time of course generation. At the time of learning users get dynamically proper and most recent pieces of information out from the pool of the CM. On the other hand, the CTM permits to manage a course topics structure and a thesaurus for providing automatically relations between subsections. The BKM dynamically provides additional information within the learning process and helps course creators to keep pace with most recent information.

Concluding Remarks

The proposed innovative user-centered compilation and presentation of learning contents and lessons and related background information provided from the static and dynamic background sources supports cognitive processes and problems solving. The AdeLE framework utilises the possibilities of evaluation and analysis of real-time eye tracking and content tracking to support adaptive teaching and learning in a technology-based e-learning environment.

Such adaptable systems could be applied for learning, especially in the sensible areas where 100% knowledge acquisition in required. Furthermore, the novel approach supports the identification of the level of expertise and provides tailored knowledge transfer and personalized knowledge management, being of value to corporate knowledge management systems. Based on the generalization of user behavior related to the learning contents, information is collected and applied for improvement of the learning content structuring, information flow, additional explanation, etc.

Potential target groups that could benefit from the presented ongoing research and proposed innovations based on eye-tracking supported real-time data capturing and adaptable systems are identified as follows:

- various end-users (100% knowledge acquisition i.e. aviation, traffic, different complex procedures, risk management, decision support, research on learning, etc.)
- eye-tracking system producers (to extend the system with dynamic real-time evaluation of contents)
- e-learning platform and knowledge management platform developers (to include these innovative approaches, and provide more adaptable platforms)
- content publishers (to improve structuring of the contents, to develop user-centered contents, to develop contents supporting various learning stiles)
- hardware producers (to develop low cost eye-tracking systems)

Thus, some results of the AdeLE project may contribute to find new ways of making advanced adaptive environments for teaching and learning feasible and affordable for institutions in a relative near future. Standardisation work regarding adaptivity and personalisation in e-learning is underway in well-known institutions such as ADL and IEEE. Standards as SCORM, IMS LIP, PAPI and GESTALT are making great contributions to this field, but as yet do not include mechanisms to describe the characteristics of real-time tracking systems. We hope that the AdeLE framework will assist in the enhancement of such standards.

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