Web-based Learning Support based on Implicit Feedback

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Abstract
In many applications concerning adaptive presentation of documents (be it web-based learning or open web in general), identification of interesting fragments is useful feature for various tasks like rewriting the content or recommending to the user where to focus. We presented a method using several implicit interest indicators with emphasis on read wear and gaze tracking to identify such fragments and implemented it in the widely used web browser with use of common webcam. Also, several scenarios employing identified fragments, specifically in context of web-based learning, are presented.

Categories and Subject Descriptors
K.3.1 [**Computer Uses in Education**]: Collaborative learning, Computer-assisted instruction (CAI)

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implicit feedback, gaze tracking, read wear, web-based learning, summarization, collaboration

1. Interesting Fragments in Learning
Identification of interesting fragments of a document can be useful feature for various tasks: document summarization, revision, recommendation or simple visual aid showing where to focus. Apart from content-based methods, where we consider only document itself and its contents, we can use user feedback – either explicit, where user is knowingly rating the content, or implicit, where user is using the system as usual and the rating is inferred from his actions. Traditional explicit and implicit feedback may pose a problem in e-learning applications: explicit rating may distract the user from his primary goal to learn and implicit rating may be difficult to infer when user opens a document and reads its portion without providing any traditional implicit interest indicators like clicking, moving the cursor, etc.

We proposed a method using classic implicit interest indicators while improving rating in described situation by using read wear and gaze tracking. As users of web-based learning system do not learn only in controlled environment in usability laboratories, we use gaze tracking from common webcam with no holder or infra-red modifications. Identified fragments can be used in several scenarios ranging from simple visualization or similar notification, to summarization, to adaptive guide to learning system and to augmented communication between users.

In this paper we present this interesting fragment identification method in general, with more details on implementation and evaluation in adaptive web-based learning system ALEF [7] and we further discuss scenarios employing collected feedback.

2. Related Work
Extensive work has been performed in the implicit and explicit feedback. It has been shown that users provide explicit feedback mostly only when they are very satisfied or dissatisfied – a problem known as J-shaped or V-shaped rating curve [5]. Implicit means are often preferred and many interest indicators were described and combined [1, 3], both in relation to entire documents (click count, printing, total count of copy operations, etc.) and in relation to document's fragments (mouse pointer movement, copy operations, gaze, etc.).

Important concept in tracking fragments of document is *read wear* [4], where document is being virtually worn out according to time user(s) spent reading its parts, effectively tracking users scrolling it. However, there are recognized problems with such tracking of users viewing content — user can pursue other activities while content is displayed, he can even leave completely. While presence of user and his gaze correlates with mouse movement to certain levels [2], not all users follow their eye movement with mouse cursor. This can be enforced: text can be made unintelligible by changes in size or colour or document can be blurred and only fragments surrounding the mouse cursor will be revealed [8]. Such methods are clearly invasive to users' natural workflows.

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Less interrupting methods involve tracking of physical user, often visually and with gaze tracking. Apart from kits involving expensive custom hardware (faceLAB, EyeLink), several methods using common webcams with open source computer vision library OpenCV exist. ITU Gaze Tracker was successfully used by disabled people for text input [6]. This solution however requires either original camera-installed or custom made infrared light, which limits selection of hardware. Image of eye must fill significant portion of camera image, so the camera must be close to the eye — authors tried two solutions: holder made of office lamp or user biting into a piece of wood with camera. OpenGazer was successfully used for document summarization and for recommendation of online content [9]. OpenGazer is advantageous in common settings as no change in camera or lighting is needed and only small adjustment of position is preferred, the camera can be conveniently placed under the display. However, as the eye fills significantly smaller portion of the camera image and no clues from infra-red reflection of retina is available, lower precision can be expected.

3. Fragment Identification Based on Implicit Feedback

We track interest indicators not only in relation to the document, but also to the application itself, where document fragments pose parts of document (e.g. text sections, pictures, exercise definitions/hints/solutions) and applications fragments pose parts of system (e.g. recommendation box, menu). We divided interest indicators into groups of untargeted, passively and actively targeted and document-related indicators. By targeting we mean whether user does this action mostly when he is working with related fragment, so cursor alone is untargeted, text selection is targeted. By passively/actively we mean whether user is just looking at the content or he is actively performing actions like copying or clicking a link. We initially set weights for each of the groups and also for each of the indicators in each group. Our main interest is in read wear and gaze indicators, which are passively targeted indicators. Experimentally, we set weights to these two indicators as 1:9, because if have direct information on which content has the user looked, we give it significantly higher weight than to information that the content was simply displayed. We combine indicators collected for fragments in the straightforward manner, where we sum up weighted values of each indicator in each group and then sum up weighted groups. Attention index is afterwards normalized by the length of fragment.

4. Scenarios for the Use of Processed Feedback

Information about user's workings with the document can be used either directly (visualize important parts) or indirectly (adaptively guide the user through the workflow in the system). We propose several scenarios.

4.1 Interesting Fragments

Identified interesting fragments can be directly visualized by highlighting them in the original document. The purpose is to allow users quickly scan through documents and aim only at important or difficult fragments, or also let them learn/review materials quickly in time restricted conditions. Another possible feature is summarization, where we select only defined number of fragments with highest attention index, however without considering their content, some part of the document that is fast to skip through, but important to notice, can be lost. Therefore, such summarization may be improved by considering fragment types (e.g. leave at least figures from any part of document) or directly their content (e.g. measure stop words, extract keywords). Other means to present the fragment importance to the user is an adaptive scrollbar, which can move the document according to importance of displayed content – it should skip through unimportant fragments (move larger portion of document per pixels moved) and slow down on important fragments.

4.2 Adaptive Guide to Learning Application

The user can be aided with learning in the web-based system by providing him with clues about functions of system he did not yet discovered. For example, if the user is not using recommendation, a message pointing this feature out can be displayed. This can be accomplished by classic tracking of user actions, even on server side (tracking the requests initiated by clicks). However, by adding gaze tracking, we can differentiate whether user has noticed such feature, but ignored it (we can ask him whether he does not like the recommended items or he does not want to use such feature at all), or whether he did not notice this feature in the first place (then we can point it out or change application design to make it more prominent). Also, when we detect that user struggles with some part of the system (e.g. he is scanning through the menu for longer time), we can provide him with a box to shortly describe his problem right there. By targeting the questions and tips more adequately to current situation, user's interest in answering explicit feedback questions or taking the tips into account should increase.

4.3 Augmented Communication

Communication of users browsing the same site can be problematic, as users may be shy about starting the contact or they may do not want to distract others while learning. If we augment instant messaging by providing the users with collected information about actions of their peers, we should encourage cooperation, especially in learning application, as students see who is browsing the same content and is possibly stuck on the same parts of document when there is a problem or difficult content.

5. Evaluation

We used OpenGazer to implement gaze tracking in a standalone desktop application which communicates with applications via local sockets in server-client model. We collect interest indicators in an extension of Firefox web browser *UTrack*, which also launches and connects to the gaze tracking application. In order to identify web systems that can make use of collected feedback, such web application has to provide file called *utrack_ def.txt* where it specifies both user (selectors describing document fragment and application fragments to be tracked) and application (where to send collected information) interfaces. Upon launch of the extension, user is presented with the screen depicted in Figure 1, which guides him through set up of camera and calibration of gaze tracking.

In the ALEF web-based learning system, we implemented general mechanisms for adaptive explicit questions and tips and we created specific questions to be displayed when the extension notifies the web application of user behaviour (e.g. gazing on an application fragment for too long). Also, we implemented fragment importance

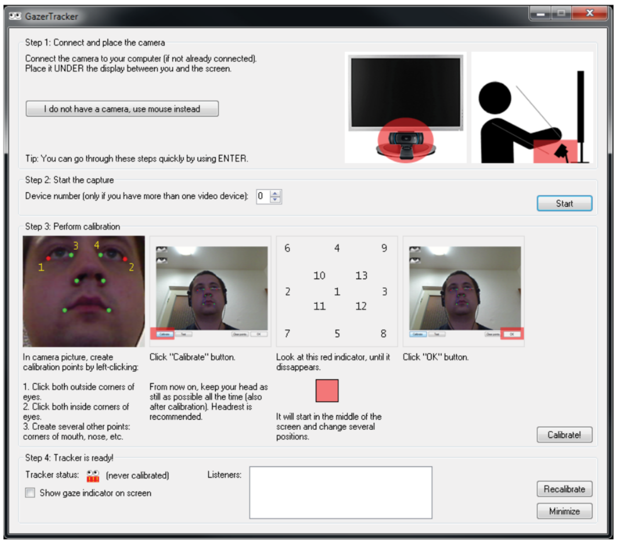

Figure 1: In-application instructions how to set up the webcam and perform the calibration.

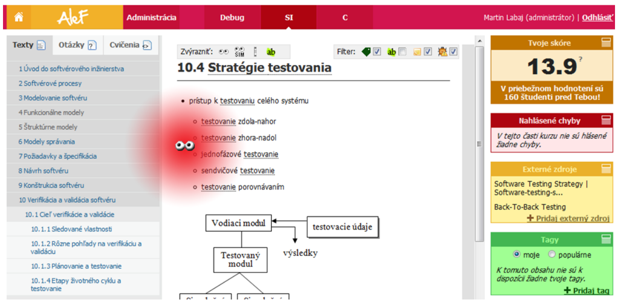

Figure 2: ALEF user interface showing document and system widgets. Fragment visualization tool is located on the left above the document.

identification. Figure 2 shows composition of ALEF instance with application fragments on sides and scrollable document in the middle. Controls for fragment visualization and approximate accuracy of gaze tracking are also shown.

We have separately evaluated gaze tracking integration in common settings, where we found achievable accuracy of approximately 90 pixels and maintainable accuracy of 200 pixels, which we have incorporated into gaze-fragment mapping by accumulating part of the detected gaze also for nearby fragments.

We also compared importance of fragments inferred using the method described against the manual explicit ratings from students using ALEF. Students used highlighting tool to highlight parts of documents they considered important in similar fashion as felt-tip highlighter with paper documents. We found that while inferred interest ratings varied throughout the documents and copied well the difficulty of fragments evaluated by domain expert, aggregated highlights (manual ratings) did not correlate at all – students perceived mostly headings as important and not more in-depth parts of content.

Furthermore, we evaluated how willing users were to provide explicit feedback when they were asked right when we detected they were working with widgets in ALEF as they gazed for 10 seconds on it. When presented with question whether they were working with detected widget, in 6.96 % cases users chose not to answer. When we used only mouse cursor position instead of gaze, we achieved better accuracy in determining correct widgets (possibly as a result of leaving mouse in the place of last action and reading on), but in 12.44 % cases users chose not to answer. As a control, such questions were also presented randomly with enough interval between any questions and in 33.33 % cases users decided not to answer. Tracking user's gaze and asking him questions about those parts of the system he has been working with yielded to more cooperation from the user.

6. Conclusions

In this paper we presented method for interesting fragment identification including gaze tracking and its implementation with common webcams in common settings. We discussed several scenarios for use of such feedback in visualization, summarization, adaptive guide or adaptive explicit feedback and augmented communication between users. Further work may be done considering content of fragments itself – e.g. by performing a keyword extraction.

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