Proactive Information Retrieval by User Modeling from Eye Tracking

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***Abstract*— In this position paper we review the results of the the eye-tracking -related part of the PRIMA project (Proactive Information Retrieval by Adaptive Models of User's Attention and Interests), carried out during 2003–2005. The project focused on how to construct and combine user models from implicit or explicit feedback signals. If proper user models can be constructed, it will be possible to build proactive applications, that is, applications that learn to anticipate the user's needs.**

Our prototype application is information retrieval, where implicit feedback signal is measured from eye movements. Relevance of read text is extracted from the feedback signal with hidden Markov models learned from a collected data set. Since relevance in general is hard to define, we have constructed an experimental setting where relevance is known a priori.

The implicit feedback signal is very noisy. Thus, it needs to be supplemented with relevance predictions from other available sources. In the prototype application an alternative relevance prediction was obtained from collaborative filtering. For new document titles the prediction accuracy with eye movements, collaborative filtering, and their combination was significantly better than by chance. The best prediction accuracy still leaves room for improvement but shows that proactive information retrieval and combination of many sources of relevance feedback is feasible.

I. Introduction

A long-term goal in user modeling for improving human-computer interaction is to understand the user's intent based on her monitored actions. If this can be done efficiently, a whole range of proactive computing applications [1] could be devised, that is, applications that predict the user's intent and adapt their behavior accordingly.

The PRIMA consortium (i.e., research groups lead by Prof. Samuel Kaski, Prof. Petri Myllymäki and Doc. Ilpo Kojo) focused on the research of a proactive information retrieval application. The key idea is to extract implicit feedback from eye movements during reading and then, in order to obtain more accurate predictions, to combine the noisy relevance predictions with other available sources of relevance information, such as collaborative filtering. In this position paper we review the eye movement part of the research.

A. Implicit relevance information from eye movements

Our first feasibility studies using eye movements were aimed at finding whether relevance can be predicted to any extent. Eye movement data was measured in controlled settings where relevance was known, and machine learning models were used to learn predictors from the data. If prediction is better than with naive models, the eye movement signal contains information about relevance.

In the first simple controlled experiment, the subject was first shown a question, and then a list of ten sentences, one of which contained the correct answer (C). Five of the sentences were known to be irrelevant (I), and four relevant for the question (R). An exploratory study [2] already showed that relevance (i.e., the class $\{C, I, R\}$ of the title) can be inferred. Later [3] we developed discriminative Hidden Markov Models for this task, resulting in a classification accuracy of 65.8 % (vs. 47.8% of the dumb model).

The eye movement data was further used in the EU PASCAL Network of Excellence Challenge during March – October 2005, organized in the form of a competition. The task of the competitors was to predict the (known) relevance of titles using eye movement data. The results were reported in a NIPS workshop in December 2005.

The project resulted in new theoretical contributions as well. We studied discriminative generative models [4] further, and developed new Expectation Maximization-type algorithms for optimizing discriminative models [5], as well as new MCMC-type methods [6].

In a second, more difficult experiment [7], the subject was instructed to choose the two most interesting titles from a list of six titles of scientific articles. Again, prediction with hidden Markov models was better than a dumb model (73.3 % vs. 66.6 %), but not by a very large margin.

B. Better accuracy through collaborative filtering

Even though eye movements carry information about relevance, the signal is very noisy. Prediction based on eye movements alone may not be accurate enough for practical purposes, and we thus investigated how much could be gained by combining eye movement information with other available knowledge. One well-studied source of relevance information is collaborative filtering, that is, generalization of relevance over similar-minded users. A new two-way probabilistic

grouping model was developed [8] to generalize over both users and documents to predict relevance.

C. Information fusion

In a realistic application there can be several different signals from which relevance information can be obtained. The availability of the signals can vary, e.g., depending on the interface used. We therefore designed a modular approach in which we constructed an individual model for each channel of relevance feedback. This approach also makes it easy to plug in new better components later to replace the ones used in our first feasibility studies.

In [7], we introduced a discriminative Dirichlet mixture model for combining the relevance predictions of collaborative filtering and eye movements. The results were better than with either method alone.

II. Conclusion

The work carried out within the PRIMA project provides the next step towards proactive information retrieval systems. We showed by controlled experiments that eye movements contain implicit feedback information which can be used in proactive information retrieval. Furthermore, we introduced a prototype application that can combine relevance information from several sources, and that the resulting predictions are better than either of the sources alone.

The very promising results are expected to improve in the on-going work where text content-based predictions are combined into the model, improving on the preliminary work described in [9]. The work includes more realistic controlled experiments that simulate search tasks, and applying text content model in a way that can be combined with information on eye movements.

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