A Learning Agent for Wireless News Access

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ABSTRACT
We describe a user interface for wireless information devices, specifically designed to facilitate learning about users' individual interests in daily news stories. User feedback is collected unobtrusively to form the basis for a content-based machine learning algorithm. As a result, the described system can adapt to users' individual interests, reduce the amount of information that needs to be transmitted, and help users access relevant information with minimal effort.

Keywords
Wireless, intelligent information access, news, user modeling, machine learning.

1. INTRODUCTION
Driven by the explosive growth of information available on the Internet, intelligent information access has become a central research area in computer science. The 20th century is commonly characterized as "The Information Age", and the sheer amount of information readily available today has created novel challenges. Numerous intelligent information agents -- software tools that provide personalized assistance for users navigating large information spaces -- have been described in the literature and deployed on the World-Wide-Web [5, 8]. However, the need for intelligent information agents is not limited to web-based applications, as we are currently witnessing an increasing trend towards "ubiquitous information access". Different types of wireless information devices, designed to tap into the Internet's vast information resources without physical constraints, are currently being released into the marketplace. For example, cell phones can access Internet-based information services, and pagers can alert users of late-breaking news. While these devices undoubtedly enhance the utility of online information and are likely to open up opportunities for revolutionary information-centric applications, they are cramped by several technical constraints. First, the small size of wireless information devices leads to inherently limited user interfaces. Second, bandwidth constraints impose limits on the amount of information to be transferred. Third -- and most importantly under current conditions -- wireless information transmission is expensive. Service providers charge users based on the amount of data transmitted, turning wireless information access into a costly luxury compared to regular Internet access. For example, transmission costs for 3Com's Palm VII amount to approximately $25 per month for 150KB, and an extra charge of 20 cents for each additional KB. We believe that intelligent information agents have the potential to significantly reduce the amount and cost of data transmitted, and will therefore be of paramount importance for ubiquitous information access applications. Agents that know about users' interests and preferences can simplify information access tasks substantially.

In this paper, we focus on a learning agent designed to help users access interesting news stories. We use 3Com's Palm VII organizer as an example of a wireless information device, noting that the learning approach and interface design reported here generalize to other devices such as cell phones or two-way pagers.

The World-Wide-Web is currently witnessing an ongoing trend towards personalized information access. As part of this trend, numerous personalized news services are emerging. For example, Internet portals such as *Yahoo*, *Lycos* and *Excite* offer personalized access to daily news stories from a large range of categories. These services are based on static questionnaires that users fill out in order to make use of news filtering capabilities. We believe that this level of personalization is not fine-grained enough for price- and bandwidth-sensitive information access. Here, we suggest the use of an intelligent news agent that unobtrusively learns about a user's interests in daily news stories by observing the user's browsing behavior. Using a content-based machine learning algorithm originally developed for a web-based client [3], the agent learns to rank-order news stories with respect to the user's individual interests.

In the following sections we first illustrate the agent's role as part of a larger architecture of personalized news services. We then describe the user interface of a client designed for the Palm VII. Porting the client from a web-browser interface that assumes a large screen and high speed Internet connection to a wireless PDA requires more than just translating the client to a new platform. We evaluated each element of the interface to determine which features are essential, reduced the number and size of the interactions between the client and server, and shifted some of the processing to the server. The interface was redesigned so that information on user preferences is inferred from the normal usage of the system while reading news rather than by explicit feedback. We briefly outline the system's machine learning approach and motivate algorithmic design decisions by illustrating domain-specific requirements. Discussions of the system's performance and directions for future work conclude the paper.

2. SYSTEM ARCHITECTURE

The agent described in this paper functions as part of a client/server architecture for personalized news access. Different clients, geared towards different requirements and usage scenarios, have access to a single server. We refer to this server as the *Adaptive Information Server (AIS)*. AIS can access various news providers on the Internet, and maintains a database containing information on current news stories and personal preferences of its users. In previous work we have reported on other clients for this architecture. For example, *News Dude* is a talking news agent designed to work as part of an intelligent car radio [3]. An additional client exists for web-based news access: the *Daily Learner* is a learning online newspaper, available for public use at *http://dailylearner.ics.uci.edu*. In the web-based version, users can browse multiple news categories and retrieve the full text of stories by clicking on headlines. The system supports explicit ratings, i.e. users can indicate whether a story was *interesting*, or *not interesting*. Alternatively, users can communicate that they *already know* about a certain event, or that they would like to read *more* about an event immediately. The server collects these explicit ratings, which form the basis for a content-based machine learning algorithm that learns a model of the user's interests. When users ask the *Daily Learner* to compile a personalized news program, the learned model is used to select stories that are likely to interest the user.

The agent described here is implemented as an additional client for the AIS framework. In short, we adapted the web-based *Daily Learner* to the requirements and constraints of wireless information access, resulting in a new client for the Palm VII organizer. It is important to note that user profiles can be accessed through any client. This means that users can, for example, use the web-based version on a workstation, and use the same personal profile remotely on the Palm VII.

3. AN INTELLIGENT USER INTERFACE FOR WIRELESS NEWS ACCESS

The interface design for the wireless *Daily Learner* is based on bandwidth, transmission-cost and usability constraints imposed by portable information devices. We aim to minimize both the required interaction between user and device, as well as the amount of data transmitted between device and server. Both of these goals are in conflict with explicit story ratings: users would have to communicate explicit ratings to the device, and these ratings would then have to be transmitted to the server. In contrast, an ideal agent for wireless information access would not require any additional work from the user, and would not increase the number of slow network operations or the amount of data transmitted. Therefore, we collect preference information implicitly, simply by observing the user's news access patterns. Successful use of implicit user feedback has previously been reported in the context of learning web agents [6].

Figure 1 shows the main menu of the *Daily Learner* Palm VII interface. As a first step, users can associate the unique device ID of their Palm device with an existing or newly created *Daily Learner* account. This is a one-time operation and ensures that users can access personal profiles without any explicit login.

Users can choose from nine news channels by tapping the corresponding on-screen button, which causes the device to retrieve a first set of personalized headlines from AIS. An example of a headline screen is shown in Figure 2. Due to the display size, bandwidth- and transmission-cost constraints, only 4 headlines are displayed at once – additional sets of 4 can be requested at any time. Headlines are transmitted and displayed rank-ordered with respect to the user's current interest profile. This helps reduce the amount of data transmitted, as headlines that are likely to interest the user are sent to the device first. Headlines may be annotated with a thumbs-up icon to indicate that the system highly recommends the story to the user. This occurs when the probability that the user will be interested in the story is greater than 0.9. When the user taps on a headline, the first paragraph and if available the headline of a related story, are displayed (see Figure 2). AIS finds related stories automatically, based on textual similarity computations using tf-idf weights [9]. From the summary screen, the user can either return to the previous headline screen, or read the next page of the story. Here a page refers to a few paragraphs (approximately 512 bytes of text). The remaining text of a story can be requested page by page. This helps the user save transmission costs and allows us to determine how much interest the user has in a story.

Figure 1: Daily Learner Main Menu on the Palm VII

An additional function allows users to use keyword queries to search for news stories. This can save time and transmission costs for a user looking for an update on a particular story. A novel aspect of this search function is that the order of the returned results is not only determined by the keyword match, but also by the user's personal interest profile. For example, the user could search for the term *"Microsoft"*, which is likely to appear in multiple different contexts. From the user's past access history, AIS might have learned that the user has an interest in Microsoft's anti-trust trial, but is not interested in its role in the presidential fund raising campaign. Although both stories might match the submitted query equally, AIS can give a preference to a certain context, and thus reduce transmission of unwanted information.

The described interface lends itself to capturing preference information implicitly. We assign scores that quantify the user's interest to every displayed headline. Since the user does not rate stories explicitly, we must infer the user's rating implicitly by observing the user's actions. In general, we interpret selecting a story as positive feedback. In order to make use of all the information available and to allow for a fine-grained rating scheme, we use the following techniques to convert the user's actions into scores ranging from *0* to *1*. As soon as the user taps on a headline and requests the first paragraph, a corresponding positive rating is generated. Initially, we set the score for a selected story to *0.8*, and increase this score as the user requests page by page of the story's body (Figure 2 shows how the user can request the next page of a story). A rating of *1.0* corresponds to a story that the user downloaded completely. We believe that this a reasonable heuristic to collect preference information. Since users are charged for all transmissions, we expect them to only click on headlines they find interesting. Likewise, we assume that the proportion of a story for which a user is willing to pay is positively correlated with the user's interest in the story. In contrast, we interpret skipping a story as negative feedback. However, instead of assigning a constant score to skipped stories, we take the system's prediction for the story into account and determine an implicit score by subtracting a constant (currently set to *0.2*) from the system's prediction. Intuitively, we can assign low implicit scores more confidently to skipped stories that already received a low prediction than to stories that were thought to be of high interest to the user. If a user does not select any story, we do not generate any implicit ratings at all, because in this case the user does not express any preference relation of one story over another. Furthermore, it is unlikely that the lack of any ratings can only be attributed to the user's lack of interest, because external factors such as loss of connection to the server in areas with weak signal strength can cause the same effect. All implicitly labeled stories are entered into the user model immediately, allowing AIS to adjust to the user's interests not only during subsequent sessions, but also during the current session as more headline pages are requested.

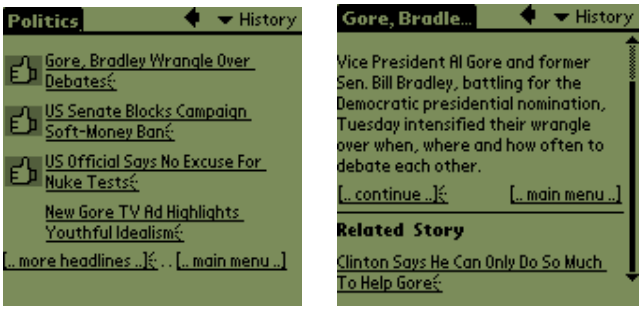

Figure 2: Daily Learner Headline and Summary Screens

4. LEARNING USER MODELS FROM LABELED TEXT DOCUMENTS

The design of the content-based algorithm that AIS uses to rank-order news stories is motivated by a number of observations and requirements. Most importantly, we take into account that the algorithm is learning about users by following several design goals. First, the algorithm must be capable of learning from a potentially small set of training examples. Second, it must be flexible enough to quickly adapt to a user's changing interests, even after a long preceding training period. Third, the algorithm should take into account that a user's information needs change as a direct result of interaction with information [2]. The last point is of particular importance for our application: a news story is only interesting as long as a user does not know about it. Even though an additional story about the same event might match the user's interest profile perfectly, it should not be transmitted if we can safely assume that the user has already read a similar story.

The above requirements led to the development of a multi-strategy learning approach that learns two separate user-models: one represents the user's short-term interests, the other represents the user's long-term interests. Learning a short-term model from only the most recent observations leads to user models that can adjust more rapidly to the user's changing interests. The need for two separate models can be further substantiated by the specific task at hand, i.e. classifying news stories. Users typically want to track different "threads" of ongoing recent events - a task that requires short-term information. For example, if a user has indicated interest in a story about a current Space Shuttle mission, the system should be able to identify follow-up stories and present them to the user in the following days. In addition, users have general news preferences, and modeling these general preferences may prove useful for deciding if a new story, which is not related to a recent rated event, would interest the user. With respect to the Space Shuttle example, we can identify some of the characteristic terminology used in the story and interpret it as evidence for the user's general interest in technology and science related stories.

The short-term model is based on a *Nearest Neighbor* text-classification algorithm [1], using the full text of news stories represented in the Vector Space model with tf-idf weights [9]. Based on proximity to recently rated news stories, the algorithm determines whether a new story is likely to interest the user. As an additional advantage of this approach, we can determine if a new story has a "very similar" neighbor in the user's short-term model, which allows for classifying stories as already known. If a new story does not have any near neighbors, classification is delegated to the long-term model.

The long-term model is based on data collected over a longer period of time and is used to represent a user's general preferences. Since most of the words appearing in news stories are not useful for this purpose, AIS periodically selects an appropriate vocabulary for each individual news category from a large sample of news stories. After the feature selection, the same set of features is used for all users. The goal of the feature selection process is to select informative words that reoccur over a long period of time. In this context, an *informative* word is one that distinguishes documents from one another, and can thus be assumed to be a good topic indicator. Therefore, we select words that consistently receive high tf-idf values throughout a large set of stories from the same news category, collected over a period of several months (currently we use 10,000 news stories per category for feature selection). These words characterize recurring themes in daily news stories, and are therefore useful for modeling users' general preferences. The long-term model uses a probabilistic learning algorithm, a naïve Bayesian classifier [4], to assess the probability of stories being interesting, given that they contain a specific subset of features. In order to increase the confidence in the algorithm's prediction, we only apply naïve Bayes if a story contains a minimum number of features -- otherwise a default score is assigned. Naïve Bayes is very efficient for both learning

and predicting and has been shown to perform competitively with more complex learning algorithms [7].

In summary, our multi-strategy approach uses the short-term model first, because it is based on the most recent observations only, allows the user to track news threads that have previously been rated, and can label stories as *already known*. If a story cannot be classified with the short-term model, the long-term model is used. The algorithm is described in more detail in [3].

5. EVALUATION AND DISCUSSION

Since 3Com's Palm VII device has not been available nationwide during the development and first evaluation of the system, the number of regular Palm VII users is still limited. However, we are beginning to see promising first trends based on data collected from the first 300 Palm VII users that have downloaded and installed the publicly-available client application. Following the nationwide rollout of the Palm VII device in October 1999, we have observed a significant increase in regular users.

In a first experiment we compared our adaptive news recommendation techniques to static news access without any personalization. During a period of ten days in October 1999 we used the system's personalized relevance prediction for half of the users, while the other half received news stories in static order determined by an editor at the news source (*Yahoo! News*). On odd days, users with odd account registration numbers received a personalized news order and even users received a static order. On even days, this policy was reversed. To quantify the difference between the two approaches, we measured the mean rank, i.e. the mean display position, of all selected stories for the personalized and static operating modes. Expressing these mean ranks as a function of the number of previously selected stories revealed a significant difference between the two approaches. Restricting the analysis to stories selected by users that previously retrieved 10 or more stories resulted in an average rank of 6.0 in the static mode, and 3.8 in the adaptive mode (the selection criteria hold for 20 users that selected 145 stories out of 777 headlines). The practical implications of this difference became apparent when we looked at the distribution of selected stories over separate headline screens (every screen contains 4 stories). In the static mode, 72.8% of the selected stories were on the top two headline screens, while this was true for 93.6% of the stories in the personalized mode. We believe that this increase makes a noticeable difference when working with handheld devices, and we interpret this result as very promising evidence for the utility of adaptive news access. In addition, this result suggests that effective personalization can be achieved without requiring any extra effort from the user.

Due to the absence of explicit ratings, it is difficult to evaluate the Palm VII client using standard Information Retrieval performance measures such as precision and recall. However, we are encouraged by a previous experimental evaluation of the *News Dude* system [3], which is based on similar learning techniques, but uses explicit feedback. If we assume that users can train their profiles with either *News Dude* or the web-based *Daily Learner* version, but access them on the Palm VII, we can predict the approximate ratio of correct recommendations on the first Palm VII headline screen. Training data was obtained from 10 regular *News Dude* users, and the system's predictive performance was measured as a function of the number of training sessions. On average, 73.2% of the system's top 4 recommendations were correct after only 3 training sessions. Given that the prior probability of a story being interesting was only 41.6% in this data set, we interpret this result as further evidence for the utility of rank-ordering news.

The University of California has licensed the *Adaptive Information Server* to *adaptiveinfo.com* that plans to make the system available on additional wireless information platforms. A version implemented for the "Wireless Application Protocol (WAP)" that can send content to Internet-enabled cell phones in either HDML or WML presents a related set of challenges because these devices have smaller screens but a slightly faster network connection than the Palm VII.

6. SUMMARY AND CONCLUSIONS

We have presented the design, functionality and underlying algorithms of a learning agent for wireless information access. The system observes users' news access patterns, and uses this implicit feedback as input for a content-based learning algorithm. As a result, news stories can be rank-ordered with respect to users' individual interests. As this can lead to a significant reduction of bandwidth, time and transmission costs, we see intelligent information agents as an important enabling technology for widespread ubiquitous information access.

7. REFERENCES

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