Adaptive Knowledge Assistants

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Abstract. Intelligent user interfaces (IUI) represent a promising approach to improving user productivity and experience in software systems. One class of users that could benefit from such interfaces is knowledge workers, who routinely process large quantities of information from various sources to form new domain-specific knowledge. However, several challenges exist in properly supporting such users, including difficulties in automatically discovering knowledge for users, insufficient resources (e.g., time, skills, user patience) to complete all assigned tasks, varying levels of domain expertise, managing complex tasks, coordinating user collaboration, and unobtrusively assisting users without increasing user frustration and decreasing productivity. To handle these challenges, we present a framework called Adaptive Knowledge Assistants that draws on multiple IUI technologies to provide customized, intelligent support to knowledge workers. We also describe the current instantiation of this framework in the Biofinity Intelligent Wiki.

Keywords: Intelligent Support, Personal Assistants, Knowledge Workers

1 Introduction

One promising application of intelligent user interfaces (IUIs) is the support of daily tasks for software users working with information. In such a scenario, users perform various general and domain-specific information generation, processing, and retrieval tasks (e.g., processing data, creating reports, and searching for previous results). Intelligent user interfaces can improve the daily lives of such workers through activities such as task management, including managing the user’s todo list and schedule [4, 13], as well as summarizing meeting notes [2] or recommending tasks for the user to perform [5] or users to collaborate with [9].

In this paper, we focus on a specific class of these users: those specializing in using information systems to generate knowledge, termed knowledge workers (e.g., [16]). While knowledge workers might perform some of the same tasks as other information users, e.g. organizing email communications from other users and meeting schedules through personal information management software, knowledge workers also perform tasks whose primary intention is to create new knowledge from information and data contained in the software system, used to both inform future activities and advance
the current state-of-the-art in their domain. For example, a biologist working with a set of bioinformatics tools (e.g. BLAST [1]) to investigate genetic data stored in a database is a knowledge worker, as is a mechanical engineer studying the effect of tension forces on a skyscraper design.

Specifically, the key question we are interested in is “How should we provide support for knowledge workers through the intelligent user interface for their daily tasks?” In this context, we recognize six important challenges to both user activities and providing adaptive, intelligent support: (1) difficulties in discovering knowledge from large quantities of raw data (e.g. not knowing how to form appropriate queries, not knowing what data to analyze versus ignore), (2) users have insufficient resources (e.g. time, skills, and patience) to complete all assigned tasks, (3) different users have different levels of expertise in the domain, (4) managing complex tasks, (5) coordinating collaboration between users, and (6) unobtrusively assisting users without increasing user frustration and decreasing productivity.

To address these challenges to providing intelligent support, we have formulated a framework for Adaptive Knowledge Assistants (AKA) as personal assistant agents for such knowledge workers, which we propose in this paper. These agents utilize various components, including user modeling, task management, information management, group support, and user training to improve user productivity and the end-user experience. The novelty of this framework lies in its integration of multiple technologies for user support of knowledge workers, along with potential improvements in the application of these technologies.

In the following, we first describe the related work from the intelligent user interface (IUI) literature used to develop our framework. Then, we introduce the AKA framework, including its components designed to handle the challenges to supporting knowledge workers. Finally, we relate this framework to an actual knowledge system currently under both development and deployment.

2 Intelligent User Interfaces

To develop our framework for providing intelligent support to knowledge workers, we draw on several key technologies from the IUI literature. In this section, we briefly describe seven such technologies.

First, personal assistants represent intelligent agents assigned to individual users to provide proactive, adaptive support, such as managing the user’s schedule [13], or to-do lists [4]. Recently, research on personal assistants has focused on modeling user tasks and potentially automating execution of tasks by agents [17, 22]. Furthermore, personal assistants have been used to provide a simplified interface by performing low-level work (e.g., executing queries across heterogeneous information sources) for users based on instructions inputted at higher abstraction levels that are more related to the way users think about their tasks [18].

Second, recommendation systems have developed methods for suggesting information for users to read, as well as activities to perform. For example, recommendations have been used for choosing resources (e.g. documents, URL links) for
knowledge workers based on current tasks and activities [16], selecting community Wiki articles for users to edit based on previous edits, links between articles, article titles, and similar author interests [5], and finally suggesting people to collaborate with in social networks [9].

Third, preference elicitation is a method for interacting with users to extract information about their goals, intentions, preferences, and other information important for providing intelligent support. For example, preferences can be elicited from users in multiple ways [3, 14], including rating items in recommender systems and predicting preferences based on a user model, such as a personality quiz [10].

Fourth, methods for interrupting users to present notifications, ask for information, etc. have been developed and their effects on users studied. For examples, researchers have studied when to interrupt users, including during breakpoints in activities [12] or based on models of user mental states [11], as well as how different types of notifications are perceived by users [8].

Fifth, IUI researchers have also investigated how to enable a system to learn from humans to teach the interface how to perform intelligent activities to support users. Examples of such learning include learning dataflows for completing tasks from observing human users in order to provide task-aware support and automated task execution [7], learning how to select resources based on complex requirements using feedback from users rather than complex queries [15].

Sixth, summarization reduces large quantities of information into more manageable forms for users while retaining the most important points. This is accomplished either by excision through removing portions of the information, leaving only the most important parts to promote speedy information absorption by users, or highlighting the most important parts to preserve information context [19]. Summarization can also be used to create rich, context-aware interfaces by using excision to identify important information, then automatically presenting related information from external sources to enhance the information presented to users [20].

Finally, intelligent collaboration support technologies have been developed to assist users to work together to both learn and accomplish tasks. For example, tools have been developed to provide cues to experts that novice workers require assistance [21] and to grow social networks based on links between users mined from various information sources [9].

3 Adaptive Knowledge Assistants Framework

Combining the aforementioned intelligent user interface technologies, we have designed a framework where intelligent software agents called Adaptive Knowledge Assistants (AKA) provide customized support tailored to the human users of the knowledge system. These agents address the six challenges to supporting knowledge workers (c.f., Section 1) using five key components: (1) user modeling, (2) task management, (3) information management, (4) group support, and (5) user training. A summary of the intelligent support provided by each component to support knowledge workers is provided in Table 1.
Table 1. Intelligent Support Provided by AKA Components

<table>
<thead>
<tr>
<th>User Modeling</th>
<th>Task Management</th>
<th>Information Management</th>
<th>Group Support</th>
<th>User Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Trace queries</td>
<td>• Learn workflows</td>
<td>• Maintain information history</td>
<td>• User matchmaking</td>
<td>• Train user from expert behavior</td>
</tr>
<tr>
<td>• Track interface actions</td>
<td>• Automate tasks</td>
<td>• Find related information</td>
<td>• User and work promotion</td>
<td>• Find experts for remote training</td>
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<tr>
<td>• Elicit preferences</td>
<td>• Monitor task execution</td>
<td>• Automated mining</td>
<td>• Offline presence</td>
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Fourth, to support not only its assigned user but also the group activities the user participates in, AKA personal assistant agents are responsible for matchmaking users: finding collaborative partners based on the users’ tasks, expertise, and information needs. In a similar fashion, AKA agents can also promote the work of their individual agent to other agents and users, trying to advance the user’s agenda. This latter is especially important in a research setting to promote the ideas of the user and works hand-in-hand with matchmaking to form collaborative groups of users with similar ideas and interests. Finally, AKA agents can also provide an offline presence for users when they are not available, keeping track of requests and messages from other users and possibly responding with the user’s permission to access private resources (e.g., data).

Finally, AKA agents can also provide online training to improve the productivity and competency of their users. This training is based on the observed behavior of experts within the system, such as training users to perform tasks better or how to use queries to investigate a data source. Additionally, agents can also find experts for more hands-on, human-human training through communication channels provided by the system (e.g. audio/video chat).

Together, these components handle the six challenges inherent in intelligent support of knowledge systems as follows. First, the problem of extracting knowledge from large amounts of data is primarily handled by the information management component of AKA agents through automated information discovery and mining, as well as summarization. Second, resource insufficiencies are mitigated by task management (e.g. scheduling tasks and workflow automation), as well as through group support (e.g. finding experts to perform tasks). The problem of differing expertise levels amongst users is dealt with through user modeling for determining which users have different types of expertise, along with group support for forming groups with the required expertise to successfully complete joint tasks, as well as user training to improve expertise. Managing the complexities of tasks is mostly mitigated through task management activities, such as learning workflows and automated execution, while organizing team coordination is handled through group support. Finally, the problem of unobtrusiveness is embedded within the various modules, such as intelligently eliciting preferences from users during modeling, as well as intelligent notification for task monitoring.

It is important to point out here that this latter problem, along with other agent-human interactions, is handled by AKA agents in a resource-aware fashion cutting across all components, where agents model the human user as a stateful resource whose behavior changes based on many factors, including her tasks, busyness, and most importantly, the interruptions and quality of support provided by the agent. This consideration is an extension of our prior research on stateful resource usage by agents, focusing primarily on information gathering with stateful resources [6]. The goal of this approach is to optimize the interactions between the agent and human resource to balance user frustration and stress with the urgency of interruptions and the behavior of the agent.
4 Applications of the AKA Framework

We have identified multiple opportunities for utilizing the Adaptive Knowledge Assistants framework to support human users. A small sample of these opportunities include: (1) intelligent tutoring systems, where students interact with an intelligent system to learn concepts and generate new knowledge, (2) computer supported, cooperative learning (CSCL) or work (CSCW) environments, where users collaborate to accomplish tasks and generate shared knowledge, and (3) cyberinfrastructures for combining various knowledge and information sources for scientific discovery and investigation. To demonstrate the broad applicability of our framework, consider that specialized versions could also potentially be applied to intelligently support humans in other applications, such as smart environment controls, where the environment models human preferences, automates tasks such as light dimming or thermostat control, manages information about the environment from embedded sensors, and accounts for group preferences.

4.1 Biofinity Intelligent Wiki

One deployed application we are currently developing and refining an instantiation of the AKA framework for is the Biofinity Intelligent Wiki¹ (BIW). The BIW is a collaborative workspace where users perform several common wiki-based activities, including reading, creating, editing, and comparing revisions of wiki pages representing various types of documents: informative articles, journals, notes, scientific procedures, data annotations, reports, pre-publications, etc. Through these activities, users produce new collaborative knowledge stored in individual pages. Users can also perform popular Web 2.0 activities, such as rating pages, conversing in threaded discussions, organizing pages through tags, and sharing pages both privately with other users and publicly through social networking tools in order to support the creation and spread of knowledge within the application.

The BIW itself is a tool within the Biofinity Project, a cyberinfrastructure for federating biology data from separate fields, including biodiversity and genomics. It was designed to support information dissemination, consensus building, and knowledge archival while users work together to bridge the knowledge gap between scientific disciplines. Moreover, the BIW has also been used to support collaborative writing activities by students in both computer science and biology classes at the University of Nebraska-Lincoln, including as part of the Duckweed Project².

Within the BIW, we have begun implementing intelligent support for users through the use of the AKA framework. Specifically, an agent assigned to each individual user is responsible for tracking all user activities (e.g., pages read, search queries performed, tags added, comments posted). Using this tracked information, we are working on developing informative user models including patterns of behavior, topics of interest, and areas of expertise in order to understand user behavior and guide the

¹ http://biofinity.unl.edu/wiki
² http://www.unl.edu/cbrasil/duckweed-project-0
intelligent support provided by the agents, tailored to each individual user’s needs. Additionally, this tracking also maintains histories of pages the users have viewed and edited to assist users with recalling recently read and posted information. Moreover, pages created and edited by users are automatically parsed for important keyword content, and related pages with matching keywords to the user’s currently viewed page are found and automatically recommended in an unobtrusive side panel. This feature is also used to help manage the information in the system for the users.

In the near future, we plan on extending our use of AKA within the BIW to include the other components of the framework: (1) we intend to use tracked user activity histories to learn workflows of activities (through pattern recognition and mining traces of user behavior) to support task management, such as recommending or automating activities necessary to complete tasks (e.g., adding citations to other pages and external resources for group reports), (2) we want to improve the information management by adding summarization of wiki pages for faster information dissemination and recommendations of external information sources, similar to [20], (3) we plan on increasing group support by matchmaking users based on similar interests or finding users with proper expertise to help with the completion of tasks (e.g., finishing a section about a particular topic on a wiki page), and (4) adding user training through recommending sequences of actions performed by expert users. Finally, we are also interested in further developing our notion of resource-aware reasoning, especially as it applies to intelligently supporting users. Specifically, we aim to balance interruptions and notifications with user cognitive effort and frustration as they interact with the BIW using reinforcement learning combined with sequential decision making techniques including partially observable Markov decision processes [6].

5 Conclusions

We have presented a novel framework called Adaptive Knowledge Assistants for supporting human users with knowledge generation tasks through the use of intelligent user interfaces and personal assistant agents. This framework addresses several challenges to supporting knowledge workers and is focused around five key components: (1) user modeling, (2) task management, (3) information management, (4) group support, and (5) user training. We also outlined the application of the AKA framework to a real knowledge system in order to support scientific investigation and discovery within the BIW for the Biofinity Project. Finally, we also discussed some short term goals to improve the usage of AKA within the BIW.

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