An Agent-Based Approach to Adaptive Hypermedia Using a Link Service

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Abstract. This paper describes an approach to adaptive hypermedia by incorporating linkbases into an agent-based system (PAADS). The agents are built on top of an agent framework developed at Southampton University. Personal agents keep a local user model and provide adaptive navigation support. This is accomplished by extracting keywords found in the user model and through the user's browsing history, and by then replacing occurrences of those words with URL's supplied by a linkbase agent. A third agent provides the ability to query these user models through a web browser.

1. Introduction

The term *Adaptive Hypermedia* means personalizing a user's browsing experience. There are a number of different methods for providing this adaptivity in existing hypermedia systems. Brusilovsky [2] describes two main types: adaptive presentation, which means changing the information conveyed on individual pages, and adaptive navigation support where the appearance and order of the links are manipulated to influence a user when they come to select the next page to visit. To facilitate these techniques, a user model is kept by the system, which contains simple personal information, and any concepts and goals the user has acquired while browsing.

Agent technologies can be used to create adaptive systems as they are quickly becoming popular as a means of building modular systems. It is their inherent flexibility that makes them ideal components for multi-disciplinary tasks. In the IAM research group we have designed our own multi agent system, SoFar (Southampton Framework for Agent Research) [5], which is a Java-implemented platform designed for rapid agent development. These agents communicate using a pre-defined set of methods (performatives, such as *inform*, *subscribe* and *request*) that can be invoked on any agent. To aid communication between agents, SoFar incorporates the idea of using ontologies (the semantic structure of data) [7], as a means of specifying particular data domains. Mobility is also provided by SoFar, allowing agents to migrate to new platforms as and when they desire.

The work described in this paper involves introducing the concept of linkbases to this agent domain to provide adaptive hypermedia. A (distributed) linkbase is a means of separating link information from the body of a hypermedia document. Linkbases, first developed as part of the Microcosm system [4], allow authors to manage web sites with greater efficiency. These links reside in a database where they can be maintained by a link service, such as the DLS [3], which provides link functionality to

other programs. The following system uses such a linkbase to add links to the web page that match a user model. One advantage of such a technique is that the structure of the existing web page is left unaltered and the user just sees more links to sites they are interested in.

2. PAADS Implementation

For this work, a collection of agents have been built on top of SoFar that all recognize a pre-defined group of ontologies. PAADS (Personal Agent information Acquisition and Delivery System) is a web-centred approach, written entirely in Java 2, to record user details, provide adaptive navigation support to users and present this information to others who can query the data. The system is shown in Fig. 1.
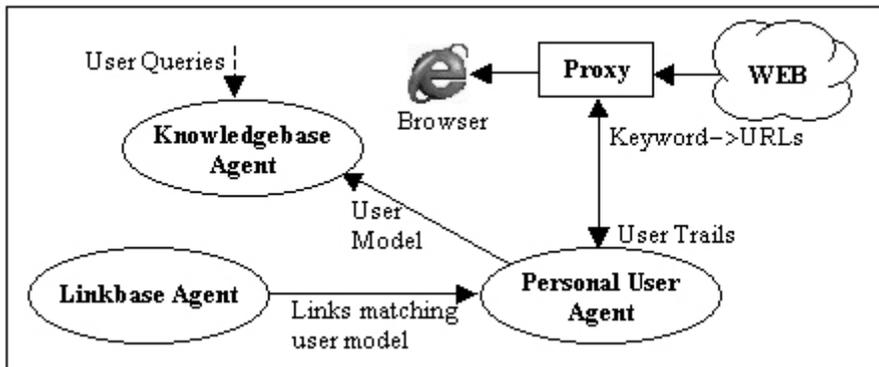

Fig. 1. A diagram showing the interaction between agents in PAADS. The user's agent supplies keyword & URL pairs from the linkbase agent to the proxy. The user model is sent to the knowledge base agent and can be accessed through user queries

2.1 The Agents

There are three types of agents running in PAADS. There are Personal User Agents, Knowledgebase Agents and Linkbase Agents, each of which has a specific purpose. The Personal User and Knowledgebase agents are *active* agents - they interact with other agents in the system to accomplish their goals, whereas the Linkbase agent is *passive* - it supplies services to other agents but has no goal itself.

Personal User Agent. In principle, Personal User agents follow a single user, accumulating information about their interests and expertise and storing this data in a user model. At present, this model is simply made up of key value pairs entered manually by the user. Agents also add keywords to the model that have been extracted from web pages visited by the user. This model is then sent to the Knowledge Base Agent.

Knowledgebase Agent. The Knowledgebase agent acts as a central repository for data accumulated by personal agents. The knowledge base agent provides an interface to this data allowing other users to query the information via a web browser. The agent can respond to questions such as "*Who is J. Bloggs?*" or "*Who can help me with my Java program?*"

Linkbase Agent. Acting as a distributed link service, the linkbase agent maintains a local linkbase and provides performatives to other agents allowing them to query the linkbase and add or remove links. At present, the Linkbase Agent only responds to requests from Personal Agents for URLs. The linkbase used by this agent conforms to the XML standard set out by the DLS [3], where a link is defined with, amongst other things, a type, a destination URL, keyword(s) and the title of the web page.

Users can enter data directly into their personal agent, or allow their agent to acquire knowledge about them implicitly. This is achieved by recording the user's trails (or paths) as they browse through the WWW and then keywords are extracted from these web pages. A frequency count is performed and the highest occurring words are stored in the user model as an *interests* field. PAADS provides a web interface giving the user a view of all the data acquired about them and allowing them to configure their agent. To provide adaptive navigation support for the user, the personal agent requests links from the linkbase agent that match the keywords found in the user model. The linkbase agent returns a set of matching links, which are then sent to a proxy. This proxy replaces all occurrences of the keywords in a web document with the corresponding URL's. Two different methods of presenting the links have been implemented. The keyword can either become a link or have the links, if there are more then one, tagged onto the end of it (e.g. a <u>standard</u> style, or a bibliographic [<u>x,y</u>] style).

3. Conclusions and Future Work

Due to the dynamic nature of agents, PAADS continues to work even if some or all of the agents are unable to be found. This makes PAADS fault tolerant, and the web front end allows it to be easily configured by users. Personal agents can refine their user models over time so that as the user moves around the web, the agent slowly gains more information about their interests, which is then fed back to provide more personalized link adaptivity. A further advantage is that the adaptivity does not destroy the original structure of the web page as links are only ever added. This means well designed web sites will remain intact and the user benefits from both their structure and the additional links PAADS provide.

However, more work needs to be done to improve the control and presentation of the links. Because there could be several URL's associated with a given keyword, the system would benefit from weighting each URL. This would give the agent a means of selecting one URL over all the others, or allow the links to be presented in an ordered list based on some criteria (adaptive link sorting). The next step is to build a more advanced learning algorithm into the system. Any improvements to automate acquisition of the user model would be beneficial to the user; reducing the time they

spend interacting with the personal agent, thereby freeing them up to focus on their own tasks. This could be done by extending the link definition to calculate the frequency of page hits or include ratings for web pages. From this new information, favourite pages (bookmarks) could be inferred by the agent and thereby given stronger weights.

This agent-based approach to the provision of distributed link services and adaptive navigation support is a good example of how agent technology can be applied to new areas. The linkbase agent can offer its services not just to these personal agents but also to any agents interested in link manipulation. Although not implemented at the moment, more linkbases need to be introduced to give the agents a better choice when finding relevant URL's. Examples could include general linkbases for a wide range of topics, linkbases that cover a specific domain (such as a corporate web site, or a technical subject) and individual user linkbases formed from a user's web trails.

Finally, by giving personal agents the ability to query other agents, possible links could be suggested to the user by comparing their trails against those of other users, creating a trail-based recommender system [1,6].

This work shows that agent technology is a viable means of providing adaptive navigation support. Maintaining separate linkbases allows greater flexibility for adaptive hypermedia systems and intergration with the personal user agents provides an ideal platform for future experimentation.

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