Dicheva, D. & Aroyo, L. (2000). *An approach to intelligent information handling in web-based learning environments.* Paper presented at ICAI 2000, San Antonio, Texas.

An Approach to Intelligent Information Handling in Web-based Learning Environments

Darina Dicheva
Department of Computer Science
Winston-Salem State University
601 Martin Luther King, Jr. Drive Winston-Salem, N.C. 27110, U.S.A.

Lora Aroyo
Faculty of Educational Science and Technology, University of Twente
P.O. Box 217, 7500 AE Enschede,
The Netherlands

Abstract *This paper discusses an integrated approach to information handling and knowledge management in web-based open-ended learning environments. It supports both learners and instructors in information structuring and task-oriented processing and usage. AIMS, a web-based intelligent tool for task-based information and performance support is implemented to exemplify the theoretical assumptions of this approach. AIMS focuses on three important aspects of the information handling process - information structuring, information visualization, and user centered approach. We employ concept maps (CM) to build a subject domain ontology and use it as a basis for defining course structures. The domain CM is also used for attractive non-linear visualization and conceptual graphical navigation of the subject domain and the search results, thus allowing for more efficient information searches. In order to provide appropriate adaptation to the individual information needs and preferences of the learners AIMS models their behavior.*

Keywords: intelligent information handling, concept maps, subject domain ontology, web-based training systems, intelligent agents

1 Introduction

The traditional way of looking at intelligent tutoring systems (ITS) research is undergoing an evolution due to the rapid development of new information and communication technologies and their penetration into educational settings. Recent research indicates that the classical ITS-paradigm no longer dominates the field of AI and Education. ITS are viewed not so much as stand-alone but as embedded in larger educational environments, which support the student in the learning process. Among the most significant current trends in ITS area is the shift of emphasis towards open domains and conceptual understanding [1]. The environments are expected to support the learner in performing open learning tasks with well-defined results.

This paper discusses an integrated approach to information handling and knowledge management in web-based learning environments, in which learners perform open learning tasks. It supports both learners and instructors in information structuring and task-oriented processing and usage. AIMS, a web-based intelligent tool for task-based information and performance support is implemented to exemplify the theoretical assumptions of this approach. AIMS focuses on three important aspects of the information handling process - information

structuring, information visualiza-tion, and user centered approach. In the paper we present AIMS objectives and information handling approach, emphasizing the agent-based architecture of the system and the way it realizes a knowledge-based approach for informational support within web-based learning environments.

2 Information Support in On-line Course Environments

The availability of intelligent information handling support in web-based course environments is essential for both students and instructors. Students need to be helped in searching, accessing, and finding information related to their course work, as well as in comprehending and memorizing the retrieved information. In this relation it is important that students get a clear and structured overview on the course content and course materials. Instructors need to be supported in their efforts to build a course structure and find, organize, and structure on-line course materials.

We call an *informational support system* (ISS) such a tool, which provides the users (in this case learners and instructors) with immediate on-line access to a broad range of structured information and with domain-related help in the working context. Such a system enables the user to identify the information necessary for performing a particular course task. ISS can be used in educational context standalone (as an extension of a traditional or on-line distance course) or integrated in a larger electronic learning environment that allows the users to perform open learning tasks in a specific subject domain. The goal is to provide an appropriate framework and architecture for informational and conceptual support, which will improve student's performance in a course thus making the learning process more efficient. Such a system is a cognitive tool [2] helping the learners not only to complete their course work more efficiently and accurately, but also to build new knowledge and comprehend better the subject domain in hand.

3 The AIMS System

We have developed a knowledge-based informational support system called AIMS (Agent-based InforMational Support) for use within the context of distance education. It is aimed not only at enhancing learner's conceptual knowledge in a specific subject area but also at providing knowledge verification tools for the teacher. The system can be used to aid learning and teaching in different subject areas and to provide user-oriented support in searching course-related information, concept teaching and learning, and conceptual and task-oriented domain structuring. AIMS has an agent-based system architecture, which accommodates a team of agents mediating the process of providing information to the individual user.

AIMS is a knowledge-based system, which helps the users to come to solutions of their problems by supporting information structuring and task-oriented search, but it doesn't contain the solutions. It contains explicit knowledge representation of the domain (subject domain concepts and relations among them) and a user model. The user model represents system's belief about the current user's knowledge. The system uses it when supporting the user to find, collect, and organize information necessary to perform a course assignment.

AIMS comes as an example of how educational systems try to meet the challenges of multimedia, hypertext and internet technologies in general and proposes a new model at the cross-road of the electronic performance support and course support systems. Conceptually, AIMS combines advantages of some existing information management and educational approaches. It attempts to set up an adequate balance between system and user locus of control, content learning and conceptual learning, graphical and textual visualization, 'dry' course material presentation and creativity stimulating approaches, quick and efficient learning, etc. The information handling

support method behind AIMS reflects all those challenges.

3.1 AIMS Objectives

The main goal behind AIMS is to improve the usability and maintenance of information in web-based educational environments by presenting an integrated working environment for both instructors and students, which facilitates the process of preparing and taking on-line courses in an intelligent and efficient way. We envisage the management of information as concerning two mutually complementing processes: these of retrieving the right information and visualizing it in the right way. Thus the focus of the work is on information search, retrieval, and effective presentation to the user. An important educational constraint is that we consider supporting learners to deal efficiently with information only within a specific subject domain and course in respect to certain educational goals (tasks).

AIMS targets to support the knowledge crystallization task, which is characterized by the use of large amounts of heterogeneous information, ill-structured problem solving, and a well-defined task. This point of view is related to externalization rather than visualization, stressing on the cognitive role of interactive visual representations [3]. The process of knowledge crystallization involves getting insights about data relevant to the task in hand, so that the user will be able to fulfil it and achieve better results.

AIMS is a web-based information handling support tool for both learners and instructors. It is aimed at representing and supporting the relations between a course, its subject domain, and relevant documents. It supports the synergy between problem solving and knowledge building. The learners can discover information and build knowledge thus preparing the problem solving process for performing their course tasks. AIMS is aimed also at supporting the instructors by providing them with an integrated authoring environment for subject domain representation, course structure building, and learning materials organization. It allows instructors to efficiently reuse their course materials, as well as be aware of the way the students will process them.

4 AIMS Informational Support Approach

On the basis of extensive review and analysis of web-based education and its needs for information support of both learners and instructors we developed an approach for information handling implying some ideas of artificial intelligence, learning theories, and human-computer factors. The approach tackles the issues of information analysis, organization, retrieval, and presentation (visual and instructional). It is domain independent and involves building domain ontology and specifying a course structure. It enables the instructors to analyze, classify, organize, and present information items optimally to the learners while focusing on a specific course targets. The result is a set of precisely defined and structured information units that are easy updateable, reusable, combinable, and extendible for different course objectives, environments, and situations. The approach provides the learners with an easy access to and an attractive visual presentation of information related directly to the course tasks as well as with a conceptual view of the whole subject domain.

The significant aspects of the proposed approach include:

- Building domain ontology and using it as a basis for defining course structures and for implementing more efficient information searches.
- Powerful visualization and graphical navigation of the domain and information search results.
- User modeling.
- Agent-based architecture.

4.1 Information Structuring Based on Domain Ontology

One of the milestones of the proposed approach is building domain ontology and using it for information structuring and classification. On a conceptual level we define three main models for representing the information content: domain model, course model, and library model. The *domain model* defines the subject domain ontology and is represented as a concept map [4] of domain concepts and links between them. The link types are based on the generic selection of link types defined in [5]. There could be a number of instances of the domain model, each describing a different subject domain within AIMS. The *course model* defines the structure of a course and includes course topics, course tasks and course evaluation items. Since the main goal of AIMS is to provide a task-based information support, a series of tasks are associated with each course. Course tasks are pre-defined and correspond to course assignments the student is supposed to perform. The main idea is that the system uses a task to constrain the information provided to the learner in support of his or her efforts to complete this task. The system keeps track of the status of all course tasks - which have been successfully completed by the user, which are not attempted or have been started but not completed yet. The tasks are represented in terms of domain concepts and contain some additional information, such as task description, task status, etc. Course evaluation items correspond to different forms of student evaluation over the timeline of the course, such as instructor's tests, student's self-evaluation of his or her knowledge of domain terms, etc. They are used on a later stage for a run-time evaluation of the current learner's knowledge on a specific course topic and for consecutive adaptation of the system's behavior and information presentation. The *library model* provides means for maintaining a whole collection of information related to different courses and domains. Its main variables are course materials and domain related documents together with their characteristics. The library documents are related to domain terms and through them - to the course tasks and topics.

4.2 Information Visualization

Information visualization refers to methods and techniques for user-oriented graphical visualization and organization of information objects. In AIMS information visualization targets the presentation of the subject domain structure and the overlaying structures of the course and user models [6, 7]. As part of the supporting information search functionality AIMS also proposes combined visualization of the search results. We use concept maps as a basic mechanism for information structuring and visual presentation of the subject domain, since CMs furnish simple and intuitive visual form of knowledge representation. The same technique is used for presenting the course components, such as tasks and subtasks and the user model. Information search results are also partly presented with this graphical approach. The result documents are still organized in the traditional way of textual list-based presentation, but are related to a result concept map of domain terms used in those documents. Some meta-data is provided in order to support a better and quicker overall search result comprehension. Meta-data in the form of short descriptive information and structured tags is also used in order to describe the context of the domain terms and links.

The combination of CM information structuring and visualization contributes to the problem solving support for more efficient learner performance within the context of a course. AIMS gives the learners freedom to create their own learning and problem solving paths, while browsing within the subject domain. This is realized by providing two parallel views on the knowledge - conceptual perspective (subject domain knowledge) and teaching perspective (task/course knowledge). The visualization and domain navigation facilities help students to get orientated within the subject domain and to build up their own understanding and conceptual

associations. It supports their visual thinking and imagination.

4.3 Task-based Search Strategy

The proposed informational support approach involves a task-based search strategy, which links the course tasks to the search algorithm and uses the domain ontology definition as a classification scheme. The CM-based classification facilitates dynamic adaptation of the system to changes in the domain. It is directly linked to the hierarchical course structure, and in addition, correlates efficiently with the user model. The use of conceptual representation of the domain knowledge and information structure provides methods for automatic manipulation, which contribute to the overall search efficiency. In AIMS we propose the *DoCS* (Document Classification and Search) model, which is keyword-based and makes use of the relations between documents and domain terms, documents and course tasks, domain terms and document keywords, while considering synonyms and other word forms of the domain terms [7,8].

The task-based search strategy provides for course-oriented results and prevents overloading the learner with information non-related to the present instructional tasks. It applies automatic reformulation of the search query to fit the limitations set by the current course task. Documents are retrieved and ranked in the context of their task relevancyAIMS provides visual and textual ways for search query refining by the user, based on the already produced search results and subject domain representation.

4.4 User Modeling

User modeling provides grounds for system adaptiveness. In AIMS, the user model (UM) refers to the learner and is related to his or her activities in the on-line course environment, such as performing a course task, browsing the domain, searching for a term, visiting documents related to a term, requesting for terms related to a specified term, etc. It is an *overlay* of the domain, course, and library models thus it is represented in terms of domain concepts, course tasks, and library documents. AIMS uses UM to provide user-oriented support for information searching in the context of an educational task, as well as for refining and adapting the search results to user's interests and course tasks. It is an *open* model, that is, built jointly by the user and the system. The user can enter information about his or her knowledge of or interest to a specific term on system's request or on his own initiative, while browsing the conceptual presentation of the subject domain or in the process of searching for documents.

The main system's source of information about the user model is the user behavior. The system monitors user performance and collects information from sources like search expression entries, course task dialogues, search result scan and usage and browsing the domain concept map. On the basis of this information the system makes its conclusions about the user's *knowledge* of and *interest* to terms and documents. Maintaining the user model involves incorporating new facts, checking that they are consistent with previously learned or inferred facts and resolving any discrepancies and contradictions.

4.5 Agent-based Architecture

We propose agent-based system architecture, which provides a team of agents mediating the process of information provision to the individual user. The collective agent's behavior results in adaptive system's behavior. Agents have their tasks and strategies. Tasks define agents' responsibilities and communication means and entities within the system, and strategies define methods and rules for performing actions related to the overall informational support task. Among agents' tasks are maintaining domain, course, library, and user models, performing search activities and presenting the final results to the user. Agents' co-operation abilities to communicate with each other and change their

behavior depending on the user's action, to exchange messages and to act even when there is no clear user request for an action, contribute to the overall system efficiency. The agents perform their tasks by working in parallel as separate but coordinated processes.

An agent can initialize and execute commands given by other agents or invoked by a change in the environment. Currently, the incoming information and outgoing information (through the commands `CommandRequest` and `CommandResponse`) are Java objects but they can be easily transformed in an agent-based message language like KQML or text queries.

Each agent is responsible for its own information consistency and is accountable for a number of commands.

The Agent environment consists of two objects `AdminServer` and `AgentServer`. The `AgentServer` object is composed of a team of agents that collaborate and communicate among each other while performing user's or other objects' requests. `AgentServer` is responsible for the general administration of agents, including creation, deletion, security, etc. It receives a configuration file, defining the types of the agents and how to initialize them. The `AgentServer` also knows how to instantiate them when a command/query for a task arrives. Along with each query/command goes identification information about the object that sends it (the name and password of the user). The end user does not see the agents; he or she only sends information queries through the `AgentServer`. `AdminServer` checks whether the announced user exists and whether he or she is authorized to give such a command.

5 AIMS Implementation

As we already said, AIMS is implemented as an agent-based architecture. This architecture supports system's intelligent behavior, which comes as a result of agents' collaboration, learning and information sharing.

AIMS is developed as a Java client-server application, where the applet part acts as a client and the servlet is resident on the server. Java appears to be a promising technology for such implementations since it provides platform independence and efficient integration with on-line course environments. The server part administers information maintenance, i.e., updates of documents, courses, and domains and controls the user profiling functions. The servlet ensures the access to the server via the Internet. The servlet accepts a query sent by the applet, decodes it and sends it to server, then waits for an answer and sends it back to the applet on the client side. All the persistency information is kept on the server.

There are two active applets on the client side: one serving the learners' needs (Viewer) and another facilitating the instructors and experts (Editor). They are responsible for the search query processing, local information visualization and library, course, and domain content storage. Both include:

- a common module responsible for transferring the queries to the server (through the servlet),
- `PseudoAgent` shells allowing visualization of the local client copy,
- interface.

The Viewer sends a user log-on command and if it succeeds sends commands to get all the information needed from the server, then stores and analyzes it locally, and visualizes it.

The Editor behaves similarly in relation to the storage, analysis, and visualization of the server information. When a change is required, it sends an update command to the responsible agent on the server and then visualizes the newly updated information. This allows several users to work in the same domain performing a synchronized information update.

6 Conclusions

The AIMS system is created to support the students from the Faculty of Educational Science

and Technology, University of Twente, participating in the course of 'Courseware engineering'. The intention is to integrate AIMS in the web-based course environment already created for this course. As AIMS is designed to be a general course support tool, there are possibilities foreseen to facilitate importing of different subject domains and to create different courses in the same subject domain.

Several pilot experiments have been performed for evaluating AIMS browser and editor GUI functionality, user-friendliness, and learning effectiveness. Students from the 'Graphical User Interface Development' course in Eindhoven Technical University, the Antwerp University, and the 'Courseware Enginnering' course at the Faculty of Educational Science and Technology, University of Twente, the Netherlands, took part in the experiments. The purpose of these formative evaluations was to validate the proposed AIMS approach and to identify any problematic aspects in order to improve it.

Acknowledgements

We would like to thank our student Ivan Velev for his implementation efforts in realizing the AIMS prototype.

References

[1] Andriessen J., Sandberg J. (1999) Where is Education Heading and How About AI?, *International Journal of Artificial Intelligence in Education*, 10, 130-150.

[2] Van Joolingen, W. (1999) Cognitive tools for discovery learning, *International Journal of Artificial Intelligence in Education*, 10, 385-397.

[3] Tweede, L. (1997) Characterising Interactive Externalisation. *Proceedings of CHI'97, ACM Conference on Human Factors in Computing Systems*, Atlanta, pp. 375-382.

[4] Jonassen, D. & Marra, R. (1994) Concept Mapping and Other Formalisms as Mindtools for Representing Knowledge. In *Educational Psychology Interactive, Readings in Educational Psychology*, William G. Huitt (Ed.).

[5] Lambiotte, J. G., Dansereau, D. F., Cross, D. R., & Reynolds, S. B. (1989) Multirelational semantic maps. *Educational Psychology Review*, 1(4), 331-367.

[6] Aroyo, L. & Dicheva, D. (2000) Conceptual Visualisation in a Task-Based Information Support System. *ED-MEDIA 2000*, Montreal, Canada (accepted).

[7] Aroyo, L. & Dicheva, D. (1999) Information Retrieval and Visualisation within the Context of an Agent-based Information Management System. In *Proceeding of ED-MEDIA'99*, Seattle, Washington, 195-200.

[8] Aroyo, L., Diana, I. & Dicheva, D. (1998) Agents to Make Your Information Meaningful and Visible: An Agent-based Visual Information Management System. In *Proceedings of WebNet'98 Conference*, Orlando, USA.