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Domain and User Knowledge in a Web-based Courseware Engineering Course

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Abstract. AIMS is a knowledge-based system for learning and teaching support 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. Each of those agents is an active system entity characterised by a set of specific roles with respect to the main system functionality. In this paper we present a general view on AIMS with an emphasis on its agent-based architecture and the domain and user knowledge.

1 Introduction

Knowledge-based systems (KBSs) refer to software programs that use explicitly stated knowledge to reason and provide solutions. KBSs can be very beneficial to decision-makers in problems that are described with large volumes of data, different sources and a related task to fulfill. They provide means to support the process of problem analysis and decision-making. Vital issue in this context is the notion of 'intelligence' – what is it and how is it realized. It closely relates to the topics of knowledge and its management - representation, storage, sharing, and maintenance. When we refer to knowledge it is to both the system knowledge of the domain and of its users. Thus it concerns modeling activities in both aspects. Various applications have been implemented in trying to capture and mimic the human expertise in this context. Numerous expert systems were built and applied in various application areas, mainly in medicine, natural languages, geology, etc. A large number of knowledge representation schemes and languages were developed in order to provide most appropriate tools. In this research we adopt the view that the system's intelligence is represented and mediated via a set of software entities referred to as

'intelligent agents'. They appear to be a very convenient tool for supporting a large number of cognitive tasks, as well as for implementing the system architecture processes. They have already proved to be quite a suitable software solution for knowledge-based systems. Our target in this research is to contribute to the rather popular lately strive to introducing agents for different activities related to education and to defend their effectiveness and actual contribution to the complex process of teaching and learning. We aim at designing agents that do a good job within educational environment and more specifically in respect to information support there for both instructors and learners. We discuss some general principles used in agents design. The major issues among them point to creating a common environment for them to 'live', to show how agents perform actions to fulfill a task, how do they learn and how do they communicate among each other and with other system entities.

In this paper we present AIMS, a knowledge-based system for learning and teaching support 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.

While AIMS is a knowledge-based system, it offers support not only in the process of problem analysis and decision making, but also in the overall process of subject matter understanding, structuring and task-oriented searching within it. It helps the users to come to the solution of their problems, but it doesn't contain the solution itself. It contains explicit knowledge of the subject domain, builds up knowledge about the user and supports him or her in the process of finding, collecting and organizing the information necessary to perform a course task or assignment.

We start this paper with a general overview of AIMS, emphasizing the agent-based architecture and the way it realizes a knowledge-based approach for informational support within learning environments. Further on, we describe the system implementation and show the possibilities where agents can play roles within the general AIMS framework. We also present some conclusions and further topics for discussion.

2 AIMS: an Agent-based Intelligent Tool for Informational Support

The main goal behind AIMS is to present an integrated working environment for both instructors and students, which will facilitate the process of preparing and taking on-line courses in an intelligent and efficient way. AIMS 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 we aim at a general course support tool, there are possibilities foreseen to facilitate importing of different subject domains or to create different courses in the same subject domain. Several experiments, within the scope of different computer-supported courses, have already been performed. They have evaluated the student's attitude towards AIMS interface and the effectiveness of its conceptual support for the learning process.

The tool could be also successfully used for in-company training needs including course authoring and information handling support.

AIMS stands for Agent-based Information Management System that aims at providing combined adaptive information support for students and instructors within the context of on-line course environments. The main goal is to improve the usability and maintenance of information in such environments. 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 [1]. This point of view is related to externalization rather than visualization, stressing on the cognitive role of *interactive* visual representations [2]. The process of knowledge crystallization involves getting insights about data relevant to the task in hand, so that the user will be able to fulfill it and achieve better results.

2.1 Agent-based architecture

AIMS is built as an agent-based architecture. The agents' behaviour is modeled in correspondence with the main activities involved in the process of task-based information retrieval. Agents have their tasks and strategies. Tasks define agents' responsibilities and communication means and entities within the system. Strategies define methods and rules for performing actions related to the overall informational support task. Among agents' tasks are maintaining subject domain, course, library and user models, performing search activities, and presenting the search 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 explicit 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.

As mediators between the users and the information content, agents are contributing to the general system adaptiveness. Their collaborative intelligent behaviour results in an intelligent user-oriented information support for learners and instructors. The general architecture of AIMS as an agent-based information support system is elaborated elsewhere [3, 4]. In this paper we will focus on the issues related to building, representation, and visualization of both domain and user knowledge.

2.2 Domain knowledge: representation and authoring

One of the milestones of the proposed approach is building subject domain ontology and using it for information structuring and classification. On a conceptual level we define three main models for representing system's information and domain knowledge: domain model, course model, and library model.

Domain Model

The domain model defines the subject domain ontology and is represented as a concept map (CM) of domain concepts and links between them. There are numerous definitions of concept mapping depending on its various applications, but for the purposes of this paper we will concentrate on the concept mapping in the context of memory, perception and meta-cognition [5] as a formalism for structural knowledge representation [6]. The most widely accepted definition of concept mapping is as a technique of graphically representing concepts and their hierarchical interrelationship. They are organised in a spatial configuration of nodes and links in a given knowledge domain. The valuable thing in our context is that

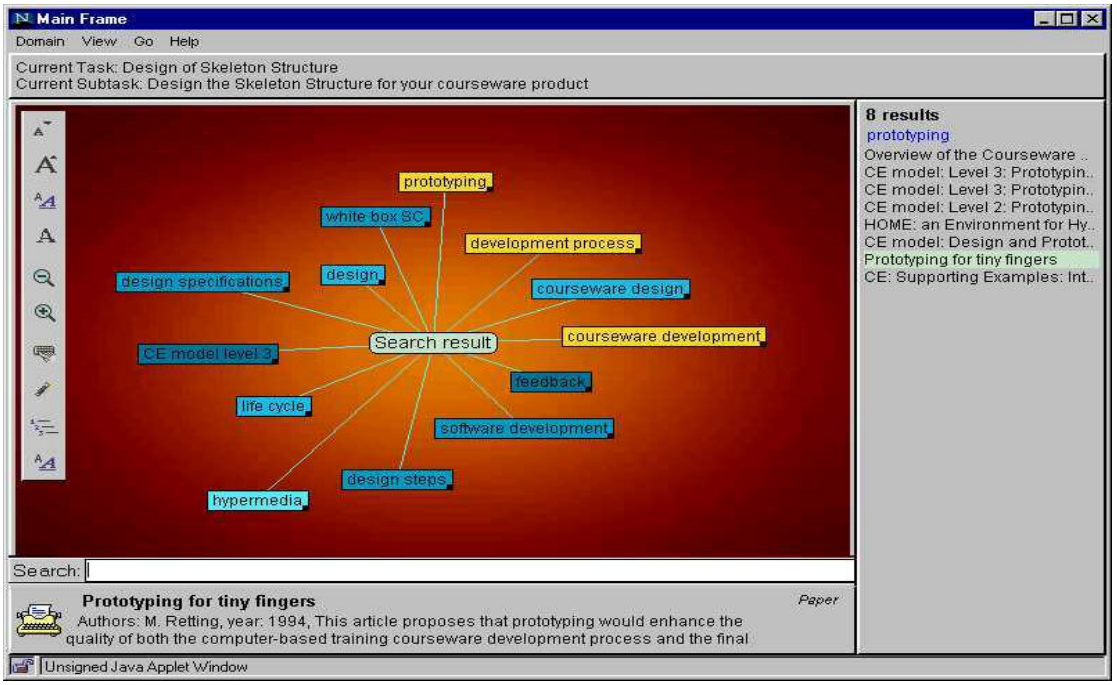

Figure 1. AIMS Domain Browsing and Search Environment for Learners

concept mapping allows the learners to connect new ideas to knowledge that they already have and to organize them in a logical structure. This way it allows them to see more complex relationships between ideas than just sequence and hierarchy [7]. It is simple and intuitive, visual form of knowledge representation [8] well applicable for subject domain structuring and course task presentation. The link types we use are based on the generic selection of link types defined in [9]. There could be a number of instances of the subject domain model, each describing a different subject domain within AIMS.

The use of CMs as a basic mechanism for information structuring allows for an effective visual presentation of the subject domain, since CMs furnish simple and intuitive visual form of knowledge representation. In AIMS, information visualization targets the presentation of the subject domain structure and the overlaying structures of the course and user models. As part of the supporting information search functionality AIMS also proposes combined visualization of the search results. 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 (see Fig. 1). 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 [10].

Course Model

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 a 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 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.

Library Model

The library model provides means for representing and 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.

Responsible for building the system domain knowledge is the domain expert (course instructor). In AIMS, the domain expert's work is supported by three editors: domain, course, and library editors.

Domain Editor

The domain editor is aimed at providing support for the instructors to build and maintain the AIMS subject domain knowledge (see Fig. 2). Its functions cover building a new domain structure, that is, building a domain concept map and linking relevant documents to it, as well as editing and updating an existing domain structure, including terms, links, and documents. There could be a number of different subject domains within AIMS. The Domain editor contains four different sections*: Domain Info, Domain Concepts, Domain Link Types and Domain Related Documents.* 'Domain Info' gives general information about the domain including domain name, author(s), creation and last modification dates, and short description. 'Domain Concepts' provides facilities for creating new and modifying existing domain concepts. Each concept is defined in terms of name, short description, synonyms, spelling and writing forms, and classification level. The labeled links between concepts are created and modified in the 'Domain Link Types' section. When linking two concepts the user can either select a link type from a predefined list or create a new one. In 'Domain Related Documents' the user can create links between domain concepts and

documents by selecting a concept and linking it to a document from a list of existing AIMS library documents (with a certain weight indicating how relevant is the documents to this concept).

Course Editor

The course editor is aimed at facilitating the instructor to build the structure of a specific course and organize along going tasks, course materials, and reference documents. 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

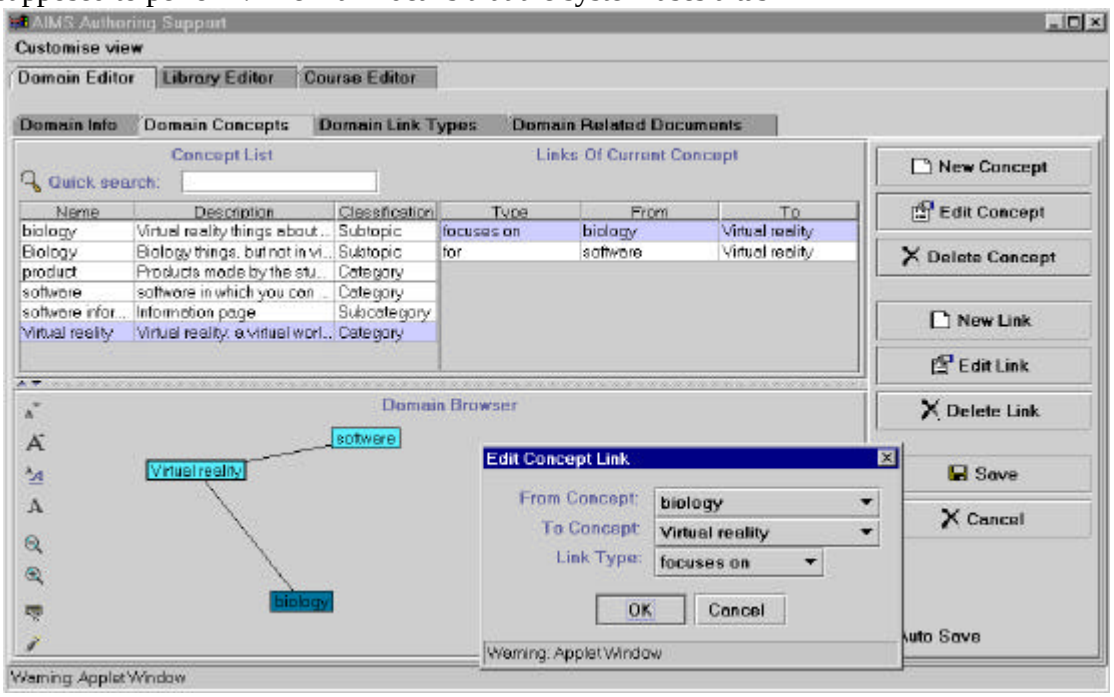

Fig. 2 AIMS Domain Authoring Environment for Instructors

to constrain the information provided to the learner in support of his or her efforts to complete this task. Each course task is associated with a list of domain terms, which the student must

Library Editor

The library editor provides means for maintaining a collection of information related to different courses and domains. Each document in the AIMS library is described by a document name, author, year of publication, location (URL or library index), short description, and list of weighted keywords. Documents have also a presentation format (text, audio, video, EXE, ZIP, etc.) and instructional format (example, definition, description, procedure, etc.)

2.3 User knowledge

User modeling provides grounds for system adaptiveness. In AIMS, the user model (UM) refers to the learner (not to the instructor) 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.

User Model

The user model is an *overlay* of the domain, course, and library models, enhanced with tags indicating user's knowledge and interests and course tasks status. Thus, it is represented in terms of domain concepts, course tasks, and library documents and related status indicators.

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 documents.

Building UM: system's perspective

The main source of system 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 dialogue, 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 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.

Building UM: user's perspective

Every user logs in the system with his or her personal username and password. The user's account contains additional information about the user type (student, instructor or administrator) and provides adaptive access to the AIMS environment. When a student logs in and selects a course, he or she is presented with a list of tasks in the current course along with their current status. The task status represents student's work on the task – 'completed', 'not completed', 'not visited' or 'forbidden'. Forbidden tasks are those, which require knowledge from previously performed tasks that are still 'not completed' by the student. The student can either select a task to work on or enter the AIMS environment in 'no-task mode'. The latter allows him or her to explore the subject domain and perform task independent search queries. When the user selects a task to work on, he or she is presented with a list of domain terms related to this task. The student is asked to indicate his or her knowledge status for each of them. This information is used later for adapting system's behaviour. All user data is stored in the user model and is used by the user agent within the AIMS architecture.

3 Conclusions

This paper describes an approach to integrated information handling support in web-based course environments for both learners and instructors. It provides 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. Instructors are facilitated with a domain- and course- authoring environment, which helps them to build a general view of a specific subject domain and over it - course structures.

Several pilot experiments have been performed at the Eindhoven Technical University and the Antwerp University, the Netherlands, for evaluating AIMS browser and editor GUI functionality, user-friendliness, and learning effectiveness. The purpose of these formative evaluations was to validate the proposed AIMS approach and to identify any problematic aspects in order to improve it.

In the last experiment, conducted in the Faculty of Educational Science and Technology, University of Twente, The Netherlands, AIMS is being effectively applied within the framework of the design for the "Courseware Engineering" course. The course topics and tasks are clearly defined by the instructor with the help of AIMS authoring support tools, and its information search and browsing tool supports students conceptually. Within this experiment we focus on one aspect of a course design: encouraging students to integrate new design concepts, procedures and methods with their existing conceptual knowledge in different educational areas as well as the field of software design and implementation. To accomplish this goal we rely on the role of concepts in learning of design, and in particular, we focus on central conceptual structure of the domain and its cross-linking with the task-oriented view of a course structure. In this experiment we explore how conceptual support, represented by concept maps, can help students to build connections between the 'dry' domain concepts and the topics in the course structure (context rich and task oriented), as well as between formal task descriptions and informal conceptual knowledge.

The results of all experiments will be summarized and will serve as a basis for developing a new improved version of the system.

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