A Concept-based Approach to Support Learning in a Web-based Course Environment

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Abstract. Intelligent information handling support is crucial for the efficiency of web-based learning. This paper presents an approach to information handling, which implies conceptual support for both learners and instructors engaged in open-learning and teaching tasks in a web-based course support environment. The proposed approach combines two powerful techniques to support web-based course learning - information retrieval and concept mapping. It involves conceptualisation of the subject domain and representation of the domain structure in an ontological way by a concept map, which is used for knowledge classification and indexing and allows for efficient information search. In addition, it includes strong visual presentation and graphical navigation of the subject domain and information search results and supports adaptive matching of the presentation to particular learners. AIMS - an intelligent tool for task-based information handling support in web-based learning/training/work environments demonstrates the main ideas of this approach. AIMS can help a learner adaptively in information retrieving and information visualisation by using a learner model. AIMS has been used in several pilot experiments focused on evaluating system’s functionality and user interface. In this paper we discuss the important aspects of the proposed approach as implemented in AIMS from a learner’s perspective – how do they help the learner in performing learning tasks in a web-based course environment.

1. Introduction

Web-based education is getting an increasing popularity due to its clear benefits - classroom independence and platform independence [1]. Web-based and web-assisted courses are becoming a common practice in both college education and business training. More and more instructors put course related information or links to such information on the web to support students’ learning and require that students use web materials when performing learning tasks such as course assignments, projects, etc. An arising problem however is that the learners have to cope with a much larger amount of information when performing course related
Among the most referenced problems when using web to support course work are the difficulties in finding relevant information and the related waste of time and frustration. These problems are mainly caused by the intrinsic nature of the web, but often - by the inherent learning behaviour of the students as well. Web-related problems are generally due to the fact that users are not aware of the aims, targets, and keywords of the web documents they receive as search results. The student-related problems ensue by students’ practice to attempt completing a course assignment without studying the required material beforehand. As a consequence, they are often unaware of the complete context of the learning task in hand and need help in getting oriented in the subject domain structure. Another point is that students often prepare their assignments in a hurry and cannot spend much time on searching additional information related to them thus missing the opportunity to learn more about the subject domain. Clearly, students will benefit a lot if they are supported in retrieving, evaluating, comprehending, and memorising information when performing (learning) tasks in a web-based learning environment. Providing students with such support would not only help for their more efficient task performance but would also contribute to the enrichment of their overall subject knowledge and enhancement of their task-oriented skills. This kind of support is closely related to information handling, i.e. organising, indexing, maintaining, searching, and presenting information. The availability of intelligent information handling support is crucial for the efficiency of web-based learning.

This paper addresses a novel approach to information handling aimed at enhancing the effectiveness of web-based learning and training. It implies conceptual support for both learners and instructors engaged in open-learning and teaching tasks in a web-based course support environment thus being in line with the current trends in the educational technology area of shifting emphasis towards open domains and conceptual understanding [2]. The proposed approach combines two powerful techniques to support web-based course learning - information retrieval and concept mapping. It involves conceptualisation of the subject domain and representation of the domain structure in an ontological way by a concept map, which is used for knowledge classification and indexing and allows for efficient information search. In addition, it includes strong visual presentation and graphical navigation of the subject domain and information search results and supports adaptive matching of the presentation to particular learners. AIMS - an intelligent tool for information handling support in web-based learning/training/work environments demonstrates the main ideas of this approach. AIMS can help a learner adaptively in information retrieving and information visualisation by using a learner model.

AIMS (Agent-based Information Management System) provides a contextual support that enables the user to identify information necessary for performing a particular task (e.g. course assignment). It can be used standalone (for example, as an extension to a traditional or on-line distance course) or integrated in a larger electronic learning/training/work environment that allows the users to perform open learning tasks in a specific subject domain. In both cases it provides the user with immediate, on-line access to a broad range of structured information and with domain-related help in the context of work, thus supporting more efficient task performance. Hence, AIMS could be seen as a type of Electronic Performance Support System, which focuses on efficient information provision and management for task-oriented problem solving. The system is a cognitive tool [3] helping the learners not only to complete their course work more accurately and efficiently, but also to build new knowledge and comprehend better the subject domain in hand. The general architecture of AIMS as an agent-based information support system is elaborated elsewhere [4,5]. In this paper we discuss the important aspects of the proposed approach as implemented in AIMS from a learner’s perspective – how do they help the learner in
performing learning tasks in a web-based course environment.

2. AIMS: Conceptual Mapping and Information Base

One of the main goals of AIMS is to improve the usability and maintenance of information in an on-line course environment. The usability of information depends on retrieving relevant information and visualising it in an appropriate way. Hence, we focus on information search and presentation. An important educational constraint in our framework is that learners are supported to deal efficiently with information only within a particular subject domain and course in respect to particular educational goals (tasks). AIMS employs concept mapping as a basic mechanism for information structuring and representation of the domain knowledge.

2.1 Concept mapping

Concept mapping becomes lately more and more popular in both educational and business fields. Concept maps have been used in education mainly as a graphical advanced organiser and assessment tool [6], and in management mostly as a problem-solving tool [7,8]. There are numerous definitions of concept mapping depending on its various applications, but for the purposes of our work we have concentrated on concept mapping as formalism for structural knowledge representation [9] in the context of memory, perception, and metacognition [10]. The most widely accepted definition of concept mapping is as a technique of graphical representation of concepts and their hierarchical interrelationship. A concept map is organised in a spatial configuration of nodes and links in a given knowledge domain [11]. It is a simple and intuitive, visual form of knowledge representation [12] well applicable for subject domain structuring and course task presentation. In our specific educational context this approach conceptually maps a subject domain of a course into terms and links. Same mapping is used for representing course items, such as tasks and sub-tasks. Search results are also partly presented with this graphical approach. The result documents are related to a result concept map of domain terms used in those documents.

According to Piaget [13,14] building cognitive structures, called also ‘mental maps’ schemes or ‘networked concepts’ is an essential part of the process of understanding, responding, and learning the surrounding environment. Those mental structures are gradually built and expanded depending on the sophistication of the mental activities in which the children are involved. The process of learning supported by AIMS can be analogously seen as a continuous process of building and altering a learner’s initial cognitive structure or ‘mental map’ through exploring a subject domain concept map. It is the process of creating an initial ‘mental map’ and then relating the new incoming information and concepts to it and using it in order to solve specific course tasks and problems. The cognitive structures not only support the process of problem solving but also help for efficient memorisation of facts and building course related knowledge. Thus their building has a crucial impact on the way the learning and teaching is performed. The curriculum must be planned developmentally and appropriately to the students’ logical and conceptual growth. The instruction must emphasise the critical role of fundamental concepts and their relationships within the teaching domain, which will gradually help building general and detailed cognitive structures. Teachers should help their students learn by focusing on the nature of the learning process, in other words by grounding their teaching on principles of psychology of learning. AIMS is designed as a tool, in which teachers externalise their subject knowledge in cognitive schemes represented as concept maps, which help the students to memorise and learn more efficiently the presented
course material in a task-oriented way. AIMS environment is open and allow students to adopt different learning styles and bring their own individual knowledge and resources to the learning process.

2.2 AIMS information base

AIMS is a generic tool, which can accommodate different subject domains and courses. Its information base includes definitions of subject domains and courses within them and a library, i.e. collection of documents related to these courses and domains. Each document in AIMS library is described by document name, author, year of publication, location (URL or library index), short description, and a list of weighted keywords. Documents have also presentation format (text, audio, video, diagram, EXE, ZIP) and instructional format (definition, description, procedure, case, example, exercise, lecture, assignment, test, manual, reader, book, chapter, journal, article). The usage context indicates different domains/courses where this document could be used as an instructional item.

The description of the documents is important for both students and instructors. Instructors use the document library to keep their own expert document database. The description of each document helps them in its easy finding and appropriate usage. As for the students, document descriptions give them a clear and comprehensive quick view of each document included in their search results. They can see the main focus of the document and what is its format.

A subject domain is represented in the system by a concept map linking the domain concepts. The link types are based on the generic selection of types defined in [11]. The following link types are currently used in AIMS:


For example, ‘design phase’ – ‘is part of” -> ‘instructional design cycle’.

Two concepts could be related by several links (with different labels). Each concept is defined in terms of name, short description, synonym-form list, and classification level. The synonym-form list is a list of weighted synonyms and other word forms, such as plurals, abbreviations, and common used forms. They are assigned weights in the range \{0,1\} that indicate how close is the word to the meaning of the concept. The word forms usually have a weight of 1 as they match completely the meaning of the concept. These weights are used in determining the relevancy of the retrieved documents to a user query. There are four
classification levels, which define a sort of hidden hierarchy within the non-hierarchical structure of the domain concept map. The four levels are: ‘category’, ‘sub-category’, ‘topic’, and ‘sub-topic’, where ‘category’ defines concepts, which are broadest and most fundamental for the domain and ‘sub-topic’ defines concepts, which are least fundamental or are specific examples. Here is an example:

**Category:** 'Web-Authoring'
**Sub-category:** 'Authoring Aids'
**Topic:** 'Authoring Environments'
**Sub-topic:** 'FrontPage'

Domain concepts are linked to documents and each link is assigned a weight indicating how relevant is the concept to a document. AIMS includes a convenient authoring tool for instructors to build or edit a domain structure, i.e. a domain concept map and to link relevant documents to it.

Since the main goal of AIMS is to provide task-based information support, a series of tasks are associated with each course. Course tasks are pre-defined in a course task library and correspond to course assignments that the student is required 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. Each course task has a description and is associated with a list of domain terms, which the student must know to perform successfully the task. Tasks are related to course topics, which are automatically associated with the whole collection of domain terms included in each related task.

3. Learner’s Support: Information Retrieval

AIMS supports students to retrieve information within a specific course domain in two ways, namely, through information search and conceptual navigation of the domain. The former enables students to search for reference information and materials needed to perform a specific task and the latter - to explore the entire subject domain for better comprehension. This helps the students to get a general conceptual view over the subject domain, in which they work and make a direct link with the course goals and assignments.

3.1 Information search

AIMS supports information search in two modes: **general search** and **task-based search**. In both modes when the learner enters a search expression the system searches not only for the keywords specified in the expression but also for their synonyms. Recall that AIMS document database includes an extensive term thesaurus that defines a special synonym relation in order to support more precise and effective search approximation and selection. As we already mentioned, every term (concept) has a list of weighted synonyms and other word forms. The weights are used in determining the relevancy of the retrieved documents to the user query. In fact, when the user enters a search expression, for each keyword in that expression AIMS finds all related terms, i.e. terms, which are:

- keyword synonyms, or
- terms in the domain concept map connected directly with the keyword.

AIMS assigns to each related term that it finds a coefficient in the range \(\{0,1\}\), called weight. The following rule is applied: the keyword itself has a weight of 1; if the keyword is a domain term all word forms have a weight of 1; all keyword synonyms have a weight equal to
the synonym’s weight defined in the thesaurus; all terms in the CM connected directly with
the keyword with a link of type ‘is-a’, ‘type-of’, ‘is-kind-of’, and ‘is-a-part’ have a weight of
0.5; all terms in the CM connected directly with the keyword with a link of different type
have a weight of 0.25. AIMS constructs an extended query using as new search keywords the
original keywords and their related terms. Thus the relevancy of a document to the specified
search query depends on both the relevancy of the document to the new search keywords
found in its description and the assigned weights of the new keywords.

The search procedure for a query calculates the degree of relevance (matching value) for
each found document. To do so, for each document it calculates the number of matches of
the search query keywords to the document keywords (N) along with an accumulated weight
(W). The following rule is applied: a match between a document keyword and a search
keyword or its word forms is counted for 2 with a weight of 1; a match between a document
keyword and a related term of a search keyword is counted for 1 with a weight equal to the
related term’s weight. Then the degree of relevance of the document to the search query is
calculated as N/W. Thus AIMS finds a list of documents with their matching values (degrees
of relevance) to the query and uses these values to sort the documents in descending order.
The documents with a higher matching value are considered more relevant to the query than
the ones with a lower value. The DoCS (Document Classification and Search) model used in
AIMS for information retrieval is described in detail in [15].

In the task-based search mode the system still constructs and runs an extended query. However, when sorting out the resulting documents it takes into account not only their
relevance to the query itself but also to the selected task. The task-related concepts influence
the weight of the documents in the search result – they are used to refine the query sorting by
pushing the documents related to them upward in the list. This helps the learner to browse
first the documents more relevant to the task in hand and prevents him or her from being
overloaded with non-relevant information thus saving time and making the work more
efficient. In the current implementation the sorted list does not exclude any documents
matching the search query but it indicates if they are relevant to the selected task.

3.2 Conceptual navigation of the domain

The second way in which AIMS can help a learner to retrieve course-related information is
through supporting conceptual navigation of the subject domain. In some open-ended tasks
the learners experience difficulties in deciding what specific information they need, that is,
they have difficulties to formulate a search query. In such cases it is helpful to enable the
learner to browse the domain concept map. AIMS supports such a conceptual navigation.
Technically the learner starts from a concept fundamental to the selected task and then
follows links in the concept map from one concept to other concepts related to it, e.g. first to
the closest ones, than to concepts on the next level, and so on. For each concept the learner
can ask about its definition and references to course materials and library documents relevant
to it. By browsing the domain concept map the student learns about concepts in the subject
domain and the way they are related. This gives the learner a better understanding of the
entire domain and the undertaken task and helps him or her in finding useful information to
perform the task.

We believe that a combined use of task-based search and conceptual domain navigation
is the most productive way for a learner to find information to solve the task in hand and
learn more about the subject domain.
4. Learner’s Support: Visualisation

Information visualisation is extremely important for the efficient informational support of learners in performing course-related tasks. In AIMS visualisation targets the presentation of both the subject domain and the information search results. Several types of information (objects) are visualised within AIMS: concept maps, textual lists, and metadata. The use of concept maps as a basic mechanism for information structuring in AIMS simplifies greatly the task of visual presentation of the subject domain, since concept maps furnish simple and intuitive visual form of knowledge presentation. Information search results are also partly presented through this graphical approach. In addition to the traditional list form presentation the result documents are also bound to a result concept map of domain terms used in the found documents (see Figure 1). The system GUI includes CM Viewer, which enables the user to navigate through the map.

The visual and graphical presentation of context information is not enough for extensive information support while performing search activities. It is important to present search results as a list of documents in order to give an impression of the volume of the found results as well as a first glance idea of the content of the documents (by their titles). In AIMS the references to the result documents are organised in the traditional way of textual list-based presentation.

Metadata is descriptive information about data - labels, catalogues, and descriptive information structured in such a way that allows web pages to be properly searched and processed. In AIMS we use metadata to organise course materials and reference documents in an appropriate way for searching. Metadata is applied in order to support a better and quicker comprehension of the search result. Metadata in the form of short descriptive information and structured tags is also used to describe the context of the domain terms and links.

4.1 AIMS Viewer

The Viewer visualises a concept map of a subset of domain concepts and links in the context of presentation of the overall domain structure or information search results. Its functionality includes navigating, bookmarking, and editing. Navigating allows using shortcuts, history, performing previous/next step, etc. The bookmarking option allows the user to bookmark terms or search sessions of interest, so that he or she can view them later by using the ‘Edit Bookmarks’ function. Editing functions include changing appearance (font, font size, etc.), arranging nodes, expanding/collapsing links, showing/hiding levels of detail, and refining.

The user can access most of the browsing functions via four menus – Domain, View, Go, and Help. The Domain menu includes general and task related functions such as ‘choose task’, ‘finish task’, ‘close task’, and ‘session log-out’. The View menu includes concept map manipulation options, such as changing font size and style, adjusting the length of the links, nodes freeze/unfreeze positioning, and nodes centred arranging. The Go menu helps learners switch between already visited nodes and go to the main domain node. It also gives the opportunity to view user work history in terms of visited nodes, documents, and searches performed. In the Help menu students can find a detailed description of all the functionality of the AIMS screen areas.

AIMS Viewer displays the terms of different classification levels (‘category’, ‘sub-category’, ‘topic’, and ‘sub-topic’) in the concept map in different colours. It uses four nuances of blue to present the four levels, where the lightest blue expresses the highest level – ‘category’ and the darkest blue expresses the lowest level – ‘sub-topic’.

Apart from the Concept Map Visualisation area, the Viewer includes several other screen
areas: Query, Documents, and Explanation Information. The Query area supports the main AIMS functionality - searching for course related information. This functionality is combined with several options for refining search queries and search results. They can be activated by:

- direct entering of text in the query area,
- graphical manipulation of terms in the concept map representing the search results.

![Figure 1 AIMS Domain Browsing and Search Environment for Learners](image)

It is also possible to refine a search query with terms related to a selected document. When pointing a document the related domain concepts in the search result concept map are highlighted (see Figure 1). By right clicking a document from the list of search results the user can initiate a new search. A new query is then formed by the keywords of the selected document. The Explanatory Information area also supports the functionality for the document search. Some metadata (labels and descriptive information) about concept map terms and search result documents are presented there. This information is shown alternatively below the concept map visualisation depending on the mouse-over position in the current moment.

The visualisation and domain navigation facilities help students to get orientated within the subject domain and build up their own understanding and conceptual associations. It supports their visual thinking and imagination and helps them to create their own problem-solving paths. Information visualisation enhances browsing by presenting more choices in a compact and meaningful overview, and complements searching by helping users understand the distribution of search results [16].

5. System Adaptation: Learner’s Model

AIMS aims at providing user-oriented support for information search in the context of an educational task and adapting the search results to user’s interests and course tasks. It
supports a model of the learner reflecting his or her activities in the on-line course environment, such as performing a course task, searching for a term, visiting documents related to a term, requesting terms related to a specified term, browsing the subject domain, etc. The user model (UM) is represented in terms of course tasks, domain concepts, and library documents, thus it is an overlay on the subject domain concept map, and course and library models maintained by the system. 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 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.

5.1 Tasks

A course consists of pre-defined course tasks, which correspond to course assignments that a student must perform. Each task is represented in terms of domain concepts and includes some additional information, such as task description, prerequisites, task status, etc. Generally a task requires knowledge from previously performed tasks, which must be completed beforehand – ‘prerequisite’ tasks. Each course task is assigned a status representing student's stage of work on the task. Four-value task status scale is used: ‘forbidden’, ‘not attempted’, ‘not completed’, and ‘completed’. All tasks are initially ‘not attempted’. In order for a student to be allowed to perform (‘attempt’) a task, he or she has to have performed all ‘prerequisite’ tasks. ‘Forbidden’ tasks are those for which the student has not performed the ‘prerequisite’ tasks. A task is ‘not completed’ if the student has started working on it and completed some of its sub-tasks but not all of them, i.e. the entire task. The student can select a ‘not completed task’ later and complete it. When the student selects a task to work on or close a task the system updates automatically the task status. The student can also enter the AIMS environment in ‘no-task mode’. This allows him or her to explore the subject domain and perform task-independent search queries.

5.2 Domain concepts

The domain concepts component of the UM is represented as an overlay on the domain concept map: each concept is marked as ‘known’ or ‘unknown’. These two states can be thought of as ‘covered’ and ‘not covered’ since we do not test the student knowledge on them. Initially all the concepts are ‘unknown’. When the user selects a task to work on, he or she is presented with a list of domain terms/concepts related to it. The student is then asked to indicate his or her knowledge status (‘known’/’unknown’) for each of them (optionally). The student can do this by simply checking a box. In addition, the system automatically updates the model when the student logs out. Upon a successful completion of a task the system marks all concepts related to it as ‘known’. The learner can inspect the model at any time and make changes.

5.3 Library documents

The documents component of the UM is represented as an overlay on the library documents: each document is marked as ‘visited’ or ‘not visited’. This information is used by the system to suggest to the student documents relevant to the performed task, which he or she has missed to visit.
The learner model is intended to support system’s adaptability to each student while working within AIMS. By reasoning on the learner's activities, information requests, and current learning state within the selected course AIMS adapts the presentation views and the search results.

Currently AIMS diagnoses all three components of the learner model but only the course tasks component is used by the system to adapt the information search and presentation. However, since the model can be inspected, the instructor can use the AIMS learner model even at this stage to track the current state of conceptual knowledge and course work of the students in a specific course. He or she can then use this information to personalise and adapt (manually) instructions/course materials to a student's knowledge level and learning pace.

Here are some examples of adapting information visualisation to individual learners:

- The welcome screen is specific for each student – it presents the course tasks assigned to the student with an indication of the status of the student’s work on them.
- In the login dialogue the system skips the terms already covered by the student.
- Colour indication is used in the concept map for the current task to distinguish the domain terms already covered by the student; a different colour is used to indicate domain terms of his or her personal interest.
- Font indication is used to distinguish documents, which are already visited.
- Icon indication is used for documents found by the student’s search query that are also related to other courses taken by that student – by clicking the icon he or she would be able to see the list of related courses in a separate window.
- The search results are sorted depending on the currently selected course task.
- There is an autonomous search collecting the search results from all user queries, which are related to terms of user’s interest.

6. Conclusions

This paper describes an approach to support learning in web-based course environments. It provides learners with an easy access and attractive visual presentation of information related directly to course tasks as well as with a conceptual view of the complete subject domain.

The AIMS system was initially planned to support the students from the Faculty of Educational Science and Technology, University of Twente, participating in the course of ‘Courseware Engineering Architectures’. The intention was to integrate AIMS in the web-based course environment already created for this course. However, AIMS is designed as a general course support tool, which allows importing of different subject domains and different courses. In order to improve gradually AIMS functionality and user interface two pilot experiments have been performed within courses at the Eindhoven Technical University, the Netherlands and the Antwerp University, Belgium. The AIMS browser and editors have been evaluated in respect to 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 recent main experiment conducted in the Faculty of Educational Science and Technology, University of Twente, The Netherlands, AIMS was applied within the framework of three design courses - ‘Courseware Engineering Architecture’, ‘ICT in Training’, and ‘Instrumentation for Instruction and Training’. For each of them instructors defined course topics and tasks by using the AIMS authoring tools. Selected reading literature and additional reference literature was also collected/validated by the instructors and entered in the AIMS document library. This information was made available to the
students in a task-oriented manner via the AIMS information search and browsing tool, in order to provide conceptual and information support to the students taking the courses. Within these experiments we focused on evaluating whether students will gain specific set of practical design skills, while also encouraging them to integrate new concepts, procedures, and methods with their existing conceptual knowledge in other subject areas as well as in the field of software design and implementation. We compared the performance of students using concept maps as a conceptual support tool to that of students using information outlining approach to structure and reflect on the course issues. To accomplish this goal we relied on the role of concepts in learning of design, and in particular, we focused on the central conceptual structure of the domain and its cross-linking with the task-oriented view of a course structure. We provided the students with a structured approach to processing course-related information in order to make their efforts in performing course assignments efficient. In these experiments we explored how AIMS conceptual support can help learners 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,**
- **be able to apply the new knowledge in other areas of their expertise,**
- **retain their newly gained knowledge longer,**
- **make more effective usage of computer tools, Internet and other network facilities, as well as spend more efficiently their time on the course and assignment preparation.**

As to the AIMS teachers’ support, in the experiment we focused our attention on the issues of preparing teaching materials that can be easily reused in other courses and of defining explicit links on a conceptual level between concepts covered in a course and other concepts that are in the same subject domain but are not covered in that course.

The results of all experiments will be summarised and will be used for developing a new improved version of the system.

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**References**


