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ABSTRACT

This paper reports on an integration of concept mapping for manipulating and structuring knowledge with multimedia presentation technology. The intelligent hypermedia system HAN (hypermedia activated network) is an authoring environment that generates small hypermedia tutorials online as they are required. A student query activates a portion of a semantic network representing the key concepts of a domain of a HAN module. The activated portion of the network and a simple model of the student are used by the system to construct a small mapped hypertext which can then be explored by the student. The HAN system combines hypermedia material for the authoring and tutorial interface provided by Apple's HyperCard with a core semantic network management system implemented in Logic Programming Associates' MacProlog. These systems communicate via Apple's Apple Event interface. Following an evaluation of the use of this system to teach second-year students of architecture at University of Sheffield (England), the authoring and inference aspects of the system were substantially improved. The system is now being extended to demonstrate the support of some aspects of cognitive science and psychology. The HAN system integrates artificial intelligence and flexible learning techniques in a dual-platform experiment with hypertext and semantic network architectures. (AEF)

Integrating Concept Networks and HyperMedia

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This paper reports on an integration of concept mapping for manipulating and structuring knowledge with multimedia presentation technology. It presents the current development of the HyperMedia Activated Network (HAN) authoring environment. HAN is an intelligent hypertext demonstrator system. The first HAN module, called ICADT, was developed initially to teach Computer Aided Architectural Design (CAAD) using the GABLE 4D™ CAAD environment at Sheffield University, (Scott and Lawson, 1990; Scott, Lawson and Ryu, 1991; Scott, 1993). Following a detailed evaluation of the use of this system to teach second year students of Architecture at Sheffield University the authoring and inference aspects of the system were substantially improved. The system is now being extended to demonstrate the support of some aspects of Cognitive Science and Psychology. The HAN system integrates artificial intelligence and flexible learning techniques in a dual-platform experiment with hypertext and semantic network architectures.

The intelligent hypermedia system HAN works as a complete experimental tutorial environment that generates small hypermedia tutorials on-line as they are required. A student query activates a portion of a semantic network representing the key concepts of a domain of a HAN module. The activated portion of the network and a simple model of the student is used by the system to construct a small mapped hypertext which can then be explored by the student. The HAN system combines hypermedia material for the authoring and tutorial interface provided by Apple's HyperCard™ with a core semantic network management system implemented in Logic Programming Associates' MacProlog™. These applications communicate via Apple's Apple Event™ interface. The system is intended to provide a radical hypermedia alternative which aims to address the classic authoring problems faced by Instructicnal Designers who are experts in their field but not experts in the presentation technology, (Nicolson and Scott 1986).

The HAN Shell

The HAN shell consists of four main sub-systems: A concept network knowledge base including authoring and maintenance; an automatic tutorial generation system; a student-record maintenance system; and a tutorial prese-⁺ation and performance monitor. This architecture is presented in figure 1.

Within the concept net sub-system, HAN maintains a number of layers of authored material. Authors create hypermedia teaching material about some concept in the domain using HyperCard. This material can be of any internal complexity and can contain for example limited links to glossary items, (but is often just a single screen - or card). This material is termed a "topic" and is seen as an essentially stand-alone chunk of knowledge in some domain. The author then defines the links between the high-level concepts that each topic explains using a simple graphical concept mapping interface. Links can be of various sorts, for example one concept (with its associated topic material) may 'depend-upon' another or be 'an illustration of' another. There are currently eight links in the concept mapping authoring system for Architectural CAD and a similar number for the Language module. The tutorial generation sub-system is responsible for spreading activation though the network of concepts, taking the activated chunk of the network and constructing a tutorial from the associated topic materials. The tutorial generated is then presented to the student by the presentation sub-system. The system manages a simple internal model of each individual user via the record-maintenance sub-system and is able to react to different individuals and different pre-defined user types.

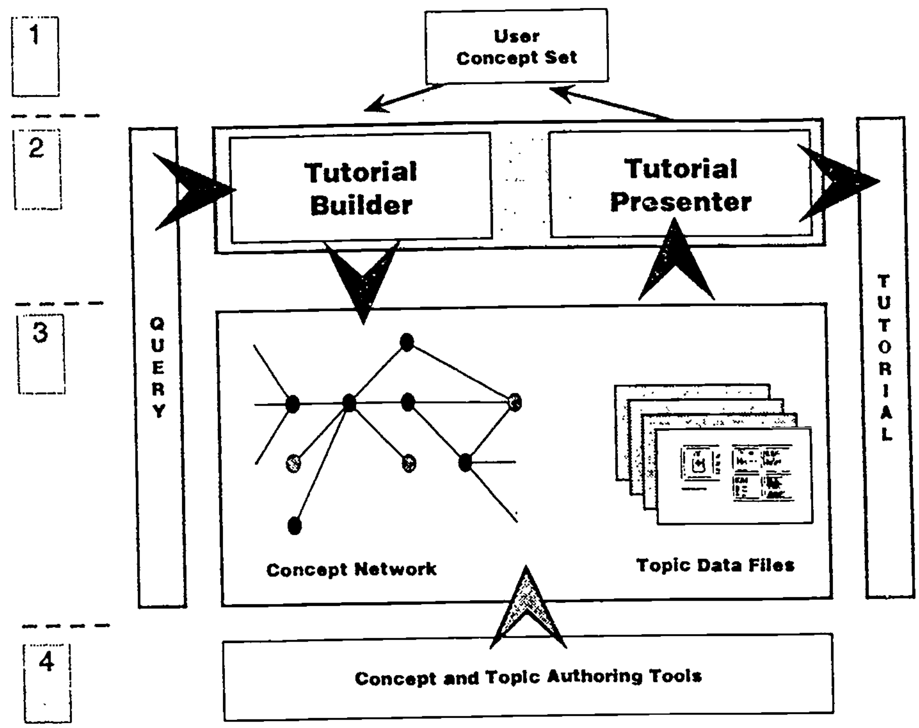

Figure 1. The Architecture of HAN.

In this figure we show that there are essentially four levels at which this system could in principle be used. Level 1 at the top is where the system is related to approaches to expert or intelligent tutoring. In the current HAN this is only supported by relatively primitive user modelling features. Level two is the "query" level where the system can react more specifically to user queries. Level three is the "browse" layer in which most hypertext systems offer users the opportunity to wander through a virtual net of related topics. Finally, level four is the network authoring level in which users could in principle generate their own networks and topics to help structure their understanding. This is the level advocated in concept-mapping systems research. The current work on HAN to date has focused on level two.

In overview then, users typically interact with the HAN system by issuing queries about some concept to be learned. The user's query is mapped onto the HAN concept network. HAN then activates a fragment of the network which it uses to generate an individualised hypertext which it can present to the user with the net fragment acting as a hypermap of the topics involved.

Some detail of the HAN System

(A) **The Topic Database.** A concept is represented by a "topic" in the ICAD Tutor system, where each topic is the basic (primitive) unit of instruction consisting of several layers. The top layer has a simple graphic representation of the essence of the design topic concept which may be sufficient to explain the core part of the knowledge to be delivered. The basic material can be taken from existing manuals (specific to the CAAD system being used) or other reference materials. In the case of the ICADT module, the topic database was general knowledge about the principles of CAAD system engineered by architects. In the case of the Psychology and Cognitive Science modules the material was collected from lecture and course notes of the individuals supplemented by edited extracts of literature and specially constructed demonstration material. Successive lower layers introduce more detailed information as textual and graphic explanations of the topic using hypertextual links.

(B) **The Concept Network Database.** Topics are represented at a high level by a knowledge base of 'concepts' each of which is linked to others in a network. The power of the generation system to provide sensitive help to a user resides in an ability to select amongst rich linkages for different and possibly complimentary purposes. The function of this network is to be interpreted by the generation system. The network is a 'virtual' net of single links in Prolog. Each topic has a unique node name in the net and can be associated with other topics by giving a specific link type which represents the semantic relationship between two concepts. Figure 2 illustrates one small fragment of the concept network of the ICADT module of HAN based around the concept of "Offset" in the Computer Assisted Design system. In this case, activation has spread down the directed links to nearby concepts and thence out into the network. The activated part of the network can then be processed by the next part of the HAN system as the basis of the tutorial. The algorithm for the spread of activation is currently very simple and is constrained more by the size of the network itself, the direction of the linkages and the context of the activation (knowledge about the status of the user - novice, intermediate or expert) than by any device for instantiating decay or any other control mechanism. Whilst the presentation mechanisms discussed next could handle any size of network chunk, in practice the network chunks activated are relatively small and can be pruned even further before being presented by knowledge about the individual student. Ongoing research in the Cognitive Science and Language HAN modules is experimenting with a variety of different network pruning heuristics based upon the semantic nature of the network links.

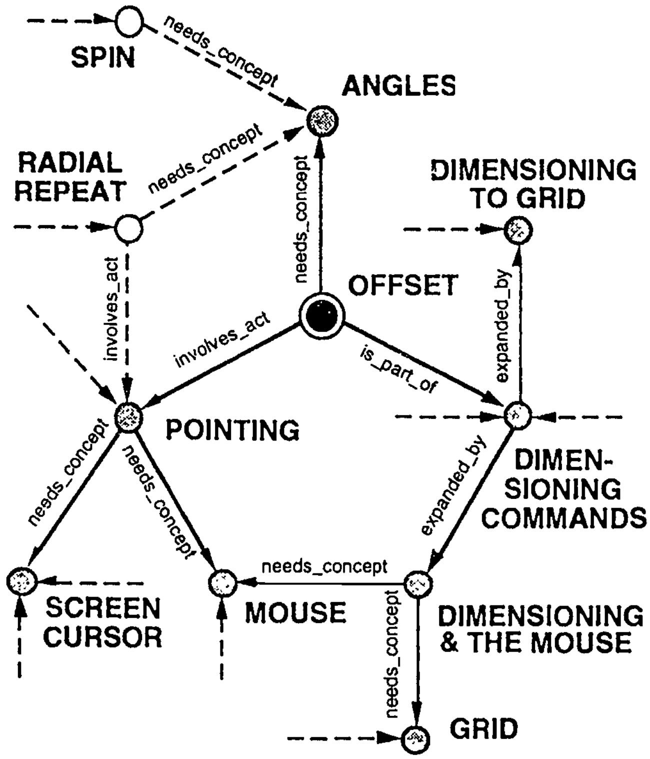

Figure 2. A fragment of the concept network for the Architectural CAD module.

(C) **The Performance and User Modelling system.** A performance monitor provides individualised record-keeping of each student's use of the system. The tutorial generation system may use this record to "prune-out" material that has already been seen - or to include more complex topic material - which a novice may not be exposed to. To serve for this purpose, it is necessary to keep record of "query topics" and "seen topics" (i.e., what kinds of questions did the users asked to the system and which topics did they studied). In order to make the "Performance Monitor" work, we must ensure that new users log-in to the program (so that the system knows who is using it) and log-out when finished. Logging-in finds the existing user file or creates a new one if necessary and the tutorial presentation system keeps a separate record of the student's query-topic and seen-topic list as it works; and logging out saves an updated version of the user's query-topic and seen-topic list.

(D) **The User Interface.** The HAN presents an interface to the user that is entirely within the HyperCard point-and-click model. The user need never be aware that the system is sending messages to and from the Prolog inference engine. Figure 3 shows the basic query interface as it is presenting information from the ICADT module of the system. The name of the user (in this instance "Hole") and the user's self selected level ("Beginner") are selected at the top right of the screen. All of the available concepts are listed down the left hand side of the screen for direct manipulation. Alternatively the user can search for keywords (via the upper right hand side window) which may be listed as associated with or paraphrases of single topics. As you would expect, the search can involve simple conjunctions, disjunctions and negations and can be phrased in a simple natural language form. The search results are shown in the lower right-hand side window, where they too can be directly called. Once a query is issued by such a call the results are passed to the Prolog sub-system where the concept net is activated for that user at that level.

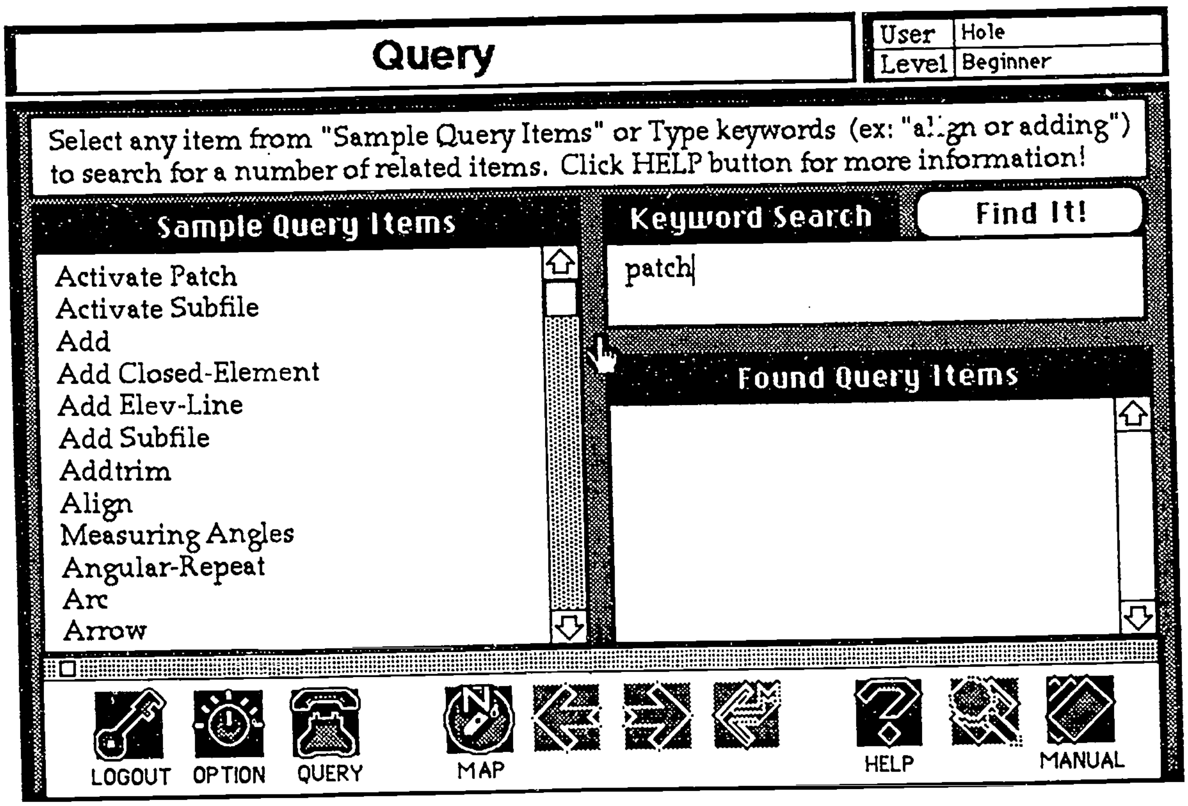

Figure 3. The basic user interface.

The Prolog inference system passes back the activated chunk to the presentation system which uses it as the core "map" of the multimedia material required to understand the chosen query. In figure 4 we see the concept "Align" in the CAD system represented as a simple graphical tree "hypermap" of related concepts leading towards the understanding of the query topic shown to the right hand side of the screen.

In figure 4 we see the user pointing to one of the nodes "Screen" which will then be expanded into the supporting "Topic Unit" for this concept. The topic unit will provide a range of materials to the user to help them understand the topic in question - whilst the map imposes the structure and enables them to explore how each individual topic relates to other concepts connected to this query. As the inference system takes note of individual user's needs and their self-stated rating of expertise, we note that it will produce different maps at different times for the same query.

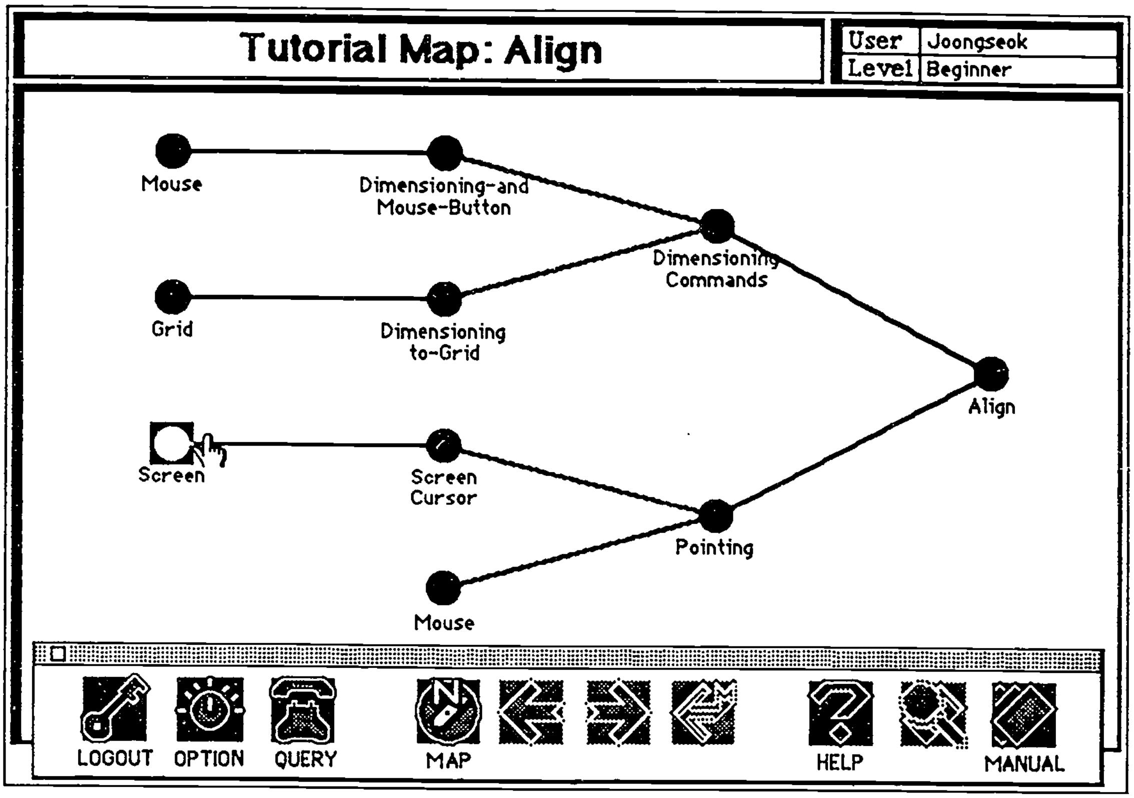

Figure 4. A tutorial map constructed for the concept "Align" for a beginner user.

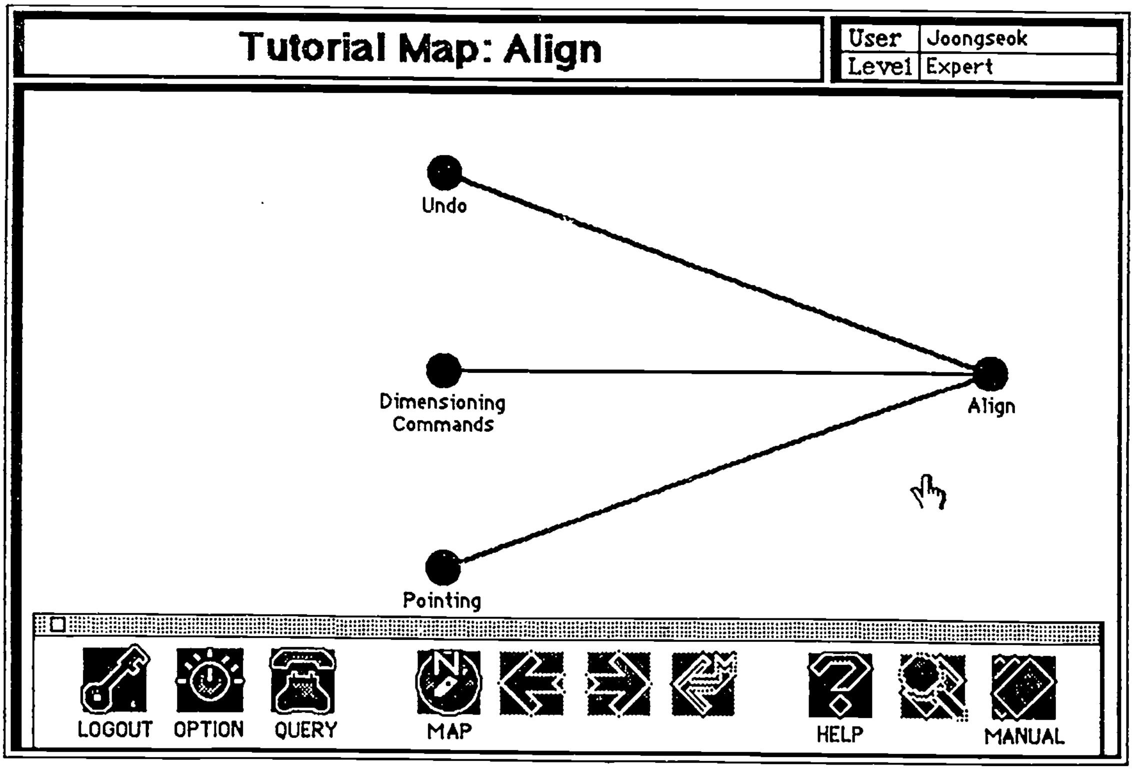

Figure 5. A tutorial map constructed for the concept "Align" for an expert user.

Compared to the identical query of figure 4 it can be seen from figure 5 that the expert user is assumed by the concept network authors to require a higher level overview of this topic - with some basic topics hidden and some extra advanced topics included. This analysis was produced by the authors of the concept network - in this module practising teachers of Architecture at Sheffield University.

Pros, Cons and Development of the HAN System

The HAN system represents a growing trend towards ExperText or ExperMedia in HyperText / MultiMedia research. It authors a HyperMedia "answer" to a student's Query on demand. Its critical strength is that it is inherently based in micro-maps of the knowledge meaning that users don't get lost in hyper space, (Novak 1983). Authored material does not fossilise as easily as traditional hand-crafted computer assisted learning projects. Neither is the system fragile like most Intelligent Tutoring Systems. But most importantly in the current version we have explored how authors can be saved from concentrating primarily on the presentation of their knowledge, but instead enabled to focus on its organisation. The HAN author focuses on the key concepts & their maps.

The HAN system has many technical limitations. The current version is still exploring techniques for using the link types in the network for tutoring reasoning in the new modules. It uses a very primitive user-model, in contrast to the focus of this sort of work within Intelligent Tutoring Systems projects (Wenger 1987). Furthermore it has a very primitive treatment of network activation compared to the sorts of models of memory in psychology and the network theories in artificial intelligence. From the evaluations with the architects of the CAD module we know that the representation is actually rather shallow leading to tutorials which tend to be rather boring for students to engage in. It is hard within the current system to provide the sort of strong lead or "story-line" which hand-crafted CAL can produce. The results often appear to students to be somewhat disjoint fragments of a multi-media glossary of related ideas. And finally, it is still quite hard for users to ask the right questions of the system as they often don't know what it is exactly they don't understand.

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