RC 21730 (Log 97903) April 24, 2000 Computer Science

IBM Research Report

Concept Mapping with Multimedia

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Abstract
C*oncept maps*™ have existed in the educational community for some time. A concept map is a visual representation of a person's (student's) knowledge of a domain. Many have reported on computer-based implementations of interactive concept map building tools. However, existing concept webs are rooted in a propositional, primarily textual, knowledge representation scheme. Further, existing computer-based versions do not fully capitalize on the potential functionality offered by the computational medium. We describe an extension to "traditional" computer-based concept mapping tools that provides representational capabilities more in line with human knowledge representation by incorporating dynamic media – sound, video, and animated images.

Keywords
concept maps, knowledge representation, multimedia, knowledge visualization

Concept mapping tools

A *concept map*™ is a visual representation of knowledge of a domain. A concept map consists of nodes representing concepts, objects, or actions, connected by directional links defining the relationships between and among nodes. Graphically, a node is represented by a rectangle or oval (for example) containing a textual name, and relationship links appear as textually labeled lines with an arrowhead at one or both ends. Together, nodes and links define *propositions*, assertions that can be about a topic, domain, or thing. For example, an arrow labeled "have," beginning at a node labeled "birds" and ending at a "wings" node represents the proposition "birds have wings" and might be a portion of a concept map concerning *birds* (see Figure 1). Representing knowledge in this fashion is similar to the *semantic network* knowledge representation scheme from the experimental psychology and AI communities (Quillian, 1968).

Figure 1. Nodes and relationship link representing the proposition "birds have wings."

Concept maps have been used in the educational community since the early 1970s in virtually every subject area: reading and story comprehension, science, math word problems, social studies, decision making (see, e.g., Fisher et al., 1990; Bromley, 1996; Novak, 1998; Chase & Jensen, 1999). In educational settings, concept maps allow students to demonstrate their knowledge of a domain, to communicate this information to others, act as tools to aid study and comprehension of a domain or story, or support idea generation and organization in preparation for prose composition. Educators have used them as both pedagogical and evaluation tools (Novak, 1998). Empirical reports have shown that concept mapping activities engender informal student-student collaboration wherein kids discuss, share ideas, support or contradict others' arguments, and justify their own or others' beliefs (Bromley, 1996). This sort of collaborative activity helps the participants to *co*-construct evolving understanding of the subject matter, ultimately resulting in advancing individual learning and understanding (Coleman, 1995). There is considerable empirical evidence that the use of graphical knowledge visualization tools such as concept maps helps improve student comprehension and learning when students construct their own maps (e.g., Dunston, 1992; Moore & Readance, 1984).

In educational environments, the use of concept maps has evolved from paper-and-pencil to computer-based tools. A number of computer-based concept mapping tools have been reported by researchers (e.g., Fisher et al., 1990; Gorodetsky, Fisher, & Wyman, 1994; Flores-Méndez, 1997; Gaines & Shaw, 1995) and there exist shareware programs and even commercial products for this activity (e.g., Inspiration®, Mind Mapper, Decision Explorer, SemNet). Concept mapping software offers the same sorts of benefits that word processors provide over composing written works on paper, that is, the facilitation of revision of existing work, including additions, deletions, modifications, or reorganizations. In fact, students often revisit their existing maps to revise them as their knowledge of a subject evolves (Anderson-Inman & Zeitz, 1993). Nonetheless, existing computer-based concept map tools do not capitalize fully on the computational medium.

This paper describes a tool, named *Webster*, which extends the capabilities of "traditional" computer-based concept mapping tools. The goal of Webster vis-à-vis existing concept map software is twofold: (1) to provide a tool that is capable of more comprehensively representing a student's knowledge of a domain, and in doing so, (2) to capitalize more fully on the capabilities of the computational medium. There are a number of characteristics of Webster that attempt to achieve these desiderata, but in this paper we focus in particular on Webster's use of multimedia. The next section of the paper is a cognitive design rationale for adding multimedia capabilities to concept maps. The remainder describes how multimedia is actually employed in Webster's concept maps.

What's missing in current concept mapping tools?

The raison d'être of concept maps is to visually represent the map author's knowledge of a particular subject. Hence, we ought to be using tools that are able to represent multiple types or forms of knowledge to allow accurate portrayal of that person's knowledge. A problem with existing concept mapping tools is that they are rooted *solely* in a propositional knowledge representation scheme. As mentioned in the opening paragraph of this paper, concept maps are very good at visually representing propositional statements—but not other forms of knowledge. Further, concepts are typically described by verbal means (that is, via textual labels). But, as Rumelhart and Norman assert, "It is important to note that not all nodes in a semantic memory system have names corresponding to words in natural language" (1985, p. 24). Hence, concept maps should allow for nodes to be something other than of a verbal or textual nature.

There's also ample support for the notion that one's knowledge for a particular domain contains more than simply propositional knowledge, certainly at the conscious and retrievable level in the mind. Kosslyn (1980), for example, proposes a cognitive model that represents information about objects with both propositional properties and images. Johnson-Laird (1983) asserts that mental models of a domain include both propositions and imagery.

Rumelhart and Norman add that “within the representing world, different aspects of the represented world might be represented through different representational formats… different representational systems have different powers” (1985, p. 59). And Baddeley states there is "abundant evidence for separate visual and verbal coding" (1985, p. 212). There’s also evidence that memory for visual imagery is more robust than that for purely textual information (Shephard, 1967). So, we see a need for imagery-based nodes in conceptual maps if we wish to more comprehensively, or more accurately, represent one’s knowledge of a domain or use maps to convey information to learners.

With regard to simple images, Inspiration, a commercially successful concept mapping product, does allow the use of *static* images as nodes in a map. But, going a step further, what about *temporally dynamic* imagery? This would include moving visual images and auditory "imagery:" what objects look like when they move, what they sound like, how they move or sound in particular contexts or situations. Returning to our example domain, one’s knowledge of birds might include what birds look like in general, the appearance of specific types of birds, what a bird looks like when flapping its wings to fly, the sight of a seagull when it faces into the wind at the beach, spreads its wings, and hovers, shifting slightly with the wind, how eagle appears as it glides to a landing on a tree branch, the “hoo” sounds made by owls, what baby birds sound like when chirping for food. Certainly these are parts of our long-term memories for birds, and we ought to be able to represent these memories in concept maps to demonstrate our *own* knowledge or to use concept maps to convey information to learners.

Intuitively then, dynamic visual and auditory memories are part of one's knowledge of an object or domain—further they are indeed acknowledged by researchers. For instance, Johnson-Laird (1983) asserts that some mental representations are of temporally dynamic nature. Numerous studies involving music cognition provide strong empirical evidence for long-term auditory memory (see, e.g., Dowling & Harwood, 1986). And as Lennon and McCartney wrote and the Beatles sang, "Penny Lane is in my ears and in my eyes," implying reminiscences involve long-term auditory and dynamic visual memories.

We can—and should—capitalize on the available capabilities of the computational medium to incorporate such dynamic content in concept maps, thereby more closely mapping cognitive knowledge representations. Webster allows for the representation of dynamic knowledge components or “media” as primitive and integral constructs of a concept map. (Gaines and Shaw (1995) report an example of using their concept map tool to access multimedia documents, but this was an *application* of their basic tool which does not include media elements per se, and required additional programming by the map *author* (the end-user) to make it “work.” In Webster, multimedia nodes are first-class, primitive elements of concept maps with the same status and ease of use as ordinary concept nodes.) Incorporating multimedia in concept mapping software to represent dynamic imagery should:

- offer richer expressive power for concept map authors,
- provide greater cognitive fidelity, that is, should allow students to more comprehensively represent their knowledge, and

- more fully capitalize on functionality available in modern personal computers (if we're using the computer to represent kids' knowledge, we ought try to more fully benefit from the computational medium).

Multimedia in Webster

To recap, it is clear that some knowledge in a person's head may be non-verbal and indeed non-propositional in nature. It may be static or dynamic visual imagery or auditory information. Hence, if we are asking students to represent their knowledge we need to be cognizant of the fact that some aspects of the student's mental model may be expressible only through visual or auditory media.

Webster provides tools for incorporating such media—animated images, video, and audio—in student-constructed concept maps. Figure 2 shows Webster running in a Web browser. Webster is implemented in Java and thereby runs in standard Web browsers, providing student access from anywhere they have access to the Internet. Webster is also integrated into a large school-and-community-based Web environment named *Wired for Learning* (Kuang, Grueneberg, & Lam, 1998; Kuang, 1998) in use in numerous school systems worldwide. Figure 3 contains a more complete view of the Web browser showing Webster integrated within Wired for Learning.

Let's begin the discussion of Webster by briefly describing its user interface. Along the left side of the interface are tools for creating elements that may reside in a Webster concept map: different-shaped concept nodes—the user may assign different semantics to different shapes as appropriate for each map, a variety of relationship links, and several other types of map elements, including image, audio, and video nodes. At the top of this toolkit are two toggle buttons that determine whether the user is in *author mode* or *viewer mode*. A user can modify a concept map while in author mode; in viewer mode, the map is read-only: it may be viewed but not modified. When teachers review student work, they do so in viewer mode only. Along the top of the interface are tools primarily for editing and modifying characteristics of elements already extant within a concept map (such as deleting, duplicating, or grouping elements, or changing their colors, fonts, alignments, etc.). In the upper right are navigation tools including one that displays a miniature view of the map and allows scrolling of the larger map in any direction.

Again, suppose a child is building a concept map to demonstrate her knowledge of birds. In addition to propositional ideas such as "a bird is an animal," "a bird has wings," and "wings have feathers" the student wishes to represent what a bird sounds like, looks like, looks like when it's flying, and so on. She therefore wants the ability to incorporate visual imagery and audio in her map.

To incorporate audio into the map, she must include an audio node; similarly for video and image data and respective nodes. To add an audio node to a concept map, the user clicks on the "radio" icon in the toolkit on the left and drops a radio—that is, audio—element onto the map. Webster responds by popping up a list of available audio files (only audio files are shown for a radio node), allowing the user to select one (see Figure 4). Available media files (as well as persistently stored concept maps) reside on the centralized Wired for Learning server, rather than a particular client machine, so that an individual concept map and its associated multimedia may be accessed and viewed from *any* machine on the Internet. (Also, a technical constraint of Java applets running in a browser is that they may not access files local to the client machine, but only files on their servers.) Users may add new media files to the Wired for Learning server at any time using a convenient browser-based file upload interface, thus expanding the list of available files for any media type. This media file upload facility appears in the lower frame in Figure 3.

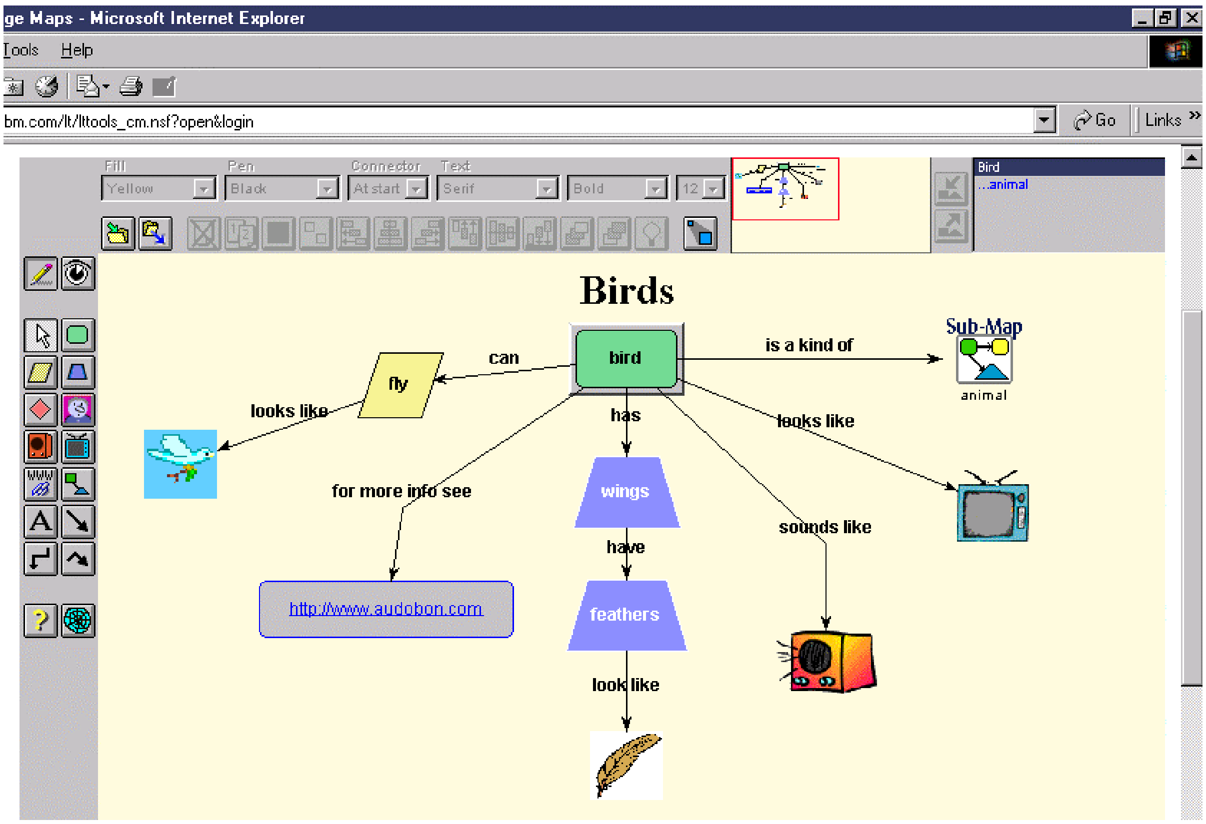

Figure 2. A Webster concept map, in a Web browser, with an animated image node (the flying bird), audio element (represented by the "radio" node), and video node (the "television" node).

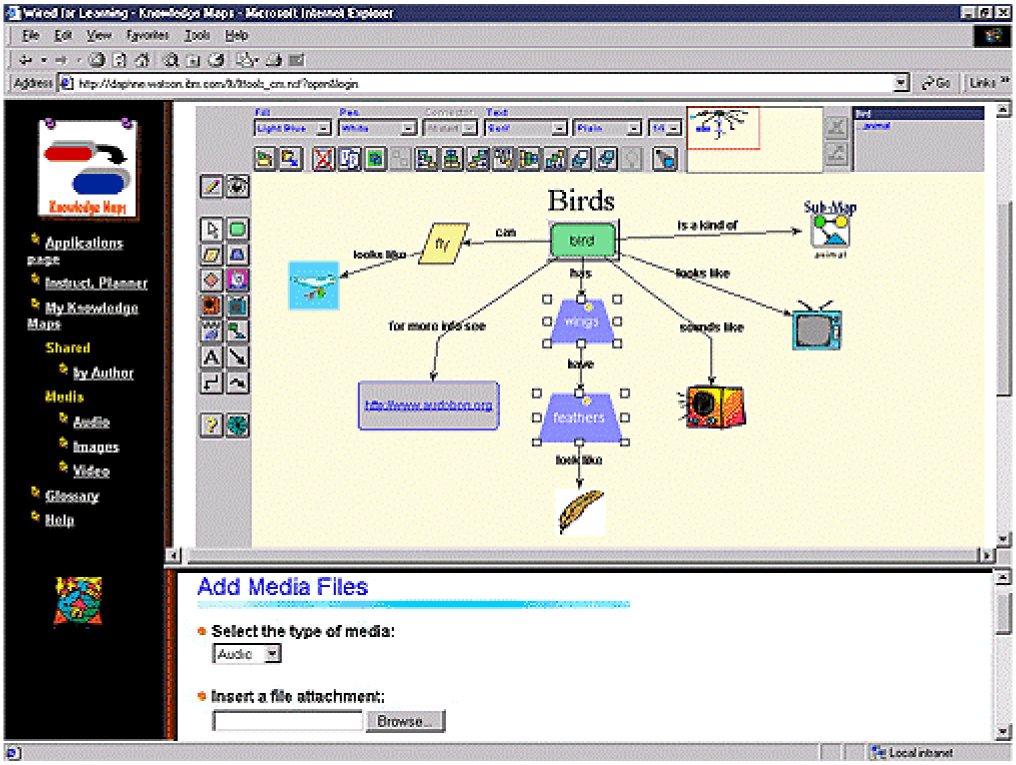

Figure 3. Webster as it appears integrated into the Wired for Learning environment. The bottom frame contains an interface allowing users to upload local media files to the Wired for Learning server.

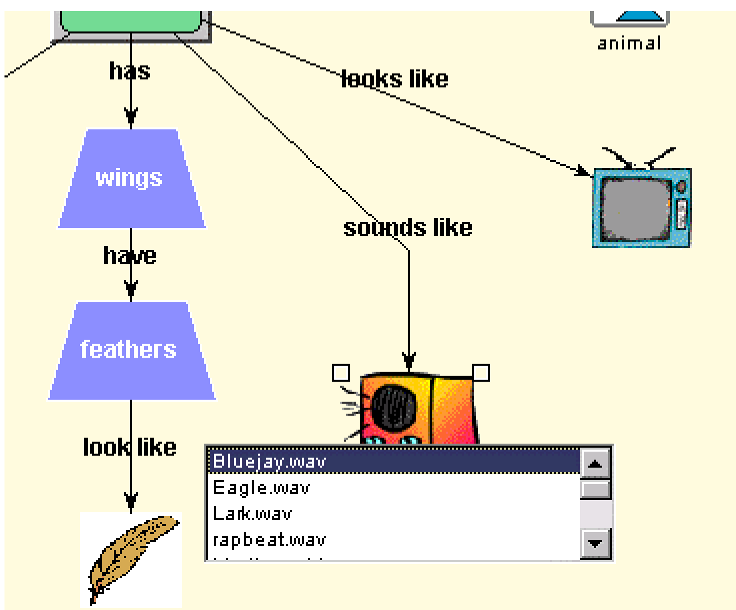

Figure 4. The user selects the file to associate with an audio node by selecting from a list of available audio files. Webster pops up the list within the concept map when the user first drops a new audio node onto the map or when the user double-clicks an audio node while in author mode. Image and video nodes are handled in the identical manner.

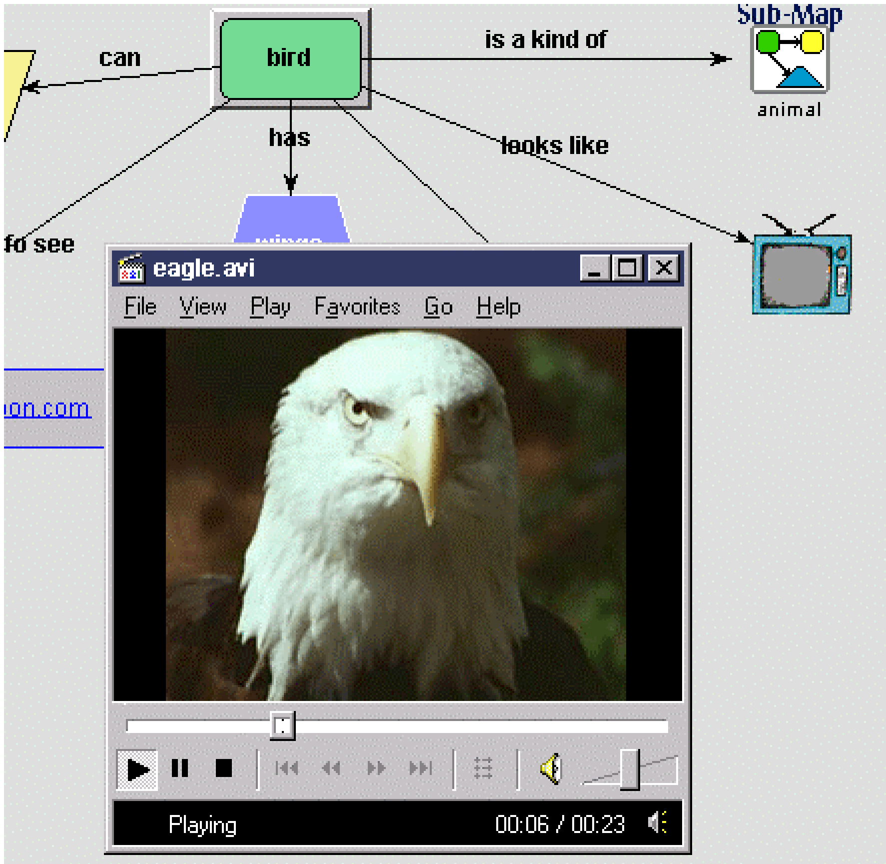

Figure 5. When a user double-clicks a "television" node while in viewer mode, Webster directs the Web browser to download and play the associated video. Radio/audio nodes are handled in the same fashion.

To listen to an audio, the user enters viewer mode and simply double-clicks a radio/audio node in the map. In response, Webster plays the associated audio file. Video playback is similarly invoked via the TV nodes within a map (see Figure 5).

With regard to images, as already mentioned, Inspiration does allow users to use static images as nodes in a map. Webster goes a step further in that image-based nodes in a concept map may be animated-GIF images (CompuServe, 1990). As noted earlier, Webster is implemented in Java and an attendant benefit is that Java "knows" how to animate GIF images. Thus, we may have animations directly within a concept map. For example, the animated bird image in Figure 2 appears to be flying within the concept map.

Adding image nodes to a concept map is performed in the same fashion as we've seen above; the user clicks on the "portrait" icon in the toolkit and drops a new image node onto the map. After choosing an image file from the Webster-provided list, that image is displayed directly in the concept map. By default, images are shown as thumbnails directly in the map, and the user may directly resize image nodes, thereby stretching or shrinking the images. Alternatively, a user may double-click an image node (while in viewer mode) to view the image in its actual size (the image is displayed in its originally created size in the lower frame of the browser).

Future Work

Future plans for Webster include the generation of Web documents, containing multimedia elements, from the contents of concept maps. As stated earlier, one activity associated with concept map usage is generating and organizing ideas in preparation for writing a report, composition, or story. Webster will automate the process of converting a concept map into a composition, a “modern” sort of composition in the form of an HTML document that can be viewed in a Web browser. Simplified natural language generation will turn propositions into sentences. Static and animated images that appear in the map will appear directly in the generated Web page. And video and audio nodes will result in hyperlinks embedded in the page. When any of these links is clicked, the Web browser will play the associated file.

So, our *birds* page would include sentences such as “A bird has wings and wings have feathers. Feathers look like this.” This would be immediately followed on the page by the feathers image from our concept map example. The generated Web page would also include text such as “A bird can fly, and that looks like this:” with the animated flying bird GIF appearing in the page contiguous to the text. It would also incorporate hyperlinks such as “A bird sounds like this.” When clicked, this link would cause the browser to play the same audio file as that used in the map. Videos would be handled in like manner.

Conclusion

Having students construct concept maps is an exercise in knowledge elicitation; we are asking students to demonstrate and communicate to others their knowledge of a domain. In doing so, we ought not limit students by restricting the types of knowledge they can they can portray – that is, the tool we supply to students should be constrained as little as possible with regard to the types of knowledge it is capable of representing. Webster offers greater expressiveness and broader representation capabilities simply by incorporating multimedia elements in concept maps, thereby offering a closer match to cognitive knowledge representations.

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Acknowledgments. The concept mapping application was built by the first author. The second author performed the work involved in integrating the Webster applet into the Wired for Learning client UI, integration with Wired for Learning's Lotus Domino server, including the design of the concept map database allowing, among other things, the facile retrieval of concept map and media data by the client applet, and the media-file upload interface.

Thanks to Cyndi Conway for the code for the server-side Domino agent that saves concept map data into its database, and her work on the client code that "talks" to this agent (Domino agents are Java

applications integrated into Domino databases). Thanks as well to Dick Lam and Peter Fairweather for discussions and suggestions regarding Webster.

Webster was built starting with JHotDraw as a foundation; JHotDraw is a Java-based graphical editor framework and toolkit. Great thanks to Erich Gamma for providing the JHotDraw source code.

Other software mentioned:
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Decision Explorer: http://www.banxia.com/demain.html
Mind Mapper (shareware):
http://www.ozemail.com.au/~caveman/Creative/Software/Mind_Mapper.htm
SemNet (shareware): http://trumpet.sdsu.edu/semnet.html