Knowledge Puzzle: A Tool for Constructivist Learning from Hypertext

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Abstract

This paper presents Knowledge Puzzle, a tool for knowledge construction from the Web. Its main contribution to Web-based learning is the adaptation of information structure on the Web to cope with the interlinked knowledge structure in the learner's mind. Self-directed learners will be able to adapt the path of instruction on the Web to their way of thinking, regardless of how the Web content is delivered. The way to achieve that is to provide the learner with a meta-cognitive tool that enables him to bring his knowledge to the surface and visualize what he has in mind. Once we get the learner's viewpoint externalized, it will be converted to a hypermedia layer that will be laid over the Web pages visited by the learner. The attached layer adapts the views of Web pages to the learner's information needs by associating information pieces that are not already linked in hyperspace and attaching the learner's notes to the page content.

1. Introduction

Self-Directed Learning (SDL) with hypertext implies that learners have different viewpoints and thus they may navigate different paths. Accordingly, they will have different interactions with the knowledge [3]. Hypertext resources, due to their static design, cannot cater for individual differences among learners. In addition, these resouces cannot be restructured or interlinked to match the knowledge structure in the mind of every single learner, unless the learner is himself the content author. This gap between the knowledge structure in the learner's mind and the information structure on the Web requires learners to make extensive cognitive and navigational effort to monitor their progress and to recall knowledge components while navigating.

In order to clarify the above problem, one can imagine a scenario of a student exploring the Web for the aim of learning about the topic of computer viruses. While navigating, he comes across different pages each of which explains a different aspect of the topic. He may obtain information about how viruses spread from a particular page. Then, he learns about virus protection from another page, while the impact of viruses is obtained from a third page. The student constructs knowledge by thinking about the content and making semantic links between the content of pages he has visited. However, pages utilized by the student may not be interlinked or organized on the Web as the student needs since there are no direct hyperlinks between them. In addition, he cannot alter the structure of pages to cope with his needs because he does not have the required ownership. Therefore, the student will encounter cognitive and navigational difficulties when he starts reviewing the acquired knowledge due to the gap between what he needs and what exists on the Web.

It is clear from the above argument that there is an emerging need for innovative user-centric technologies that enable learners, rather than content authors, to break the "static" barrier of hypertext and become "active" players who can manipulate and interlink information on the Web in accordance with the progress of their own learning processes, instead of being conventional readers or viewers of information. Learners need a way to physically integrate segments of information on the Web in order to make them intelligible. Although this integration is often performed cognitively inside the human mind, if large amounts of information need to be retained the cognitive efforts needed to process it can cause learners to fail in knowledge construction [4]. It should be emphasized that learners should have the tools to build new associations of Web content even if they have no control over updating or adapting the Web content. The desired technologies should work with any Web page.

This paper demonstrates the Knowledge Puzzle, a tool for knowledge construction from the Web. It offers a constructivist approach to SDL by helping learn-

learners to: 1) plan their navigation path with the least cognitive effort. 2) Personalize the information structure on the Web to accommodate the learner's self-constructed knowledge. The main contribution of the proposed tool is the personalization of information structure on the Web to accommodate the interlinked knowledge structure in the learner's mind. Self-directed learners will be able to adapt the path of instruction on the Web to their way of thinking, regardless of how the Web content is delivered. At the first stage, learners use a meta-cognitive tool to reference and structure what they gain from the Web navigation process. The visualized structure will be then converted to a hypermedia layer that will be attached over the Web pages visited by the learner. The attached layer adapts the views of pages to the learner's information needs by associating information pieces that are not already linked in hyperspace and attaching the learner's notes to the page content.

2. Related Work

Many systems have tried to overcome the gap between user needs and information in hypertext by providing adaptive hypermedia (AH) techniques such as link adaptation. Such systems are based on the hypothesis that disorientation and cognitive overload can be mitigated by annotating, hiding, organizing or recommending links with respect to the user's information needs [1]. However, link adaptation is based on manipulating links which already exist in the visited Web pages. It offers nothing if the pieces of information that make up the learner's knowledge are not already linked in hyperspace. In addition, AH is mainly based on the designer's predictions of learners' needs, and these may not match their real needs. It is hard to believe that any adaptive system will be able to predict precisely what learners want as even human experts may fail to do so. Although there are some user-driven techniques that give learners control over the adaptation process [6], this control is still limited to what the designer allows, and requires specific design steps prior to the learning session. What is needed is a solution that goes further by enabling the learner to inject new hyperlinks and annotations in the visited Web pages in accordance with his/her knowledge structure without any limitations or preconditions.

Annotation, concept mapping and spatial techniques can help learners organize the history of the navigated pages and thus facilitates information recall and linking. Examples of these tools are the Interactive History System [4] which encourages learners to annotate the navigation history to rethink their explo-

ration processes, and Nestor [5] which promotes constructivist learning by allowing learners to add their personal annotations and plan their navigation path using concept mapping. Despite the efficiency of these tools in promoting learning from hypertext, the main pitfall is the separation between the navigation and planning processes, which are often performed in different spaces. This separation splits the attention of the learners and places an additional cognitive load on them as they are required to continually move between hyperspace, where they navigate the Web pages, and the concept mapping space, where they structure and visualize what they gained from the Web [2]. In addition, when the map gets larger, the learner can be cognitively overloaded due to the effort required to trace a large number of nodes. Although we have designed a space for concept mapping as part of the tool presented in this paper, we have tried to resolve the above problem by reducing the dependence on the mapping space by using it only during the planning and monitoring stages of the learning process.

3. The knowledge Construction Tool

In order to help learners bring their thinking to the surface and visualize the knowledge that they gain from the Web, the Knowledge Puzzle tool shown in Figure 1 was developed. It is divided into two windows: a standard browsing window (to the left) and a planning space (to the right). The planning space is a meta-cognitive tool that allows learners to build a sequence of Web pages fulfilling specific learning goals. When the learner needs to set up a navigation goal in visiting a page, he/she can add a graph node representing the page where the goal arises. The graph
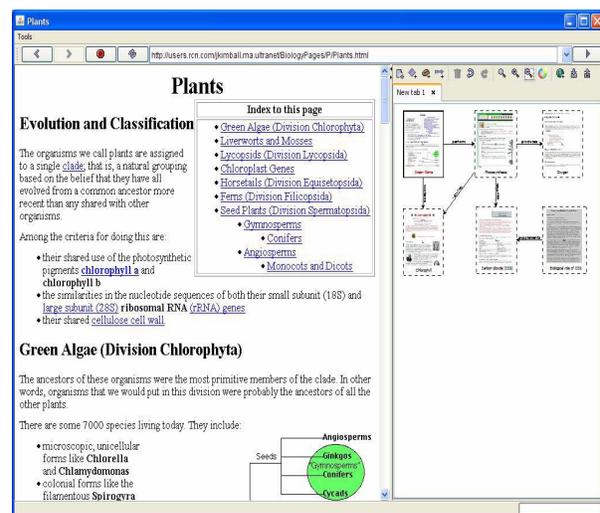

Figure 1: The Knowledge Puzzle tool

node could denote either a whole Web page, or a selected text portion. Similarly, when the learner finds the information that fulfils the learning goal, he/she can add another node denoting the terminal page, or a particular portion of it, that fulfils the learning goal. The learner can then annotate each node with the main concept learned from the corresponding Web page. Subsequently, the learner links the source and terminal nodes and annotates the connecting link to describe the relationship between them. Each graph node is represented as a thumbnail for the source Web page. Clicking on the node causes the corresponding page to open in the browsing area and the part of interest to be highlighted in a different color. The learners can look at the constructed graph whenever they wish during navigation and can also directly manipulate it. Learners can also take a note about the contents learned from any page through a special form attached to each node. Later on, these added notes can be embedded into the Web pages so that the learner can preview information on the Web along with his/her own notes. The main advantage of the planning space of the tool over traditional concept mapping tools is that it combines the benefits of both navigation path planning and concept mapping: it facilitates path planning by offering the ability to connect information units on the Web and to directly access them by simple clicking on the corresponding nodes. This helps learners to remake the path at any time. At the same time, it supports concept mapping by enabling learners to annotate the nodes with the key concepts gained and to define the relationships among them. Accordingly, the constructed graph mirrors the knowledge map in the learner's mind and enables him to think reflectively about what he gained from the Web.

Figure 2 shows an example of a knowledge graph constructed for the goal of understanding the photosynthesis process in plants. It shows the nodes denoting the Web pages visited and the primary exploration processes that have arisen. For example, the learner visited the pages labeled "Chlorophyll", "Carbon Dioxide (CO_2)" and "Oxygen" in order to explore the requirements and products of the photosynthesis process described in a previously visited page. The learner then visited the page "Biological role of CO_2" since it supplements the information found in the page "Carbon Dioxide". Each node is annotated by the learner with the main concept learned from the corresponding page. The learner also annotates the links between pages to describe the exploration goal from one page to another. When the learner annotates a link connecting a source with a terminal node, he/she should de-
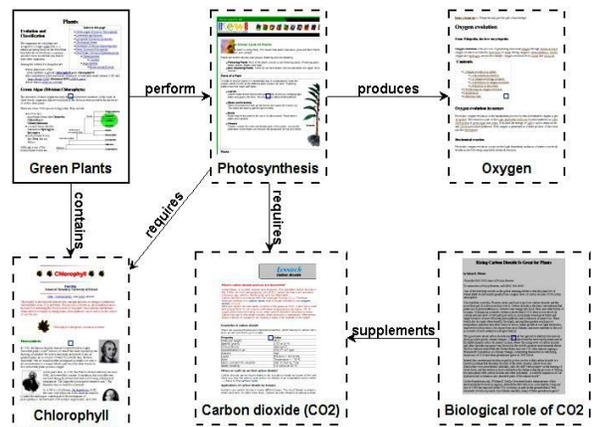

Figure 2: A sample knowledge graph

scribe both the relationship and its inverse. For example, if the link from "Photosynthesis" to "Oxygen" is labeled "produces", the inverse link should be something like "is produced by". While, for simplicity, the inverse names are not displayed in the graph, they will be used in the next stage when the knowledge graph is converted to a hypertext layer.

4. Hypertext Layering

An emerging requirement for SDL with hypertext is to adapt the information structure on the Web to learners' individual needs. The proposed approach to achieve such adaptation is to convert the cognitive links that learners mentally create between information components while navigating the Web into real informative hyperlinks and annotations in hyperspace. The Knowledge Puzzle tool automatically transforms the knowledge map, which was constructed by the learner on the planning space, to a layer of hyperlinks and annotations. The constructed layer is then attached over the visited Web pages. Thus, the leaner will be able to see the knowledge components on the
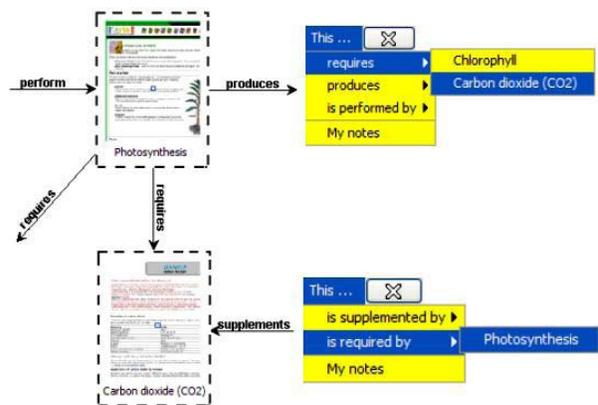

Figure 3: Converting knowledge graph to hypertext

Web interlinked and structured exactly as he/she planned. The layering process is done as follows: 1) The links connecting any source node with terminal ones are converted to a menu of hyperlinks. The constructed menu is then embedded inside the Web page represented by the source node. The aim of this menu is to link information pieces in the source page with any related information pieces in terminal pages. 2) Similarly, menus are created in the terminal pages to include inverse hyperlinks that link information pieces in terminal pages with related information in source pages. Figure 3 shows an example for the conversion process. It depicts two graph nodes from Figure 2 with the associated relationships (to the left) and the created hypertext menus (to the right). Each menu contains hyperlinks representing the relationships associated with each node. Since the pages on the Web are static and hence can not be modified, the menus will

be embedded inside the local copies of Web pages after being loaded on the browser. Once any of the pages is loaded, the system automatically creates the corresponding menus based on the relationships defined on the planning space. The created menus are then embedded inside the loaded copy of the page by altering its HTML DOM. Figure 4 shows how the Web pages look after the menus are attached. The information piece that the learner is interested in is highlighted in red and a new hyperlink labeled "Click here" is attached to its end. Clicking on the link causes the menu to be displayed. The attached menus link Web pages and reveal how they are related from the learner's perspective. Thus, they enable seamless and direct movement between information pieces that make up the learner's knowledge. Note that the original pages on the Web do not include these changes and thus they are not directly linked in a way that matches the learner's viewpoint. Using the above hypertext layering approach, there is no longer a need to own the pages in order to make the links from source to target pages. In addition,

the labeling of the new associations enables the learners to recall why they navigated each Web page, how they processed its content and what was the goal fulfilled from each navigation process, thus providing support for learners to rebuild their cognitive models. In addition, both menus show a link labeled "My notes". Clicking on this link will open a small frame, as shown in Figure 4, showing the notes made by the learner about this information piece. This enables learners to preview their notes side by side with the related page content, something that cannot be achieved by traditional note-book and annotation tools which keep user-added notes separate from the Web content. After altering the pages, learners can now hide the planning space and focus their attention on the Web navigation process which becomes guided by the added hyperlinks and annotations. They need to recall the planning space only if they wish to add new
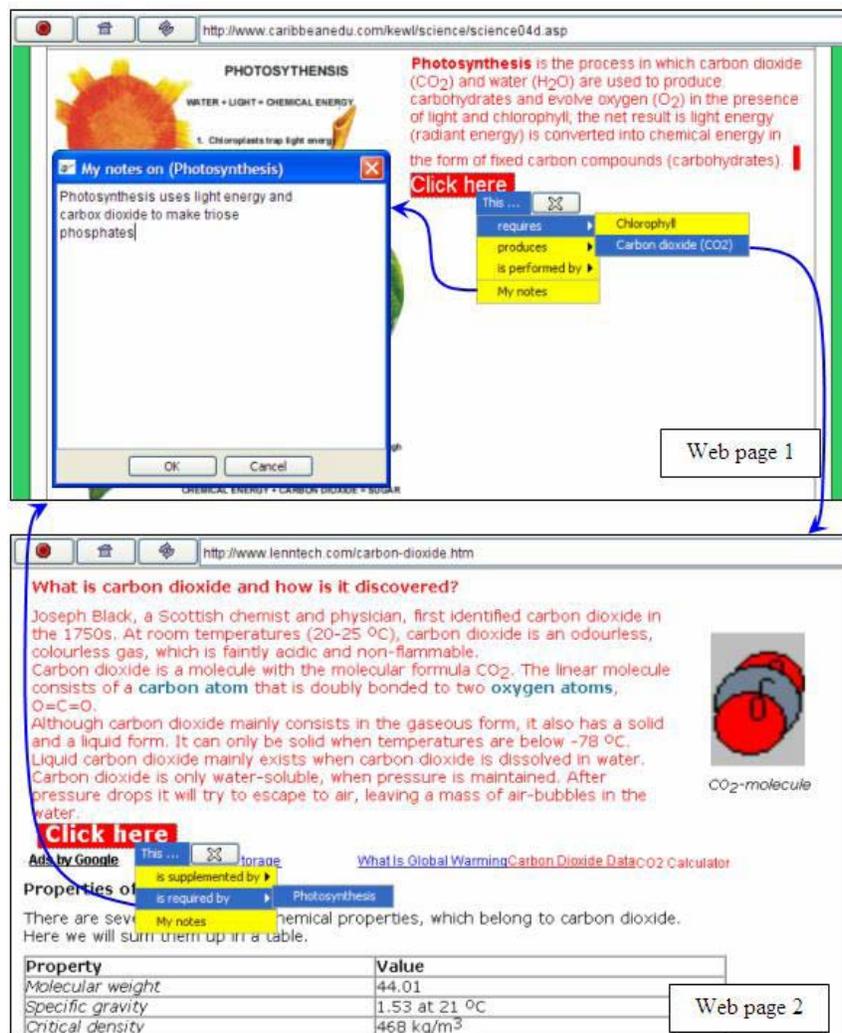

Figure 4: The Web pages after attaching the hypertext layer

relationships or modify the existing ones. Any changes made in the graph will automatically be applied in hyperspace. Therefore, the learner can manipulate the hypertext layer by adding, deleting and modifying components and links on the planning space.

5. Evaluation

A 2-week-long study was performed to evaluate the Knowledge Puzzle tool. Participants were 44 first-year undergraduate students at the department of computer science. Students used the tool to do a course assignment in which they were asked to explore and study a collection of Web resources for the aim of writing a report about computer viruses and how they relate to computer networks in particular. After the students finish the assignment, they were asked to fill out a questionnaire and send it back to us.

The first part of the questionnaire consisted of multiple choice questions with a four-point scale (from "Strongly Agree" to "Strongly Disagree"). Focusing on the tool's main goal, which is the ability to link separate information available on the Web, the majority of students (77%) responded with either "Agree" or "Strongly Agree". Moreover, most of them (80%) very positively rated the fact that the tool helped them directly access information of interest inside Web pages. On the other hand, only 57% of the students acknowledged that the tool helped them navigate effectively. At first sight, this result indicated a drop in the overall satisfaction with the tool's support for Web navigation. However, having the usage of the tool observed, the reason for such low satisfaction has been regarded to the lack of familiarity and the additional effort needed to learn to use the new functionalities. This additional effort, even if little, can affect the students' motivates and satisfaction.

Regarding the layer of hyperlinks and annotations added by the tool over Web pages, most of students' opinions (77%) were positive, i.e., either "Strongly Agree" or "Agree", indicating that the new components facilitated navigation through the web pages. This result proved that students realized the benefit of adapting and linking pages as a way to enhance learning from hypertext resources. Another encouraging result was the students' responses on whether the tool reduced the amount of information they need to remember. 73% of the opinions were positive, indicating that the tool had effectively reduced the cognitive load. Finally, about 88% of participants agreed, or strongly agreed, that the tool supported the accomplishment of the assignment compared to the assignment without it.

In the second part of the questionnaire, students were asked to comment on the advantages and disadvantages of the tool in comparison with other similar tools. 16 students almost shared the same opinion when they considered the linking of Web pages with hyperlinks that describe effectively the way they are related as the most beneficial aspect which was not provided by any other tool. They also liked the ability to attach their own notes to the page content. However, some students reported that the user interface should be a little more intuitive. Another student suggested the development of the tool as a plug-in to Firefox or Internet Explorer because this is the best way to benefit from the advantages of the tool as well as the usability of traditional Web browsers.

6. Conclusion

A tool for knowledge construction from the Web has been proposed. The tool benefits from the theory of cognitive constructivism in order to stimulate learners to visualize the navigational behavior and semantic processing of Web content using a meta-cognitive tool. Afterwards, the constructed map is converted to a layer of expressive hyperlinks and annotations over Web pages, causing the appearance of the pages to be adapted to the student's needs. Such kind of adaptation differs from traditional AH in terms of being entirely user driven, without any limitations or preconditions. The intended goals have been considerably met according to the experimental results, which proved the success of the tool to promote a constructivist approach for Web based learning.

7. References

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