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A Knowledge Visualization and Its Evaluation

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Abstract: Visualizing the contents to be learned about an instructional material is an effective way to facilitate learning. However, the effectiveness is not always obtained only by looking at the visualized representation. The knowledge visualization accordingly requires learners to devote more attention it. Considering the context of learning a text, this paper gives an effective knowledge visualization called Diagram Tailoring, and demonstrates an intelligent learning system. This system presents part of a diagram as a visual representation, and encourages learners to construct the whole diagram so that their attention can be devoted to the visualized representation. This paper also describes an experiment on Diagram Tailoring. As a result, we have ascertained that partial diagram presentation makes a contribution to retaining knowledge to be learned from a text. Diagram Tailoring can be consequently viewed as an available way for allowing learners to obtain the intrinsic fruitfulness of knowledge visualization.

1. Introduction

Visualizing the contents to be learned about an instructional material enables learners to make sure knowledge which they are learning from the material, and to realize what has not been understood. Such knowledge visualization can be viewed as a fruitful way to facilitate learning [Merrill et al. 1992; Larkin and Simon 1987]. However, learners may only glance at the visualized representation, and may not elaborate on their knowledge with it [Barnard and Sandberg 1996]. In order to certainly get good results for learning with knowledge visualization, therefore, it is necessary to focus their mind on the visualized representation [Cox 1997; Kashihara et al. 1996].

This paper proposes an effective knowledge visualization which encourages learners to construct a visual representation by externalizing knowledge which they learn. In general, the knowledge externalization does not always occur because what to and how to externalize are often unclear [Chi et al. 1994; Cox and Brna 1995; Kashihara, Hirashima, and Toyoda 1995b]. Alternatively, the representation construction is not so easy because the learners may make excessive mental efforts which cause cognitive overload [Kashihara, Hirashima, and Toyoda 1995a]. In order to overcome these difficulties, we consider presenting part of the representation to be finally constructed. This corresponds to visualizing part of knowledge which they would learn. Such partial knowledge visualization gives the learners the directions what to and how to externalize, and contributes to reducing their mental efforts to complete the whole visual representation. In addition, moderate mental efforts of the representation construction will lead them to devote more attention to the visualized representation. The partial knowledge visualization can be consequently viewed as a fairly available way for allowing learners to obtain the intrinsic fruitfulness of knowledge visualization.

The technical issue in the partial knowledge visualization is how to decide which part of visual representation should be presented according to each learner. Considering the context of learning a text describing computer vocabulary, we have proposed an adaptive knowledge visualization called Diagram Tailoring [Kashihara et al. 1996]. This paper gives an overview of Diagram Tailoring, and demonstrates an intelligent learning system which accomplishes it. In this system, learners are encouraged to construct a diagram as visual representation. In order to facilitate such diagramming, the system presents part of the diagram so that the learners can elaborate on their knowledge with the presented partial diagram. This paper also describes an experiment on the basic idea of Diagram Tailoring which we have made compared with the whole diagram presentation. As a result, we have ascertained partial diagram presentation makes more contribution to retaining knowledge to be learned finally from a text.

We will first explain the knowledge visualization in learning a text in the next section.

2. Knowledge Visualization

2.1 Context

In this paper, we consider that learners learn a number of text describing computer technical terms in related order. In this situation, the learners are expected to identify the difference between and to classify the new term and the known terms they have already learned from the previous texts. Completing such an integration process can be viewed as building up a knowledge structure in mind [Chan et al. 1993]. Such knowledge-structuring process facilitates and deepens learning of a give text [Kashihara, Hirashima, and Toyoda 1995a]. The knowledge structure represents the contents which learners are expected to learn from a text.

2.2 Visual Representation

We provide a diagram such as IS-A hierarchical network with tables to visualize a knowledge structure finally constructed. Figure 1 shows a diagram which consists of three technical terms. A node in the diagram indicates a technical term, in which its name is described. The attributes with values which characterize the term are described in a table attached to the node. A link shows the relationship between nodes. There are two pre-defined links: difference link and *is a* link. Each link possesses its own table. This table describes the attributes which have different values between nodes.

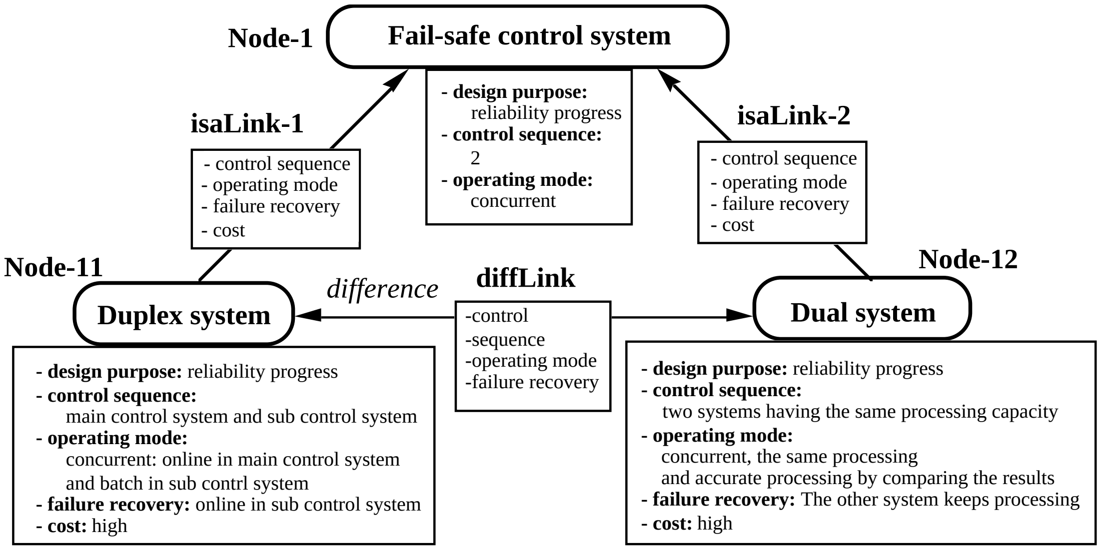

Figure 1: A Diagram

A text given to learners is represented as a sequence which consists of several units. Each textual unit gives a textual description of what attributes and values a component (node or link) includes. The text shown in Figure 2 has a textual unit sequence which consists of Duplex system (indicated by Node-11) and *is a* link between Duplex system and Fail-safe control system (indicated by isaLink-1).

The design purpose of duplex system is to enhance the reliability of the system. This system has two control sequences, called main control system and sub control system. These systems operate concurrently. The main control system usually executes online processing, and the sub control system executes batch processing as background processing. When the main control system fails, the online processing is kept on the sub control system. The cost of operating duplex system is high. (**Node-11**) The duplex system is a kind of fail-safe control system. The fail-safe system has two control sequences which operate concurrently. In the system, the failure recovery, operating, and cost are not considered. (**isaLink-1**)

Figure 2: A Text

Looking at a diagram with a text does not always enable learners to build up the knowledge structure in their mind. One way to lead them to structure their knowledge is to focus more attention on the diagram. Our approach to this problem is to encourage the learners to construct a diagram with a text and existing knowledge.

2.3 Representation Construction

The diagram construction process involves the following three mental operations: textual unit extraction from a text, related knowledge retrieval, and inference. These operations are externalized by making tables attached to nodes or links. The first operation requires learners to focus on keywords in the text to identify the components corresponding to the textual units. The second operation requires them to recollect related knowledge. The third operation requires them to distinguish and classify the identified textual units and the recollected knowledge to generate nodes and links. To generate a link, they particularly need to compare a node with the other node. The comparison involves discriminating, categorizing, or instantiating the attributes. To generate a node, they also need in some situations to differentiate and in other situations to generalize or specialize attributes (or values).

The amount of the mental operations can be viewed as cognitive load. There are three kinds of load in diagramming: the load of textual unit extraction, the recollection load and the inference load. Confronting each load contributes to retaining the knowledge structure built up [Kashihara, Hirashima, and Toyoda, 1995a]. However, the diagram construction is not so easy for some learners since it may impose cognitive overload on them. Therefore, we need to adapt the load to each learner. This adaptation corresponds to Diagram Tailoring.

2.4 Partial Knowledge Visualization

The basic idea of Diagram Tailoring is to present part of a diagram to reduce the load of constructing the whole diagram. The important point is how to decide which part of the diagram should be presented.

A diagram to be constructed consists of three parts: the part to be composed by extracting keywords from a text, the part composed by recollecting related knowledge, and the part to be inferred. We call these parts, text-scope, knowledge-scope, and inference-scope of the diagram. The basic procedure of Diagram Tailoring is as follows. When learners are expected to have difficulty in constructing a diagram, the text-scope is presented as partial diagram. When they are expected to have more difficulty, the knowledge-scope is also presented in addition to the text-scope. This intends to reduce the textual unit extraction load or recollection load, and to focus their still more attention on the inference scope. The inference operation requires the learners' attention not only to the inference-scope but also to the text-scope and the knowledge-scope. It is therefore the most important operation for calling the learners' attention to the diagram. That is why reducing the inference load is not considered.

3. Knowledge Visualization System

3.1 Interface

We have already implemented an intelligent tutoring system with a graphical user interface shown in Figure 3. Looking at a text, learners can construct a diagram by mouse-selecting NODE and LINK buttons. They can also use tables attached to these components as supplementary means. The attributes and their values to be described in the tables are prepared as menus. The learners can select words from the menus and put them into the tables.

When the learners reach impasses, they can receive supporting information by pushing Q/A button. The occurrence of the impasses is recognized when they are asked or an interval between the operations is longer. Although some learners may also make mis-diagramming, the system does not currently distinguish the support for their mis-diagramming from the impasse support.

3.2 Framework

We will next give an overview of Diagram Tailoring. The detailed explanation of Diagram Tailoring is omitted in this paper [See Kashihara et al. 1996].

Providing a number of computer technical terms in related order, the system exercises learners in constructing a number of diagrams. In the exercise, the system builds up and updates learner models representing the capabilities of textual unit extraction, recollection, and inference. These capabilities are diagnosed according to the number of impasses which learners cause in text-scope, knowledge-scope, and inference-scope of a constructed diagram. In other words, the fewer impasses learners result in, the higher their diagramming capability is. The learner models are used for Diagram Tailoring.

In the diagramming exercise, Diagram Tailoring is executed for each diagram construction. The system first decides a diagram as learning goal in consideration of the technical terms a learner has known. The system next generates a text including some components in the diagram. The system also estimates the diagramming process that the learner is expected to perform with the text and existing knowledge. Considering his/her diagramming capability and the diagramming load estimated from the process, the system then decides which part of the diagram should be presented.

The learner is next asked to complete the whole diagram. If the learner reaches an impasse, the system provides the supporting information as a text or as another part of the diagram. Using the monitored information, the system updates the learner model to adapt Diagram Tailoring for the next diagram construction in the diagramming exercise.

3.3 Examples

Let us show an example of Diagram Tailoring as shown in Figure 3. In this example, we assume that a learner has known the term of Dual system, and the system generates the text as shown in Figure 2. When his/her capability of textual unit extraction is diagnosed as low, the system displays the text-scope of the diagram as shown in Figure 3. In this case, the learner is encouraged to recollect Dual system and to infer the node of Fail-safe control system and the *is a* link between Dual system and Fail-safe control system although he/she does not need to extract keywords from the text. If his/her capability of recollection is moreover diagnosed as low, the system displays still more the node of Dual system in addition to the text-scope, and he/she is encouraged only to execute the inference operation. In this way, Diagram Tailoring individualizes a displayed diagram according to learners' diagramming capability.

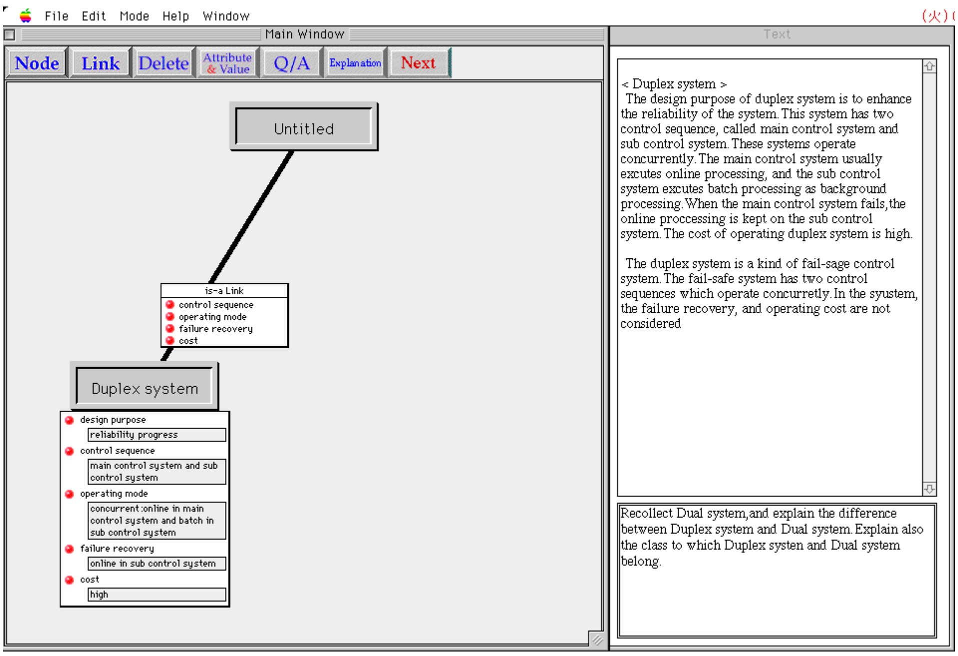

Figure 3: Examples of Diagram Tailoring

4. Evaluation

In this section, we will explain an experiment on the basic idea of Diagram Tailoring that we made. The main purpose of the experiment was to ascertain if completing a diagram with the presented part of the diagram is more effective for learning than just looking at the whole diagram without diagram construction. The learning effect was measured by retention of the diagram [Barron and Atkins 1993]. Tailoring the partial presented diagram to each learner is not considered in the experiment.

A diagram was composed of three nodes as shown in Figure 4 (a). Each node included 4 attributes. Each link included 2 different attributes between nodes. Subjects were 14 graduate and undergraduate students. We set two conditions. These were as follows: (1) the whole diagram presentation, and (2)the partial diagram presentation. In order to make each subject learn a text on each condition (within-subject design), we prepared two similar diagrams although these describe different domains. The influence of the domains on the results was counterbalanced.

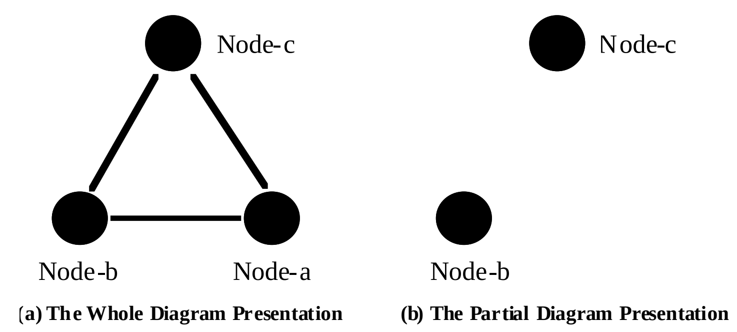

Figure 4: Diagram Presentation in Experiment

The experiment was done with the system as follows. The system first displayed a text which described a node indicated by Node-a, and required a subject to carefully read it. The aim of this careful reading was to make him/her acquire knowledge about Node-a.

On the first condition (Condition-1), the system next displayed a text which described all components of the diagram and the whole diagram such as Figure 4(a). The subject was then required to carefully read the text and to look at the diagram.

On the second condition (Condition-2), the system displayed a text which described Node-b and Node-c, and the partial diagram including Node-b and Node-c such as Figure 4(b). The subject was then required to complete the whole diagram by recollecting Node-a, and by inferring other components. When the subject reached impasses or made mistakes, he/she was given correct attributes with values. Learning on each condition took the same time (about 30 minutes).

After two hours, a retention test was conducted. In this test, each subject was requested to reconstruct each diagram with the system. The perfect score was 21. Table 1 shows the average score and standard deviation of the retention on each condition. The average score on Condition-2 was quite higher than the one on Condition-1. In addition, we performed an analysis of variance on the retention test. The result indicated that there was a significant difference between the average scores ($F(1, 13)=28.52$, $p<.01$). From this result, it was ascertained that the partial diagram presentation accompanied by the diagram construction made more contribution to reinforcing the retention of the visualized diagram than the whole diagram presentation.

Learning	The Whole Diagram Presentation Condition-1	The Partial Diagram Presentation Condition-2
N	14	14
Mean	5.14	12.93
SD	2.66	5.01

Table 1: Scores in Retention Test

Nevertheless, there were four students on Condition-2 whose scores of the retention test were less than 10. This indicates that the presented partial diagram and the diagramming operations required are not adapted to them. This finding implies that it is necessary to tailor the partial diagram to be presented according to each learner.

5. Conclusion

In this paper, we have claimed that visualizing knowledge should be accompanied by letting learners construct the visual representation. Following this claim, we have proposed a knowledge visualization with representation construction called Diagram Tailoring in learning a text. This paper has also demonstrated a system which has been already implemented. The system provides a graphical user interface in which learners can externalize knowledge learned from a text to construct a diagram. In order to facilitate the diagram construction, the system presents part of the diagram properly with the learner models which represent their capability of diagramming. The Diagram Tailoring technique makes the knowledge visualization more effectively since it leads the learners to devote attention to the visualized representation. In addition, we have evaluated the partial diagram presentation compared with the whole diagram presentation. As a result, it made more contribution to retaining knowledge learned from a text.

In our future work, we will apply the Diagram Tailoring technique to other learning contexts to make clear the limitation.

6. References

[Barnard and Sandberg 1996] Barnard, Y.F., & Sandberg, J.A.C. (1996). Self-explanations, do we get them from our students? *European Conference on Artificial Intelligence in Education*, Lisbon, Portugal, 115-121.

[Barron and Atkins] Barron, A.E., & Atkins, D.(1993). Audio Instruction in Multimedia Education: Is Textual Redundancy Important? *Educational Multimedia and Hypermedia 1993*, Orlando, U.S.A., 39-46.

[Chan et al. 1993] Chan, T.W., Lin, C.C., Lin, S.J., & Kuo, H.C. (1993). OCTR: A Model of Learning Stages. *6th World Conference on Artificial Intelligence in Education*, 257-264.

[Chi et al. 1994] Chi, M.T., Leeuw, N., Chiu, M.H., & LaVancher, C. (1994). Eliciting Self-Explanations Improves Understanding. *Journal of Cognitive Science*,18, 439-477.

[Cox and Brna 1995] Cox, R. & Brna, P. (1995). Supporting the Use of External Representations in Problem Solving: The Need for Flexible Learning Environments. *Journal of Artificial Intelligence in Education*, 6(2/3), 239-302.

[Cox 1997] Cox, R. (1997). Representation Interpretation versus Representation Construction: An ILE-Based Study Using switchERII. *8th World Conference on Artificial Intelligence in Education*, Kobe, Japan, 434-441.

[Fung and Adam 1996] Fung, PW. & Adam, A. (1996). Questioning Students on the Contents of Example Solutions., *European Conference on Artificial Intelligence in Education*, Lisbon, Portugal, 108-114.

[Kashihara, Hirashima, and Toyoda 1995a] Kashihara, A., Hirashima, T., & Toyoda, J. (1995a). A Cognitive Load Application in Tutoring. *Journal of User Modeling and User-Adapted Interaction*, 4(4), 279-303.

[Kashihara, Hirashima, and Toyoda 1995b] Kashihara, A., Hirashima, T., & Toyoda, J. (1995b). How to Elicit Self-Explanation. *7th World Conference on Artificial Intelligence in Education*, Washington D.C.,U.S.A., 282-289.

[Kashihara et al. 1996] Kashihara, A., Okabe, M., Hirashima, T., & Toyoda, J. (1996). A Self-Explanation Assistance with Diagram Tailoring. *European Conference on Artificial Intelligence in Education*, Lisbon, Portugal, 122-128.

[Larkin and Simon 1987] Larkin, J.H. & Simon, H.A. (1987). Why a Diagram is (Sometimes) Worth Ten Thousand Words. *Journal of Cognitive Science*, 11, 65-99.

[Merrill et al. 1992] Merrill, D.C., Reiser, B.J., Beekelaar, R., & Hamid. A. (1992). Making Processing Visible: Scaffolding Learning with Reasoning-congruent Representations. *2nd International Conference on Intelligent Tutoring Systems*, Montreal, Canada, 103-110.

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