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Facilitation of Collaborative Concept Formation by Visualizing Thought Space Structure

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Abstract

This paper describes a method which helps people working cooperatively form new concepts in areas such as science and engineering, by conveying individual thoughts to others. The proposed method supports personal or group concept formation by visualizing relationships between concepts and their micro-concepts given by users in a metric space. Spaces which *CSS*, a tool implemented by this method, displays can effectively help users form new concepts in collaborative concept formation as well as individual reflection. Showing individual spaces presented by *CSS* to each other and merging them are useful in manifesting personal backgrounds and viewpoints.

KEYWORDS: creativity, concept formation, CSCW, human communication, visualization, thought space.

1 Introduction

This paper describes a method which helps people working cooperatively form new concepts in areas such as science and engineering. This method supports conveying individual thoughts to others by visualizing relationships between concepts and their micro-concepts given by users in a metric space.

There has been an increase in the number of large-scale problems that cannot be solved using expert knowledge in only a single discipline in recent years. This has necessitated cooperative work among specialists from multiple disciplines. Specialists spend much more time in problem formulation and concept formation than they do in problem solving [1].

From the viewpoint of concept formation, one main process of human creative activities is divergent thinking in which broad alternatives are searched for. Another process is convergent thinking in which a unique solution is sought [2]. Divergent thinking is indispensable especially in an early stage of creative activities, although these two processes must be repeated in concept formation. When people fall into closed personal thought, they will have communications with others in order to search for alternatives to their ideas, sometimes unconsciously. This is an important role of collaborative work for human creativity.

Therefore, they need methods and tools to help them convey the mental contents (i.e. ideas, personal knowledge, background, subjective views) of participants to others in early stages of group interaction. This can lead groups of people to new ideas and shared understanding. In this paper, we propose a tool which supports divergent thinking during collaborative work as well as individual reflection.

Today significant collaborative work is being done using networked computers. This relieves groups of people from the restrictions of time and space. Consequently, various systems for CSCW (Computer-Supported Cooperative Work) or groupware have been proposed to support collaborative work using computers, such as co-authorship [3], project management [4], software development [5], and meetings [6], [7]. In particular, [6] is the work most related to this paper, as it proposes a tool for aiding concept formation and shared understanding during collaborative work.

The main feature of our tool, proposed in this paper, different from existing CSCW systems is the strategy for building the space presented to the user. The tool is as non-prescriptive as possible, but it stimulates users in forming concepts not possible by using only pencil and paper.

2 Visualization of thought space

The authors have proposed several computer tools to aid in creative concept formation by visualizing snapshots of the topological structure of a user's thought space[1] using statistical methods [8], [9]. These tools have been successfully applied to idea generation, knowledge acquisition, software requirements acquisition, information retrieval, and so on. One of these, *CAT1* [9], visualizes a user's thought space structure by automatically mapping electronic memos, called *text-objects*, into a two-dimensional metric space according to the number of common *keywords* declared in the text-objects.

CAT1 works successfully on visualizing the global structure of the users' thought space. These visualizations encourage the users' further thinking, such as finding the axes of the semantic structure in the presented space, or finding new ideas in empty regions in the presented space. *CAT1* also has the potential to show the users' subjective ideas and views to their colleagues. Currently, however, text-objects which are mapped on the space by *CAT1* are too rough to be utilized for analyzing and getting the users' thought space by their colleagues.

This paper introduces another statistical method called the *dual scaling method* [10] for visualization. This method is used to find eigenvectors of multivariate data from sets of data objects with multiple quantified attributes. The eigenvectors are measures to qualify the relationship between data objects and their attributes. This method is derived from a conventional statistical method, called principal component analysis, with a peculiar feature to evaluate a vector of data objects and attributes on the same measure together. Now, we apply this method to qualify relationships between text-objects and their keywords in one metric space by taking keywords declared by users as attributes and their defined weight values as attribute values.

Using this method, we implemented a new tool, called *CSS* (Communication Support System), which enables users to recognize relationships between fragments of ideas (text-objects in this case), which compose their mental world, and micro-concepts (keywords) which verbalize these fragments, at a glance. *CSS* visualizes a two-dimensional space on a computer display by choosing two calculated higher-ranking eigenvectors. This way, it makes easier for users to recognize and analyze not only their own thoughts, but also those of their colleagues.

3 Externalization of personal thought

In Figure 1, we apply *CSS* in oder to arrange research memos written by one of the authors. *CSS* is implemented under the X Window System on a UNIX workstation, and offers a user interface

[1]Here, we define the *thought space* as an externalized mental space consisting of fragments of ideas or knowledge and relationships among them in thinking activities.

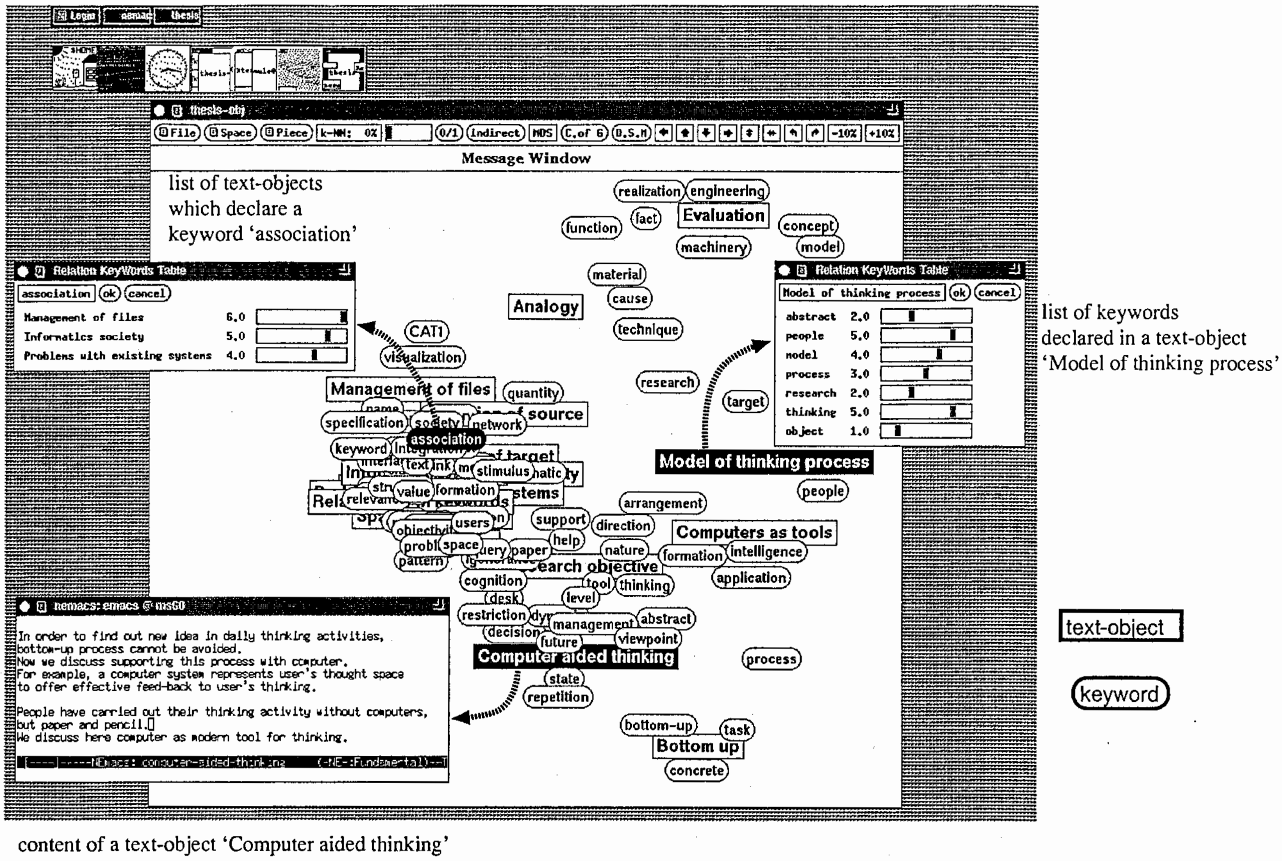

Figure 1: Usage of *CSS*. Rectangular icons in the main window indicate text-objects, and oval shapes represent keywords.

with multiple windows. *CSS* manages a data table which contains text-objects, keywords, and weight values given by users to text-object and keyword pairs. The users reflect their thought in changing the data set. Whenever the users instruct *CSS* to reconfigure the space, it calculates and shows the new configuration according to the current data.

Looking at the space presented by *CSS* enables users to reconsider their own ideas, structured within a certain context, from *another person's view*. For instance, Figure 1 prompts the user to find out several axes indicating the directions of his research and to analyze his own thought. Empty regions in the space suggest the possible existence of a novel research theme. Moreover, this space is useful for illustrating the user's mental contents to his colleagues.

CSS can also store results for other users in databases, which users can use for new thinking activities. These precedent thought spaces can be used as tentative spaces at the beginning of new thinking activities. Moreover these can be stimuli for new concepts or views from the outside of current users' thinking, which has the potential *to rescue them from a morass of usual thoughts.*

We assume that concept formation is the repetition of clustering and segregating of micro-concepts. Moreover, we believe that the combination of micro-concepts changes dynamically through interaction between the mental and external world. Thus, communication with others is essential for creative concept formation as stimuli. If we suppose that keywords represent a user's micro-concepts which are coalesced to form new concepts, and text-objects are triggers which externalize the micro-concepts,

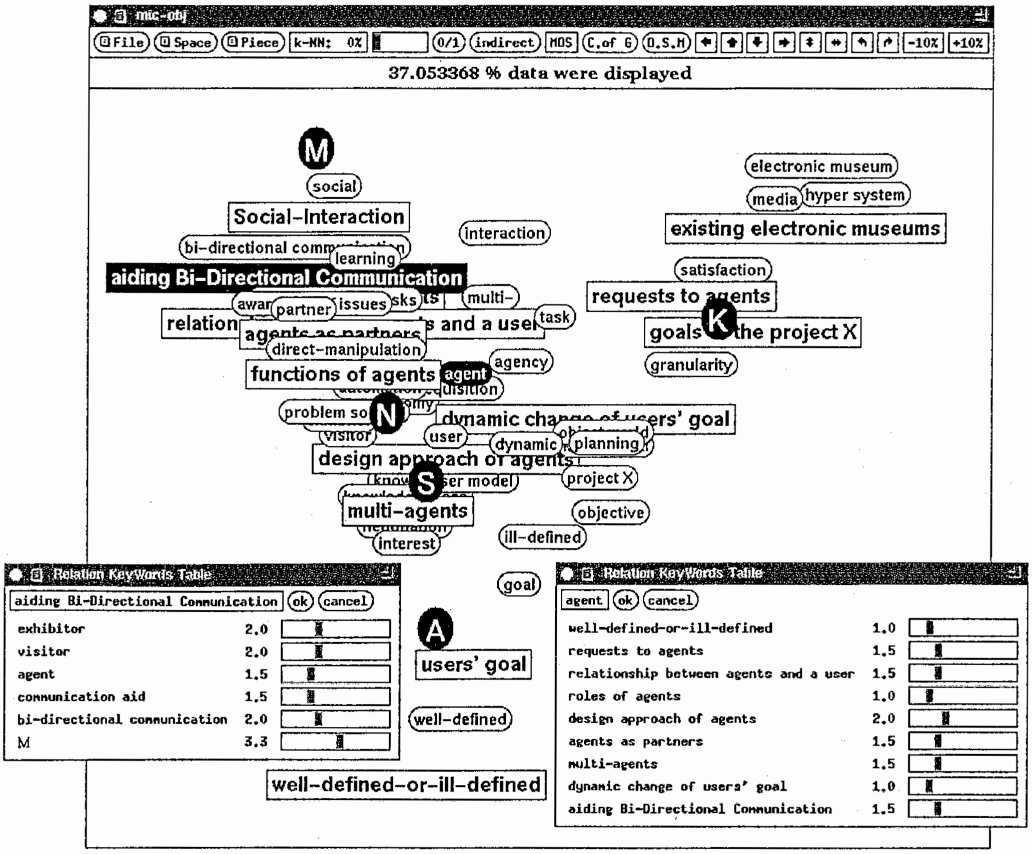

Figure 2: Snapshot of semantic structure of a group discussion.

we can say that *CSS* is a tool which externalizes the dynamics of concept formation.

4 Visualizing semantic structure of group meeting

CSS is not limited to use by an individual user. That is, *CSS* can provide a common space for a group meeting, where text-objects may be given by multiple users.

Figure 2 shows an example of using *CSS* to visualize a snapshot of a group discussion. In this group meeting, five people join to discuss "project X" which is not an articulated idea yet. The rectangular icons are text-objects, which show topics discussed at this meeting. The oval icons are keywords which are verbalized by the participants. The big black round icons in the space show the participants [2].

The space which is presented by *CSS* visualizes relationships among participants, topics, and their keywords. Most participants pay attention to an empty region in the space, which leads them to further discussions about their future works.

5 Merging multiple users' thought spaces

In an early stage of collaborative work, we often encounter a communication gap due to an unconscious difference in personal knowledge or viewpoints. Even when we have conceptual discussions about

[2] In this example, we define participants as keywords of a type, due to the contribution to each topic discussed.

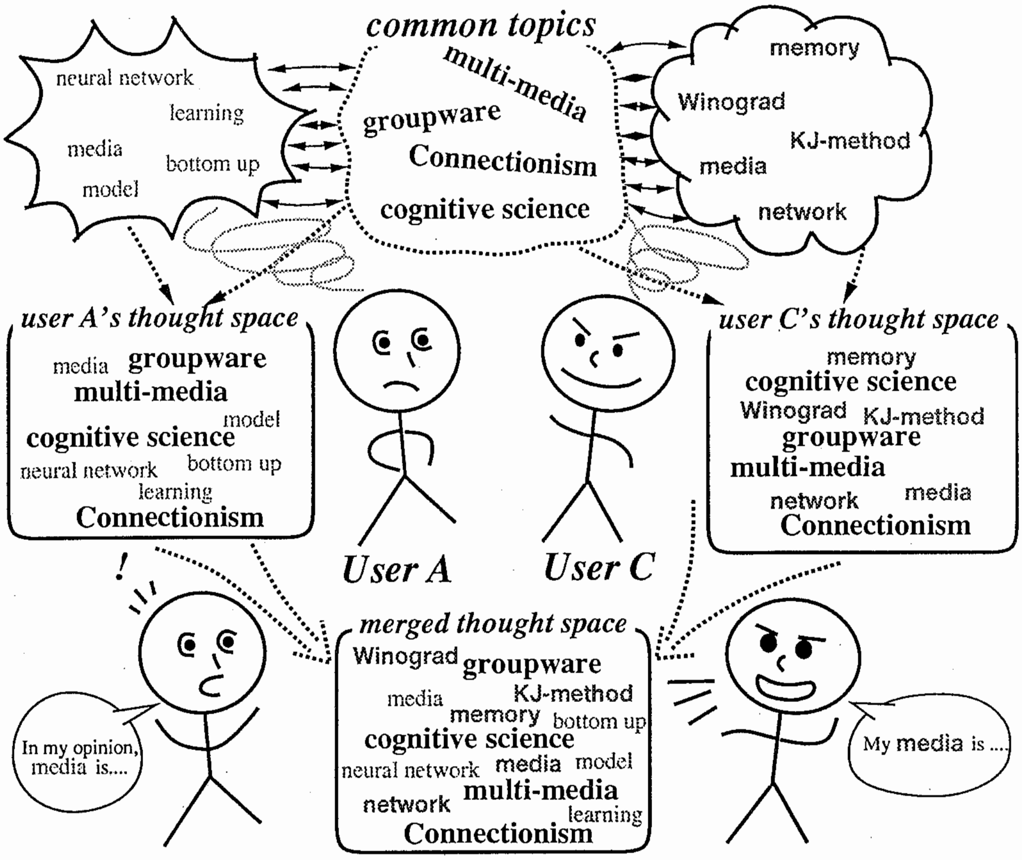

Figure 3: Merging multiple users' thought spaces.

common topics in collaborative work, the background and viewpoint of each participant differ (see Figure 3). The difference will appear in the variety of keywords sets given by each participant in using *CSS*. In such situations, *CSS* is useful for revealing the difference between the participants' thought spaces reflected by their viewpoints or backgrounds.

Now, we make another trial of visualizing relationships among micro-concepts, which compose each personal thought space, by merging multiple users' thought spaces on *CSS* with a common set of text-objects, corresponding to common topics given. We employ a simple method that constructs a new data table of keywords and text-objects by mixing together several personal data sets extracted independently from each user. This method distinguishes between a keyword given by a certain user and one given by another even if those keywords coincidently have the same expression. This enables, for example, users to contrast one individual's 'media' with another's 'media' in a merged space presented by *CSS*.

Figure 4 is an example of a merged thought space of two users' thought spaces based on the method. Note that the result presented by *CSS* is not a simple pile of the two users, but a *novel emergent one*. Both user A and user C, in this case, notice a difference in positions between pairs of keywords which have the same expression in their own text-objects. As a result, they become aware of the difference between their views. Furthermore, both users can exchange personal knowledge with each other by noticing some clusters mixed with keywords given by them, and achieve the *cooperative creation* of a new idea which could not have been noticed by the individuals alone.

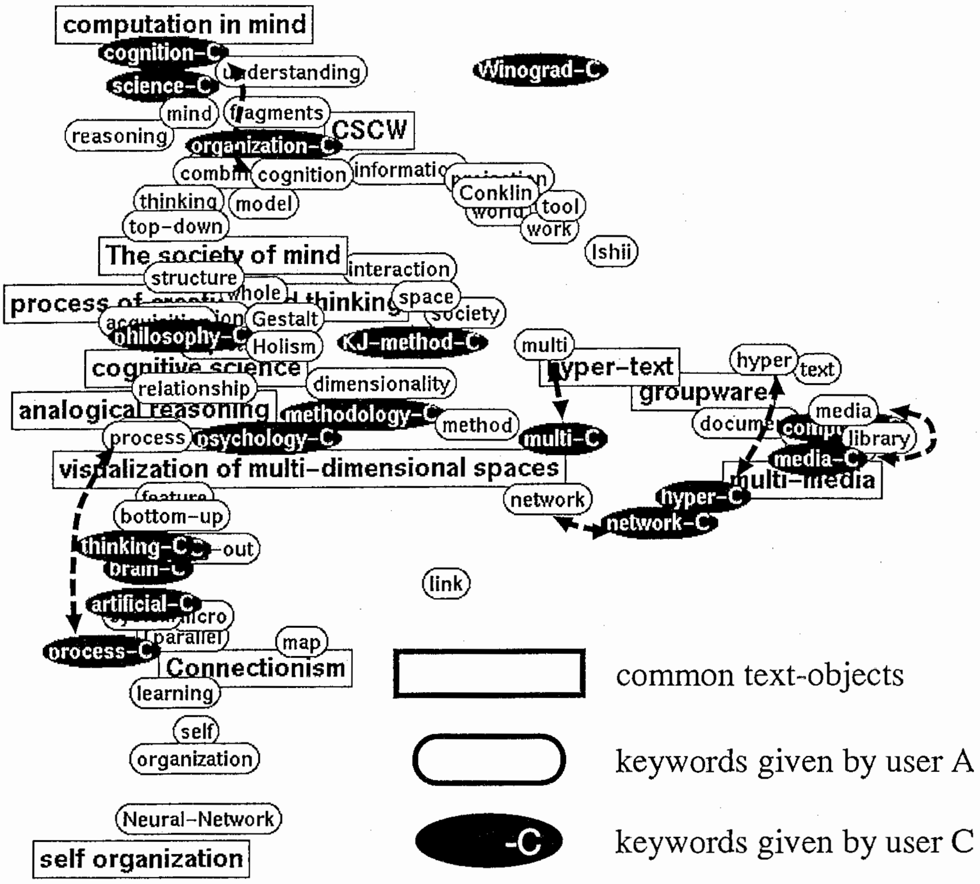

Figure 4: An example of a merged thought space of two users'. Annotated arrows indicate keywords which have the same expression given by the users.

6 Conclusion

A tool for aiding creative concept formation, called *CSS*, was introduced. *CSS* visualizes the users' mental worlds by mapping text-objects and their keywords, which externalize the users' ideas, into a metric space. We showed three typical examples of using *CSS*: 1) individual reflection, 2) visualizing the semantic structure of a group meeting, and 3) merging two users' thought spaces to fill a communication gap which depends on the connection between verbalized keywords and concepts in individual mental worlds.

A flood of electronic documents exist today due to many intellectual activities being done with computers. Furthermore, with the spread of electronic mail, BBS (Bulletin Board Systems), and the WWW (World Wide Web), a novel form of communications is emerging in the computer network society. Therefore, it is strongly expected that electronic information can be utilized effectively to stimulate further creative activities, adapting to problems being faced and users interests. *CSS* is one solution to this issue. Currently, however, *CSS* requires users to provide whole text-objects and keywords to represent their thinking. This is a heavy burden. We are examining the integration of our approach with other methods to extract topics or keywords representative of users' thoughts automatically from huge databases or computers on networks (for example, see [11]).

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