Knowledge Nebula Crystallizer for Knowledge Liquidization & Crystallization – from a Theory to a Methodology of Knowledge Management -

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In this paper, we propose a concept of knowledge management "Knowledge Liquidization and Crystallization", and a system "Knowledge Nebula Crystallizer" to support the process. "Exhibition designing" was chosen as an application of our methodology to a real work place in cooperation with a Japanese advertising company, as it is an example of the tasks that highly depend on implicit knowledge of professionals and that require a methodology of knowledge management. A methodology for knowledge acquisition in the domain and "Knowledge Nebula Crystallizer for Exhibition Designing" are described.

Introduction

We propose a new concept of knowledge management "Knowledge Liquidization and Crystallization", and a system "Knowledge Nebula Crystallizer" to support the process. Though there are several theories about knowledge creation (Nonaka et al. 1995, Fischer 2001, Shneiderman 1998) and a number of companies have realized their importance, most of them face to difficulty of applying them to their real workflows. It is because they have not mentioned how companies should apply them to their workflows. Though traditional knowledge management methods have tried to capture and accumulate "knowledge" itself, it is impossible because knowledge is not something clear-shaped but is embedded in a "context" where a person interacts with an artefact. What can be captured is data or information that describes knowledge and can be used to generate new knowledge (Hackbarth and Grover 1999). In this paper, we are going to describe our approach to a new methodology for knowledge management. As exhibition designing is an example of a task that highly depends on implicit knowledge of professionals and that requires a methodology of knowledge management, it was chosen as an application of our concept to a real work place. Results of the application are described.

1. Related Work

In business fields, though an importance of knowledge has been recognized, the main concern of business theory is how to obtain and accumulate established knowledge and little research has been conducted on knowledge creation.

Our methodology and system aim to provide proper information to create new knowledge and to amplify reflective thinking of a user. A tool must provide not solutions to problems the user encounters (= traditional expert systems) but a place to refer such information that helps the process where the user solves problems (Smith and Farguhar 2000). The tool should be not only knowledge base and retrieval system but also it should support to create new knowledge.

Hori (1994, 1996) has concluded that by articulation of knowledge it is possible to support creative activities. And he also concluded that a spatial representation helps the user clarify his/her concept gradually and generate new concept by looking at blank areas on the space. We adopt the spatial representation to support knowledge creation processes.

Aihara et al. (1998) have developed En Passant 2 that stores a user's research notes and gives triggers to recall his/her memories in his/her current context. It was observed that a subject crystallized his study after browsing all pages and that a subject recognized a new meaning in the page chosen in Adviser (a component of En Passant 2 with the spatial representation) that was eight months ago.

In marketing, human-computer interaction, ethnography and cultural anthropology field, several methods to investigate human behaviour and their cognitive processes have been also proposed and practiced (Ishii 2001, Underhill 2000, Ericsson and Simon 1993, Emerson et al. 1995).

In our research, retrospective report method of protocol analysis is adopted because it focuses on investigation of a visitor' s "context", or "transitions of a visitor's cognitive processes and situations the processes were provoked". This type of microscopic investigation on visitors has not been conducted so far. The main aim is to find actual connections among "what they look at or interact with", "what they think" and "how they behave" at the actual exhibition site.

2. Knowledge Liquidization and Crystallization

2.1. Traditional Approach to Knowledge

Traditional knowledge management methods have failed because they aim at capturing knowledge itself. It is necessary to capture "information with its context" (Fischer and Ostwald 1999). The contexts where knowledge is embedded are observable and obtainable. The dependency of knowledge on a context should be taken into consideration when it comes to knowledge management. From our viewpoint, knowledge is embedded in a process where a human being and an artefact interact with each other. This process is utilized for knowledge creation. In the next section how to utilize the information in our approach is described.

2.2. "Knowledge Liquidization & Crystallization" and "Knowledge Nebula Crystallizer"

A basic concept of our approach is to utilize information for knowledge creation by restructuring information in accordance with a user's context. Norman (1988) have claimed that much of the information a person needs to do a task can reside in the world and that behaviour is determined by combining the information in memory in the head with that in the world.

We have previously suggested a basic concept of Knowledge Liquidization and Crystallization (Ostwald et al. 2003). Now we are going to extend the concept to more practical phase.

Figure 1 shows the Liquidization process in a context of exhibition designing. In designers' mental world, there are a number of implicit and explicit "design rationale". Some of articulated design rationales will be dissolved into small elements and stored in "Knowledge Nebula Crystallizer (KNC)" explained in the next section. This process is what we call "Knowledge Liquidization". Liquidization means "dissolving information into elements and adding them to KNC". Protocol data (verbal data) obtained from visitors is also liquidized into KNC.

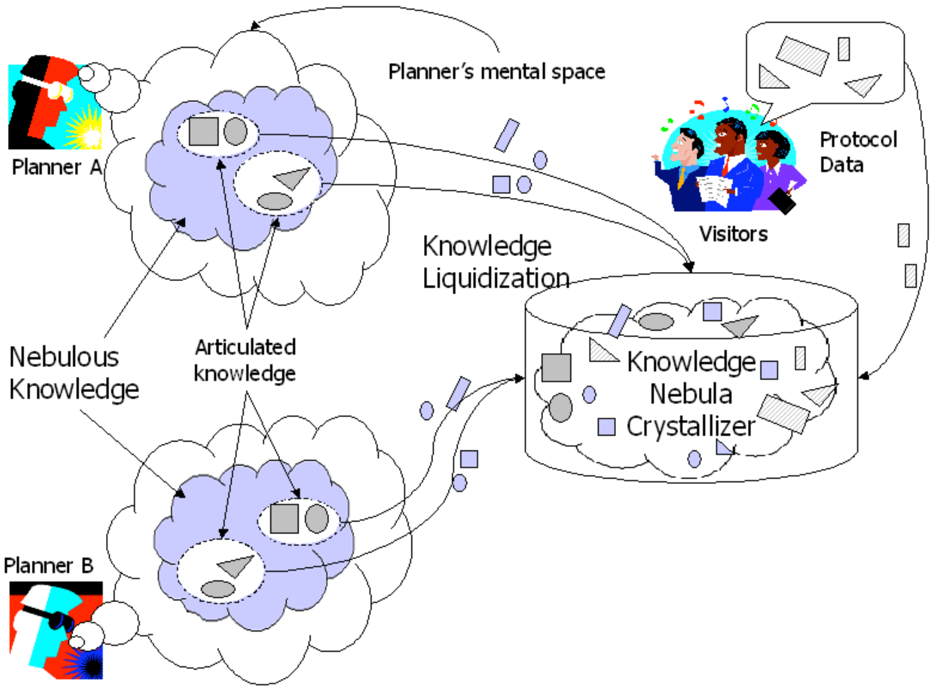

Figure 1 - Knowledge Liquidization Process

Figure 2 shows the Crystallization process in a context of exhibition designing. Crystallization means "restructuring information in accordance with various possible contexts". KNC outputs external representations of crystallized knowledge as stimuli for knowledge Crystallization in planners' mental space.

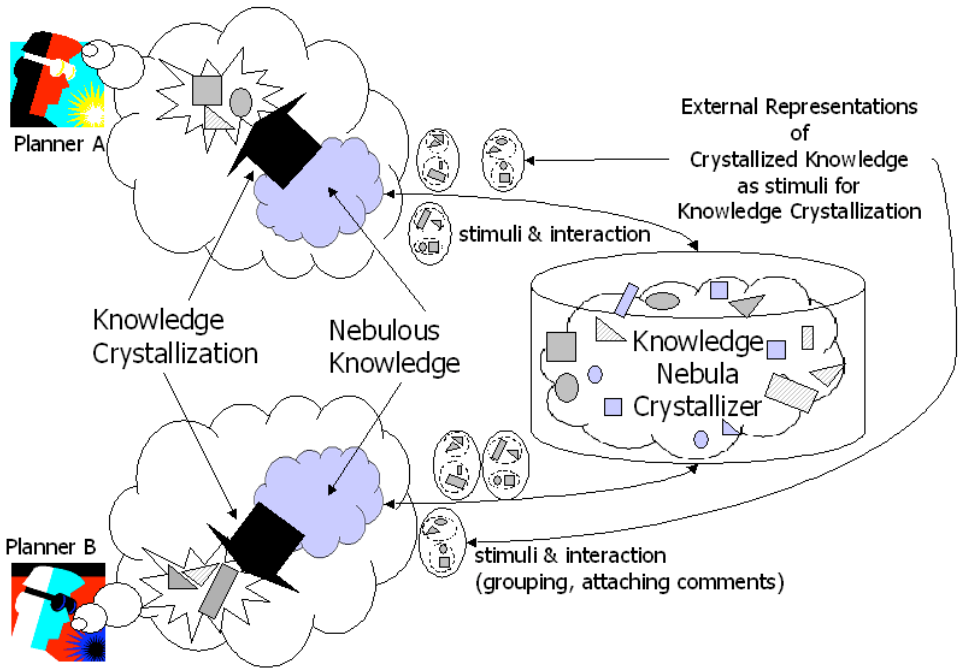

Figure 2 - Knowledge Crystallization Process

Figure 3 shows how knowledge Nebula Crystallizer works. Liquidized information is input. This is an external representation of what we call Knowledge Nebula that is a repository of elementary information. In this repository, any pieces of information in text format can be stored.

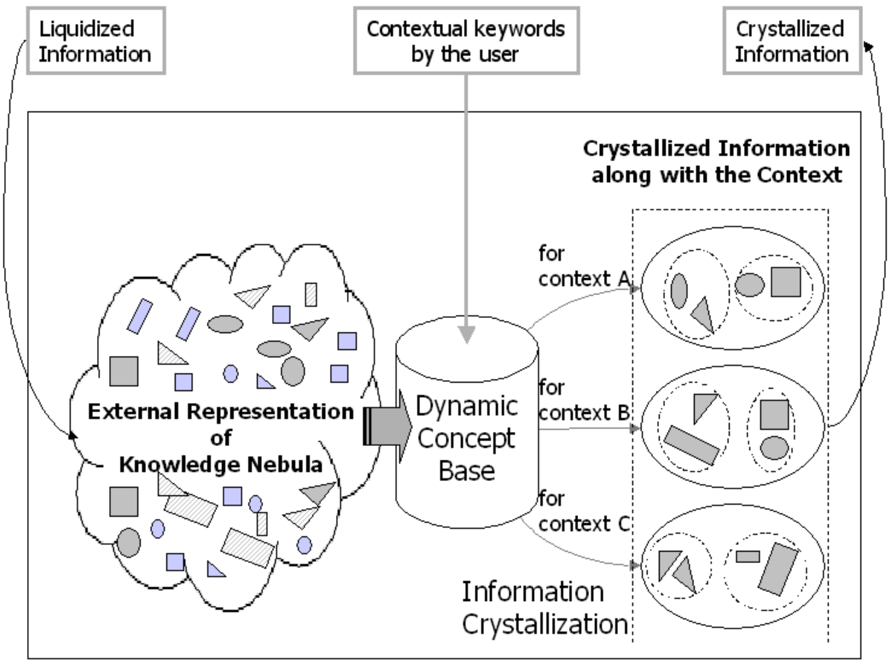

Figure 3 - Knowledge Nebula Crystallizer

If a user would like to retrieve a set of information related to the user's current context, the user inputs a "contextual keyword". Then KNC collects and restructures related information. A contextual keyword is a word, which represents a current viewpoint of the user. "Dynamic Concept

Base (DCB)" implemented inside of KNC accepts the input and it expands the contextual keyword to keywords that have similar concept. DCB is necessary to retrieve "conceptually similar information" to the input contextual keyword. It retrieves not only information containing the input keyword but also conceptually similar information to the input. Details about DCB are described in chapter 4.4. Then a set of information is output. It is regarded as "an external representation of crystallized knowledge". KNC restructures and presents conceptually similar information to an input contextual keyword as output. The output works as a trigger to crystallize knowledge in the user's mental space.
We applied our methodology of knowledge management to a real work place, exhibition designing. We have developed a methodology for capturing visitors' mental transition at a real exhibition site and Knowledge Nebula Crystallizer for Exhibition Designing (KNC4ED) in cooperation with a Japanese advertising company.

2.3. Approach to Exhibition Designing

2.3.1. Traditional Exhibition Designing Process

Every year, exhibition designing companies hold various exhibitions. So far exhibition designing is conducted with implicit knowledge of experienced planners and effectiveness of exhibitions is measured only by questionnaires and group/depth interviews. Figure 4 shows the traditional exhibition designing process. A planner obtains the information through statistical reports and comments. Then the planner is sometimes inspired by the reports and intuitively creates innovative design rationales. The planner makes a presentation of his/her plans for a coming exhibition to his/her clients or reports about the last exhibition.

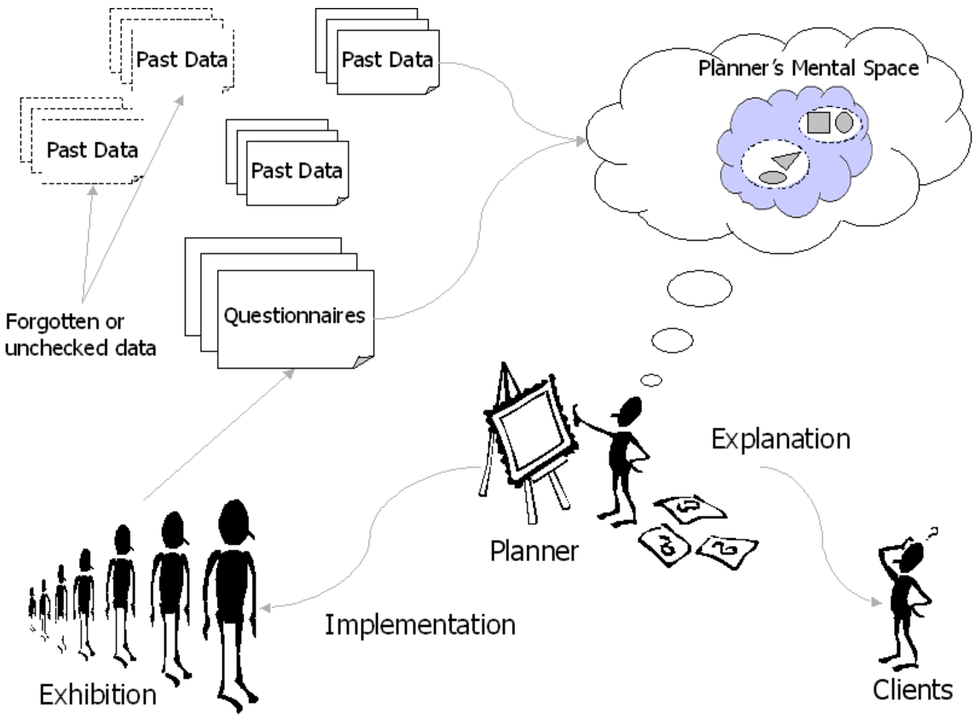

Figure 4 - Traditional Exhibition Designing Process

In exhibition designing, planners first access to past data. They conduct case studies to understand:

- What kind of methods have been conducted for exhibition designing
- What kind of impressions visitors had

There are such problems as:

- It is a time-consuming work to find related materials that they need at certain timing in planning, according to them.
- Though it is necessary for planners to observe visitors' impressions and actions, in a real exhibition site, planners have to stay at a back office. This is the real workflow of planners.

In actual situations, planners claim that they cannot obtain adequate and proper knowledge for future planning from statistical data derived from questionnaires because:

- The questions are composed of only what planners pay attention to in advance. That means they fail to obtain something unexpected.
- The planners cannot understand how and why the data was produced. It makes it difficult for the planners to utilize the information as knowledge (Fischer 2001).
- Even though free-answer questionnaires are adopted, at real exhibition sites it is difficult to have visitors remember and describe their impressions in detail after browsing the exhibition site. Information from free-answer questionnaires and interviews should be used to investigate what were the most impressive things to the visitors.

Because of these reasons planners are unable to evaluate exhibitions they design and unable to make a persuasive explanation about their plans to their clients. This is one of the most important problems in their real workflow. Planners need to know what visitors to exhibitions actually feel and how they behave when they are at the exhibition booth in order to construct strategies for next exhibition. Of course it is possible for planners to observe their booths and check if the booth attracts visitors, but it is impossible for planners to observe and ask the visitors what they look at and how they think about it in detail at an actual exhibition site. In addition, as planners are supposed to stay in backyards of their booths (in case somebody has to contact with the booth planner), it is difficult for them to take time to visit the booth.

We do not intend to deny quantitative methods. Qualitative and quantitative methods should complement with each other. The former is for establishing the hypotheses and the latter for verification.

2.3.2. Our Approach

First of all, to investigate what planners intended and how they implemented exhibition objects to express exhibition concepts, we had interviews with the planners in advance. The procedures are:

- Planning papers were obtained in advance to extract messages and themes that the planners tried to convey to visitors. If the connections are unclear, they are listed as questions to planners.
- Asking a planner to explain concepts of a booth the planner designed with his own vocabulary.
- Ask the listed questions and clarify the connections among concepts and objects. A question asked to the planners was: "how did you implement exhibition objects to express exhibition concepts?"

Answers of the interviews and protocol data were compared how much they matched.
To obtain a context of information, we attempt to record all what a visitor looks at, his/her thought in looking at an exhibition object and his/her actions with wearable computers. Protocol data is collected through "retrospective report method" of protocol analysis. This approach covers the problems in traditional questionnaires mentioned in the former sections.

Protocol data is liquidized into Knowledge Nebula in "Knowledge Nebula Crystallizer for Exhibition Designing (KNC4ED)". The Liquidization here means to decompose obtained huge protocol data into a unit composed of "perceived exhibition object", "visitors' thought on the object" and "visitors' action". This is a unit of information that connects a concept and a real object. That is, this unit works in designing a concept to convey and its realization. And planners' intentions are also liquidized into KNC4ED. Planners have a number of implicit and explicit knowledge. Liquidized data of planners are composed of "an exhibition object" and "an intention on the object".

Obtained information should be analyzed and formalized. As mentioned in the former section, knowledge should be formalized in accordance with a context to which a user faces (Shipman et al. 1999). In the case of exhibition designing, it is necessary for planners to analyze data to know what is going on in a real exhibition site and to formalize data to see what should be done in a exhibition site to bring about a certain effect on visitors' mental spaces. In Liquidization protocol data and planners' intentions are combinations of a certain exhibition object and a concept. As its amount is huge, they should be formalized to understand what could cause what kind of effect.

This process is regarded as a design process of information. In design works, it has been one of the most important challenges to externalize a

designer's mental space (Schoen 1983, Hori 1994, Hori 1996, Fischer 2001). As we regard externalization of mental space is important for knowledge creation, we are going to implement along with this concept.
As described in the next section, these supports help planners to conduct a persuasive explanation to their clients. This is one of the most important supports for works in the real world.

3. Knowledge Nebula Crystallizer for Exhibition Designing

3.1. System Overview

Figure 5 shows an expected scheme of exhibition designing after introducing KNC4ED. The proposed methodology supports to obtain information with its context that it was difficult to obtain with the traditional methods. User's reflective thinking phase and knowledge creation (= Crystallization) phase are also supported through the user's interaction with the system. KNC4ED is expected to work as a communication tool between a planner and his/her clients, because the system provides information with its contexts and it is possible to share the planner’s way of thinking with the clients by showing how the planner restructures and interprets information.

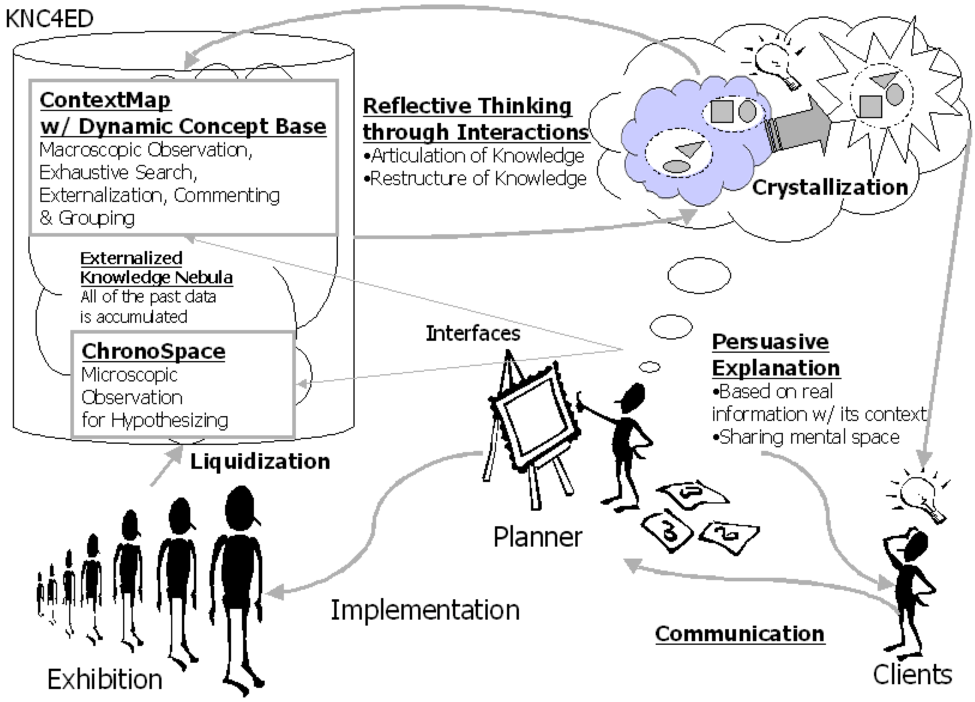

Figure 5 - Exhibition Designing Process with KNC4ED

Figure 6 shows the system overview.

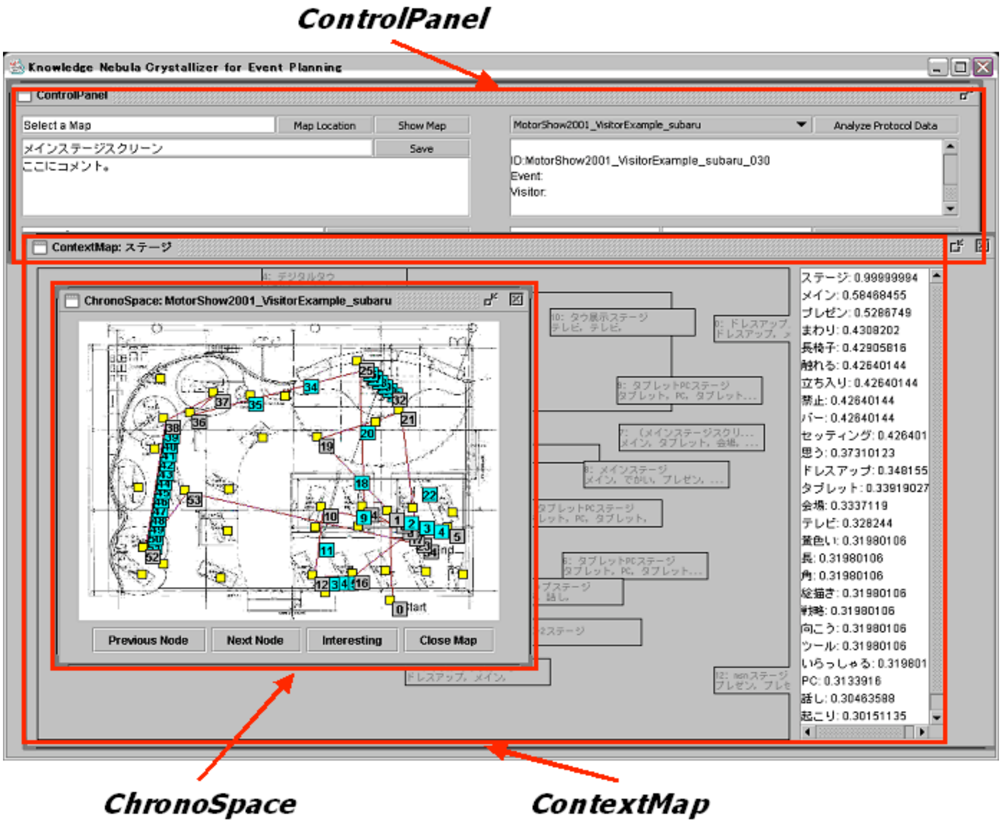

Figure 6 - Knowledge Nebula Crystallizer for Exhibition Designing

From the discussion above, KNC4ED should:

- Support to observe information with its context for a planner to understand it
- Provide a space to restructure the relationship among information to interpret it along with the context to which the planner faces

The system is composed of following components:

- ChronoSpace: a tool for detailed observation on each visitor at each exhibition
- ContextMap: a tool for observation across all of obtained data and a space for formalizing concepts
- Dynamic Concept Base: a concept base that changes structures of concepts dynamically in accordance with a user's input.
- ControlPanel: Operation window for attaching comments on objects and showing protocol data (Figure 7)

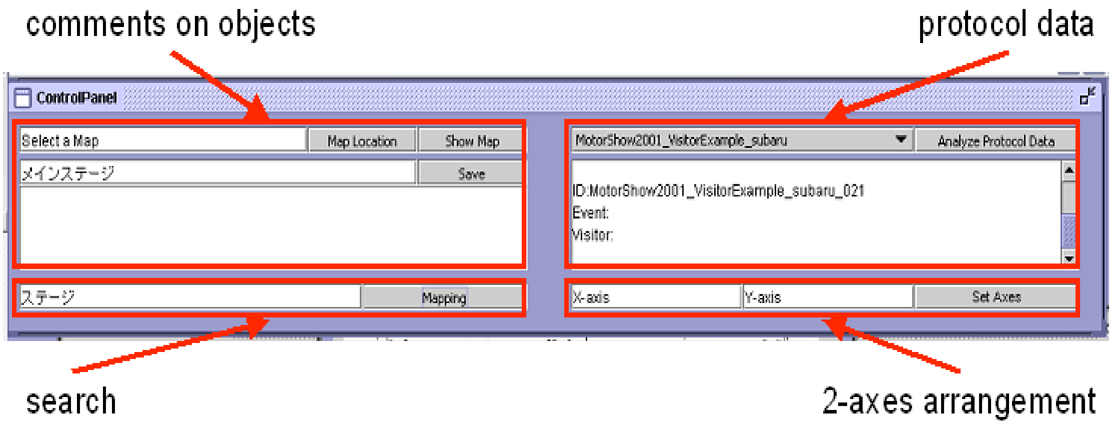

Figure 7 - Control Panel

The proposed methodology and system cope with theoretical frameworks on transition of knowledge modes and knowledge creation, such as SECI model (Nonaka et al. 1995) and Creation-Integration-Dissemination (Fischer 2001), and also cope with a theoretical framework on creativity support Collect-Create-Consult-Disseminate (Shneiderman 1998). The methodology is to activate the transitions in the models for knowledge creation and the system is to realize the transitions.

3.2. ChronoSpace

ChronoSpace is a tool to enable a user who cannot observe on the spot of an exhibition to observe what visitors look at, what they think about it and how they behave as detail as possible. From an ethnographic viewpoint, observation is one of the hallmarks to understand thoughts and actions of people. Its functions are described below with its expected interactions.

ChronoSpace automatically generates a line of a visitor's flow by matching time-sequential protocol data of a visitor with plotted object data. This function facilitates the user to grab and confirm in what root a visitor looks around and what they think about objects (Figure 8). It also promotes planners' reflective thinking. ChronoSpace allows the user to grab a line of a visitor's flow easily and to analyze how and why the line is different from an expected line.

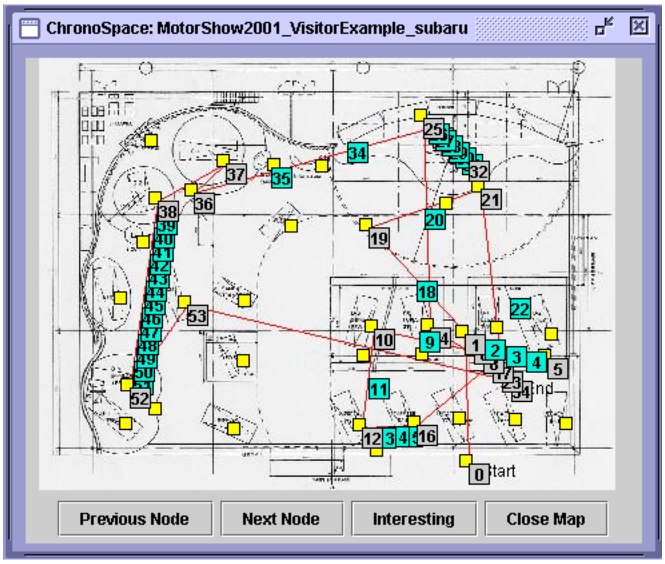

Figure 8 - ChronoSpace (Automatic Generation of a Visitor's Flow with Protocol Data)

This is a better way to observe visitors' viewpoints, thoughts and actions than observation through just watching VTR because:

- It is quicker than watching VTR that takes at least the same time period as visitors' browsing.
- It provides a gestalt view of visitors' movement.

For automatic flow generation, it is necessary to provide information about the booth with a map. The user can plot exhibition objects on a map in ChronoSpace in advance. This is a function to promote the user's reflective thinking by clarifying what objects are located in the designated booth and where they are. ChronoSpace loads a map of the designated booth and allows a user to plot objects on the map (Figure 9) and it also allows the user to attach comments on each object in ControlPanel (Figure 7). The user can attach comments about expected effects. This is a process of what we call Knowledge Liquidization. This may sound that an extra work is added to planners' workflow, but since planners are required to make a presentation to clients to explain their intentions for booth design, this is not a new extra work.

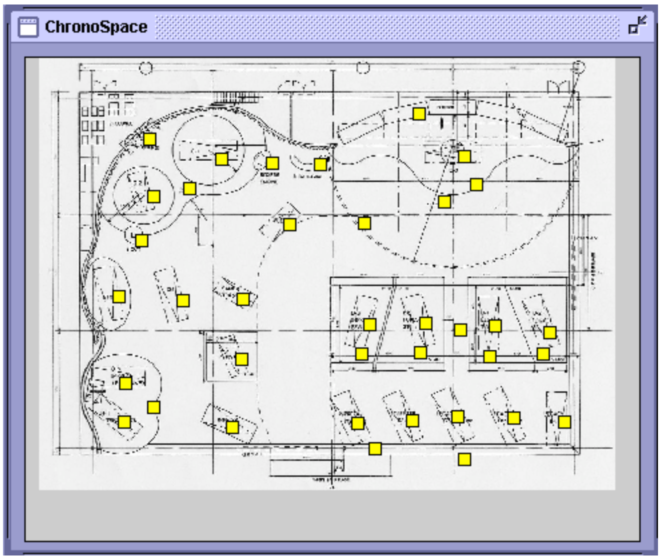

Figure 9 - ChronoSpace (Plotting Objects)

From a viewpoint of persuasion support, this function helps the user to articulate their ideas, and after plotting objects ChronoSpace provides not only the booth map but also planners' intentions on its design. It facilitates both planners and clients to grab both physical and conceptual aspects of the booth.

There are two types of protocol data: one is verbal report on the plotted objects and another is that on objects the user did not specify in advance. For example, the user cannot plot "other visitors" on the map in advance. Planners can utilize the former protocol data to see if their intentions matched visitors' impressions. This promotes planners' reflective thinking. The latter can be a trigger to discover something planners did not expected in advance.

There is a button "interesting" below the map on ChronoSpace to save findings if the user discovers interesting phenomena. The saved data are utilized when ContextMap presents information on its two-dimensional space described later.

3.3. ContextMap

Figure 10 shows a snapshot of ContextMap. This is a place for Knowledge Crystallization.

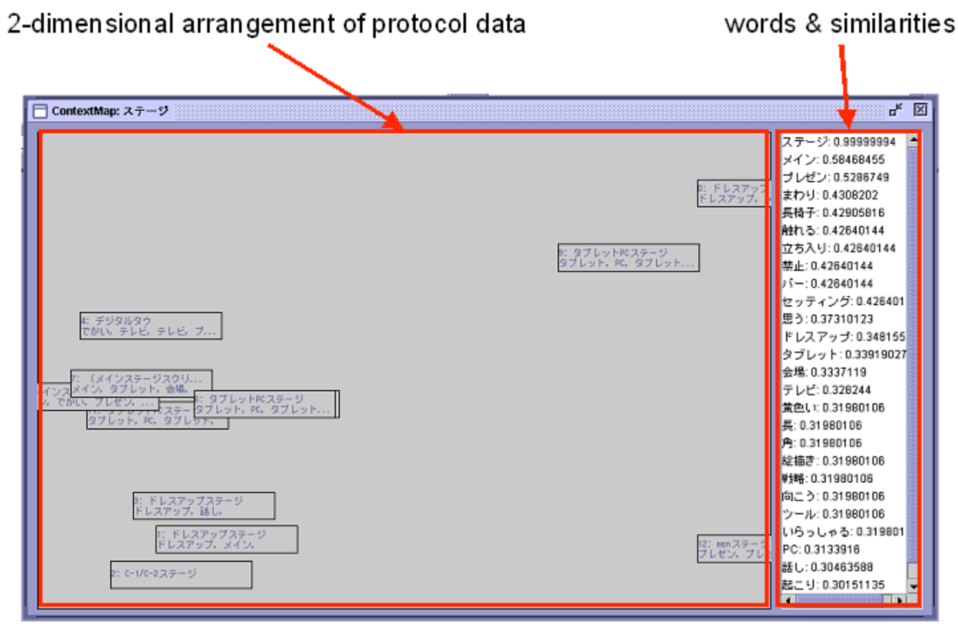

Figure 10 - ContextMap

The system exhaustively searches protocol data by matching the data with an entered keyword and keywords extended by Dynamic Concept Base (DCB) described later. A space on the left of Figure 10 shows a result of the retrieval and a list on the right side presents keywords extended by DCB with their similarities to the original keyword.

In planning, planners usually conduct case studies. ContextMap with DCB enables the user to search and retrieve what he/she needs exhaustively. And ContextMap also allows the user to formalize their knowledge through grouping and attaching comments on the protocol data, the space and the group the user made. These functions allow the user to observe relationships among protocol data and formalize information incrementally (Shipman et al. 1999).

Obtained protocol data should be formalized from viewpoints of, for example, "what kinds of visitors' mental transitions have been caused by a certain method?" "what kinds of methods have been conducted so far to cause a certain effect on visitors' mental space?" etc. A problem is that protocol data are too huge to find out relationships among them or to relate with each other. Even so it is necessary to formalize information to some degree, otherwise they are to be useless.
Moreover, formalization differs from situation to situation. No formalization is universal. ContextMap supports to find relationships among protocol data by the user in accordance with situations the user faces.

First it calculates similarities among protocol data. Then ContextMap arranges protocol data on a space shown in the left side of Figure 10. Similar data are arranged closely with each other. In this retrieval, DCB is used to extend the original keyword. It extends the original keyword to conceptually similar keywords and the extended keywords are used to retrieve protocol data. As they are arranged in accordance with their similarity, it is possible to analyze the reason why the chunks of protocol data are grouped.

A spatial representation should allow the user to modify its space in accordance with a situation currently the user faces to. The user can rearrange, group and label the objects on ContextMap. These interaction supports the formalization process Shipman suggested. Grouping, labelling and formalizing data by the user leads to knowledge creation for the situation the user faces. This is the Knowledge Crystallization process. The user articulates his/her own thought based on the protocol data on the space and formalize their idea incrementally. It leads to create knowledge for user's current context. ContextMap allows multiple formalizations in accordance with multiple contexts. As Yamamoto (2001) mentioned, what is necessary in knowledge creation is not to provide solutions but to provide a space to explore problem spaces and solution spaces.

This interaction is an analytical process of data. The user articulates his/her way of thinking with his/her own vocabularies. For example, the user can search protocol data with a keyword "main stage" and the user can analyze a general tendency of main stages by investigating a chunk. And also the user can analyze special cases about main stages by investigating protocol data arranged apart from a big chunk on the space. It is possible to analyze what is general evaluation on main stages, why the user clarifies his/her own viewpoints for evaluation and so on. This process is also regarded as articulating the user's thinking process from data to his/her conclusions. It enables the user to share his/her ideas to clients, that is, it supports persuasion processes to clients.
Moreover, ContextMap allows the user to decide axes of the space and analyze arrangements of data. In an analytical task using spatial representations, there are two types of analysis:

- Clustering objects along with their similarities
- Clustering objects along with certain axes

The former is a usage of ContextMap we mentioned above. The latter is also taken into consideration. This is also one of the cases of Knowledge Crystallization. ContextMap used in the former way becomes a trigger for user's discovering new attributes. That means the user obtains a new viewpoint and he/she will set attributes of axes on the space to analyze the data further.

For example, by choosing axis X "company A" and axis Y "company B", ContextMap can arrange the protocol data.
ContextMap extends keywords from the two input keywords. First it searches protocol data that contains the extended keywords of "company A". Then it calculates similarities among the retrieved protocol data and

one-dimensional coordinates by MDS (Multi Dimensional Scaling). They are X-coordinates on the space of ContextMap. The same process is conducted for the other extended keywords. The calculated coordinates are Y-coordinates on the space (Figure 11).

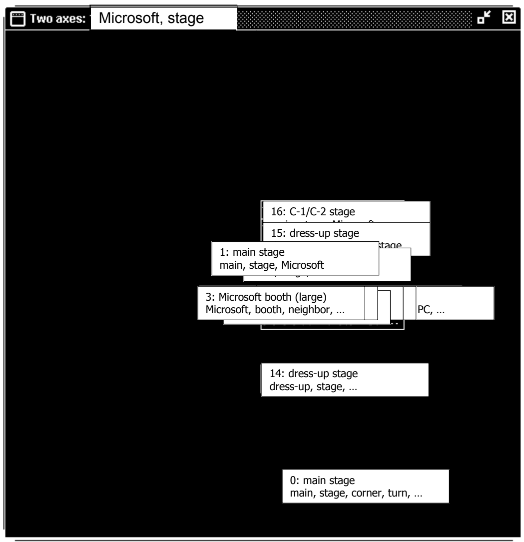

Figure 11 - Two-axis Arrangement (X-axis: "Microsoft", Y-axis: "stage")

In this case, some of protocol data are arranged in the top-right area. The area expresses "something company A and company B have in common". The top-left and bottom-right stands for something either of them has. And the bottom-left represents something neither of them has. Then the user can analyze the difference between the two companies and it can support to create new strategies for future planning.

The important thing about this function is that it is the user that decides the axes. Ahlberg et al. (Ahlberg et al. 1992) have suggested and implemented "Dynamic Query" to present information dynamically to queries in real time. Though this facilitates the user to browse data, it provides only fixed axes. It highly depends on users' viewpoints what kinds of axes the user would like to set. During browsing data from a certain viewpoint, the user sometimes discovers other viewpoints and then system should allow the user to analyze the data from the viewpoints. The function the user can set axes takes a design perspective into consideration. In design processes, what is necessary for designers is not a solution to a problem but a place to discover and explore a problem space and a solution space.

By clicking on an object on ContextMap, ChronoSpace appears with correspondent maps of correspondent visitors. These two components facilitate the user to move back and forth between real data (ChronoSpace) and concept spaces (ContextMap) and promote knowledge creation.

3.4. Dynamic Concept Base

The concept base we mention here is to be utilized for searching. There are two reasons to construct a concept base from protocol data.

Firstly, when a user retrieves protocol data, he/she can specify a keyword for searching. If simple exhaustive search is conducted, protocol data with the specified keyword is retrieved. But in a certain context (in this case "exhibition"), it is possible to define semantic similarities among words.

For example, in a context of "exhibition", presentations are presented on stages at a booth. So "presentation" and "stage" can be regarded as semantically similar words in this context. By calculating co-occurrence frequencies among words in all protocol data, similarities among words are defined.

Secondly, if semantically similar words are required, it is impossible to use a general thesaurus because semantic similarities among words are highly dependent on contexts the words are used. For example, in a context of this paper, when we use a word "planning", it appears with "exhibition". No general thesaurus connects "planning" to "exhibition". As it is difficult to find a thesaurus in some fields, a concept base has to be constructed if it is necessary.

A concept base so far has been constructed and left statically. Though dynamic configuration of a concept base has been proposed (Kasahara et al. 1994), few practical applications have been appeared. As problem solving, analysis and design problems are processes dependent on their situations and relations among concepts are essentially dynamic, a supporting system should allow the user to restructure structures of concepts dynamically.

In this research, the concept base is restructured by changing the similarities among index words. The concept base is restructured by the user's grouping and attaching comments on protocol data on ContextMap and saving data as an "interesting data" on ChronoSpace.

4. Methodology and Experiment

We conducted experiments to see if our concept works in real exhibition designing processes. To obtain actual cognitive processes at exhibition sites, the experiment was conducted at following two exhibitions held at Makuhari Messe in Japan.

- World PC Expo 2001 (WPC: 19-22, Sept., 2001)
- Tokyo Motor Show 2001 (Motor Show: 26, Oct. - 7, Nov., 2001)

Three booths for WPC and one booth for Motor Show were selected for the experiment in cooperation with a Japanese advertising company and exhibition organizers.

Nine subjects (one person for three sessions + one pair for three sessions) at WPC and twelve subjects (one person for each session) at Motor Show were employed.

To articulate visitors' mental impression, we adopted retrospective report method of protocol analysis with visual aid (Ericsson and Simon 1993, Suwa et al. 1998). The subjects were asked to have a recording device on. The recorded data were used as the visual aid. As recording devices, two wearable computers were prepared. A normal digital video camera was also prepared. But this time the wearable computers were limited because of sponsors' intention. This is an example of difficulty to conduct an experiment in the real world. We consider that validity of a wearable computer was proved to investigate human cognitive processes in the real world. A wearable computer and our methodology were adopted in another project conducted by the advertising company to investigate effectiveness of POP (Point Of Purchase) at a real super market. Figure 12 shows the wearable computers.

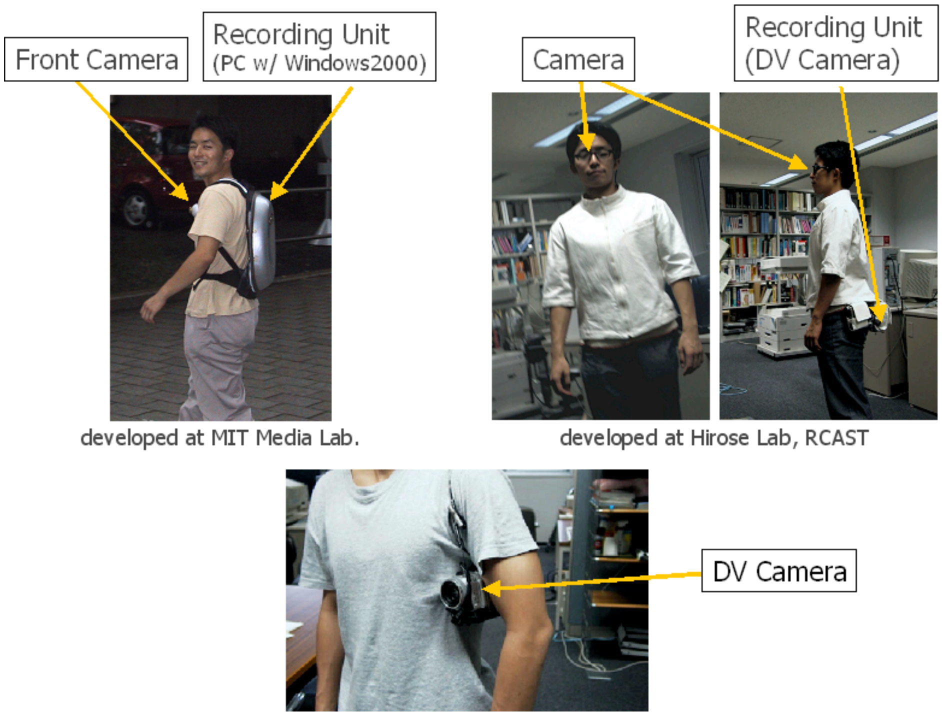

Figure 12 - Wearable Computers

The subjects were asked to look around designated booth(s) and report "what they looked at", "what they thought" and "how they behaved" with watching the recorded data. The recorded data worked as an aid for retrieving their memories. It is pointed out that it is important to avoid changing memories in protocol analysis to obtain precise ones.
Here is the procedures conducted in the investigation:

- In advance to the exhibition, recruit subjects and explain the purpose of the investigation, time, place to meet and so on.

- On the day before entering the exhibition site, explain which booth are the targets and how long subjects are able to browse booths. In our case, basically duration of browsing was up to subjects with a limitation of maximum one hour. And tell where to meet after browsing.
- Take a subject to the exhibition site and tell the time limit. Then a staff goes to the meeting point.
- After browsing, the waiting staff meets the subject and goes to an interview room.
- Conduct interview with retrospective report method.

5. Results and Discussion

The protocol data obtained from subjects and planners' intentions are liquidized into "Knowledge Nebula". It was observed that the Knowledge Nebula devoted to realize "Knowledge Crystallization", that is, to create a new knowledge. Our microscopic approach successfully obtained a number of information with its context that is beyond planners' expectations. Moreover, it was observed the obtained contextualized information worked as stimuli for Knowledge Crystallization.
In this section, some observed examples of Knowledge Crystallization are described. Our methodology successfully articulated gaps between planners' intentions and visitors' impressions through the microscopic observation and analysis. It enabled planners to observe thoughts and actions of visitors in a microscopic way and it successfully worked to articulate visitors' viewpoints and their impressions, and gaps between them.

5.1 Example 1: Effect of the Other Visitors

Following protocol data was obtained that indicates that other visitors raised a degree of satisfaction of the visitor.

> A companion took a picture with a family. Both of the companion and the child smiled. My children also like cars. They would be delighted if I took them here. That is a good idea.

When a planner saw this, he hit upon a following strategy, i.e., Knowledge Crystallization was caused:

> By inviting families that are customers of the company, the other visitors will feel in a way mentioned above. Moreover, the invited family will also feel better because they feel "they are invited as special guests" and this family can enjoy being a customer of the company, which will be great benefit to the company, too.

This is a good example of Knowledge Crystallization because implicitly they might know:

- Another visitor at an exhibition site affects a visitor.
- Customers are delighted if they are invited as special guests.

- If customers like the company, it is beneficial to the company.

But these pieces of information have not been connected. They have been "Knowledge Nebula" in planners' mind. The important thing is that the methodology could provide information with the "real context" which worked as "an external representation of crystallized knowledge", that is, stimulus for knowledge creation.

5.2. Example 2: Effect of Another Booth

Following phenomenon was observed from a subject at WPC. The author summarized his protocol data.

- A subject first went into one of the booths. He was interested in a laser printer because he personally would like to buy one and a presentation of a laser printer at the booth was good.
- Next he went into the second booth with saying "I wonder where laser printers are". Though the booth did not exhibit laser printers, he was looking for them from the beginning to the end.
- He finally said, "I cannot find laser printers" and left the booth, having set a low valuation on the booth.

The planners were impressed by this phenomenon:

> Normally planners do not take it into consideration that what kinds of commodities appear in the next booth. It is something out of our sight. It is too much for us if commodities next to our booth make visitors' evaluation on ours low!

For the planners, "a commodity in a neighbour booth" was not a design variable. Our approach could manage to reveal one of the hidden variables because it articulates visitors' mental transitions in temporal order. It provides planners with phenomena that have not been reported through traditional questionnaires and interviews.

5.3. Discussions

The information was liquidized and stored in Knowledge Nebula in Knowledge Nebula Crystallizer, and it worked for "Knowledge Crystallization" of the planners. Because the information was beyond planners' expectation and accompanied with its context, it successfully worked as stimuli for Knowledge Crystallization, the planners hit upon a new strategy.

The goal of our research is to establish a methodology to apply the theories for knowledge creation to practice. Our methodology has been established based on various and precious results of human-computer interaction, knowledge management, cognitive science, wearable computers and so on. The integration and application to problems in the real world are highly required. We successfully indicated an example of it.

6. Conclusion

Our approach attempts to establish a methodology to apply the theory of knowledge creation to actual work places. Our approach integrates results of such research fields as creativity support, cognitive science, knowledge management, wearable computer, marketing, human-computer interaction, and so on. Our research contributes to integrate theories and techniques for knowledge creation and transfer the theory for knowledge-mode transition into "a methodology for knowledge-mode transition in a real work place".

We are going to have further user studies of the system. We often have discussion with the advertising company to fit it to their real workflow. It is necessary to cut cost of time and money to apply to the actual working sight. This is also another challenge to overcome.

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References

Ahlberg, C., Williamson, C., and Shneiderman, B. (1992) Dynamic queries for information exploration: An implementation and evaluation, Proc. ACM CHI'92: Human Factors in Computing Systems, pp 619-626.

Aihara K. and Hori K. (1998) Enhancing creativity through reorganising mental space concealed in a research notes stack, Knowledge-Based Systems, vol. 11, no. 7, pp 469--478.

Emerson, R. M., Fretz, R. I. and Shaw, L. L. (1995) Writing Ethnographic Fieldnotes (Chicago Guides to Writing, Editing, and Publishing), University of Chicago Press.

Ericsson, A. K. and Simon, H. A. (1993) Protocol Analysis: Verbal Reports as Data, Cambridge, MA: MIT Press.

Fischer, G. and Ostwald, J. (2001) Knowledge Management: Problems, Promises, Realities, and Challenges, IEEE Intelligent Systems, Vol.16, No.1, pp 60-72, January/February.

Hackbarth, G. and Grover, V. (1999) The knowledge repository: Organizational memory information systems, Information System Management, Vol.16, No.3, pp 21-30.

Hori, K. (1994) A System for Aiding Creative Concept Formation, IEEE Trans. Systems, Man, and Cybernetics, Vol.24, No.6, pp 882-894.

Hori, K. (1996) A Model to Explain and Predict the Effect of Human-Computer Interaction in the Articulation Process for Concept Formation, Information Modelling and Knowledge Bases, Vol.7, pp 36--43, IOS press.

Ishii, E. (2001) Diagram to Understand Marketing Research, Management Center of Japan Management Association.

Kasahara, K., Matsuzawa, K., Ishikawa, T. and Kawaoka, T. (1994) Viewpoint-Based Measurement of Semantic Similarity between Words, Journal of Information Processing Society of Japan, Vol.35, No.3, pp 505-509.

Nonaka, I. and Takeuchi, H. (1995) The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation, Oxford University Press.

Norman, D. A. (1988) The Psychology in Everyday Things, Perseus Books.

Ostwald, J., Hori, K., Nakakoji, K. and Yamamoto, Y. (2003) Organic Perspectives of Knowledge Management, Proceedings of I-KNOW'03 Workshop on (Virtual) Communities of Practice within Modern Organizations, Graz, Austria, July.

Schoen, D A (1983) The Reflective Practitioner: How Professionals Think in Action, Basic Books, NY.

Shipman, F. M. and McCall, R. J. (1999) Incremental formalization with the hyper-object substrate, ACM Transactions on Information Systems, Vol.17, Issue 2, pp 199 - 227.

Shneiderman, B. (1998) Codex, memex, genex: The pursuit of transformational technologies, International Journal of Human-Computer Interaction Vol.10, No.2, pp 87-106.

Smith, R. G. and Farguhar, A. (2000) The Road Ahead for Knowledge Management -- An AI Perspective, AI Magazine, pp 17--40, winter.

Suwa M., Purcell T. and Gero, J. (1998) Macroscopic analysis of design processes based on a scheme for coding designers' cognitive actions, Design Studies, Vol.19, No.4, pp 455--483.

Underhill, P. (2000) Why we buy: The Science of Shopping, Touchstone.

Yamamoto, Y. (2001) Amplifying Representational Talkback: Interactive Systems Using Spatial Positioning to Support Early Stages of Information Design, Ph.D thesis at Graduate School of Information Science Nara Institute of Science and Technology.