Journal of Universal Computer Science, vol. 13, no. 2 (2007), 135-148
submitted: 31/7/06, accepted: 15/1/07, appeared: 28/2/07 © J.UCS

Sustainable Memory System Using Global and Conical Spaces

Hidekazu Kubota
(Dept. of Intelligence Science and Technology,
Graduate School of Informatics, Kyoto University, Japan
kubota@ii.ist.i.kyoto-u.ac.jp)

Satoshi Nomura
(Dept. of Intelligence Science and Technology,
Graduate School of Informatics, Kyoto University, Japan
nomura@ii.ist.i.kyoto-u.ac.jp)

Yasuyuki Sumi
(Dept. of Intelligence Science and Technology,
Graduate School of Informatics, Kyoto University, Japan
sumi@i.kyoto-u.ac.jp)

Toyoaki Nishida
(Dept. of Intelligence Science and Technology,
Graduate School of Informatics, Kyoto University, Japan
nishida@i.kyoto-u.ac.jp)

Abstract: We present a concept and implementation of a computational support for spatial memory management and describe its temporal evolution. Our essential idea is to use an immersible globe that consists of a global space and a conical space, thereby providing arbitrary memory space for humans. We developed a sustainable knowledge globe (SKG) for constructing a memory space, and proposed a system called Contents Garden to expand the SKG into immersive space. We carried out the user study of SKG to evaluate its effectiveness. We also proposed and discussed three perceptual operations on Contents Garden to improve the operativity of the SKG.

Keywords: contents management, information visualization, sustainable knowledge globe, SKG
Categories: H.3.7, H.5.1, H.5.2

1 Introduction

There has been an increase in the proliferation of intelligent media technologies for capturing and utilizing our daily activities. We can record our activities by using a movie camera, a voice recorder, or any other multimedia authoring tool; moreover, many studies have endeavored to study techniques to capture daily conversational situations by increasingly sophisticated processes [Nishida, 05] [Sumi, 04] [Minoh, 03]. In a repository of captured records, a sustainable memory system is indispensable for extending knowledge using previous knowledge. Here, sustainability implies the development of a knowledge repository that accelerates subsequent development.

The purpose of this paper is to build a sustainable memory system that can provide arbitrary memory space for humans. Our essential idea is to develop a content space in a virtual landscape. The spatial world generally serves as a good space to store a large number of objects. People can glance around objects if they are arranged spatially. Moreover, it is simpler for people to locate an object by using several spatial clues in terms of directions and distances such as left and right, high and low, and near and far. Therefore, we expect that the virtual landscape will be effective for managing large data content intuitively.

File management systems using spatial clues were discussed in [Ballay, 94][Card, 96][Robertson, 98]; however, these discussions focused only on a memory system. We, on the other hand, lay more emphasis on the spiral development of memory, which is generally observed in knowledge processes like a conversational knowledge process [Nishida, 05] and the SECI model [Nonaka, 95].

We propose the concept of an immersible globe to facilitate the development of the content space. This concept is similar to a garden of memory that comprises a global space and a conical space. Both these spaces provide a space for building a customizable intellectual world of a user. The global space provides a user an overview for the conceptual operations of the content. Meanwhile, the conical space provides an immersive field for the perceptual operations. The user can switch between the two spaces according to his/her requirements. All content on the global space can be projected onto the conical space, and vice versa. The acceleration of content development is achieved by repeating the overlooking and immersive processes.

The immersible globe concept was first implemented on a sustainable knowledge globe (SKG) [Kubota, 05]. Subsequently, we proposed a system called Contents Garden to expand the SKG into the immersive space. This paper describes the concept and the systems for the computational support of spatial content development and its temporal evolution.

2 Immersible Globe Concept for Sustainable Memory System

We will now examine the immersible globe concept in additional detail. When designing and exploring the space, we usually use two different styles—overlooking style and immersive style. Designing and exploring large buildings is a good example that illustrates our concept. A ground plan and an elevation are required to understand the structure of a building. In addition, a perspective is required to imagine the view of the completed building. We can subjectively browse an immersive landscape by using the perspective. In other words, in order to clearly understand the layout of a town, a person would not only require a map but would also need to walk through the town.

The immersible globe concept also adopts two different styles that provide a user both objective and subjective views of the memory space. The user can arrange contents anywhere in the space and investigate them from contrasting views. We implement this concept by using a global space and a conical space correlated by the azimuthal equidistant projection (Figure 1). We adopt a geographical metaphor to facilitate user spatial cognition. The azimuthal equidistant projection appears to be a good projection that will prevent a user lost in both spaces because it maintains both direction and distance.

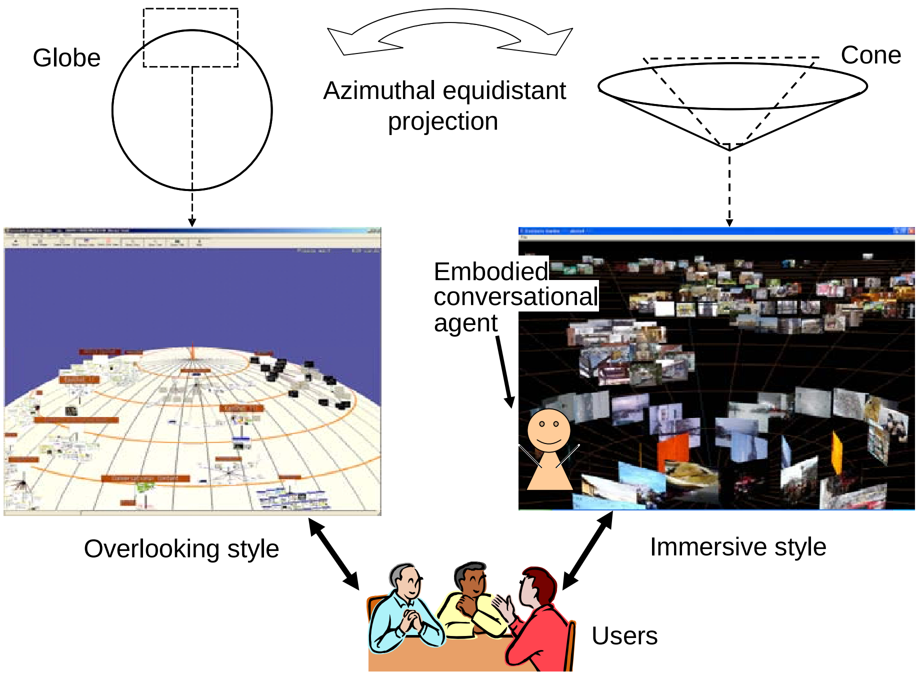

Figure 1: Immersible Globe Concept

The global space is an overlooking map like a terrestrial sphere. The user can browse entire contents in the objective (third person) view using conceptual interface actions such as typing on a keyboard and selecting a menu. Such actions are suitable for editing functions that require overview and precise revision. On the other hand, the conical space is the ground that is an immersive 3D world using perspective projection. The user can focus on specific contents in the subjective (first person) view. The immersive 3D world makes it easy to utilize the perceptual user interface and converse with an embodied conversational agent (ECA) situated in a specific content. It is expected that the ECA will entrain participants into the content in a conversational fashion.

These contrasts between the global space and the conical space are described in Table 1. Such an overlooking-immersive approach would also be supported by zooming paradigm [Bederson, 94] in the visualization domain and the SECI model [Nonaka, 95] in the knowledge management domain. In the SECI model, the transformation of tacit/explicit knowledge facilitates knowledge creation. Here, subjectivity and objectivity are one of the characteristics of tacit and explicit knowledge. Our approach differs from that of visualization and the SECI model in that we focus on building a long-term memory space in a virtual 3D environment. Our previous concept, the knowledge channel [Kubota, 04], facilitates knowledge evolution by using an editorial space and a conversational agent. The knowledge channel mainly focuses on the conversational agent. The immersible globe reinforces the knowledge channel by expanding the editorial space.

Shape / Attribute	Globe	Cone
Metaphor	Terrestrial sphere	Ground
Projection method	Parallel	Perspective
Distance from a user	Detached	Immersive
View	Objective	Subjective
Target	Whole	Focused
Interface	Conceptual	Perceptual
Interaction	Editorial	Conversational

Table 1: Contrasts between the global space and the conical space

3 Sustainable Knowledge Globe (SKG)

SKG is a sustainable memory system that primarily has an objective view. SKG enables a user to edit contents on a global surface by using geographical arrangement, topological connection, and contextual relation. It also provides an overview of large data content by means of a zooming interface [Kubota, 05].

3.1 Virtual landscape

SKG has a virtual landscape resembling a terrestrial globe that includes a sand-colored sphere with latitude and longitude lines, landmarks for the north and south poles, and an equator (see the overlooking style in Figure 1). Many kinds of space topologies are possible: finite plane, infinite plane, two-dimensional torus, and so on. In a finite plane, it might be difficult for a user to expand the content at the edges of the plane. The use of an infinite plane does not pose this problem; however, it is difficult for people to perceive infinite space. Similar, the two-dimensional torus has no edges; however, people might not be familiar with its topology. As a consequence, a spherical landscape was adopted in the SKG. A spherical surface is a finite space, but people can arrange content on a sphere more freely than on a finite plane because a sphere has no edges. Moreover, people will find a sphere to be a more familiar shape than the two-dimensional torus because it resembles a terrestrial globe. The shape of the SKG sphere resembles that of a terrestrial globe. Each content item is represented as a content card and placed on the global surface. A user can create content on any location on the surface of the globe and browse the contents by rotating and zooming into the globe. The rotation of the globe is restricted to along the latitudinal and longitudinal lines because the nonrestricted rotation of the globe can often confuse people about their location and distance.

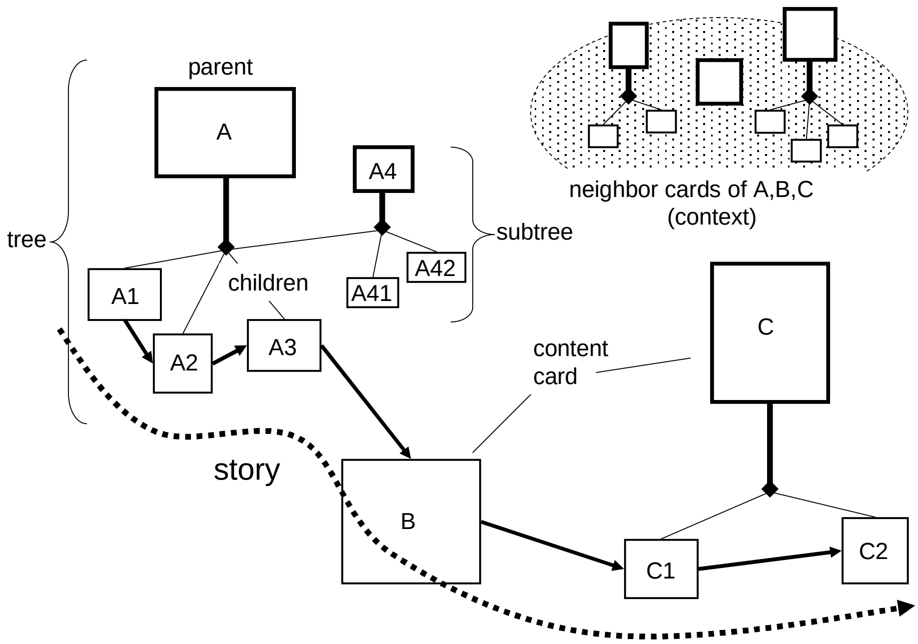

Figure 2: Model of the virtual landscape

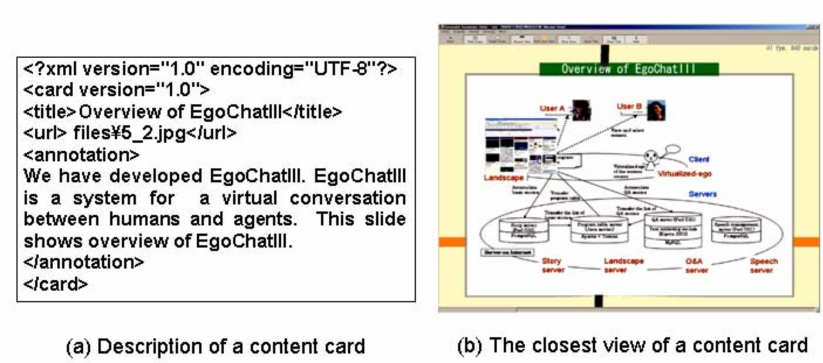

Figure 3: A sample content card

The model of the virtual landscape comprises content cards, their geographical arrangement, their topological connection, and their contextual relation (Figure 2). A content card consists of three parts: a URL of an embedded file, a card title, and a card annotation (Figure 3 (a)). On the global surface, the content card appears upright along with a thumbnail image (Figure 3 (b)). The geographical arrangement of the cards enables a user to judge the locations of the cards by using spatial clues. The topological connection between the cards represents a story structure of a conversation. A tree structure represents a card category. In Figure 2, A1, A2, and A3 are the children of the card A, and A4 represents a subcategory of card A. A story structure is the other topological structure that shows a story line linking the cards. Therefore, the sequence from A1 to C2 is a story. The tree structure is clear clue for the user to explain the hierarchical content, and the story structure is helpful to follow the story line of the presentation.

The contextual relation explains the context of a conversation to a user. The user can record the contexts and jump to any one of them at any time. A context consists of a latitude value, longitude value, and zooming value that determine the user's field of vision. Geographically neighboring cards are loosely related to each other. Such neighborhoods facilitate productive digression.

3.2 User study of SKG

We have conducted a study to determine SKG usage by individuals for personal objectives. This study focused on investigating the diversity of the card arrangement that SKG offers. Three of the authors (user (I), user (II), and user (III)) sustainably constructed their individual virtual landscapes on SKG in order to manage their contents. The contents were mainly research slides and movies, and also included photos, bookmarks, and memos. The content cards were created by using a built-in editor on SKG or converted from the contents on the user's PC. We discuss the virtual landscape created between August 9th, 2004 and January 28th, 2005. This was the period during which contents that could be quickly collected were imported and nearly arranged on the SKG.

The number of cards and trees created during this period is shown in Table 2. Over 95% of the cards were grouped into trees by the users. The number of cards in a tree had some outliers because the unarranged cards were grouped into rough and large trees. A tree included two or three subtrees. The medians of the number of cards in a subtree are 6 (user (I)), 3 (user (II)), and 6 (user (III)). The size of the subtrees appears to be reasonable because these numbers are near the so-called magical number 7.

	Number of trees	**Number of tree structured cards/all cards (percentage)**	**Average (median) number of cards in a tree**	**Average (median) depth of trees**	**Average (median) number of cards in a subtree**
User (I)	28	2554/2582 (98.9%)	91.2 (29)	2.6 (2)	27.4 (6)
User (II)	23	594/620 (95.8%)	25.8 (10)	3.0 (3)	5.9 (3)
User (III)	25	1194/1219 (97.9%)	47.8 (28)	2.3 (2)	14.5 (6)

Table 2: Number of trees and cards created

We observed highly personalized arrangements on the virtual landscapes. Examples of how the individual cards were arranged are shown in Figure 4. (a) User (I) selected a square arrangement style based on the premise that a square is a regular shape that can be used to easily explore his catalog of CDs and shoes. (b) User (II), on the other hand, chose a star arrangement style, where a parent card was at the center with its children spread out in all directions, based on the premise that this style was suitable for representing the parent-child relationships in his content.

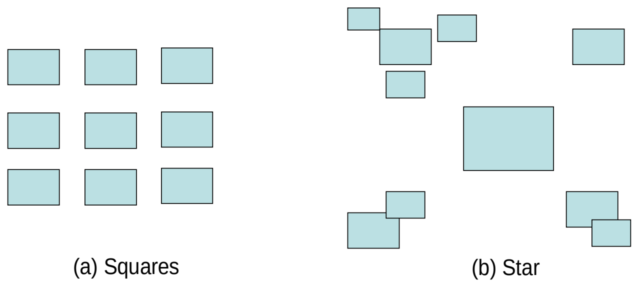

Figure 4: Examples of card arrangement styles

Examples of the story arrangement styles are shown in Figure 5. The story in (A) (horizontal turn style) courses horizontally from back left to front right, while the story in (B) (vertical turn style) courses vertically from front left to back right. In both these arrangement styles, the card queues are turned at the ends of the semantic sections 1 and 2. When a user follows a story from the front, (A) emphasizes the flow of the story from left to right, while (B) emphasizes the beginning of the semantic section of the story. (C) Waterfall, (D) spiral, and (E) clockwise are smooth arrangements without sharp curves. (C) is a variant of (A). (C) is smoother than (A) in terms of curvature; however, (C) often inverts the story direction. (D) is a space-saving compact spiral. (E) is a clockwise arrangement that depicts time flow by using a clock analogy.

Each user arbitrarily created individual arrangement styles and used them. The number of story arrangement styles that were adopted by users is shown in Tables 3, 4, and 5. In these tables, “Numbers of cards” implies the number of cards included in the stories. Users (I) and (II) arranged their contents mainly by using the horizontal turn style. User (III) arranged his contents mainly by using the spiral style and the counter-clockwise style. Therefore, each user had a different preferred style. User (II) used the line style and the zigzag style. The line style is a linear arrangement towards a certain direction. The zigzag style is formless zigzag arrangement. The horizontal and vertical turn styles in Table 5 imply that the arrangement was first in the horizontal turn style and then changed halfway into the vertical turn style.

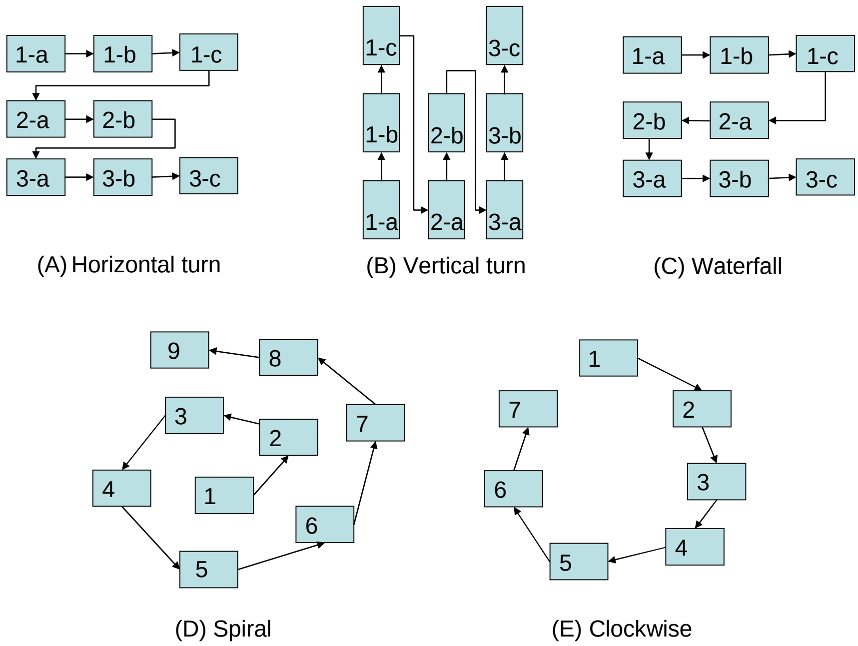

Figure 5: Examples of story arrangement styles

	H-turn*	Waterfall	Clockwise	Total
Number of stories	32 (65.3%)	10 (20.4%)	7 (14.3%)	49 (100%)
Number of cards	2143 (93.8%)	104 (4.6%)	37 (1.6%)	2284 (100%)

* H-turn is the abbreviation of "Horizontal turn."

Table 3: Story arrangement styles of user (I)

	H-turn*	**Line**	**V-turn****	**Zigzag**	**Total**
Number of stories	14 (73.7%)	3 (15.8%)	1 (5.2%)	1 (5.2%)	19 (100%)
Number of cards	113 (83.1%)	9 (6.6%)	7 (5.1%)	7 (5.1%)	136 (100%)

* H-turn is the abbreviation of "Horizontal turn."
** V-turn is the abbreviation of "Vertical turn."

Table 4: Story arrangement styles of user (II)

	Spiral	**C-clock wise** ***	**H-Turn** *	**V-turn** **	**Line**	**H-V Turn** ****	**Total**
Number of stories	21 (27.6%)	18 (23.7%)	14 (18.4%)	14 (18.4%)	8 (10.5%)	1 (1.3%)	76 (100%)
Number of cards	155 (13.6%)	87 (7.7%)	487 (42.9%)	341 (30.0%)	27 (2.4%)	39 (3.4%)	1136 (100%)

* H-turn is the abbreviation of "Horizontal turn."
** V-turn is the abbreviation of "Vertical turn."
*** C-clockwise is the abbreviation of "Counter clockwise."
**** H-V turn is the abbreviation of "Horizontal and vertical turn."

Table 5: Story arrangement styles of user (III)

A distorted map is another characteristic arrangement style selected by user (II). This style does not have a story structure, but involves a meaningful arrangement in which photos are located on a cognitively distorted map. An example of the map is shown in Figure 6. Photos of England (Castle Combe Village, Oxford City, London City, and Stonehenge) and Japan (Otaru City and Sapporo City) were arranged relatively according to the actual locations of the cities. However, the photos of England and Japan were placed too close in comparison to the actual locations of the countries .The photos of England were arranged near the photos of Japan because user (II) especially liked both photos.

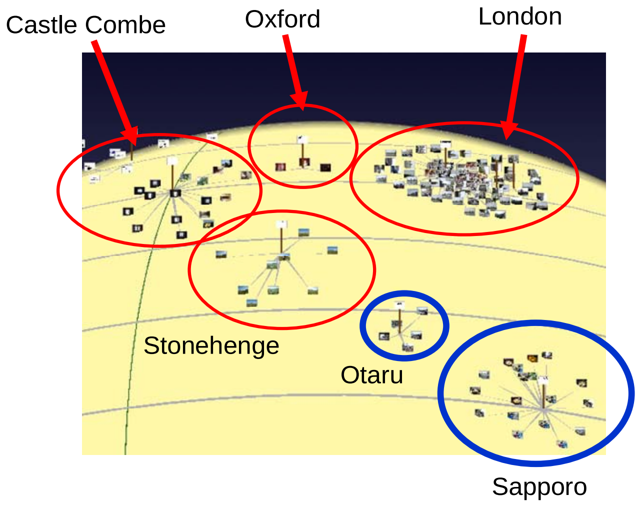

Figure 6: Example of a distorted map

The results of the user study revealed that the SKG provides general methods to arrange contents by using tree structures. In addition to using tree structures, most contents were also arranged according to various story arrangement styles. Such characteristic arrangements seem to help people remember the locations of their contents. It also seems that the SKG is a good platform for people to manifest the arbitrary structures that are stored in their brains. The virtual landscapes are subjective rather than objective; they reflect a kind of cognitive map rather than an ontological map. Arranging the landscape on the SKG is akin to arranging objects in a room that provides a personalized environment for managing a large number of objects.

4 Contents Garden

We have developed a novel system termed "Contents Garden" that expands the SKG into the immersive space (see the immersive style in Figure 1). A terrestrial sphere is generally projected onto a disc-shape area; however, we have adopted a cone-shaped region so that distant contents are not concealed by nearby contents. The inclination of the ground is 20°. The user can arrange contents anywhere within the cone. The user can also browse through the contents by moving and rotating the cone, zooming tha camera in/out, and changing the centered location using a mouse.

We propose three methods for perceptually operating the contents. The SKG is suitable for operating a strong connection like a tree structure; however, it is unsuitable for operating an ad hoc group of contents. The experiment described in section 3 reveals another possibility. The desirable ad hoc operations are listed below:

(1) making crowded contents sparse, and vice versa
(2) transforming broadly arranged contents into a narrow arrangement

(3) creating space in crowded contents to add new contents
(4) moving a group of contents by pushing and pulling roughly

We have carried out these operations by the following three operations: “distort,” “make space,” and “push.” The user can select an operation from the context menu and then indicate a target region by drawing a closed circle using a mouse.

Distort: This operation moves contents from one region to another (Figure 7 (a)). Each region is indicated by a mouse gesture. The contents in the source region are rearranged in the destination region while maintaining their relative vertical and horizontal positions.

Make space: This operation moves contents away from a region (Figure 7 (b)). This operation creates an empty area. The source region is indicated by a mouse gesture. The contents in the source border (a) and extended border (b) (which is three times the size of border (a)) are rearranged in the destination region (A), which is sandwiched between borders (a) and (b), while maintaining the direction and distance of the contents from the center of border (a).

Push: This operation creates a broad rake to push and pull the contents (Figure 7 (c)(d)). The size of the rake is indicated by a mouse gesture. The direction of the rake face can be rotated.

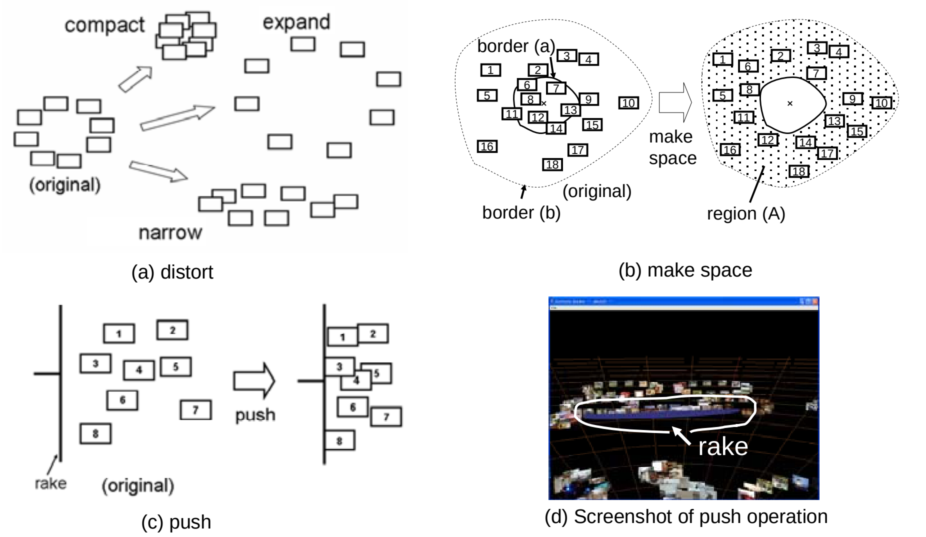

Figure 7: Three perceptual operations for positioning cards

These perceptual operations are currently under development. For the primary user study, one of the authors arranged 800 photos using these operations. The author took these photos during various events and tours. They were grouped into the PC folders. Initially, Contents Garden imported all the photos from the PC folder. The photos in a folder are automatically arranged in a circle in Contents Garden. As a result of the initial import, many circles were present on the conical space; however, trees and stories as internal data structures were absent. The aim of this user study was to investigate how the three operations worked to arrange unstructured contents. The user finished arranging his photos in two hours. The completed arrangements are shown in Figure 8. The distort operation was frequently used to move and scale the cards. Further, the distort operation appears to be more suitable for arranging rough groups of cards as compared to operations on the SKG because it does not initially require internally structured data. The initial circle shapes were more than satisfactory for the user and thus, the make space and push operations were not used. These operations are expected to be useful for temporary sweeping; however, they destroy the surrounding arrangements.

We plan to evaluate Contents Garden under more complex situations and improve its functionality by using perceptual devices like motion capturing systems.

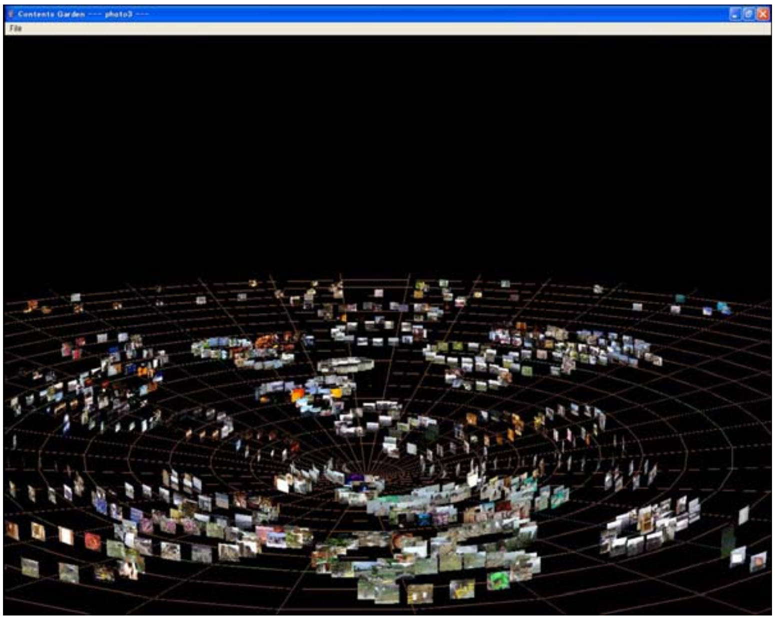

Figure 8: Screenshot of 800 contents on Contents Garden

5 Discussion

We developed SKG for constructing a memory space; further, we developed the Contents Garden for expanding the SKG into the immersive space. They are individual, data-compatible systems. We are now planning to combine them so that a user can build and explore contents while still being able to smoothly switch between the global and conical spaces. In comparison to related studies on gestural interfaces for organizing spatially arranged contents [Moran, 95] [Myantt, 99], Contents Garden focuses on the rearrangement and management of large data contents on the basis of the immersible globe concept. The SKG and Contents Garden have now been implemented on standard PC hardware. They are suitable for popular applications; however, an immersive environment with a perceptual user interface is more suitable to make the best use of the operations in the Content Garden. Thus far, our mouse gesture operations have been simple; however, they could be extended by using a motion capturing system or another tracking system in the immersive environment.

6 Conclusion

We have introduced the concept and the systems for the computational support of spatial content building and its temporal evolution. We developed the SKG for constructing a memory space, and the Contents Garden for expanding the SKG into the immersive space. We have carried out the user study of the SKG to evaluate its effectiveness. The result of this study indicates that the SKG is a good platform for people to externalize and visualize arbitrary structures. We have also proposed three perceptual operations on Contents Garden to improve the functionality of SKG, and discussed the advantages of the distort operation.

References

[Ballay, 94] Ballay J.M.: Designing Workscape: an Inter-disciplinary Experience, SIGCHI Conference on Human Factors in Computing Systems: Celebrating Interdependence, pp. 10–15, 1994.

[Bederson, 94] Bederson B.B., Hollan J.D.: Pad++: A Zooming Graphical Interface for Exploring Alternate Interface Physics, User Interface and Software Technology (UIST '94), pp.17–26, 1994.

[Card, 96] Card S.K., Robertson G.G., York W.: The WebBook and the Web Forager: an Information Workspace for the World Wide Web, SIGCHI Conference on Human Factors in Computing Systems: Common Ground, pp. 111–117, 1996.

[Kubota, 04] Kubota H., Hur J., Nishida T.: Agent-based Content Management System. The 3rd Workshop on Social Intelligence Design (SID 2004), pp. 77–84, 2004.

[Kubota, 05] Kubota H., Sumi Y., Nishida T.: Sustainable Knowledge Globe: A System for Supporting Content-oriented Conversation, in Proceedings of AISB 2005 Symposium Conversational Informatics for Supporting Social Intelligence & Interaction, pp. 80–86, 2005.

[Minoh, 03] Minoh M., Nishiguchi S.: Environmental Media - In the Case of Lecture Archiving System, International Conference of Knowledge-based Intelligent Information & Engineering Systems (KES2003), Vol. II, pp. 1070–1076, 2003.

[Moran, 95] Moran T.P., Chiu P., van Melle W., and Gordon Kurtenbach: Implicit Structure for Pen-based Systems within a Freeform Interaction Paradigm, Proceedings of CHI '95, pp. 487–494, 1995.

[Mynatt, 99] Mynatt E.D., Igarashi T., Edwards W.K., and Anthony LaMarca: "Flatland: New Dimensions in Office Whiteboards," ACM SIGCHI Conference on Human Factors in Computing Systems, ACM CHI '99, Pittsburgh, May 15–20, pp. 346–353, 1999.

[Nishida, 05] Nishida T.: Conversation Quantization for Conversational Knowledge Process, Special Invited Talk, S. Bhalla (Ed.): DNIS 2005, LNCS 3433, Springer, pp. 15–33, 2005.

[Nonaka, 95] Nonaka I., Takeuchi H.: The Knowledge-Creating Company, New York: Oxford University Press, 1995.

[Robertson, 98] Robertson G.G., Czerwinski M., Larson K., Robbins D.C., Thiel D., Dantzich M.V.: Data mountain: Using Spatial Memory for Document Management, the 11th Annual ACM Symposium on User Interface Software and Technology (UIST ’98), pp. 153–162, 1998.

[Sumi, 04] Sumi Y., Mase K., Christof C., Iwasawa S., Ito S., Takahashi M., Kumagai K., Otaka Y., Tsuchikawa M., Katagiri Y., Nishida T.: Collage of Video and Sound for Raising the Awareness of Situated Conversations, International Workshop on Intelligent Media Technology for Communicative Intelligence (IMTCI 2004), pp.167–172, Warsaw, September, 2004.