What Is the Space For?
The Role of Space in Authoring Hypertext Representations

[1]Yasuhiro Yamamoto [1]Kumiyo Nakakoji
[2]Yoshiyuki Nishinaka [2]Mitsuhiro Asada [3]Ryouichi Matsuda

[1]RCAST, University of Tokyo
4-6-1 Komaba, Meguro
Tokyo, 153-8904, Japan
+81-3-5452-5286

[2]SRA-KTL Inc.,
3-12 Yotsuya, Shinjuku
Tokyo, 160-0004, Japan
+81-3-3357-9011

[3]SRA Inc.
2-32-8 MinamiIkebukuro, Toshima
Tokyo, 171-8513, Japan
+81-3-5979-2111

{yxy, kumiyo}@kid.rcast.u-tokyo.ac.jp {nisinaka, m-asada, r-matuda}@sra.co.jp

ABSTRACT
This paper describes our approach of using spatial hypertext as a means separated from an end representation for hypertext authoring. By taking advantage of the power of rich interpretation and constant grounding capabilities of a spatial hypertext representation, ART001, ART006, and ART014 use spatial hypertext as a means for authoring linear, hierarchical, and network structures, respectively. The role of the space of the tools includes controlling a structure and annotating a structure. The three prototyped tools have been developed to demonstrate what visual interaction design concerns need to be taken into account to integrate a spatial hypertext as a means with another structural representation as an end. The paper concludes with a discussion of what it means to separate representations as a means from those as an end in hypertext authoring.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Graphical User Interfaces, Interaction styles.*

General Terms
Design, Human Factors

Keywords
Spatial hypertext, separation of means from end, creative knowledge work, amplifying representational talkback, interaction design

1. INTRODUCTION
This paper describes our approach of using spatial hypertext *as a means* for hypertext authoring. Graphical hypertext authoring tools have inherently used spatial representations as a part of an *end* product in hypertext writing. Spatial hypertext tools [20] have extended this use to include spatial representations not only as an *end* but also as a *means* for hypertext authoring. Our approach is to use spatial representations solely as a means for authoring; an end representation is provided separately.

HT'05, September 6–9, 2005, Salzburg, Austria.

Spatial representations have conventionally been used for hypertext authoring from the early years. Classical graphical hypertext editors, such as WE [33] and gIBIS [10], used spatial layouts of nodes and links. Such spatial representations constituted a part of an end product of hypertext editing.

Researchers in spatial hypertext had come to recognize the expressive power of spatial representations as a means for hypertext authoring [21]. Spatial hypertext has been used for interpreting a nebula of information pieces [21] and experiencing emerging relationships among elements [27]. In the former approach, spatial hypertext representations are gradually transformed into a more formal structure. In the latter approach, spatial hypertext representations are designed and provided for readers to experience emerging structures, giving them a rich space of interpretations [4] (such as conjunctive links [27]).

In contrast to those approaches, we have demonstrated a third approach in which spatial hypertext representation is used as a means to produce a linear text as an end representation [36]. In ART001 (see Figure 3 for an example), text elements placed in the space are appended vertically from top to bottom and displayed in the linear document view. Changing the vertical arrangement of elements in the space is dynamically reflected in the sequential order of text elements in the linear document view. Horizontal relationships among the elements, distances between the elements, and sizes and shapes of elements in the space remain "free" for users to interact with without affecting the linear representation [37].

This paper further extends this notion of using spatial hypertext as a means separated from an end representation for hypertext authoring. In addition to ART001, we have developed ART006 for hierarchical structure authoring, and ART014 for network structure authoring, both of which use spatial hypertext representations as a means. The three prototyped tools have been developed to demonstrate what visual interaction design concerns need to be taken into account to integrate a spatial hypertext as a means with another structural representation as an end.

In this paper, we first articulate the power of spatial hypertext representations for creative knowledge work from the hermeneutic design perspective, and then discuss how existing spatial

hypertext systems use spatial representations as a means and an end, motivating our approach of using the space solely as a means. Section 3 presents the tools, ART001, ART006, and ART014, that use spatial hypertext as a means for authoring linear, hierarchical, and network structures, respectively. Section 4 first describes the role of the space in the three tools, which includes controlling a structure and annotating a structure, and discusses interaction design principles for using spatial hypertext as a means and integrating it with an end structure to be produced. The paper concludes with a discussion of what it means to separate representations as a means from those as an end in hypertext authoring.

2. SPACE: AS A *MEANS* OR AS AN *END*

Much ethnographical and empirical evidence has been reported on the need for spatial hypertext [11][20], but the power of spatial representation can never be overstated. This section starts with a theoretical account of the role of spatial hypertext representations from the hermeneutic design perspective. It then gives an overview of existing spatial hypertext tools and their mechanisms in terms of serving as *means* to produce *end* representations.

2.1 Spatial Representations for Creative Knowledge Work

Hypertext authoring is a type of knowledge work that requires psychological creativity [6]. A hypertext author iterates a cycle of collecting, interpreting, modifying, and generating information pieces to make sense out of them, and then expressing the meaning using hypertext structures. It is an ill-defined argumentative design task for which neither well-formulated goals nor strategies exist [25][32].

By viewing creative knowledge work as a design task, we have been able to identify four issues and challenges in designing tools to support this type of work [38]. First, available means of externalizations influence designers in deciding which courses of action to take. Different representations demand different types of cognitive load to remember and process information [39][40]. People choose problem-solving strategies depending on what externalization methods are available to them either consciously or unconsciously [30].

Second, designers generate and interact not only with a partial representation of the final artifact but also various external representations. By hand-drawing sketches, for instance, architects doodle not only floorplans but also constraints and meta-comments about partially expressed potential solutions [12].

Third, designers produce externalizations not only to express a solution but also to interpret the situation. Designers are engaged in a "drawing-seeing-drawing" cycle [28], having a type of conversation with the material. A designer produces an externalization, and then "the situation talks back to the designer" [28].

Fourth, a design task proceeds as a hermeneutic circle in which designers proceed with projected meanings of representations and gradually revise and confirm those meanings [34]. For representations to drive the cycle going forward, the representations must be not only easily interpreted in a wide variety of ways but also easily remembered with their projected meanings.

Hand-drawn sketches have been regarded as powerful representations for designers engaged in visual thinking [1][17]. A number of studies report that many professional designers prefer paper-and-pencil hand-drawn sketching to computational drawing tools because hand-drawn sketching is much less obstructive allowing them to think better [18].

By examining how and why sketching works well for the early stages of design tasks, we have identified the following three interaction design principles [38]: (1) interpretation-rich representations, (2) representations with constant grounding, and (3) interaction methods for hands-on generation and manipulation of the representations.

We argue that spatial hypertext representations follow these three principles, serving like sketch representations [14] for hypertext authoring. As argued by spatial hypertext researchers, spatial layouts are rich in interpretations [21][27]. A vague relationship between two elements can be represented in an infinite number of ways, thus coping with the tyranny of the link problem [15]. A vague relationship in a spatial representation can, in return, be interpreted in a number of ways, providing a space for rich interpretation and emerging structures [13].

Spatial representations are vague, but they also provide constant grounding with meanings. In the same way as sketched objects with thicker more straight lines seem more committed than those with thinner, limper lines, elements placed in a straight line seem more related to each other than those just placed close to each other. With this aspect of having the capability of providing constant grounding, spatial hypertext representations can afford both formal and informal representations.

In addition, through graphical user interfaces (GUIs), people can directly manipulate objects in a space [37]. This makes it possible to have hands-on generation and manipulation of the representations, lessening the cognitive load of a user in interacting with the representations, and enabling informal interactions [21].

2.2 Making the Space Serve as a Means

As mentioned in Section 1, hypertext authoring tools have traditionally used spatial representations in their graphical editors. The expressive power of spatial representations for human cognitive processes, however, had not been seriously taken into account until the introduction of the notion of spatial hypertext: "*Thus, spatial hypertext is not only a means of presenting readers and authors with visualizations of existing structures; it is also a way to take advantage of human perceptual abilities in hypertext navigation, and to provide users with a fairly intuitive medium through which they may express new structures and manipulate existing structures*" [20; p. 89].

Spatial hypertext tools incorporate the above expressive power of spatial representations within hypertext structures. Spatial hypertext narratives use spatial layouts of elements both as a means to produce a hypertext structure and as an end representation to be produced. By interacting with the spatial hypertext representation, readers experience emerging structures in the spatial layout among elements, allowing readers also to partially have the experience of writers [26].

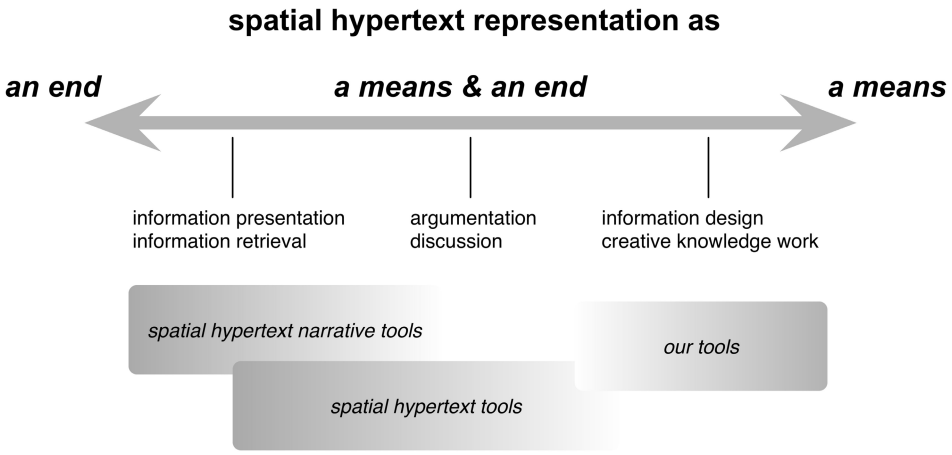

Figure 1: A Spectrum of the Role of Spatial Hypertext Representations

Spatial hypertext authoring tools, such as VIKI [21] and VKB [29], allow users to repeat a cycle of interpreting a nebula of information pieces and externalizing a partial understanding of them by using spatial representations. By repeating the process, spatial hypertext representations are gradually transformed into more formal structures.

Mechanisms have been proposed and developed to support users in interacting with the spatial representation while integrating the means to the end:

- Nested containers allow users to interact with multiple layers of spatial representations. A space containing elements could become an element in another space, allowing users to structure multiple spaces.
- Visual parsers of VIKI and VKB identify possible relationships noted by spatial arrangement, visual properties of objects, collection, and composition. The parsed results are not imposed on the representations but are suggested for users to consider.
- Adornments (as in Tinderbox [35]) provide a way to visually annotate the space without affecting elements and relationships among the elements represented by using spatial layouts. Adornments serve as meta-comments by providing contexts for interpreting a part of constructed representations.
- Explicit links and labels might be added to spatial representations, for instance, with Compendium [9]. Although using explicit links may not conform to the rigid definition of spatial hypertext, such a tool uses spatial representation as a means to construct a hypertext structure, and the emerging spatial layout constitutes a part of the produced hypertext representation as an end.

2.3 Our Approach: Separating the Means from the End

Figure 1 illustrates how the view of the treatment of spatial representations has changed over the years. In the early years, hypertext authoring tools used spatial representations only as end representations where linked nodes were spatially laid out. Those tools were mostly for organizing and finding information.

Spatial hypertext tools since then have started to use spatial representations not only as an end but also as a primary means for producing an end product. Those tools are for interpretation and argumentation of information.

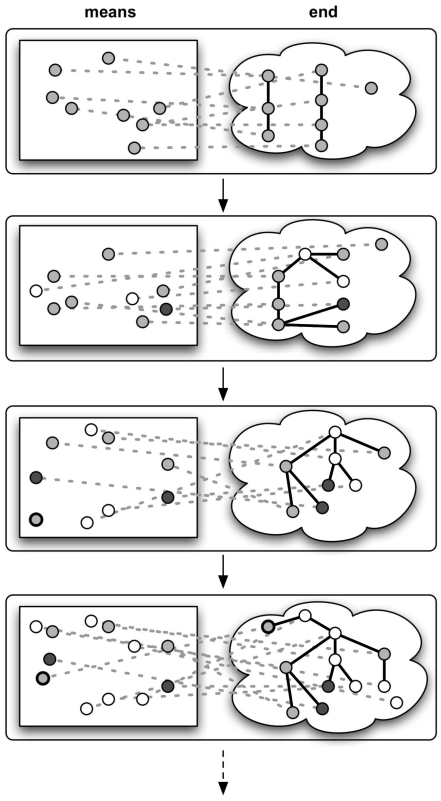

Figure 2: Spatial Hypertext Representations as a Means

Our approach is to extend this direction to use the spatial representation only as a means and to have a separate end representation. By "*means*," we do not refer to media or intermediate representations that are transformed into final artifacts. To the contrary, we refer to representations that serve as instruments or as annotations for the end representation to be produced.

By having a separate end representation, spatial hypertext representations in such an approach would be more freely used while the expressive power of spatial representation would be fully utilized by authors engaged in complex information design tasks. In this regard, we think our approach will be useful for tools for creative knowledge work.

Figure 2 shows what we mean by having a spatial hypertext as a *means* and a separate *end* representation in hypertext authoring.

VITE [16] is one of a few examples that use spatial hypertext as a means to design information. When associated a priori by a user, changing spatial layouts and visual properties of elements dynamically results in modifying inherent data values of each element. Even though the end product of VITE is not directly a structuring task, our goal is to use spatial hypertexts as a means to construct an end representation, whether the end representation is linear, hierarchical, or networked.

The next section shows the three tools we have developed that integrate those representations.

3. CASE STUDIES: THREE TOOLS

This section presents three tools that illustrate our claims: ART001 for linear text authoring, ART006 for hierarchical text authoring, and ART014 for network information authoring[1].

3.1 ART001: Space for the Linear Structure

ART001 is a tool for early stages of writing a linear document, which is described in detail elsewhere [22][36]. A user produces a text chunk as an element in ElementEditor and places it in a space called ElementSpace. DocumentViewer appends the contents of all the elements positioned in ElementSpace from top to bottom. Thus, when a user drags an element in ElementSpace, and thus changes the vertical relationships in terms of other elements, the corresponding text in DocumentViewer is updated. A user may change the size and the shape of an element in ElementSpace, but such a change would not affect the content of the document displayed in DocumentViewer; nor the horizontal relationships among elements in ElementSpace.

[1] The names of the systems start with "ART" because they are developed by applying the ART (Amplifying Representational Talkback) interaction design principle [23]. A lineup of the uses of other ART tools includes: for image annotation (ART002), for exploratory video analysis (ART003), for movie editing (ART004), for hand-drawing (ART005), for presentation making (ART008), for Web site construction (ART009), for hand-drawing and text editing (ART010), for page layout (ART011), for Web exploration (ART012), and for hand-drawn animation authoring (ART013).

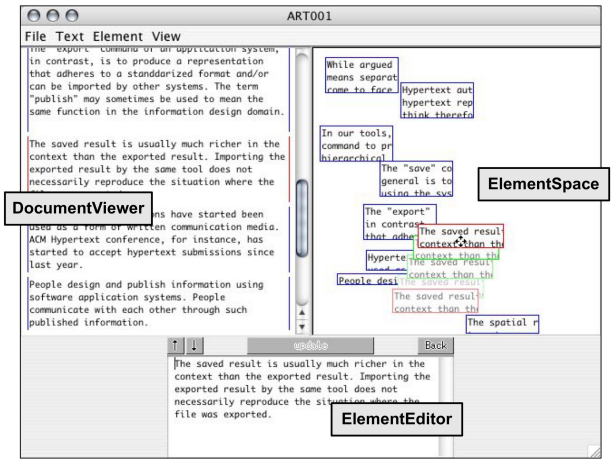

Figure 3: ART001
A tool for linear text authoring. See [22] and [36] for more details.

Figure 3 and Figure 6 illustrate how the space is used to produce a linear structure in ART001. The vertical relationship is mapped to the linear structure among elements.

3.2 ART006: Space for the Hierarchical Structure

ART006 is a tool for writing a document in a top-down manner by using a hierarchy editor to structure text elements. A document is constructed as a tree structure consisting of elements. Each element consists of a leading text chunk with zero or more sub-elements.

As shown in Figure 4, the tool consists of ElementSpace, DocumentViewer, ElementEditor, HierarchyColumn, and NomadList. A user focuses on an element by clicking on it in either ElementSpace, DocumentViewer, or HierarchyColumn. A focused element is always shown with a dark color in the center column of HierarchyColumn. Its parent, sibling, and children elements are also visually emphasized (with darker backgrounds and border lines) in the same three spaces. DocumentViewer shows appended contents of the elements in the order specified by the hierarchy (depth first from left to right).

A new element can be added by clicking on one of the plus-shaped icons displayed in HierarchyColumn, which refers to the point in the hierarchy where the newly added element is inserted. The user then edits the title and the content of the element in ElementEditor. The position of the focused element in the hierarchy can be changed by using the topward and downward arrows in HierarchyColumn.

In addition to elements that constitute document hierarchy, a user can create a nomad element by clicking on an empty space in ElementEditor. Nomad elements, each of which also consists of a title and content, are collected in NomadList, and displayed with dashed boarder lines in ElementSpace. The text contents of the nomad elements are appended to the end of the DocumentViewer. Each nomad can be inserted into the hierarchy by using the "move to hierarchy" command in the menu as the oldest child of the currently focused element in the hierarchy. Each element in the

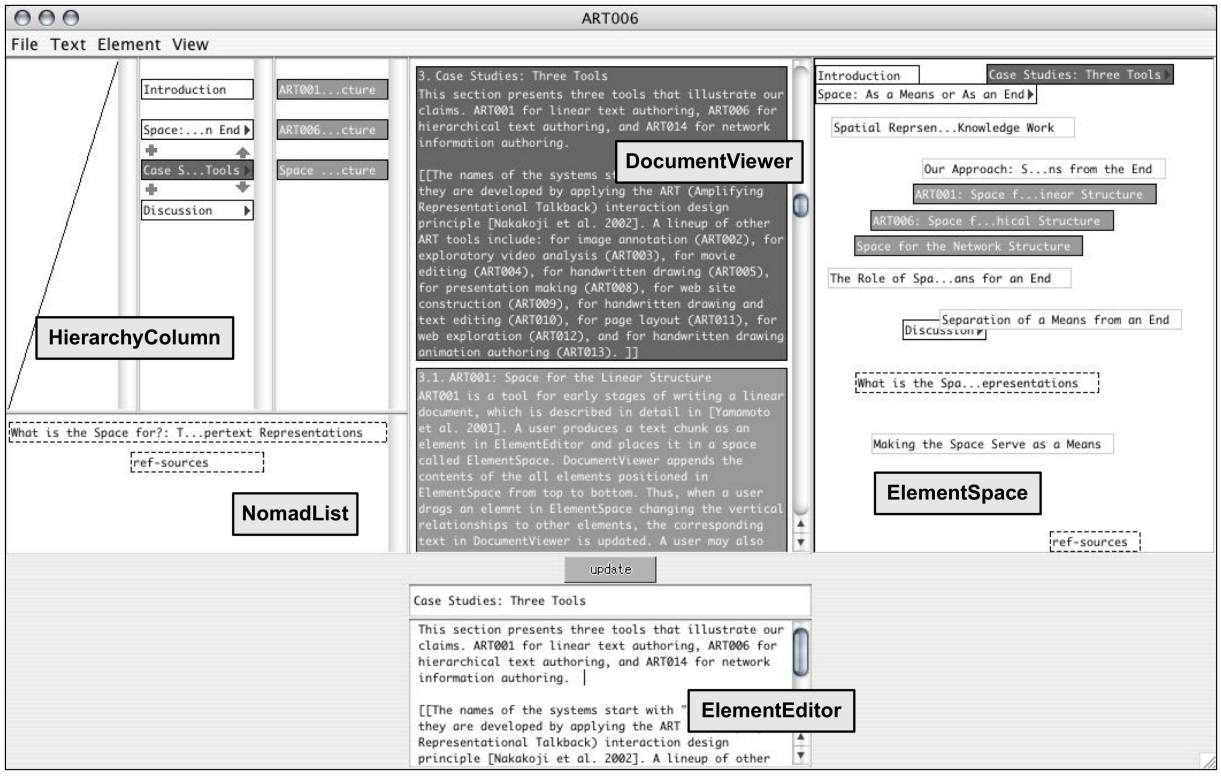

Figure 4: ART006
A tool for text authoring through hierarchical structuring.

hierarchy can also be converted into a nomad element if the element has no children.

Different from ART001, ART006 currently does not take into account the spatial arrangements of elements in ElementSpace except for the order of nomad elements in NomadList (see Figure 4).

3.3 ART014: Space for the Network Structure

ART014, which is described in detail elsewhere [23], is a tool for authoring a network of information using spatial hypertext. Each node consists of a title, text content, and a list of inbound and outbound links to other elements. By using ART014, a user authors a bidirectional network of textual elements.

ART014 (Figure 5) consists of ElementSpace and StructureColumn. StructureColumn consists of ElementEditor, InboundLinkList, and OutboundLinkList. A user can specify a title and content of an element in ElementEditor, and associate with inbound/outbound links by using In/OutboundLinkList, in which the upper pane lists elements that have in/outbound links to the element, and the lower pane lists the rest of the elements.

A user can focus on an element by clicking on it in ElementSpace. All the related elements, which have in/outbound links to the focused element, are visually emphasized. Lines will follow when the user moves the element in the space.

Another way to focus on an element is to select it in In/OutboundLinkList. This allows a user to traverse each link in the networked structure.

Currently, ART014 supports what we call sculptural and calligraphic hypertext authoring, in which newly created nodes are linked to all the other nodes (sculptural mode) or to no nodes (calligraphic mode) [5]. Whether these options affect the user's cognitive process in authoring is an interesting research question, but it is not the focus of this paper.

Currently, the spatial arrangements of elements in ElementSpace of ART014 are not reflected in any way (see Figure 6).

4. Discussion

Figure 6 summarizes how the three tools use the spatial hypertext representation as a means and integrate it with the end structures to be produced. By designing, developing, and using the three tools as case studies to examine our approach, we have identified the roles of space in this framework as well as a set of interaction design principles to build tools for such a framework. By having different representations for a means and an end for a hypertext authoring tool, we realize how obscure the boundary between the means and end has been in hypertext authoring.

4.1 The Role of Space as a Means for an End

Because they have the expressive and flexible representational power discussed in Section 2, spatial hypertext representations have been well understood as supportive representations as a means in hypertext authoring. In this section, we focus our discussion on the role of the space that has been recognized by requiring a separate end representation to be produced.

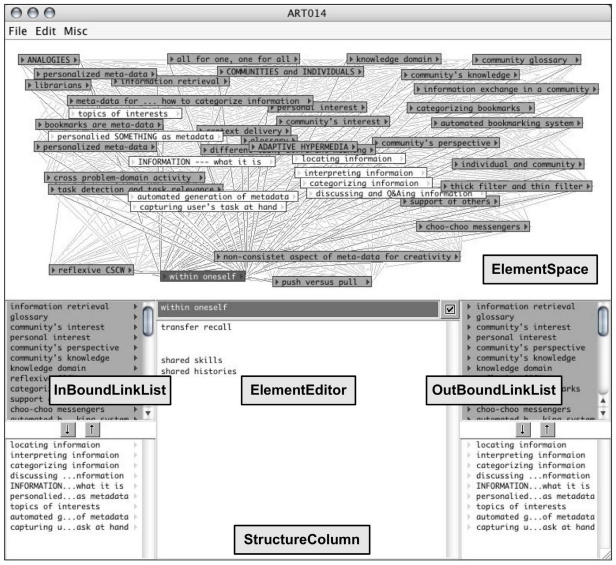

Figure 5: ART014
A tool for network structure authoring. See [23] for more details.

The primary roles of the space of the three prototype tools discussed here include: (1) controlling a structure and (2) annotating a structure.

(1) *Controlling a structure*

In ART001, moving elements in ElementSpace results in updating the sequential order of corresponding elements in DocumentViewer. In ART006, moving nomad elements in ElementSpace also results in changing the vertical position of the elements in NomadList. Although ART014 currently does not take into account any interactions with elements in ElementSpace to be reflected in the structure to be made, we plan to extend the system to use the vertical order of elements in ElementSpace for the order of elements listed in the In/OutboundLinkList panes in StructureColumn. This change is in response to users who had reported difficulty in finding elements in the In/OutboundLinkList panes during informal user observation sessions.

In these situations, a spatial hypertext representation can be viewed as an *interaction instrument* to control a structure to be authored. *Instrumental interaction* [2] is the notion that extends the principles of direct manipulation [31]. An interaction instrument is "*a mediator between the user and objects of interest: the user acts on the instrument, which in turn acts on the object,"* which is similar to how people interact with physical objects in everyday life by using tools [3]. A user of ART001, for instance, moves elements in ElementSpace in ART001 to change the structure of the document to be constructed (displayed in DocumentViewer); elements in DocumentViewer, in contrast, cannot be changed directly in DocumentViewer. Thus, elements in the space in this case are instruments for manipulating elements in the document structure.

(2) *Annotating a structure*

Even though spatial layouts in ART006 do not have any effect on the hierarchical structure constructed in HierarchyColumn, we have observed users using the space to represent meta-comments about the structure. For instance, one user placed elements toward the right, commenting that these elements would need more attention later. ART006 allows a user to create nomad elements, which do not constitute a structure being produced, but may become potentially useful later in the authoring task. Nomad elements have been found quite useful by users of ART006; we have frequently observed users spatially arranging a nomad element in terms of related elements in ElementSpace.

Annotation has been found to be quite useful in serving as a design rationale for understanding a designed artifact [7]. The spatial representation used as a means would serve as a powerful non-symbolic design rationale representation if stored together with a produced structure. This might especially be true for collaborative authoring settings [8].

Annotation has also been regarded as a fundamental activity in active reading [19]. Although we have investigated using a spatial hypertext representation only as a means for hypertext authoring, it might also be useful to have such a separate means for hypertext reading.

4.2 Interaction Design Principles

To serve as a good interaction instrument that requires minimum cognitive overhead in controlling a structure, and to serve as effective meta-comments for annotating a structure, spatial hypertext as a means needs to be carefully designed in terms of visual representation and interaction.

First, elements in ElementSpace must be easily identified with the corresponding elements in a structure to be produced. In addition, how operations with the space result in changes in the structure must be consistent and intuitive. To achieve these goals, we have designed these three tools so that a part of the structure currently produced is overlaid into the space.

For instance, in ART001, an element selected in DocumentViewer is visually emphasized in ElementSpace and vice versa. In ART006, the focused element together with its parent, sibling, and children elements are visually emphasized in ElementSpace with darker backgrounds and borderline colors. Similarly, in ART014, the focused element is emphasized in ElementSpace, simultaneously emphasizing elements having inbound links and outbound links by changing their background colors. Clicking on one of the elements in In/OutboundLinkList will emphasize the link in ElementSpace.

Spatial representations always need to cope with a screen estate problem. Whether one should have the entire space visible all the time or allow a user to focus in a particular part with a scrolling mechanism is not a simple question to resolve and must be determined by considering trade-offs. Because we view hypertext authoring as a design task following a hermeneutic circle, we view the whole-parts relationships to be most essential. In this regard, we use the space to represent the whole, and therefore take the first approach, having the entire space constantly visible for a user. The spaces in the three tools are implemented with the dragging-by-zooming-out mechanism; when the user drags out an element toward an edge of the space, it will dynamically zoom out, maintaining the relative positions and sizes of all the elements in the space.

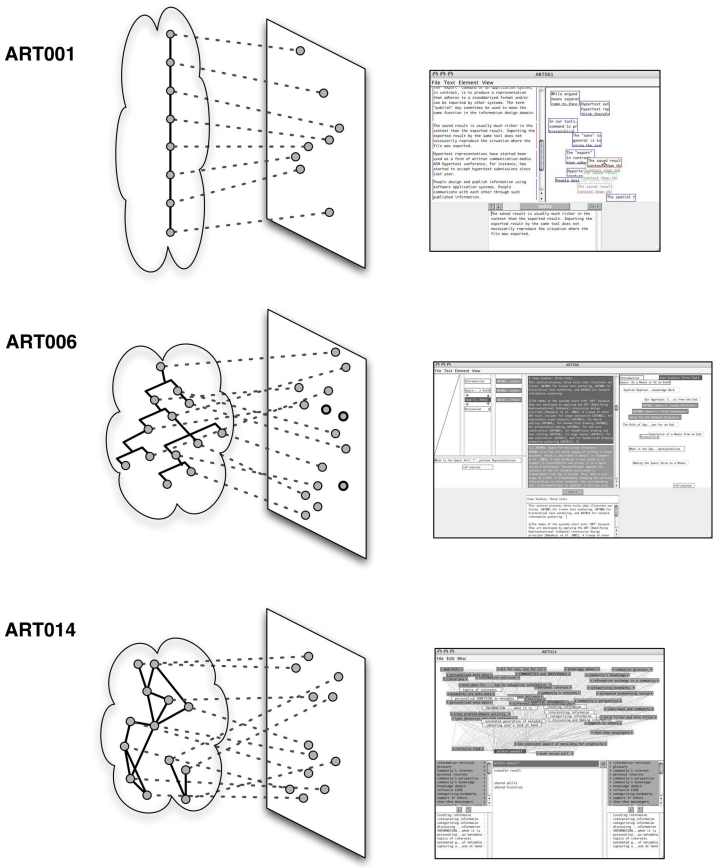

Figure 6: Comparison of the Three Tools
The three tools use spatial hypertext as a means for authoring linear, hierarchical, and network structures.

4.3 Separation of a Means from an End

While arguing for having representations as a means separated from those as an end, we have come to face an interesting question of what really is the end product using a hypertext authoring tool and what it means for the tool to have a *means* for producing an end product.

Hypertext authoring tools are used to produce hypertext representations. We may casually think, therefore, that "saving" a file by using such a tool will result in a required hypertext representation.

In our tools, however, it is the "export" command that produces a final hypertext (linear, hierarchical, or networked) representation. The "save" command stores the state of the production, containing both the currently constructed hypertext representation and the current spatial hypertext representation, which is a means to control and annotate the representation to be produced.

The "save" command of an application system in general is used to store the current work situation using the system so that the user could regenerate the same situation in the future. The purpose of the saved result (file) often is for the user to continue working on it at a later time. In contrast, the "export" command of an application system produces a representation that adheres to a standardized format and/or can be imported by other systems. The term "publish" may sometimes be used to mean the same function in the information design domain.

The saved result is usually much richer in context than the exported result. Importing the exported result by the same tool does not necessarily reproduce the situation of the time when the file was exported.

Hypertext representation has started to be used as a form of written communication media. Since last year, the ACM Hypertext Conference, for instance, has accepted hypertext submissions. There have been discussions on the format for such submissions.

A question that needs to be asked is whether such written communications media should be an exported result or a saved result in terms of application systems that are used to author such information. An exported result would not be accompanied by representations used as a means to produce an end representation. Independence of the authored tool might result in losing richer context for the communication media.

The rising popularity of blogging and the increasing awareness of the need for scholarly hypertext both indicate that the boundary

between a means and an end is expected to become even more obscure. Designing tools for those domains by introducing separate representations as a means from those as an end would be an interesting research challenge, as well as helping us to better understand what the nature of hypertext authoring is.

5. ACKNOWLEDGMENTS

This research is partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research (A), 16200008, 2004-2007.

6. REFERENCES

[1] Arnheim, R., Visual Thinking, University of California Press, Berkeley, 1969.

[2] Beaudouin-Lafon, M. Instrumental Interaction: An Interaction Model for Designing Post-WIMP User Interfaces, Proceedings of Human Factors in Computing Systems (CHI2000), ACM Press, New York, pp. 446-453, 2000.

[3] Beaudouin-Lafon, M., Designing Interaction, not Interfaces, Proceedings of the Working Conference on Advanced Visual Interfaces, May 25-28, Gallipoli, Italy, 2004.

[4] Bernstein, M., Joyce, M., Levine, D., Contours of Constructive Hypertexts, Proceedings of Hypertext'92, ACM Press, New York, pp. 161-170, 1992.

[5] Bernstein, M., Millard, D., Weal, M.J., On Writing Sculptural Hypertext, Proceedings of Hypertext 2002, ACM Press, College Park, MD, pp. 65-66, 2002.

[6] Boden, M.A., The Creative Mind: Myths and Mechanisms. Weidenfeld and Nicolson: London, 1990.

[7] Buckingham Shum, S.J., Hammond, N., Argumentation-based Design Rationale: What Use at What Cost? Int. J. Human-Computer Studies, vol. 40, pp. 603-652, 1994.

[8] Buckingham Shum, S.J., Workshop Report: Computer-Supported Collaborative Argumentation for Learning Communities, ACM SIGWEB Newsletter, Vol. 9, No.1, pp. 27-30, February, 2000.

[9] Compendium, http://www.compendiuminstitute.org/

[10] Conklin, J. Begeman, M., gIBIS: A Hypertext Tool for Exploratory Policy Discussion, ACM Transactions on Office Information Systems, Vol 6, No. 4, pp. 303-331, 1988.

[11] Czerwinski, M., van Dantzich, M., Robertson, G.G., Hoffman, H., The Contribution of Thumbnail Image, Mouse-over Text and Spatial Location Memory to Web Page Retrieval in 3D, Proceedings of Interact'99, A. Sasse & C. Johnson (Eds), Edinburgh, Scotland, IOS Press, pp. 163-170, 1999.

[12] Do, E.Y.L, Gross, M.D., Thinking with Diagrams in Architectural Design, Artificial Intelligence Review. A. Blackwell, Academic Publishers, Dordrecht, The Netherlands, pp. 135-149, 2001.

[13] Gaver, B., Beaver, J., Benford, S., Ambiguity as a Resource for Design, Proceedings of Human Factors in Computing Systems (CHI2003), ACM Press, Ft. Lauderdale, FL, pp. 233-240, 2003.

[14] Gross, M. D., Do, E.Y.L., Ambiguous Intentions: A Paper-like Interface for Creative Design, Proceedings of Symposium on User Interface Software and Technology (UIST '96), ACM, pp. 183-192, 1996.

[15] Halasz, F.G., Seven Issues Revisited, Keynote Address at the Third ACM Conference on Hypertext'91, San Antonio, TX, 1991.

[16] Hsieh, H., Shipman, F.M., Manipulating Structured Information in a Visual Workspace, Proceedings of the ACM 2002 User Interface Software and Technology, 2002.

[17] Landay, J.A., Myers, B.A., Sketching Interfaces: Toward More Human Interface Design, IEEE Computer, Vol. 34, No. 3, pp. 56-64, 2001.

[18] Lawson, B, Design in Mind, Architectural Press, Oxford, UK, 1994.

[19] Marshall, C.C., Toward an Ecology of Hypertext Annotation, Proceedings of Hypertext 98, pp. 40-49, 1998.

[20] Marshall, C.C., Shipman, F.M. Spatial Hypertext: Designing for Change. Communications of the ACM, pp. 88-97, 1995.

[21] Marshall, C.C., Shipman, F., Coombs, J.H., VIKI: Spatial Hypertext Supporting Emergent Structure, Proceedings of the 1994 ACM European Conference on Hypermedia Technology, pp. 13-23, September 19-23, 1994, Edinburgh, Scotland.

[22] Nakakoji, K., Yamamoto, Y., Reeves, B.N., Takada, S. Two-Dimensional Positioning as a Means for Reflection in Design of Interactive Systems (DIS 2000), ACM Press, New York, pp. 145-154, 2000.

[23] Nakakoji, K., Yamamoto, Y., Akaishi, M., Hori, K., Interaction Design for Scholarly Writing: Hypertext Representations as a Means for Creative Knowledge Work, New Review of Hypermedia and Multimedia, Special Issue on Scholarly Hypermedia, Buckingham Shum, S.J. (Ed.), 2005 (in print).

[24] Nakakoji, K., Yamamoto, Y., Aoki, A., Third Annual Special Issue on Interface Design, Interactions, ACM Press, Vol. 9.2, pp. 99-102, March-April, 2002.

[25] Rittel, H.W.J., Webber, M.M., Planning Problems Are Wicked Problems, Development in Design Methodology, N. Cross (Ed), John Wiley and Sons, New York, pp. 135-144, 1984.

[26] Rosenberg, J., The Structure of Hypertext Activity, Proceedings of Hypertext 1996, ACM, New York, pp. 22-30, 1996.

[27] Rosenberg, J., And And: Conjunctive Hypertext and the Structure Acteme Juncture, Proceedings of the Twelfth ACM Conference on Hypertext and Hypermedia, August 14-18, pp. 51-60, Arhus, Denmark, 2001.

[28] Schoen, D.A., The Reflective Practitioner: How Professionals Think in Action, Basic Books, New York, 1983.

[29] Shipman, F., Hsieh, H., Airhart, R., Maloor, P., Moore, J. M., The Visual Knowledge Builder: A Second Generation Spatial Hypertext, Proceedings of Hypertext 2001, ACM, New York, 2001.

[30] Shirouzu, H., Miyake, N., Masukawa, H., Cognitively Active Externalization for Situated Reflection, Cognitive Science, Vol. 26, No. 4, pp. 469-501, 2002.

[31] Shneiderman, B. Direct Manipulation: A Step Beyond Programming Languages. IEEE Computer Vol. 16, No. 8, pp. 57-69, 1983.

[32] Simon, H.A., The Sciences of the Artificial (Third ed.), The MIT Press, Cambridge, MA, 1996.

[33] Smith, J.B., Weiss, S.F., Ferguson, G.J., A Hypertext Writing Environment and Its Cognitive Basis (panel session), Proceedings of the ACM Conference on Hypertext, pp. 195-214, Chapel Hill, NC, 1987.

[34] Snodgrass, A.B., Coyne, R.D., Is Designing Hermeneutical? Architectural Theory Review, Journal of the Department of Architecture, The University of Sydney, pp. 65-97, 1997.

[35] Tinderbox, http://www.eastgate.com/Tinderbox/

[36] Yamamoto, Y., Nakakoji, K., Aoki, A., Spatial Hypertext for Linear-Information Authoring: Interaction Design and System Development Based on the ART Design Principle, Proceedings of Hypertext2002, ACM Press, New York, pp. 35-44, June 2002.

[37] Yamamoto, Y., Nakakoji, K., Takada, S. Hands-on Representations in a Two-Dimensional Space for Early Stages of Design. Knowledge-Based Systems Journal, Elsevier Science, pp. 375-384, 2000.

[38] Yamamoto, Y., Nakakoji, K., Interaction Design of Tools for Fostering Creativity in the Early Stages of Information Design, International Journal of Human Computer Studies (IJHCS), Special issue on Creativity, E. A. Edmonds and L. Candy (Eds.), 2005 (in print).

[39] Zhang, J., The Nature of External Representations in Problem Solving. Cognitive Science, pp. 179-217, 1997.

[40] Zhang, J., A Representational Analysis of Relational Information Displays, International Journal of Human Computer Studies, Vol. 45, No. 1, pp. 59-74, 1996.