Can We Talk about Spatial Hypertext?

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ABSTRACT

Spatial hypertexts are difficult to explain and to share because we have so little vocabulary with which to discuss them. From examination of actual spatial hypertexts drawn from a variety of domains and created in a variety of systems, we may identify and name several common patterns.

Categories and Subject Descriptors

H5.4 [**Hypertext/Hypermedia**]: Theory. I7.2 [**Document Preparation**]: hypertext/hypermedia

General Terms

Documentation, Design, Human Factors,

Keywords

Spatial hypertext, hypertext, patterns, diagrams, visualization, graphs, knowledge representation.

1. SPATIAL HYPERTEXT

Hypertext research rests on the conviction that information is richly structured and that expressing this structure will improve our ability to understand and to use information. Because writers may not immediately grasp the structure of new information, nor will they always wish to take time to express that structure, spatial hypertext seeks to provide fast and informal ways to express inchoate structure and contingent relationships [22] [24].

While people understand their own spatial hypertexts, many find it difficult to understand spatial hypertexts that other people created [28]. To interpret a spatial hypertext requires us to decode how the organization of elements in space reflects the relationships among the things or concepts those elements represent. If our collaborator does not understand how we have set things up, we have few ways to explain it. Yet representing complex, contingent, provisional structure of an incompletely-understood domain is the core goal of spatial hypertext.

I submit that spatial hypertext is difficult to explain and to share because we have so little vocabulary with which to discuss it. A shared vocabulary need not preclude representational or notational innovation. This is not a formal system, but rather an effort to elucidate some features of actual (hyper)texts, with all their ambiguity of construction and openness to interpretation [10].

This paper proposes some elements of a vocabulary of spatial hypertext. This vocabulary is neither exhaustive or prescriptive; these are not the only patterns, nor the best. To call for a shared vocabulary is not to seek to impose a standard, either on the presentation of spatial hypertexts or on their interpretation. I hope, however, that just as “Patterns of Hypertext” [1] may have facilitated discussion of hypertextual link structures, this vocabulary may help us talk more clearly about the structures we find and create in spatial hypertexts.

2. THE PARSING PROBLEM

The earliest spatial hypertext system [24] incorporated a spatial parser that tried to interpret the layout of nodes in space and could use that interpretation to correct accidental errors, to facilitate selection of groups of objects, and to reveal emergent structure.

The initial parser grammar was quite limited – chiefly, horizontal and vertical lists, piles, and clusters. These limitations were appropriate, as at that time no one could have much experience with spatial hypertext. A further consideration was the reaction against premature formalization in systems like Aquanet and SEPIA [35]. The continuity of geometrical space allows contingent or speculative gestures that need not be explicit or even deliberate, and capturing this contingency was rightly seen as crucial to practical use of spatial hypertext in domains that were not thoroughly understood – that is, in precisely those situations where it could be beneficial.

The result, though, was that the spatial parser could not say very much; without a richer visual vocabulary, the parser cannot seem to tell us all of what we want to hear.

3. VISUAL NOTATIONS

Maps, blueprints and schematics project spatial phenomenon into abstract representations. In the work considered here, in contrast, we typically want to represent things that may be entirely non-spatial (like “love” or “requirements for the major”) as well as those that might have a spatial component (like “English 32”, which does arguably exist in space and time, but for which spatial representation is not particularly germane). We occasionally see hypertextually-annotated maps of cities and countries, and locative hypertexts embed hypertexts in physical places [40] [14]. Ron George’s *gesturcons* create a symbolic language for representing interaction with touchscreens [13]. Though they are not without interest, these approaches are inherently tied to specific geographies, and we will not further consider such literally spatial organizations.

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Other visual representations approach space less literally, mapping abstract properties onto visible coordinates. As early as 1989, Michael Lesk [21] experimented with automatic layout of a collection of books by mapping their Dewey Classification to one Cartesian axis and their Library of Congress Classification to the other. Timelines visualize events in time by arranging their description in space [32]. VITE [18] is arguably the spatial hypertext system most closely concerned with these continuous mappings.

Visual notations can be invaluable for representing well-defined abstract information, as in Whitehead's taxonomy of links [9], Feynman diagrams, or UML. Our chief interest here the use of spatial hypertext to represent tentative, inchoate, or intuitive relationships. The classic applications of spatial hypertexts are drawn from the tasks of gathering, analyzing, and pruning information that we often call "taking notes" or, more broadly, "learning," the ancient practice of using external media to improve memory, promote reflection, and gain understanding [6].

4. VISUAL ATTRIBUTES

In spatial hypertexts, meaning may be carried by words and symbols on the screen, by the placement of objects with respect to other objects, and by the size, shape, color, and other visible attributes of objects both in isolation and in relation to neighboring objects. Some spatial hypertext systems also express conventional links between two objects, or unconventional multi-headed or multi-tailed links among groups of entities. A selection of the most frequently-used visual attributes in one such system, Tinderbox [3], is listed in Table 1.

Table 1: Selected visual attributes in Tinderbox

Badge	Border	BorderBevel	BorderColor
Color	AccentColor	Opacity	Pattern
Shadow	ShadowBlur	ShadowColor	ShadowDistance
Shape	Fill	FillOpacity	Height
InteriorScale	NameAlignment	NameBold	NameColor
NameFont	NameLeading	NameStrike	TitleHeight
Width	Xpos	Ypos	

Some visual attributes may be derived directly from properties of the underlying object. The size or color of objects might be from their price or due date, or from metadata, such as their read wear or modification date.

In practice, some or all attributes are usually chosen manually by users for various reasons and various audiences. Similarities in position and appearance suggest connection or linkage among objects. Spatial hypertext systems have been most frequently applied for personal note-taking and for coordinating the plans of small groups, and so these connections are often made for the benefit of the user herself – or, more precisely, for the expected benefit the user might derive from the connection at some future time. Thus, a group of notes might be distinctively colored in order to call attention to them when the document is next opened, or to ensure that they are not overlooked at some indefinite future review. In this case, the investment of effort to mark the object is weighed against the future utility of the signifier, and also the likelihood that the user will understand what the signifier means when she returns to it.

5. ELEMENTS OF A VOCABULARY

Over the years, descriptions of spatial hypertext systems have recorded their use in a host of tasks, from competitive analysis to intelligence assessments, from building an art portfolio to composing a research paper. In the course of answering technical support queries for Storyspace (starting in 1991) and Tinderbox (starting in 2002) I have had an opportunity to take at least a short glance at hundreds of spatial hypertexts. This sample is unsystematic and anecdotal, to be sure, but it also consists chiefly of actual documents in which people were performing actual work rather than exercises conducted to prosecute an artificial task [5]. Moreover, most of these maps were shared not to impress a researcher nor to demonstrate the creator's ability, but simply because technical support was required to overcome some obstacle that impeded ongoing work.

These examples, and my own use of spatial hypertexts, suggest a range of elements or patterns of meaning in spatial hypertext. I am here projecting an abstract structure onto documents that were constructed without any intention of abstraction – a list of groceries to buy, an outline of a novel, or notes about language translation software. Even when abstracting a visual vocabulary from my own notes and sketches, I seldom recall intending to express the structure I describe here.

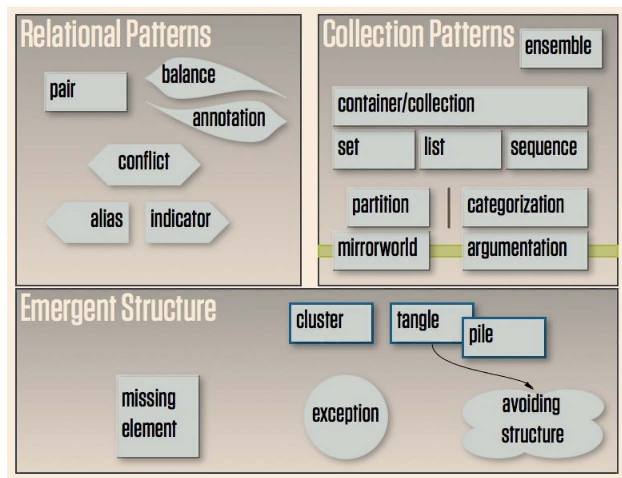

Figure 1. A spatial hypertext of the vocabulary proposed in this section.

5.1 Pair

We might begin with two notes that respond to each other. This relationship may be expressed by proximity, or it may be reinforced by an explicit link, by symmetry, or by other forms of visual connection. One green object among a collection of objects of various colors in unexceptional, but two adjacent green objects in such a collection may form a conspicuous pair.

Pairs often feature in larger ensembles[1]. A property list, for example, is a list of attribute-value pairs. Annotation frequently pairs two notes, or pairs a note with a larger structure.

5.2 Balance

Balance pairs two or more notes. Where Pair merely asserts a connection, Balance also asserts a sense of equivalence or reciprocation, a suggestion that the two members of a pair differ in

[1] The term "ensemble" here means any unified object composed from several notes, what programmers commonly call a composite. The spatial hypertext literature uses composite in the more restricted sense of "a repeated pattern of objects of different type, arranged in a horizontal or vertical list." [33]

some respects but, in other respects, hold equal weight or importance.

Balance may be expressed through a pair of identical or reciprocal shapes or by pairing a large, lightweight object with a smaller but denser one. Where two or more objects are situated with respect to a fulcrum, balance may involve both perceived density and distance from the center.This principle of lever arms and the implicit fulcrum is central to modern graphic design descended from the Bauhaus, De Stijl, and Futurism[20].

A Balance often involves ensembles of notes. A Balance involving two ensembles is a Partition of equal or commensurate components.

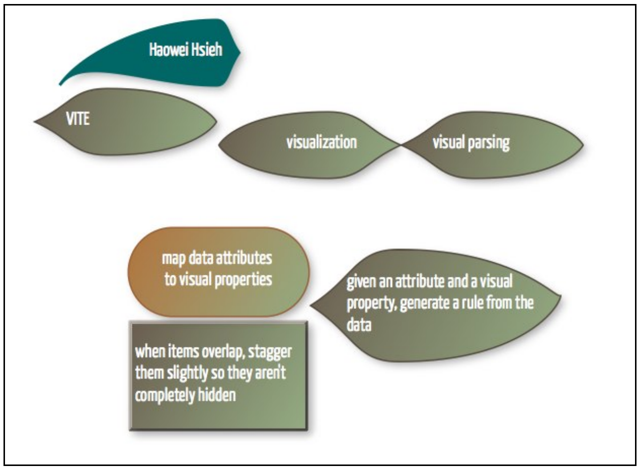

Figure 2. Notes by the author on a lecture by Prof. Haowei Hsieh at IVICA 2009, Austin Texas. Note the explicit balance of visualization and parsing, and the implicit balance of the speaker and his system.

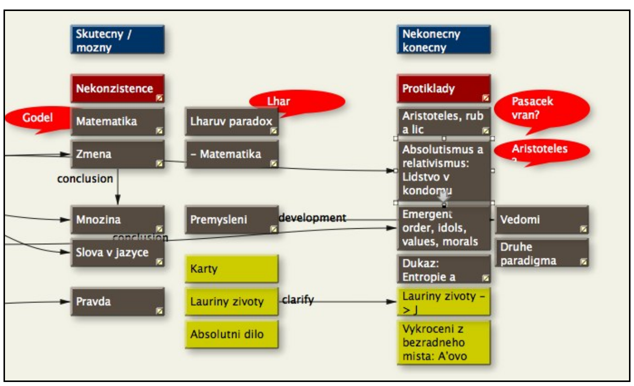

Figure 3. Detail of a map of a projected novel by Filip Dousek. Several notes are annotated with potential sources

5.3 Annotation

Annotation [26] pairs a note with another individual note or with an ensemble of notes, upon which it comments or to which it responds. Entire hypertexts may be built from annotations surrounding a core text; Landow's pioneering rhetoric of arrival and departure, for example, is predominantly annotative [19].

In print, authorial or editorial annotation is usually accorded more respect than marginalia added after publication. This was not always true; in the early age of print, volumes that had been annotated by notable scholars and jurists were especially prized [6]. Electronic text helps remedy the invidious position of reader annotation [23]. The precedent of the footnote [15] casts some light on the tensions that influence the representation of annotation: each annotation provides an opportunity to divert the reader from the expected path, while overly prominent annotations can submerge the original argument in a morass of clamoring counter-claims and advertisements.

5.4 Conflict

A conflict represents two or more alternative ideas, plans, or concepts. In its simplest form, we often depict a conflict as a simple, antisymmetric pair. Three or more options may appear as a set of ensembles radiating from a central core issue.

The core need not be explicitly represented. Conflicts usually involve ensembles and a conflict may act itself as an ensemble. Conflicts are often trees, though many trees are not conflicts. The conflict pattern is often central to "mind mapping" applications for decision support [37].

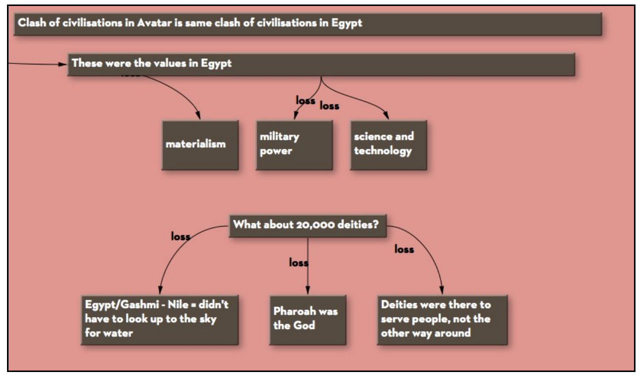

Figure 4. Detail, reformatted for legibility, of a classroom by Rabbi Andrew Saffer.

5.5 Alias

Many hypertexts situate nodes within a structural framework such as an overall hierarchy. In such cases, it may be representationally convenient for the same node to appear in two or more places at once[2], either to support transclusion [30], to avoid premature commitment, or to represent ambiguity.

The presence of an alias creates a connection and, in consequence, a tension between the portion of the map that contains the alias and some other part – often remote and out of sight – that contains the original. Like the link (and the cross-reference in conventional books), the alias represents a jump, leaping outside the current context. Early hypertext theory, influenced by *structured*

[2] The semantics of aliases are surprisingly tricky. Aliases must retain a reference to their original note, since most attributes of an alias are shared with the original and with all other aliases. Deleting an alias does not delete the original, but deleting an original note must delete all its aliases, and those deletions must be performed before the original is deleted. Undoing a deletion, similarly, requires care that the original is restored before the aliases can reference it. Though most properties of an alias are shared with the original note, some are necessarily inherent or intrinsic to the alias itself; if the purpose of the alias is to represent the same note in two places, the location of the note must be inherent to the alias.

programming controversies that seemed still unsettled in the late 1980's, distrusted such jumps, but they cannot be avoided in realistically complex representational tasks and users (though perhaps not implementers) find them straightforward.

5.6 Indicator

An Alias repeats the same information in two different places. An Indicator, on the other hand, extracts or summarizes information found in one or more places and presents it in a new context. Aliases transclude; indicators both transclude and transform [3].

For example, at the head of a research proposal that we are sketching, we might place a note that reminds us of a deadline. Other notes might keep track of the total word count, progress in writing each chapter, and alert us to the outstanding research needs of each section, helping us deploy the aid of assistants in meeting the most urgent requirements.

The notes examine properties of other notes or ensembles of notes, extract a specific representation such as a word count or a count of research queries, and then display the summary in new context.

A collection of Indicator notes is a Dashboard. Indicators frequently condense or summarize an pile, list, or tree. When an Indicator appears in isolation, it is often an Exception to the prevailing pattern.

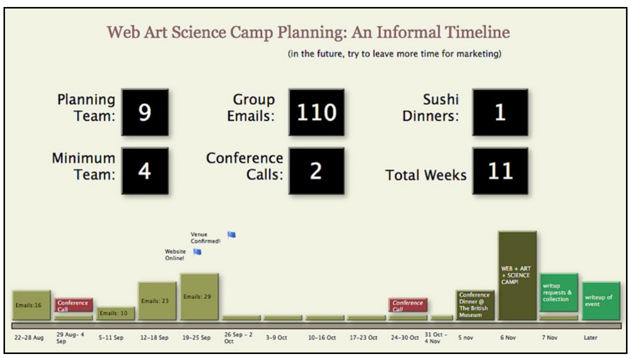

Figure 5. Milestones and deliverables are arranged chronologically near the bottom of the map, and a dashboard above tracks key performance metrics. J. Nathan Matias, planning document for a small conference.

5.7 Ensemble

An ensemble collects a group of notes in a structure that lets the reader consider them individually or as a group. The distinction among varieties of ensembles in a hypertext has not always been clearly drawn.

Ensembles may themselves contain ensembles. Indicators are often used to summarize key properties of an ensemble.

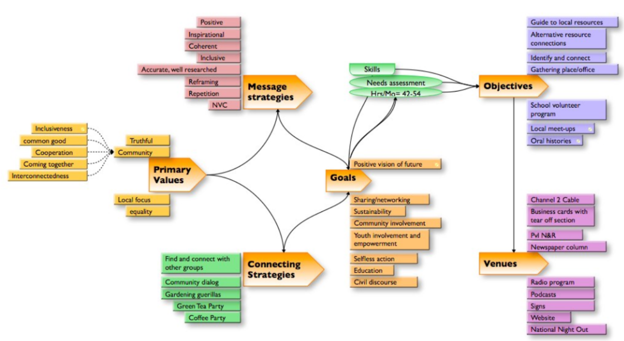

Figure 6. Ensembles of issues involved in planning a community magazine, by John Robert Cornell.

5.8 Container and Collection

A container or collection aggregates several elements, often establishing a hierarchy, taxonomy, or ontology into which the elements are organized. Unlike clusters (Section 5.14), containers have boundaries or walls. Containers might not always show all of their contents. In Storyspace, for example, [2], containers suppress display of links inside the container, display their contents at reduced scale, and do not display the contents of nested containers at all. Elision helps focus attention while reducing the complexity of layout, especially in a link-rich document.

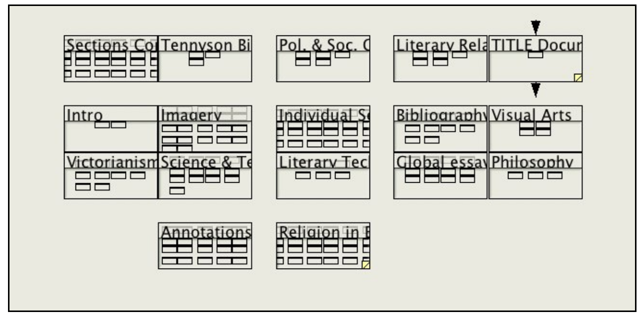

Figure 7. Storyspace map of George P. Landow's *In Memoriam Web.*

The rigid walls and elision rules associated with containers sometimes threaten premature formalization, either because the initial assignment of a note to a category might be wrong, or because the writer wants the note to be, at the same time, correctly classified and ready to hand. A variety of lightweight containers or collections[3] have been proposed that offer permeable boundaries. iMapping [17] uses a continuously zooming interface to represent ensembles at successively tinier scales. Web Squirrel neighborhoods [36] presented fuzzy, agglomerative boundaries. Tinderbox adornments [3] label regions of the hypertext map, and can act upon notes that are placed atop them or serve as a persistent query to gather notes.

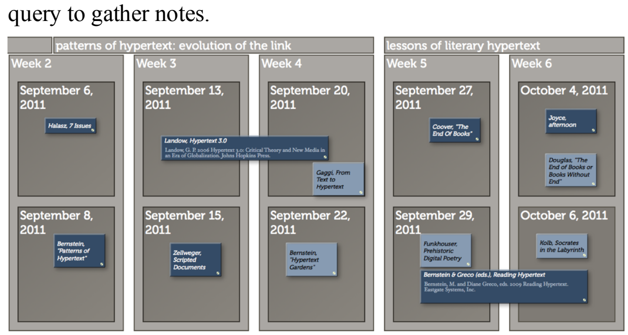

Figure 8. Tinderbox syllabus of assignments for a hypothetical course. Adornments organize lightweight collections, allowing lengthy or difficult readings to span several course meetings. Adapted from a Tinderbox document by Derek van Ittersum.

5.9 Set, List, and Sequence

Beyond containers and collections, we often observe aggregates of hypertext nodes such as sets, lists, and sequences.

[3] The "collection" in VIKI is, in our parlance, a container.

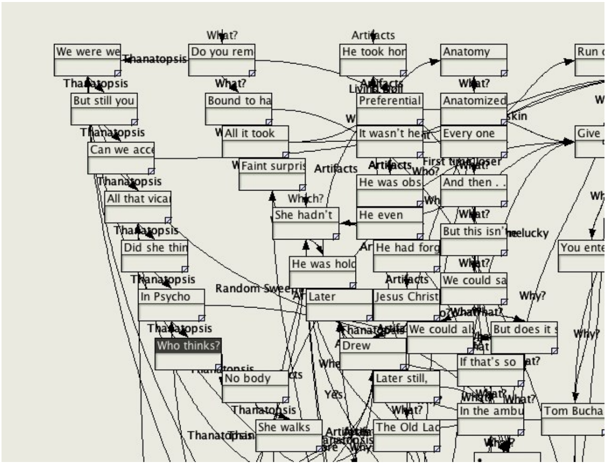

Figure 9. Storyspace map detail from Jane Yellowlees Douglas, "I Have Said Nothing". Though the pattern of linkage is complex sequences converge to a central Conflict.

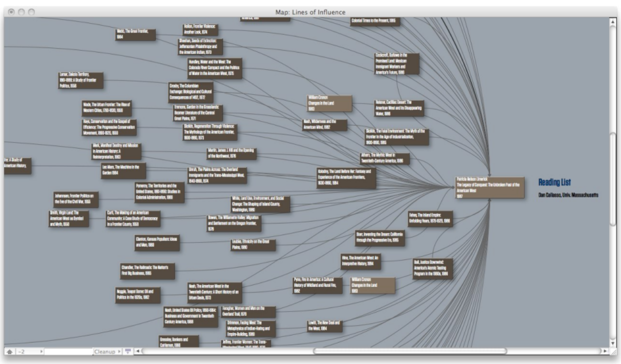

Figure 10. Tracing lines of historiographic influence. Dan Callosso, University of Massachusetts

A small, generalized ensemble is a *list*. A *set* is a list that has unique elements; the order of elements in a set is typically unimportant. A *sequence* is a list that emphasizes its order. Sequences are often chronological, though other organizing principles may be applied as well. Piles are sometimes lists, but programs like iPhoto also treat them as containers.

Ensembles can readily replace individual notes in structures. Below, for example, we see a sequence of ensembles that formally resemble annotation. The central element, recording a typical day in the Gombe reserve, is unremarkable; the center of interest lies in the activities that radiate from it.

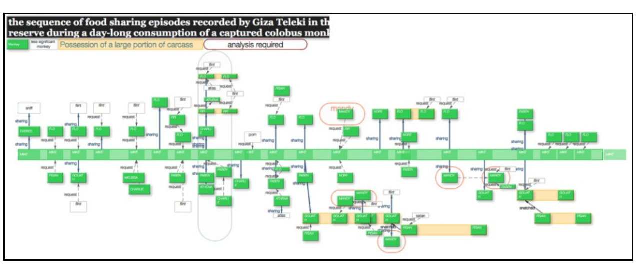

Figure 11. J. Nathan Matias, diagram of food sharing episodes recorded for a Colobus monkey by Giza Teleki, based on Martin Jones, *Why Humans Share Food,* p. 29.

In Fig. 12, a detail from a large VKB project, the proposed reading for a course is organized as a horizontal list (or perhaps a sequence) of topics, where each topic is an aggregate of a headline and a list of research papers.

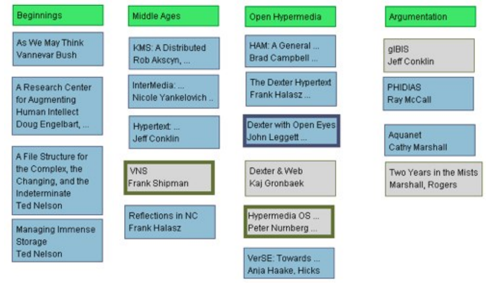

Figure 12. Detail: readings on hypertext. Course planning notes by Prof. Frank Shipman, Texas A&M.

Lists of ensembles frequently appear even in improvised, informal note-taking, as in the lecture notes recording an oral discussion shown below. Here, the size and placement of notes represent topics and themes developed in the lecture and relate them to each other; often, structure is adjusted or expanded later as the listener gains a better appreciation for the speaker's rhetorical plans and for the subject at hand.

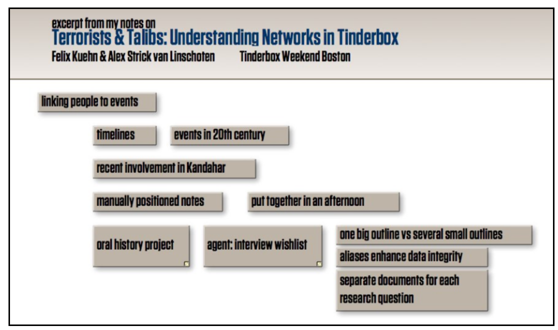

Figure 13. Notes taken by the author during a lecture. Note how placement suggests the element's role, and how irregular widths suggest that the ensemble should be interpreted as a pile of horizontal lists rather than an array of vertical lists.

5.10 Partition

Just as adjacent items might represent a pair, a balance, or a conflict, adjacent lists may represent either a collection or a partition. Partitions divide an ensemble into two or more parts, expressing internal structure while maintaining membership in the larger entity. Partitions may emerge gradually through *ad hoc* clustering, or they may be cultivated in deliberate campaigns of refactoring and structure discovery.

Partitions are important in the life-cycle of incremental formalization. We frequently observe that a pile or cluster may be cleaned up into a more formal and structured ensemble, and that ensemble itself, eventually growing unwieldy, may in time be partitioned. As additional information is accreted, the initial partitioning is sometimes perceived as unhelpful and the structure reverts to a list or pile, awaiting reorganization along new lines.

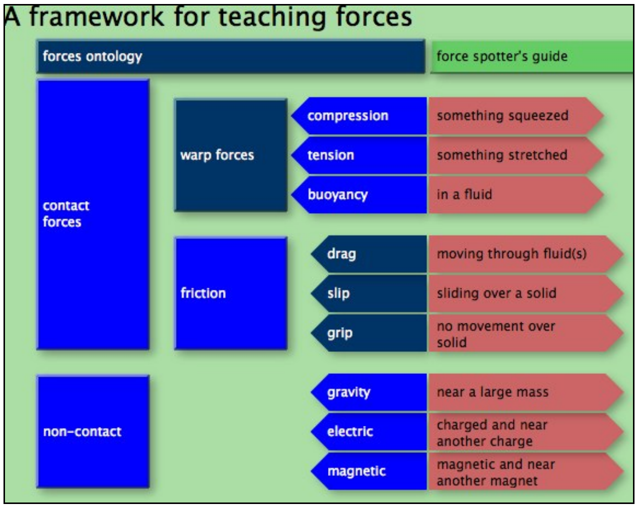

Figure 14. Detail of a Tinderbox document by Ian Lawrence for planning a course on teaching physics.

5.11 Categorization

Elaborated partitions may ramify into more complex schemes of classification, categorization, and property visualization. Spatial hypertext maps sometimes emulate familiar visualizations such as Venn diagrams, time lines, Gantt charts, and scattergrams. In some cases, these arrangements are merely diagrammatic, but in others , changing the placement of an item may also modify its underlying metadata. The user both envisions the data as they stand and, by rearranging elements, asserts new metadata or corrects old or missing data. Categorization is thus an umbrella term for a variety of structures implicated in *representational talkback* [41].

5.12 Mirrorworld

Mirrorworlds appear surprisingly often in spatial hypertexts. In a mirrorworld, two or more ensembles of notes are implicitly compared by juxtaposing their elements. The elements need not be in strict correspondence with each other, as they would be in a Pair or a property list. Where the point of a Partition is the permeability of the boundary and the emergence of structure, the boundaries of a mirrorworld are often evident and impermeable and their interest lies not in separating elements from a pile or cluster but in establishing tentative relationships among components.

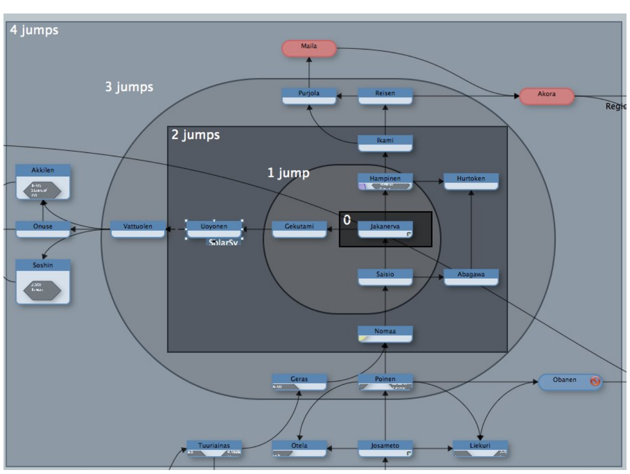

Figure 15. Notes on Eve Online, by William Cole.

Mirrorworlds emerge naturally in conference notes, where each talk, panel, or session invites comparison to its predecessors, and in group task planning, where each person or facility's delegated tasks invite comparison to those of their peers.

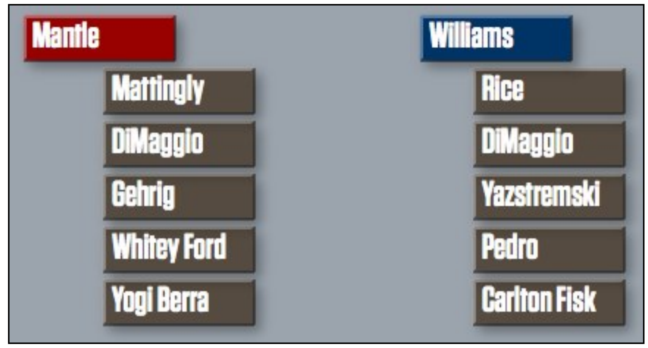

Figure 16. A mirrorworld suggests analogies between disparate historical figures who, it might be argued, played similar roles.

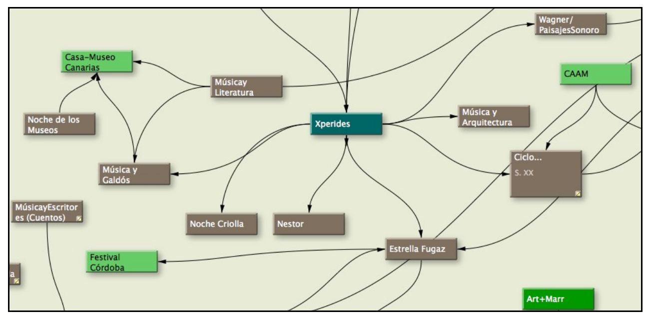

Figure 17. Argumentation structures are most often associated with formal domains, but are seen here in a detail from a document in which composer Juan Manuel Artero assigns new projects to different venues and performances.

5.13 Argumentation

Representation of argumentative structure in spatial hypertext has been a conspicuous goal since gIBIS [7] and Sepia [38]. Though Marshall and Shipman's arguments against formality [35] have convinced most spatial hypertext researchers, gestures toward explicit representation of argumentative structure frequently emerge spontaneously as an expression of the purpose or role of individual links. Related structures frequently appear when writers seek to adapt a story to generic structure (the three-act drama, the musical comedy, the RFC), to coordinate events unfolding across time (PERT charts, flowcharts), or to reason about chains of evidence in support of litigation or legislative deliberation.

5.14 Pile, Cluster, and Tangle

These structures are ensembles with little or no internal structure, or whose internal organization has not yet been elucidated. Physical piles, stacks, and other informal collections of documents play a familiar role in personal information management, and people are surprisingly proficient in their use [27]. A good deal of effort was expended on representing similar *ad hoc* collections in computer interfaces in the 1990's, though their adoption may have been inhibited by a 1994 patent [22].

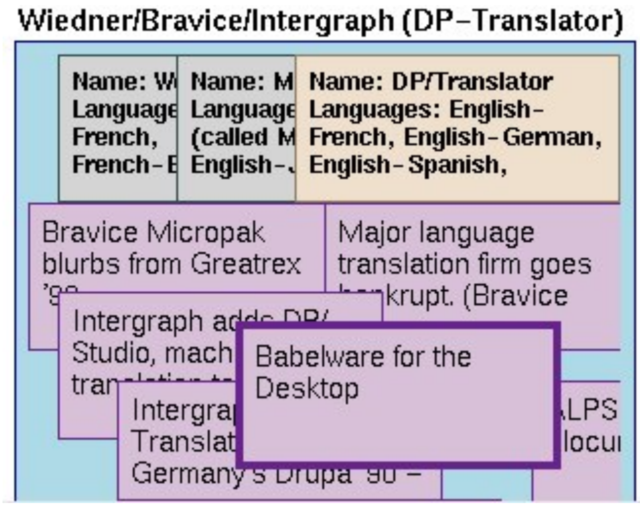

Figure 18. A pile of notes from a VIKI information triage task [25].

A Pile stacks several notes atop each other, so some notes are partially or completely obscured. A cluster simply places the notes close together while setting them apart from other notes. Adornments (Fig. 14) and other decorative elements often delineate and reinforce clusters.

The Tangle [1] is often seen as a failure or anti-pattern, but it might be better conceived as a linked pile or cluster. Like a pile, a tangle is not necessarily unstructured or incoherent. Its structure is not of present interest, and so closer examination of its organization may await future need.

5.15 Missing elements

Though the missing link and feint are familiar link patterns [1], these are sometimes dismissed as creative or artistic indulgences. Missing elements play an important and, frequently, a central role in constructive spatial hypertext. Leaving a gap in a list or sequence is a straightforward way to suggest that a structure is incomplete, or to group members of a list into preliminary or speculative sub-categories.

5.16 Exception

Exceptions highlight elements that require closer attention or additional investigation. Exceptions might highlight apparent outliers, observations that are not completely trusted, items that might have been mistakenly classified, assertions that ought to be pondered, or tasks for which deadlines loom.

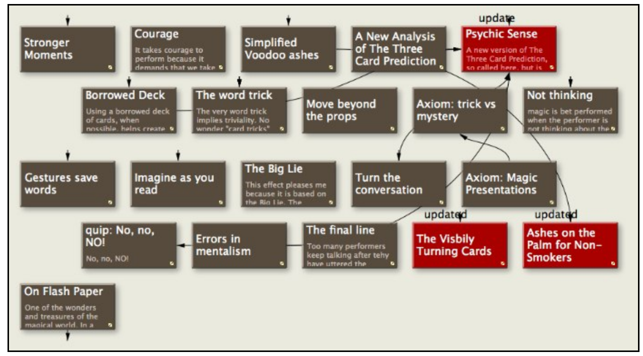

Figure 19. Notes on the art of conjuring, by Gordon G. Meyer. Recent updates are highlighted exceptions.

Exceptions in a spatial hypertext map are most easily expressed through visual attributes that are elsewhere consistent. If most notes are dark, a light-colored note is conspicuous; if most notes are arranged in a regular pattern, a discordant placement calls for attention.

5.17 Avoiding Structure

Spatial hypertext authors sometimes take pains to avoid suggesting the presence of structure by avoiding unintentional alignments and symmetries. In Fig. 20, for example, Robert Brook is preparing remarks for a lecture on the notion of "the gentleman" in historic literature and contemporary life.

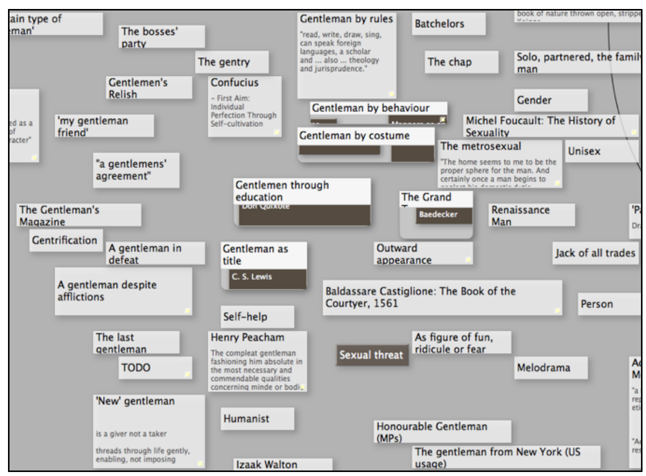

Figure 20. Robert Brook, detail from notes for a lecture, "Honourable Gentlemen: practices and roles in history and today."

Considerable care has been exerted here to avoid accidental alignments, an effort complicated by the coarse grid imposed on the map by the Tinderbox software. One alignment – between the topic of "self-help" and the note beneath it on Henry Peacham, author of an 17th-century self-improvement manual, is all the more conspicuous by the many narrowly-avoided alignments like that between "The gentry" and "Confucius".

6. DYNAMICS

Linkage and composition establish connections among objects in a hypertext, and those connections in turn may facilitate querying the hypertext and computation in (and over) hypertextual structures[3; 16]. We can easily associate computation with hypertext nodes. If these computations can refer to other nodes in the network and potentially trigger additional computation, a hypertext becomes a complex and distributed computational mechanism.

Hypertexts may themselves interact with other programs, either to present dynamic content or to gather information from the internet. These interactions might themselves trigger further computation. Some parts of a document may synchronize with a cloud-based cache of texts, others may download email messages or course assignment bulletins, and still others may create new hypertext nodes that represent RSS or Atom feeds. Node metadata may reflect the user's computational environment; for example, a dashboard note might reflect one's Facebook status or most recent Twitter upload. Other metadata, such as current stock prices or service requests, might be updated autonomously or create new hypertext nodes.

The volatility of collaborative hypertexts has always challenged the user's ability to grasp a changing document, and the dependence of spatial hypertexts on live feeds and data presents new difficulties: not only may new things appear suddenly, but we may not know the agent or mechanism of their appearance. To respond to this complexity, dynamic systems may organize the data stream autonomously, or provide mechanisms to allow the data to self-organize. The development of Twitter conversations through adoption of the @name convention is one familiar example of such quasi-autonomous organization.

VITE [18] can associate the placement of a note in Cartesian space with the values of its attributes. Moving a note changes its metadata, and changing the metadata moves the note. Tinderbox notes use prototype inheritance [31] to pass data from abstract prototypes to concrete instances or to share it among several instances. Tinderbox prototypes are represented as links, and other link types may, through reference in rule-based constraints, serve to propagate information through the link network. A constraint language can be useful in automatically adapting the layout of a spatial hypertext as new elements are added and old elements are moved or modified [39].

Computational structures familiar from object-oriented frameworks find interesting counterparts in hypertext dynamics. Suppose, for example, we have a set of adornments, and want each adornment to represent a different class meeting (Fig. 8). Entering the date for each individual adornment might be tedious. Instead, we may save the initial date in a special note that acts as a timestamp. Each adornment's OnAdd action triggers the timestamp's action; the timestamp in turn sets the date of the adornment and advances its own date to the next class meeting. By moving the timestamp in turn to each adornment, we set each adornment's date; this is, in effect, an implementation of the familiar Visitor pattern[12].

Conversely, designated regions of the spatial hypertext map may act upon those notes that enter them. Tinderbox adornments and containers possess an OnAdd action to be performed on a note when that note is created inside or added to the container. Often, this action is used to set the initial prototype for newly added notes. For example, the container `Weblog Archive` might use the action

```
OnAdd: Prototype="Weblog Post"
```

to assert that notes in this container are assumed to be weblog posts unless the user specifies otherwise. In this way, the note's location determines its type.

Tinderbox agents scan the document for notes that satisfy their queries, which may refer to both the contents of the note and to their hypertextual structure [8]. Very often, these agents are used to move notes to a specific container. For example, an agent may move notes marked as "completed" into a bin of completed tasks. Here, the note's type determines where it should be put.

Additional dynamics appear where the components of the spatial hypertext themselves change in time. A hypervideo may require or prefer distinct patterns of connection, especially since recurrence, while common in print, is uncanny in perfluent video [34]. Social media, moreover, reinforce the liveliness of our data; where once a friend's representation in our notes would consist mostly of static information and pointers (e.g. telephone numbers), we might now reasonably expect to represent their Twitter timeline, recent photographs, and perhaps their current location. Our own location, in turn, can itself transform the hypertexts on which we are working if the hypertexts provide location-based links.

Dynamic spatial hypertexts remain novel, and their behaviors and capabilities vary radically between systems. Though developing a common vocabulary may require a good deal of additional implementation and experience, I anticipate that this will be an especially fruitful area for research.

7. EVALUATION AND DISCUSSION

Examination of people's working documents reveals several common structures that differ in rhetorical intent but that may be represented in similar ways. A *pair* is not a *conflict*, though both juxtapose two notes; a *partition* is not merely a list. A shared vocabulary lets us quickly distinguish our intent, and may let us establish a convenient visual shorthand for expressing the intent, to our collaborators as well as to the system.

This vocabulary of patterns found in spatial hypertexts is not comprehensive or complete. How might we judge whether it is any good?

I have used these patterns myself in writing notes, gathering information for articles, planning software releases, and managing a small firm. I have also used them to discuss spatial hypertexts with customers who required technical support or training. These are the terms and the structures I find to be used most often. Reflexive evaluation can be problematic, but its judicious use can sometimes reveal important facets of software behavior that brief and casual encounters will not [11].

We might adopt a *critical* approach [5] to assess the performance of this vocabulary. Do we observe these structures in actual use? Are the distinctions drawn here helpful? It is worth noting that not all the structures discussed here map cleanly onto the affordances of contemporary software: the distinction between pair, conflict, balance, and annotation is not, for example, baked into Tinderbox or VKB. Critical judgment, then, might indicate whether these four structures are distinct (and perhaps merit native software support) or whether we are here splitting ontological hairs (suggesting that all four might then be lumped together).

As I speculated above, a richer vocabulary of spatial hypertext could facilitate the use of automatic spatial parsers by giving the parsers would have a wider range of structures to propose and discuss. It is important to remember, however, that meaning does not lie exclusively in the layout or, indeed, on the page. To know whether a group of notes represent a *list* or a *sequence,* we may need to look at (and understand) the notes. Recognizing potentially ambiguous patterns (for example, *pair, conflict,* and *balance*) as well as accidental imposition of unwanted structure (for example, when a group of unrelated notes are mistakenly interpreted as forming a list), we may ultimately devise notational conventions to clarify the writer's intention.

This vocabulary is not proposed as standard, either for the presentation of spatial hypertexts or for their interpretation. Hypertext has long been plagued by calls for premature standardization. By sharing elements of terminology, however, we may more readily discuss interchange and more quickly identify the facilities offered by innovative tools. Understanding the distinctions among patterns that might easily be mistaken for each other – for example, whether two clusters form a partition or simply happen to be adjacent – could easily lead us to develop conventional notations to help clarify our intent.

A shared vocabulary of spatial hypertext, however flawed or incomplete, helps us explain our hypertexts to colleagues and collaborators. Recent work on distributed version control for shared spatial hypertext [29] makes this need more urgent, but even in face-to-face collaborations across a shared screen, we need richer and more accurate ways to propose suggestions or explain changes. The development of multi-touch tablets and tables, as well as ubiquitous computing and augmented reality techniques, suggest a variety of new modes of collaboration for which we will need, at minimum, some way to ask or collaborator to write or revise those parts of the spatial hypertext we don't wish to undertake ourselves, and the more clearly we can describe those parts, the more pleasant our work may be.

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9. REFERENCES

[1] Bernstein, M. 1998. Patterns of Hypertext. *Hypertext '98*. 21-29.

[2] Bernstein, M. 2002. Storyspace 1. *Proceedings of the 13th ACM Hypertext Conference*. 172-181.

[3] Bernstein, M. 2003. Collage, composites, construction. *Proceedings of the fourteenth ACM conference on Hypertext and hypermedia*. 122–123.

[4] Bernstein, M. 2003. *Tinderbox*. software for Macintosh computers. http://www.eastgate.com/Tinderbox

[5] Bernstein, M. 2010. Criticism. *Proceedings of the 21st ACM conference on Hypertext and hypermedia*. 235–244.

[6] Blair, A. 2010 *Too much to know : managing scholarly information before the modern age*. Yale University Press.

[7] Conklin, J. and Begeman, M. L. 1988. gIBIS: A Hypertext Tool for Exploratory Policy Discussion. *ACM Transactions on Office Information Systems*. 6, 4, 303-331.

[8] Croft, W. B. and Turtle, H. 1989. A retrieval model incorporating hypertext links. *Proceedings of the second annual ACM conference on hypertext*. 213–224.

[9] E. James Whitehead, J. 2002. Uniform Comparison of Data Models Using Containment Modeling. *Hypertext '02*. 182-191.

[10] Eagleton, T. 2003 *After theory*. Basic Books.

[11] Efimova, L. 2009. Weblog as a personal thinking space. *Proceedings of the 20th ACM conference on Hypertext and hypermedia*. 289–298.

[12] Gamma, E., Helm, R., Johnson, R., and Vlissides, J. 1995 *Design Patterns: Elements of Reusable Object-Oriented Software*. Addison-Wesley.

[13] George, R. 2010. Gesturcons: an icon language to describe natural user interface gestures. *Modern*.

[14] Gibson, W. 2007 *Spook country*. G.P. Putnam's Sons.

[15] Grafton, A. 1997 *The Footnote: A Curious History*. Harvard University Press.

[16] Halasz, F. G. 1991. "Seven Issues": Revisited Hypertext '91 Closing Plenary.

[17] Haller, H. and Abecker, A. 2010. iMapping: a zooming user interface approach for personal and semantic knowledge management. *Proceedings of the 21st ACM conference on Hypertext and hypermedia, HT '10*. 119–128.

[18] Hsieh, H., Pauls, K., Jansen, A., Nimmagadda, G., and Shipman, F. 2010. Assisting two-way mapping generation in hypermedia workspace. *Proceedings of the 21st ACM conference on Hypertext and hypermedia*. 99–108.

[19] Landow, G. P. 1987. Relationally Encoded Links and the Rhetoric of Hypertext. *Hypertext 87*. 331-344.

[20] Leborg, C. 2006 *Visual grammar*. Princeton Architectural Press.

[21] Lesk, M. 1989. What to Do When There's Too Much Information. *Hypertext '89*. 305-318.

[22] Mander, R., Salomon, G., and Wong, Y. Y. 1992. A "pile" metaphor for supporting casual organization of information. *Proceedings of the SIGCHI conference on Human factors in computing systems*. 627–634.

[23] Marshall, C. C. 2009 *Reading and Writing the Electronic Book (Synthesis Lectures on Information Concepts, Retrieval, and Services)*. Morgan and Claypool Publishers.

[24] Marshall, C. C., III, F. M. S., and Coombs, J. H. 1994. VIKI: Spatial Hypertext Supporting Emergent Structure. *ECHT'94*. 13-23.

[25] Marshall, C. C. and Shipman, I. I. I., Frank M. 1997. Spatial hypertext and the practice of information triage. *Proceedings of the eighth ACM conference on Hypertext*. 124–133.

[26] Marshall, C. C. 1998. Toward an ecology of hypertext annotation. Proceedings of the ninth ACM Conference on Hypertext and Hypermedia, 40-49.

[27] Marshall, C. C. 2007 *How People Manage Information over a Lifetime*. In Personal Information Management,William Jones and J. Teevan,Eds University of Washington Press.

[28] Marshall, C. C. 2001. NoteCards in the Age of the Web: Practice meets perfect. *ACM Journal of Computer Documentation*. 25, 96-103.

[29] Matias, J. N. and Cheung, F. 2010. Emberlight: share and publish spatial hypertext to the web. *Proceedings of the 21st ACM conference on Hypertext and hypermedia, HT '10*. 311–312.

[30] Nelson, T. 1982 *Literary Machines*. Mindscape Press.

[31] Noble, J., Taivalsaari, A., and Moore, I. 1999 *Prototype-Based Programming: Concepts, Languages and Applications*. Springer-Verlag Singapore Pte Ltd.

[32] Rosenberg, D. and Grafton, A. 2010 *Cartographies of time*. Princeton Architectural Press.

[33] Shipman III, F. M., Marshall, C. C., and Moran, T. P. 1995. Finding and using implicit structure in human-organized spatial layouts of information. *CHI '95*. 346–353.

[34] Shipman, F., Girgensohn, A., and Wilcox, L. 2005. Hypervideo expression: experiences with hyper-hitchcock. *Proceedings of the sixteenth ACM conference on Hypertext and hypermedia, HYPERTEXT '05*. 217–226.

[35] Shipman, F. and Marshall, C. C. 1999. Formality Considered Harmful: Experience, emerging themes, and directions on the use of formal representations in interactive systems. *CSCW*. 333-352.

[36] Simpson, R. M. 2001. Experiences with Web squirrel: my life on the information farm. *Proceedings of the 12th ACM conference on Hypertext and Hypermedia, HYPERTEXT '01*. 127–128.

[37] Straker, D. 1997 *Rapid problem-solving with Post-it Notes*. Fisher Books.

[38] Streitz, N., Haake, J., Hanneman, J., Lemke, A., Schuler, W., Schutt, H., and Thüring, M. 1992. SEPIA: A cooperative Hypermedia Authoring Environment. *ECHT 92*. 11-22.

[39] van Wyk, C. J. 1982. A High-Level Language for Specifying Pictures. *ACM Trans. Graph*. 1, 2, 163–182.

[40] Weal, M. J., Hornecker, E., Cruickshank, D. G., Michaelides, D. T., Millard, D. E., Halloran, J., De Roure, D. C. and Fitzpatrick, G. 2006. Requirements for In-Situ Authoring of Location Based Experiences. *8th ACM International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI 06)*. 121-128.

[41] Yamamoto, Y., Nakakoji, K., and Aoki, A. 2002. Spatial Hypertext for Linear-Information Authoring: Interaction Design and System Development Based on the ART Design Principle. *Hypertext 2002*. 35-44.