

"It's the journey and the destination": Shape and the emergent property of genre in evaluating digital documents

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Abstract

Navigation is a limited metaphor for hypermedia and website use that potentially constrains our understanding of human-computer interaction. In the present paper we trace the emergence of the navigation metaphor and the empirical analysis of navigation measures in usability evaluation before suggesting an alternative concept to consider: shape. The shape concept affords, we argue, a richer analytic tool for considering humans' use of digital documents and invokes social level analyses of meaning that are shared among discourse communities who both produce and consume the information resources.

Introduction

To anyone versed in the literature on hypermedia, it is clear that the last 10 years' worth of research on usability since Conklin's (1987) seminal article has largely been ignored by web designers. Surfing web sites even casually will likely expose a user to screens of badly formatted text, superfluous graphics, mixed fonts, unreadable color combinations, and dangling or dead links. While the issue of knowledge transfer between research disciplines and design practice is fraught with problems and is a fascinating topic in and of itself (see e.g., Klein and Eason, 1993), this is not the focus of the present paper. Instead we wish to extend work that started with the birth of hypertext systems and continues to demand attention in these days of free-for-all web design: the evaluation of user behaviour in electronic space.

Specifically, this paper will extend the analysis of 'user navigation' to the evaluation of user behaviour in web environments. In so doing, the present authors will attempt to unify work in the area of structural representation of content with models of navigation based on physical movement. To do this, we will partly jettison the metaphor of navigation as it has generally been employed in hypermedia literature in favor of the concept of shape, which Dillon and Schaap (1996) invoked to explain expert user performance in information structuring tasks. As we will attempt to demonstrate, shape offers a more cohesive construct for understanding user behavior in digital domains, and

reconciles the logical division in the hypermedia literature between navigation through physical and semantic domains. Throughout, we will provide examples of our work which tap this construct in user testing.

2. The state of our knowledge on human use of hypermedia

Despite the rush to digitize the world of information, few examples of well-designed hypermedia exist. While such a statement may appear unreasonable to most people, we need to clarify what we mean by well-designed. In HCI terms, a well-designed system is one that offers utility and usability to its intended users at a reasonable price. By utility is meant the support of meaningful tasks which the user wishes to or needs to perform. By usable is meant that intended users can exploit the utility of the technology in an efficient, effective and satisfying manner (Shackel, 1991). What constitutes reasonable with respect to cost will not be discussed further here.

To claim there is little evidence for the existence of well-designed hypermedia is like trying to prove a null hypothesis, no matter what you demonstrate, there is always room for another view. However, it is remarkable that the published literature on usability evaluations of hypermedia have produced but a handful of results that are encouraging. Perhaps the most pointed critique in recent years has been Landauer's (1995) review of the evidence for hypermedia. He concluded that:

"There have been nine scientifically satisfactory studies...In almost all cases, users were quicker and more successful using paper and print than the electronic form" (p. 260).

While the conclusion is counter-intuitive to most people, we should perhaps be more surprised by the apparent paucity of studies on this technology that Landauer found scientifically acceptable. Reports on hypermedia design and use fill journals and conference proceedings, frequently suggesting powerful improvements in learning and efficiency through the use of this technology, yet Landauer can find only nine that are scientifically satisfactory. Chen and Rada (1996) identified 23 studies of hypermedia use for their review of effect sizes, and reached slightly less disappointing conclusions, but their criteria appear to have been much less stringent than Landauer's, and they included unpublished dissertations and studies that have been critically received elsewhere.

Dillon and Gabbard (in press) report a detailed review of the findings on learning outcomes from hypermedia use in educational studies, an area where the utility of hypermedia is taken for granted. They concluded that the new technology most often failed to yield any significant difference in learner performance. Like Landauer (1995) they noted that many of the experimental studies in the literature are poorly designed, fail to adequately manipulate variables, utilize controls, or report statistical analyses. These authors summarized the literature as indicating that hypermedia had largely failed to

demonstrate any practical advantage to learners in most critical thinking tasks - a conclusion completely at odds with the positive endorsement of this technology at the practical level.

If controlled experimentation with constrained hypermedia is demonstrating the difficulties involved in designing usable hypermedia, then the emergence of the web only exacerbates matters. While an evolutionist might argue that time will select the best forms of digital documentation, the scientist cannot sit idly by. If we are interested in improving human performance with computing technologies, then we must learn to design more useful and usable digital documents.

McKnight et al (1991) argued that the major problem with hypertext was navigation, and despite the occasional dismissals of this as an issue that truly affects users (e.g., Landow, 1992), this topic is continually raised in the writings on hypermedia use, and regarded as a serious form of cognitive overhead for users of extended digital documents. Furthermore, the literature reviews cited above all note that user difficulties in locating and organizing information are major sources of the performance deficit in hypermedia. Thus, in the present paper we will examine what is known about navigation, and then suggest an alternative view of information organization that may help designers and evaluators improve matters.

3. The navigation issue - an update

Conceptually, navigation in hypermedia environments has been likened to movement through physical space. However, Dillon, McKnight, and Richardson (1993) argue that in terms of navigating physical spaces, theory and research suggest that individuals form three types of mental representations over time (landmarks, routes, and surveys) which have never been adequately measured in electronic environments. In the physical world, a person begins to represent their surroundings by developing landmark knowledge of a geographical location (Siegel & White, 1975; Siegel, Kirasic, & Kail, 1978). Landmark knowledge is primarily a function of visual stimuli and a person who has just entered a new location will attend to the local topography (Mandler, 1984) and identify unique spatial configurations (Siegel & White, 1975). Dillon et al describe landmarks as "any features of the environment which are relatively stable and conspicuous" (p. 173). For example, a woman arrives in a new city and takes a cab from the airport to her hotel. She sees a restaurant on the way to the hotel and decides to stop there for dinner. To get there, she will recall that the restaurant was across from building X but past the park. After traversing to the restaurant a few times, she will begin to develop route knowledge.

Route knowledge is developed as a function of physically navigating a path to a destination (Siegel, Kirasic, & Kail, 1978; Thorndyke & Hayes-Roth, 1982). Dillon et al (1993) define route knowledge as "the ability to navigate from point A to point B, using whatever landmark knowledge we have acquired to make decisions about when to turn left or right" (p. 173). Our woman, when leaving the restaurant to return to the hotel, would begin to get a sense that the hotel lies around the corner and up that road a ways. After visiting this particular restaurant a few more times, she would begin to develop a

sense of survey knowledge regarding the terrain between the hotel and the restaurant. Survey knowledge has been described as a gestalt sense of a physical environment that allows an individual to visualize the environment in terms of an external map (Siegel & White, 1975; Thorndyke & Hayes-Roth, 1982). Dillon et al (1993) argue that this ability "allows us to give directions or plan journeys along routes we have not directly traveled as well as describe relative locations of landmarks within an environment" (p. 174). Our traveler at this point, would begin to navigate the distance to the restaurant in terms of "west on main to the intersection at 5th."

The literature on navigation frequently assumes an invariant developmental sequence of landmark to route to survey which might not be correct. Conceivably, a person may develop survey knowledge independent of actually navigating a physical space through the use of external representations such as maps. Furthermore, several studies suggest that landmark, route, and survey knowledge are each best suited to different types of tasks (Thorndyke, 1980; Thorndyke & Hayes-Roth, 1982), and that individual differences such as spatial ability (Pellegrino, Alderton, & Shute, 1984; Stanney & Salvendy, 1995), sex differences (Geary, 1995), or learning techniques (Thorndyke & Stasz, 1980) may influence the use of different mental representations. The physical theory also falls short of explaining how other human factors such as value judgments about a location or affective responses to a location, such as symbolic landmarks (Presson & Montello, 1988), may influence the formation of mental representations.

Dillon et al (1993) argue that one way to tie all these representations together is to consider each of them a form of schematic representation. Schema theory suggests that a person's knowledge is generally organized and structured, and that a person develops this mental structure through repeated interactions with the environment (Mandler, 1984). These mental structures are abstract "models" that guide future interactions with the real world. In turn, these models are then updated based on new encounters. This general approach to knowledge representation would seem to fit well with the development of knowledge for physical spaces. Landmark, route, and survey knowledge each guides a person's interactions with three dimensional space and develops through repeated interactions with the environment. There is evidence to support this interpretation. Knowledge for places (e.g. a room and its contents) (Mandler, 1984), and memory for maps (Okabayashi & Glynn, 1984) have both been interpreted as schematic in form, and there is evidence that spatial knowledge may be organized into hierarchically ordered chunks based on perceived boundaries (Johnson & Hasher, 1987).

If schematic representations are involved, then it is likely that navigation through semantic space is a more complicated than simply acquiring a sense of physical place. Dillon et al (1993) point out that any physical form of information is at best a three-dimensional representation of n-dimensional concepts. However, this point is rarely addressed in the literature where the analogy between navigating physical space and electronic space is common (though see an interesting attempt in Kaplan and Moulthrop, 1994). As testament to the perceived importance of navigation and hypertext, navigational strategies have become a means of assessing the usability of hypermedia products (e.g. Leventhal, Teasley, Instone, Rohlman, and Farhat, 1993). In addition,

several studies have sought to improve the navigational performance of users through better system and interface design (e.g. Gray & Shasha, 1989; Kerr, 1990; Kim & Hirtle, 1995; Parunak, 1989), as well as to characterize users' navigational strategies (Canter, Rivers, & Storrs, 1985). For more understandable reasons, navigation in physical spaces remains the dominant model for work in virtual world wayfinding also (see e.g., Darkin and Silbert, 1996).

However, the conceptualization of hypermedia navigation as emerging through landmark, route, and survey representations has rarely been the subject of research in the human-computer interaction (HCI) community. A fine example of the empirical tradition of HCI research on hypermedia is the study Simpson and McKnight (1990) who found evidence for a link between the accuracy of a user's mental map and her efficiency in navigating a hypertext space. In this study they used a hierarchically organized hypertext, and two forms of a table of contents to aid navigation, a hierarchical list of contents and an alphabetical index. Subjects using the hierarchical list provided more accurate graphical maps of the hypertext and proved to be more efficient than subjects using the alphabetical index. The hierarchical list, which reflected the hierarchically organized hypertext, apparently provided users with a more accurate representation of the hypertext space. In terms of hypermedia spaces, this suggests that the tighter the coupling between an access device and the underlying information structure, the more effectively a person will be able to use it. While the authors utilize the navigation construct to describe the process of interaction, they are not wed to it as a means of explaining knowledge development or user behavior at the interface and their findings are explicable without needing to mention navigation as it is understood in the physical world.

There have been some specific studies of the development of navigation knowledge in electronic space and the relationship between this and user performance, but the results are mixed. Kerr (1990) examined cues in a manner which could be regarded as assessing the nature of landmark characteristics in an information space. Subjects used a database with one of four different sets of navigational cues (text, color, graphics, and a combination of all three). No significant differences were found on speed, accuracy, or efficiency measures for the set of tasks, but subjects reported being significantly more aware of and using more often textual and graphic cues, to a lesser extent combination cues (textual, color, and graphic cues), and least of all color cues. Kerr also asked subjects to give their impression of the database, verbally and/or graphically, to capture the subjects' conceptualizations of the database. The descriptions, both verbal and graphic, were coded for complexity and degree of graphic detail. The faster searchers tended to give more detailed and graphic impressions, while the slower searchers tended to give simpler, more verbal impressions. This suggests that the faster searchers had a more accurate and rich mental representation of the database and could reproduce this representation. However, since these differences were observed independent of environmental cues manipulated, it suggests that the form of knowledge manifest by users was driven more by individual differences in cognition than any characteristic of the electronic space.

Leventhal et al (1993) examined the navigational strategies of users working with a hypertext system over three trials. The system was designed to facilitate hierarchical

navigation, linear navigation, text searching, and hyperlinked navigation. Their data demonstrate that users made significantly more use of hierarchical navigation aids in the earlier stages of using the system and with more complicated task types, suggesting, according to these authors, the emergence of distinct forms of navigational knowledge in line with the evolutionary model of physical navigation. Certainly number of cards visited dropped over time, suggesting greater efficiency of use but use of the hierarchical navigation aids was not significantly related to performance.

Heffron, Dillon, & Mostafa (1996) explicitly tackled that notion of what constitutes a landmark in hypertext. They asked subjects to complete an in-depth searching task on a web site and afterwards to recall features of the web site they remembered seeing. Interestingly, half of the subjects were unable to recall even one feature, and while the authors note that this may have been a function of the manner in which the recall task sought to elicit responses, these data are a surprise to anyone who thinks that visual features are automatically encoded for recall. Features of the web site that were recalled included specific locations, i.e. two home pages, as well as color, high-lighted terms, and keywords.

Evidence so far has suggested that users do make use of some landmark-type information, although what constitutes landmarks in information space remains unclear, and common sense ideas of memory for details may not accurately describe what is happening. Missing from these data is evidence which suggests that users create distinct stages of landmark, route, and survey representations of an information space over time, or a clear indication that more sophisticated navigational knowledge (however measured) leads to better performance. Thus, while navigation may be a useful process measure to take in evaluation in order to better understand what users are doing, the theoretical framework that this metaphor carries with it is largely unsupported in the literature on hypermedia. Furthermore, it seems mostly related to efficiency measures of performance at best i.e., how fast a user can find information, therefore tapping knowledge of physical structures. In terms of building a map of the semantic space, the navigational model sheds no light.

4. Shape - a reasonable alternative?

While the physical model of navigation has many attractions as a lens for viewing the process of hypermedia use, there are some serious shortcomings to its theoretical value. In the first instance, the user of a hypermedia system is largely static, with a view that changes in front of him or her. If we are to invoke navigational literature based on studies in physical environments, then it would appear logically more appropriate to do so for findings based on studies of drivers or pilots (see e.g., Wickens, 1992) where cues for movement are exploited differently and relative position cannot be related easily to kinesthetic memory for direction. To date, few hypermedia researchers have made this link, and given our general reservations about the utility of the physical framework, the present authors will not extend this analysis here though it appears ripe for further

review.

In the second instance, and perhaps more importantly, the physical navigation framework fails to tackle the issue of semantic space which Dillon et al, (1993) suggested to be the more important of the senses of space employed in hypermedia. Certainly from the user's perspective, semantic space has immediate resonance. Arguments must be followed, information has sequence and structure, and while the mapping between physical and semantic space might be tight in restricted domains such as menu hierarchies, this coupling can be very loose in extended, detailed documents incorporating multiple media.

However, all metaphors extend only so far. In HCI it is apparent that the metaphors of desktops and trashcans have limitations for encouraging use of computers, and the information superhighway metaphor for the internet is already a cliché. In our view, the metaphor of navigation in hypermedia use is perhaps better than most, but it also serves to limit our analyses of interaction more than inform them in general research studies. As we evaluate usability, a concern with the process of movement through the information space is important, but by thinking always of navigation there is a tendency to concentrate on physical behaviors that are reflections or indices, at least in part, of semantic processes, without directly examining the semantic component of information use (comprehension, finding meaning and relevance) that for most hypermedia designers is central.

Dillon (1994) proposed the TIMS framework for conceptualizing hypermedia for evaluation purposes. This framework posits four general components of user activity in information usage: task formation and monitoring, information modeling, manipulation of resources, and standard reading activities of visual processing. Each of these components is manifest in the verbal protocols of digital document users (see Dillon, 1996 for extended analysis). A central issue in TIMS is the information model users employ, which it is argued can be based on experience (the invocation of schematic structures from long-term memory) or on the perception of structure in the current environment. The latter example will occur where there exist no previous structural equivalents for the user in their knowledge base, but even then, experience is likely to drive the search for structural cues on the part of the user. Regardless of primary source, the user's information model mediates task activities and psychophysiological interaction with the digital document by serving to direct attention and assimilate data on the organization of the information resource with which the user is interacting.

In purely physical navigation terms, the cognition underlying the information modeling act could be seen as supporting the formation of a mental map of surroundings, influenced by knowledge of previous environments one has encountered, but in so doing, the physical world is represented only in terms of the connectivity and clustering of landmarks into routes and complete maps. In the conceptual space of hypermedia such a map is not enough, equating as it does to knowledge of where information is located, not what it means. Physical navigation has as its raison d'être the arrival of a user at some destination. Once there, the model or map has served its purpose. In hypermedia, such a

model would only be useful in part, if at all, since the object of the user's interaction is to gain some information for use, not merely to arrive at a screen containing it. This might not matter if use could be factored out, but it is not sensible to do so since processing the information even partially serves to impact the user's model.

A case can still be made for maintaining the physical model (and indeed we shall do so in the conclusion of this paper, albeit on more limited grounds) but doing so as our primary evaluative strategy requires a blurring of distinctions between physical and semantic forms that is more likely to confuse than enlighten (if the previous 10 years of writing on this topic is any guide). One alternative we would like to propose is the re-focusing of efforts on this topic away from the physical issues associated with navigation towards the potentially more fruitful concept of shape.

Why shape?

The concept of shape in information space has several antecedents that are worth considering here to establish what we mean by this term. Bazerman (1987) spoke of shaping information as part of the writing process scientists engage in, and while this term is close to the meaning intended here (and has practical significance for design that we will allude to later), a closer approximation can be found in the literature on human cognition in discourse processing. Particularly, the work of van Dijk and Kintsch (1983) and Mandler (1984) which focused on schematic superstructures is closer to the meaning intended here.

Shape is a property of information that is conveyed both by physical form and information content. Separating these elements completely is perhaps impossible but one can talk of the distinction between the layout and sequencing of information as viewed by the consumer (user or reader) and the cognitive representation of meaning that employs (at least in theoretical terms) knowledge structures such as schemata, mental models and scripts. The representation of meaning is crucial to any analysis of hypermedia design and use as it gives the task real human value, yet it is precisely this component that is frequently by-passed in evaluations rooted directly in physical navigation terms.

By invoking shape as a construct to consider in design and evaluation of hypermedia we anticipate tapping more directly the variables that determine the success or failure of a hypermedia - namely the facility with which a user can exploit the information resource to satisfy their task requirements. For users to gain from their interaction, they must do more than locate target information, at least in most real-world tasks. They must assimilate information into their own knowledge structures, an activity that extends processing beyond layout (the classic physical navigation concern) to meaning.

Meaning emerged as an important variable in our research into experts' abilities to exploit cues in isolated paragraphs of text to determine location in an unseen article (Dillon 1990). The capability to perform this task with approximately 80% accuracy without reading for meaning demonstrated that members of a discourse community were capable of determining organization on the basis of perceptual cues. When novices were shown

to be unable to perform this task as well (Dillon and Schaap, 1996) it suggested a phenomenon that was more than the classic form of navigation considered heretofore in the hypermedia literature. Instead, it appears that physical properties of information structure are tightly linked to conceptual properties according to rules that are more complex than those of pure physical organization, and that experts seem to be aware of these and to respond to many of them automatically.

A further set of investigations by the present authors (Dillon and Vaughan, 1997) sought to tap into this process by examining the verbal protocols of expert users of this document form. Manipulating the presence or absence of obvious perceptual cues in the paragraphs employed in Dillon and Schaap (1996), it emerged that experts were using more complex rationales for their classification than simple perceptual cues. Information content, wording, relationships to a process were all seen as indicators of location. While in part this may result from the necessity to generate a rationale rather than merely classify as before, the protocols frequently alluded to the manner in which authors were referring to points, or the inferences that authors seemed to be drawing. In other words, the semantic content of the paragraphs was important in gaining a sense of location, not just the perceptual cues inherent in the display. Experts employed both. As such, the scientific article appeared to have a shape similar to that shown in Fig 1. Here, the article seems to build relationships between elements into a structural form that starts broad and narrows before broadening again over time.

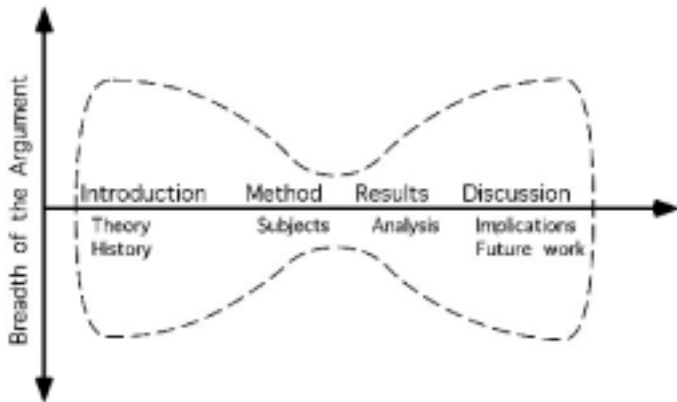


fig. 1

All well and good one might say, but surely this only means people are comprehending as well as navigating? One may proceed with this line of argument, but to us it misses the point. Comprehension is not something 'other than' navigation, some form of task that is independent of the process of moving through the information space. Rather it is an intrinsic component of information use. Furthermore, in an unpublished study, the first author attempted to mimic expert performance with novice users who were provided with a set of rules for allocating paragraphs (i.e., visual cues rather than semantic processing was involved), but novices were unable to do so at levels anyway close to expert performance. So, while physical navigation might be neatly divorced from the purpose of the journey, interactions with digital documents are not so easily divided. The purpose of

moving through the information space is frequently the same purpose as the journey, to reach an end point of comprehension - and in this case the journey is the destination.

For sure there are scenarios where the user is navigating in a form that is more typical of the physical model but these occasions are not the norm, and are more likely to reflect situations where the user is trying to locate a specific detail, or place in the document that is not marked or linked, occasions that mark a breakdown in the ideal form of interaction between information user and medium. To limit our conceptualizations (and by extension our evaluations) of interaction to issues of this kind is unlikely to serve us well.

Furthermore, it is rare that a user would develop a model of the information space that attains full map or survey knowledge status without a commensurate gain in knowledge of content, but we fail to appreciate that knowledge gain if we concentrate solely on physical form, and it is precisely that approach which leads to speculation about novices acquiring an expert's knowledge by following the experts links in a semantic network (see Jonassen, 1993).

So how does the concept of shape help? Clearly, it embraces much of what we know about navigation in information environments by acknowledging the value of physical attributes in aiding or hindering access to material. Thus shape has a very physical component to it as a construct for information design and it subsumes what is known from research on navigation. However, in terms of content, shape invokes concerns with discourse organization, such as form, flow, genre, and argument. It assumes users must manipulate and move through information space, but instead of by-passing concerns with the nature of the material being read or viewed, shape issues focus attention on the regularities of discourse that are followed by both creator and user in an ideal sense.

In so doing, shape draws on both social and cognitive theories of reading, writing, communication and design. It seeks to focus on the traditions, expectations and stylisms of discourse communities as well as to focus on the principles and findings of the HCI community to create usable hypermedia. While users can still be thought of as navigators in some sense, it is not as models of physical space, but as travelers in semantic environments that interest us here - and shape would appear a stronger hypothetical construct.

Applying shape to hypermedia evaluations

It is important to re-iterate that the metaphor of navigation is not being rejected wholesale. It is still our view that capturing process measures of interaction is vital to improving hypermedia design, and data relating to user movement through an information space is always necessary to capture. Thus, in one very important way, nothing has changed by shifting the emphasis to shape. In the usability lab or the field, we still capture data on selections, paths, route to goal etc.

What shape does bring to the evaluation however is a new focus on the form of content - the semantic relationship between information elements. Rather than merely examining the navigation aids present in the interface, e.g., ensuring that there are easily marked

exists on every screen (Nielsen,1993), this construct also draws attention to the logic of order that a discourse community might share. This could be the superstructure of the scientific article, the plot of a narrative, or the clustering of a newspaper. In this way, an understanding of genre becomes central to the evaluation and design process, and user expectancies are not violated, no matter how easy it might be for users to move around.

Of necessity, the concept of genre invokes ideas of discourse communities, traditional forms and emerging digital document types. Users are assumed to base their decisions on movement through information space in part on these attributes of genre. Where the genre is violated, ignored, or may not yet exist (a likely occurrence in hypermedia forms of document) then the user is left to rely on the more traditional interface features of back-forward buttons and hot links to gain perspective. In such a situation, we would capture navigational data in a manner typical of the physical model of navigation. Where the users have experience with the genre, evaluation would seek to identify the presence or absence of design cues that enhance the user's perception of order. Raw navigational data would only tell part of the story here and verbal protocols, clustering exercises, drawings (e.g., see Figure 2) and assembly tasks are all techniques that have been usefully employed.

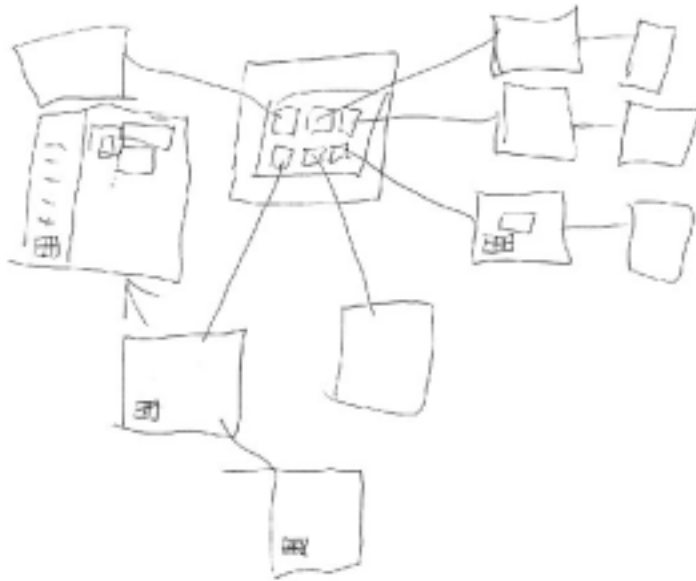


fig. 2

Clearly, this approach does not establish a new method or require that evaluations are performed differently. Rather the construct of shape draws attention explicitly to the mix of perceptual, cognitive and social variables at the interface between people and information. Process measures of navigation such as time spent on screens, buttons selected, menu options taken, back-forward movements etc. are all still taken but they are complemented with other measures as suggested here. Furthermore, analysis of navigation is placed in the context of semantic as well as physical relationships by considering the shape of information. Hence, our suggestion is to keep navigation but in a

less central analytic role than before, and more a supplement to or even an index of shape. In figure 2 for example, we would employ the user's diagram to solicit comments on organization, semantic relationships, and sense of order perceived by the user. In short, we gain all we would from a typical navigation analysis and extend it to assess semantics.

5. Conclusion

The present paper has explored the most common process metaphor in hypermedia evaluation and shown the inconsistencies and limitations inherent in its use. As an alternative, the concept of shape is offered. In practical terms this does not mean that we reject navigation measures in our evaluations but that we resist the temptation to rely on them as crucial indices of the outcome of interaction. At best, navigation measures yield insight into the efficiency with which users can move through the information space, but the relationship between this and the value of the interaction to the user in terms of information retrieved or comprehended is at best oblique. Navigation measures can yield insight into interface usability in efficiency terms only but understanding the information space meaningfully requires more than an ability to navigate it.

Thus we advocate navigation's retention as a measure but only one in a mix of measures needed to gain the full impression of a hypermedia's worth. By subsuming it under the umbrella term 'shape' we seek to establish an appropriate context for performance measures to be taken and for re-design options to be considered. Thus, we can consider research at the interface level to establish the form of features that aid users locating themselves and moving through the information space. We are strongly of the view that within this framework, longitudinal studies of users' interactions with digital documents or sites are needed to determine how well the physical metaphor holds up to learning the organization of digital spaces. However, as far as understanding the true utility of hypermedia systems, the concept of shape demands we focus on the evolution of semantic knowledge of content which, while it may be influenced by and partly rest on navigational knowledge, is much more than just a sense of organization and requires integration of meaning and form in a manner that is guided by socio-cultural forces.

Shape remains a somewhat elusive construct and we recognize our own limitations in attempting to extract it for analysis, however we believe evidence for its existence is strong and its pragmatic utility is clear. Future research efforts must concentrate on developing a reliable and valid means both of extracting users' conceptualizations of shape and providing designers with the tools for applying shape characteristics to their information spaces.

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