The world has glimpsed a subset of hypermedia functionality and its potential for structuring and accessing information through the recent surge in World-Wide Web (WWW) activity. Yet, we lack guidelines and tools to design and develop hypermedia applications. This is especially true for commercial scale systems which involve frequently changing information. Without such design guidelines and tools, the ever-growing network of interlinked applications is becoming increasingly spaghetti-like and hard to maintain. ■ The contributions in this special issue address the concerns of authors who design specific applications and system developers who design hypermedia authoring environments. The issue discusses ideas, puts forwards guidelines, proposes tools and elaborates on a number of important hypermedia design topics. It also offers choices. By illustrating different paradigms for hypermedia, the articles and sidebars show designers options for representing information beyond those typically found, in Toolbook, HyperCard, and the WWW, among others.

Designing

Hyper

media

Applications

M i c h a e l   B i e b e r
T o m á s   I s a k o w i t z

Guest Editors

n order to provide readers a first-hand experience of hypermedia, we have conceived and developed a WWW version of this special issue to complement the hardcopy you hold in your hands. The box describes the hypermedia version to be found through URL http://www.acm.org/siglink/.

Why hypermedia?1 It is the science of relationships. It concerns structuring, presenting, and giving users direct access to the content and interconnections within an information domain. Hypermedia functionalities—such as navigation (browsing, "blazing trails'' [1] and backtracking), annotation, and information overviews—enhance applications.

Perusing the related special issues that have appeared in *Communications* since July 1988, and the ED-Media, HICSS,2 and ACM Hypertext and ECHT conferences, reveals a diverse range of applications including environments for authoring papers collaboratively, decision support, document management, documentation, educational and corporate training, financial benchmarking, software engineering, and team collaboration. While most people have been introduced to hypermedia via the WWW or Apple's HyperCard system, the concept was first described by Vannevar Bush in 1945 [1]; and Ted Nelson coined its terminology in the 1960s while Doug Engelbart was constructing the first fully functional hypertext systems. Today, hypermedia is, in many ways, a proven technology.

What's so special about *hypermedia design*? First, hyper-media applications involve many different components, such as navigation, user-interface, content storage and existing preparation. Second, as a consequence, data models such as data flow diagrams, entity-relationship (E-R) diagrams, and object-oriented hierarchies cannot represent the design intricacies of hypermedia applications encompass. Third, as many of today's WWW pages will attest, many hypermedia developers have little experience incorporating hypermedia into their designs and implementations effectively. They also have little experience in evaluating hypermedia systems. Thus, there is a clear need to address a number of important issues in the area of hypermedia design.

We begin the special issue with formal design methodologies. Until the development of Garzotto, Paolini and Schwabe's HDM [3], no formal design data model targeted specifically for hypermedia applications existed. The article by Isakowitz, Stohr and P. Balasubramanian contributes the first full hypermedia design methodology, Relationship Management Methodology (RMM). The article describes the principal aspects of RMM and illustrates its use via a sample application. The sidebar by V. Balasubramanian, Ma and Yoo further demonstrates the utility of RMM, describing its use in developing ACM SIGLINK's LINKBase system (through which the electronic version of this special issue is also reachable). Schwabe and Rossi's sidebar complements Isakowitz *et al.*'s article, by presenting an alternate design methodology based on object-oriented modeling.

The article by Jocelyne and Marc Nanard contributes to our understanding of the design process. Instead of rigidly following the sequential steps prescribed by formal methodologies, the Nanards focus on the oft-neglected human factor. Their insights yield important consequences for developers of hypermedia authoring environments on how to support prototyping and seamless movement among design stages, allowing authors extensive freedom in designing applications.

Next, we turn to guidelines specifically for hypermedia authoring. Thüring, Hannemann and Haake contribute a set of design principles solidly grounded in cognitive principles. While their guidelines are illustrated in the multiwindowed SPI environment, the sidebars by Paul Kahn and by V. Balasubramanian *et al.* demonstrate that the issues raised and resulting principles also apply to other environments such as the WWW. Thüring *et al.*'s principles are as important for authors as for developers of hypermedia environments.

Developing robust hypermedia applications requires effective evaluation. Garzotto, Mainetti, and Paolini contribute a set of heuristics for evaluating deployed hypermedia systems. Moreover, we believe they also would serve as valuable guidelines for appli-

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It's one thing to read a work about hypermedia; it's another to experience it through hypermedia. We have placed this special issue's opening statements, six articles, and 10 sidebars on the WWW for you. Our authors have crafted over 150 links among their contributions, most with labels explaining the interrelationships they capture. Many links are at the sentence level, providing a degree of specificity unavailable in this printed version. We also experimented with link appearances—you'll have the option of viewing link labels in several different formats. We have included five kinds of labeled links: to text, figures, footnotes, citations and external works on the WWW. When available, citation links lead to article abstract's in ACM SIGLINK's LINKBase bibliographic system. We hope the electronic version brings the special issue's discussions to life for you, and we welcome your feedback.

The WWW version was developed with the following assistance: Sajeev Joseph of the New Jersey Institute of Technology (NJIT) programmed much of its infrastructure with technical assistance from V. Balasubramanian of Hoffmann-La Roche. Rong-Shyan Chen and Chao-Min Chiu of Rutgers University spent several person-weeks converting the issue's works for the WWW and manually inserting each link. We are extremely grateful for their skill and endurance. —*Michael Bieber and Tomás Isakowitz*

cation developers. The concepts of richness and readability they discuss not only reinforce Thüring *et al.*'s techniques for orientation and coherence, they also help the designer evaluate possible trade-offs between strict adherence to guidelines and artistic license. Scott Johnson's sidebar, in turn, provides insight into Garzotto *et al.*'s article by describing an automated tool for evaluating hypermedia applications.

Marshall and Shipman discuss authoring in spatially oriented hypermedia environments. Authors should consider spatial hypertext as a powerful alternative to the traditional node- and link-based hypermedia seen in most systems and discussed in the other feature articles in this issue. Spatial relationships may be left implicit. In addition, authors do not have to commit to a structure and its enforced consistency in advance. One could view this as an excuse to bypass the guidelines proposed in other articles; alternatively, time may show that the best spatial applications evolve to a state consistent with these guidelines. Dieberger and Bolter's sidebar discusses spatial hypermedia from other vantage points, considering the intrinsic structure within a "hyperspace," alternate representations and consequences for navigation.

The article by Bieber and Kacmar concerns a range of application domains little addressed in hypermedia circles: computation-oriented applications. While applications which calculate or otherwise generate information dynamically at run-time constitute a major portion of an organization's systems today, analysts and end-users of these systems rarely benefit from hypermedia functionality. Bieber and Kacmar use a geographic information system to illustrate design issues when augmenting a computational system with hypermedia. This article should help convince software developers that it is indeed possible to incorporate hypermedia functionality into computationally oriented applications.

A number of sidebars presented in this issue address additional design aspects. Hugh Davis discusses the internal representation of links in hypermedia systems. Different approaches inherently enable different levels of system support for authors. This discussion may help authors determine what kind of authoring environment to employ, based on the ramifications of this important system-level design choice.

The sidebars by Streitz and by Schnase *et al.* address aspects of distributed collaboration. Streitz focuses on various levels of support that hypermedia environments can provide hypermedia design teams. Schnase *et al.* describe unique challenges developers and authors face in a heterogeneous, mobile hypermedia environment.

Furuta and Stotts present an alternate model of browsing along with a unique authoring technique. Authors design a progression of state changes, in which link traversal is akin to process execution. This alternate view of hypermedia authoring demonstrates yet another option open to authors and developers when choosing the best way to support a particular application.

Uffe Kock Wiil's sidebar does not address design *per se*, rather it describes the infrastructure that Hyperform, and similarly other hyperbases, can provide developers so they do not have to implement all hypermedia support entirely from scratch.

Finally, we are honored with contributions from two major pioneers in the hypermedia field. Ted Nelson describes transclusion, the central feature embedded within the design of the Xanadu paradigm. Despite much progress, current hypermedia environments still lack support for this fundamental relationship. Doug Engelbart describes features central to the design of an open hyperdocument system, which he believes will constitute the core of organizational information systems in the future. We open this special issue with both pieces as beacons of hypermedia's potential to support people, teams, and organizations [5, 6].

As the current generation of hypermedia systems comes of age, options, guidelines and techniques for robust design and development become increasingly critical. We truly hope the works we present in this special issue contribute to the healthy growth of the hypermedia field and its applications.

Acknowledgments

Readers further interested in hypermedia design may wish to obtain the proceedings of the recent International Workshops on Hypermedia Design [2,4]. ◪

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[1]We do not distinguish between hypertext and hypermedia.

[2]The Hawaii International Conference on System Sciences has sponsored a subtrack on "Hypermedia in Information Systems and Organizations" since 1993.

[3]We hope readers will also devote countless hours to enjoying this special issue.