AM+A

Aaron Marcus and Associates, Inc.
1196 Euclid Avenue, Suite 1F
Berkeley, CA 94708-1640, USA

Email: Aaron.Marcus@AMandA.com
Tel: +1-510-601-0994, Fax: +1-510-527-1994
Web: www.AMandA.com

Integrated Information Systems and Information Design

Date and Status

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Contact Information

Mr. Aaron Marcus, President
Aaron Marcus and Associates, Inc. (AM+A)
1196 Euclid Avenue, Berkeley, CA 94708-1640, USA
Tel: +1-510-601-0994, Fax: +1-510-527-1994
E-mail: "Marcus, Aaron" <Aaron.Marcus@AMandA.com>
Web: www.AMandA.com

Abstract

The article explains the nature of integrated information systems (IISs), that is, complex, computer-mediated, interactive systems of information content that are accessed by their user-interfaces, which, in turn, are artifacts of metaphors, mental models, navigation, interaction, and presentation techniques. Information designers are professionals who can design the usability, usefulness, and appeal of such IISs. The author presents a prototype educational curriculum to assist such professionals and encourages its adoption by universities and design schools.

Keywords

curriculum, design, experience, interface, user, visualization

Introduction

Information designers comprise those professionals concerned with analyzing, evaluating, and designing (including both conceptual and perceptual, both textual and visual) solutions to challenging tasks of informational communication (as defined, for example, by Moles (Moles)). Information designers have much to contribute to the development of computer-based, integrated information processing and display systems, although not enough of these professionals are involved. Information designers are sometimes constrained by their understanding of key principles, terminology, and issues that are part of information technology. The objectives of this article are to introduce the concept of integrated information systems to information designers, to outline how these professionals can contribute their skills, and to summarize the benefits of such collaboration. In addition, the article outlines an educational curriculum that would contribute to design schools offering information design and visualization to their students. While a complete discussion of the subject is beyond the scope of this journal, the author seeks to summarize essential elements in this description.

Integrated information systems (IISs) are defined to be those computer-based systems for information processing that semi-automatically organize the contents being displayed on interactive screens; provide navigation through that organization as well as contents; determine appropriate verbal, typographic, graphic, and sonic formats; and display them in an interactive system that allows users to adjust what they see, hear, or touch. One of the most salient factors is the importance of systematic solutions to communication challenges, i.e., not a primary emphasis on ad-hoc and purely intuitive solutions.

Such systems typically comprise computers (including smartphones or embedded products/services inside of others, such as vehicle systems (see, for example, Marcus, 2004)), software (applications and operating systems), databases, and telecommunication networks. The general human-computer circumstances of human-computer interaction and communication are called a *user interface*, and the overall characteristics encountered by users is called the *user experience*. The user interface may encompass visualization as well as sonification of content.

Some examples that the author's company has produced appear in the accompanying figures. Many of these projects have been explained in great detail in case-study articles cited in the Bibliography.

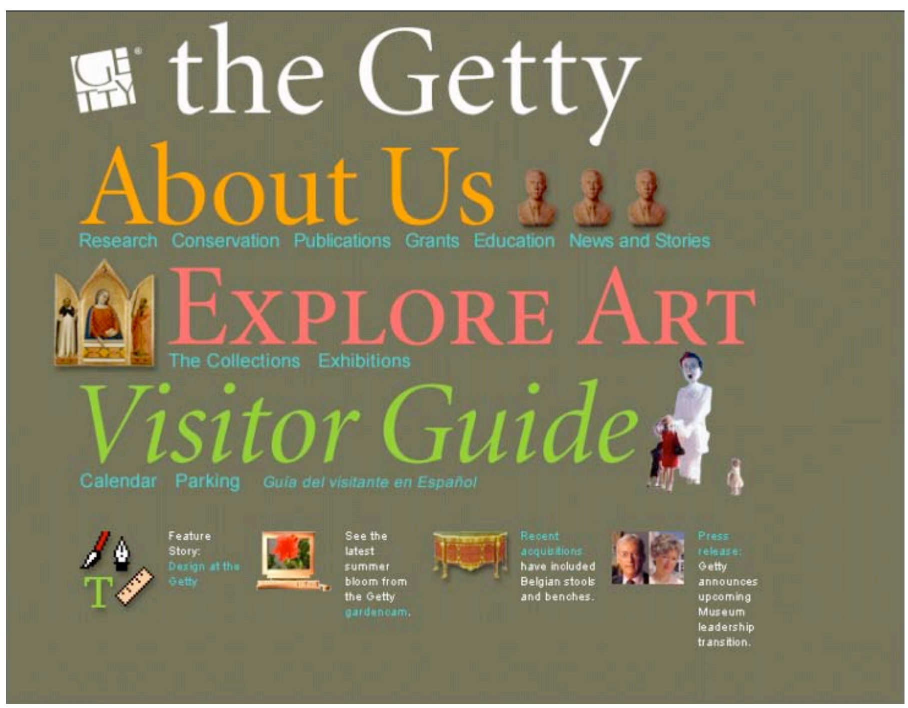

Figure 1: J. Paul Getty Trust, Getty Museum Website redesign, home page, 2000, www.getty.org. Aaron Marcus and Associates, Inc. (AM+A) designed the "look and feel" of the user-interface design to integrate approximately half-a-dozen independent Websites into a coordinated system that appealed more to the diverse audience of the greater Los Angeles community. The colors and layout were more playful than the previous versions.

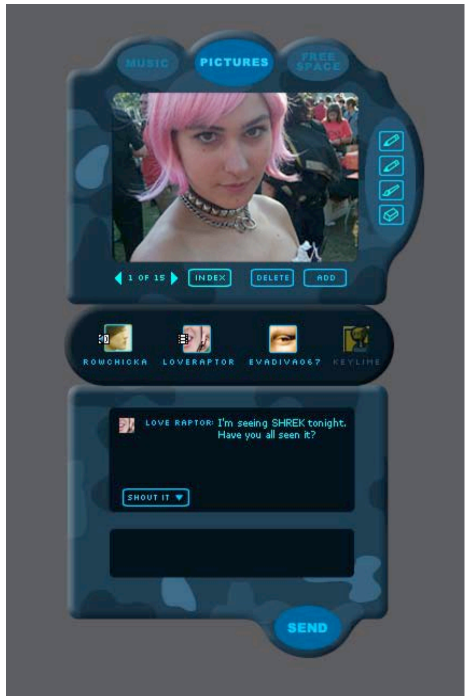

Figure 2: Microsoft, Three Degrees Web-application user-interface prototype, 2002. AM+A designed prototypes for one of Microsoft's first user-centered development projects. This file-sharing and messaging application targeted teenagers specifically. The design used shapes and images suitable for the target market.

Figure 3: Cogito Learning Media, Eye-to-Mind computer-based training (CBT) product, 1999. AM+A designed an award-winning, innovative user-interface to attract college faculty and students to summaries of entire disciplines as subject-matter. The contents included text, video, music, narration, computer animations, scientific and technical imagery, and photography combined into a design that was very different from conventional CBT products and slightly mysterious to engage the viewer.

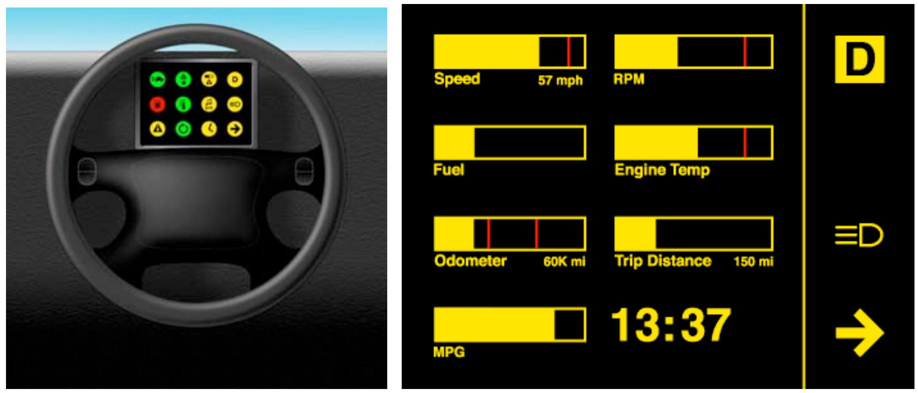

Figure 4: Prototype redesigned vehicle dashboard using only pictograms/ideograms, 2002. AM+A experimented with the design of a dashboard that used only icons and that used other innovative approaches to information-visualization, such as charts. Examples appear in (Marcus, 2002).

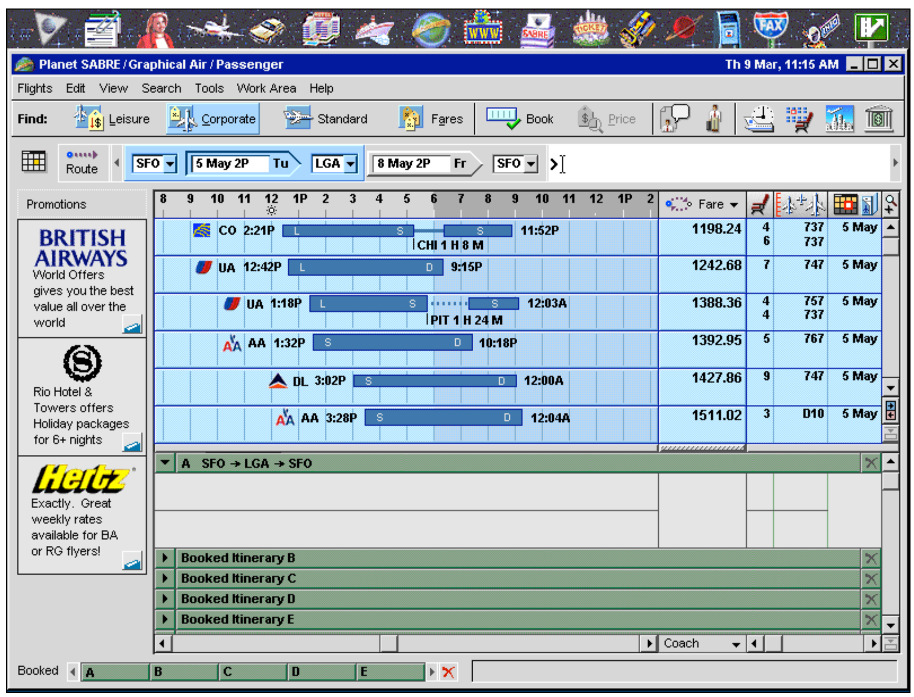

Figure 5: SABRE, near-final prototype redesign of the air travel booking screen, for an air travel reservation system, 1994-2000. An example of a complex information system targeted to one-third of the world's travel agents in one of the world's largest extranets, containing some 40 terabytes of data. AM+A worked on the project over a six-year time frame and involved more than 20 user tests of revised versions of the design. Many innovations in information visualization appeared, such as the time chart that visualized plane departures and arrivals. A case study of the redesign of the user-interface project appears in (Marcus, 2001).

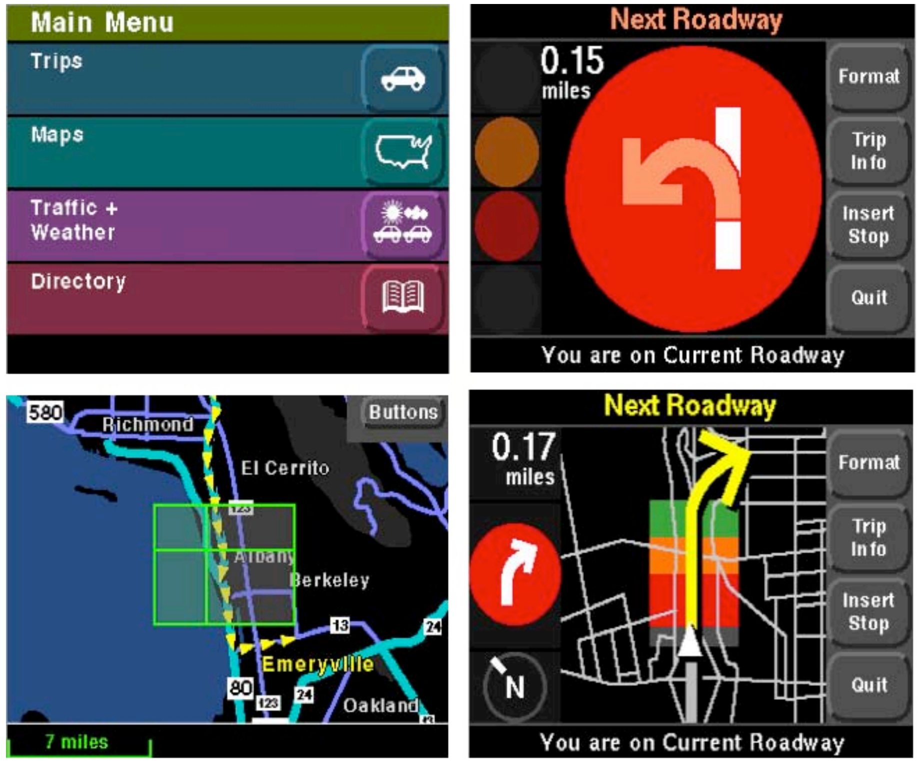

Figure 6: Motorola In-Car Vehicle Navigation System user-interface design, 1989-92. Near-final prototype screens of a complex global-positioning system product that was about five years ahead of competitive products in the USA. The information designers' (the author's firm, AM+A) concerns about the mental model caused the development team to redesign the two opening screens of 18 selections to a single screen of five selections. A case study of the design of the user interface appears in (Marcus, 2000).

Figure 7: Samsung, prototype smartphone design concepts, 2000. Sample of more than 100 design concepts of advanced phones intended for about three years in the future for North America, designed by AM+A for Samsung's user-interface design group in Korea. Note the use of a large touch-screen display similar to that which eventually appeared in the Apple i-Phone about seven years later. A case study of the project appears in (Marcus, 2005d).

Figure 8: Hewlett-Packard, Halo "telepresence" system, www.hp.com/halo, about 2006. AM+A interviewed executives before recommending designs for the control screen of the first commercial version of the telepresence system just emerging from HP Lab in 2004. One year later, AM+A carried out usability tests of the second version of the system at meetings occurring in four cities simultaneously. The user tests helped to pinpoint "bugs" in the user-interface design caused primarily by lack of consistency.

Information designers now are involved increasingly in the design of global, cross-cultural solutions to the UX of IISs. The development of these systems involves extensive analysis and design, skills that are typically considered part of an information designer's professional education. However, these are only two tasks of a more complete user-centered development process (Marcus, 2005a). The mission of information designers working with IISs is to shape the way technology affects everyday life through effective and compelling, information-oriented user interfaces and knowledge visualization, where knowledge may be defined as significant patterns of information with action plans (see, for example, Marcus, 2002). Successful user-interface design and knowledge-visualization design helps people make smarter decisions faster: anyone, any time, any place, any technology, any market, and any subject matter.

UI Development Process and UI Components

Let's look for more carefully at the *user-interface development process* and at the *components* that result from this process. The essential tasks comprise the following. Each appears with typical artifacts involved in the task. These are the verbs or action words of the information designer working with IISs:

- **Plan**: brainstorming, envisioning, strategy,
- **Research:** technology, design issues, tactics
- **Analyze:** user profiles, use scenarios, prototypes
- **Design**: content, applications, brand, "storyselling"
- **Implement:** scripting, coding, final production
- **Evaluate:** focus groups, user tests, heuristic evaluations
- **Document:** guidelines, patterns, specifications
- **Train:** courseware, tutorials, mentoring
- **Maintain:** continuing, ongoing client relations and system improvements

User-Interface components refer to the interim and end results of the processes, the artifacts, or nouns. What is being analyzed? What is being designed? The following are the primary components:

- **Metaphors:** Essential concepts in words, images, sounds, touch
- **Mental Models**: Organization of data, functions, tasks, roles of people at work or play, static or mobile
- **Navigation:** Movement through mental models via windows, dialogue boxes, buttons, links, etc.
- **Interaction:** Input/output techniques, feedback, overall behavior of systems and people
- **Appearance:** Visual-verbal, acoustic, tactile qualities

A subset of the components are concerned specifically with information visualization and sonification. Classical examples of visualization are the tables, forms, charts, maps, and diagrams by which one can visualize complex structures and processes in abstract or representational forms. Many innovative techniques have been invented in the past few centuries. Recent examples include the hyperbolic browser invented at the Xerox Palo Alto Research Center (PARC) by Lamping and Rao (Lamping and Rao, 1996), Tree Maps™ invented at the University of Maryland by Shneiderman and his colleagues (Johnson and Shneiderman, 1991), Parallel Coordinates invented at IBM by Inselberg (Inselberg), and the N-Vision system of multiple embedded Cartesian co-ordinate systems invented at Columbia by Feiner and Beshers (Feiner and Beshers, 1990).

Information visualization techniques are able to achieve significant improvements in comprehension, memory, and decision-making. For example, parallel coordinates has been shown to improve the ability of air traffic controllers to predict near collisions upon viewing flight data. AM+A has carried out a design project to improve program code visualization. Independent human factors testing showed that the designs improved comprehension of code by novice programmers by 20 per cent (Baecker and Marcus, 1990).

Examples of the use of some of these information-visualization approaches appear below:

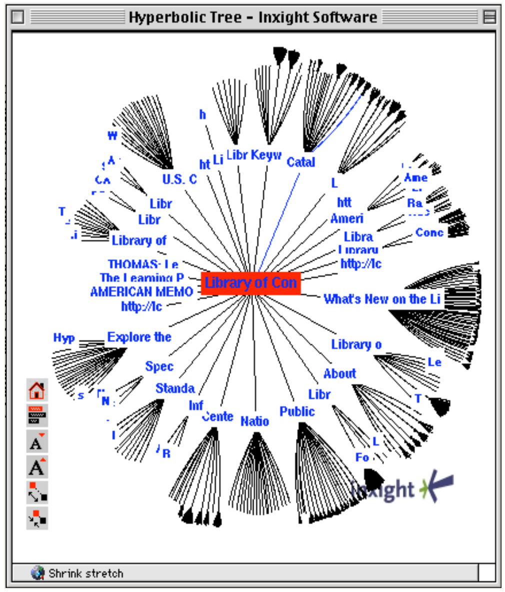

Figure 9: An example of a hyperbolic browser, about 1996, which was developed at Xerox PARC, but commercialized by InXight Systems, Inc., now part of SAP. The browser makes it easier to navigate very large tree structures of information.

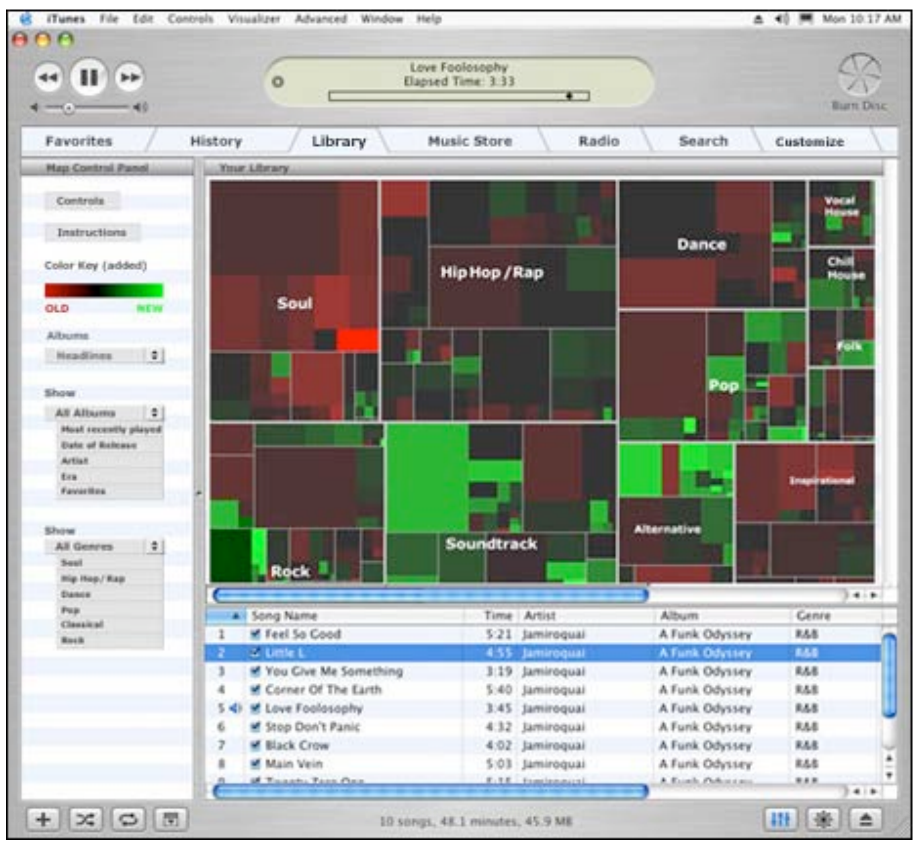

Figure 10: An example of Tree Maps, a kind of Venn or Euler diagram of a large collection of information, as incorporated into a prototype music searching application user-interface designed by AM+A called My Music, in which all of one's music collection might be viewed and managed within a single screen image, 2002.

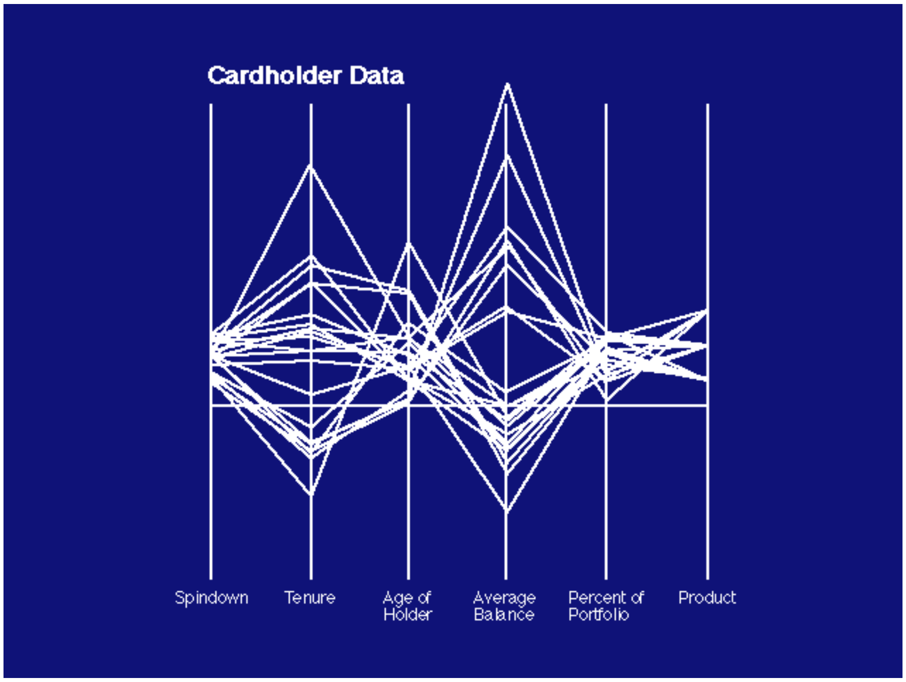

Figure 11: An example of the parallel coordinate systems, which "breaks apart" the Cartesian axes familiar to most chart users, and places them in parallel. AM+A designed a prototype user-interface to show data for multiple dimensions of financial data, 1994. This technique has been shown to be effective for enabling viewers to track complex patterns in multi-dimensional data.

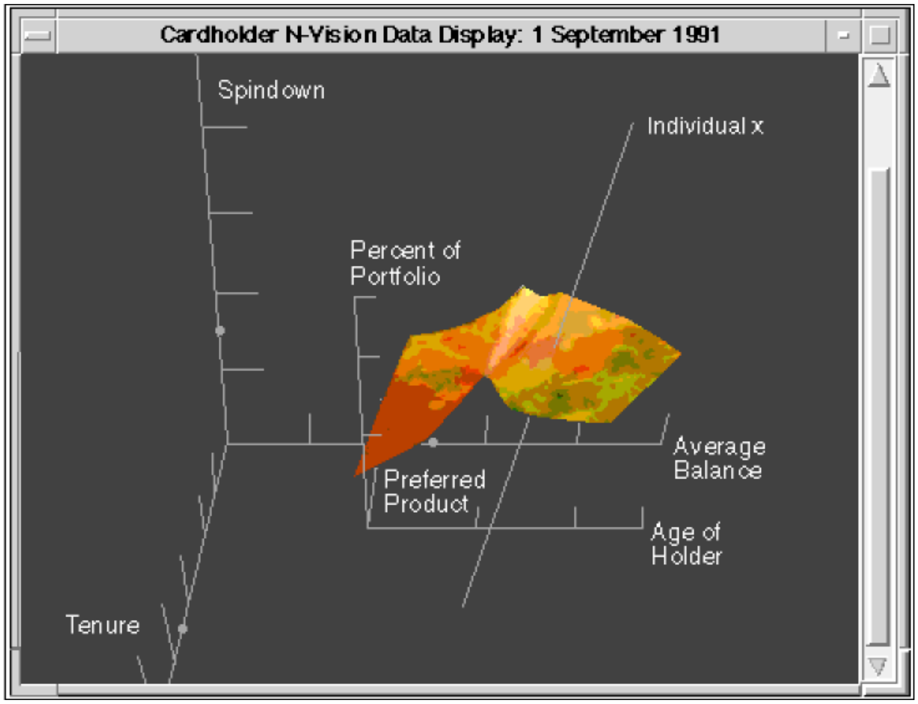

Figure 12: An example of N-Vision simulating the display of energy information in multi-dimensional, nested set of Cartesian coordinate axes within a user-interface prototype designed by AM+A, 1994.

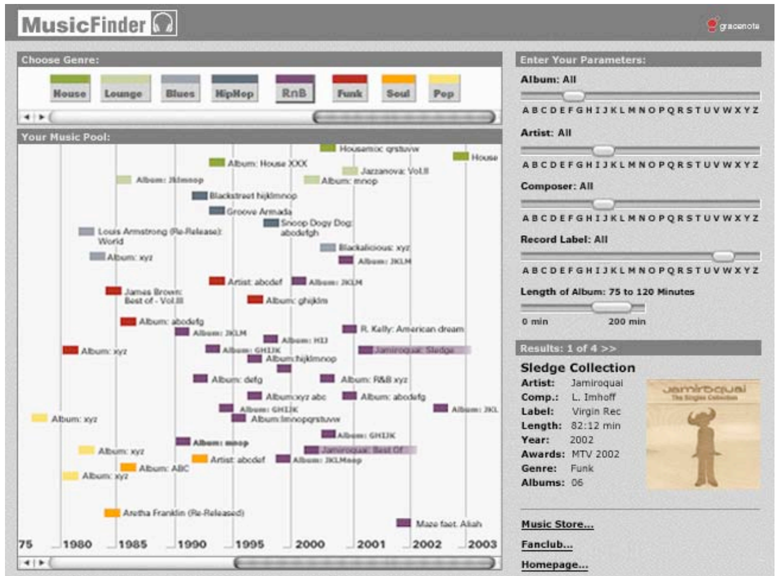

Figure 13: An example of a music visualization technique. AM+A designed Music Finder in 2003 based on the visualization system called Film Finder developed at the University of Maryland. The intention was to make it easier to track patterns in a large collection of music files displayed on a single screen.

Figure 14: An example of music visualization using geographic location. AM+A designed My Music Buddies prototype in 2003 to locate people listening to the same music and to connect with them.

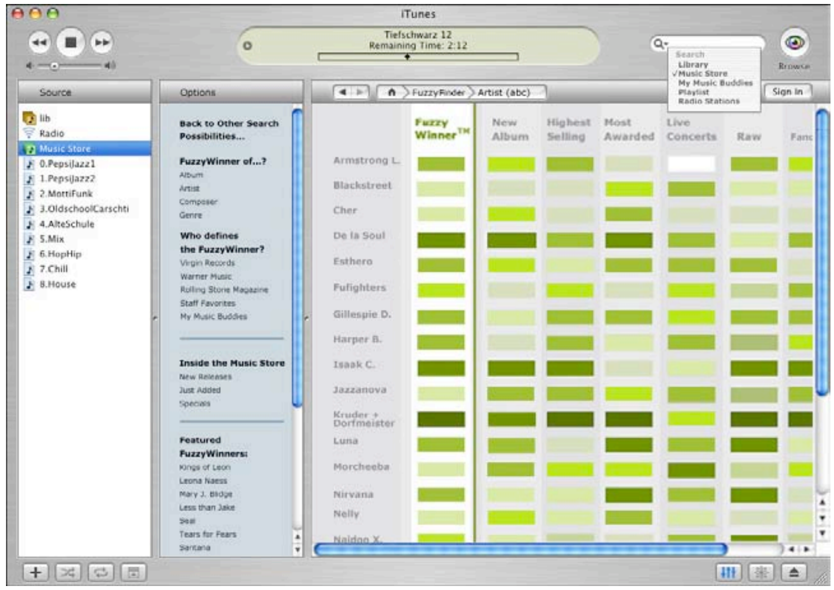

Figure 15: An example of music visualization using fuzzy logic and fuzzy math, which was pioneered by Lofti Zadeh (Zadeh). AM+A designed this prototype in 2003, which enabled viewers to quickly locate a "winner" among several candidates and to simultaneously view the factors leading to the winning entry.

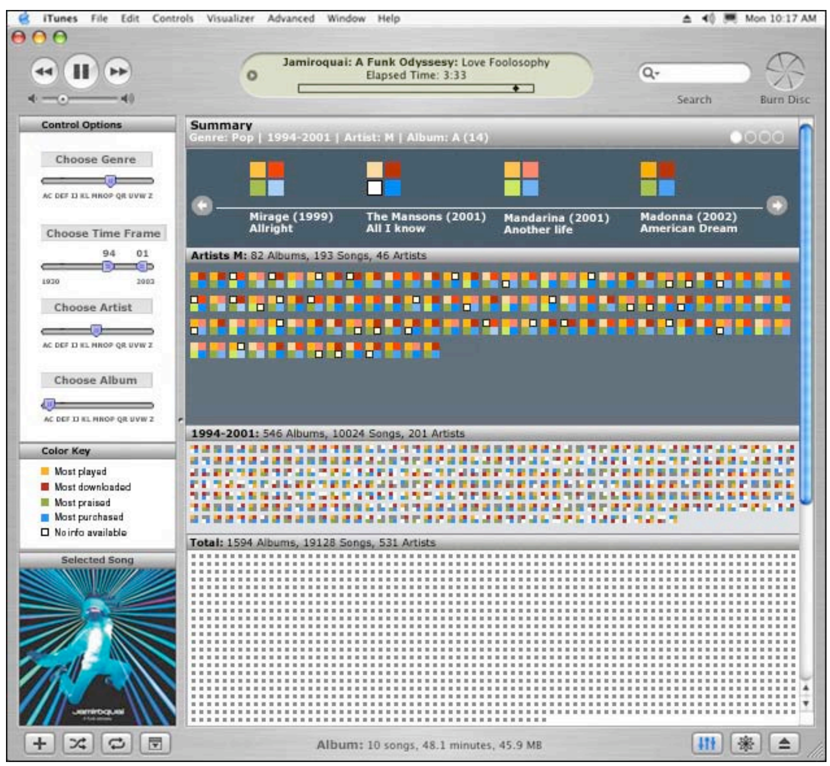

Figure 16: An example of music visualization using "musical pixels" or "muxels" that play portions of music when they are "located" by a cursor. AM+A designed this prototype in 2003, which sought to give viewers a way to quickly navigate among many sounds or pieces of music.

What is the return on investment for involving information designers and other usability-oriented professionals in the design of IISs? Fortunately, the savings of time and money in development, the savings of money and time by users who are able to find and understand information more easily, and the greater satisfaction achieved, have all been explored in the literature. These results are handily summarized in (Marcus, 2005b).

In the past decade, the user-interface designers, graphic designers, ethnographers, and anthropologists in design, among others, have focused on user-experience design. The enlarged scope of objectives for products and services go beyond making them simply usable. Usability is defined by ISO 9241-11 (ISO) as effectiveness, efficiency, and satisfaction. Beyond this basic objective is making products and services useful and appealing. Usefulness means well-suited for the user's needs and wants (both conscious and unconscious) and the user's context (physical, emotional, cultural, etc.) Appeal means a combination of delight, fun, engagement, in short, an emotional metric, that goes beyond the more ergonomic measure of usability. Experience covers all "touch points" where stakeholders encounter the product, company, and brand. Stakeholders include not only customers (buyers or direct users), but indirect users (who may be nearby or impacted by the usage), as well as groups within the development company or organization (engineering, marketing, business, manufacturing, distribution), investors, journalists, etc.

The author has identified six essential "user-experience spaces" for products and services. These spaces are visualized in the diagram of Figure 17 and are explained in (Marcus, 2004). Each space represents a significant growth area for new products and services across all platforms of hardware and software.

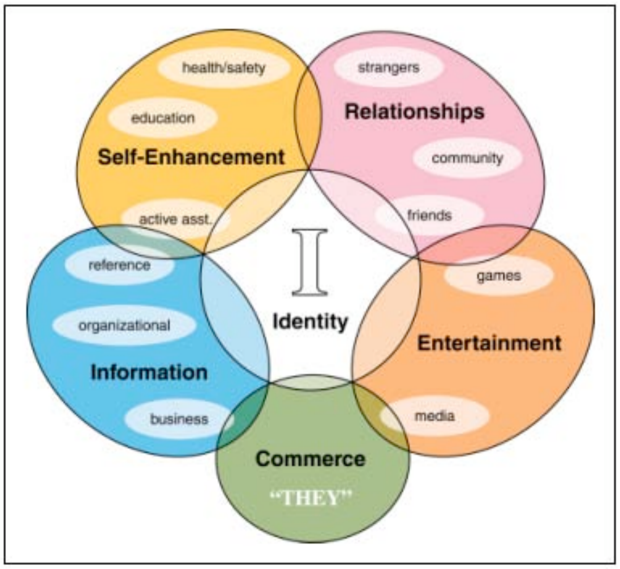

Figure 17: Six user-experience spaces. Each represents a significant, orthogonal development area for IISs. Each segment represents a large area for development of new products and services.

Experience design has focused emphasis on new evaluation techniques, such as ethnographic analysis, video analysis, remote testing, and contextual analysis, as well as the traditional techniques of focus groups, tests in usability labs, and interviews. The objective is to discover hidden, sometimes "non-rational" factors in motivation and behavior, and socio-cultural contexts of the users. One of the most challenging areas of development has been to recognize the importance of cultural differences and similarities in how people use IISs. The role of culture the design of user interfaces is explained in (Marcus, 2006; Marcus, 2007). Information designers gradually are taking into account how culture affects usability and even the design of classical information-visualization techniques.

How Should ISS Professionals be Educated?

Decades ago, information designers typically were educated in complex typographic layout and the design of pages, posters, or exhibits, and, for the most part, non-interactive signs/symbols, charts, maps, and diagrams, as well as an introduction to human factors, statistics, and scientific bases for legibility and readability. In the past two to three decades, organizations and curricula have arisen that focus on computer-based, interactive, integrated information systems.

Among other organizations, the following have emerged as cross-disciplinary leaders in the emerging field of IIS:

- American Institute of Graphic Arts (AIGA), especially its Center for Cross-Cultural Design:
- Association for Computing Machinery's Special Interest Group on Computer-Human Interaction (SIGCHI): www.sigchi.com
- Human Factors and Ergonomics Society, especially its HCI-oriented special interest groups: www.hfes.org
- International Institute for Information Design: www.iiid.net

- Society for Technical Communication, especially its CHI-oriented special-interest groups: www.stc.org
- Usability Professionals Association: www.usabilityprofessionals.org

Specialized organization or SIGs have emerged in many vertical markets, such as banking, education, finance, government, healthcare, insurance, medicine, and travel. Localized organizations and chapters of the above-mentioned organizations have also emerged, such as AIGA/Beijing, CHI/Brazil, or UPA/Moscow. Many of these organization offer industry conferences that provide extensive tutorial/workshop programs to update professionals training in the latest principles and techniques.

Over the past two-three decades, university and design-school faculty have succeeded in building new curricula that respond to industry and customer needs. In some cases, they now offer master-degree and PhD programs with specialized concentration. Of note in the USA are the Illinois Institute of Technology's Institute of Design in Chicago, which emphasizes design planning, or Carnegie Mellon University's Human-Computer Interaction (HCI) Program in Pittsburgh. So-called "i-schools" (information schools) have arisen around the world, *e.g.*, in the USA at the University of California in Berkeley and the University of Texas in Austin, or in the UK at the London College of Communication. A variety of design and technical universities worldwide offer the requisite graduate education. Examples include the Tama Art University in Tokyo, the Polytechnic University in Hong Kong, the Swinburne University of Technology in Australia, the Chinese Academy of Fine Arts and Tsinghua University in Beijing, and elsewhere too numerous to mention.

Core Curriculum for IIS

The feasibility of a core curriculum for information design in relation to IIS is evidenced by the existence of several competing *Handbooks of Human-Computer Interaction* (Helender *et al*, 1997; Jacko and Spears, 2002). Based on these books, the author has prepared a preliminary course curriculum (Marcus, 2005) based on merging the two existing Handbooks, plus topics from the literature of design patterns and user-experience design. The following list is useful for information-design students and professionals interested in developing their careers further, and for faculty considering enhancing their curricula.

Issues, Theories, Models, and Methods in HCI

- The Evolution of HCI: From Memex to Bluetooth and Beyond
- Human-Computer Interaction: Background and Issues
- Mental Models and User Models
- Information Visualization
- Model-Based Optimization of Display Systems
- Task Analysis, Task Allocation and Supervisory Control
- Models of Graphical Perception
- Using Natural Language Interfaces
- Virtual Environments as Human Computer Interfaces
- Behavioral Research Methods in Human-Computer Interaction

- Perceptual-Motor Interaction: Some Implications for HCI
- Human Information Processing: An overview for Human-Computer Interaction
- Emotion in UI Development
- Cognitive Architecture
- Modeling Humans in HCI
- Branding, Persuasion, User Experience, Patterns

Design and Development of Software Systems

- How to Design Usable Systems
- Participatory Practices in the Software Lifecycle
- Design for Quality-in-use: Human-Computer Interaction Meets Information
- Systems Development
- Ecological Information Systems and Support of Learning: Coupling Work Domain Information to User Characteristics
- Task Analysis's Role in the Design of Software
- Ethnographic Methods: Use in Design and Evaluation
- What do Prototypes Prototype
- Rapid Prototyping
- Scenario-Based Design

HCI Fundamentals

- Multimedia User Interface Design
- Visual Design Principles for Usable Interfaces
- Multimodal Interfaces
- Adaptive Interfaces and Agents
- Network-Based Interaction
- Motivating, Influencing, and Persuading Users
- Human Error Identification in Human Computer Interaction
- Design of Computer Workstations

Designing User Interfaces For Diverse Users

- Genderizing HCI
- Designing Computer Systems for Older Adults
- HCI for Kids
- Global / Intercultural UI Design
- Information Technology for Cognitive Support
- Physical Disabilities and Computing Technologies: An Analysis of Impairments
- Perceptual Impairments and Computing Technologies

UI Issues for Special Applications

- Documentation: Not yet implemented but coming soon!
- Information Visualization
- Groupware and Computer Supported Cooperative Work

- Online Communities: Sociability and Usability
- Virtual Environments
- User-Centered Interdisciplinary Design of Wearable Computers
- A Cognitive Systems Engineering Approach to the Design of Decision Support Systems
- Computer-Based Tutoring Systems: A Behavioral Approach
- Conversational Speech Interfaces
- The World-Wide Web
- Information Appliances

User-Interface and Screen Design

- Graphical User Interfaces
- Metaphors: Their Role in User Interface Design
- Direct Manipulation and Other Lessons
- Human Error and Use Interface Design
- Screen Design
- Menus
- Color and Human-Computer Interaction
- How Not to Have to Navigate Through Too Many Displays

Multimedia, Video, and Voice

- Hypertext/Hypermedia
- Multimedia Interaction
- A Practical Guide to Working with Edited Video
- Desktop Video Conferencing
- Design Issues for Interfaces Using Voice Input
- Designing Voice Menu Applications for Telephone
- Auditory Interfaces
- Applying Speech Synthesis to User Interfaces

Programming, Intelligent User-Interface Design, and Knowledge-Based Systems

- Expertise and Instruction in Software Development
- End-Use Programming
- Interactive Software Architecture
- User Aspects of Knowledge-based Systems
- Paradigms for Intelligent Interface Design
- Knowledge Elicitation for the Design of Software Agents
- Decision Support Systems: Integrating Decision Aiding and Decision Training
- Intelligent Vehicle Highway Systems

Input/Output Devices, Human Factors/Ergonomics, and Design of Work

- Input Technologies and Techniques
- Keys and Keyboards
- Pointing Devices

- Conversational User-Interface Technologies
- Visual Displays
- Haptic User Interfaces
- Non-speech Auditory Output
- Ergonomics of Computer-Aided Design Systems
- Design of the Computer Workstation
- Work Injuries on The Operation of Visual Display Terminals
- International Ergonomics HCI Standards

Application Domains

- E-Commerce UIs Design
- The Evolution of HCI during the Telecommunications Revolution
- Government Roles in HCI
- UI Development in Health Care, Finance, and Travel
- A Framework for Understanding the Development of Educational Software
- Understanding Entertainment: Narrative and Gameplay
- Motor Vehicle Driver Interfaces
- Human Computer Interaction in Aerospace
- User-centered Design in Games

Computer-Supported Cooperative Work (CSCW) and Organizational UI Issues

- Research on Computer-Supported Cooperative Work
- Organizational Issues in Development and Implementation of Interactive Systems
- The Organizational Context of Human-Computer Interaction
- Psychological Aspects of Computerized Office Work

Development Process: Requirements Specification

- Requirements Specification within the Usability Engineering Lifecycle
- Task Analysis
- Contextual Design
- Ethnographic Approach to Design

Design in Development

- Guidelines, Standards, and Style Guides
- Prototyping tools and techniques
- Scenario-based Design
- Participatory Design
- Unified User-interface Development

Evaluation, including Testing

- Usability Engineering Framework for Product Design and Evaluation
- User-Centered Software Evaluation Methodology

- Usability Inspection Methods
- Cognitive Walkthroughs
- Goals, Operators, Methods, and Selection (GOMS) Model for Usability Evaluation
- Return on Investment (ROI): Cost Justifying Usability Engineering in the Software Life Cycle
- User-based Evaluations
- Inspection-based Evaluations
- Model-based Evaluation
- Beyond Task Completion: Evaluation of Affective Components of Use

Managing UI Development and Emerging Issues

- Technology Transfer
- Human Values, Ethics, and Design
- Cost Justification
- The Evolving Role of Security, Privacy and Trust in a Digitized World
- Achieving compatibility in HCI design and evaluation

Individual Differences and Training

- From Novice to Expert
- Computer Technology and the Older Adult
- Universal Design: UIs for People with Disabilities
- Computer-Based Instruction
- Intelligent Tutoring Systems

Future and Conclusion

The next generation of IISs will involve a ubiquitous computing experience, in which computers are everywhere, invisible, and providing massive amounts of information. Portable devices, such wrist-top, pen-top, or mobile phone-like devices will become a primary computing and telecommunication platform. In addition, social networking services will proliferate in relation to the use of IISs, linking people to people, information, and technology more closely than ever before. Users will be able to customize their user-interfaces more extensively enabling them to make IISs fit their personal circumstances better.

These developments suggest that information designers will be even more crucial to the success of computer-based storytelling and decision-making. Breakthroughs in knowledge visualization may make it feasible for progress to be made in dealing with challenges facing world civilization, such as poverty, pollution, global warming, obesity, political conflict, etc. The author carried out one such project thirty years ago at the East-West Center, Honolulu, HI, to visualize global energy interdependence, in an audio-visual format suitable to the general public, professionals such as economists, and political leaders (Marcus, 1979). The modest success of that project in providing a useful story-telling technique for the East-West Center to explain its mission gives one hope for further such projects of combining information design, social-political information, and IISs.

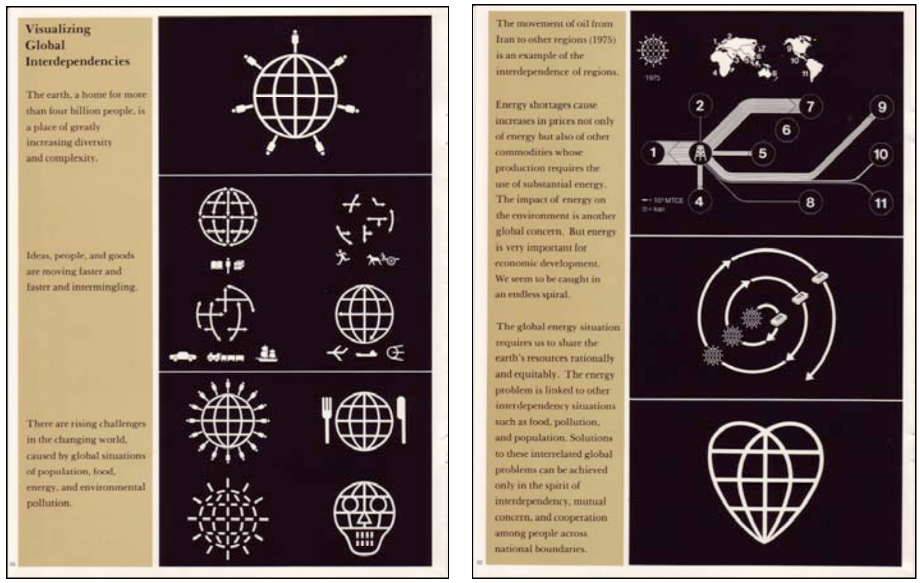

Figure 18: Example images from "Visualizing Global Energy Interdependence," a non-verbal, multi-cultural, pictographic/ideographic, audio-visual, information-visualization storytelling narrative using tables, charts, maps, and diagrams to communicate important concepts to heads of government, professionals, and the general public. A team of professional visual communicators headed by the Author and including Yukio Ota from Japan, a noted sign/symbol designer, completed this research project for the East-West Center, Honolulu, Hawaii, USA, in 1978.

Our ability to visualize and communicate important issues and to prepare the general public, professionals, and world leaders for effective action resides, in part, with the efforts of information designers to take advantage of the power of integrated information systems.

Acknowledgements

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Author Biography

Aaron Marcus, President
Aaron Marcus and Associates, Inc. (AM+A)
Berkeley, California, USA

Educated in physics from Princeton and in graphic design from Yale, Mr. Marcus studied computer programming in 1966 and became a researcher in 1967 at AT+T Bell Telephone Labs, Murray Hill, NJ., becoming the world's first graphic designer to be involved full-time in computer graphics. He programmed a prototype desktop publishing application in 1969-71 for Bell Labs, programmed virtual reality art in 1971-73 while a faculty member at Princeton, and directed an international team of visual communicators as a Research Fellow, East-West Center, Honolulu, in 1978. He exhibited his computer graphics and conceptual art work beginning in the 1960s. His works are in the collections of the Princeton University Art Museum and the Victoria and Albert Museum, London. In 1980, after teaching in universities for more than ten years, he became a Staff Scientist at Lawrence Berkeley Laboratory. In 1982, he founded AM+A. Mr. Marcus has written/co-written over 250 articles and six books, including *Human Factors and Typography* *for More Readable Programs* (1990), *Graphic Design for Electronic Documents and User Interfaces* (1992), and *The Cross-GUI Handbook for Multiplatform User Interface Design* (1994), and Mobile TV: *Content and Context* (2009). He has also published two monographs of his computer graphics and conceptual art, *Soft Where, Inc.*, Vol. 1 and 2, West Coast Poetry Review Press, Reno, 1975, 1982. Mr. Marcus continues to do user-interface design and information-visualization for computer technology, heads AM+A, is Editor-in-Chief of *User Experience*, an Editor of *Information Design Journal*, and is on the Advisory or Editorial Boards of three other journals. The National Computer Graphics Association awarded him its Industry Achievement Award in 1992. ICOGRADA included him in its International Graphic Design Hall of Fame in 2000. The American Institute of Graphic Arts named him a Fellow in 2007. The ACM/SIGCHI elected him to its CHI Academy in 2009. The Business Forms Management Association awarded him its Jo Warner Award for lifetime contribution to the forms system design profession.