# Introduction to Information Science and Technology

## Semi-Structured and Unstructured Information Systems

## Information Visualization

**Dr. Ray Uzwyshyn**, University of West Florida

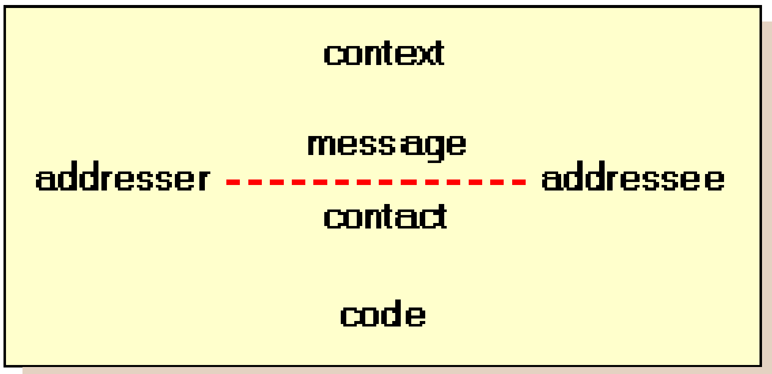
Sumerian Tablet (3000 B.C.)

By augmenting human intellect we mean increasing the capability to visualize a complex information situation. (Douglas Engelbart, *Augmenting Human Intellect*, 1956)

Visual Information Systems have longstanding antecedents. This section focuses on a fairly recent history related to digital developments, information visualization and human-computer interaction. In designing visual information systems, success is dependent on both sender and receiver, addresser and addressee. To begin with an illustrative example, how does a newborn convey information? How does a parent understand and communicate with a newborn?

A newborn infant relies on the human visual and spatio-motor apparatus for communication

In their first months, infants let out largely undifferentiated gestures and cries. Language is unfixed, largely ‘free floating’—communication predicated on social, or phatic, aspects. The entire human somatic apparatus—head, body, hands, feet, eyes, spine—participate in a communicative gestural practice to make primary needs known. A visual language between parents and child develops as a community of gestural practice. Roman Jakobson’s *Structural Model of Communicative Functions* (1963) is useful in characterizing these natal information systems.

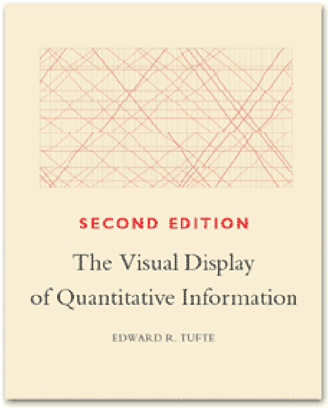



Roman Jakobson’s *Structural Model of Communicative Function* (1963)

For information visualization, the preferred mode of contact and code between addresser and addressee is defined through vision and the visual. Information visualization to a large extent poses and answers questions regarding how to best materialize complex relationships through visual methodologies.  Donald Norman has put this with regards to the digital, the pragmatic implementation of  information visualization is the first step in human-computer interaction and should naturally include all perceptual systems - auditory, spatio-temporal, motor and tactile.

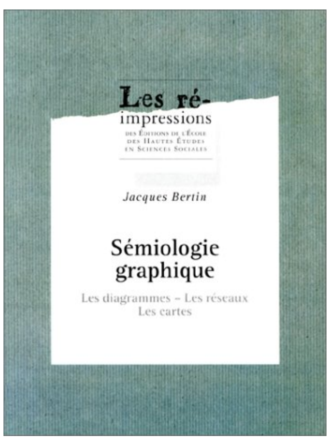
## 20th Century Visual Theoreticians

An important strand of 20th century Information visualization research begins to crystallize with John Tukey, Rudolph Arnheim, Erwin Panofsky and their surrounding school’s early explorations on visual systems, statistics, aesthetics, perception and the visual. These schools’ legacy would be more widely systematized by various later figures. For example, Edward Tufte’s important books on information visualization, *The Visual Display of Quantitative Information* and *Envisioning Information*, encourage the use of visual paradigms to augment understanding of complex relationships by synthesizing both statistics and aesthetic dimensions.




Tufte would self-publish his books which would become standards on visualization.

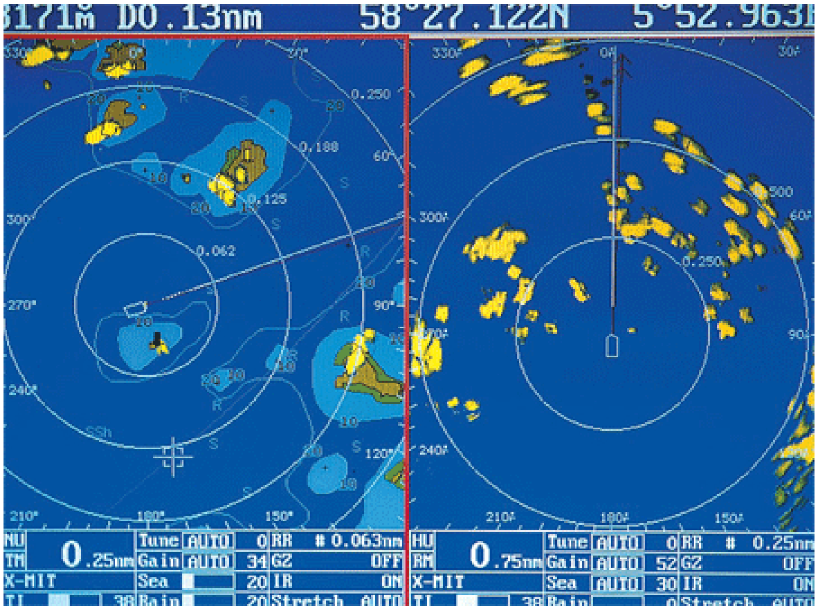
A little earlier, Jacques Bertin, the French cartographer and geographer, introduces a suite of ideas parallel to Tufte's, cogently detailed in *Semiologie Graphique*. The basis of Bertin's work is the acknowledgement that graphic tools present a set of signs and a rule-based language that allow one to transcribe existing complex relations of difference among qualitative and quantitative data.




Bertin's North America English translation *of Semiologie Graphique* did not appear until 15 years after the original 1967 publication

For Bertin and Tufte, the power of visual perception and graphic presentation has a double function, serving both as a tool for discovery and to augment cognition. Ideas emanating from the orbits surrounding these figures subsequently later influenced a generation of information system designers. To note, the sometimes overlooked visual semiological school provides room for further exploration. Although currently out of fashion, Robert Stam's, *New Vocabularies in Film Semiotics: Structuralism, Poststructuralism and Beyond,* which delineates structuralist visual taxonomies through an analysis of film grammar, would be a fertile unexplored avenue.

## Computing and Information Visualization



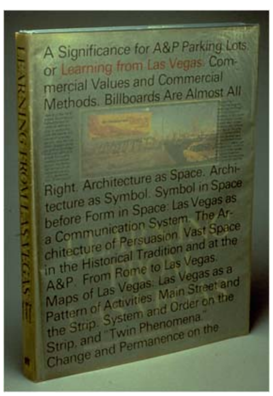

Waypoint Color Synchronized Dual Screen Radar and Chart, circa 1974.

Interest in wider pragmatic possibilities of information visualization began to explode with the beginnings of the micro-computing revolution during the late 1960s and early 1970s. During this period computing costs declined rapidly; this prompted the rise and cheaper costs of the workstation, access to more robust processing capabilities and the willingness of experts from disparate groups to think across disciplines.

As the price of computing power declined, universities and research-oriented institutions took advantage of new developments in technology to move research initiatives from realms of interdisciplinary journals to information visualization products, interfaces and services. A good example of an early innovator was the visual designer and researcher, Muriel Cooper. Bringing a heterodox visual design agenda to the engineering-dominated halls of MIT, Cooper took advantage of new computing possibilities to synthesize visual design concepts with computer and information design.

MIT Visual Language Workshop, Circa 1978.

The experiments and legacy of MIT's Visual Language Workshop, which Cooper initiated, lent credibility to a fledgling discipline. Essentially, Cooper began mapping principles of modern graphic design to the display of digital information. Informed by people such as Tufte, Bertin, Arnheim, Gombrich and more eclectic sources such as Bauhaus architectural modernists and early film theoreticians, theoretical conceptualizations became grist for new digital possibilities such as information landscapes, cartographic fly-throughs and the use of three-dimensionality to structure complex information systems.

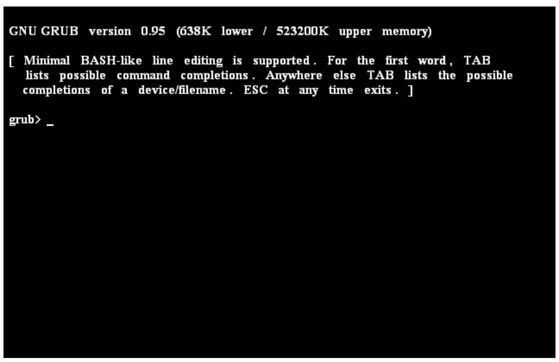



Muriel Coopers' cover design for Robert Venturi's *Learning from Las Vegas* (MIT, 1972)

Cooper's and her students' work introduced many in the next generation of innovators to new possibilities for computers and the potential use of graphics to build information systems and enhance information conceptualization through visualization, aesthetics and interactive methodologies.

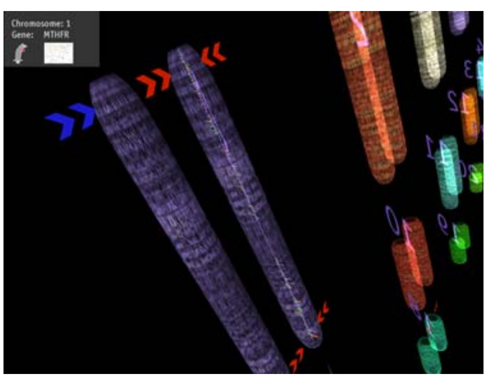
Early Cooper Zoomable Typographic Map – Weather had previously been reported by talking heads.

Now-commonplace displays such as typographic landscapes, interactive visual media and cartographic zoomable maps were pioneered by the MIT *Visual Language Workshop*. The computer interface at the time was still predominantly command-line interaction, unlike the graphical interfaces common today.



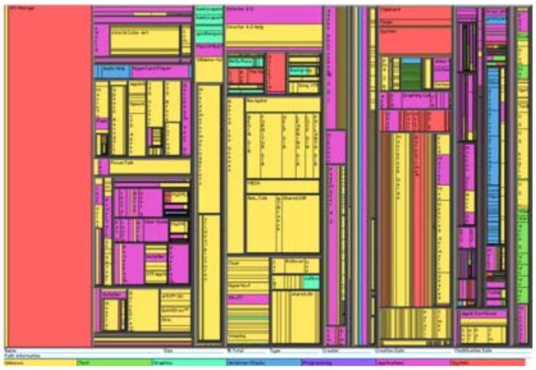

Typical computer interface circa 1983, empty screen and the command line dominate

Cooper’s doctoral students contributed to the nascent field of information visualization from a variety of perspectives. For example, David Small developed innovative methods to visualize the human genome.

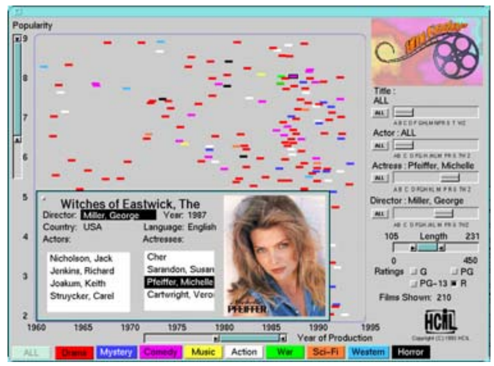


David Small, Fly-through Chromosome Approach: Genome Visualization

Further synthesizing these interdisciplinary trends, Ben Shneiderman founded the *Human Computer Interaction Laboratory* at the University of Maryland, College Park. This group was known for its strong focus on visual models and information visualization strategies for human usability. Here, they pioneered progressive interactive interface design possibilities for digital libraries including dynamic database queries, starfield displays for information recognition and treemap methodologies to visualize and interactively explore large data sets.



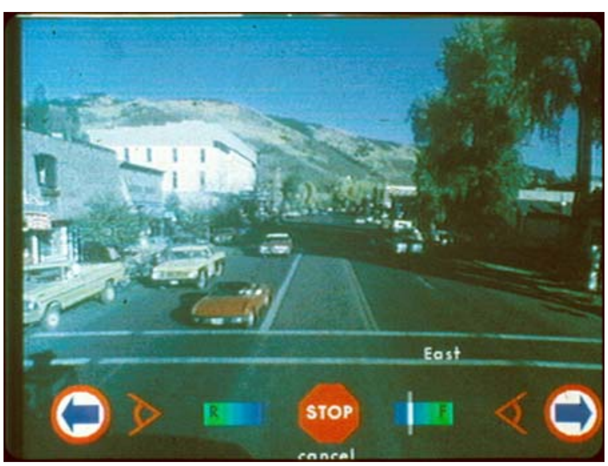
HCIL Treemap, large-scale database visualization (circa 1990)




Starfield Display (1994), Later Commercialized as Spotfire

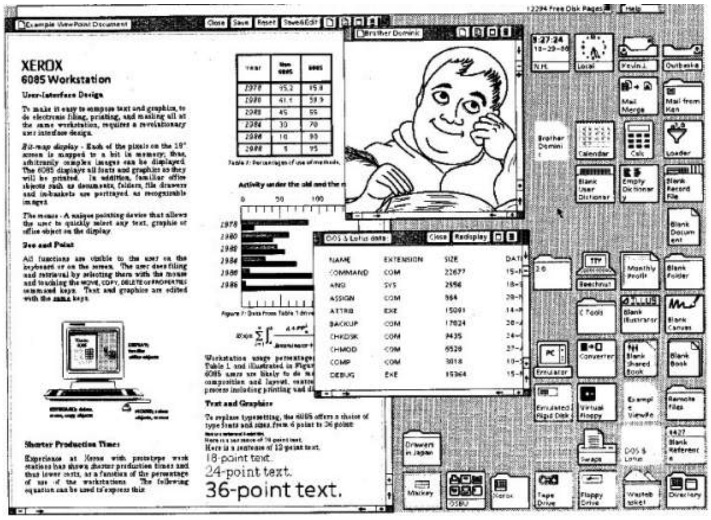
As information visualization research and products flourished on university research campuses, efforts were stepped up at innovative U.S. companies and their research arms, particularly, Bell Labs, Xerox PARC and a nascent computer manufacturer called Apple. Bringing together a disparate group of thinkers in the early 1970s, PARC built upon the U.S. military's innovative early research work with visualization at DARPA (*Defense Advanced Research Projects Agency*).

Early projects were prescient. For example, Doug Engelbart's *Aspen Movie Map* presented an interactive digital video tour of Aspen Colorado, a system more widely realized in commercial products such as *Google Maps* some thirty years later.



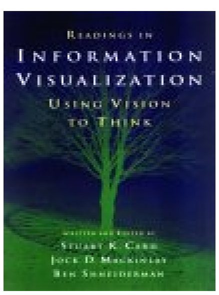

A screenshot of the Aspen Movie Map (1978). The navigation schema here became commonplace some 30 years later. The touch screen possibilities have yet to be realized on wider commercial levels.

Better known is the PARC invention, in 1979, of the graphical interface (GUI) using icons, windows and frames. These ideas were first popularized by Apple's Macintosh computer and later duplicated in the Microsoft Windows operating system.




Early Xerox graphical Interface (Star, circa 1979). Note the use of icons, folders for directories and multiple window/frame structures - information visualization metaphors now ubiquitous on computing platforms.

To say the least, this was a prolific phase for the exploration and development of future information visualization possibilities. A good source for this period of innovation is Jock Mckinley and Stuart Card's early years compilation, *Readings in Information Visualization: Using Vision to Think.*




*Readings in Information Visualization: Using Vision to Think* (1999). Many ideas presented in these early articles hold promise for future implementation.

Many of these information visualization research experiments became standard in subsequent computer developments but several remain unique and unrealized on commercial levels. Much of the territory remains fertile for further exploration.

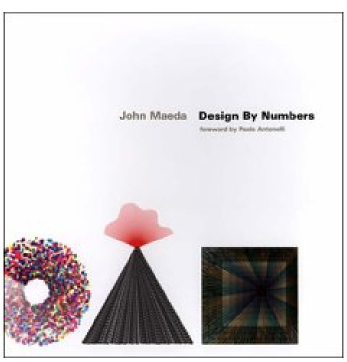
## Information Visualization Flowers

The late nineties and turn of the millennium heralded a renaissance in dissemination and productivity for information visualization. Two major trends converged during this period: the rapid adoption of research by information visualization's pioneers and the work's democratization by a new generation of practitioners who had access to wider bandwidth networks.

John Maeda built on Cooper's legacy at MIT, establishing the *Aesthetics and Computation* group. This was emblematic of a late '90s trend for classically trained computer and information scientists to work with aesthetic paradigms.


Maeda's invitation to designer Paul Rand for a series of lectures at MIT and the Media Lab, 1996

Maeda's teaching and work influenced directions of information design as a tool for expression combining skilled computer programming with openness to aesthetics and information design. This work helped champion the interactive motion graphics that are commonplace on the Internet today.



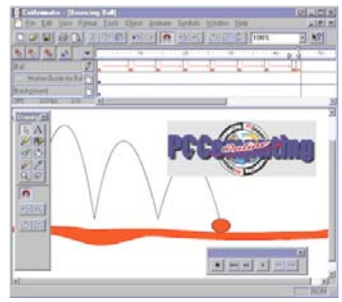

John Maeda's *Design by Numbers* (2001) with foreword by Museum of Modern Art Curator of Architecture and Design, Paola Antonelli

Maeda's *Design by Numbers* project was a global initiative to teach visual artists about computer programming through a freely available, custom, software system. The book's foreword by Paola Antonelli, curator of the *Department of Architecture and Design* at

New York's Museum of Modern Art, spoke of information visualization's lofty period ambitions — to synthesize previously segregated disciplines of aesthetics and technology, right and left brain, through the fulcrum of information visualization.

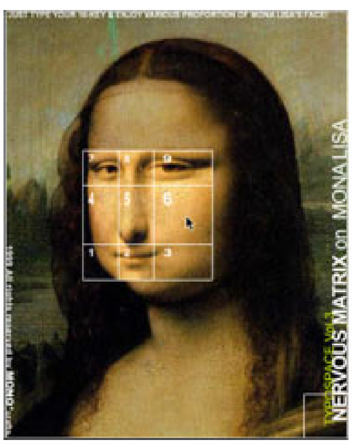
Blurring of lines between programming and art, design and information, spread with the proliferation of networked computer applications and possibilities for further synthesis of graphic manipulation and computer programming. This could be seen through the rise of new hybrid applications such as Macromedia (now Adobe) Flash programming/graphical environment.

Early Macromedia Flash logo



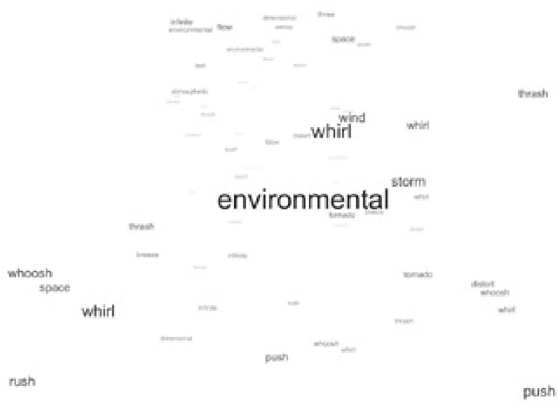
Flash Interface (notice the top timeline)

Flash presented a networked application environment in which previously segregated and traditionally left-brain, programming logic could be combined with right-brain, visual tools in a syncretic modality.



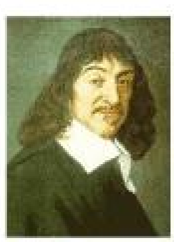

Yugo Nakamura's Flash Programmed *Nervous Matrix on Mona Lisa* (1999)

As a graphic design and web animation program, Flash offered artists a new tool for online design. Its  increasingly robust object-oriented programming environment provided interactive programming and information visualization possibilities previously restricted to high-end research institutions with heavyweight programming capacity. Flash combined two previously out-of-reach capabilities in a single, economical, commercially available program with backend database connectivity. This extended the range of information visualization, interface and application design to a larger design/programming community.




Early Flash Typographic Subject Heading TAG Cloud Flythrough, Jared Tarbell 2002

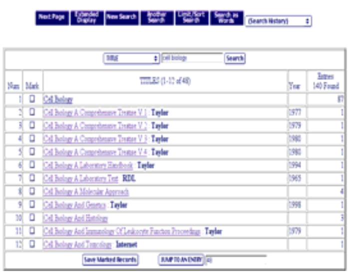
Early Flash programming/design pioneers such as Joshua Davis, Yugo Nakamura, Eric Natzke and Jared Tarbell brought possibilities for information visualization to the web, pushing limits for a new level of global dialogue and innovation. Combining traditional information architecture and interactive navigation created a range of new possibility for information visualization with interface design. The previous command-line query-response interface and scrolling list metaphor for information display was overturned. Looking a little closer, at Tarbell's visualized fly through Tag Cloud (2002, *see appendix* I for Tag Cloud Code), we may ask why these models provide clues to re envision a larger information system dataset such as that of a library catalog? The larger idea is that keywords and subject headings may be mapped to a 3D space (x,y,z) and Cartesian coordinate system based on 'subject proximity'.





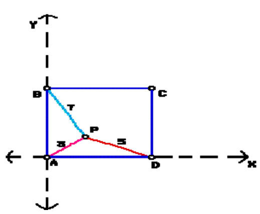
In his "Discourse on the Method (1637) the philosopher Rene Descartes combined Euclidean Geometry with mathematical algebra to produce the Cartesian Coordinate System.

To step back, Rene Descartes' innovation in the seventeenth century combined mathematical algebra with Euclidean geometry inaugurating a new set of scientific possibility through the Cartesian coordinate system (x, y axis) and analytic geometry. A little later in the eighteenth century, George Boole combined this same algebraic notation with Greek postulate logic to give us Boolean logic and logical operators prefiguring much of our dominant information system database search methodology. In the early 20th century, Claude Shannon combined Boolean algebra and binary arithmetic with electrical switch properties to form the theoretical basis for the digital computers.



Typical long scrolling list boolean logic generated information system early 2000’s

With regards to our own information systems, we currently work with long scrolling lists from databases searched through Boolean logic. We search visually and scan visual screen spaces. The questions information visualization grapples with regard possibilities of combining Boolean logic and visual paradigms of online screen space through a Cartesian (x,y,z) coordinate methodology. How can a structured algebraic application of data be mapped to our own information systems and ‘universes of knowledge to augment cognition and make them more searchable.



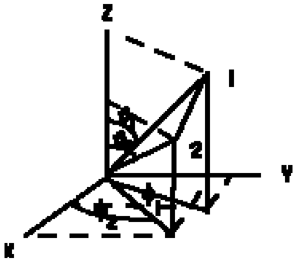

A numerically coherent taxonomy mapped to a visualized Cartesian coordinate system opens new possibilities

Dewey's early 'nineteenth century' innovation in the Dewey Decimal System (1851) was to map and systemize our universe of knowledge to a base ten decimal system (i.e., 100, 200, 300 = various subject categories, 110, 120, 130 = various divisions of those categories).

**Dewey Decimal System**

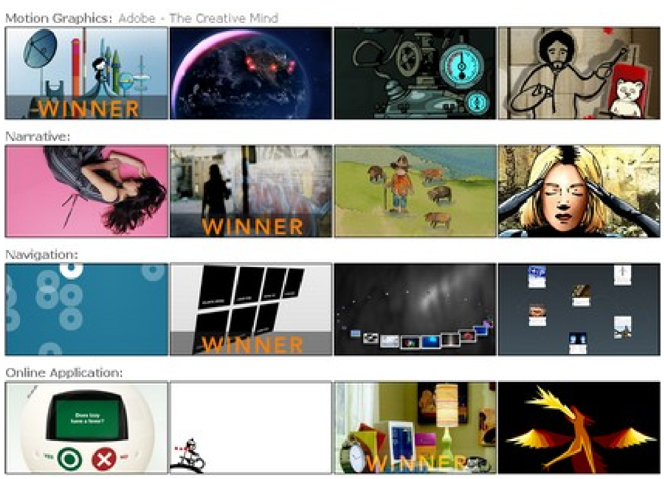
000 Generalities
100 Philosophy & psychology
200 Religion
300 Social sciences
400 Language
500 Natural sciences & mathematics
600 Technology (Applied sciences)
700 The arts
800 Literature & rhetoric
900 Geography & history

This universe of knowledge mapped to a humanly created decimal system categorical/taxonomic division allows the 3D analytic geometric visual relationships mentioned above.  Visualization is enabled online by mapping a numerically consistent knowledge universe to a Cartesian analytic geometric coordinate system. This allows subject categories to find each other in graphic information space. With regards to these paths of information visualization, various researchers begun to explore these possibilities digitally in the early twenty first century, among them Tim Bray (inventor of XML), a younger group of Flash programming visionaries and continuing historical groups in the American Society of Information Science and Technology. The later possibilities of attaching other media (film, sound, images, datasets) and possibilities of interactivity in this information space expanded this to explore more facile searching, pattern' recognition, knowledge augmentation and also importantly, knowledge collaboration.



What are the strategic possibilities of visually mapping knowledge sets  into visual space?

This fertile period of experimentation was evident in conferences such as Lynda Weinmann's *Flash Forward* (1998-2008), where new information visualization options, computing possibilities and future challenges were born. These also set ground for later fortuitous still emergent, heterodox programming/API synergies and synthetic programming methodologies such as Machinima, Ruby on Rails and AJAX (*Asynchronous JavaScript and XML*).

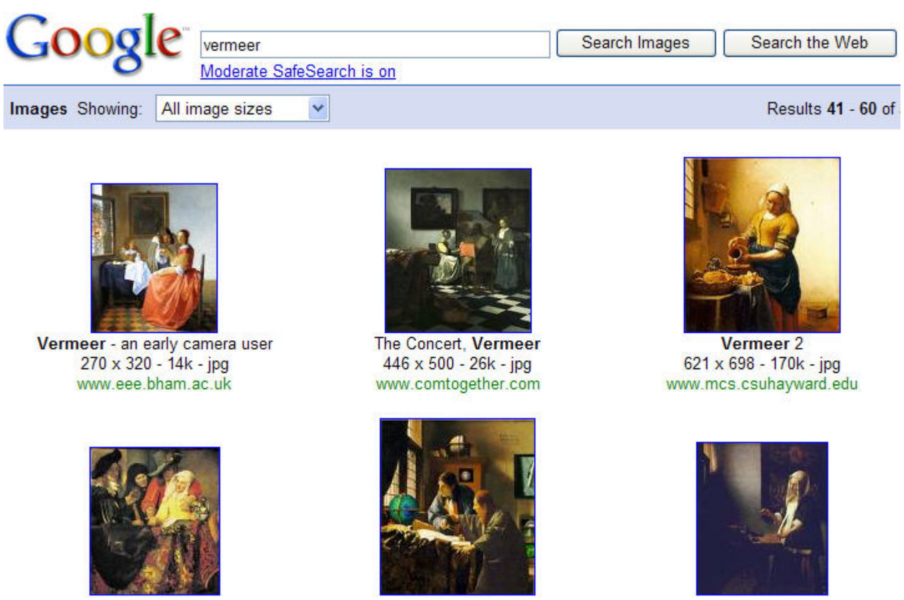



Flash Tableau. Beginning in 1997 FlashForward set the groundwork for a spectrum of information visualization possibilities bringing together information science with unconventional design to create a new genre of information products.

## Information Visualization Research Communities

Information visualization research communities in the academic sphere are multidisciplinary and synthetic, to say the least. Focused groups in professional associations include the American Society for Information Science and Technology's (ASIS&T) Special Interest Group on Information Visualization, Images and Sound (SIGVIS), the Association for Computing Machinery's (ACM), Special Interest Group on Graphics and Interactive Techniques (SIGGAPH) and a few other groups dealing with similar interests and concerns (IEEE, SIGCHI. The pioneers of information visualization were an eclectic and irascible bunch who published and dipped into academic conferences in a variety of scholarly associations, society and heterodox institute journals (Korfhage, 1997). They demonstrated remarkable breadth of interdisciplinary research.

Because of the high cost of computing and limited access to computer networks many early, higher-end R&D efforts petered out. Ironically, this nadir at the higher end occurred just as effective information visualization was becoming possible on lower-priced, commercial, networked computers. Much early research was later commercialized in specific information visualization software. A good example is Google's Image Search which used 'metadata' to conduct image retrieval though a popular search engine in 2002. These systems built on research that had earlier explored the possibility of retrieving images by adding captioning, keywords and descriptors. There is room for further exploration of earlier academic research pioneers' work but also the still largely uncharted territory of more advanced challenges presented by online digital 'video' retrieval methodologies.

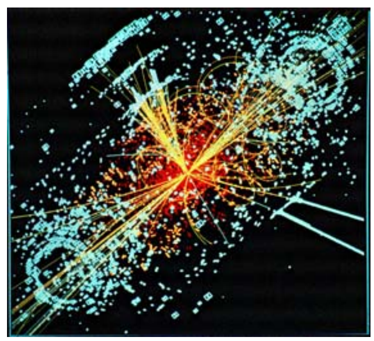



**Google Image Search (2002)** is a good example of the commercialization of early academic information visualization research efforts. This continues with the Luis von Ahn inspired Google **Image Labeler** (2008).

A new wave of interest in visualization appeared in the early 21st century. This was evident perhaps in the increased popularity of ACM's SIGGRAPH conferences and also in the resurrection of ASIST's SIGVIS by a new generation of practitioner/theorists. SIGVIS colloquia presented a spectrum of historical and new infovisualization topics: multimedia visualization, 3D mapping, social image tagging, digital visual copyright, video retrieval, sense-making through information visualization, visual indexing, new image browsing and progress regarding images, visualization and classification. Earlier generations of work were built upon and directions continued to remake, remix and remodel historical legacies.

## The Future and Future Directions

Information visualization is a maturing discipline. Visual information systems permeate our lives from interfaces at which we sit to how we see to our world.



Deep Starfield from Hubble Telescope (2008)

Hadron Particle Collider Print (2008)

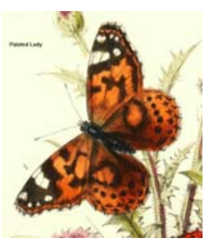
To talk about information visualization is to speak of the future synergies and developments for interacting with the human perceptual apparatus. Developments in information visualization continue to expand in scope and impact. Online games are being transformed into more serious information centered endeavors. *Star Trek*'s "holodeck" may not be far off. As processing power increases and the cost of computing decreases, the potential for mapping virtual worlds for information centered applications has yet to be fully imagined.

Kate Walker, Syberia XBOX Game 2003

For current information system designers, the trick is to take information gathering puzzle environments and productively map these to robust cognitive cartographies. How might a scrolling, text-based list of search results be mapped most effectively using 3D displays?


Interactive Flythrough, ASIS&T SIGVIS Website 2003,  Ray Uzwyshyn from algorithms of Jared Tarbell.

Currently interactive tag clouds deal with words or subject headings in 3D Space. The patron or user flies through categories as a plane flies through a cloud landscape. The unit being navigated through may be a subject heading but it is not difficult to envision this space as containing either static or moving images. Similarly, information visualization poses questions regarding the potentialities and semiotics of color and sound. When a knowledge cloud cluster of books has a similar subject heading or taxonomic place in an information hierarchy say 500 (Natural Science), this could all be coded in a single color cloud. These models are readily available from Cartography and GIS but also more unexplored terrain such as classificatory biology (descended from Lineaus) for how organic classification systems may inform our own information schemas. Sound can also be applied harmonically and semiotically. Users could acoustically differentiate gradients of 'subject heading from subject heading and find semantic 'sync' and harmony with various knowledge configurations to see and hear new polyphonies of knowledge coordinating patterns for discovery.



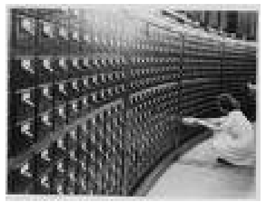
500--Natural Science
590--Zoological Sciences
595--Other invertebrates
595.7--Insects
595.78--Lepidoptera
595.789--Butterflies

DDC taxonomic chains can be translated spatially from wide angle categories to subject close ups.

To begin to conclude, what happens when we begin to think of the voyage of finding a book through the metaphor of an aerial landing. From an entire overview of the knowledgscape or universe of knowledge one navigates and zooms down a taxonomic chain. From the knowledge cloud, the universe of knowledge is seen globally. One then 'navigates' to one's particular continent, say *'Natural Sciences'* (*500*) . From here one navigates further down the taxonomic chain to say ‘*Zoology*’(*590*) One then lands into a specific 'cluster' of 'subject headings' or 'book items' say ‘*Butterflies*’ (*595.789*) .

Papyrus ‘*Kata-logos*’

200 B.C



Card Catalog

1940


Search Box OPAC

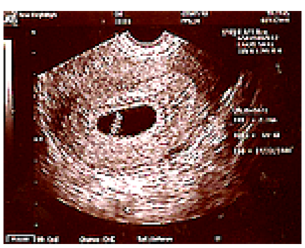
2008

3D Cognitive Cartography

2028

**Historical Catalog Paradigm Shifts**

3D environments visualized through the metaphor of a holodeck open the door to interesting challenges for future information systems. Most paradigms being commercialized today were paper ideas of researchers 50 years ago. These were realized as specialized projects by a few elite institutions twenty years back. Today many of these applications permeate our world. Others offer the seeds for information system development. Information visualization’s future herald intriguing and compelling, naturally human angles on how future generations may interact with information, each other and our world.



Human Fetal Sonogram 2008, first trimester, approximately 6 weeks gestation.

## Summary

This section has introduced a few of the parameters and historical concerns of the growing field of information visualization. We began with a look at historical antecedents and early pioneers. From here we moved to an exploration of first phase information visualization focusing on early computer dialogue with information visualization. On a parallel path we explored information visualization research communities. Questions regarding the potential of information visualization were posed while glancing at information visualization’s current renaissance and overlooked areas. Finally, a few new directions and possible futures for information visualization were examined. The field is growing. Large challenges loom and early research is ripe to be redeployed. We have included a brief bibliography for various sections discussed and encourage the reader to explore this terrain further. It remains vast and fertile.

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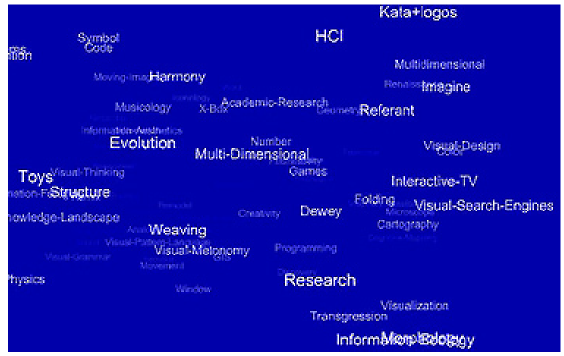
## Appendix I – Flash Interactive Tag Cloud

//The terse, elegant Actionscript Code below presents the routine needed in the Flash Development Environment to Create a Fly-Through Tag Cloud. This variation was originally adapted from Jared Tarbell's open source 3D code at Levitated.net (2002). From 2003-2006 a version of this algorithm was utilized on the ASIS&T SIGVIS website to spur thinking regarding new information visualization possibilities for the American Society of Information Science and Technology Special Interest Group in Visualization Images and Sound. There is room for furthering the trajectory of this algorithm to more fully converse with current taxonomic systems .




```
// register root as environment
Object.environment = this;

// create camera object
this.cam = {x:0, y:0, z:500, dx:0, dy:0, dz:-500};

// set environmental constants
this.fl = 1000;

// create Cartesian 'space' to which all words will be attached
this.createEmptyMovieClip("space",1);
// center 'space' on the stage
space._x=300;
space._y=169;

// a string of words related to Information Visualization or a Subject Category
this.somewords = "taxonomy, subject word, Visualization, 3D, Walkthrough, Typography, Cartesian Coordinate System, ";
// convert the string of words into an array of words
this.wordList = new Array();
this.wordList = this.somewords.split(" ");

// create one instance for each word in the list
for (n=0;n<this.wordList.length;n++) {
        // pick a word from the list
        var word = Object.environment.wordList[n];
        var x = random(600)-300;
        var y = random(337)-169;
        var z = random(Object.environment.fl*2)-Object.environment.fl;

        // create an instance of the SpaceWord object
        nombre = "word"+String(depth++);
        initialization = {txtword: word, x: x, y: y, z: z};
        space.attachMovie("spaceWord", nombre, depth, initialization);
}

this.onEnterFrame = function() {
        this.cam.dz+=.5;
        // move the camera to its destination
        this.cam.x+=(this.cam.dx-this.cam.x)/10;
        this.cam.y+=(this.cam.dy-this.cam.y)/10;
        this.cam.z+=(this.cam.dz-this.cam.z)/30;
}

stop();
```