Readings in Information Visualization: Using Vision To Think

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Readings in Information Visualization, Using vision to think
Stuart T. Kard, Jock D. Mackinlay, Ben Scheiderman

As this 15-year period draws to a close, there is a need for collecting together the results to date, organizing them, understanding the essence of this field, and providing materials for teaching. In the next period, information visualization will pass out of the realm of an exotic research specialty and into mainstream of user interface application design." (xiii)

"The power of the unaided mind is highly overrated. Without external aids, memory, thought, and reasoning are all constrained. But human intelligence is highly flexible and adaptable, superb at inventing procedures and objects that overcome its own limits. The real powers come from devising external aids: it is things that make us smart" (Norman, 1993, p.43) (1)

But then direct computational devises themselves become a component of an even more powerful visually based system. (3)

As our brief examination illustrates, visual artifacts aid thought; in fact, they are completely entwined with cognition action.

Information visualization is just about that—exploiting the dynamic, interactive, inexpensive medium of graphical computers to devise new external aids that enhance cognitive abilities. (5)

Visualization: The use of computer-supported, interactive, visual representations of data to amplify cognition. (6)
Cognition is the acquisition or use of knowledge. This definition has the virtue of focusing as much on the purpose of visualization as the means. Hamming (1973) saud, "the purpose of computation is insight, not numbers." Likewise for visualization, "the purpose of visualization is insight not pictures." The main goals of this insight are *discovery, decision making, and explanation.* (6)

Visualization dates as an organized subfield from the NSF report *Visualization in Scientific Computing* (McCormick and DeFanti, 1987). There it is conceived as a tool to permit handling large sets of scientific data and to enhance science's ability to see phenomena in the data. Although it is not a necessity of the original conception, scientific visualization tends to be based on physical data—the human body, the earth, molecules and other. (6)

There is a great deal of such abstract information in the contemporary world, and its mass and complexity are a problem, motivating attempts to extend visualization into the realm of the abstract. (7)

External cognition is concerned with the interaction of cognitive representations and processes across the external/internal boundary in order to support thinking. *Information* design is the explicit attempt to design external representations to amplify cognition. *Data Graphics* is the design of visual but abstract representations of data for this purpose. *Visualization* uses the computer for data graphics. *Scientific Visualization* is visualization applied to scientific data. The reasons why these two diverge are that scientific data are often physically based, whereas business information and other abstract data are often not.

However, humans with visualization displays are good at picking out new patterns as they occur and thus can respond to changes in the patterns quickly. Information visualization allows human adaptivity to be brought to bear for large sets of data under time pressure. (10)

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Knowledge crystallization tasks are one form of information-intensive work can themselves be part of more complex forms of knowledge work, such as design. (11)

1. Information foraging.	Collecting articles and data On laptop computers.
2. Search for schema (representation)	Identification of **attributes** on which to compare. laptops.
3. Instantiate schema with data. Residue is significant data that do not fit the schema. To reduce Residue, go to Step 2 and improve Schema.	Make table of laptops x attributes. Use “remarks” column to record interesting properties that don’t fit into table.
4. Problem-solve to trade off features.	Reorder rows and columns Of laptop table. Create plots. Delete or mark laptops that Are out of the running.
5. Search for a new schema that reduces the problem to a simple trade-off.	Cluster into three groups by rearranging the rows in the table, one each for power, Multimedia capability, and portability. Within each cluster delete all but the top one or two machines.
6. Package the patterns found in Some output Product.	Create concise briefing on decision for workgroup.

Knowledge crystallization involves getting insight about data relative to some task. This usually requires finding some representation (schema) for the data that is efficient for the task.

There appears to be a general principle of Selective Omission of Information at work in all biological information processing systems. The sensory organs simplify and organize their inputs, supplying the higher processing centers with aggregated forms of information which, to a considerable extent, predetermine the patterned structures that the higher centers can detect. The higher centers in their turn reduce the quantity of information which will be processed at later stages by further organization of the partly processed information into more abstract and universal forms. (Resnikoff, 1987, p.19) (11)

In order to do knowledge crystallization, there must be data, a task, and a schema. If the data are not to hand, then information visualization can aid in the search for it. If there is a satisfactory schema, then knowledge crystallization reduces to information retrieval. If there is not an adequate schema, then knowledge visualization is one of the methods by which one can be obtained. (11)

We have associated subtasks with particular main tasks of knowledge crystallization; however, many of the subtasks could be associated with more than one task.

VISUALIZATION LEVELS OF USE

1) visualization of the inosphere: the information outside the user's environment. (www., digital libraries, document collection).
2) visualization of an information workspace is the use of visualization to organize possibly multiple individual organizations or other information sources and tools to perform tasks.
3) visual knowledge tools, they arrange information to reveal patterns, or they allow manipulation of information for finding patterns, or they allow visual calculations. They are some times called *wide widgets* to emphasize that they are often not just presentations but also controls.
4) visual objects. These refer to objects, especially virtual physical objects such as the human body or books, that have been enhanced with visualization techniques to package collections of abstract information. (example both conceptual and spatial browsing data on a human body).

We propose six major ways in which visualizations can amplify cognition.

1) by increasing the memory and processing resources available to the users.
2) By reducing the search for information,
3) By using visual representations to enhance the detection of patterns,
4) By enabling perceptual inference operations,
5) By using perceptual attention mechanisms for monitoring,
6) By encoding information in a manipulable medium

(16)

Data Transformation map *Raw Data*, that is, data in some idiosyncratic format, into *Data Tables,* relational descriptions of data extended to include metadata. *Visual Mappings* transform Data Tables into *Visual Structures*, structures that combine spatial substrates, marks, and graphical properties. Finally, *View Transformations* create *Views* of the Visual Structures by specifying graphical parameters such as position, scaling,, and clipping. User interaction controls parameters of these transformations, restricting the view to certain data ranges, for example, or changing the nature of the transformation. The visualizations and their controls are used in service of some task. (17)

A tool for discovery and understanding

AUTOMATING THE DESIGN OF GRAPHICAL PRESENTATIONS OF RELATIONAL INFORMATION
Jack McKinlay Stanford University

3. The Graphical Presentation Problem
The graphical presentation problem is to synthesis a graphical design that expresses a set of relations and their structural properties effectively. (67)

4. Approach
An expressiveness criterion, which is derived from precise language definition, is associated with each graphical language. A graphical language can be used to present some information when it includes a graphical sentence that expresses *exactly* the imput information, that is all the information and only the information. Expressing additional information is potentially dangerous because it may not be correct. (69)

5. Expressivness

All communication is based on the fact that the participants share conventions that determine how messages are constructed and interpreted. For graphical communication these conventions indicate how arrangements of graphical objects encode information.
A set of facts is *expressible* in a language if it contains a sentence that
1.- encodes all the facts in the set,
2.- encodes only the facts in the set. (70)

6. Effectiveness

Given two graphical languages that express some information, the obvious question is which language involves a design that specifies the more effective presentation.
…unlike expressiveness, which only depends on the syntax and semantics of the graphical language, effectiveness also depends on the capabilities of the perceiver.

7. Composition

Expressiveness and effectiveness criteria, which were described in the previous two sections, are not very useful without a method for generating alternative designs. (74)

Information Animation Applications in the Capital Markets.
William Wright, Visible Decisions Inc. Toronto Canada

In 4D information animation applications, the success of the graphics visual design (i.e. the shapes, layout, colors) is critical to the success of the application. Graphical elements need to be carefully selected and arranged to reveal **data and relationships**. Poor graphics design will obscure the data and its meanings. The visual design simply needs to be perfect. Users must see the message and not the medium.

Edward Tufte articulates this discipline best. According to Tufte, excellence in graphics consists of complex ideas communicated with clarity, precision, and efficiency. Graphical displays should induce the viewer to think about the substance, present many numbers in a small space, make large data sets coherent, encourage the eye to compare different pieces of data, reveal the data at several levels of detail, from a broad overview to the fine structure.

Information workspaces are not oriented around visualizations themselves, but around tasks. An information workspace might contain several visualizations related to one or several tasks.
At the third level are ***visual knowledge tools* or “wide widgets”.** These are sort of visualization tools described in many of the papers so far in this books. **They contain a visual presentation of some data set and a set of controls for interacting with that presentation**. The focus is on **determining and extracting the relationships in a particular set of data.**
At a fourth level are *visually enhanced objects, coherent information objects enhanced by the addition of information visualization techniques.* (463)

USING VISION TO THINK

This chapter returns to the central topic of this book: using vision to think. In particular, the focus is on developing theoretical and engineering principles for the design of effective visualizations.

Moving from information foraging to sense making, we have Pirolli and Rao’s paper (1996). Sense making basically requires building schema or description into which many pieces of information fit (Russel et al., 1993), that is, providing a compact description of some set of phenomena. (580)

. The point of view is primarily cognitive, including the use of the term *externalization* rather than *visualization* to indicate the cognitive role of interactive visual representations. (581)

The first dimension, representation, divides data into value and structure. The second dimension, interactivity, ranges from direct manipulation to indirect manipulation. This leads to the final axis of the taxonomy based on Draper’s observation that input and output can reference each other. These input and output relations form the basis of a more detailed discussion of the various user actions that must be supported by a visualization. (581)

CONCLUSIONS

Information visualization is the use of computer-supported interactive visual representations of abstract data to amplify cognition. Its purpose is not the pictures themselves, but insight (or rapid information assimilation or monitoring large amounts of data). Information visualization is a part of the new media made possible by the development of the real-time visual computer. This medium has promise for five reasons:

1. It brings increased resources to the human in the form of perceptual processing and expanded working memory.
2. It can reduce the search for information.

3. It can enhance the recognition patterns.
4. It enables the use of perceptual inference and perceptual monitoring.

The medium itself is manipulable and interactive.

Another potential use of information visualization is in complex documents, such as scientific papers, technical manuals, film scripts, or computer programs. **In each of these, readers often try to get sense of the whole or to cross-reference one part from the other**.

Information Visualization

Robert Spence
ACM Press Essex: England 2001

Visualization is a process of forming mental model of data, thereby gaining inside into that data....I concentrate on the acquisition of insight through the identification of patterns and other features of a display. (xiii)

Visualize: (vb) to forma a mental image or vision of....
Visualize: (vb) to imagine or remember as if actually seeing.
Indeed , it results in something rather ephemeral (which we later call a mental model or internal model), something that cannot be printed out on paper or viewed through a microscope. The result is, as we say, *internal* to the human being. The potential value of visualization—that of gaining insight and understanding—follows from these definitions but so also, in view of the cognitive nature of visualization does the difficulty of its study. (1)

Sometimes we refer to the internal model as a **cognitve map** to distinguish it from a material map, which is real in the sense of being an object pasted to the wall of the underground station.

Issues
Selection; representation; presentation; scale and dimensionality; rearrangement, interaction and exploration; externalization; mental models; invention, experience and skill. (9-12)

Anyone who has seen, and specially *used,* a highly responsive interactive visualization tool will be struck by two features. First, that a mere *rearrengement* of how the data is displayed can lead to a surprising degree of additional insight into that data. Second, that the very property of interactivity can considerably enhance that tool's effectiveness, especially if the computer's response follows a user's action virtually immediately, say within a fraction of a second. (14)

ENVISIONING INFORMATION

Edward R. Tufte

Graphic Press. Cheshire, Connecticut 1990

Introduction

To envision information—and what bright and splendid visions can result—is to work at the intersection of image, word, number, art. (9)

To speak of statistics as the study of variation also serves to emphasize the contrast between the aim of modern statisticians and those of their predecessors. (22)

We envision information in order to reason about, communicate, document, and preserve that knowledge—activities nearly always carried out on two-dimensional paper and computer screen. (33)

2. Micro / Macro Readings

We thrive in information-thick worlds because of our marvelous and everyday capacities to select, edit, single out, structure, highlight, group, pair, merge, harmonize, synthesize, focus, organize, condense, reduce, boil down, choose, categorize, catalog, classify, list, abstract, scan, look into, idealize, isolate, discriminate, distinguish, screen, pigeonhole, pick over, sort, integrate, blend, inspect, filter, lump, skip, smooth, chunk, average, approximate, cluster, aggregate, outline, summarize, itemize, review, dip into, flip through, browse, glance into, leaf through, skim, refine, enumerate, gleam, synopsize, and separate the sheep from the goats. (50)

Micro/Macro designs enforce both local and global comparisons and, at the same time, avoid the disruption of context switching. All told, exactly what is needed for reasoning about information.
High-density design also allow viewers to select, to narrate, to recast and personalize data for their own uses. Thus control of information is given over to *viewers,* not to editors designers, or decorators. (50)

Clutter and confusion are failures of design, not attributes of information.

The concept that “the simpler the form of a letter the simpler its reading” was an obsession of beginning constructivism. It became something like a dogma, and is still followed by “modernistic” typographers.
The notion proved to be wrong, because in reading we do not read letters but words, words as a whole, as a “word picture”. Ophthalmology has disclosed that the more the letters are differentiated from each other, the easier is the reading. (51)

3. Layering and Separation

Confusion and clutter failures of design, not attributes of information. And so to point is to find design strategies that reveal and detail and complexity—rather than to fault the data for an excess of complication. Or, worse, to fault viewers for a lack of understanding.
Among the most powerful devices for reducing noise and enriching the content of displays is the technique of layering and separation, visually stratifying various aspects of the data.
Effective layering of information is often difficult; for every excellent performance, a hundred clunky spaces arise. An omnipresent, yet subtle, design issue is involved: the various elements collected together on flatland *interact* , creating non-information patterns and texture simply through their combined presence. Joseph Albers described this visual effect as 1 + 1 = 3. (53)

4. Small Multiples

At the heart of quantitative reasoning is a single question: *Compared to what?*

5. Color and Information

At work in this fine Swiss mountain map are the fundamental uses of color in information design: *to label* (color as noun), *to measure* (color as quantity)*, to represent or imitate reality*(color as representation)*, and to enliven or decorate*

VISUAL EXPLANATIONS
Eduard R. Tufte

Many of our examples suggest that clarity and excellence in thinking is very much like clarity and excellence in the display of data. When principles of design replicate principles of thought, the act of arranging information becomes an act of insight. (9)

..The idea is to make designs that enhance the richness, complexity, resolution, dimensionality, and clarity of the content. By extending the visual capacities of paper, video, and computer screen, we are able to extend the depth of our own knowledge and experience. (9)

Modern scientific graphics were now in place; the two-dimensional plane was quantified, available for measured data. Used with fitted models, graphics could describe and characterize relations between variables—thus displaying the essential evidence necessary for establishing cause and effect. (16)
…More generally, when scientific images become dequantified, the language of analysis may drift toward credulous descriptions of form, pattern, and configuration—rather than answers to the questions *How many? How often? Where? How much? At what rate?.* (23)

Once again Jonson's Principle: these problems are more than just poor design, for a lack of visual clarity in arranging evidence is a sign of lack of intellectual clarity in reasoning about evidence. (48)

…Reliable knowledge grows from evidence that is collected, analyzed, and displayed with some good comparisons in view. (52)

…Failure to think clearly about the analysis and presentation of evidence opens the door for all sorts of political and other mischief to operate in making decisions. (52)

: if displays of data are to be truthful and revealing, then the design logic of the display must reflect the intellectual logic of the analysis:
Visual representations of evidence should be governed by principles of reasoning about quantitative evidence. For information displays, design reasoning must correspond to scientific reasoning. Clear and precise seeing becomes as one with clear and precise thinking. (53)

..Display architecture recapitulates quantitive thinking; design quality grows from intellectual quality. Such dual principles—both for reasoning about statistical evidence *and* for the design of statistical graphics—include (1) *documenting* the sources and characteristics of the data, (2) insistently enforcing appropriate *comparisons.* (3) demonstrating mechanisms of *cause and effect,* (4) expressing those mechanisms *quantitatively,* (5) recognizing the inherently *multivariate* nature of analytic problems, and (6) inspecting and evaluating *alternative expressions.*

Parallelism connects visual elements. Connections are built among images by position, orientation, overlap, synchronization, and similarities in context. Parallelism grows from a common viewpoint that relates like to like. Congruity of structure across multiple images gives the eye a context for assessing data variation. Parallelism is not simply a matter of design arrangements, for the perceiving mind itself actively works to detect and indeed to generate links, clusters, and matches among assorted visual elements. (82)

Multiple images reveal repetition and change, pattern and surprise—the defining elements in the idea of information. (105)

Multiples amplify, intensify, and reinforce the meaning of images. (b105)

Since many slices of information are displayed within the eyespan, alert viewers may be able to detect contrasts and correspondences at a glance—**uninterrupted visual reasoning.** (112)

Information Visualization: Perception for Design

Colin Ware

Academic Press, San Diego, CA. 2000

Visualization meant constructing a visual image in the mind. But now it has come to mean something like a graphical representation of data or concepts. From an internal construct of the mind to an external artifact supporting decision making. (1)

Critical Question
How best to transform the data into something that people can understand for optimal decision making. (4)

The brain is clearly not an undifferentiated mass; it is more a collection of highly specialized parallel-processing machines with high-bandwidth interconnections. The entire system is designed to extract information from the world in which we live, not from some other environment with entirely different physical properties.

Sensory aspects of visualizations derive their expressive power from being well designed to stimulate the visual sensory system. In contrast, arbitrary, conventional aspects of visualization derive their power from how they will be learned.

The distinction between the sensory and social aspects of the symbols used in visualization also has practical consequences in terms of research methodology. It is not worth expending a huge effort carrying out intricate and highly focused experiments to study something that is only this year's fashion. Howeever, if we can develop generalizations that apply to large clasases of visual representations, and for a long time, the effort is worthwhile. (13)

There is an intricate interweaving of learned conventions and hard-wire processing. The distinction is not as clean as we would like, but there are ways of distinguishing the different kinds of codes. (14)

Our visual systems are built to perceive the shapes of 3D surfaces.

A sensory code is one for which the meaning is perceived without additional training.

Sensory immediacy: The processing of certain kinds of sensory information is hard-wired into the brain... .. the way in which visual systems divides the visual world into regions is called segmentation. The evidence suggests that this is a function of early rapid-processing systems. (15)

Cross-cultural validity: a sensory code will in general, be understood across cultural boundries. (16)

Sensory Research Metholologies

Psychophysics: techniques that are based on applying the methods of physics to measurements of human sensation... extremely succesful in defining the basic set of limits of the visual system. (what is the smallest relative brightness change that can be detected?).

If a psychophysical measurement is highly sensitive to changes in instructions, it is likely to be measuring something that has higher level cognitive or cultural involment.

Cognitive Psychology: The brain is treated as a set of interlinked processing modules. (short and long term memory). MRI techniques allow researchers to actually see which parts of the brain are active when subjects perform certain tasks. (17)

Arbitrary Symbol Research

Anthropoligists, social sciences: They advocate “thick description”. This approach is based on careful observation, immersion in culture, and an effort to keep ‘the analysis of social forms closely tied to concrete social events and ocassions” (Cliford Geertz 1973).

Complex user interfaces that they call artifact analysis (Carroll, 1989). In this approach, user interfaces (and presumably visualization techniques) are best viewed as artifacts and studied much as an anthropologist studies cultural artifacts of a religious or practical nature. Formal experiments are out of the question in such circumstances, and if they were actually carried out, they would change the cultural symbols being studied.

Unfortunately for researchers, sensory and social aspects of symbols are closely intertwined in many representations. Pure instances of sensory or arbitrary coding may not exist but doing analysis is not invalid. We must carefully determine which aspects of visual coding belong in each category. (21)

For the visualization designer, training in art and design is at least useful as training in perceptual psychology. For those who wish to do good design, the study of design by example is generally most appropiate. But the science of visualization can inform the process by providing a scientific basis for design rules, and it can suggest new design ideas and methods for sipalying data that heve not been thought of before. Ultimately, our goal should be to create a new set of conventions for information visualization designed to be optimal based on sound perceptual principles. (21, 22).

Gibson's Affordance Theory

He assumed that we perceive in order to operate on the environment. Perception is designed for action. *The perceivable possibilities for action* he called *Affordances.* He claimed that we perceive these properties of the environment in a direct and immediate way, this theory is clearly attractive from the perspective of visualization, because the goal of most visualizations is desicion making. Thinking about perception in terms of action is likely to be much more useful than thinking about how two adjacent spots of light influence each others appearence (typical approach of classical psicophysicist). (22)

Instead of reasoning like theorists to first understanding how a single point of light is perceived and then gradually understanding how two points of light interact and gradually build to understand the vibrant, dynamic visual world we live in. Gibson took a radically different approach. He claimed that we do not perceive points of light, we perceive possibilities for action (affordances) of the environment *directly*, not indirectly by piecing together evidence from our senses. To create a good interface, we must create it with appropiate affordances to make the user's task easy. ** He rejects the view of the brain deducing things out about the environment based on available sensory evidence in favor of the idea that our visual system is tuned to perceiving the visual world and that we perceive it accurately except under extraordinary circumstances. He preferred to concentrate on the visual system as a whole and not to break perceptual processing down into components and operations. He used the term *resonating* to describe the way visual system responds to properties of the environment. (23)

*** ejemplo categorias en mi metodo visual

Visualization and Direct Perception: 3 problems

1) Even if perception of the environment is direct, it is clear that visualization of data through computer graphics is very indirect. There may be many layers of processing between the data and its representation (abstract data, microscopic etc.)
2) There are no clear *physical* affordances in *any* graphical user interface.

Beyond the visual stages, the visual object identification process interfaces with the verbal linguistic subsystems of the brain so that words can be connected to images. The perception-for-action subsytem interfaces with the motor systems that control muscle movements. (25, 26)

Bertin 1977 Data values and data structures. A more modern way of expressing this idea is to divide data into entities and relationships.

***Entities* are the objects we wish to visualize; *relations* define the structures and patterns that relate entities to one another. We can also talk about the *attributes* of an entity or a relationship.** Concepts of entity, relationship and attribute have a long history in database design and more recently in systems modeling.

Entities & Relationships

Are generally the objects of interest. Relationships can be structural and physical (a house) or conceptual (store and customers). They may be causal or temporal. (28).

Attributes of Entities or Relationships (29)

Attribute is property of some entity and cannot be thought of independently.

Attribute Quality

It is useful to describe data visualization methods in light of the quality of attributes they are capable of conveying. A useful way of considering the quality of data is the taxonomy of number scales defined by Stevens 1946.

Nominal.- Labeling function (ruta 100)
Ordinal.- Ordering things in a sequence (best, second best)
Interval.- The gap between data values. (schedules)
Ratio.- We have the full expressive power of a real number (A as twice as B)

Definiciones

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