NETWORK NATIONS

We express many of our plans, feelings and ideas visually, but have we lost the ability to communicate through images? There are plenty of other, perhaps more effective, ways of expressing ourselves: using the letters of the alphabet as building blocks we can mass-produce information. But the limitations of text become abundantly clear when we try to query information on the web, using search engines like Google or AltaVista, where most of the retrieved information turns out to be irrelevant to our needs. Text may be more effective than graphics for conveying abstract concepts such as "freedom" or "efficiency" (do you "see" anything when you say these to yourself?). Other information is more easily remembered when represented visually.[1]

The ascendant field of information visualization draws on ideas from several intellectual traditions, including cartography, art, graphic design, semiotics, cognitive psychology, computer graphics and human computer interaction. Through the use of maps, diagrams, animations and other visual structures, information visualization creates context and facilitates the interpretation of data. As Tamara Munzner, of the University of British Columbia, puts it, "interacting with a carefully designed visual representation of data can help us form mental models that let us perform specific tasks more effectively."[2]

Three recent interactive visualizations of global data — temperature, population, GNP (Gross National Product) or even news stories — provide a useful study of the visualization principles currently at work. In City'O'Scope, data was collected at a fixed moment in time and is therefore more or less static. In Newsmap, dynamic global data is visualized in real time as it is continuously collected. In Logicaland, dynamic global data is visualized in "virtual real-time" as predicted through a world simulation game independent of clock time.

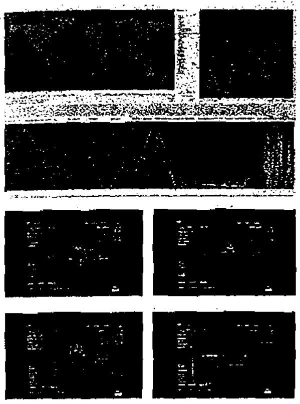
City'O'Scope tries to shed light on the question of where in the world we might travel — or perhaps even relocate — to pay less, earn more, and improve our living conditions. Socio-economic comparisons between 58 cities around the world are made possible through 42 different data attributes such as the average price of a hamburger, the salary of an engineer, the number of paid vacation days, or the cost of renting a three-room apartment. This data is visualized in three interactive display panels: a zoomable world map (Geographic Locations), a city comparison chart (Thematic Similarities) and a chart with "parallel-coordinates" (Attributes).

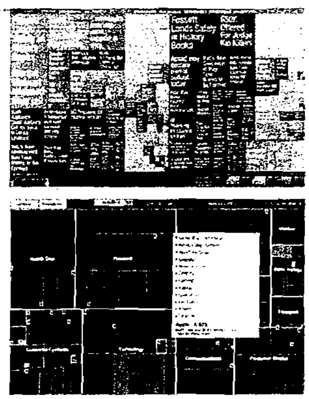
Newsmap is a software application that reflects the constantly changing landscape of global news stories collected by the Google News aggregator by mapping this into a visual space using the "tree map" visualization technique. Google News continuously crawls over 4,500 news sources from around the world, and selects headlines for its homepage entirely by a computer algorithm based on factors that include how often and on what sites a story appears elsewhere on the web. This reflects the tradition of Google's web search mechanism, which relies heavily on the collective judgment of web publishers to determine which sites offer the most valuable and relevant information.

In Newsmap, those news stories with the greatest number of other stories related to them are given the biggest surface area. News coverage can be monitored as it develops through the day, allowing visual comparison of media coverage in different countries. On an average day, far more stories are devoted to international news in UK news outlets than in the US. On the other hand, a smaller proportion of UK news is devoted to sports than in the US. According to Newsmap's creators, this visualization "is not thought to display an unbiased view of the news" but rather accentuates its bias.

1. G. H. Bower, "Mental imagery and associative learning," in L. W. Gregg (ed.), *Cognition in learning and memory*. New York: John Wiley & Sons, 1972, pp. 51–88. L. J. Najjar, "Principles of educational multimedia user interface design," *Human Factors*, 40:2, 1998, pp. 311–323.

2. Tamara Munzner, Guest Editor's Introduction to Special Issue on Information Visualization, *IEEE Computer Graphics and Applications*, 22:1, January-February 2002, pp. 20–21.





Network maps

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Logicaland is an online visualization of global economic, political and social systems that can be regarded as a multiplayer long-run strategic simulation game in which any Internet user can adjust the variables. The calculated average of all users' adjustments determines the state of the simulation. The simulation model is roughly based on the scientific global world model described in the mid-1970s by the Club of Rome.[3] Three different views of the same world data may be chosen:

1. an abstracted geographic world map in which each country is represented by a square whose surface areas are proportional to selected parameters such as geographical surface area, population, gross national product, per capita income, oil consumption, education and the like.

2. a classical bar chart.

3. an abstracted geographic map, which measures and distinguishes between regions in terms of the North/South divide.

Within the game, changes can be made to the parameters representing each country. Clicking on the individual countries reveals a pop-up control panel: various sliders can then be manipulated to control the distribution of parameters such as investments (between industry, agriculture, high-tech) and the relative amount of aid given to developing countries.

VISUALIZATION PRINCIPLES

Our well-developed visual processing skills — such as the ability to detect patterns, search quickly for specific visual details, or make visual comparisons — are hindered when data is presented in text, tables or databases. Comparison and exploration of abstract data are much easier when it is mapped into a visual structure: conceptual similarity may be visualized as shape or color similarity, or as spatial proximity. Various perceptual aspects of visual structures offer ways of representing relationships such as hierarchy, proportionality, category, order and connections. Proportionality can be visualized in spatial distances; categorization can be visualized by spatial divisions of the graphic display or by a color-coding system; hierarchy may be expressed through connections by arrows.[4] The three examples shown use specific visualization techniques to display multi-dimensional data:

SIMILARITY CHARTS AND PARALLEL COORDINATES

In City'O'Scope, a similarity chart (top right of interface) positions items — cities in this case — on the display surface according to a similarity algorithm so that those items with similar characteristics are displayed close to each other, while dissimilar items are far apart. Parallel coordinates (bottom of interface) involve many parallel axes, usually oriented vertically, one per attribute or dimension. In this case, each of the curves represents the data for one specific city.

TREEMAPS

A treemap is based on the proportional division of a display surface into sub-surfaces, where the surface areas stand for some quantitative attribute in the represented domain. Treemaps are ideal for visualizing quantitative proportions within hierarchically-nested data structures. In Newsmap, the surfaces represent the number of other news stories related to a particular story. Most treemaps also use some kind of color-coding; the SmartMoney Map of the Market, designed by Martin Wattenberg, Marc Frons, Joon Yu and Jonathan Bellack in 1998, is another well-known treemap application in which red represents losses, green represents gains and black represents neutrality.

MULTIPLE VIEWS

Both City'O'Scope and Logicaland offer multiple views of the same data set — in map-format as well as chart-format — although organized in different ways. City'O'Scope displays its three views in parallel (all three are visible all the time) while Logicaland displays its three views in serial

3. Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, and William W. Behrens III. *The Limits to Growth*. New York: Universe Books, 1972. Donella H. Meadows, Dennis L. Meadows and Jorgen Randers. *Beyond the Limits*. New York: Doubleday Press, 1992.

4. Yuri Engelhardt. "Meaningful Space." in Janet Abrams (ed.). *If/Then: Play—Design Implications of New Media*. Amsterdam: Netherlands Design Institute BIS Publishers, 1999, pp. 72–74.

(the user can switch between the views by clicking on the relevant buttons at the bottom of the display). Linking is a very useful enhancement of multiple views; see Selection/Highlighting below.

SIZE AND COLOR-CODING
Size is often used to visualize proportional quantities, as in the size of the squares representing each country in Logicaland, and the rectangles representing each news story in Newsmap. Color is often used to visualize categories, as in the colors of the news stories in Newsmap.

INTERACTION PRINCIPLES

Modern interactive information visualization is based on three principles:

1. INFORMATION DISPLAY IN SPATIAL STRUCTURES
Users should be able to interact with the data in a more meaningful way than via mere hypertext linking, and actively customize what is seen in a single display; hypertext embeds linked words in text but does not show the relationships involved, so it merely enables users to jump from one predetermined display to another. City'O'Scope enables zooming and more choices in graphic display than hypertext jumps could offer.

2. FILTERS AND VIEWS
The user should be able to generate questions or look at the subject from different points of view, by using filters that tailor the displayed information. In Newsmap, both countries and news categories can be switched on and off to enhance the comparison of news coverage. In City'O'Scope, dynamic queries on a combination of attributes can be executed by using range sliders.

3. INTERACTIVE TECHNIQUES
The user should be able to explore new insights by mining information for underlying patterns and structures. In Logicaland, the oil consumption of African versus European countries is visualized as an abstract pattern.

These three general principles can be applied through the following interaction techniques:

SELECTION/HIGHLIGHTING
Highlighting is a very helpful feature of linked multiple views, such that an interaction performed within one view (e.g. highlighting of certain selections) is automatically reflected in the other two views. In City'O'Scope, multiple cities can be highlighted in different colors so these cities can be easily compared in all three views.

ZOOMING, FISH-EYE ZOOMING
A good balance of focus and context can help reduce "information overload," on the one hand, and the limitations of displays and users, on the other. As Ben Shneiderman advises, "Overview first, zoom and filter, then details on demand."[5] Zooming is possible in both the geographic and parallel-coordinates views in City'O'Scope, while Newsmap allows zooming, both by country and by news category.

DETAILS ON DEMAND
Because there is insufficient screen real estate to show all information simultaneously, good visualizations make use of details on demand, so users can retrieve further information by rolling the cursor over, or selecting, a link to obtain further information about a given country in Logicaland, or a given news story in Newsmap, where story headlines are active.

MANIPULATING THE DATA
Unlike the other two examples, Logicaland is interactive to the second power: in addition to changing the display of the data, the user can change the data itself by adjusting the settings of the simulation game.

5. Stuart Card, Jock Mackinlay and Ben Shneiderman. *Readings in Information Visualization, Using Vision to Think*. San Francisco: Morgan Kaufmann Publishers, 1999.

6. Donald A. Norman. *Things that Make Us Smart*. Reading, MA: Addison-Wesley Publishing Company, 1993.

WHY VISUALIZATIONS ARE USEFUL

The external representation of knowledge has a long history, the most basic form being writing with pen and paper. The visualizations discussed here are external knowledge representations, cognitive tools that help us think and communicate. As Donald Norman has remarked, "The power of the unaided mind is highly overrated. Without external aids, memory, thought, and reasoning are all constrained. . . . The real power comes from devising external aids that enhance cognitive abilities."[6]

The visual representations in City'O'Scope take advantage of our cognitive skills in filtering and choosing focus and context on demand, making outliers, patterns and anomalies easy to spot. Its interface encourages exploration and stimulates formulation of new questions and hypotheses such as: What are the differences in working conditions between Europe and the US and how big is the earnings gap between North and South America? Interactive maps are more than merely external aids to personal memory; they are becoming tools of communication and collaboration.

THINGS TO COME

The development of tools that display and process data, transforming it into relevant information, presents both exciting and difficult challenges. On the one hand, we may wish to include an enormous quantity of information; on the other, the amount of information that can be displayed on a given canvas, and handled by a given user, may be very limited. To balance these desires, most visualizations rely on display principles such as multiple views, zooming, and color-, size- and texture-coding. Many of these visualizations offer the same functionality in different layouts.

Most information visualizations offer displays of a priori data, optimized according to parameters set by the user — an effective way of reducing information overload so users can handle large sets of information. However, most such visualizations are one-way streets. More complex information search queries will only be possible when additional contextual information is provided by the user. In the future, visualizations in a multi-user environment may combine the whiteboard functionalities of collaborative work with individual interactions and eye movement tracking. The most exciting prospects may be the possibility of perceptual inference with the user. It is the task of multidisciplinary research to incorporate more elements of human experience into mapping technologies. In one example of perceptual inference, the PARISS interface (Panoramic, Adaptive and Reconfigurable Interface for Similarity Search), textiles can be selected visually from a database by dragging and dropping a subset of displayed examples. The interface can then be instructed to mimic classifications and provide additional textiles matching the user's preference.[7]

Multi-dimensionality of data remains a tough problem, since display surfaces (computer screens) are two-dimensional, but many important aspects of information are often not limited to two dimensions and can vary over time. Multi-dimensional display techniques such as the parallel coordinates used in City'O'Scope can help solve this problem. However, with developments in ubiquitous computing, the field of information visualization stands to benefit from more immersive and pervasive interfaces. Increased computer power and better hardware will enable 3D visualizations, and human interaction will be transformed through distributed interfaces (screens, gloves). By combining methods of interaction with the functionalities of collaborative work, social interactions become possible.

In a multi-sensory environment, supported with pervasive computer technology, new bio-inspired information systems can capture and interpret what users are doing and assist them in realtime. Such systems are expected to appear in public places, on work floors and in home environments. Ramana Rao, founder of Inxight, looks forward to when we'll have overcome some past distractions: "We were willing to drop back considerably in interface quality for many years because of the rich sources of information and knowledge, new services, and connections to other people available through the Internet. Only now are we getting back to considering simpler and richer ways of interacting with content, services, people."[8]

As the real world becomes the computer interface, communicating via visualizations may become as easy and direct as communicating with language.

7. G. Caenen, G. Frederix, A.A.M. Kuijk, E.J. Pauwels and B.A.M. Schouten, "Show me what you mean: PARISS: A CBIR-interface that learns by example," in *Lecture Notes on Computer Science, Fourth International Conference on Visual Information Systems* (VISUAL 2000), Lyon, November 2000. Springer Verlag, 2000, pp. 257–268.

8. Ramana Rao, "Rao's Information Flow," *Information Flow* email newsletter, Issue 2.2, February 2003. <http://www.ramanarao.com/informationflow/archive/2003-02.html>.