Visual Language and Converging Technologies in the Next 10-15 Years (and Beyond)

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Background

Introduction

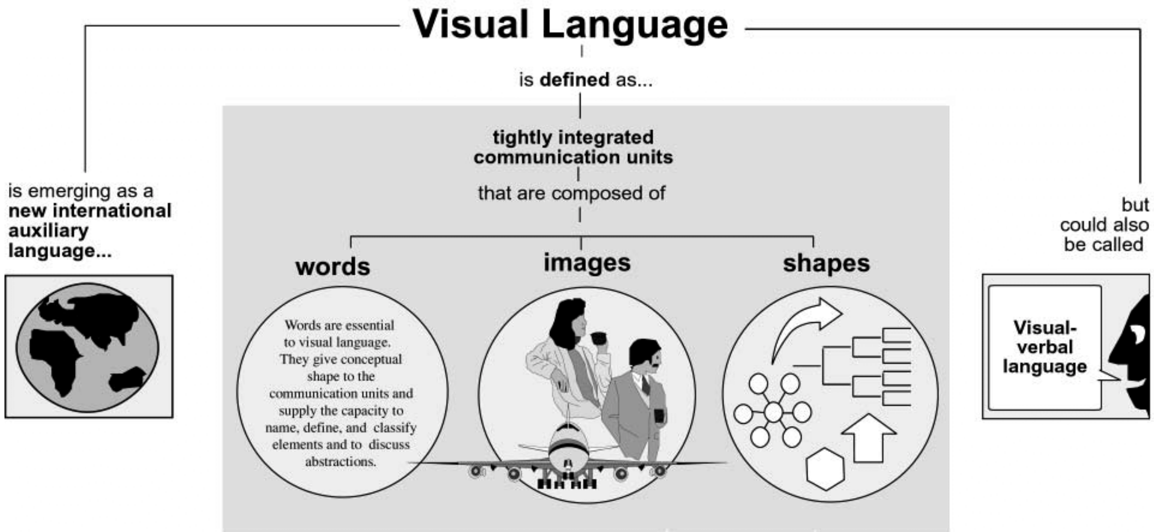
Visual Language is one of the more promising avenues to the improvement of human performance in the short run (the next 10 to 15 years). The current situation is one of considerable diversity and confusion as a new form of communication arises. But visual language also represents many great opportunities. People think visually. People think in language. When words and visual elements are closely intertwined, we create something new and we augment our communal intelligence.

Today, human beings work and think in fragmented ways, but visual language has the potential to integrate our existing skills to make them tremendously more effective. With support from developments in information technology, visual language has the potential for increasing human "bandwidth," the capacity to take in, comprehend, and more efficiently synthesize large amounts of new information. It has this capacity on the individual, group, and organizational levels. As this convergence occurs, visual language will enhance our ability to communicate, teach, and work in fields such as nanotechnology and biotechnology.

Definition

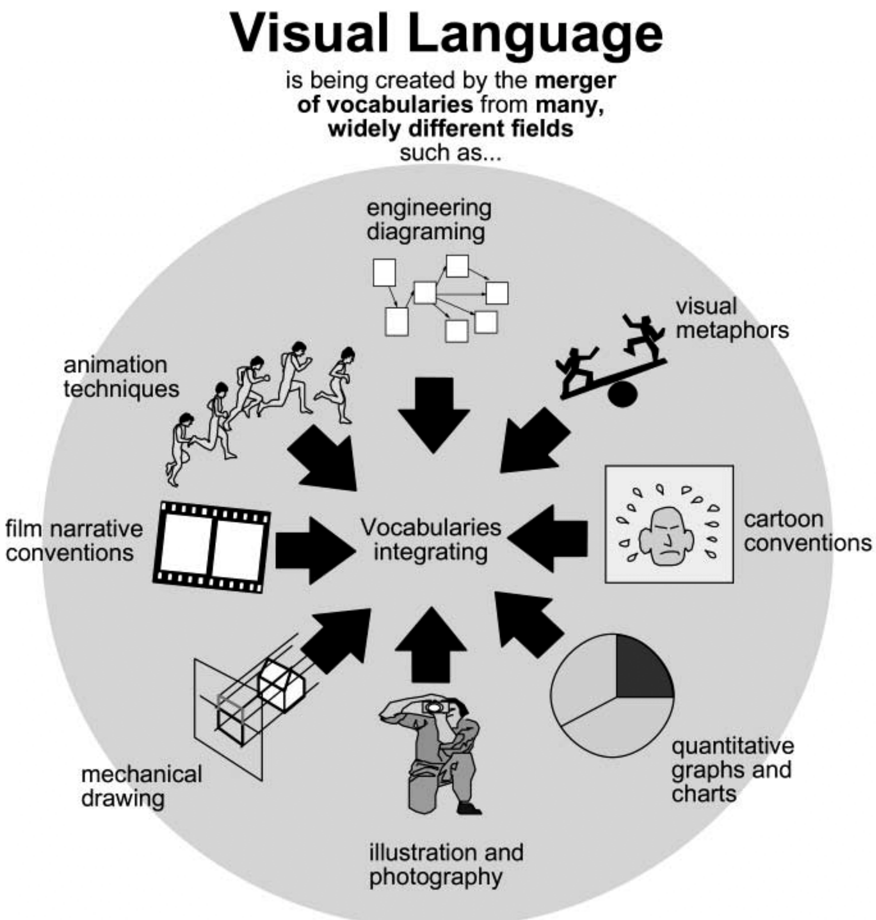
Visual language is defined as the tight integration of words and visual elements and as having characteristics that distinguish it from natural languages as a separate communication tool as well as a distinctive subject of research. It has been called visual language although it might well have been called visual-verbal language.

A preliminary syntax, semantics, and pragmatics of visual language have been described. (Horn, 1998) Description of, understanding of, and research on visual language overlap with investigations of scientific visualization and multimedia.



History

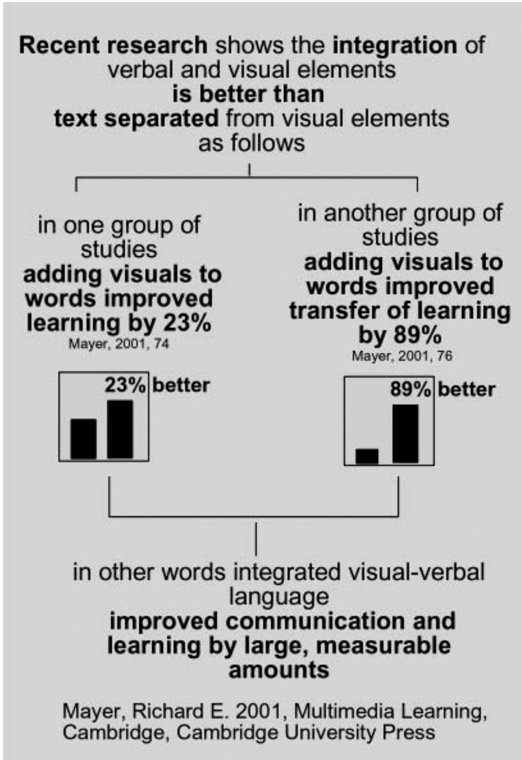
The tight integration of words and visual elements has a long history. (see Horn, 1998, Chapt. 2) Only in the last 50 years, with the coming together of component visual vocabularies from such widely separate domains as engineering diagramming technologies developed in medical illustration, and hundreds of expressive visual conventions from the world of cartooning has something resembling a full, robust visual-verbal language appeared. (Tufte, 1983, 1990)



Its evolution has been rapid in the past 10 years, especially with the confluence of scientific visualization software; widespread use of other quantitative software that permits the creation of over one hundred quantitative graphs and charts with the push of a single function key; and the profusion of multi-media presentation software, especially PowerPoint which, it is said, has several million users a day.

More effective communication

There is widespread understanding that visual-verbal language enables forms and efficiencies of communication that heretofore have not been possible. For example, improvements in human performance from 23 to 89% have been obtained by using integrated visual-verbal "stand- alone" diagrams. In this case, "stand-alone" diagrams refer to diagrams that have all of the verbal elements necessary for complete understanding without reading text elsewhere in a document. (Chandler and Sweller, 1991; Mayer 2001, Horton, 1991)



Facilitates representation. This new language facilitates complex, multi-dimensional visual-verbal thought, and -- with multimedia tools -- it incorporates animation as well. Researchers and scholars are no longer constrained by the scroll-like thinking of endless paragraphs of text.

Big, complex thoughts. Human cognitive effectiveness and efficiency is constrained by the well-known limitations of working memory that George Miller identified in 1957 (Miller 1957). Large visual displays have for some time been known to help us overcome this bandwidth constraint. But only since the recent advances in visual language have we been able to imagine a major prosthesis for this human limitation. The prosthesis consists of a suite of visual language maps. This visual-verbal language (together with computer-based tools) may eliminate the major roadblocks to thinking and communicating big, complex thoughts — i.e. the problem of representing and communicating mental models of these thoughts efficiently and effectively. This especially includes the so-called messy (or wicked or ill-structured) problems. (Horn, 2001a) Problems have solutions. Messy problems do not have straightforward solutions.

They are
- more than complicated and complex. They are ambiguous.
- filled with considerable uncertainty — even as to what the conditions are, let alone what the appropriate actions might be
- bounded by great constraints; tightly interconnected economically, socially, politically, technologically
- seen differently from different points of view, and quite different worldviews

- comprised of many value conflicts
- often a-logical or illogical.

These problems are among the most pressing for our country, for the advance of civilization, and for humanity.

Premises
The deep understanding of the patterns of visual language will permit
- More rapid, more effective interdisciplinary communication
- More complex thinking, leading to a new era of thought
- Facilitation of business, government, scientific, and technical productivity
- Potential breakthroughs in education and training productivity
- Greater efficiency and effectiveness in all areas of knowledge production and distribution
- Better cross-cultural communication

Ready for major research and development. Major jumping-off research platforms have been created for rapid future development of visual language e.g. the Web; the ability to tag content with XML; database software; drawing software; a fully tested, widely used content-organizing and tagging system of structured writing known as Information Mapping¤ (Horn, 1989); and a growing, systematic understanding of the patterns of visual-verbal language. (Kosslyn, 1989, 1994; McCloud, 1993, Horton, 1991, Bertin, 1983)

Rationale for the visual language projects
A virtual superhighway for rapid development in visual language can be opened and the goals listed above in the premises can be accomplished if sufficient funds over the next 15 years are applied to the creation of
- Tools
- Techniques
- Taxonomies

and systematically conducting empirical research on effectiveness and efficiency of components, syntax, semantics, and pragmatics of this language. This in turn will aid the synergy produced in the convergence of biotechnology, nanotechnology, information technology, and cognitive science.

Some of the goals of a visual-verbal language research program

A research program requires both bold, general goals and specific landmarks along the way. A major effort to deal with the problem of increasing complexity and the limitations of our human cognitive abilities would benefit all human endeavors, and could easily be focused on biotechnology and nanotechnolgy as prototype test beds. We can contemplate, thus, the steady incremental achievement of the following goals as a realistic result of a major visual language program:

1. **Policy-makers provided with comprehensive visual-verbal models**. The combination of the ability to represent complex mental models and the capability of collecting real-time data will provide sophisticated decision-making tools for social policy. Highly visual 'cognitive maps' will facilitate the management and navigation through major public policy issues. These maps provide patterned abstractions of policy landscapes that permit the decision-makers and their advisors to consider which roads to take within the wider policy context. Like the hundreds of different projections of geographic maps (e.g. polar or Mercator), they provide different ways of viewing issues and their backgrounds. They enable policy makers to drill down to the appropriate level of detail. In short, they provide an invaluable information management tool.

2. **World-class, worldwide education provided for children.** Our children will inherit the results of this work. It is imperative that they receive the increased benefits of visual language communication as soon as it is developed**.** The continued growth of the internet and the convergence of intelligent visual-verbal representation of mental models and computer-enhanced tutoring programs will enable children everywhere to learn the content and skills needed to live in the 21^{st} century. But this will take place only if these advances are incorporated into educational programs as soon as they are developed.

3. **Large breakthroughs in scientific research.** The convergence of more competent computers, computer-based collaborative tools, visual representation breakthroughs, and large databases provided by sensors will enable major improvements in scientific research. Many of the advances that we can imagine will come from interdisciplinary teams of scientists, engineers, and technicians who will need to become familiar rapidly with fields that are outside of their backgrounds and competence. Visual language resources (such as the diagram project described below) will be required at all levels to make this cross-disciplinary learning possible. This could be the single most important factor in increasing the effectiveness of nano-bio-info teams working together at the various points of convergence.

4. **Enriched art of the 21^{st} century.** Human beings do not live by information alone. We make meaning with our entire beings: emotional, kinesthetic, somatic. Visual art has always fed the human spirit in this respect. And we can confidently predict that artistic communication and aesthetic enjoyment in the 21^{st} century will be enhanced significantly by the scientific and technical developments in visual language. Dynamic visual-verbal murals and art pieces will become one of the predominant contemporary art forms of the century — as such complex, intense representation of meaning joins abstract and expressionistic art as a major artistic genre. (This has already begun to happen with the artists creation of the first generation of large visual language murals. Horn, 2000)

5. **Emergence of smart, visual-verbal thought software.** The convergence of massive computing power, thorough mapping of visual-verbal language patterns, and advances in other branches of cognitive science will provide for an evolutionary leap

in capacity and multi-dimensionality of thought processes. Scientific visualization software in the past 15 years has led the way in demonstrating the necessity of visualization to the scientific process. We could not have made advances in scientific understanding in many fields without software that helps us convert "firehoses of data" (in the vivid metaphor of the 1987 National Science Foundation report on scientific visualization) into visually comprehensible depictions of *quantitative* phenomena and simulations. Similarly, every scientific field is overwhelmed with tsunamis of new *qualitative* concepts, procedures, techniques, and tools. Visual language offers the most immediate way to address these new, highly demanding requirements.

6. **Wide open doors of creativity.** Visualization in scientific creativity has been frequently cited. Einstein often spoke of using visualization on his gedanken experiments. He saw in his imagination first and created equations later. This is a common occurrence for scientists, even those without special training. Visual-verbal expression will facilitate new ways of thinking about human problems, dilemmas, predicaments, emotions, tragedy, and comedy. The limits of my language are the limits of my world, said Wittgenstein. But it is in the very nature of creativity for us to be unable to specify what the limits will be. Indeed, it is not always possible to identify the limits of our worlds until some creative scientist has stepped across the limit and illuminated it from the other side.

Researchers in biotechnology and nanotechnology will not have to wait for the final achievement of these goals to begin to benefit from advances in visual language research and development. Policy makers, researchers, and scholars will be confronting many scientific, social impact, ethical and organizational issues, and each leap in our understanding and competence in visual language will increase our ability to deal with the complexity. Normally, as a language advances in its ability to handle complex representation and communication, each such advance can be widely disseminated because of the modular nature of the technology.

Major goals along the way to the next 15 years

The achievement of these goals will obviously require advances on a number of fronts.

1. **Goal: Diagram an entire branch of science with stand-alone diagrams.** In many of the newer introductory textbooks in science up to one-third of the total space consists of diagrams and illustrations. But often, the function of scientific diagrams in synthesizing and representing scientific processes has been often taken for granted. However, recent research cited above (Mayer, 2001, Chandler and Sweller, 1991) has shown how stand-alone diagrams can significantly enhance learning. Stand-alone diagrams do what the term indicates. Everything the viewer needs to understand the subject under consideration is incorporated into the diagram or from other diagrams linked to the one in focus. The implication of the research is that the text in the other two thirds of the textbooks mentioned above should be distributed into diagrams.

"Stand-alone" is obviously a relative term, because it depends on previous learning. One should note here that automatic prerequisite linkage is one of the easier functions to imagine being created in software packages designed to handle linked diagrams. One doesn't actually have to make too large a leap of imagination as scientists are already exchanging PowerPoint slides that contain many diagrams. However, this practice frequently does not have either the stand-alone or linked property.

Stand-alones can be done at a variety of styles and levels of illustration. They can be abstract or detailed, heavily illustrated or merely shapes, arrows, and words. They can contain photographs and icons as well as aesthetically pleasing color.

Now, imagine a series of interlinked diagrams for an entire field of science. Imagine zooming up and down in detail -- always having the relevant text immediately accessible. The total number of diagrams could reach into the tens of thousands. The hypothesis of this idea is that such a project could provide an extraordinary tool for cross-disciplinary learning. This prospect directly impacts the ability of interdisciplinary teams to learn enough of each other's fields to collaborate effectively. And collaboration is certainly the key to benefiting from converging technologies.

Imagine that these diagrams were *not* dependent on getting permissions (one of the least computerized, most time-consuming tasks a communicator has to accomplish these days). Making permissions automatic would remove one of the major roadblocks to the progress of visual language and a visual language project.

Then imagine being able to send a group of linked-stand-alone diagrams to fellow scientists.

2. **Goal: Create "Periodic table(s)" of types of stand-alone diagrams.** Once we had tens of thousands of interlinked diagrams in a branch of science, we could analyze and characterize all the components, structures, and functions of all of the types of diagrams. This would advance the understanding of "chunks of thinking" at a fine-grained level. This metaunderstanding of diagrams would also be a jumping-off point for building software tools to support further investigations and to support diagramming of other branches of science and the humanities.

3. **Goal: Automatically create diagrams from text.** At the present moment, we do not know how to develop software that enables the construction of elaborate diagrams of many kinds from text. But if the stand-alone diagrams prove as useful as they appear, then it creating diagrams, or even first drafts of diagrams, from verbal descriptions will turn out to be extremely beneficial. Imagine scientists with new ideas of how processes work speaking to their computers and the computers immediately turning the idea into the draft of a stand-alone diagram.

4. **Goal: Launch Human Cognome Project.** In the Converging Technologies workshop I suggested that we launch a project that might be named "Mapping the Human Cognome Project." If properly conceived, such a project would certainly be

a project of the century. If the stand-alone diagram project succeeds, then we would have a different view of human "thought chunks." And human thought-chunks can be understood as fundamental building blocks of the human cognome. The rapid achievement of stand-alone diagrams for a branch of science could, thus, be regarded as a jumping off platform for at least one major thrust of a Human Cognome Project.

5. **Goal: Create tools for collaborative mental models based on diagraming.** The ability to come to rapid agreement at various stages of group analysis and decision-making supported by complex, multidimensional, visual-verbal murals is becoming a central component of effective organizations. This collaborative problem solving, perhaps first envisioned by Douglas Engelbart (1962) as augmenting human intellect, has launched a vibrant new field of computer-supported collaborative work (CSCW). This community has been facilitating virtual teams working around the globe on the same project in a 24/7 asynchronous time frame. An integration of the resources of visual language display, both the display hardware needed and the visual display software, with the interactive possibilities of CSCW work offers the possibilities of great leaps in group effectiveness and efficiency.

6. **Goal: Crack the unique address dilemma with fuzzy ontologies.** The semantic web project is proceeding on the basis of creating unique addresses for individual chunks of knowledge. Researchers are struggling to create "ontologies" (by which they mean hierarchical category schemes, similar to the Dewey system in libraries.) But researchers haven't yet figured out really good ways to handle the fact that most words have multiple meanings. There has been quite a bit of progress in resolving such ambiguities in language translation, so there is hope for further incremental progress and major breakthroughs. An important goal for cognitive scientists and computer wizards will be to produce breakthroughs for managing multiple, changing meanings of visual-verbal communication units in real-time on the web.

7. **Goal: Understand computerized visual-verbal linkages.** Getting computers to understand the linkage between visual and verbal thought and their integration is still a major obstacle to building computer software competent to undertake the automatic creation of diagrams. This will likely be less of a problem as the stand-alone diagram project described above progresses.

8. **Goal: Crack the "context" problem.** In meeting after meeting, people remark at some point that "it all depends on the context." Researchers must conduct an interdisciplinary assault on the major problem of carrying context and meaning along with local meaning in various representation systems. This may very well be accomplished to a certain degree by providing pretty good, computerized "common sense." To achieve the goal of automatically creating diagrams from text, there will have to be improvements in the understanding of "common sense" by computers. The CYC project or something like it will have to demonstrate the ability to reason with "almost any" subject matter from a base of 50 million or more coded facts and ideas. This common-sense database will somehow be integrally linked to visual elements.

Conclusion

It is essential to accelerating research in the fields of nanotechnology, biotechnology, cognitive science, and information technology to increase our understanding of visual language. We must develop visual language research centers, fund individual researchers, and ensure that these developments are rapidly integrated into education and into the support of the other converging technologies in the next decade.

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