**Scientific Diagrams Made Easy with IVEO™**

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**Abstract:** Virtually all modern scientific documents and textbooks use graphical illustrations and/or data displays. The ViewPlus IVEO™ technology, based on Scalable Vector Graphics (SVG) is being developed to permit scientists to publish such graphics in a form fully usable by all people. The first release of IVEO™ was designed to make simple graphics accessible. Development of the second release, which includes improved text accessibility, linking, and interactivity, is described in this paper. We also discuss new research to expand accessibility of quantitative data in IVEO™ documents by using non-speech audio.

**1 Introduction**

Charts and diagrams are essential in both pedagogical and professional scientific literature. They are typically “made accessible” to blind people either by word descriptions or by tactile diagrams. Word descriptions are also conventionally used to assist people with other print disabilities to comprehend graphical information. Neither word description nor tactile graphic representation is fully satisfactory. Scientists would not use diagrams if word descriptions were equally informative. An English proverb is that “a picture is worth a thousand words”. Indeed, many scientific pictures could not be described adequately with many thousands of words.

A tactile diagram can be very useful to a blind person. Unfortunately very few blind people are adept at reading tactile diagrams. Opinions differ on why tactile diagrams are difficult to read, but most people would agree that one needs to learn to read tactile diagrams, and few blind people have had any opportunity to learn and practice that skill. The tactile sense has much less spatial resolution than normal sight, so transcribers must enlarge and simplify most published graphically displayed information in order to make it comprehensible to a blind reader [1].

The concept of using both tactile and linked audio information was pioneered approximately two decades ago by Parkes [2-6] with the Nomad concept. Blind users felt tactile graphics that were mounted on a touch-sensitive pad connected to a computer. When one pressed in various regions, the computer provided speech feedback to identify the object and then permitted the user to bore in for additional information. Nomad was used in a number of commercial products [7, 8] and hailed as a major advance in “making graphics accessible”, but creation of tactile copy and the associated computer audio information was quite laborious. Consequently Nomad has been used largely for special sets of curricular diagrams prepared for large numbers of student users, and not to convert scientific graphics to accessible form for single users “on request”. Most mainstream scientific literature has remained solidly inaccessible.

The authors of this paper, in collaboration with colleagues at Oregon State University and ViewPlus®, set out systematically to develop the missing technologies that would permit “Nomad accessibility” to mainstream scientific graphics [9-13]. It was clear that one such missing technology had to be a simple method of producing tactile graphics from mainstream pictures that could have sufficient tactile resolution for one to discern features of interest. That research direction led to the Tiger® embossing technology and the popular ViewPlus® Tactile Graphics and Braille embosser products [14, 15]. Any graphic that is adequately represented by a gray scale image will be faithfully converted to a tactile copy by embossers employing Tiger® technology. Dark regions are represented by big dots, and light areas by small dots. Generally it is possible to distinguish tactually the features of such graphic pictures even if one may have no idea what all the bumps and waves actually represent.

The second major missing technology was some simple way to create the audio information needed by a blind user to understand the meaning of those bumps and waves. This research direction led to the IVEO™ software applications introduced commercially by ViewPlus® in 2005. The IVEO™ Creator application and an associated utility, the IVEO™ Converter, permit one to create simple Scalable Vector Graphic (SVG) files directly or to scan in images from paper or convert files from other electronic formats to SVG. Authors can easily provide labels and, if desired, long descriptions of graphical objects. SVG permits both title and description fields for graphical objects within the SVG format. When a user of the IVEO™ Viewer application clicks on that object, the label is spoken. Descriptions can be heard by pressing a hot key. Braille users can “hear” these words with an on-line Braille display. The title and description attributes would be useful to a wide variety of users, so it is possible that widespread use of the IVEO™ technology could persuade mainstream authors of the value of taking the small amount of extra time required to insert title and description attributes for important objects. If this becomes routine practice, IVEO™ would achieve the intended goal of providing universally usable graphical information. Many scientific graph, bar/pie chart, and diagram authoring applications could automatically insert object titles as well as quantitative data, making the SVG graphic information-rich as well as accessible.

IVEO™ Creator automatically structures SVG text into geometrically-associated portions that are normally semantically related. When a user presses any of that text, the phrase is spoken. A substantial fraction of scientific diagrams can be understood by a blind person who feels the diagram and reads the labels audibly, so these are automatically made accessible simply by saving from Creator. Good text structure is important, so improvements in the capability of authoring systems to export structured text would be an improvement. IVEO™ Creator currently guesses at the text structure and doesn’t always get it right.

SVG is a new but increasingly popular graphics language [16]. IVEO™ files can be viewed by sighted users with the popular Adobe [A] SVG Viewer or with the IVEO™ Viewer [A]. Both viewers are free and of comparable size. Only the IVEO™ Viewer provides access to blind users. It also has good accessibility features for people with other visual and learning disabilities.

**2 IVEO™, Release 1**

The first release of the IVEO™ software was intended primarily for access to relatively simple graphics. It was intended to be useful by a small number of blind power users and by agencies that make simple graphics accessible to people with print disabilities. Maps and diagrams with sparse text labels that have been created with standard Windows® graphics author/editing applications can easily be converted to SVG by printing from the original application to IVEO™ Converter. The resulting SVG file is opened in IVEO™ Creator where important graphical objects may be labelled by a transcriber. Long text labels can be checked to assure that the groupings made by Creator are semantically correct. The IVEO™ SVG file is then saved and sent to the end-user by e-mail, CD, or other convenient media. Tactile copy can be made by the transcriber or by the end user. It is made by printing the IVEO™ page to a ViewPlus® embosser. If the end user creates his own copy, he has control of size and various user options for printing. More importantly, the user can zoom features and make additional printouts to access smaller features that may be difficult to understand on the original diagram. Figure 1 is an example of a moderately complex scientific diagram, the solar system that is accessible with IVEO™ release 1. The dots that are embossed when tactile copy is made are illustrated in Figure 2.

**Fig. 1.** Screen image of a solar system diagram as displayed with the IVEO™ Viewer application. Several display modes are selectable including an uncluttered full screen “accessibility mode”

**Fig. 2.** Illustration of the dots made by printing the file of Fig.1 to a ViewPlus embosser. Dark dots are high, and light dots are low when embossed.

When Creator is used by a blind person, the user makes a tactile copy and has access to text labels. Typical diagrams used in science, math, and business are often reasonably accessible without any intervention by transcribers. Examples include line diagrams with explanatory text labels, simple flow diagrams, and many kinds of charts. The diagram shown in Figure 1 can be made accessible simply by converting the original document to an IVEO™ SVG file, creating an embossed copy, and reading the labels while feeling the orbits. A good caption or figure description and additional labels identifying the orbits would make the diagram more rapidly comprehensible, but an experienced blind user should understand diagrams of this complexity with no intervention by a transcriber.

The IVEO™ Viewer also has features intended to enhance access by people with other print disabilities. People with low vision are finding that the customizable status bar that repeats audio information is helpful. It is expected that the same will be true for most people with learning and cognitive disabilities. Work is currently in progress to test such users and to improve IVEO™ display features to make IVEO™ as usable as feasible for them. The new ViewPlus® Emprint™ Haptic color printer produces both an embossed and superposed color image that has been long anticipated by professionals working with students having learning disabilities. Emprint™ images used with the IVEO™ Viewer and a touch pad should provide very good access for many people with severe print disabilities, e.g. dyslexia.

The first IVEO™ release permits access to text only by touching a portion of a phrase and hearing it. This is good access for diagrams with small labels, such as Figures 1 and 2, but it is ponderous for charts having large amounts of text in tables, lists, etc. New features for better text access are needed for blind users. Transcribers also need some additional features, and current development for second and future releases are described below.

**2.1 Testing**

IVEO™ was developed over a number of years during which time, many testers and consultants influenced its development and feature set. Extensive beta testing was done by a small but dedicated group of blind users prior to commercial release. These people suggested some expansion in the feature set but mostly assisted ViewPlus® to find bugs and make the software more robust. This is the appropriate way to test commercial software.

The most important question for IVEO™ developers was whether IVEO™ could provide good Nomad-like access to mainstream information without extensive editing by transcribers. Alpha and beta testing was sufficient to establish that it could. ViewPlus® did not attempt to answer more detailed questions such as percentage of people with print disabilities who could usefully access mainstream literature without assistance, or whether mainstream use of IVEO™ could provide access to all users. These are interesting and worthy questions but are more appropriate to research by disinterested academic researchers than by a company marketing the product.

**3 IVEO™ Expansions**

**3.1 Linking**

The first IVEO™ release permits users to hear labels, descriptions, and text in synthesized speech. Synthetic speech is generally considered inferior to recorded human voice, and many students with learning disabilities understand human speech much more easily. Beta testers and early adopters requested that IVEO™ be expanded to permit recordings instead of or in addition to ability to use of synthetic speech. This capability will be included in the upcoming second release.

The capability to play digital recordings is provided by links within the IVEO™ SVG file that open audio applications in the background to play audio files in various file formats. The linking feature has been implemented more broadly so that users can now open up other applications by clicking a link in the file. A common example would be a link to some web page that transfers control to the users default web browser. The user returns to the SVG document when the web page or pages have been read. This link-to-external-files feature is included in the second release. Beta testing had just begun at the time this paper was written, and no results are yet available.

**3.2 Interactivity**

SVG is a powerful language that permits authors to introduce a rich variety of interactive content. Interactivity was not permitted in the first IVEO™ release but will be introduced in a later release. The next release of the Viewer will support some limited interactive content, but it is largely a research tool for ViewPlus® and academic researchers. Providing accessible interactive content is still very much a subject of research. Authoring tools permitting some limited interactivity may be available soon, but it is expected that adequate accessible authoring applications will take years to develop.

**3.3 Improved Text Access**

Short text phrases are commonly used on diagrams and maps to identify objects, on graphs to label axes and give titles, and for many other purposes. Blind users can read them easily by pressing on such text. Unless the graphic is considerably enlarged, common text is reproduced by the embosser as a ragged line and is usually easy to distinguish from graphics. However when text is dense it becomes cumbersome to read intuitively by touching it. It is difficult to locate the position of a text phrase in standard sized text. Fingers do not have the resolution of vision, and it is difficult to move right and left or up and down without losing ones place.

Figure 3 illustrates the difficulty of accessing such text with the current IVEO™ touch-and-speak method. The fingers examining the tactile copy have fingertips that are larger than the spacing between the text lines. The second IVEO™ release will permit users to select regions and read the text with the keyboard much like reading text in a word processor. This development is still in early stage when this paper is written, and beta test information is not expected for some time.

**Fig. 3.** Photograph of hands examining a print/embossed image made with the new ViewPlus Emprint color Haptic printer. The file is a converted PDF image of a document from a US government web site, http://www.doi.gov/ocio/architecture/fea.htm. This document is a diagram with a great deal of text and will be much easier to read by people with print disabilities with IVEO™ Release 2.

**3.4 Non-Speech Access to Quantitative Data Graphs**

Color hue or intensity is occasionally used to represent quantitative information as a function of position in two-dimensional data plots. The most common example is geographic based display of variables such as population density, wealth, presence of natural resources, medical data, etc. Such displays cannot easily be represented accessibly with IVEO™ release 1. Research has recently begun on the feasibility of using audio tone and/or other non-speech audio to substitute for the hue or intensity. The visual variable would be represented by an audio tone whose pitch changes as the user moves the mouse over the diagram. The SVG file could be extended to permit original data to be included so that the audio tone can be derived from data instead of the hue/intensity of the visual image. Introduction of these new display capabilities is expected within one to two years.

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