Vector graphics

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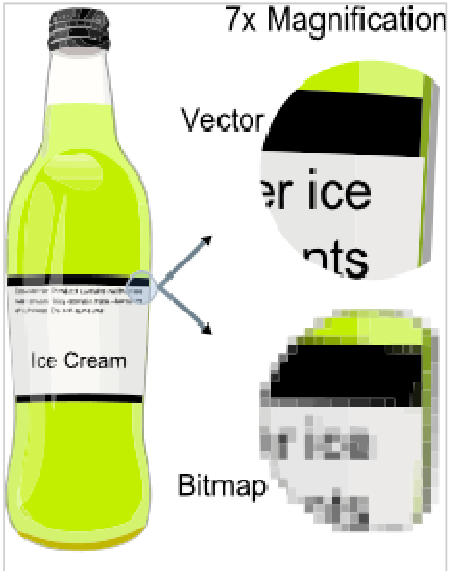
Vector graphics is the use of geometrical primitives such as points, lines, curves, and shapes or polygon(s), which are all based on mathematical equations, to represent images in computer graphics.

Vector graphics formats are complementary to raster graphics, which is the representation of images as an array of pixels, as is typically used for the representation of photographic images.[1] There are instances when working with vector tools and formats is the best practice, and instances when working with raster tools and formats is the best practice. There are times when both formats come together. An understanding of the advantages and limitations of each technology and the relationship between them is most likely to result in efficient and effective use of tools.



Example showing effect of vector graphics versus raster graphics. The original vector-based illustration is at the left. The upper-right image illustrates magnification of 7x as a vector image. The lower-right image illustrates the same magnification as a bitmap image. Raster images are based on pixels and thus scale with loss of clarity, while vector-based images can be scaled indefinitely without degrading quality.

Contents

Overview

Computer displays are made up from grids of small rectangular cells called pixels. The picture is built up from these cells. The smaller and closer the cells are together, the better the quality of the image, but the bigger the file needed to store the data. If the number of pixels is kept constant, the size of each pixel will grow and the image becomes grainy (pixellated) when magnified, as the resolution of the eye enables it to pick out individual pixels.

Vector graphics files store the lines, shapes and colors that make up an image as mathematical formulae. A vector graphics program uses these mathematical formulae to construct the screen image, building the best quality image possible, given the screen resolution. The mathematical formulae determine where the dots that make up the image should be placed for the best results when displaying the image. Since these formulae can produce an image scalable to any size and detail, the

quality of the image is limited only by the resolution of the display, and the file size of vector data generating the image stays the same. Printing the image to paper will usually give a sharper, higher resolution output than printing it to the screen but can use exactly the same vector data file.

Editing vector graphics

Vector graphic drawing software is used for creating and editing vector graphics. The image can be changed by editing screen objects which are then saved as modifications to the mathematical formulae. Mathematical operators in the software can be used to stretch, twist, and color component objects in the picture or the whole picture, and these tools are presented to the user intuitively through the graphical user interface of the computer. It is possible to save the screen image produced as a bitmap/raster file or generate a bitmap of any resolution from the vector file for use on any device.

The size of the file generated will depend on the resolution required, but the size of the vector file generating the bitmap/raster file will always remain the same. Thus, it is easy to convert from a vector file to a range of bitmap/raster file formats but it is much more difficult to go in the opposite direction, especially if subsequent editing of the vector picture is required. It might be an advantage to save an image created from a vector source file as a bitmap/raster format, because different systems have different (and incompatible) vector formats, and some might not support vector graphics at all. However, once a file is converted from the vector format, it is likely to be bigger, and it loses the advantage of scalability without loss of resolution. It will also no longer be possible to edit individual parts of the image as discrete objects. The file size of vector graphic depends on the number of graphic elements it contains.

Vector formats are not always appropriate in graphics work. For example, devices such as cameras and scanners produce raster graphics that are impractical to convert into vectors, and so for this type of work, the editor will operate on the pixels rather than on drawing objects defined by mathematical formulae. Comprehensive graphics tools will combine images from vector and raster sources, and may provide editing tools for both, since some parts of an image could come from a camera source, and others could have been drawn using vector tools.

Standards

The W3C standard for vector graphics is SVG. The standard is complex and has been relatively slow to be established at least in part owing to commercial interests. Many web browsers now have some support for rendering SVG data but full implementations of the standard are still comparatively rare.

Applications

An original reference photograph before vectorization

One of the first uses of vector graphic displays was the US SAGE air defense system. Vector graphics systems were only retired from U.S. en route air traffic control in 1999, and are likely still in use in military and specialised systems. Vector graphics were also used on the TX-2 at the MIT Lincoln Laboratory by computer graphics pioneer Ivan Sutherland to run his program Sketchpad in 1963.

Subsequent vector graphics systems, most of which iterated through dynamically modifiable stored lists of drawing instructions, include Digital's GT40.[2] There was a home gaming system that used vector graphics called Vectrex as well as various arcade games like *Asteroids* and *Space Wars*. Storage scope displays, such as the Tektronix 4014, could display vector images but not modify them without first erasing the display.

Modern vector graphics displays can sometimes be found at laser light shows, where two fast-moving X-Y mirrors are used to rapidly draw shapes and text on a screen.

The term "vector graphics" is mainly used today in the context of two-dimensional computer graphics. It is one of several modes an artist can use to create an image on a raster display. Other modes include text, multimedia, and 3D rendering. Virtually all modern 3D rendering is done using extensions of 2D vector graphics techniques. Plotters used in technical drawing still draw vectors directly to paper.

Detail can be added or removed from vector art. Vector illustrations can have their own color, allowing artists to achieve desired results.

Information

For example, consider a circle of radius *r*. The main pieces of information a program needs in order to draw this circle are

1. an indication that what is to be drawn is a circle
2. the radius *r*
3. the location of the center point of the circle
4. stroke line style and color (possibly transparent)
5. fill style and color (possibly transparent)

Advantages to this style of drawing over raster graphics:

- This minimal amount of information translates to a much smaller file size compared to large raster images (the size of representation does not depend on the dimensions of the object), though a vector graphic with a small file size is often said to lack detail compared with a real world photo.
- Correspondingly, one can indefinitely zoom in on e.g. a circle arc, and it remains smooth. On the other hand, a polygon representing a curve will reveal being not really curved.
- On zooming in, lines and curves need not get wider proportionally. Often the width is either not increased or less than proportional. On the other hand, irregular curves represented by simple geometric shapes may be made proportionally wider when zooming in, to keep them looking smooth and not like these geometric shapes.
- The parameters of objects are stored and can be later modified. This means that moving, scaling, rotating, filling etc. doesn't degrade the quality of a drawing. Moreover, it is usual to specify the dimensions in device-independent units, which results in the best possible rasterization on raster devices.
- From a 3-D perspective, rendering shadows is also much more realistic with vector graphics, as shadows can be abstracted into the rays of light from which they are formed. This allows for photo realistic images and renderings.

Typical primitive objects

- Bézier curves
- Bezigons
- Circles and ellipses
- Lines and polylines
- Polygons
- Text (in computer font formats such as TrueType where each letter is created from Bézier curves)

This list is not complete. There are various types of curves (Catmull-Rom splines, NURBS etc.), which are useful in certain applications.

Often, a bitmap image is considered as a primitive object. From the conceptual view, it behaves as a rectangle.

Vector operations

Vector graphics editors typically allow rotation, movement, mirroring, stretching, skewing, affine transformations, changing of z-order and combination of primitives into more complex objects.

More sophisticated transformations include set operations on closed shapes (union, difference, intersection, etc.).

Vector graphics are ideal for simple or composite drawings that need to be device-independent, or do not need to achieve photo-realism. For example, the PostScript and PDF page description languages use a vector graphics model.

Printing

Vector art is key for printing. Since the art is made from a series of mathematical curves it will print very crisply even when resized. For instance, one can print a vector logo on a small sheet of copy paper, and then enlarge the same vector logo to billboard size and keep the same crisp quality. A low -resolution raster graphic would blur or pixelate excessively if it were enlarged from business card size to billboard size. (The precise resolution of a raster graphic necessary for high-quality results depends on the viewing distance; e.g., a billboard may still appear to be of high quality even at low resolution if the viewing distance is large enough.)

If we regard typographic characters as images, then the same considerations that we have made for graphics apply even to composition of written text for printing (typesetting). Older character sets were stored as bitmaps, therefore to achieve maximum print quality they had to be used at a given resolution only; these font formats are said to be non-scalable. High quality typography is nowadays based on character drawings (fonts) which are typically stored as vector graphics, and as such are scalable to any size. Examples of these vector formats for characters are Postscript fonts and TrueType fonts.

Vector illustration

Vector illustration is a popular technique of many digital illustrators worldwide. Some of the greatest internationally acclaimed artists in the field are Catalina Estrada, Petra Stefankova, Nathan Jurevicius, J. Otto Seibold, Leo Blanchette and others.

3D modelling

Main article: 3D modelling

In 3D computer graphics, vectorized surface representations are most common (bitmaps can be used for special purposes such as surface texturing, height-field data and bump mapping). At the low-end, simple meshes of polygons are used to represent geometric detail in applications where interactive frame rates or simplicity are important. At the high-end, where one is willing to trade-off higher rendering times for increased image quality and precision, smooth surface representations such as

Bézier patches, NURBS or Subdivision surfaces are used. One can, however, achieve a smooth surface rendering from a polygonal mesh through the use of shading algorithms such as Phong and Gouraud.

Formats

Main article: Vector formats

One example of vector graphics format is SVG (Scalable Vector Graphics), an open standard created and developed by the World Wide Web Consortium to address the need (and attempts of several corporations) for a versatile, scriptable and all-purpose vector format for the web and otherwise. Another example is VML, a proposed standard that was adopted by Microsoft. Arguably, the AI format, the native format for Adobe Illustrator, is also standard in vector graphics.

The SWF Adobe's (formerly Macromedia's) file format is also a vector based container used to store animation. Web pages created in Flash can be enlarged to fit any monitor size while retaining the same graphic quality.

Adobe Fireworks, which is also (mostly) a vector-based application, saves its files in PNG format; vectors created in Adobe Fireworks can be transferred to Adobe Illustrator, and vice versa.

See also

- Adobe Fireworks
- Adobe Illustrator
- Anti-Grain Geometry
- Cairo (graphics)
- Cardboard engineering
- Computer-aided design
- Corel DRAW
- Electronic maps
- Graphics file format summary
- Graphics software
- GTX Image Cad Software
- GXL (Graph eXchange Language)
- Inkscape
- List of vector graphics editors
- List of vector graphics markup languages
- Raster to vector
- Scalable Vector Graphics (SVG)
- Shapefile
- Turtle graphics
- Vector game
- Vector graphics editor
- Vector Markup Language (VML)
- Vector monitor
- Vexel
- VRML
- Wire frame model

References

1. ^ Ira Greenberg (2007). *Processing: Creative Coding and Computational Art* (http://books.google.com/books?id=WTl_7H5HUZAC&pg=PA115&dq=raster+vector+graphics+photographic&lr=&as_brr=0&ei=llOVR-ywBw&sig=YEjfPOYSUDIf1CUbL5S5Jbzs7M8) . Apress. ISBN 159059617X. http://books.google.com/books?id=WTl_7H5HUZAC&pg=PA115&dq=raster+vector+graphics+photographic&lr=&as_brr=0&ei=llOVR-ywBw&sig=YEjfPOYSUDIf1CUbL5S5Jbzs7M8.
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