Review

Handling digital images for publication

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Abstract

Currently, images in medical journals are produced in the form of digital image files. The quality of printed images can be easily recognized. However, what comprises the quality of a digital image file is more complex. Some images appear to have good quality when displayed on a computer monitor but do not have sufficient quality for scholarly publication. In this review, basic concepts of digital images for scholarly publication, such as resolution, raster images, and vector images, will be explained. The advantages and limitations of using PowerPoint for processing digital image files will also be touched on briefly.

Introduction

Before the year 2000, most images for manuscript submission were printed on paper. Determining whether a printed image is of sufficient quality is easy. An image that appears large enough and clean enough on paper should be acceptable for publication. By the year 2000, most editorial offices had begun to use digital image files for their work. More recently, paper-printed images have no longer been accepted at all in most cases. Determining the quality of a digital image file is not as simple as that of a printed image. It can be said that "all digital images are not created equal." In some cases, an image may appear to be of good quality when viewed on a computer monitor, but the quality is far below that needed for print publication. Some institutions offer assistance to researchers through a graphic image specialist. However, sometimes this specialist cannot help salvage poor-quality image files if the researcher does not have a basic understanding of digital imaging. The author must generate a high-quality original image for the graphic image specialist to work with. This article will review some of the most important concepts necessary to produce high-quality images for manuscript preparation.

A Suggested Simple Universal Standard Resolution of 900 ppi and 4 inches

Resolution refers to a measurement of clarity or detail of the displayed image and is expressed as the number of pixels displayed per unit length [1,2]. The resolution of a printed image is

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most commonly expressed in terms of dots per inch (dpi) or pixels per inch (ppi). The most commonly recommended resolution for printing on paper depends on the nature of the images: 1) 300 dpi for color pictures, 2) 300 to 600 dpi for black and white pictures, 3) 600 to 900 dpi for combination art (photo and text), and 4) 900 to 1,200 dpi for line art.

In the digital image file, the number of pixels per inch itself has no meaning in terms of the image quality. For instance, if a color picture image file with 600 ppi is printed as a 1-inch picture, the image quality will certainly be good. However, if the same image file of 600 ppi is printed as a 10-inch picture, the final image quality will be much poorer. In a digital image file, the image "quality" (that is, the information density) is not determined by the number of pixels per inch but the number of actual pixels. A 1-inch 600 ppi image file has the same "quality" as a 10 inch 60 ppi image file because the horizontal pixel number is 600 for both images. Therefore, the actual number of pixels is the key determinant of the image quality for a digital image.

In order to determine the number of pixels, the physical size of the image must first be determined. But this introduces a problem. Only a few journals recommend the size of the artwork in their author guidelines. In most journals, only the minimum required number of pixels per inch is stated. *Gastroenterology*, for example, indicates that images "should be of high quality (300 ppi or greater, clear, and in good focus)" [3]. With the same number of pixels per inch, the effective image quality can vary widely by the image size in the printed article. The publisher may choose to greatly change the size of the image in the final editing step, without input from the authors. Therefore, the authors cannot know the final size of their image during preparation of images for submission. Some journals print the images quite large, but others prefer small images. Early in the research process, authors need to review the previously published articles in the same journal to guess at the final image sizes of their planned research article.

It is the opinion of this author that a universal recommendation could help authors prepare their images. The standard figure size of most academic journals is about 86 mm (single column). The standard pixels per inch for line art is 900 to 1,200 ppi. Therefore, an image file of 900 ppi and 4 inches is of sufficient quality for most publications; this means 3,600 pixels in a horizontal line. It is recommended that authors use this number as a universal guide.

Vector Images Should Be Used Instead of Raster Images Whenever Possible

There are two types of digital images: raster images and vector images. A raster image, also called a bitmap image, is a collec-

tion of pixels (picture elements) arranged on a rectangular grid. Usually, more pixels mean higher image quality. Raster images are resolution-dependent, meaning they cannot be scaled up to an arbitrary resolution without loss of quality. The original raster image is always the most detailed image. Any manipulation of the raster image makes the apparent quality poorer. Popular graphic formats for raster images are Graphic Interchange Format (GIF), Joint Photographic Experts Group (JPEG), Portable Network Graphic (PNG), and Tagged Image File Format (TIFF). The most popular image editor for raster images is Photoshop.

A vector image is based on vectors. A vector graphic is composed of mathematical formulas that describe each object in an image in terms of its outline shape, line weight, fill, and exactly where it is on the page. Because pixels do not exist in a vector image, it can be scaled up without loss of image quality. Popular graphic formats for vector images are Encapsulated PostScript (EPS), Scalable Vector Graphics (SVG), and Adobe Illustrator (AI). The most popular image editor for vector images is Adobe Illustrator. The Portable Document Format (PDF) is unique that it can handle both raster images and vector images.

How can vector images and raster images be distinguished? The simple way is to magnify the image to 500% or more. When raster images are scaled up, a loss of image quality can be expected. The text, lines, and curves become jagged. On the other hand, vector-based images can be scaled up by any amount without degrading the image quality (Fig. 1).

Images taken by a camera, a scanner, or from a picture archiving communication system (PACS) are always raster images. Vector images can be made using a vector-based image editor, such as AI, CorelDRAW, or Prism. An original raster image cannot be converted into a vector graphic. However, a vector image can be converted into a raster graphic through
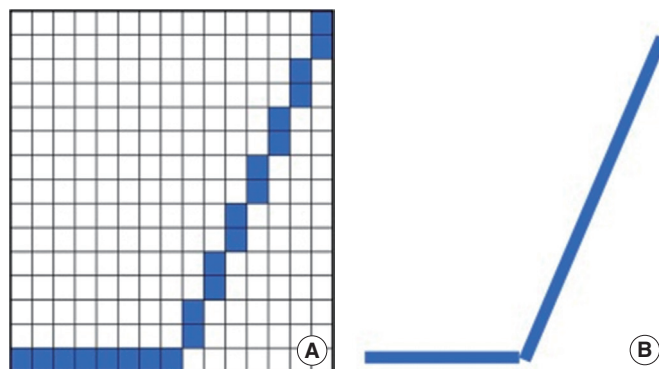

Fig. 1. Two methods for producing an image of a line: (A) many dots are combined to comprise a raster image and (B) lines are used composing a vector image.

the process of 'rasterizing' using an image editor like Photoshop. If a researcher produces a figure using a graphics program, the final image can be stored in either a raster format or a vector format. It is strongly recommend that a vector format be used because the file size of the figure is much smaller in a vector format. Furthermore, most graphics editors at scientific journals prefer vector graphics due to the small size of the file and the superior image quality.

Original JPEG Files May Be Good Enough

JPEG is the standard lossy format for raster images. The amount of compression of JPEG files can easily be adjusted. JPEG is a commonly used file format for digital capture due to its small file size and relatively good image quality. Nearly all digital cameras include JPEG format. JPEG should not be used as a working file format in Photoshop because it loses data every time it is opened and then resaved.

JPEG files also lose quality as compression increases. This is why most journals do not accept image files in the JPEG format. TIFF is the most commonly used standard format for biomedical journals. However, the JPEG format has certain advantages. Picture files taken by a high-quality digital camera and saved in TIFF format are too large to handle. In this case, the JPEG format can be a good alternative with minimal loss of quality. When pictures are printed in one-column width, most JPEG images are of sufficient quality. In addition, JPEG images may be the original files taken directly from PACS, scanners, and endoscopes. The quality of the original image file is always better than any processed image. Journal editors should accept JPEG files selectively, particularly when they are the original uncompressed files from various image sources.

Using PowerPoint for Producing High-quality Images

PowerPoint is an excellent presentation application [4]. It can handle various kinds of graphic images and video files. Simple vector-type graphic images can be generated with tools embedded in PowerPoint (Fig. 2). However, PowerPoint is not a professional graphics application like Photoshop or AI. PowerPoint can be used to prepare images for publication of an article, but only with care.

The most common error encountered when preparing images with PowerPoint involves the "Save As" function. If TIFF or JPEG image files are created directly from a PowerPoint file using the "Save As" function, it typically produces a low-resolution image, such as a 960×720 pixel image. These low-quality images cannot be used for publication purposes. Consider the proposed universal standard resolution of 900 ppi and 4
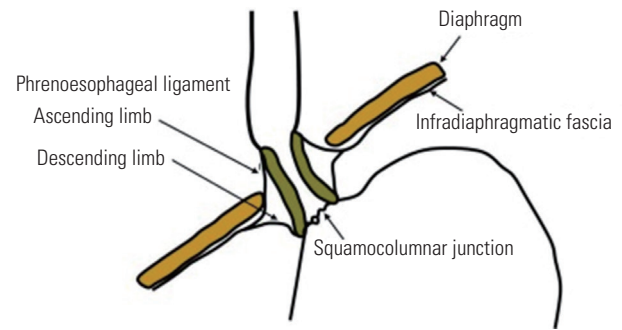

Fig. 2. An example of artwork produced with PowerPoint.

inches. This means that an image has 3,600 pixels in a horizontal line. PowerPoint typically produces 960×720 pixel images, which is far below the universal standard pixel number of 3,600. To produce a high-quality raster image for possible publication, professional graphics applications like Photoshop should be used.

PowerPoint can internally handle both raster images and vector images. Using PowerPoint, it is very easy to make a good combination artwork (raster image plus vector-type line art). The problem is that PowerPoint cannot make a separate high-quality raster image file or a separate vector file. It is recommended that authors use PDF as an interim format, because a PDF file can handle both raster images and vector images [5]. This can be accomplished by the following steps: first, create a high-quality image using PowerPoint. Second, convert the PowerPoint file into a PDF file using the "Save As" function. Third, open the PDF file with a sufficient resolution using Photoshop. This step is called "rasterization." Fourth, convert the image to a high-quality TIFF file using the "Save As" function of Photoshop. This image file should be acceptable for medical publication.

The abovementioned steps can be difficult for the average medical researcher. However, any graphics specialist can do this very easily. Most editorial offices have full-time or part-time graphics specialists. It is thus unclear why so many journals do not accept PowerPoint files. A carefully prepared PowerPoint file is an excellent starting point to generate high-quality graphic artwork for a journal. Raster images should be prepared separately. However, vector images in a PowerPoint file should be accepted. A special vector program like AI is not needed for simple work.

Tips for Using a Graphics Application Such As Prism

Prism is a very useful tool for producing complicated graphs from a large quantity of data. Images produced by Prism are

basically vector images. However, when a separate image file is produced using the "Export" function, most of the file type options are raster formats such as PNG, TIFF, Bitmap (BMP), Personal Computer Exchange (PCX), and JPEG. Only Windows Metafile (WMF) can handle a vector image without losing image quality. Actually, WMF is a vector graphics format that also allows the inclusion of raster graphics. It is strongly recommended that the WMF format be used to produce an image file. This file can then easily be transformed into a high-quality TIFF file using Photoshop.

Saving the Original Image File Safely

In the process of image preparation, it is very easy to accidentally lose the original untouched high-resolution image files. It is crucial to save a copy of the original digital or analog data exactly as it was acquired [6]. Keeping a copy of the original image is a mandatory step for all image processing. It is recommended that at least three copies of the original image be saved in three physically separate locations.

Conclusion

To summarize, in the internet age, graphic files are an important part of published articles. The quality of graphic files uploaded to the Web shapes the quality of an article and even the entire journal; therefore, high-quality graphic files are required. The minimum number of pixels should be suggested based on the width of graphic on the journal page. The width is usually a single column of 86 mm. In general, vector images are better than raster images with regard to image quality, file size, and versatility. A PowerPoint file may be a convenient solution for producing a high-quality vector image file. Editors and authors should be acquainted with the production of graphic files using vector images.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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