Technical Note

Introducing 3-Dimensional Stereoscopic Imaging to the Study of Musculoskeletal Anatomy

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Abstract: The stereoscopic imaging technique is an option for a more realistic understanding of what we normally see in 2 dimensions on paper or on a screen. To produce a 3-dimensional image of an object, it is necessary to register 2 different images of the same object at the same distance and height with the use of cameras that focus on one particular point. A convergence between the left and right images is required for human vision. The distance between the camera and the images necessary to create the stereo pair should be proportional to the normal distance between the pupils. Stereoscopic or polarization techniques are used to create the images, and special glasses are required to view them. In medicine, 3-dimensional images are an extremely effective resource in the study and teaching of anatomy at both the macroscopic and microscopic levels. With advancements in technology and the emergence of new diagnostic imaging techniques and innovative therapeutic modalities, 3-dimensional images can be an excellent educational tool.

We live in a world in which the objects that surround us are seen by us in 3 dimensions but records are documented as 2-dimensional images. The discrepancy between what we see and our mental abstractions can make images difficult to understand. In this context, medical studies often present barriers to the understanding of a particular anatomic region, the description of a surgical technique, or even the ability to understand various issues during medical specialization. The 3-dimensional (3D) view that allows a real sense of depth is called stereoscopic vision. This type of vision allows a more precise orientation and interaction with the environment.

An overlap of 2 or more recorded images at a point corresponding to the view from the left eye and a point corresponding to the view from the right eye creates a 3D image. The merger of these 2 images in the brain gives us depth perception and allows an appreciation of distance, location, and the size of objects. A set of 2 images is called a stereo pair. The sense of apparent displacement of the object photographed after images are overlaid from 2 different points of view is called parallax. In contrast to binocular vision, monocular vision gives us a limited sense of depth based on the automatic application of knowledge and experience. Despite being effective for daily activities, monocular vision is of limited use in executing complex tasks that involve greater precision.

Stereoscopic imaging techniques are quite old, but previous technologic limitations made production difficult. The computer revolution and development of new photographic and video cameras with digital ca-
Capabilities, lenses, and flashes with longer ranges allowed improvements in 3D documentation, providing an exponential increase in imaging applications.\(^1\)

To photograph a 3D image, it is necessary to take photographs, overlap the images, and print or project these images together. To create stereoscopic images, the simplest and most widespread method is the anaglyph technique. Projection of these images on screens can be performed by use of this or other forms of polarization, such as horizontal-vertical polarization. Because the propagation of light occurs through constant-pulse waves expanding in all directions and at right angles to the axis of propagation, the interposition of filters that have only vertical or horizontal openings causes the beam of light passing through each filter to propagate in only one of these directions.

To view these images, special glasses are required that allow visualization of the overlaid images in 3 dimensions. These glasses are made with special lenses for 3D interpretation, most often blue and red lenses for polarization of the image.

For motion pictures, the technique of sequential or alternating fields is a more sophisticated way to carry out 3D projection. In this technique, 2 films produced in synchronization are integrated by a multiplexer circuit that switches frames sequentially during projection. With the use of special glasses made with liquid crystal lenses that act as shutters that open and close as the corresponding frames are projected (i.e., LCD shutter glasses), one can visualize the stereoscopic images projected. Such glasses fitted with shutters are called active glasses; glasses with polarizing filters are called passive glasses.

Projections using the sequential-field technique can be made on normal screens, and this method can also be used for viewing stereoscopic digital computer displays. The communication mechanism between the shutter glasses and the medium that generates the image (i.e., projection system or monitor) is made by wires or an infrared signal.

Historically, communication by means of symbols (alphabets) and pictures has been limited to 2 dimensions. However, in our rapidly changing world, 3D images are becoming increasingly common in our daily lives and appear to be moving toward becoming essential, especially in the areas of education and documentation.\(^2,4\) Three-dimensional medical studies are documented in the literature.\(^1,5\) A clearer understanding of anatomic structures is essential in medical education, and the use of 3D images\(^6\) can help greatly in the study of anatomy.

**TECHNIQUE**

To produce a 3D image of an object, it is necessary to register 2 different images of the same object at the same distance and height with the use of cameras that focus on 1 particular point. A convergence of left and right images is required for human vision. The distance between the camera and the images needed to create the stereo pair should be proportional to the normal distance between the pupils (62 to 66 mm).\(^7\) This process can be performed by use of either 2 different cameras on the same bar on a tripod to prevent displacement and loss of proportion required between the camera and object or by a single camera attached to a slide bar that enables photographing an image first from 1 position, then from a second position (Fig 1), with a scale and a level that allow for the maintenance of the distance described previously.

With the single-camera slide bar technique, the first step is to focus on a specific point on the object with the camera at zero on the scale of the slide bar. The second step is to slide the camera by the bar 3 cm to the left and again focus on the same specific point. This is the first picture. The third step is to do the same but now to the right side, sliding the bar 3 cm to the right of zero on the scale. This is the second picture. Using cameras particularly made for stereoscopic imaging is another alternative.\(^8\)

To perform the techniques described, a 35-mm single-lens reflex camera with attached lenses for macrophotography (e.g., 105 mm, 1:2.8) can be used. In the case of microscopic visualization, another option is to use 2 cameras attached on each side of an electron microscope to perform the imaging, following the same principles of proportionality and distance between the camera and the object.

**FIGURE 1.** Manfrotto Slide Bar (Manfrotto, Ramsey, NJ)—the instrument used to create the 3D picture with a single camera.
After capturing the images, we then begin the process of building the final image for printing or projection. There are several ways to edit an image to make it 3D, but the most common form is the anaglyph method.¹

Certain computer programs are able to colorize each of the images, followed by an image overlay (e.g., AnaBuilder; freeware available at http://anabuilder.free.fr). In the anaglyphic method, each image is dyed with a corresponding color, commonly blue and red. Thus the image corresponding to the left eye is dyed blue, and the image corresponding to the right eye is dyed red. These colors correspond to the polarizing filters of the special glasses that will be used, for example, with a blue lens in the left eye and a red lens in the right eye. It is important that each image correspond to the same color lens. When loaded, the overlapped image (with both blue and red colors) will yield a 3D aspect of the image. People who need corrective glasses must use the polarizing glasses over their corrective glasses.¹

With the image ready, one can choose to physically print the image for production or create projection slides for presentation and teaching. Examples of our results are illustrated in Figs 2 through 6.

**FIGURE 2.** Intercondylar notch of knee (left knee, anterior view); posterior cruciate ligament (1) and anterior cruciate ligament (2), showing an example of the relation of 2 different structures with an empty space providing a greater sense of depth.

**FIGURE 3.** Example for study of human body: 3D image of pelvis (right hemi-pelvis, lateral view).

**FIGURE 4.** Example for study of human bones and ligaments: 3D sagittal view of ankle and its ligaments (left ankle, lateral view).

**FIGURE 5.** Muscle of posterolateral corner of knee in 3D view (right knee, lateral view).
DISCUSSION

Vision is one of the 5 senses that enables humans to perceive their environment. Stereoscopic reproduction methods are not new and were already described by the middle of the 19th century. The first film to use this technology dates back to 1922. From the second half of the last century, various techniques were developed for stereoscopic projection and printing. At the turn of this century, stereomicroscopy—which enables a 3D view from 2 photographs obtained and properly positioned in front of each eye—became quite popular. In recent years, advances in photography and computer optimization have facilitated the creation and dissemination of 3D images.

In medicine, 3D images are an extremely useful resource in the study and teaching of anatomy at both the macroscopic and microscopic levels. With advancements in technology and the emergence of new diagnostic imaging techniques and innovative therapeutic modalities, including arthroscopic and microsurgical endoscopic techniques, the need for new teaching material for applied anatomy has been met by the use of 3D images. However, the use of such images has not until now been widespread, probably because of the high costs and difficulty of large-scale reproduction.

Thus the application of stereoscopic images is fundamental to the development of future virtual reality models, which in turn will be particularly useful in the medical field. Activities such as medical education and training, development of new surgical techniques, and performing surgery remotely all certainly depend on the technology used to generate 3D images.

The potential applications of this technology are enormous; the feasibility of such methods on a larger scale promises to contribute to better illustrations by way of 3D images and a powerful new teaching tool.

REFERENCES