

Autostereoscopy – Three-Dimensional Visualization Solution or Myth?

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Introduction and Motivation

The use of three-dimensional visualization of spatial and non-spatial data and entities is a well-established practice in many applications of geographic science. The basic process of topographic map creation has relied on stereographic viewing of photographs as the primary basis for creation of the three-dimensional surface commonly shown as contour lines. Paper maps of other types also use three-dimensional presentations, some in stereo as actual three-dimensional formats, such as raised relief, but more commonly as two-dimensional representations showing the surface information. With the advance of cartography and visualization, coupled with the advances in technologies, such as video, image systems, and computer graphics, three-dimensional presentations have become a standard for geospatial datasets. In addition, the availability of these technologies support the use of visualizations in exploratory and confirmatory analysis with real and synthetic datasets. The capability to place the data in motion sequenced to time or to other data changes greatly expanded the use of maps and visualizations in analytical and scientific work. These technologies have also increased the availability of three-dimensional representations for presentation and exploratory analysis. While tremendous progress has been made in the representation of three-dimensional data and phenomena, the standard methods rely on two-dimensional display with embedded depth cues or three-dimensional display based on physical devices that separate images into left and right views for the left and right eyes, respectively. It is the thesis of this paper that autostereoscopy, *i.e.*, three-dimensional display without artificial physical devices, such as anaglyph or polarized glasses, is a viable alternative and that research and development of effective autostereoscopic methods can greatly increase the viability and use of geospatial data in three-dimensions. Simply stated, if we can remove the glasses and not require specialized hardware, we can reach many more users with three-dimensional data.

Background and Concepts

Human stereo vision relies on primary or physiological and secondary or psychological, sometimes called pictorial, depth cues to interpret three-dimensional information from a scene received on the two-dimensional surface of the eye or retina ((Braunstein, 1976; Okoshi, 1976). The physiological depth cues are based on the physical structure of the eyes and include accommodation or change of the lens shape, convergence from the two different perspectives of the individual eyes, and retinal disparity because of the different eye positions. Humans have two eyes to support three-dimensional interpretation of physical scenes based on these physiological depth cues. These physiological depth cues, particularly convergence and retinal disparity, can be

simulated in images presented to the eyes if the images are from slightly different perspectives of the same scene and are presented independently and simultaneously to the two eyes. At one time this was the accepted basis of human stereo vision.

Psychological depth cues are used to explain depth perception in photos and paintings and include relative size, linear perspective, height of objects above the line of sight, interposition, shading, shadow, relative brightness, color (chromostereopsis), and atmospheric attenuation. These pictorial cues are widely used in terrain representations such as shaded relief, which relies on shading and shadowing. Many of these can be combined with the physiological cues to produce enhanced three-dimensional effect. Motion is often classified as a pictorial cue, but since it produces changes in relative retinal displacements of objects at different distances, it actually produces a physiological response to convey the three-dimensional information (Jules, 1971).

Three-Dimensional Display Technologies

Display technology includes paper, film, video, and computer systems to convey either physiological or psychological cues that impart the depth information. Printed representations commonly use psychological cues, but anaglyph prints rely on the physical separation of left and right images based on splitting the color spectrum into red and green/blue components that are masked to the appropriate eyes to render the three-dimensional scene. Film products can include polarized films for separation and allow color images to be printed. These still require glasses, commonly with horizontal polarization for one eye and vertical polarization for the other to convey separate images.

Video and computer systems use both anaglyph and polarization and these methods are commonly implemented in softcopy photogrammetry systems to accomplish the left/right separation. These systems also allow motion and other specialized approaches with technologies such as lenticular and holographic displays to enhance the stereo image separation.

Autostereoscopic Methods

Autostereoscopic methods of three-dimensional display are based on a variety of concepts and methods to achieve synthesis of depth information in the human eye-brain system. One innovative concept proposed by Marr (1982) is that stereovision is not a reflex action but is in fact an intellectual activity. In this theory of stereovision, one depth map, for example, the left image of a stereo pair, is received by the eye-brain combination and stored, and later merged with a second depth map, the right image of the stereo pair. Current alternatives for achieving virtual three-dimensional displays based on this concept include motion parallax systems based on single images, stereo and alternating pair systems using two images, and varifocal mirror and holographic systems using more than two images (Kraak, 1988; Hodges, 1992). Not all of these technologies are applicable extraction and display of geographic phenomena from geospatial data, but the stereo and alternating pair methods hold particular promise for enhancing the productive capability of cartographic visualization systems (Fornaro et al., 1985).

Autostereoscopy can be achieved in printed representations using special films based on lenticular materials. Orasee (2003) uses a microoptical lenticular material to print stereo pairs of images in different layers that can be perceived by the eyes separately and convey three-

dimensional images. The potential of this technology for printed visualizations of geospatial data is extensive and forms a major research area for autostereoscopy.

Autostereoscopic display with video and computer systems has been extensively investigated and there are a variety of methods relying on basic concepts of stereo and alternating pairs of images. Alternating pairs use motion parallax combined with other physiological and psychological depth cues to convey three-dimensions. Visidep is a method developed by McLaurin *et al.* (1986) and takes advantage of the capability of video and computer technology to rapidly display alternating pairs of images. While this method works reasonably well for motion images, it has considerable problems with still images of geographic data (Usery, 1993). Other technologies based on special lenticular display screens have also been developed and require investigation for specific application to geospatial data (Shan, 2003).

Research Problems for Autostereoscopic Display of Geospatial Data

To date all autostereoscopic methods suffer from a variety of problems that require significant research to become viable techniques for routine use in visualization of geospatial data. Among the problems are the actual achievement of alternation by changing color lookup tables or multiple frame buffers (Hodges and McAllister, 1985; Usery, 1991). Additional problems of alternating pairs include the rocking motion that results from the changing scenes of still images (McLaurin *et al.*, 1986; Usery, 1993). Use of vertical parallax appears to provide better depth information than horizontal parallax, but no theoretical justification for this result has been established (McLaurin *et al.*, 1986; Jones *et al.*, 1984). Resolution, both spatial and spectral (color), are critical issues for alternating pair and other autostereoscopic methods. Finally, the alternation rate of the images appears to be user specific and although rates of 4 to 30 frames per second work, most users perceive the stereo effects better in the range of 8 to 10 frames per second. All of these problems are addressable in computer displays and with improved display technology, *e.g.*, high spatial and color resolution and high frame rates, now widely available in commercial-off-the-shelf computer systems, the prospects for autostereoscopic display in standard software for use with geospatial data is promising.

The research needs are to examine the above problems in the context of geospatial data. Development of approaches to these problems and theories that account for the results is needed to move autostereoscopy from concept to implementation in current visualization systems. A brief bibliography including cited references in this brief paper follows.

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