Chapter 17
On Volume Based 3D Display Techniques

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ABSTRACT
In the case of certain applications in which a need exists to visualize and interact with voluminous data sets and complex 3-D geometrical models, the conventional computer interface inhibits key human-computer interaction processes. Here, several deficiencies of the standard interface are identified with emphasis on a failure to make optimal use of the complex human sensory systems. Various general forms of interaction modality are outlined together with several types of image space. This provides a basis for brief discussion of emerging ‘creative’ 3-D display systems with emphasis on computational holography, varifocal techniques, and volumetric systems.

1. INTRODUCTION
The fundamental techniques used in computer graphics to map three-dimensional (3-D) image data onto the conventional two dimensional (2-D) display can be readily traced back to the Renaissance that flourished in Italy from the fourteenth to the sixteenth centuries. The Renaissance is widely viewed as a period of cultural rebirth and scholarly enlightenment in which the coalescence of art and mathematics played a vital role in the development of perspective drawing techniques by means of which artists are able to render (in a geometrically accurate framework) 3-D scenes on 2-D media. Filippo Brunelleschi is generally credited with providing the first demonstration in the Renaissance period of the use of such techniques (c1420)1 and subsequently, in Della Pittura (Italian version c1435) Leon Battista Alberti described a formalized methodology (Edgerton, 1976).

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The Renaissance denotes an important turning point in western culture. During this period scholarly traditions were established, knowledge was widely disseminated, and the image depiction techniques that were gradually refined led to the creation of works which exhibit, and even transcend, photorealism.

The depiction of images on 2-D tableaux, the inclusion of relief through carving and the creation of wholly 3-D representations via sculpture have, from the earliest times, provided outlets for a quest to depict and record our physical surroundings and also as a means of facilitating creative expression. The methodologies outlined by Alberti (coupled with subsequent additions and refinements) are used today in the depiction of 3-D images on the standard computer display. However, various emerging ‘creative’ 3-D display technologies offer to support true 3-D image depiction thereby enabling the formation of images that possess the attributes that we associate with traditional carving and sculpture.

In the next section we consider the depiction of images on the standard flat screen computer display and emphasize issues relating to the interface between the visible image and the human visual system. Subsequently, we identify three interaction modalities and five forms of image space (the tableau supporting image depiction). In the case of each form of image space, we briefly consider key attributes which impact on the visual characteristics of the depicted image and on interaction opportunities. Subsequently, in Section 4 we focus on three exemplar 3-D display paradigms that are particularly suited to the visualization of volumetric (voluminous) data sets.

2. INTERFACING WITH THE DIGITAL WORLD

In a number of key applications (including medicine, petroleum exploration, education and computer aided design) it is often necessary to visualize and interact with complex voluminous (3-D) data sets. Interaction is most commonly achieved using the conventional flat screen computer display accompanied by the keyboard, mouse and joystick. However, as 3-D applications grow in complexity, these conventional interface tools are inhibiting our ability to efficiently visualize the results of the computational process, and can cause the interaction process to become both clumsy and non-intuitive. In short, in an increasing number of situations conventional interface techniques are limiting the bandwidth of the bi-directional human-computer interface and in turn this reduces the efficiency with which we are able to utilize computer technologies.

This problem primarily arises because conventional interface technologies fail to properly capitalise on the powerful and complex human sensory systems (particularly the full capabilities of our visual sense and aspects of proprioception). We briefly outline some of the limitations of current interface technologies:

1. **The Conventional Display:** The flat screen display supports 3-D image depiction by presenting a number of cues to depth to the visual system. These include linear perspective, height in the visual field, occlusion, shading and aerial perspective. By judiciously employing these cues, Renaissance artists were able to embrace photorealism and because of their association with traditional image depiction techniques, they are referred to as ‘pictorial cues’ (Boff, Kaufman, & Thomas, 1986; Blundell, 2008). However, when we view our surroundings, we receive additional important information (concerning relative and absolute distances) from other sources. These are commonly classified as oculomotor and parallax cues. The former comprises accommodation and convergence and the latter binocular parallax (stereopsis) and motion parallax. When the conventional flat screen display is used for