ABSTRACT

Traditionally, the subject of “scientific visualization” focuses on the creation of novel or innovative graphical representations: essentially, new types of images to perceive. A truly complete approach to scientific visualization should include not only the perceived object, but also the abilities of the perceiver. Human “visual common sense” is a product of evolution, suited to the survival of the species; but it has severe and recurring limitations for the purposes of scientific understanding and education. People cannot readily understand phenomena that are too fast, slow, or complex for their visual systems to take in; they cannot see wavelengths outside visual spectrum; they have difficulty understanding three-dimensional (or, even worse, four-dimensional) objects. This chapter explores a variety of ideas and design themes for approaching scientific visualization by enhancing the powers of human vision.

INTRODUCTION: CHANGING HOW WE SEE

When the subject of “scientific visualization” comes up in the context of educational research, the usual assumption is that we are talking about creating better or more informative graphics. Perhaps the way to improve scientific visualization is through developing animated simulations; or interactive interfaces to large information spaces; or embedding aural cues within diagrams.

All of these approaches are promising, and thoroughly deserve to be pursued; but at the same time, a truly complete view of visualization research needs to look beyond an exclusive focus on the perceived object. Visualization, after all, requires both an object and a perceiver. We might thus seek to explore new types of visualization both by creating novel objects-to-perceive and by creating new tools and agents of perception. That is, by remaking the nature and equipment of vision itself, it might well be possible to achieve an expanded understanding of scientific ideas and the world in which we are embedded.

The purpose of this (frankly speculative) chapter is to suggest and enumerate a variety of potential avenues for creating visual technologies to enhance scientific education and understanding. The central
theme of these examples is to think about the human visual system as the biological core of what could be an expandable visual apparatus, combining both biological and non-biological elements. The process of evolution has provided us with visual powers tuned to the survival challenges that have historically faced our species; but at the same time, those powers constitute a sort of “visual common sense” that is not always, and not necessarily, suited to understanding ideas that challenge our inherited intuitions.

An Example: High Speed Vision

An introductory example might help to illustrate the motivation behind this chapter. In Fischbein (2002), there is a discussion of diSessa’s notion of “phenomenological primitives” (or p-prims) that act, essentially, as intuitive “building block” scenarios for understanding the behavior of physical objects. One provocative example involves explaining the reason that some objects (say, a ping pong ball) will bounce when dropped onto a hardwood floor, whereas others (say, a ball of wet clay) will not. When diSessa asked one student to explain the difference, She could not think by herself of springiness, and the interviewer suggested the compression of a spring. The subject had a clear intuitive understanding of the behavior of a compressed spring but nonetheless could not accept that the same explanation holds for the ball and generally, for every kind of piece of matter (for instance a ball made of steel). Her justification was that many objects are rigid and then they cannot be squished (deformed). For that subject rigidity and “squishiness” were p-prims, that is to say properties which may be understood intuitively by themselves and which, in turn, may explain other phenomena (Fischbein, p. 169).

For this student, the reason that a steel ball bounces is not identified with the deformation of the ball, but precisely because (in her view) the ball does not deform at all. And the ability for a ball to bounce is somehow—though not entirely clearly—associated with the “rigidity” (and thus, “bounciness”?) of the substance itself.

Why would someone have this intuition—that the act of bouncing involves no deformation? The most natural hypothesis is simply that we cannot see the deformation take place: it occurs too rapidly. My own intuitions about this scenario were fundamentally altered long ago when I saw a high-speed photograph (taken by Harold Edgerton) of a man hitting a softball with a bat: the photograph clearly shows what the naked eye cannot see, namely, a surprisingly deformed softball poised to “spring” off the bat (which is also visibly slightly bent in contact). Our visual limitations prevent us from seeing the deformation directly, without the aid of high-speed photography; and as a result our “common sense” notions of how the act of bouncing takes place are impaired.

Indeed, one of the very earliest anecdotes in “scientific visualization” similarly highlights the surprising difficulty of unaided vision of rapid motion. In 1872, Leland Stanford (later the founder of Stanford University) commissioned the photographer Eadweard Muybridge to photograph a horse in motion, with a particular interest in determining whether all four of the horse’s hooves were above the ground at any point in its stride. Muybridge’s classic series of photographs showed definitively that the answer was positive for a galloping horse; and the result was a triumph for the extension of human intuition via technology (Cf. Braun, p. 68ff).

To return, then, to the theme with which this chapter opened: a standard “scientific visualization” approach to the difficulty of high-speed perception would be to increase our access to photographs such