Variable-Resolution Displays: A Theoretical, Practical, and Behavioral Evaluation

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Variable-resolution display techniques present visual information in a display using more than one resolution. For example, gaze-contingent variable-resolution displays allocate computational resources for image generation preferentially to the area around the center of gaze, where visual sensitivity to detail is the greatest. Using such displays reduces the amount of computational resources required as compared with traditional uniform-resolution displays. The theoretical benefits, implementational issues, and behavioral consequences of variable-resolution displays are reviewed. A mathematical analysis of computational efficiency for a two-region variable-resolution display is conducted. The results are discussed in relation to applications that are limited by computational resources, such as virtual reality, and applications that are limited by bandwidth, such as internet image transmission. The potential for variable-resolution display techniques as a viable future technology is discussed.

INTRODUCTION

One of the factors determining the quality of a visual display is the presented level of detail. The detail that can be rendered in real time for most applications is limited by the available processing power (e.g., in virtual reality applications) or the available communication bandwidth (e.g., in image transmission applications). In light of these restrictions, it is important to allocate resources efficiently. Presenting a uniform level of detail across a display wastes resources because the human visual system does not process visual detail equally over the whole visual field. Rather, it focuses processing resources near the center of gaze. This property of the visual system can be exploited to minimize resource requirements by rendering a high degree of visual detail only in a portion of the display. Variable-resolution displays do this by presenting visual information using more than one level of detail.

A number of variable-resolution display techniques have been developed. First, gaze-contingent variable-resolution displays allocate resources for image generation preferentially to the area around the center of gaze. It is known that the visual sensitivity of the human visual system is at least an order of magnitude greater at the center of gaze than in the peripheral visual field (Adler, 1965). If this is to be exploited, the viewer's point of gaze must be tracked and the visual display updated in real-time so as to maintain a high level of detail at that location.

The potential resource savings (compared with presentation in uniform resolution) are substantial given that with this technique, a high level of detail need be maintained only in a small area around the center of gaze. This is especially true for head-mounted or projection-based displays that subtend a large portion of the visual field; however as will be shown later, substantial savings can also be obtained for smaller displays such as computer monitors. (Note that for the purposes of this paper, "smaller" and "larger" displays should always be understood in terms of visual angle.)

Gaze-contingent variable-resolution displays have been used primarily in virtual reality

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