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Spatial density distribution as a basis for image compensation

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The paper highlights an approach to provide custom-fit, non-invasive image compensation and remapping by which to magnify and optimize central vision for humans. Medical evidence supports that the visual density lies mostly within the limited range of the central vision. The technique is, consequently, based on both practical viewing considerations as well as the spatial density distribution in human retinal cells. The perceived image is divided into three vertically distributed sections (top–center–bottom), each warped according to its respective visual significance. Optimization is also used to ensure the smooth flow and transition of the image from one region to the other. The technique is expected to serve in applications such as low-vision, surveillance, machine operation, gaming, and text-enhancement.

1. Introduction

Electronic vision enhancement systems (EVES) involve a growing scientific research field that requires development in such areas as vision optimization as well as the application into different forms of image enhancement, such as selective area magnification and edge highlighting [1]. There has been a focus on EVES in low vision applications, which involve maximizing the remaining healthy vision using techniques that go beyond that of optical magnification aids. Loshin and Juday have conducted research (at NASA, Johnson Space Center), creating warped, fish-eye images designed to compensate for loss of peripheral vision (e.g. retinitis pigmentosa) and central vision (e.g. age-related macular degeneration) [2–4]. Amerijckx et al. also demonstrate the use of two CCD cameras into clustering images onto the healthy part of RP and AMD visual fields [5]. Another ongoing research effort is Peli and co-worker’s augmented vision, see-through HMD (helmet-mounted display) which superimposes a low-resolution, cartoon (or contour) image of the surrounding over the patients’ natural view [6, 7].

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2. Methods

This paper follows the footsteps of previous research whereby the peripheral image is completely introduced into the individual’s FOV (Field of vision), followed by a process of custom-fitting. The technique uniquely takes the human spatial viewing resolution as grounds for image warping, taking into account that the highest spatial density of retinal cells (more than 5000 cells mm$^{-2}$) lies mostly within the first 10 mm or so of the retinal eccentricity [8]. The compensation, customization algorithm is schematically demonstrated in the figure shown below.

A two-dimensional capture of the image is divided into three equal sections, each granted a different viewing and resolution priority. The top portion is given the least priority as it provides the least valuable/necessary information, as in the case of a high obstacle. The highest priority is provided in the image center, thus the highest resolution, as it contains the most valuable, spatial information in the image, although the significance decreases radially. The bottom is granted a low resolution priority, although higher than the top layer, since the lower layer practically involves seeking hazardous, obstructive objects. The result of this initial stage is a compensated image consisting of three vertically arranged regions, with smooth, gradual transitions that fortify the realistic appearance of the image.

The second stage involves customization, whereby the compensated image is convolved (by either magnification or minification) to the available field of view. One approach to achieve this is to match the compensated image to a predefined, best-match area of interest with the use of imaging or programming software. The other option is that of warping the image to the exact, discontinuous borders of the desired field of view. Individual feedback parameters are used at the end of each stage to determine both the efficiency of the compensation and customization techniques, and to subsequently improve the appearance of the image.

3. Discussion

The research aims at implementing regions of spatial resolution as grounds for warping. However, the existence of several distinct regions within an image poses a challenge both in the formation of the image as well as to the user’s visual adjustment. This latter point is mentioned in the past research by Juday and Loshin, and by Peli and co-worker, existing due to the inherent presence of discontinuities, low resolution, as well as the unrealistic appearance of the image, or sections thereof.

The technique has been targeted potentially towards low-vision (such as RP) patients. Other users include machine operators requiring optimized or more detailed perspectives of certain portions of a device. Military applications include that of conducting surveillance to concentrated regions of an image. General uses include gaming, by producing a larger, more realistic or animated look of objects in a game, as well as enhancing views of text (e.g. on a monitor or reading a book). The product could be integrated into a head-mounted display (HMD) that conducts the image compensation/customization procedure, or eyeglasses that produce either an
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Stage I: Compensation
- Divide as shown: ratios are optimized using individual feedback
- Map each “world” section (left) into respective empty section (right)
- Target FOV (determined experimentally)

Stage II: Customization
- Approach 1: Customize according to “best-fit” warp
- Approach 2: Customize according to exact FOV contour ("exact" warp)

Use individual feedback to reach a conclusion regarding:
which is the better of the two customization methods and
whether customization significantly enhances image quality

Figure 1. Research matrix showing major steps of image compensation and customization, including various optimization factors.
independent or superimposed view of the surrounding as integrated in any or all of the series of potential applications listed above.

References