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Electronic Notes in Theoretical Computer Science 329 (2016) 169–179

Electronic Notes in Theoretical Computer Science

www.elsevier.com/locate/entcs

Visual Impairment Simulator Based on the Hadamard Product

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Abstract

In this paper, a real-time image processing system designed to simulate visual impairment for the normally sighted is presented. The system consists of a video camera, a computer, and a virtual reality (VR) headset. Based on the Hadamard (or Schur) product of the camera's video signal and a set of predefined masks, users can experience eye diseases such as macular degeneration, diabetic retinopathy, glaucoma, hemianopsia, among others. A quantitative user study is presented to illustrate the most complex daily task people with visual impairments face: reading.

Keywords: Hadamard product, image processing, simulator, visual impairment, wearable system.

1 Introduction

In August 2014, the World Health Organization (WHO) released its latest report on Visual Impairment and Blindness [27]. This report estimates that there are 285 million visually impaired people worldwide. Of these, 246 million present low vision and 39 million are blind primarily from cataract, glaucoma, and age-related macular degeneration. The prevalence of blindness is both age and demography dependent: about 82% of the world's visually impaired are aged 50 and above and 90% of the people with visual impairments live in low income settings. These figures

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http://dx.doi.org/10.1016/j.entcs.2016.12.010

represent an important social and health care problem that requires the involvement of society.

For most normally sighted, blindness and visual impairment seem a far issue. The daily limitations experienced by this population cannot be imagined when sight is taken for granted. Any common activity (such as information access, mobility, way finding, interaction with the environment and with other people, etc.) represents a serious challenge. Few sighted have ever wondered what would be like to be visually impaired. The possibility of experiencing the disability and facing its challenges would certainly represent a step forward to a better understanding of visual impairment.

Within this context, we have developed a computer-based system that gives the user an accurate idea of the consequences of several eye diseases in human vision. The system essentially consists of a virtual reality (VR) headset that projects image and video within an immersive environment.

Upon the use of digital image processing techniques, the VR headset's input can be modified to simulate the most common causes of visual impairment.

The main goals of this project are to educate normally sighted about low vision and to provide a technological platform that recreates low vision conditions for the normally sighted in order to test new concepts of assistive devices.

The rest of the paper is organized as follows: Section 2 presents a brief state of the art review of low vision simulators. Section 3 describes the design, prototype, and operation principle of the proposed simulator. Section 4 evaluates the system's performance through a reading task performed on a group of voluntary subjects. Finally, Section 5 concludes summarizing the paper's main contributions and future work perspectives.

2 Related work

The easiest way to represent impaired vision is by drawings and paintings. There are some artistic works made by people with visual impairment that illustrate the consequences of eye diseases. For example, the compilation of paintings in [17] shows the perception that an artist with macular degeneration has of the environment.

A popular way to simulate visual impairments is with lenses. Several simulators of this kind already exist and are commercially available [9,28]. They consist of welder's goggles that have their lenses modified to simulate low vision. They are simple, robust, and inexpensive. The main inconvenience of goggles is they can simulate only one eye disorder.

Computer technology has been employed to simulate low vision. Several projects can be found in the literature. They all consist of software tools that, upon the use of digital image processing techniques, are capable of simulating myopia, macular degeneration, cataract, glaucoma, etc. [1,11,13] as well as different levels of color blindness [26,21]. The user normally selects the eye pathology to apply over 2D static images and visualizes the results on the computer's screen.

In the VR field, Jin et al. designed a virtual apartment that had to be explored