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Kasim Terzić, Miles Hansard



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Methods for Reducing Visual Discomfort in Stereoscopic 3D: A Review

Kasim Terzić^{a,*}, Miles Hansard^a

^a*School of Electronic Engineering and Computer Science, Queen Mary University of London*

Abstract

Visual discomfort is a significant obstacle to the wider use of stereoscopic 3D displays. Many studies have identified the most common causes of discomfort, and a rich body of literature has emerged in recent years with proposed technological and algorithmic solutions. In this paper, we present the first comprehensive review of available image processing methods for reducing discomfort in stereoscopic images and videos. This review covers improved acquisition, disparity re-mapping, adaptive blur, crosstalk cancellation and motion adaptation, as well as improvements in display technology.

Keywords: Stereoscopic 3D, Visual Discomfort, Image Processing

1. Introduction

Stereoscopic 3D is a popular form of entertainment, and is fast becoming a large industry. Stereo vision can improve performance on vision-based tasks [121], as well as audience immersion. However, many people find stereo 3D uncomfortable. Estimates of the number of people affected vary between 14% and 50%, depending on the study [144, 175]. Stereo discomfort is also known to affect viewers' emotional responses [11].

There are many symptoms of discomfort [160], which are typically associated with unnatural viewing conditions, or perceived instability of the visual world [60]. The basic causes are well understood, and their effects are quantified in a wealth of literature [90, 57, 179, 8, 185, 138, 103]. Despite this agreement on the causes, there is less consensus on how to go about improving the situation. Much research has gone into modelling and reducing these effects which is not addressed by the existing reviews. This work is spread through multiple fields, including display technology, optics, graphics, image processing, computer vision, and ophthalmology.

This paper presents the first comprehensive review of computational and technological solutions to the problem of viewer discomfort and is intended to serve as a

reference for researchers, companies and content developers interested in following this emerging field. Approximately 70% of the material presented here was published between 2011 and 2016, which indicates the recent level of activity in the field, and the need for a review at this point.

In order to understand the possible solutions, we begin with an overview of discomfort factors in this section. We follow it with a set of best practices for image and video acquisition compiled from the literature in Sec. 2. Then we discuss computational models of discomfort in Sec. 3, an essential part of any automated solution. Sec. 4 introduces algorithmic improvements intended to reduce discomfort. Sec. 5 gives a short overview of recent technological and hardware advances in display technology. We follow with a discussion in Sec. 6 and a conclusion.

1.1. Major Causes of Discomfort

There is a wealth of information in the literature about the causes of discomfort in stereo viewing [90, 57, 179, 8, 185, 103]. For completeness, we briefly introduce the main causes of discomfort here before we address models and solutions, and refer the reader to one of these reviews for a more detailed discussion of biological mechanisms underlying visual discomfort.

Crosstalk refers to the incomplete separation of images when viewing stereo 3D. Instead of one separate view for each eye, there is interference between images. Crosstalk is considered particularly annoying and it affects both depth perception and visual comfort [88]. We

*Corresponding author at: EECS, Queen Mary University of London, Mile End Road, London E1 4NS

Email addresses: k.terzic@qmul.ac.uk (Kasim Terzić), miles.hansard@qmul.ac.uk (Miles Hansard)

URL: www.eecs.qmul.ac.uk/~kasim (Kasim Terzić), www.eecs.qmul.ac.uk/~miles (Miles Hansard)

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