Virtual Glasses: The Myopic Revenge

Adrien Bousseau

ARTIS - INRIA / Grenoble University

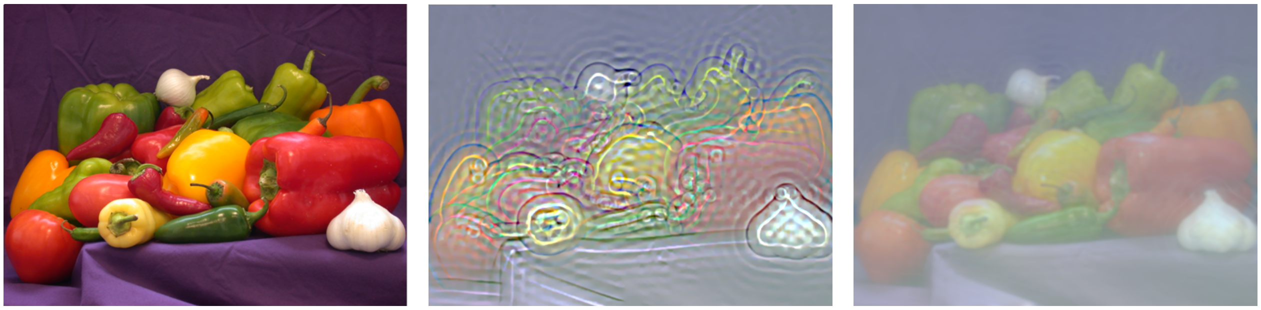

Figure 1: *The original image (left) is processed by the virtual glasses (center) so that a myopic observer can perceive a sharp image without glasses (right).*

Abstract

In this **fake** paper we introduce the *virtual glasses* that allow myopic or hyperopic people to see a sharp image without wearing glasses. Virtual glasses improve existing image preconditioning methods by making use of the recent advances in computer graphic and image processing. Thanks to virtual glasses, myopic people will finally be able to have a sharp vision of the world, while still being good looking.

1 Introduction

Vision abnormalities such as myopia or hyperopia affect a large proportion of the population. People that suffer from such abnormalities perceive a blurry image of their surrounding world, due to an imperfection of the eye causing inability to focus on near or far objects.

Glasses are a simple and effective way of correcting the eye aberration and refocus the image of the world on the retina. However on an aesthetic point of view, people wearing glasses are hardly seen as very cool people, and often suffer from a low self esteem. In this paper we adopt an opposite approach: instead of imposing a correction to the patient's eye so that he can correctly see the world, we precondition the world so that it can be correctly seen through the patient's eye. We call this preconditioning the *virtual glasses*. Thanks to virtual glasses, myopic or hyperopic people will no longer need to be disfigured by glasses.

2 Previous work

Image preconditioning for visual impaired has been an active research topic for many years. Early work by Peli and Peli [1984] applies contrast enhancement filters on an image to compensate the low-contrast vision of patients with macular disease. Fashionable portable devices (Figure 2) based on this technology have been developed to allow the patient to see a highly contrasted image of the world at anytime [Massof et al. 1994]. Fullerton and Peli [2006] have recently proposed a video codec based on a similar method, providing the first TV adapted to people having visual impairments.

For the particular case of blur compensation, Alonso et al.[2005] proposed to apply a deconvolution on an image in order to compensate for the convolution produced by a myopic or hyperopic eye. A similar approach has been used in the virtual reality community to compensate the out-of-focus blur produced by the projection of an image on a plane that is not parallel to the projector [Brown et al. 2006; Oyamada and Saito 2007]. However, when dealing with large blur preconditioning, image deconvolution tends to produce ringing artifacts and severe lost of contrast.

Figure 2: *The Vision Enhancement System developed by Massof et al. allows patients that suffer from macular disease to perceive a high contrast version of the world, with style.*

In the following section we give the mathematical basis of image deconvolution and describe how recent progress in computer graphics and image processing can significantly improve the results of deconvolution-based image preconditioning.

3 Virtual glasses

3.1 Background on image deconvolution

Image deconvolution is an inverse filtering method classically used for image deblurring. In such image restoration applications, a blurry image g is modeled as the convolution of a sharp image f with a blurring kernel h (called the point spread function or *psf*). The deconvolution consists to estimate an image f' that best fits g when convolved with the psf h.

A simple solution to this problem consists to perform the deconvolution in the frequency domain. The convolution theorem expresses a convolution in the spatial domain as the multiplication of two spectrum in the frequency domain. Applying this theorem leads to the solution of the deconvolution as the division of two spectrum in the frequency domain. Giving the spectrum G and H of the blurry image and the psf, the deconvolved image corresponds to the inverse Fourier transform of G/H. This method is the basis of a popular deconvolution algorithm called the Wiener filter [Rosenfeld and Kak 1982].

3.2 Improving image preconditioning

Previous methods for blur compensation [Miguel Alonso et al. 2005; Brown et al. 2006; Oyamada and Saito 2007] use the Wiener filter to deconvolve a sharp image so that it gives a sharp result when blurred by a known psf. In the case of myopic or hyperopic compensation, the psf must be the one of the observer's eye, which can be measured using a wavefront analyser [Liang et al. 1994].

However, applying a deconvolution on a sharp image creates very high contrasted features, especially around edges. This increase of contrast typically produces very high dynamic range images that cannot be displayed on standard monitors. The solution adopted by the previous methods consists to linearly compress the resulting dynamic range into a more practical low dynamic range, which produces a severe lost of contrast on the final image. The second drawback of the deconvolution method used in previous work is that it tends to produce the so called *ringing artifacts*. These ringings appear along edges and are propagated in the uniform regions of the image, while intuitively the deblurring of an uniform region should remain uniform. Low contrast and ringings can be observed on Figure 3(a).

The first contribution of this paper is to reduce the lost of contrast induced by the dynamic range compression. To do so we replace the linear compression by a *non-linear* compression inspired by the recent methods proposed in the computer graphic community to display high dynamic range images. In practice we use the method of Fattal et al. [2002] that performs a gradient domain compression on high contrasted features, while preserving the low contrasted ones. The second contribution of this paper is to replace the Wiener filter by the recent deconvolution algorithm proposed by Levin et al.[2007]. This new algorithm makes use of natural image priors to reduce the ringing artifacts produced by the deconvolution.

The application of these two recent algorithms significantly increases the contrast of the preconditioned images, as illustrated on Figure 3(c)(d).

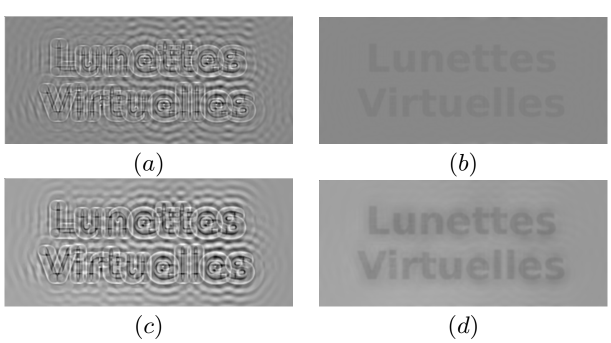

Figure 3: *Image preconditioning: (a) using a Wiener filter and a linear dynamic range compression, (b) the resulting reblurred image presents a very low contrast, (c)(d) our method produces fewer ringing and a higher contrast in the final image.*

3.3 Application

The method described in this paper finally makes image preconditioning practical to facilitate the everyday life of myopic or hyperopic people. The current implementation of the deconvolution and dynamic range compression algorithms is not real time, which implies that this image preconditioning should be used as a precomputation for image visualization. One could for example propose a preconditioned version of the fonts used in usual text editor, so that myopic people could write documents without wearing glasses. However we believe that a GPU implementation of these algorithms could allow real time preconditioning, bringing new area of applications such as the first TV for myopic people.

4 Discussion and future work

Although the presented method effectively produces images that are perceived sharp by myopic observers, we noted in our experiments that observers tend to suffer from headache after watching preconditioned images during long periods. However, in the case of a preconditioned TV, this can be seen as an advantage as it forces people to carefully choose their TV programme instead of watching random reality TV shows.

Another drawback of the proposed method is that the preconditioning depends on the particular psf of the patient. This means that only the patient will be able to watch a preconditioned TV, unless the other people wear special glasses to reblur the preconditioned image. This would represent the true myopic revenge, as this time the patient would be the only one to not wear glasses.

For future work we would like to extend the idea of adapting the world to particular impairments to other kind of illness. A promising application would be the development of a radio for deaf people.

References

BROWN, M. S., SONG, P., AND CHAM, T.-J. 2006. Image preconditioning for out-of-focus projector blur. In *CVPR '06: Proceedings of the 2006 IEEE Conference on Computer Vision and Pattern Recognition*, 1956–1963.

FATTAL, R., LISCHINSKI, D., AND WERMAN, M. 2002. Gradient domain high dynamic range compression. *ACM TOG (Proceedings of SIGGRAPH 2002) 21*, 3, 249–256.

FULLERTON, M., AND PELI, E. 2006. Post-transmission digital video enhancement for people with visual impairments. *Journal of the Society for Information Display 14*, 15–24.

LEVIN, A., FERGUS, R., DURAND, F., AND FREEMAN, W. T. 2007. Image and depth from a conventional camera with a coded aperture. *ACM TOG (Proceedings of SIGGRAPH 2007) 26*, 3, 70.

LIANG, J., GRIMM, B., GOELZ, S., AND BILLE, J. 1994. Objective measurement of wave aberrations of the human eye with the use of a hartmann-shack wave-front sensor. *Journal of Optical Society of America 11*, 7, 1949–1957.

MASSOF, R., RICKMAN, D., AND LALLE, P. 1994. Low vision enhancement system. *Johns Hopkins Applied Physics Laboratory Technical Digest 15*, 120–125.

MIGUEL ALONSO, J., BARRETO, A., AND CREMADES, J. G. 2005. Image pre-compensation to facilitate computer access for users with refractive errors. *Behaviour and information technology journal 24*, 161–173.

OYAMADA, Y., AND SAITO, H. 2007. Focal pre-correction of projected image for deblurring screen image. In *CVPR '07: Proceedings of the 2007 IEEE Conference on Computer Vision and Pattern Recognition*, 1–8.

PELI, E., AND PELI, T. 1984. Image enhancement for the visually impaired. *Optical Engineering*, 23–47.

ROSENFELD, A., AND KAK, A. C. 1982. *Digital Picture Processing*, vol. 1. Academic Press, Inc., Orlando, FL, USA.

Figure 4: *Result on the Lena image: (a) using a Wiener filter and a linear dynamic range compression, (b) the resulting reblurred image, (c)(d) our results.*