Towards perceptual colour for virtual environments

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ABSTRACT

In most computer graphics today, the goal is to make visualizations that "look good and natural" rather than to make correct simulations of reality[1,2]. However, for using Virtual Reality (VR) as a colour design tool, one has to be able to trust that light and colour in VR appear as in reality. In our project, the aim is to simulate perceptual light and colour phenomena more correctly. Real rooms are compared to digital models. In digital models, some contrast phenomena did not show. To propose a solution to these problems, digital renderings are filtered with the ACE algorithm. By filtering rendered textures of each multicoloured wall, the virtual reality model improved in colour appearance.

1. INTRODUCTION

At present, light and colour cannot be simulated in a realistic and reliable way in Virtual Reality (VR)[3,4]. The main objective of our research project is to simulate light and colour phenomena more correctly. This paper presents a step in this process were we have focused on problems concerning realistic reproduction of contrast effects in rooms.

Research on rendering of images is moving from colour reproduction towards colour perception[5]. Can results from this research on images be applied on Virtual Reality models? That is, photo-realistic image synthesis might not be enough for computing the best visual stimuli for Virtual Reality purposes. The main difference between colour reproduction and colour perception is given by human adaptation capabilities. These abilities are partially reduced when the human observer look at a digital reproduction of reality. Thus, even if the light-material interaction is accurately described, still the problem of the 'out of context' image display remains. *I. e.,* if the rendered image is shown to an observer, the human visual system treats it differently from the real scene 'in context'.

The goal of reproducing scenes in accordance with the perception of reality is difficult. In our opinion there are two main problems: Simulating physical light-material interaction and simulating human colour perception. These two tasks should be solved independently. The simulation of physical light-material interaction raises problems, such as the translation from paint to digital counterparts, and the calculation of bouncing light. In order to simulate human colour perception, various computational models in the field of digital imaging have been developed[6,7,8,9,10].

The ACE algorithm[11,12] is developed for local and global colour correction of digital images characterized by a lower dynamic range compared to the high range of real world scenes. In order to approximate the visual appearance of a scene, this algorithm considers mechanisms of spatial interaction, such as lateral inhibition and local-global contrast[13,14]. The aim of the algorithm is to simultaneously combine some of the mechanisms involved in the human visual perception. Within this model, every basic principle is considered a part of a unique adaptive behaviour involving the contribution of each mechanism to the final result. Each adaptive mechanism has global and local effects as a consequence of a number of simple local operations across the image.

A real room, due to light interaction, provides a more complex situation than images[15]. How can the ACE, developed for digital images, be applied to interactive Virtual Reality models? Our previous studies between real rooms and virtual environments have proved significant differences[3]. Three specific problems were detected: (1) Incorrect reproduction of reflections, (2) The simulation of different fluorescent lights showed poor agreement, due to too simplified chromatic information on light sources in 3ds max/Lightscape, (3) Incorrectly reproduced contrast effects and too few color variations. *E.g.*, the one surface that was perceived as the whitest one in the room was far too grey.

To solve the first problem, a development of the equations behind the light calculations is necessary. The second problem is that one cannot specify the spectral composition for the light sources. A possible development is algorithms that filter the light more nuanced than today. The third problem evolves around the difficulty to simulate different visual phenomena. Certain contrast phenomena noticeable in reality are lost in the light calculation and rendering.

This is a work in progress where we address the third of the problems. In order to solve the incorrect reproduction of contrast effects, we have begun to "filter" the models with an algorithm that recreates the human contrast vision. Initially, the algorithm was tested on video clips and images of digital renderings, thereafter applied on an interactive virtual reality simulation.

2. METHODS

We first analysed the differences in colour perception between reality and virtual reality[3]. Comparisons were made between (1) a 25 m^2 real room, (2) digital 3D models (3ds max 6 /Lightscape) on desktop PC, and (3) VR models in an Immersive/CAVE based system, and (4) Monographic and stereographic VR models on desktop PC. A process was developed to translate and visually compare real colors to digital counterparts. The real room was multi-coloured and designed to give examples of different color phenomena. It was studied in three different light situations: incandescent, fluorescent 2700K and fluorescent 3000K. A 3D model of the room was made. This model was exported to Virtual Reality[16] and showed stereographic and monographic on a desktop PC. The process to translate real paints into their digital counterparts is described in[3]. Data were collected from video recorded interviews and questionnaires. In total, 56 participants were involved; 20-30 participants assessed light, colors and space in each situation.

The colour samples, picked out by the observers to match the surfaces in the real room, were placed in a small viewing cabinet[17] to make a direct comparison between the display and the samples. With this analysis as a ground, the parameters of colour bleeding, reflectance and colour temperature were manipulated so that the digital model agreed with the real one; the changes needed were noted. Models simulating all three light situations used in the real room were analysed. All surfaces with the same inherent colour were treated in one instance in the same way. The default rendering motor of the software was used, the rendering motor Brazil was tested for comparison.

In the following phase of the project, we applied the ACE algorithm on video clips of the real room and renderings of the digital models. By comparing the original clips and images with the observer's results from the real room, we defined the discrepancies. Thereafter, the clips and images were filtered with the ACE. These images were compared to the observer's results of the real room, in order to see any colour rendering improvement.

Finally, we filtered rendered textures of walls and floors. They were put together to Virtual reality models and compared to the results from reality. We used the ACE algorithm to perform a 'partial' adjustment to the context, considering the spatial distribution of colours in the image. The ACE algorithm has different parameters that can affect the final result. In this paper we discuss some specific parameters (SLOPE, ALPHA, KOG) in respect to the goal. The SLOPE affect the output image contrast, the greater the SLOPE the greater the output contrast. The SLOPE affects also the ability of ACE to remove colour cast. Small values of SLOPE allow us to keep the colour cast. Typical values are from 1 to 20. The ALPHA parameter affects the locality of the ACE algorithm. It means that we can change the wideness of the colour induction behaviour. Using small values for ALPHA (i.e. 0,01) a colour can be influenced by other colours further away, while using greater values (i.e. 0,1) the resulting colour is more dependent on colours closer by. The KOG (Keep Original Gray) is a feature that does not allow ACE to modify the average values of each RGB channel of the input image.

3. RESULTS AND DISCUSSION

In the real room the differently painted surfaces had strong effects on each other by reflections, *i.e.* light interacts with the surfaces. Surfaces perpendicular to or opposite each other became more similar. However, on each uniformly painted area, different colour variations[17] were clearly visible. Moreover, between differently painted surfaces on the same level, effects of simultaneous contrast were evident. For example, a greenish light yellow square (NCS 0510-G90Y) on a green background (2040-G10Y) appeared pinkish, and a reddish light yellow square (0510-Y10R) on a red background (2045-Y80R) appeared greenish. Especially interesting was a light square (0510-Y10R) on a yellow wall (1030-Y10R) in the darkest corner, which was perceived as whitest and brightest of all surfaces, although five other areas in the room were painted in the same nuance (0510-G90Y, 0510-Y10R). This appears to be the kind of brightness phenomenon that is illustrated with the Adelson checker board[19] (see Fig 1).

Our studies proved significant differences between real and virtual rooms. The VR-room had incorrect reflection effects between surfaces, too few color variations and too achromatic shadows. The areas in the whitest nuances were difficult to simulate. Also it had incorrectly reproduced contrast effects for the lightest surfaces. The one surface that was perceived as the whitest one in the room was for example far too grey (see Fig 2a). This small square in the darkest corner of the room appeared distinctly greyish both on the video and in the virtual environments. The squares on the red and green backgrounds lost their chromaticness.

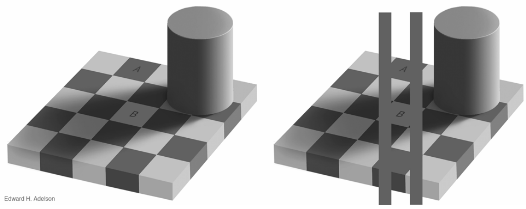

Figure 1: Adelson checker shadow illusion. ©1995, Edward H. Adelson[20].

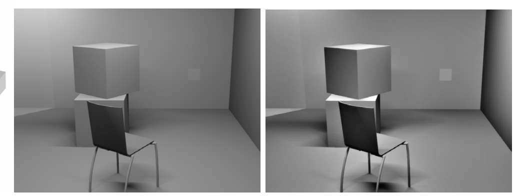

Figure 2a: Original rendering in 3ds max 6.0. **b:** Image filtered with ACE. The white square (NCS 0510-Y10R) is enhanced, but contrast effects between floor and walls are visible. (Settings in ACE: SLOPE 5, ALPHA 0,15, KOG on.)

In this phase of the project, we have focused on the contrast effects. The use of ACE has shown promising results. When filtered with the ACE this square became distinctly whiter and closer to its real appearance (see Fig. 2a and b). The other two white squares regained the greenish and pinkish appearance they had in reality.

However, the ACE also showed contrast phenomena between all differently coloured parts of a room, regardless of where in the room they were placed. This led to unrealistic contrast effects between the walls, and between wall and floor. In the real room, they did not contrast; instead they strongly affected each other by reflectance and became more similar. Thus, ACE can be used in restricted context. It can be used for filtering one multi-coloured flat surface at a time, i.e. each multi-coloured wall separately. As a result of this analysis, the course of our work took a new direction. This new process for using the algorithm in the production of VR models is shown in Fig 3.

4. CONCLUSION AND FUTURE WORKS

ACE has proven to be able to reproduce contrast effects visible in reality, which are lost in the digital renderings. However, further adjustments of the ACE will be necessary. At this stage it exaggerates the contrast effects, which will have to be corrected in the parameter settings of the algorithm.

Moreover, ACE cannot stand alone as a method for filtering images of the whole room, because it treats the contrast effects between all surfaces as a whole, disregarding their location in space. In reality, there are contrast effects between coloured areas on flat surfaces, while angled surfaces affect each other by reflections. Therefore, in the process of making Virtual Reality models (see Fig 3); we can use ACE for filtering rendered textures of multi-coloured flat surfaces in a 3D model. Rendered textures can be made of separate images of walls, floor and other multi-coloured elements in the room, which are put together to a Virtual Reality model.

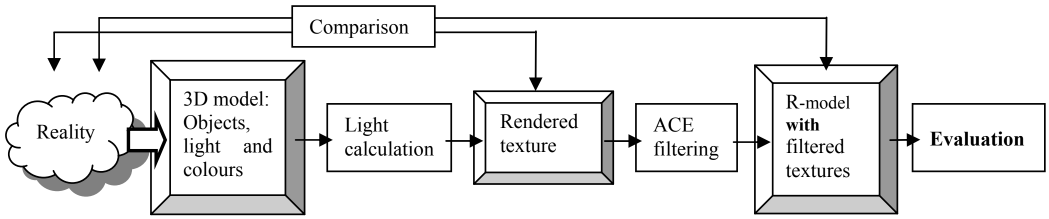

Figure 3: The ACE can be used for filtering rendered textures in a 3D model. These rendered textures are separate images of walls, floor and other surfaces in the room, used in Virtual Reality-models.

References

1. M. Slater and A. Steed and Y. Crysanthou, Computer graphics and virtual environment: From realism to realtime; University College London, Pearson Education Limited; 2002, p. 72.
2. P. Wishar, *Digital Space: Designing virtual Environments* (McGraw-Hill, New York, 1998).
3. M. Billger, I. Heldal, B. Stahre, K. Renström, Perception of Colour and Space in Virtual Reality: a comparison between a real room and virtual reality models, Proceedings for IS&T/SPIE 16th annual conference on Electronic Imaging, San José USA, 18-22 Jan 2004, pp. 90-98.
4. Billger, Monica and d'Elia, Stefano, Colour appearance in virtual reality: a comparison between a full-scale room and a virtual reality simulation. In: AIC Color 2001, Proceedings of the Ninth Congress of the International Colour Association, Rochester NY, USA; 2001; pp. 122-126.
5. D. Marini, A. Rizzi, M. Rossi, Color Appearance for Photorealistic Image Synthesis, Electronic Imaging 2001, 20-26 January 2001, San Jose, California USA, (Invited Paper) Proc. SPIE EI-2001, Vol. 4300 (2001) pp. 208-215.
6. E. Land., J. McCann, 1971. Lightness and retinex theory. J. Opt. Soc. Am. 61, pp. 1-11.
7. D. Marini, A. Rizzi, 2000. A computational approach to color adaptation effects. Image Vis. Comput. 18, pp. 1005-1014.
8. S. N. Pattanaik, J. A. Ferwerda, M. D. Fairchild, D. P. Greenberg, 1998. A multiscale model of adaptation and spatial vision for realistic image display. In: Proceedings of the SIGGRAPH98 Orlando, Florida, USA.
9. H. Spitzer, E. Sherman, 2002. Color contrast: A biological model and its application for real images. In: Proceedings of the CGIV02 the First European Conference on Color in Graphics Image and Vision Poitiers, France.
10. G. Buchsbaum, 1980. A spatial processor model for object color perception. J. Franklin inst. 310 (1), 1-26.
11. A. Rizzi and C. Gatta and D. Marini, From Retinex to ACE: Issues in Developing a New Algorithm for Unsupervised Color Equalization, Journal of Electronic Imaging, 13, No.1, 2004, pp. 75-84.
12. A. Rizzi, C. Gatta, and D. Marini. A new algorithm for unsupervised global and local color correction. Pattern Recognition Letters, 24: 2003, pp. 1663-1677.
13. Hartline, H.K., Wagner, H.G., Ratcliff, F., 1956. Inhibition in the eye of limulus. J. General Physiol. 39 (5), pp. 651–673.
14. McCann, J.J., 1987. Local/global mechanisms for color constancy. Die Farbe 34, pp. 275-283.
15. M. Billger, Colour In Enclosed Space: Observation of Colour Phenomena and Development of Methods for Identification of Colour Appearance in Rooms. CTH: Doctorate thesis, 1999. p.11, pp. 18-21.
16. The plug-in, called osg-exp, was developed by R. Schmidt Jensen and M. Grønager , http://osgexp.vr-c.dk.
17. M. Billger, Evaluation of a Colour Reference Box as an Aid for Identification of Colour Appearance in Rooms. Colour Research and Application; no 3; pp. 214-225; 2000.
18. E. H. Adelson, Lightness Perception and Lightness Illusions, Chapter 24 in M. Gazzaniga, ed., The New Cognitive Neurosciences, 2nd ed. MIT Press, 2000, pp. 339-351.
19. www.michaelbach.de/ot/lum_adelson_check_shadow/index.html. According to the www. the image can be reproduced and distributed freely.