Experience of light, colour and space in Virtual Environments

A work in progress about how to make light and colour phenomena appear as in real rooms

Introduction

The actors in the design process have difficulties to visualize and predict how the not yet built environment is going to be experienced. Realistic virtual environments could make it easier for architects, users and clients to participate in the planning process of material choices, illumination and colouring.

Today, you cannot make realistic models with Virtual Reality (VR), since there is a lack of knowledge about how different parameters work regarding light and colour in rooms. If we can trust that different visual qualities are correctly reproduced in the virtual environments, VR can be used as a pedagogical tool in order to learn more about how light and colour work together.

This poster presents results of comparisons between real rooms and different VR-simulations and one tested solution to improve colour appearance.

Aim

THE AIM WITH THIS PROJECT is to develop the knowledge of how different aspects of the virtual environment affect the spatial experience. The focus of our research lies on simulating light and colour phenomena more correctly.

***Figure 1.** View of the VR- model (incandescent light). The subjects found the colours in the room to agree fairly well with reality. However, the light areas appeared too greyish and the yellow ones appeared too alike in the VR-rooms. In reality they were perceived as many different colours. The numbers refer to the areas in Table 1.*

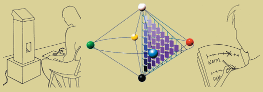
Methods

THE STARTING POINT FOR OUR STUDIES is the experience of a 25 m^2 multi-coloured real room, which has been compared with virtual models of the same room.The room was designed to get clear examples of how simultaneous contrast and reflections cause different appearances of the 6 different paints used. Three different light situations were used: tungsten, fluorescent 2700K and fluorescent 3000K. A digital model (3dsmax 6.0) of the room was made. This was exported to VR and showed stereographic and monographic on a desktop PC.

How light, colour and the spatial experience were experienced in the different light settings were investigated through video recorded interviews with 56 observers. People were asked to qualitatively describe the appearance of colour and light in the real room and in different simulations of the room. Their sense of presence and involvement were investigated through a separate questionnaire *.

Visual assesment techniques:

- Free description of the room as a whole
- Size estimation
- Semantic differential scaling with open scales (+ verbous motivation)
- Visual evaluation of light and colour
- Memory matching
- Colour matching



Physical measurements:

- The reflectance of each painted area was measured with a spectrophotometer. The L*a*b*-values were compared to the Lab-values of the digital colours.
- The spectral composition of the differently painted areas was measured with a spectroradiometer at different locations around the reference room and in the VR-room. We used the average values of L (Luminance), x and y (CI E 1931, 10 o) in the real room.
- The L, x and y-values were measured for the closest matching colour patch placed in the light box.

Results

IN THE REFERENCE ROOM, surfaces perpendicular to or opposite each other became more similar due to reflections. However, on each uniformly painted area, different colour variations were clearly visible. Moreover, between differently painted surfaces on the same level, effects of simultaneous contrast were evident. A brightness phenomenon appeared, i.e. a light surface in the darkest corner was perceived as whitest of all surfaces.

The interviewes showed significant differences between the real and the virtual room. The VR-room had incorrect reflection effects between surfaces, too few colour variations and too achromatic shadows. The lightest areas were not simulated well; they became too grey. The contrast effects for the lightest surfaces were incorrectly reproduced. The one surface that was perceived as the whitest one in the real room was for example far too grey.

L*a*b*-values measured in reality could not be directly applied as digital Lab-values. Corresponding Lab-values on the display were too brownish for the light paints. The strong red and green needed to be adjusted in the opposite way. Otherwise the simulation became too brilliant and whitish.

The luminance was very different between the reference room and the VR-room. Nevertheless, the light level in the VR-room was assessed almost the same and the colours agreed fairly well. Spectral composition of the areas in the reference room and the matching colour patches in the light box were close. However, the corresponding areas in the VR-room had distinctly different L, x and y values.

	Reference room						VR-room	
AREA	A NCS-code	B Refl.	C SpCom	D Light box	E M.E. (NCS)	F Verbal	G Display Lab	H Display Sp.Com.
1	1030-G90Y	L*84,24 a*-2,97 b*34,36	L=96,8 x=0,491 y=0,450	L=452 x=0,492 y=0,450 (NCS 1030-G70Y)	2030-G60Y	Greenish yellow	L=92 a= -12 b= -12,39	L=18,8 x=0,422 y=0,430
2	1030-G90Y	L*84,24 a*-2,97 b*34,36	L=92,0 x=0,490 y=0,443	L=359 x=0,490 y=0,443 (NCS 1010-Y10R)	1020-Y10R	Clear, light yellow.	L=92 a= -12 b= -12,39	L=15,5 x=0,415 y=0,421
3	0510-G90Y	L*92,08 a*-2,76 b*15,27	L=83,4 x=0,474 y=0,429	L=506 x=0,478 y=0,426 (NCS 0502-R)	0005-Y90R	Brillant, pinkish white	L=99 a= -7 b= 22	L=27,1 x=0,366 y=0,380
4	0510-Y10R	L*91,01 a*-0,54 b*17,65	L=88,2 x=0,480 y=0,429	L=476 x=0,480 y=0,438 (NCS 1010-G70Y)	0710-G70Y	Whitish green	L=98 a= -3 b= 20	L=24,2 x=0,371 y=0,375

***Table 1.** Reference room vs VR-room (flourescent light): examples of the collected data for four areas in the room, as well as the NCS-codes for the paints and results from magnitude estimation and verbal description.*

Defined problems

In the digital models there are:

- **Too few colour variations**
- **Too achromatic shadows**
- **Too small contrast effects**
- **The whitest areas are too greyish**
- **Incorrectly reproduced contrast effects**
- **Too simple chromatic information on light sources**

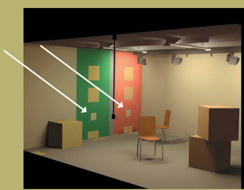


***Figure 2A.** Appearance in 3dsmax 6.0.*

***Figure 2B.** "Real" appearance (edited in Photoshop).*

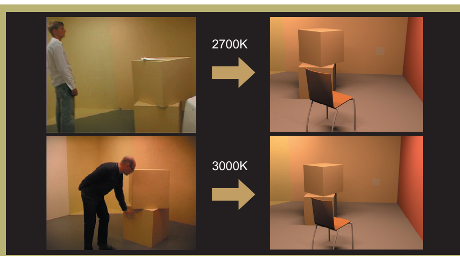


***Figure 3.** Too simple chromatic information on light sources.*

Solution to one problem?

The focus of our research lies on simulating light and colour phenomena more correctly. A step in this process is to focus on problems concerning realistic reproduction of contrast effects in rooms.

In the digital models, some contrast phenomena did not appear.

In collaboration with the Dep of Information Technology at the University of Milan, we applied the Automatic Color Equalization (ACE)** algorithm to our models***.

ACE aims to:

- **Combine mechanisms of spatial interaction: lateral inhibition and local-global color induction**
- **Increase the dynamic range**

ACE applied on one image:

- \+ **Brighter squares**
- \+ **Brigher walls**
- \+ **Contrast phenomena appear on the small squares**

- \- **Too strong contrast effects**
- \- **Unrealistic contrast effects in the corners**

***Figure 4.** 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.*

ACE applied on rendered textures:

IN REALITY, there are contrast effects between coloured areas on flat surfaces, while angled surfaces affect each other by reflections. The problem with ACE is that it treats the contrast effects between all surfaces as a whole, disregarding their location in space. ACE is based on theories of 2D-colour phenomena. Our studies showed that it cannot be applied for rendering the complete 3D-model.

Therefore, in the process of making VR-models we used ACE for filtering rendered textures of multicoloured flat surfaces in a 3D model. Through this process, the light areas in the VR-model improved in colour appearance (see Fig 5A-C).

***Figure 5A.** Rendered textures from the model in 3dsmax 6.0.*

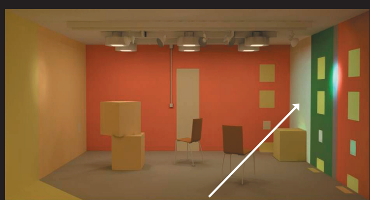


***Figure 5B.** ACE applied on rendered textures:*
• Better contrast effects
• Increased brightness for the white areas

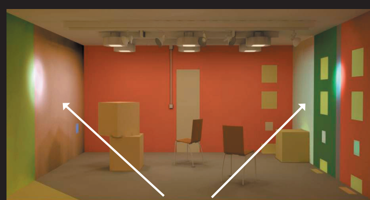


***Figure 5C.** Same settings - different results; contrast increases with less information. This problem might be diminished by using anchor points with reference colours.*

Reflections do not exist in 2D, but are evident in 3D. Therefore, theories on colour perception in 2D cannot automically be applied in 3D.

Conclusions

The study showed various problems related to the translation and comparison of reality to VR. The complexity of the task requires further systematic research in connection with elaborations in VE's. It is not enough to measure and mathematically model the physical conditions; we need to include psychological phenomena and the way our human vision works.

Problems to solve concern, for example, how to compare visual results between different medias, mixed adaptation and arbitrary parameter setting in the software.

ACE has showed 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. We conclude that the ACE can be used as a starting point for a new algorithm.

Future work

A development of better algorithms is needed. We want an algorithm that can take into account the amount of information given in different parts of the image.

Our strategy is to list and specify spatial light- and colour phenomena, including comparing physical data to visual appearance of colours, in order to make them programmable. We plan to create an algorithm which is adjusted to the eye's perception of reality and the threedimensional vision.

Vision

- **Better balance between reflections and contrast effects**
- **Better represented spectral composition for the light sources**
- **Increased colour variations**

References

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