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Application of spectral computing technics for color vision testing using virtual reality devices

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Abstract

Color deficiency tests are well known all over the world. However, there are not applications that attempt to simulate these tests with total color accuracy in virtual reality using spectral color computing.

In this work a study has been made of the tools that exist in the market in VR environments to simulate the experience of users suffering from color vision deficiencies (CVD) and the VR tools that detect CVD. A description of these tools is provided and a new proposal is presented, developed using Unity Game Engine software and HTC Vive VR glasses as Head Mounted Display (HMD). The objective of this work is to assess the ability of normal and defective observers to discriminate color by means of a color arrangement test in a virtual reality environment. The virtual environment that has been generated allows observers to perform a virtual version of the Farnsworth-Munsell 100 Hue (FM 100) color arrangement test.

In order to test the effectiveness of the virtual reality test, experiments have been carried out with real users, the results of which we will see in this paper.

Introduction

Virtual reality has grown very quickly in the last decade. Without a doubt, it is one of the technologies that will have great importance in the very near future. Today, we can see how virtual reality is applied to different sectors such as video games, medicine or the car industry.

However, few applications have been developed to be key in helping to detect visual problems in users, since at present virtual reality is not yet sufficiently developed to ensure quality in the assessment of users with visual problems. This would be very interesting because it would save costs of devices needed to perform these tests.

On the other hand, from a colorimetric point of view we can verify that there are different tests to validate the degree of deficiency that the user perceives in a color. All these tests are physical and require different devices, in some cases very expensive. In addition, they need the user to move to a place where they have these tests to assess their color deficiency. An example of these tests is the FM 100 [1]. The FM 100 hue test is one of the most famous color vision tests available. It belongs to the group of hue discrimination, also called arrangement tests. The aim of the test is to order the shown color plates in the correct order—any misplacement can point to some sort of color vision deficiency.

Therefore, if we are able to develop an application that simulates the development of FM 100 in virtual scenes, we will be able to evaluate the deficiency of users through virtual reality devices and check their difference with the real world.

The objective of this work is to study the validity of commercial virtual reality systems to be used in research tasks in color vision and lighting laboratories. This validity arises from a point of view of what we have previously called virtual psychophysics, since it uses the simulation of the physical laws related to the light-matter interaction. Virtual reality software platforms carry out this simulation together with colorimetric transformations through a color management system. Specifically, a virtual version of the FM100 Hue test has been implemented in a virtual reality environment to verify its validity by comparing it with a real version of said test. This comparison is based on the analysis of the results obtained by both versions on the same population sample. The study of the validity of this specific test on this type of virtual reality systems does not validate these systems for all use in research tasks related to color vision research but if the result is positive, it opens the door to a possible future use previously validating each of its applications.

Methods

We are going to divide the methodology into 5 steps to explain the whole procedure followed until we get the results shown in this work. We will begin by explaining previous works in which different steps were carried out to obtain a chromatic characterization and a color management in virtual environments. We will continue analyzing the development of the software, which contains spectral material and finally we will explain which has been the procedure used to evaluate the results obtained.

Chromatic characterization of HMD

Previous work has shown that it is possible to obtain a chromatic characterization of virtual reality devices. So it is the first step if we want to make a faithful representation of the color vision by computer, something that is highly recommended to develop test of visual impairments in color.

Therefore, we are going to show the data obtained from the chromatic characterization and we are going to use for the next step elements such as the ICC profile obtained from this characteristic [2].

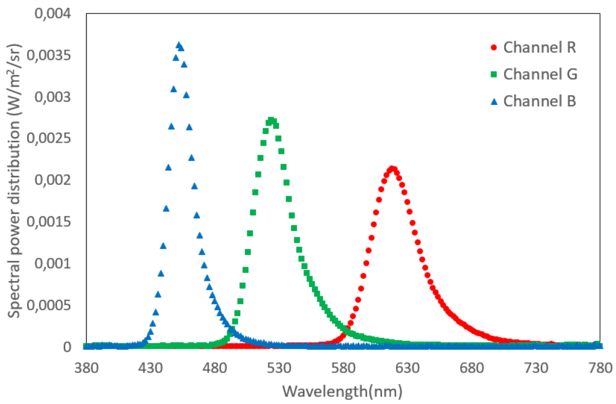

Figure 1. Spectral Power Distribution of HMD

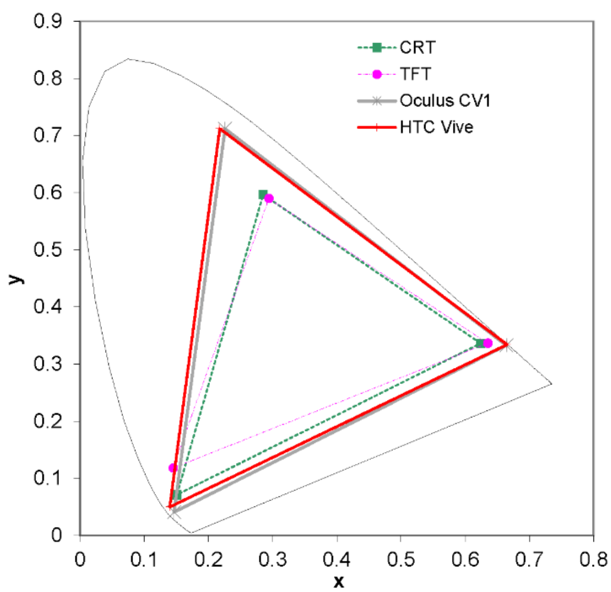

Figure 2. Gamut comparative

To verify that the chromatic characterization performed fits well with the model used, 30 random measurements of RGB values have been made, obtaining an average color error of 1.78 units in terms of CIEDE2000 with a standard deviation of 1.2.

Color Management Module for VR

To achieve our goal, we have introduced a Color Management System (CMS) into Unity's software [3], whose native color space is RGB. The starting point was the color characterization of the HMD HTC Vive display device and the definition of its associated colorimetric profile. The Little CMS [4] color management library has been introduced and, by means of colorimetric transformations, the tristimulus values of different light sources defined by their spectral distribution of power. Subsequently, a color transformation has been applied from the CIE XYZ color space 1931 to Unity's native RGB color space, via ICC profiles and the color management system [5].

Spectro radiometric Farnsworth-Munsell 100 test

We measured the reflectance of each of the 85 tablets in the FM 100 test with a spectro-radiometer to simulate the reflectance obtained in the virtual environment and achieve a realistic color calculation.

Software developed: Virtual Scenes

As stated above, our main objective is to develop and implement a complete test of FM 100 Hue, in a controlled VR environment, for effective evaluation. One of the advantages of VR is that we eliminate external factors that could modify the results of a test, since the observer when putting on the virtual reality glasses, abstracts himself from the world that surrounds him, immersing himself in the environment that we will create for this experience.

Observers and procedures

The population sample was composed of 10 observers (5 men and 5 women) aged between 21 and 56 years. Observer 1 to 8 checked in color vision according to the Ishihara Test. Observers 9 and 10 fail Ishihara Test and were classified as defective observer by Panel D-15 test. Each observer answered the test three times randomly in different sessions. The test requires two parts: one corresponding to the physical test and another one corresponding with the virtual version. All sessions have been carried out on different days and varying the order randomly.

The methodology employed with the physical test follows the recommendations of the original author of FM 100 test. The methodology applied to the virtual test follows this sequence: first, all color samples correctly ordered are shown to the observer (Fig. 3). Subsequently, test starts only showing the samples belonging to a single row. This row is chosen randomly, leaving the first and last capsules at a fixed position in the same way than the physical test is applied (Fig. 4). The observer must place all the samples in the order that they consider correct with a remote control of the VR device. The remote control has an equivalent in the virtual scene and the observers can see this remote control controlled by a virtual hand. Observers can modify the position assigned to each sample all the times they consider necessary. After finishing each row, the next row is shown and at the end of the test, the score obtained and the time spent are reported.

Figure 3. Farnsworth-Munsell virtual test

Figure 4. Final virtual test

Results

After completing the test sessions realized to the 10 observers, the results obtained have been processed, calculating the average score and the standard deviation of each observer. This has been done with both results: from the physical tests and the virtual tests (Table 2). The same calculation has been done with spent time.

The analysis of the results indicates that there is a great fluctuation in the score obtained by each observer in each of the three repetitions, which justifies the considerable high value of standard deviation. This variation occurs in both versions of the test, physical and virtual, although it is greater in this second one. Likewise, time spent by each observer in the realization of the virtual test is higher compared with the physical test.

The statistical analysis of the results (Wilcoxon test) indicates that there is a significant difference between the results of both tests, however, there is also a high correlation between the two tests (Pearson coefficient= 0.97, p-value< 0.01). The results of both tests indicate that there is a difference in scale between the two tests, with greater difficulty in the case of the virtual test, but the classification of the observers done by the test may be the same. To confirm these results, more tests with more observers and more repetitions would have to be carried out to classify the observers as good, normal or defective, just like the physical test do.

Table 2. Numerical results of FM 100 test for 10 observers

Observer			Physical test		Virtual test	
#	Age	Sex	Score	Time	Score	Time
1	27	W	0±0	15±4	24±0	20±6
2	26	M	4±0	10±1	25±13	15±6
3	26	W	6±3	9±3	40±10	24±5
4	45	M	9±13	7±1	23±15	18±3
5	56	W	25±14	7±3	27±5	16±3
6	54	W	36±14	6±1	45±18	12±2
7	56	M	44±14	10±5	92±23	11±5
8	55	W	47±5	6±1	101±63	14±2
9	25	M	189±8	8±2	191±108	17±4
10	25	M	212±9	9±2	268±60	9±3

W= Woman, M= Man, Time in minutes

Conclusions and Discussions

In this work we have implemented an application that allows the user to perform a color defect test. We have detected after making tests with real observers, that the accomplishment of the virtual test requires a greater time for the user and the results are not equal to those obtained by the physical tests.

If more data will be collected with more observers and more repetitions, the virtual test could classify the observers according to their capacity of chromatic discrimination in an equivalent way than the physical test. This virtual version of FM 100 can also be valid for detecting deficiencies in color vision.

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References

[1] D. Farnsworth, "The Farnsworth-Munsell 100-Hue and Dichotomous Tests for Color Vision," *Jour. Opt. Soc. Am.,* vol. 33, no. 10, pp. 568-578, 1943.

[2] F. Díaz-Barrancas, P. J. Pardo, M. I. Suero and A. L. Perez, "Is it possible to apply color management technics in Virtual Reality devices?," in *XIV Conferenza del Colore*, Firenze, 2018.

[3] "Unity Technologies," 2019. [Online]. Available: https://unity.com/es. [Accessed 12 2019].

[4] M. M. Saguer, "Little CMS," 2018. [Online]. Available: http://www.littlecms.com/. [Accessed 12 2019].

[5] H. Cwierz, F. Díaz-Barrancas, P. J. Pardo, A. L. Perez and M. I. Suero "Colour Management in Virtual Reality applied to Lighting Simulations" in AIC Lisboa 2018.

Author Biography

Halina Cwierz *received the B.S degree in computer engineer in 1987, and the M.S degree in computer technologies research in 2016, both from the University of Extremadura (UEx), Mérida, Spain. She is currently working toward the Ph.D. degree in application of virtual reality devices to the screening of colour vision deficiencies.*

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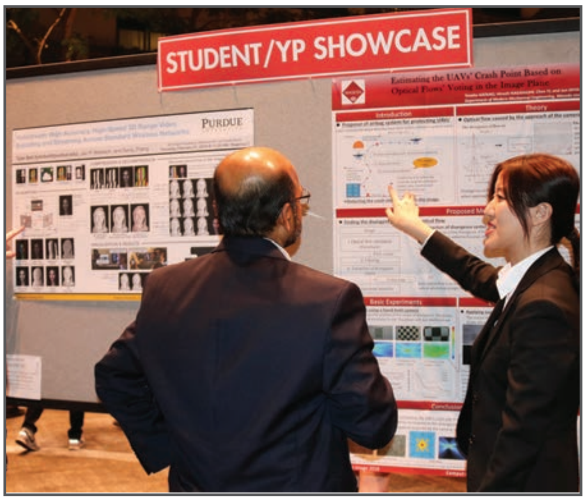

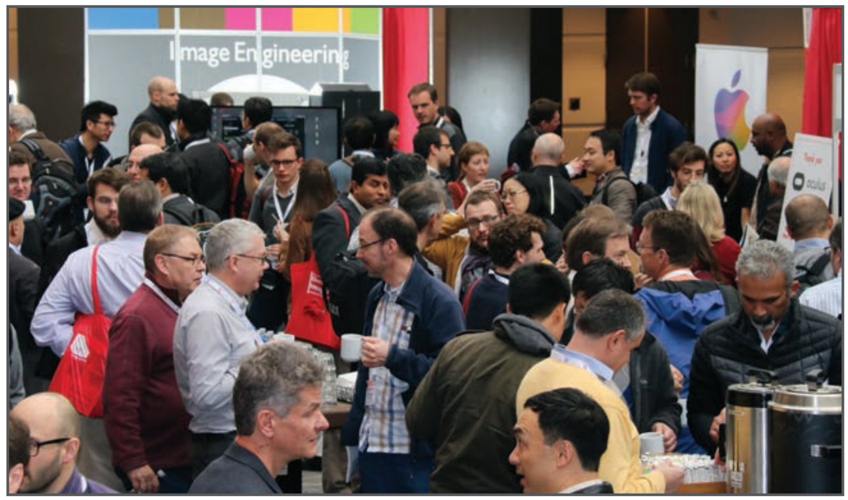

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