Augmented Reality as a Tool to Support the Inclusion of Colorblind People

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Abstract. Color blindness is a condition that affects the cones in the eyes, it can be congenital or acquired and is considered a medium disability that affects about 8.5% of the world population and it occurs in children, who have special difficulties to the newly enter an educational environment with materials developed for people with normal vision, this work focuses on the development one technology, to allow people with a visual disability known as color blindness, to improve their daily activities which in turn leads to a better inclusion in the social and educational environment.

To help the inclusion of these people an application was made that allows an identification of the type of condition of the user through the Ishihara test, which worked with two versions, the traditional and a variation to work with children, and subsequently the result It is taken into account to work with another Augmented Reality application which first uses an identification of the colors of an image through a color classification system, for this different algorithms were implemented one with automatic programming and another with a particle swarm optimization (PSO), once the algorithm identifies the colors it modifies them in real time to a spectrum of colors that if distinguishable by the student but at the same time identifies the centroids of the objects and labels them in real time with the real color, two forms were used for labeling, the word with the color and a color code ColorADD proposed or by Neiva in 2008.

Keywords: Inclusion · Augmented reality · Colorblind · Code ColorADD

1 Introduction

1.1 A Subsection Sample

The inclusion of people in areas such as social, work, educational, among others, is a topic of great interest and relevance at the international level. Organizations such as the Organization for Economic Co-operation and Development (OECD) that drives the inclusion of people as an important part for the economic development of a city [1], and

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the United Nations (UN) that strive for the realization of inclusion as established by the Universal Declaration of Human Rights, which indicates that this is a right that must be applied regardless of gender, race, nationality, socioeconomic status, far from a physical or mental faculty [2]. In recent years, the countries have opted for public policies that seek to guarantee the inclusion, above all, of the most vulnerable, so they have proposed, generated and applied, laws and programs that seek the inclusion of women and people with some disability or who belong to a vulnerable group.

On the other hand, technology has evolved by leaps and bounds and today is not conceived of daily life without the use of it. From appliances to autonomous vehicles or smart phones and devices. Many research projects have focused on the use technologies not only to facilitate tasks, but to improve the lives of people living some kind of inequality, focusing on the use of information and communication technologies to facilitate and improve the teaching and learning process we have for example, learning objects, open educational resources or intelligent tutors, some works made have been focused to support the teaching-learning process in people with Dawn syndrome, autism or Asperger, but also laboratories virtual chemistry or physics that allow schools with lack of facilities and/or equipment, so that their students can do virtual practices.

One of the most used technologies in recent years is Augmented Reality that allows virtual environments to be mixed with reality.

This paper show the development one technology, to allow people with a visual disability known as color blindness, to improve their daily activities which in turn leads to a better inclusion in the social and educational environment. Color blindness is an unfavorable situation, it occurs in people who have a diminished perception of color compared to the average, this condition was described in a scientific work for the first time in 1793 by John Dalton, it is difficult for them to interact with activities that imply a correct perception of color, some examples of these are recreational activities with games, discussion about objects and their identification, interpretation of signs or driving signs, educational activities with color material, among others.

Such difficulties make color blindness a disability. This affectation occurs since in the retina there are two types of cells that detect light, these cells are the rods and cones. The sticks only detect light and darkness and are very sensitive to low light levels, while the cones detect the colors and are concentrated near the center of vision. There are three types of cones each of which detects a color (red, green and blue) and the brain interprets the information they send to determine the color we perceive. Color blindness occurs when one or more types of cones are absent, do not work, or detect a different color than normal. Within the disease levels the serious occurs when all three types of cones are absent, while the mild occurs when all three types of cones are present, but one of them does not work well. Color blindness can be classified, according to the cone with which one has problems and their severity. In the first instance, color blindness is classified according to its severity in: anomalous trichromacy, dichromacy, monochromacy or acromatopsia and its affectation is 8.5% of the world population, being 8% men and only. 5 women with a distribution in the types of color blindness that can be seen in the Table 1 [3].

Table 1. People distribution with color blindness according to the type of affectation [3].

Type	Denomination	Prevalence	
		Men	Women
Monochromacy	Achromatopsia	0.00003%	
Dichromacy	Protanopia	1.01%	0.02%
	Deuteranopia	1.27%	0.01%
	Tritanopia	0.0001%	
Anomalous trichromacy	Protanomaly	1.08%	0.03%
	Deuteranomaly	4.63%	0.36%
	Tritanomaly	0.0002%	

As part of the tests it is shown how the images look to blindness people and how they look through the application in different types of color blindness.

At present, inclusion is a social problem, but it is important to combat it especially in areas such as educational, economic and social, to ensure equal opportunities for all.

Nowadays there is a great interest on promoting the use of technology in the classroom, because of this we can see a lot of tools such as LMS, Learning Objects, Open Educational Resources, Tangible Interfaces, among others. In this sense, some research projects focused on inclusion in the educational area can be seen using these tools to support teaching and learning processes such as: Learning objects for the inclusion of indigenous people [4], open educational resources for people with visual disabilities [5], design of mobile applications for people with visual disabilities [6], use of augmented reality in learning objects for teaching people with visual disabilities [7, 8], among other.

2 Related Works

2.1 Ishihara Test

The most commonly used pseudochromatic plates are Ishihara plates and their popularity is such that they have become a reference icon for color blindness [3].

The diagnosis is made by presenting the patient with a series of plaques, which are marked with colors that people with color blindness often confuse, so they are based on the theory of copunctual points, the plates are discs with numbers that are confused with the background, and its misidentification serves as a reference to diagnose the variant of color blindness that occurs, however, the severity of the condition cannot be detected [9].

Ishihara Plates are designed for the detection of protanopia, protanomaly, deuteranopia and deuteranomaly, however, other variants cannot be detected by the original Ishihara designs.

2.2 Augmented Reality

As for augmented reality, it is a technology that integrates real-world objects with the virtual. Basogain et al. [10] referred to Augmented Reality as a technology that complements the interaction with the real world and allows the user to be in an augmented real environment with additional information generated by the computer. In this regard Fabregat [11] mentioned that the applications of RA “It uses information and computer-generated images that are superimposed on the user’s field of vision.” Some of the characteristics of augmented reality are:

1. Mix the real and the virtual. Digital information (text, 2d and 3d images, audio, multimedia) is combined with real world images.
2. It works in real time. The mix of the real and the virtual is done in real time.

The AR is part to a mixed reality can see in Fig. 1, it is made up of the monitor of the computer or mobile device, where the combination of real and virtual elements is reflected; the webcam that takes real-world information and transmits it to augmented reality software; software, which takes the real data and transforms it into augmented reality; and the markers, printed symbols that the camera captures and the software interprets to respond specifically [11].

Fig. 1. Type of Mixed reality [12].

Currently, this technology has been used in various fields such as health, entertainment (games), training, marketing, education, among others. Focusing on the educational part we can see different applications in areas of knowledge and specific topics such as mathematics [13], biology [14], chemistry [15], anatomy [16], among others.

2.3 Color Identification System ColorADD

The ColorADDTM color code to assist the colorblind is proposed by Miguel Neiva in a master thesis dissertation made in 2008 [17, 18]. The symbology created by Miguel Neiva, has been widely accepted and has been recognized by associations such as “Color Blind Awareness”, “Non-Anonymous Daltonics”, “GALILEU” magazine, the “ICOGRADA” organization, and the UN recognizes it as the best 2014 alternative, in the Inclusion and Empowerment category. Company B, which evaluates the concept of business success, has certified it and also has already been presented at a conference within the well-known TEDx program [18]. ColorADDTM allows colors to be identified by symbols. A scheme with the representation of these codes is shown in Fig. 2.

Fig. 2. ColorADDTM color code [18].

2.4 Related Works

Some projects and research papers can see in Table 2.

Table 2. Projects a research papers related to colorblind.

1. Augmented Reality Solution for Color Vision Deficiency CHROMA [19]	Researchers from the Department of Computer Science and Engineering at the University of California in San Diego, CA have developed an augmented reality solution call CHROMA: a wearable, real-time AR app that utilizes the Google Glass to address the real-life issues that people with color blindness face. CHROMA is a digital aid for patients, and can deliver information about shades of colors that the user cannot determine
2. Wearable Improved Vision System for Color Vision Deficiency Correction [20]	Color vision deficiency (CVD) is an extremely frequent vision impairment that compromises the ability to recognize colors. In order to improve color vision in a subject with CVD, they designed and developed a wearable improved vision system based on an augmented reality device. The system was validated in a clinical pilot study on 24 subjects with CVD. The primary outcome was the improvement in the Ishihara Vision Test score with the correction proposed by their system

(*continued*)

Table 2. (*continued*)

3. An Adaptive Fuzzy-Based System to Simulate, Quantify and Compensate Color Blindness [21]	This paper presents a software tool based on Fuzzy Logic to evaluate the type and the degree of color blindness a person suffer from. In order to model several degrees of color blindness, herein this work they modified the classical linear transform-based simulation method by the use of fuzzy parameters. They also proposed four new methods to correct color blindness based on a fuzzy approach: Methods A and B, with and without histogram equalization. All the methods are based on combinations of linear transforms and histogram operations
4. Image Content Enhancement Through Salient Regions Segmentation for People With Color Vision Deficiencies [22]	The contributions of this work is to detect the main differences between the aforementioned human visual systems related to color vision deficiencies by analyzing real fixation maps among people with and without color vision deficiencies. Another contribution is to provide a method to enhance color regions of the image by using a detailed color mapping of the segmented salient regions of the given image. The segmentation is performed by using the difference between the original input image and the corresponding color blind altered image. A second eye-tracking of color blind people with the images enhanced by using recoloring of segmented salient regions reveals that the real fixation points are then more coherent (up to 10%) with the normal visual system. The eye-tracking data collected during our experiments are in a publicly available dataset called Eye-Tracking of Color Vision Deficiencies
5. Color Blindness Correction using Augmented Reality [23]	Introduction Augmented Reality provides a real-time world environment and allows the viewers to interact with game live. This happens with the help of various augmented factors such as audio, visual, computer graphics and even global positioning input. Augmented reality synchronizes the environment with the graphical structure to provide an ultimate virtual reality gaming experience. Using the same technology, we can alter the saturation of an image in real time to print the correct color that can be perceived as it is by a colorblind person

(*continued*)

Table 2. (*continued*)

6. An Efficient Naturalness Preserving Image Recoloring Method for Dichromats [24]	They present an automatic image-recoloring technique for dichromats that highlights important visual details that would otherwise be unnoticed by these individuals. Their approach preserves, as much as possible, the image's original colors. The results of a paired-comparison evaluation carried out with fourteen color-vision deficients (CVDs) indicated the preference of our technique over the state-of-the-art automatic recoloring technique for dichromats. When considering information visualization examples, the subjects tend to prefer they results over the original images. An extension of our technique that exaggerates color contrast tends to be preferred when CVDs compared pairs of scientific visualization images. These results provide valuable information for guiding the design of visualizations for color-vision deficients

3 Developed Applications

As part of the development of the application of augmented reality as support for people with color blindness, we worked on the development of the Ishihara test for the detection of this condition in users for this the traditional test was automated and a modification was made for children small plates in which plates like those shown in Fig. 3 were used.

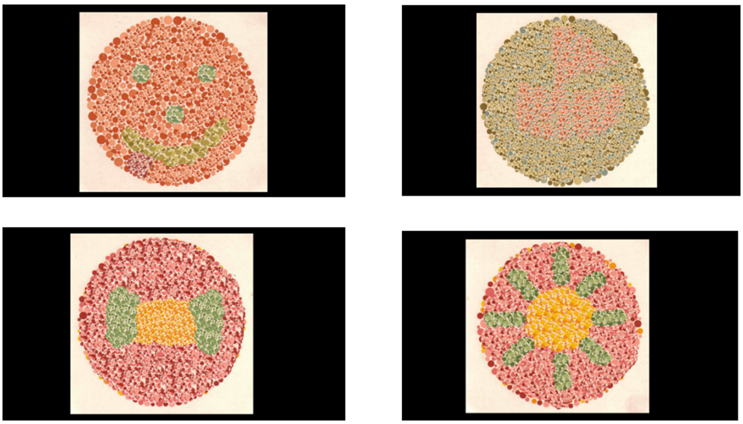

Fig. 3. Plates used to Ishihara test for children.

Another important point is the inclusion since this type of applications can help the user to perform tasks that he cannot do in a normal way since he has to identify objects or parts of the environment where he is located, a common problem in educational institutions is that most of the educational resources are designed for normal students, so it makes it difficult to integrate people with disabilities, to help in this problem the application recolors the image so that the user with color blindness sees it with other distinguishable colors by him facilitating thus user interaction by providing an accessible interface, see Fig. 4.

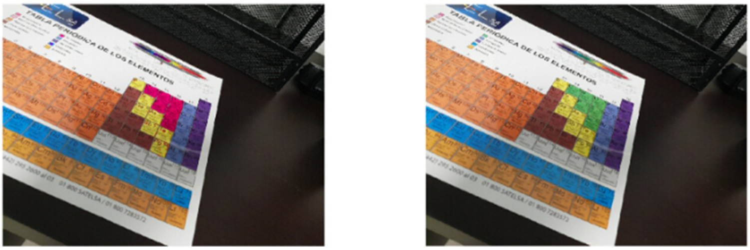

Fig. 4. Recoloring image in real time with the Augmented Reality application [25].

In order to achieve this in the Augmented Reality application it is important to perform several tasks, the first is that the system is able to automatically identify the colors of the original image and then transform the color gamut into based on the type of color blindness of the user, for this task several evolutionary algorithms were identified that identify and classify colors, such as the particle swarm optimization algorithm (PSO) and the genetic algorithms (GA) [26], see Fig. 5.

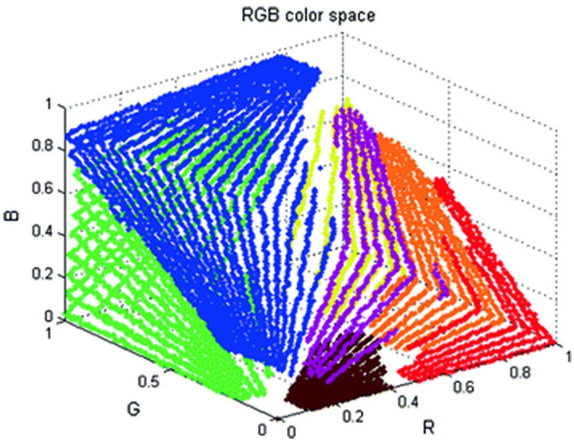

Fig. 5. RGB representation of red, orange, yellow, green, blue, purple and brown colors in RGB [26]. (Color figure online)

Another important application of this system is in the use of safety signs, which is important for the institutions (industries, schools, …) within their security systems to have the appropriate signals, however, some of these are just for they find in colors that are not perceived by colorblind people see Fig. 6, which is a problem, and this application can help save the lives of colorblind people [27].

Fig. 6. Security signals.

Finally other characteristics of the application is that the user is able to identify the colors, for this the image can be maintained with its original colors and use a label on each section that belongs to the same color, this labeling is done in two ways, one is through labels where the original color is written with text and the second type of labels using the ColorADDTM code see Fig. 7.

Fig. 7. On the left image with text labels, on the right image with labels using ColorADDTM code.

Color Enhancement Tool Tested with four People with Colorblindness. In this test, four patients with color blindness are subjected to the Ishihara test with and without the assistant color enhancement system. Table 3 shows a comparison between the results obtained. In the LP record it means that a line path is seen and N means that it sees nothing, according to the parameters accepted by the Ishihara test.

Table 3. Results when presenting Ishihara's plaques with and without the proposed system to four patients.

Plate number	Plate to be displayed	View plate without enhancement tool				View plate with enhancement tool			
		P1	P2	P3	P4	P1	P2	P3	P4
1	12	12	12	12	12	12	12	12	12
2	8	3	N	3	N	8	8	8	8
3	29	29	N	N	N	29	29	29	29
4	5	N	N	N	N	5	5	5	5
5	3	N	8	N	N	3	3	3	3
6	15	N	15	15	N	15	15	15	15
7	74	N	21	84	N	74	74	74	74
8	6	N	N	N	N	6	6	6	6
9	45	N	N	N	N	45	45	45	45
10	5	N	8	11	N	5	5	5	5
11	7	N	7	7	N	7	7	7	7
12	16	N	N	16	N	16	16	16	16
13	73	N	N	N	N	73	73	73	73
14	LP	N	N	N	LP	LP	LP	LP	LP
15	LP	N	N	N	LP	LP	LP	LP	LP
16	26	N	26	26	26	26	26	26	26
17	42	N	42	42	4	42	42	42	42
18	LP	N	LP	LP	LP	LP	LP	LP	LP
19	LP	N	N	N	LP	LP	LP	LP	LP
20	LP	N	N	N	N	LP	LP	LP	LP
21	LP	N	N	N	N	LP	LP	LP	LP
22	LP	N	N	N	N	LP	LP	LP	LP
23	LP	N	N	N	N	LP	LP	LP	LP
24	LP	LP	LP	N	LP	LP	LP	LP	LP
Efficiency		8.33%	29.16%	29.16%	25%	100%	100%	100%	100%

4 Conclusions

As it could be seen in several real-life situations to which a color blind person is exposed in his daily life in different social, family, industrial, school environments, etc. This can have problems constantly compared to a normal person, however the use of technology such as the use of augmented reality through a mobile device (smart phone) of medium or high range is possible to reduce or eliminate some of these problems. This is achieved through an interaction through the device with the real world with a friendly interface that guarantees the use of it.

As you can see the inclusion is a problem that must be addressed by society in different areas including education, and to achieve this we can make use of technology as is in this case the use of augmented reality, you can see in the experiment that on controlled cases this type of applications can have an efficiency of 100% by supporting colorblind people to identify objects and their real colors, however there are problems in real situations where the main objects are mixed with the environment and if this has the same colors, there are problems with the identification of the objects and their efficiency can be affected considerably. It can also be seen that the use of technology in computer science can provide tools that support inclusion in different fields, including education.

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