Development of hyperrealistic simulations to teach concepts about colours

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Abstract

A set of computer simulations with a higher degree of realism is presented. These hyper-realistic simulations, used to teach basic concepts about color, were developed using the POV-Ray software. The main aim of these simulations is to provide our students with a didactic tool in addition to their traditional laboratory practice, which can be easily implemented in e-learning teaching platforms. The simulations of optical systems developed have resulted in graphical outputs that achieve photographic quality, which helped our students, even those with less capacity for abstraction, to combat misconceptions about color.

Keywords: Colour, teaching, simulations, hyperrealism, additive mixing, subtractive mixing, filters, scattering.

Introduction

In this work, we have created a set of computer simulations that exhibit greater realism than traditional simulations, which we call hyper-realistic simulations [1]. The purpose of these simulations is to show the student concepts related to color generation, mixing, and dispersion.

Methodology

For the programming and development of these simulations, we used computer tools specifically designed for rendering photorealistic graphics environments, such as the POV-Ray software, an open-source ray-tracer [2]. Our choice of this program was determined by our need for a technique capable of imitating faithfully the optical system in a manner that was consistent with the theoretical models involved. POV-Ray (Persistence of Vision

Raytracer) uses a geometrical optics-based ray-tracing technique that synthesizes images with great realism [3].

The software models the light's path by following the rays as they interact with optical surfaces, yielding accurate simulations of optical phenomena. These simulations emerge as a natural result of the combined use of the ray-tracing algorithm and a specific Monte Carlo algorithm for the synthesis of three-dimensional images with perspective.

The program implements additional algorithms, such as photon mapping, which add realism to the overall illumination of the scene. In addition, the program is open-source and available for almost all computer platforms. It allows the user to represent objects internally with mathematical functions using a scene description language. This is a major advantage; the user then only has to be concerned with the geometric description of the optical system (light source, object, and observer) because all of the underlying optics already form part of the program's source code.

To add interactivity, the user is encouraged to alter the scene, modifying directly the source code or by means of an interactive JAVA environment.

Results

As we pointed out, the novelty on this work is that these simulations provide the user with a more realistic perception of the physical phenomenon being simulated. Hyperrealistic simulations are especially useful for the representation of optical phenomena, because the phenomenon being simulated is what is seen, so that the user identifies what he sees happening in the simulated model with what he sees happening in reality, thus preventing problems for users with less capacity for abstraction.

The environments were designed to serve as an educational resource to help the user to understand better the functioning of light, and and they were intended to complement observations made in real systems.

To validate our simulations qualitatively, we compared the results with those predicted by the theory and photographs of real systems.

Hyperrealistic simulation of basic elements

We first simulated some basic components, such as light sources, filters, lenses, etc. (Figure 1). These elements were used in the following simulations.

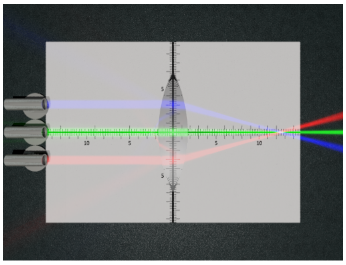
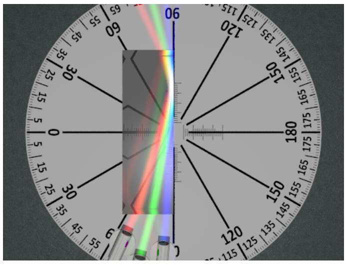
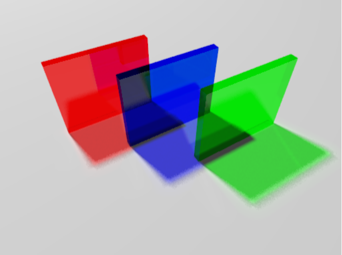
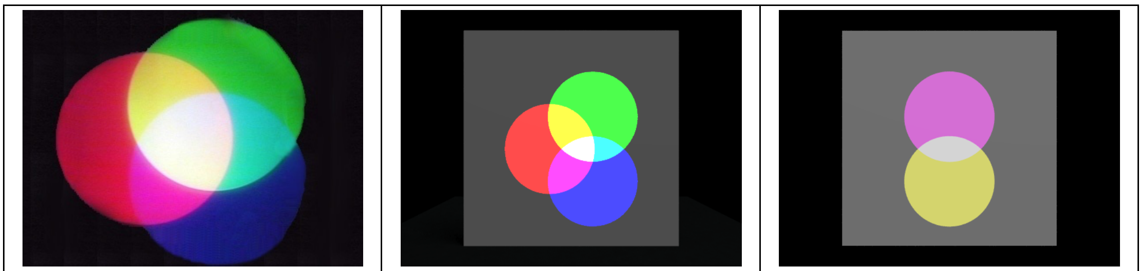
		
Hyperrealistic simulation of three beams of light through a convergent lens	Hyperrealistic simulation of the total reflection in a plane-parallel slab	Hyperrealistic simulation of some colour filters

Figure 1. Some basic simulated elements

Hyperrealistic simulation of additive mixing

Additive color mixing refers to the mixture of lights of different wavelengths, and can be easily shown superimposing the lights on a white projection screen.

When we overlap red light, green light, and blue light over a white screen, the sensation perceived in the real world is white color. This result agrees with what we get in our graphical outputs, where the projections of colored lights over a white screen were simulated (Figure 2).



Photograph of an additive mixing

Hyperrealistic simulation of an additive mixing

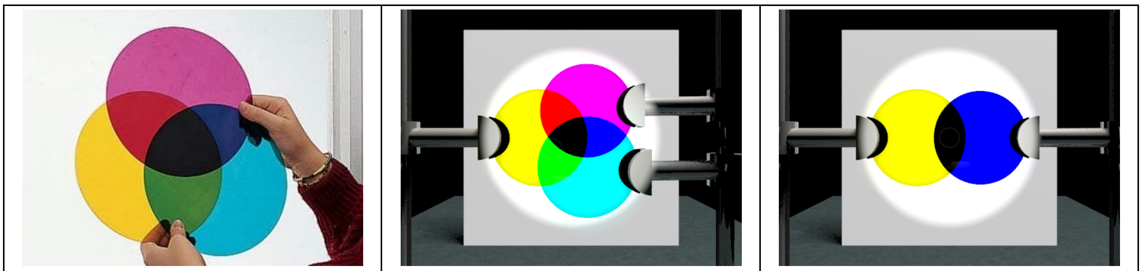
Another hyperrealistic simulation of an additive mixing

Figure 2. Additive mixing

The user could modify the number, position, and color of the light sources at will.

Hyperrealistic simulation of subtractive mixing

Subtractive color mixing refers to the mixture of different dyes, paints, or pigments, which absorb certain wavelengths and reflect others. It can be easily shown overlapping colored filters and illuminating a screen through them together. When we overlap a cyan filter, a magenta filter, and a yellow filter, the sensation perceived in the real world is absence of color (black). This result agrees with what we get in our graphical outputs, where the projection of a white light trough several colored filters was simulated (Figure 3). As in the previous simulation, the user could freely modify the scene (number, color, and position of the filters).



Photograph of a subtractive mixing

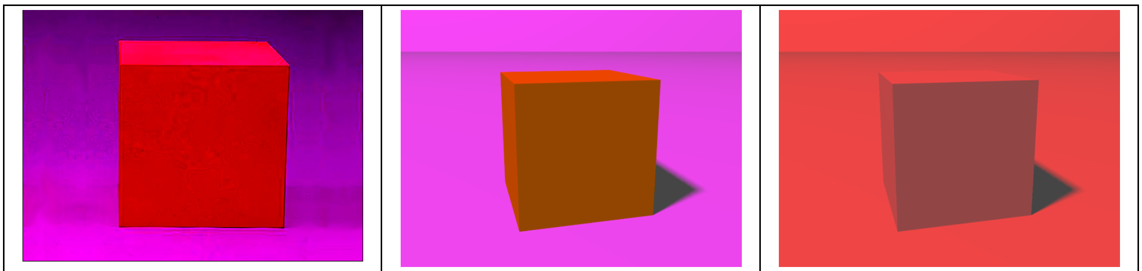
Hyperrealistic simulation of a subtractive mixing

Another hyperrealistic simulation a subtractive mixing

Figure 3. Subtractive mixing

Hyperrealistic simulation of coloured objects under coloured illumination

Another clear example of subtractive mixing is the color perceived from the interaction of a colored object with a colored light source. A yellow object observed under a magenta light would be seen as red. This does not mean that the object emits red light (we cannot see the object in the dark), for in that case the color perceived would be the result of an additive mix (and the object should be seen as a reddish white). Actually, it reflects the red component of the light and absorbs the rest. We simulated objects of different colors under different colored lights, to observe how the interaction between light and the object influences color perception (Figure 4). We consider that this kind of simulation may be relevant from a didactic point of view, since most of our students have deep misconceptions about color perception [4]. In this simulation the user could change not only the color of the light source and the illuminated object, but also the geometry of the object itself, or even add more complex objects previously designed (from toys to trees).



Photograph of a yellow cube illuminated with magenta light

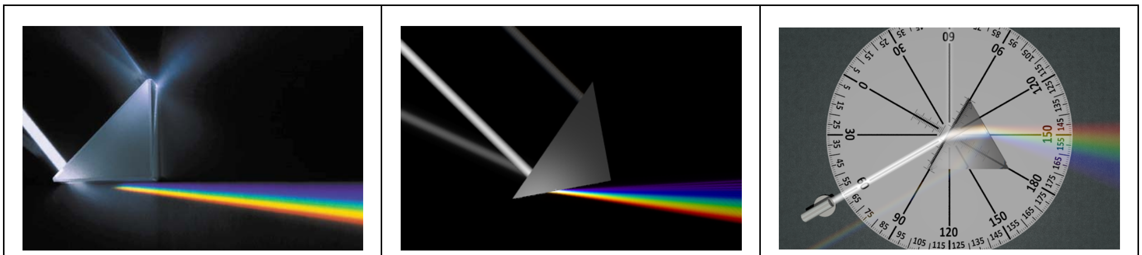
Hyperrealistic simulation of a yellow cube illuminated with magenta light

Hyperrealistic simulation of a white cube illuminated with red light

Figure 4. Coloured objects under coloured illumination

Hyperrealistic simulation of light dispersion through a prism

Dispersive prisms are used to disperse light, that is, to break up light into its constituent spectral colors. A white light beam entering the prism will emerge scattered, with blue light more bent than red light. We simulated these prisms, which behave as their real counterparts (Figure 5). In these simulations the user could change the number color and position of the light beams, and they had absolute control over the prism, changing variables such as form, index of refraction, behavior (refractive, dispersive or both), angles, etc.



Photograph of a prism scattering a white light beam

Hyperrealistic simulation of a prism scattering a white light beam

Another hyperrealistic simulation of a prism scattering a white light beam

Figure 5. Light scattering

Conclusions

Appropriately designed hyperrealistic computer simulations are very effective teaching tools in certain educational contexts, such as e-learning teaching platforms. Our classroom experience shows us that these kind of hyperrealistic simulations are very useful to combat typical misconceptions about color that most students hold. Students using the simulations are able to relate them without difficulty with their real counterpart, noting that sometimes are virtually indistinguishable.

References

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