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The Application of Computer Graphics Technology in Optical Teaching

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Abstract

Using the computer graphics technology for a classroom demonstration is highly stimulating and encouraging for students in an optical course. In this paper, we present several examples of using computer graphical technology to make teaching and learning optics more effective and efficient, Which include that using pattern displays the results of numerical computation, using the "visualization" shows the process of solving mathematical problems, using color images shows simulation results, and using image processing technology enhances the picture of experimental results.

Index Terms: Computer graphics; optics teaching; image processing

1. INTRODUCTION

In recent decades, applications of computer technology have pushed forward reform of physics education and improved teaching efficiency. Using computer simulation can assist students to understand the physical concept and the processes of physical experiments. Simulation results by different software have been successfully applied in all aspects of physical education. [1-5]. A good picture is worth one thousand words, [6] because of the more information contained in the image. Among these technologies, demonstration of static images or the continuously changed images (video), showing the complex physical process and the result, is an important means of teaching and learning. In practice, we can achieve better effect through the visual stimulation of graphical images in teaching process.

Optics is an important part of the university physics, and related to more complex physical patterns and processes, compared to other parts of physics [7]. Therefore, putting emphasis on physical concepts and physical phenomena is more significant in optical education. Using the "visualization" of classical optical experiment for a classroom demonstration is highly stimulating and encouraging for students in an optical course [8]. Nowadays, MATLAB, Mathematica and other software have powerful graphical process function, which provide a variety of simulation method. How to use computer graphics technology to promote the students to understand the physical concepts and the experimental process is a significant issue. In this article, we discuss the application of

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computer graphics technology in optical teaching. We focus on the three aspects as follows: using pattern displays the results of numerical computation, using the "visualization" shows the process of solving mathematical problems, using color images shows simulation results, and using image processing technology enhances picture of experiment results.

2. Using Pattern displays The Results of Numerical Computation and Using The "Visualization" Shows The Process of Solving Mathematical Problems .

There is much difficulty in understanding of the mathematical formulas in optical course. If we focus on solving mathematical problems, physical concepts should be diluted. In order to solve mathematical problems in optics, we use MATLAB software to help students solving mathematical formula, which favors the understanding of physical concepts.
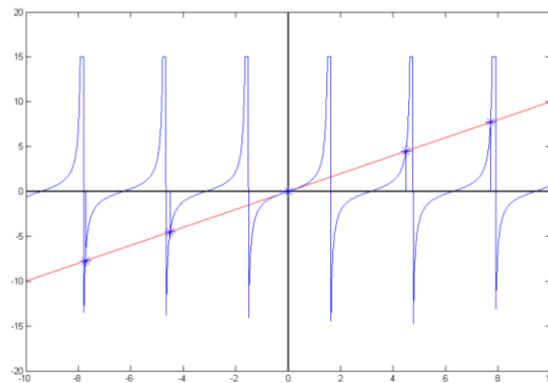

Figure 1.　the solution of equation *u=tan(u)*

For example, the experiment of Fraunhofer single slit diffraction, the minimum value of the solution is obtained by a transcendental equation $u = tan(u)$. Firstly, we use tracing point method to dynamically described the curves of $y=tan(u)$ with the parameter u range from u = -10 to 10 (the blue curves in Fig. 1). Then we use the numerical calculation method starting from u = -10 to 10 to dynamically draw the curve of $y = u$. If the value of abs (*tan (u)-u*) less than the specified value of the error which is assumed previously, an asterisk is remarked on the curve. By dynamic image processing, the errors in hand-drawing were overcome and high precision solutions were obtained.

Fraunhofer diffraction at a circular aperture is an effect of great practical significance in the study of optical instrumentation. According to Huygens - Fresnel principle, the expression for the optical disturbance at *P*, arising from an arbitrary aperture in the far-field case [7], is :

$$\vec{E}_P = \frac{A_0}{\pi R^2} e^{i[k(r_0+R\sin\theta)-\omega t]} \int_0^R \int_0^{2\pi} e^{ik\rho\cos\varphi\sin\theta} \rho \, d\varphi \, d\rho$$

!

where *R* is the radius of hole, A_0 is the amplitude of the diffraction plane, θ is angle of diffraction. ρ and φ are the polar radius and the polar angle of observation points (*P*) respectively.

Finally, (1) can be simplified as:

$$I_p = A_0^2[1-\frac{1}{2}m^2 +\frac{1}{3}\left(\frac{m^2}{2!}\right)^2 -\frac{1}{4}\left(\frac{m^3}{3!}\right)^2 +...]^2$$

.

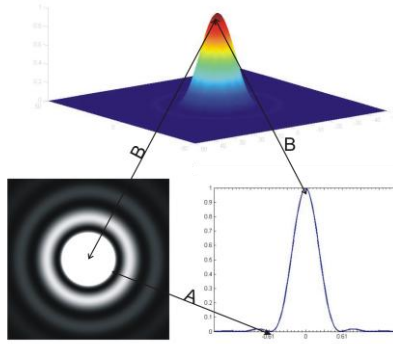where I_P is light intensity of point (*P*), m is equal to $\pi R sin\theta/\lambda$.

Figure 2.   The Franuhofer diffraction pattern of circular aperture

Understanding of this formula is difficult, so that we have drawn light intensity (I_P) by MATLAB. Fig. 2 shows one-dimensional, two-dimensional and three-dimensional patterns. Line A and B correspond to the maximum distribution and the location of first dark location ring, respectively. From the picture, students can clearly see the distribution of light intensity. Furthermore, we also use a similar method as described in the previous example to dynamic display the radius value of first dark ring.

3. Using Color Images Shows Simulation Results

Applications of "visualization" simulation methods in optical teaching are extensive. Due to the features of optical course, color photographs showing the results of simulation experiments can promote the interest of students in learning optical course.

RGB color model, in which red, green, and blue light are added together in various ways to reproduce a broad array of colors, is an important model of computer display. When humans view a color object, we describe it by its hue, saturation, and brightness (HSI model). In HSI model, hue is a color attribute that describes a pure color corresponding to different frequencies. To describe the different shade of interference and diffraction behavior, we calculate the frequency corresponding to the hue in the HSI model. Then using (3) converts HSI to RGB. Finally, we display these color patterns using computer.

$$\begin{cases} B = I(1-S) \\ R = I\left(1 + \dfrac{S\cos H}{\cos(60^o - H)}\right) \quad 0^o \le H < 120^o \\ G = 3I - (R+B) \end{cases}$$

$$\begin{cases} R = I(1-S) \\ G = I\left(1 + \dfrac{S\cos(H-120^o)}{\cos(180^o - H)}\right) \quad 120^o \le H < 240^o \\ B = 3I - (R+G) \end{cases}$$

$$\begin{cases} G = I(1-S) \\ B = I\left(1 + \dfrac{S\cos(H-240)}{\cos(300^o - H)}\right) \quad 240^o \le H < 360^o \\ R = 3I - (G+B) \end{cases}$$

Fig. 3 exhibits the color pattern of red, green and blue corresponding to frequencies of 4.5×10^{14}, 5.5×10^{14} and 6.8×10^{14} respectively. From these pictures, Young's interference of different shade can be understood clearly.

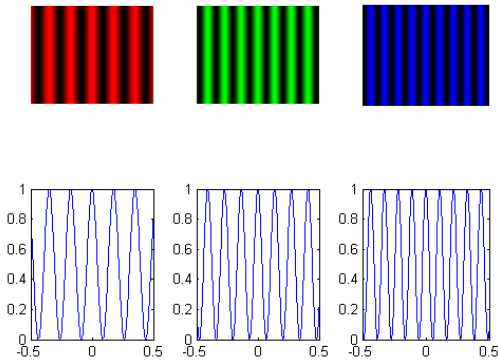
Figure 3. The color pattern of Young's interference experiment d=1mm and r=500mm

## 4. Enhanced Picture Of Experiment Results Using Image Processing Technology

In the optical experiments, the results are often shown by a large amount of images. However, Because of the reason of technology of imaging, the obtained photographic picture may be unclarity due to underexposure or overexposure. These problems can be solved by using histogram equalization method of digital image processing [9].

The quality of the fringes produced by an interferometer system can be described quantitatively using the visibility *V*, which is given by [8]

$$V(r) = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} .$$

Here I_{max} and I_{min} are the irradiances corresponding to the maximum and adjacent minimum in the finger system.

Fig. 4(a) and Fig. 4(c) corresponding to the underexposure picture and the overexposure picture, which are obtained from the Michelson interference experiment. Fig. 4(b) and Fig. 4(d) are the result of enhanced Fig. 4(a) and Fig. 4(c) using histogram equalization.

（a）   （b）
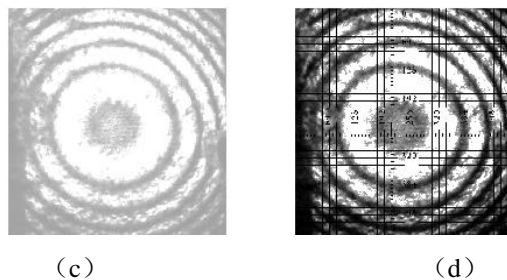
（c）   （d）
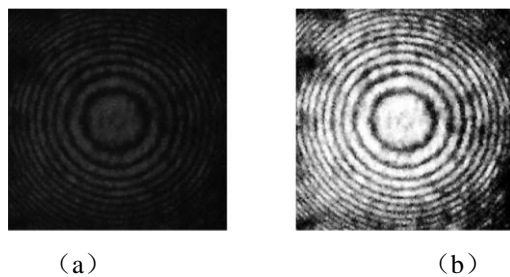
Figure 4. The contrast between original image and enhanced image

For studying the effect of enhanced images, the picture, which obtained from experiment, is divided into 256 images with size 32×32. For each small image, we seek the brightest and darkest pixels and the values of the brightest and the darkest substituted in (4).   The max value, the min value, and the average value are corresponding to the max value, the min value, and the average value of fringe visibility of all blocks in the picture. The results are shown in Table 1. Moreover, In order to better analyze the characteristics of the image, we add the ruler in the images. Fig. 4(d) exhibits the effect drawing.

TABLE I.   FRINGE VISIBILITY RESULTS

Image	Fringe Visibility		
	Max value	*Min value*	*Average value*
Fig. 4(a)	0.80488	0.31765	0.593042
Fig. 4(b)	1	0.096774	0.885891
Fig. 4(c)	0.25	0	0.174637
Fig. 4(d)	1	0	0.769854

5. Conclusion And Discussions

With developing of computer technology, the development of optical education is confronted with pressure and challenges. In this study we gave the application of computer graphics technology in optical Teaching with three examples. The results presented here show that computer graphics technology can help students understanding optical concepts and optical phenomena.

Acknowledgment

References

[1] A. Jimoyiannis and V. Komis, "Computer simulations in physics teaching and learning: a case study on students' understanding of trajectory motion," Computers & Education, vol. 36, pp. 183-204, 2001.

[2] T. Jong de and W. R. Joolingen van, "Scientific discovery learning with computer simulations of conceptual domains," Review of Educational Research, vol. 68, pp. 179-202, 1998.

[3] K.-C. Lee and J. Lee, "Programming physics softwares in Flash," *Computer Physics Communications,* vol. 177, pp. 195-198, 2007.

[4] T. Mart ń-Blas and A. Serrano-Fernández, "The role of new technologies in the learning process: Moodle as a teaching tool in Physics," Computers & Education, vol. 52, pp. 35-44, 2009.

[5] K.-E. Chang*, et al.*, "Effects of learning support in simulation-based physics learning," *Computers & Education,* vol. 51, pp. 1486-1498, 2008.

[6] Anita Woolfolk,Educational Psychology, 8th ed.Beijing: Higher Education Press, 2003, pp. 281-282.

[7] Eugene Hecht, Optics, 4th ed.BeiJing:Higher Education Press., 2008, pp. 672-679.

[8] R. Machorro and E. C. Samano, "Simulation of michelson and young experiments using moire fringes," vol. 51, Sociedad Mexicana de F śica, 2005, pp. 108-111

[9] R.C.Gonzalez and R.E.Woods, Digital Image Processing, 3rd ed. BeiJing: Publishing House of Electronics Industry, 2010,pp .142-160.