VIRTUAL OPTICAL ILLUSIONS FOR CREATIVE LEARNING

Alexander Kazachkov, Tetyana Ignatova, Andrey Zholobenko

ABSTRACT
An amazing "rotating ring" optical illusion was studied in the frames of the students' educational computer-based research work. Virtual images of differently shaped moving objects were simulated in QBasic 71, MS Visual C++ 6.0 and Borland Pascal and compared with the real-time frames and disks observed spinning against the contrast background. Space distribution of background screening time τ was defined by direct measurement in virtual experiments. Its perfect agreement with the dependence predicted by the kinematical model of the effect has proved the illusion to be caused by space non-linearity of the ring's background screening.

KEYWORDS
Optical illusions, kinematics, computer simulation of moving objects, QBasic 71, Visual C++ 6.0, Borland Pascal MS, virtual measurements

INTRODUCTION

Computer based education opens new and really unlimited possibilities for creative learning. In Physics and relative subjects rote memorization and mechanically doing standard experimental labs fails to train a creatively educated person. Learning by inquiry (Trowbridge, Bybee and Powell, 2000; Kawakatsu, 2001) is aimed at development of students' skills and abilities to solve non-trivial problems by directed gathering of information, its critical analysis, building and testing models of the observed phenomena. To stimulate students' interest in this – often complicated – educational approach, it is crucial to find intriguing objects and processes to be studied and explained. It is no less important for the successful and instructive educational inquiry to use attractive and efficient research facilities, like personal computers and modern software.

Visual illusions caused by motion of an object of observation seem to be a splendid topic of the computer-based students' inquiry. To observe the "third coin" illusion (Gardner, 1986) and the famous Pulfrich stereo illusion (Pulfrich, 1922; Walker, 1978), the simplest demonstrational equipment is needed, no preliminary training required. In the authors' experience, no one is left untouched by those amazing visual effects, or unwilling to comprehend their mechanism. A well-developed Web-site *http://www.siu.edu/pulfrich* presents, in particular, computer animations based on Carl Pulfrich's hypothesis of the delayed perception of dimmer images. Recently, computer-animated explanations of a strikingly interesting "rotating" Pulfrich effect (Nickalls, 1986) have been reported (Nickalls, Kazachkov, Vasylevska and Kalinin, 2002), together with the explicit kinematical model of the "third coin" illusion. Three-dimensional computer simulation of the latter model is put on-line at *http://khpg.org/vsesvit*.

The "rotating ring" illusion was noticed by one of the authors (Alexander Kazachkov) in his preparation of the report on spinning tops at the *GIREP* International Conference *"Physics in New Fields and Modern Applications – Opportunity for Physics Education"* (Lund, Sweden, August 2002). Spinning a ring made of stiff black rubber (a vacuum chamber seal) on the paper-covered table he was surprised to "see an axis of rotation" (!). A bright strip of about the ring's thickness wide made the ring's vertical diameter visible from any angle of observation. Taking that particular ring (50 mm in diameter, 5-mm thick, black surface) and a white background was a lucky chance since an effect is extremely sharp with it even at slow rotation. Thereafter, an illusion was tested on other objects of the kind easily available: key rings, coins with the holes in the center (Yens, Denmark Crones) and never failed to be observed. Moreover, if the conditions of illumination provide for sharp shadows, an "axis" is clearly seen in the shadowy image also.

KINEMATICAL MODEL AND COMPUTER SIMULATION

Educational research of the "ring's axis illusion" was performed in a truly computer-based fasion. It seemed quite natural to computer-simulate a spinning ring and try to obtain an effect by varying the parameters of moving image (diameter and thickness of a ring, its color and frequency of "rotation", direction of "lightening", color of the background, etc.). Three-dimensional ring images (see Figure 1) were simulated with the popular OpenGL API used. Console application with GLUT or GL Utility Toolkit libraries was chosen, to provide for the single interface for work with windows independently of the platform. So, the structure of an application remains unchanged for Windows, Linux and other operational systems. To observe the most realistic effects, video cards with 16Mb RAM and a minimum 500 MHz processor with 128 Mb RAM are needed. It should be noticed separately that color and intensity of an object and the background should be chosen carefully to get rid of the visual after-effects strong with bright contrast images.

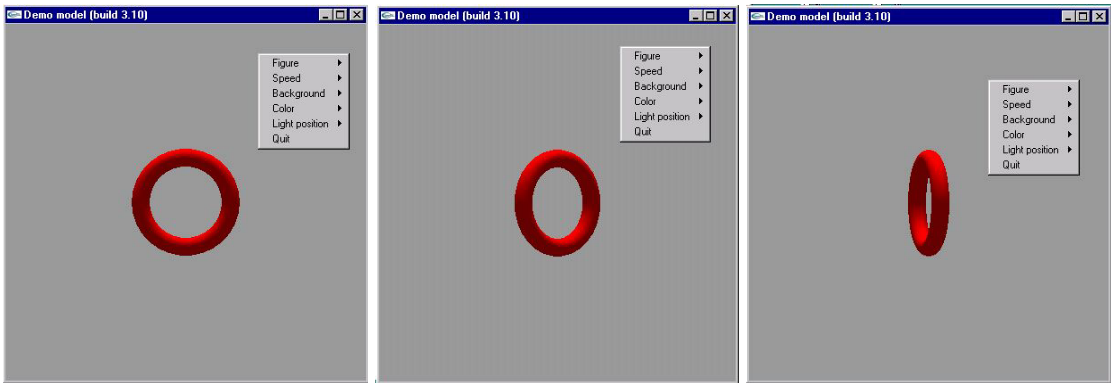

Figure 1. Rotating ring, three-dimensional computer simulation

Spinning virtual rings visualized an axis of "rotation" nearly as clearly as their real prototypes. The question yet remained whether an illusion is of a purely physiological nature or caused by physical conditions of an experiment.

So, our educational inquiry was focused on building and testing an adequate model to explain the rotating ring illusion. The best way to start this research was to consider a simplified problem of two rectangular non-transparent oscillators moving antiphasely along the straight line (Figure 2).

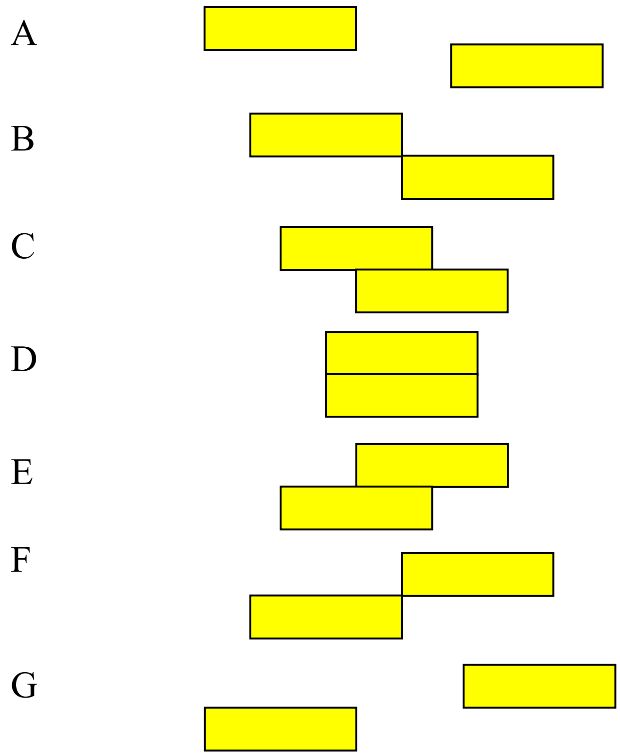

Figure 2. Rectangular oscillators as seen from above; *A…G* – consecutive stages of antiphase motion

VIRTUAL MEASUREMENTS

Screening of the field of observation is determined by the oscillators' law of motion. Simulation of moving rectangles in MS Visual C++ 6.0, Borland Pascal and QBasic 71 allowed to define the duration of screening τ of any chosen point along the rectangles' path (*x*- axis) by direct "virtual measurement". It appeared that even in the simplest case of the constant velocity of rectangles' motion, a rather sharp peculiarity appears on the $\tau(x)$ graph – see Figure 3. For an observer, this reduced screening of bright background is manifested in a lighter strip of an area dimmed by moving dark rectangles.

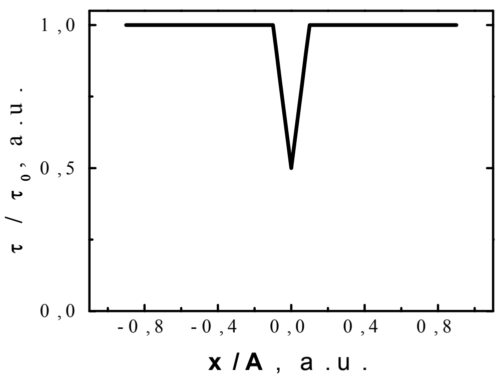

Figure 3. Screening time of the oscillators' background; *d* - the width of moving rectangles, $V = const$, A – respectively, velocity and amplitute of antiphase motion along an *x*-axis, $\tau_0 = d/V$

Just the same peculiarity is virtually "measured" on the $\tau(x)$ dependence of screening time for the case of harmonic antiphase oscillations. That is a scenario close enough to an original observation of the rotating ring. Virtual rectangles simulate segments of a spinning ring cut off by two parallel horizontal planes, while symmetry axis of antiphase oscillators corresponds to the ring's axis of rotation. An axis neighborhood is visualized due to its minor screening (Figure 4). Rectangles' turning points yield the longest screening which in real time experiment is manifested in observation of the dark ring boundary circling the gray inside area (here inertia of human vision plays the role also).

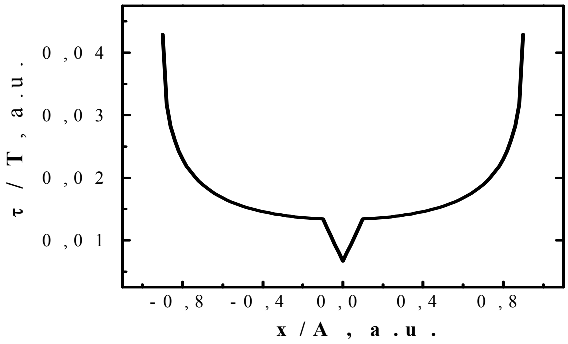

Figure 4. Screening time of the harmonic antiphase oscillators' background; *T, A* – respectively, period and amplitute of oscillations

Reduced screening of the neighborhood of the ring rotation axis (and corresponding area in the case of two-dimensional simulation) must be due to overlapping of non-transparent ring segments (dark rectangles for simulation) moving towards each other in the plane of view – see Figure 1. This hypothesis is supported by calculations of τ values for given x coordinates: $\tau(x)$ dependence obtained in the antiphase harmonic oscillators model coincides with the one presented in Figure 4. An exact solution gives a non-monotonical function:

$$\tau(x) = \frac{2}{\omega}\left[ar\cos\left(\frac{x + d/2}{A}\right) - ar\cos\left(\frac{x - d/2}{A}\right)\right]$$

for off-axis area: $-A \le x \le -d/2$, $d/2 \le x \le A$, and

$$\tau(x) = \frac{1}{\omega}\left[ar\cos\left(\frac{|x| + d/2}{A}\right) - ar\cos\left(\frac{-|x| - d/2}{A}\right)\right]$$

in the axis neighborhood: $-d/2 < x < d/2$.

Here A is amplitude of rectangles' oscillations (the rotating ring radius); d is their width (thickness of the ring). As clearly seen from the exact solution, the width of the visualized axis area must be close to the ring thickness d. That is in the full agreement with the observations of both real-time rotating rings and their virtual simulators.

EVALUATION AND CONCLUSIONS

When explained, the "ring's axis" illusion was started to be used as a computer-based students' research problem and a lecture demonstration. To evaluate educational impact of the proposed activity we should emphasize keen interest in these studies displayed by the involved high school (graduation level) and university (first and second year) students. Another "motional" optical illusion proved to be highly educationally motivating. Students found it exciting to be engaged in a thorough – and no less amusing – scientific investigations. Programming of electronic simulators of differently moving objects, performance of "virtual measurements" and real-time graphing has advanced their computer skills and knowledge. Learning Physics was also enhanced. Development of kinematical models followed by derivation of spatial screening $\tau(x)$ dependencies for different laws of motion $x(t)$, calculations and final analysis were also instructive. Demonstration and explanation of the “axis” illusion to the younger students was lively and well accepted.

ACKNOWLEDGEMENT

Authors are thankful to Dr. V.G. Piryatinska for useful advice.

REFERENCES

Gardner, M., (1986). Amusing Experiments. Science Reader for the Eighth Form of Secondary School. Prosveshcheniye, Moscow, Russia.

Kawakatsu, H., (2001). Structure of Science Education for More Joyful & Fruitful Experiments, in: Abstracts of International Conference on Physics Education in Cultural Contexts, ICPEC2001, KNUE, Cheongwon, Korea, 97.

Nickalls, R.W.D., (1986). The Rotating Pulfrich Effect, and a New Method of Determining Visual Latency Differences. Vision Research. 26**,** 367-372.

Nickalls, R.W.D., Kazachkov, A.R., Vasylevska, Yu.V. and Kalinin, V.V., (2002). Motional Visual Illusions On-Line, in Proceedings of the International Conference on Information and Communication Technologies in Education, ICTE2002. Edited by A.M.Vilas, J.A.Gonzales, Badajos, Spain. Available online at: http://khpg.org/vsesvit

Pulfrich, C., (1922). Die Stereoscopie im Dienste der isochromen und beterochromen Bhotometrie. Die Naturwissenschaften, 10, 553. Paper available online at: http://www.siu.edu/pulfrich

Trowbridge, L.W., Bybee, R.W., Powell, J.C., (2000). Teaching Secondary School Science: Strategies for Developing Scientific Literacy. Prentice-Hall Inc., Upper Saddle River, NJ, USA.

Walker, J., (1978). The Amateur Scientist. Scientific American, 3, 142.

Associate Professor Dr. Alexander Kazachkov
Physical Depatment
Kharkov National University
4, Svobody Sqr.
Kharkov
61077, Ukraine
Email: kazachkov@ilt.kharkov.u, akazachkov@yahoo.com

Tetyana Ignatova
Institute for Low Temperature Physics and Engineering
47 Lenin Ave.
Kharkov
61103, Ukraine
Email: ignatova@ilt.kharkov.ua

Andrey Zholobenko
Institute for Low Temperature Physics and Engineering
47 Lenin Ave.
Kharkov
61103, Ukraine
E-mail: zholobenko@ilt.kharkov.ua