Auto-random-dot stereograms

We perceive depth in our normal vision because our brain stereoscopically combines the two slightly different views from our horizontally separated eyes. Although there are other (monocular) depth cues such as shading and perspective, humans are particularly receptive to this binocular disparity. In fact, picture pairs (or stereograms) can induce stereopsis when they are contrived binocular disparity.

Typical stereograms, such as 3-D movies, contain several monocular depth cues because each component image forms a realistic, two-dimensional scene when viewed separately. Conversely, random-dot stereograms combine two seemingly random black-and-white patterns of dots, which, when viewed stereoscopically, produce a three-dimensional figure solely on the basis of binocular disparity.[1] Because of the lack of several interacting depth cues, it may take several minutes for the observer to recognize depth from the random-dot patterns, while it only takes milliseconds to perceive ordinary stereograms.

While most stereograms require special viewing equipment, such as polarized glasses or color filters, the auto-random-dot stereogram[2] in Figure 1 works by free viewing. In this case, you must only focus your eyes correctly on a single pattern of "random" dots to perceive a three-dimensional scene. You may have already experienced a simple version of this type of stereopsis if you've ever looked at a repetitively tiled floor and had the disconcerting sensation of seeing the tiles floating above your feet.

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To view the auto-random-dot stereogram in Figure 1, focus your eyes on the page while holding a pencil between the stereogram and your eyes. You should see two misfocused pencil images. Move the pencil to align the blurred images with the two fixation markers—the heavy black dots—on the stereogram. Then, without moving your eyes, focus on the pencil. The two blurred pencils should converge into one sharp image that points at the central spot of three blurred markers. Continue focusing on the pencil until the central spot sharpens in focus. (This may take seconds or minutes.) When this happens, you should begin to see the raised checkerboard pattern.

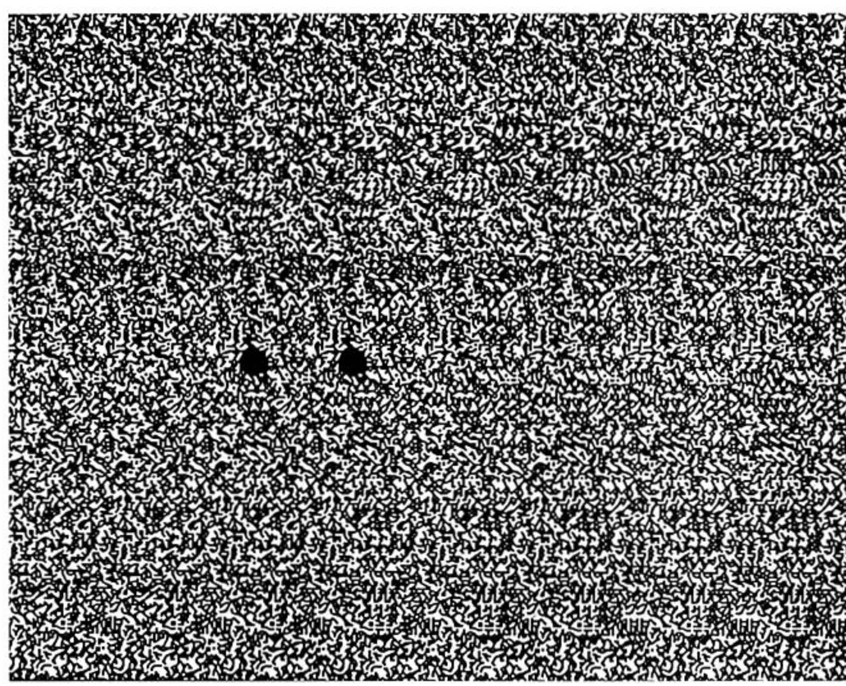

Figure 1. A raised checkerboard pattern appears from this auto-random-dot stereogram. Viewing instructions are given in the text.

The fixation markers are separated by the convergence distance. This distance is the amount by which the image in the left eye is shifted from the image seen by the right eye. As you saw in trying to view the stereogram, each eye sees both markers, but they are shifted horizontally such that only the right marker in the left eye's image overlaps the left marker in the right eye's image. Thus, you saw three markers at correct convergence. In fact, each eye sees its own view of the entire stereogram shifted with respect to the other by the convergence distance. These two views correspond to the two sides of a stereo pair. However, unlike a standard stereogram, both views are identical, so the single dot pattern itself contains the depth discontinuity information.

Depth is encoded into the stereogram by assigning a nearly random pattern of black-and-white dots to each row of the stereogram array with a length corresponding to the convergence distance. This pattern repeats itself along the row until a depth discontinuity is encountered. The pattern is interrupted by a number of dots

Continued on page 62

Crosstalk—from page 7

3. J. Bronowski, *Magic, Science, and Civilization*, Columbia University Press, New York, 1978, 46-49.
4. G. Ifrah, *From One to Zero*, Viking Penguin, New York, 1985, 475-484.
5. T.S. Kuhn, *The Structure of Scientific Revolutions*, New American Library, New York, 1986, 16.
6. P. Medawar, *The Limits of Science*, Oxford University Press, Oxford, 1984, 9-11.
7. J. Fauvel, *et al.*, *Let Newton Be!*, Oxford University Press, Oxford, 1988, 127.
8. M. Kline, *Mathematics: The Loss of Certainty*, Oxford University Press, New York, 1980.
9. On the modern ill of incessantly seeking instant gratification, my sole comment here is to nudge the reader to a splendid essay: R. Rosenblatt, "Snuff this book! Will Bret Easton Ellis get away with murder?" The New York Times Book Review, Dec. 16, 1990, 16.
10. J. Bronowski, *op. cit.*, 12.
11. "Attitudes toward scientists," Optics and Photonics News, September 1990, 34.
12. J. Fauvel, *et al.*, *op. cit.*, pp. 38, 79, 151.
13. J. Gleick, "The man who reshaped geometry," New York Times Magazine, December 8, 1985, 64+ (especially p. 123).
14. T.S. Kuhn, *op. cit.*, p. 16.
15. S.G. Bush, *et al.* (eds.), *Maxwell on Saturn's Rings*, MIT Press, Cambridge, Mass., 1983, 22-23.
16. "Fraud in the lab needs policing, say researchers," R&D Magazine, October 1990, 146-150.
17. "R.S. Wolff replies," Computers in Physics, November/December 1990, 581.
18. "Pork barrels and test tubes: Mixing politics and science," Optics and Photonics News, November 1990, 31-32.
19. D. Shapley and R. Roy, *Lost at the Frontier*, ISI Press, Philadelphia, 1985, 18-22.
20. "Export rules spawn uncertainty, confusion," Optics and Photonics News, December 1990, 60.
21. J. Bronowski, *op. cit.*, p. 69.
22. J. Bronowski, *op. cit.*, p. 81.
23. W. Whewell, *History of the Inductive Sciences*, 3rd ed., John W. Parker and Son, West Strand, 1857, Book VIII, Chap. II.

Engineering—from page 52

manufacturing environment. Restoring American competitiveness requires putting increased emphasis on high quality efficient manufacturing methods.

- Engineering problems are rarely as "clean" as a course's homework problem set. Advanced courses should involve engineering trade-offs, including the ambiguities that usually accompany real engineering tasks.
- Participation in cooperative education programs and development of summer student internship programs must be encouraged and expanded.

Education—from page 53

week and was consequently more intensive. Future workshops, following the 1990 format, will likely be held every two years beginning in 1992. Proceeding of the 1990 workshop was videotaped and copies are available. For further details, please contact the authors.

Acknowledgements

CHTM is an interdisciplinary organization with a central mission to support research, advanced study, and technology transfer in optics and optoelectronics. Overall management of both workshops was handled by John G. McInerney and Steven R.J. Brueck, with assistance from Vivienne H. Mattox of Management Plus Inc. The authors are grateful to her and to the technical and administrative staffs of the Center for High Technology Materials for extensive logistical support before and during each workshop. We acknowledge financial support from the National Science Foundation through contract numbers USE-8854282 and USE-8954342. Finally, we thank all the workshop alumni for their enthusiastic participation and follow-up.

Advertisers' index

Light touch—from page 59

proportional to the perceived height of the discontinuity. A new pattern arises from the remaining dots that continues until the next depth discontinuity is reached. Following this recipe, crude stereograms can be made using a typewriter. The more sophisticated stereogram in Figure 1 was produced by David G. Stork at Stanford University using a Macintosh computer. Using his program,[3] a typical stereogram containing 18,000 dots takes only a few minutes to create. According to Stork, future auto-random-dot stereograms will use gray levels and color to enhance the 3-D effect.

References

1. B. Julesz, *Foundations of Cyclopean Perception*, University of Chicago Press, 1971.
2. C.W. Tyler, "Sensory processing of binocular disparity, in *Vergence Eye Movements: Basic and Clinical Aspects*," C.M. Schor and K.J. Ciuffreda, eds., Butterworth, Boston, 1983.
3. D.G. Stork and C. Rocca, "Software for generating auto-random-dot stereograms," Behavior Research Methods Instruments and Computers **21**, 1989, 525-534. Also see the inside front cover of "Seeing the Light," by D. Falk, D. Brill and D. Stork, Wiley, 1988.

Abstract deadlines

March 4: OSA Coherent Laser Radar Topical Meeting, July 8-12, Snowmass, Colo.

March 15: OSA Photorefractive Materials, Effects and Devices Topical Meeting, July 29-31, Beverly, Mass.

March 28: OSA Nonlinear Guided Wave Phenomena Topical Meeting, Sept. 2-4, Cambridge, UK

April 5: Optical Amplifiers and their Applications Topical Meeting, July 24-26, IEEE-LEOS/OSA, Snowmass, Colo.

May 1: OSA Persistent Spectral Hole-Burning Science and Applications Topical Meeting, Sept. 26-28, Monterey, Calif.