Behavior Research Methods, Instruments, & Computers
1986, 18 (3), 321-322

PROGRAM ABSTRACTS/ALGORITHMS

Occluding edge displays and random-dot stereograms on the Apple II

CHARLES C. TORREY
Macalester College, St. Paul, Minnesota

Accretion, deletion, and shearing of structure at boundaries in the optic array carry information about position and displacement of an observer relative to environmental surfaces, or of those surfaces relative to each other (Gibson, Kaplan, Reynolds, & Wheeler, 1969). Although such disturbances of optical structure and the "occluding edge" effects that they generate are the subject of a generally available film (Gibson, 1968), the ability to produce and manipulate original displays of this sort has been largely restricted to researchers having access to substantial computing power.

The package described here permits the generation of random-texture arrays, using the high-resolution graphics capabilities of the Apple II microcomputer, and the systematic transformation of such arrays at speeds sufficient to demonstrate convincingly these types of information regarding surfaces and displacements. In addition, the package can be used to produce original random-dot stereograms, suitable for demonstrations or research (Julesz, 1960). The key programs of the package, written in machine language, display an array of texture stored in one of the two hi-res pages of memory while computing a transformation of that array and storing it in the other page. Upon completion of the transformation, the second page is shown, while its transformation in turn is computed and stored on the first page. Alternating display of pages is possible at rates producing compelling impressions of continuous motion over a considerable range of velocities.

BASIC Programs. The package includes a service program, MAKE TEXTURE, written in Applesoft, which generates an array of random texture in HGR1 and then copies it into HGR2. Texture density is determined by a parameter that is input by the user at the top of the program. Initial array generation by this program is a slow process, taking about 10 min to fill both pages. Prior generation of needed arrays and their storage on disk as binary files permit relatively fast (18-sec) loading into memory for use in the desired display. The package includes three sample arrays of varying texture density.

The author's mailing address is: Macalester College, 1600 Grand Avenue, St. Paul, MN 55105.

A second service program, STEREOPAIR, uses stored random-dot arrays to print a pair of stereograms with disparity (number of displaced rows and direction of displacement) determined by the user. The vertically disparate stereograms are printed one below the other; when the printed page is turned sideways and trimmed to size, it is immediately usable in a standard brewster-type stereoscope.

The third Applesoft progam, EDGE DEMO, is a front-end host program for the various machine language routines. The user selects a texture file and chooses a direction of motion (up or down). The resulting display is seen as a randomly textured surface with a rectangular "window" in the center, through which a second textured surface is seen moving in the specified direction. By pressing any key, the user can freeze the display; a second keypress restores motion. Observations of interest include the unequivocal depth relation of the two surfaces and the sharply defined edges of the window in the occluding surface. These phenomena vanish quickly when motion is halted and abruptly reappear when it is restored. The moving display also generates a powerful negative aftereffect (the waterfall illusion), visible when motion is arrested.

Machine Language Routines. The EDGE DEMO program CALLs a machine language control table, WINDOW, which in turn determines the sequence in which further routines are invoked. A complete cycle through WINDOW involves moving transformed data once in each direction between HGR1 and HGR2. In addition, during each half cycle, the keyboard is read for a stop or start command, and the built-in routine WAIT is called to reduce speed of apparent motion. As stored on disk, WINDOW produces an upward-moving display, at the maximum possible rate (62 HGR pages/sec). Direction of motion is set by POKEs from EDGE DEMO to three addresses in WINDOW, or can be changed directly through monitor commands. Speed of motion, up or down, can be reduced as low as 5.5 pages/sec by storing values up to 255 ($FF) at zero-page address 13 ($ØD).

The binary file ROUTINES can of course be BLOADed directly and entered by way of the monitor (CALL-151). ROUTINES begins at address 38144 ($9500) with WINDOW, and extends through address 38388 ($95F4). Machine language routines occupying this range of addresses constitute the operating basis of the entire package.

MLIN links an address in HGR1 with a corresponding address in HGR2, moves the content of one to the other, and iterates through a sequence of indirect indexed addresses to move the specified line segment. The addresses so linked are controlled by a pair of routines, SETPA and SETPB. The first of these links each HGR1 address within the display window to the HGR2 address directly below it, by storing in zero page the high bytes of the two starting addresses. Thus, depending on which address is used as source and which as destination, the display can move downward from HGR1 to HGR2, or upward from HGR2 to HGR1. SETPB provides the address linkages required for the other two possibilities.

The direction of data transfer between linked addresses is determined by DOLIN or UPLIN, which make the needed modifications of MLIN. The left-most and right-most addresses in the line segment to be moved (and hence the width of the display window) are controlled by two values in MLIN, which are easily changed by the user through monitor commands. Such changes of window width, however, also affect the speed of seen motion.

Values stored in zero page by SETPA or SETPB are used in turn by MPAG to control the sequence of line linkages for which MLIN is invoked. The relation between sequential lines in the screen display and ranges of addresses in HGR memory is complex, as described in the *Apple II Reference Manual* (Apple Computer, Inc., 1981), and the structure of MLIN is correspondingly intricate. Basically, an HGR memory page divides the screen into three major strips, each containing 64 raster lines. As written, MPAG operates on the middle such strip, and any changes in either the vertical position or the height of the display window require major redesign of the MPAG routine.

A final routine, STOPPER, reads the keyboard and stops a moving display or restarts a previously halted display in response to a keypress. WAIT, used to control speed, is a built-in monitor subroutine.

Hardware Requirements. The programs as stored on disk will run on either the Apple II+ or the IIe, equipped with 64K of memory. The machine language routines occupy only 1K of memory, however, and can easily be relocated downward to run on smaller systems.

A sufficiently rapid phosphor decay is critical for effective CRT display of the motion demonstrations. The standard green phosphor used in the Apple Monitor III (Model A3M0039) leaves trailing streaks that can be reduced but not eliminated by adjusting the brightness and contrast controls. A Roland Model CB-141 monitor gives a satisfactory color display, but the small Panasonic Model TR-930 (black-and-white) monitor has worked best.

The STEREOPAIR program includes subroutines for output to a printer via an interface card installed in Slot 1. As stored on disk, the program uses commands appropriate to the Orange Grappler+ interface. By changing four program lines, as indicated in the program by REM statements, STEREOPAIR can drive a standard Apple Silentype printer, but that printer will produce satisfactory stereograms only at relatively low densities of texture.

Availability. The author will provide a copy of the program disk and an index and listing of the machine language routines. Please include $5 to cover the cost of a disk and mailing.

REFERENCES

Apple Computer, Inc. (1981). *Apple II reference manual*. Cupertino, CA: Author.

Gibson, J. J. (1968). *The change from visible to invisible: A study of optical transitions* [Film]. University Park, PA: The Pennsylvania State University, PCR FILMS.

Gibson, J. J., Kaplan, G. A., Reynolds, H., & Wheeler, K. (1969). The change from visible to invisible: A study of optical transitions. *Perception & Psychophysics*, **5**, 113-116.

Julesz, B. (1960). Binocular depth perception of computer-generated patterns. *Bell System Technical Journal*, **39**, 1125-1162.

(Revision accepted for publication April 8, 1986.)