

# SESSION XI

## TECHNICAL AND METHODOLOGICAL DEVELOPMENTS

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### A low-cost method for digitizing videotaped continuous movements on the Macintosh

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We describe an inexpensive means of digitizing videotaped positions of moving points, such as the positions of the joints of a person who is performing an action. Single-frame video images and a Macintosh computer monitor are optically superimposed, using a half-silvered mirror, and the positions of reference points in the video image are manually clicked in by the operator, so that the screen coordinates of the reference points on each frame can be stored in a text file for later analysis. The digitizing program records comments and identifying information along with the position data.

For many research purposes, it is necessary to measure precisely the positions of external objects at consecutive points in time. For example, in motor control research, the time-varying positions of the effectors are used to characterize movement kinematics. Unfortunately, the equipment necessary for automatic digitization of successive positions of moving objects in real time is very expensive. As a result, many researchers have been forced

to rely on summary measures such as total movement time, in spite of the fact that such gross measures may obscure detailed features of the movement being studied. The computer program and digitizing method described here provide an inexpensive means for coding kinematic data or, as in the example presented below, for accurately recording the position of the limbs at specified times in a task.

The method involves the use of a Macintosh computer, a video monitor, a video-cassette player (with single-frame advance capabilities), and a half-silvered mirror. A digitizing program records the cursor positions at which the mouse is clicked during each video frame. The program is written as a standard Light Speed Pascal program, so the software can easily be adapted to meet individual research needs.

The use of the half-silvered mirror for digitizing on the Macintosh was inspired by A. Bullinger (personal communication, 1988; see also Page, Figuet, & Bullinger, 1989), who has previously developed a program for the IBM AT computer that exploits the same optical superimposition technique.<sup>1</sup>

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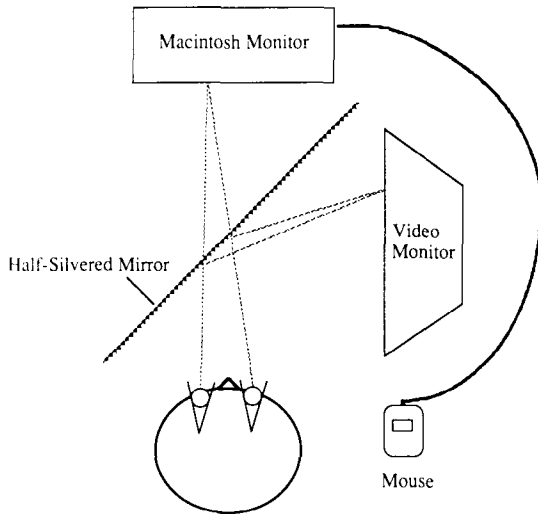


Figure 1. Overhead view of the equipment in place to begin digitization of videotaped movements. The dotted lines represent the lines of sight of the operator to a pair of corresponding (i.e., superimposed) points on the two monitors, to which the cursor has simultaneously been moved with the mouse.

The raw data are obtained by videotaping subjects while they perform movements, with high-contrast markers placed on reference points on the limbs. Figure 1 shows an overhead view of the equipment in place to begin digitization of these data. The Macintosh monitor and the video screen are placed at right angles to each other. The half-

silvered mirror is positioned at a  $45^\circ$  angle from the vertex of the two monitors. When the operator looks at the Macintosh monitor, the image from the video monitor appears to be superimposed on it. Note that because of the half-silvered mirror, the images of the video monitor and the Macintosh monitor fall, ideally, in the same virtual plane, from the observer's point of view. Thus, there is no parallax error if the superimposed monitor surfaces have the same degree of curvature, although in practice, the monitor faces depart slightly from this ideal.

The program prompts the operator for header information that serves to define the data. Then the program allows for frame-by-frame recording of videotaped movements. Finally, the program stores the data in a Macintosh file for analysis.

Once the equipment is in place and the program is initiated, the program begins by prompting the operator for header information. This includes the name of the video tape, the subject, the session and position code, the number of marker positions, the location of the markers, and any other notes the operator may wish to include. After this information is collected, digitizing can begin.

Figure 2 illustrates the Macintosh screen at the beginning of the digitizing process, in an experiment where the positions of the finger, hand, and arm are to be recorded at the endpoints of an oscillatory movement. To digitize the data, the operator clicks the mouse on the various limb markers and on one of the buttons on the left side of the screen. The recording of marker positions for each video

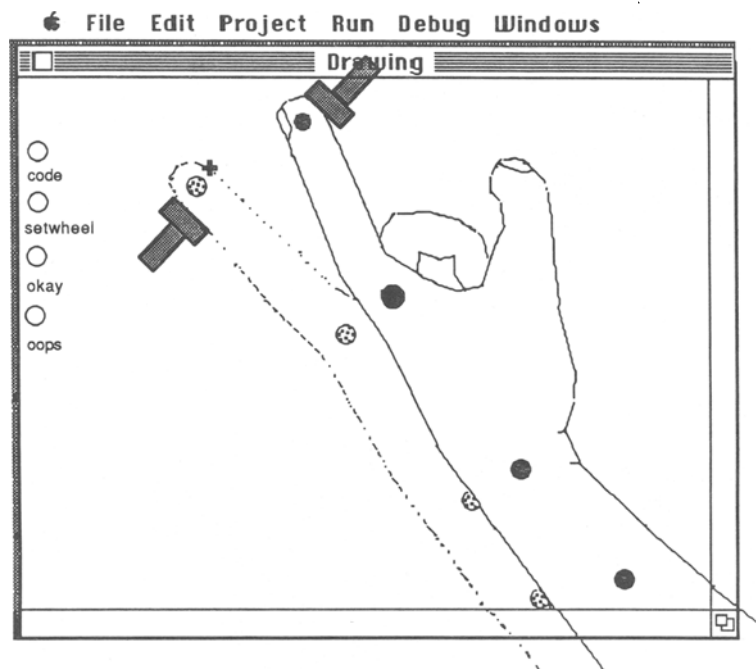


Figure 2. Sample Macintosh screen at the beginning of the digitization process, for an experiment in which the finger is to be moved between two stops (Vaughan et al., 1988). The right hand is indicated as it would appear at two extremes of movement. The Macintosh screen is viewed directly through the half-silvered mirror, whereas the video monitor is seen in reflection. The mouse-controlled cursor (a plus sign) is near the fingertip in the extended position.

frame proceeds as follows: Each mouse click on a limb marker indicates its position, in the order in which the markers were originally defined. Marker positions are recorded as the  $x$  and  $y$  coordinates of the cursor when the mouse is clicked, with each unit representing one pixel on the Macintosh screen.

An incorrectly recorded data point can be corrected if the error is noticed immediately after being clicked, by means of clicking on the same location again: each mouse click is tested for its distance from the immediately prior mouse click. If the next click is within 14 pixels of the prior marker position, the prior marker is erased. The correct marker position can then be entered.

Once the last marker position has been clicked, three options are available. The "okay" button allows the data to be permanently recorded in the data file. The "code" button allows for the addition of an arbitrary code to be associated with the current frame's data. The "oops" button may be used to cancel the frame's data in case an error was not immediately noticed.

Some specialized video-cassette players (e.g., Panasonic AG-1950) have a jogwheel, which simulates the forward and backward frame-by-frame movement of a traditional motion-picture film editor. If the operator is coding consecutive frames with such a sophisticated video editor, the digitizing program has the ability to automatically assign a code to each frame's data, to ensure synchrony between the videotape and digitized data. Clicking on the "setwheel" button causes the jogwheel position code to be associated with each frame's data.

The program stores the data in a Macintosh text file for eventual analysis by special-purpose or spreadsheet

programs. Figure 3 illustrates a sample data file; information provided by the operator is in boldface. The header information includes identifying information: the file name, the data videotape name, a character string (defining the subject, the session number, and a short code for defining conditions). It also includes a definition for each marker position. The header information is followed by a line that identifies the columns of the individual frame records that follow. After the header information, the data file consists of one line of data per video frame. This line contains the frame number, the horizontal and vertical positions (Macintosh screen pixel address) of each marker in the frame, and a code string if a code has been associated with that particular frame. The pixel address of each marker is translated into appropriate metric units in a subsequent analysis program. The data file ends with a distinctive end marker (a nominal frame number of 99999).

The reliability of the digitizing process was examined by having an experienced operator digitize a  $4 \times 4$  matrix of dots that had previously been videotaped. After digitizing the 16 dots from one frame, the operator advanced the videotape one frame and digitized the 16 dots on that frame. Forty frames of the matrix were digitized. The within-operator reliability coefficient (Myers, 1979) was .99.

The digitizing process allows researchers to sample data from continuous movements at a rate limited by the video frame rate (30 Hz). Thus, it is possible to analyze the detailed time course of videotaped movements in laboratories that lack more expensive automatic digitizing systems. The actual digitizing process (clicking on the limb markers) requires about 5 sec per frame of video data for a practiced operator, not counting the time required to position the videotape recorder on the desired frame.

To digitize movement kinematics at higher than 30 samples per second requires more sophisticated (and expensive) apparatus, such as the WATSMART (Northern Digital, Canada) or SELSPOT (Selcom, Sweden) system. Despite their sophisticated design, these systems sometimes misrecord because of light reflections or other noise sources (Samuelson, Wangenheim, & Wos, 1987; A. Wing, personal communication, 1988). Users of such systems are advised to corroborate automatically obtained digital readings with another method. The method described here provides a manner of doing so, with the advantage that digitizing is performed on records that are simultaneously visible to the operator.

Our method provides an inexpensive means of digitizing videotaped positions of moving points. It was designed for use in the study of movement kinematics, but it could also be used in other ways: to generate stimuli for the study of the perception of motion in complex systems, by videotaping reference points on a taped performance and then using the recording to play back the points in a dynamic display, or to quantify the activity levels of animal or human subjects, for example.

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Experiment mss 2
Subject, session & condition mg 2 4.5
    4 marker positions
Marker      1 is positioned on the finger
Marker      2 is positioned on the knuckle
Marker      3 is positioned on the wrist
Marker      4 is positioned on the arm

Frame x1 y1  x2 y2  x3 y3  x4 y4  optional code
1  336 407  296 292  207 186  123 118  4  0:25:24:3
2  167 431  178 314  124 189  58 117
3  332 391  287 276  187 181  105 115  6  0:25:40:2
4  167 417  198 301  137 183  67 115
5  336 409  318 292  228 192  144 126  2  0:25:58:9
6  168 430  167 312  118 194  56 117
99999

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Figure 3. A sample data file from the experiment shown in Figure 2, edited for clarity of exposition. Data that were typed in by the operator are in boldface; those input by mouse click are in plain characters, and those generated by the program are in italics. The data are stored in a file named "mss 2 mg 2 4.5", which identifies the experiment (mss 2), subject (mg), session (2), and distance condition (4.5 in). Four markers are used, as shown in Figure 2; the identification of each marker is permanently associated with the data file. In this example, only representative frames of the videotape have been digitized. The data record limb positions sampled during four movements (eight collisions of the fingertip with one of the stops), along with a code indicating the speed of the movement (2, 4, or 6 repetitions per second) and the time of the sample (read from the onscreen stopwatch of the videotape).

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NOTE

1. Those interested in the use of the digitizing technique in the IBM environment may contact André Bullinger at University of Geneva, F.P.S.E., 24 rue Général Dufour, 1121 Geneva 4, Switzerland. See also Page, Figuet, and Bullinger (1989).