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'INSTANT' ANALYSIS OF MOVEMENT

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The study of walking and other dynamic behaviour patterns has challenged the experimental ingenuity of researchers since Muybridge first demonstrated in a series of still pictures that galloping horses raise all four legs from the ground at once. The use of moving film improves the situation but still suffers from a fundamental disadvantage in the time required to process and analyse the changes in the image from frame to frame. A number of suggestions have been made to make film analysis more time effective but the difficulties are an inherent feature of the storage medium.

This paper describes a novel approach to these problems incorporating computerized video data-capture with digital storage so that instantaneous position information can be processed in real time and stored on magnetic disc for later computer analysis. At the same time a conventional video record of the behaviour of the whole animal can be made. This method has been used to record movements of all six legs of a walking stick insect with spatial and temporal resolution comparable to normal ciné techniques but with the advantage that the data can be processed at high speed and in a variety of different ways. The technique can be generally applied and is suitable for a wide range of experimental measurements.

The essential component of this system is a Micro-Works Digisector 65 (see reference). This inexpensive plug-in board can be instructed by an Apple II or S-100 computer to examine the video signal generated by most low-cost TV cameras and measure the intensity of the image at the coordinates X, Y in the viewing field. A 6-bit digital register successively approximates the brightness of a given point and assigns one of 64 levels of grey scale to each point analysed. The point under examination is displayed as a momentary bright spot on the video image. This composite signal incorporating the video image and the brightened cursor point may then be recorded using a conventional video tape recorder and stored on tape. A simple video camera (Sony 100CV), and a Toshiba V-8600B video tape recorder complete the system as shown in Fig. 1A.

In this particular application the insect is mounted on a rod above a pair of light Rohacell wheels (Graham, 1981), and viewed by a black and white video camera mounted vertically above it. The video signal is passed to the DS-65 board in the computer and the output from the board is led out to the VTR and the video/computer monitor. The board can be programmed using BASIC to digitize the brightness of any point on the TV image but where rapid scanning is required only machine code is fast enough to access consecutive lines of the video image and digitize points in a vertical or oblique line down the screen.

The procedure involved in this particular application is as follows. The scanning

Key words: Behaviour, locomotion, position-detector.

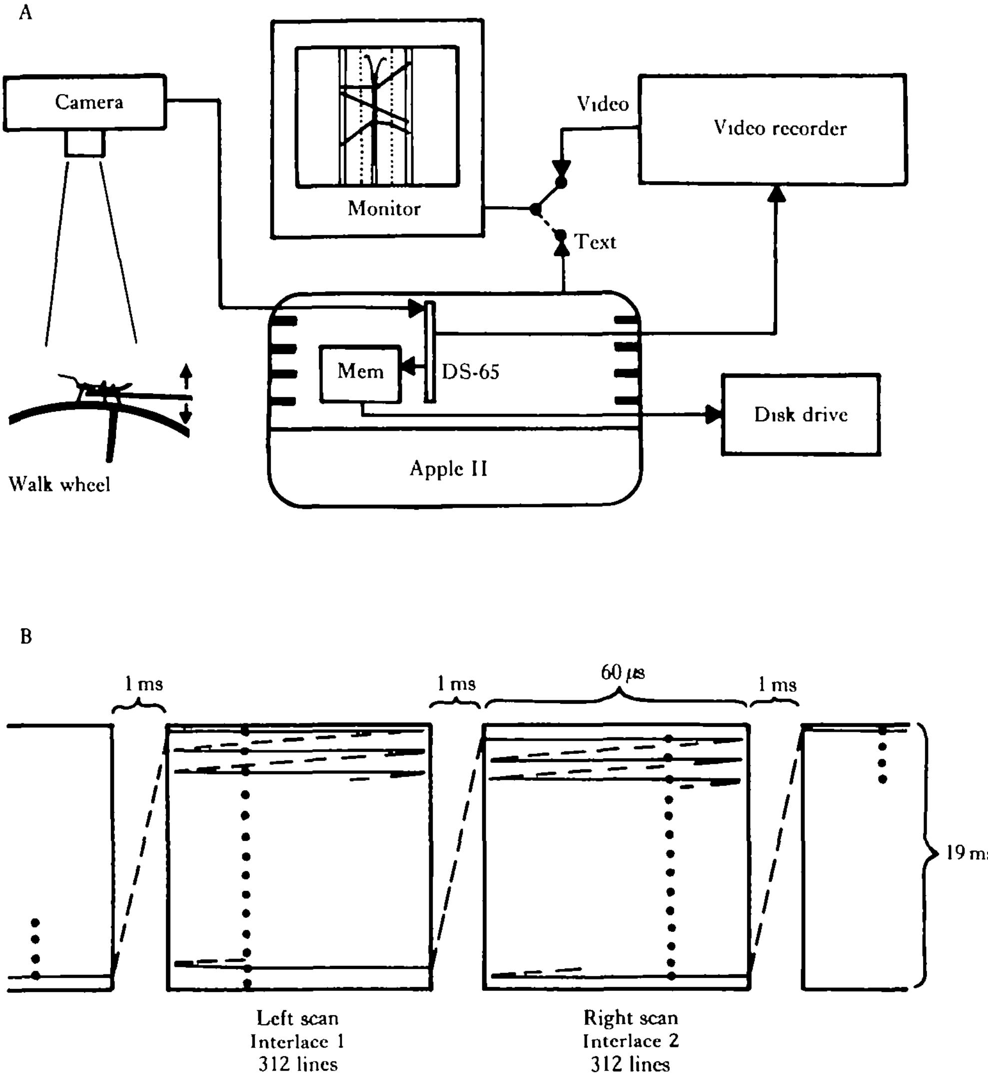

Fig. 1. The equipment arrangement for the leg scanning experiment. (A) Incoming video information is examined by the DS-65 under programme control and certain features are detected and stored in memory. The video signal with the digitized points intensified is then passed onto the video recorder. A single video monitor is used to view the image or programme text as required. (B) Digitization of consecutive interlaces showing sequential scanning of right and left sides of the screen.

spot passes successively down two vertical lines positioned on each side of the body 7 mm from the longitudinal axis (Figs 1, 2A, B). For higher temporal resolution the two scans may be superimposed on the legs of one side (Fig. 2C). Each raster point is compared with a set intensity and if a leg is found the Y coordinate of that leg is stored in the memory. The scan then moves downward several lines to avoid storing further values for the same leg. The scan then continues its search for the second and third legs.

The machine language scanning programme is controlled by a host programme

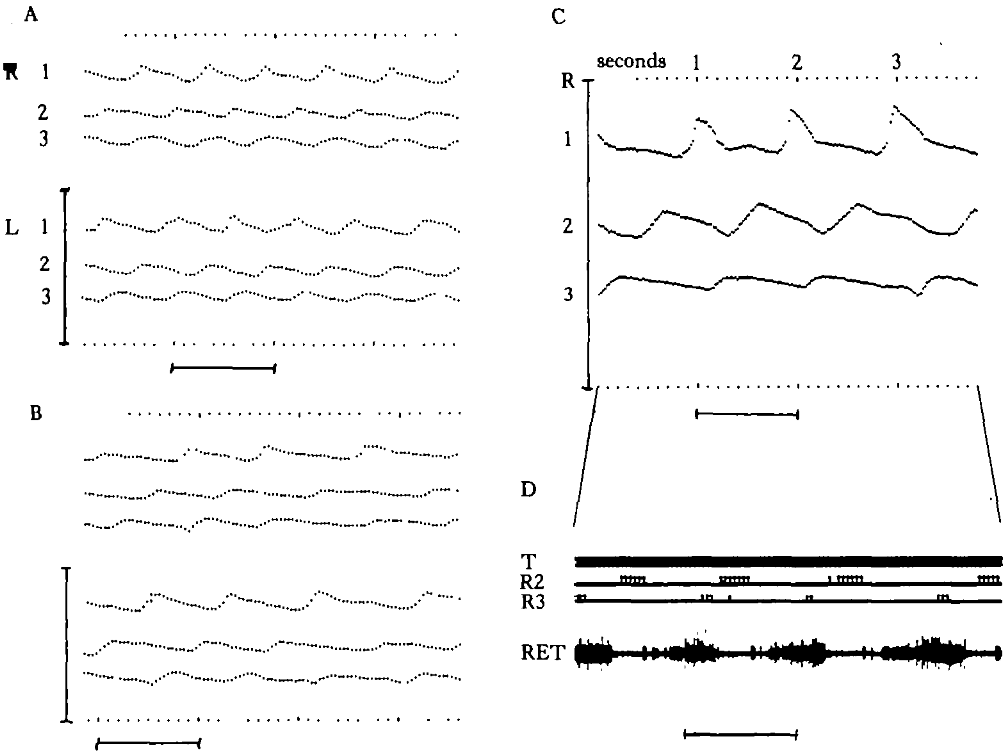

Fig. 2. Examples of leg movement plots for a stick insect walking on a light treadmill. (A) and (B) are scans of both sides of the body with a time resolution of 40 ms. The step patterns show fast and slow walking, respectively, for an intact animal, with a load along the body axis of less than 20 mg (force). (C) is a walk under the same external conditions for an operated animal with a recording electrode on the retractor nerve of the right middle leg. (D) shows the nerve record for the steps in (C). Only one side is scanned with a time resolution of 20 ms (T). The upper trace is a record of an annunciator which gives a 0 V signal for the right scan and 5 V for the left scan which are superimposed in this instance. Traces 2 and 3 show a 5-V pulse when legs R2 and R3, respectively, are moving forward in protraction. The vertical bars represent 70 mm on the displacement axis and forward movement of the leg is upwards. The horizontal bar and time scales represent 1 s and 100 ms respectively. RET is a recording from the nerve supplying the retractor-coxa muscle of the middle leg.

written in BASIC. Leg positions are temporarily stored in the Apple memory and then dumped to disc. The scan can then be restarted to acquire a further block of data. If three appendages are monitored on each side the Apple II stores a 6 kilo-byte block of data representing 30 s of real time. For a single moving object, interrupting the scan line, the available memory in a 48 kilo-byte Apple would be filled in 12 min. To increase the time available some form of data reduction may be carried out. As an example, a change of direction might be the parameter of interest and only the time of this event need be stored.

Considerable on-line data processing is possible between scans and immediately following the detection of each leg. For example, it is possible to identify and evaluate the direction of movement of each leg and pass this information out through the game port and record it along with nerve or muscle activity (Fig. 2D). Alternatively, the parallel port could be used to output 8-bit representations of step period, frequency or phase.

In the walking application, outlined here, the digitizer scans both sides with a frequency of 25 Hz. One side alone can be scanned at 50 Hz with a spatial resolution of 1 part in 255 for the total range of movement. Where only three legs are scanned on one side the position could be evaluated to within 1 part in 25, which is equivalent to 0·25 mm. A synchronization signal from the scanning programme provides a 5 V TTL output when the scan starts on one side of the animal and a 0 V output for the other side.

Immediately, after an experiment, the trajectory can be displayed on the Apple high-resolution screen to determine if the parameters are appropriate or if the experiment should be repeated. The scan programme provides for the input of scaling data. Using mirrors to view both sides of the animal it is possible to reconstruct the movement of the femur in three dimensions.

The video-digitizer can be used for bar code or text analysis; as a graph or histogram digitizer or for point following in the X, Y plane (maze running, for example) and is particularly valuable in the teaching environment. The system is versatile and with suitable software is capable of following any movements that can be detected by the camera. Originally, the board was designed as part of a low-cost portraiture system but the X, Y digitizing capability at processor speed makes it ideal for movement detection with negligible memory overhead.

Other currently available systems have similar dot resolution but only provide access to the high resolution screens for data processing after each screen is filled. In such a system all data reduction must be performed between successive scans and in addition 16 kilo-bytes of memory must be reserved for picture storage.

REFERENCES

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MICRO-WORKS DS-65. For further information on software and digisector boards for various applications contact Micro-workshop, 17 Hastings Road, Bexhill-on-Sea, Sussex, England.