NASA TECH BRIEF

Ames Research Center

Scanning Technique for Tracking Small Eye-Movements

The problem:

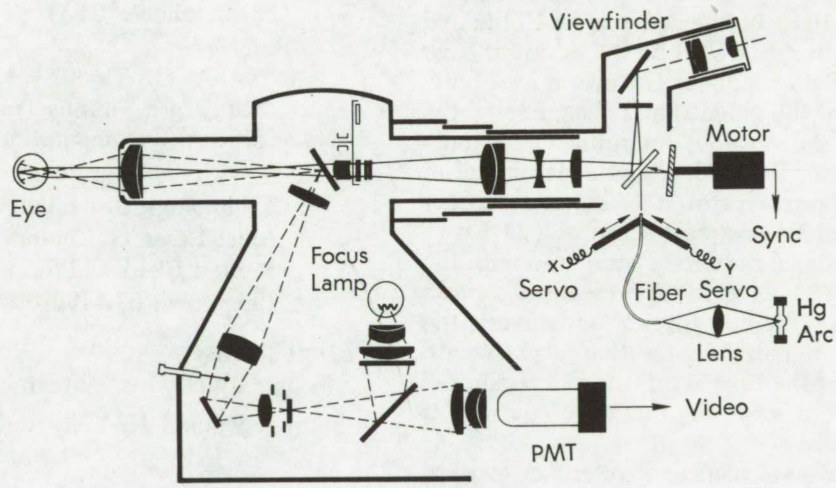
To track the small, involuntary movements made by the eye for the purpose of stabilizing an image on the retina; the technique must not require physical contact with the eye.

The solution:

Image a small spot of blue light on the fundus and, while it is scanned at high speed in a small circle around the optic disk, measure variations in reflectance of the spot and compare the reflectance pattern with a stored reference pattern; convert the difference from the stored pattern into inferred eye motion.

How it's done:

The apparatus that has been developed for projecting a spot of blue light and causing it to scan in a small circle is shown in the diagram; it is a modified Zeiss fundus camera from which the xenon flash tube has been removed and replaced with a very sensitive photomultiplier. A digital processor operates on the video signal output of the photomultiplier, provides X- and Y-servo signals, and indicates the magnitudes and directions of eye motions. The mercury lamp is a 100-watt high pressure arc in a quartz tube cooled by



an airjet. A microscope objective images the arc onto the end of a 0.13-mm fiber which is mounted in a 3-way rack-and-pinion arrangement for precise focusing and positioning. A special interference filter at the lamp house passes light between 400 and 500 nm wavelength.

The scanning motion of the light spot is caused to take place by reflection from a spinning mirror which is mounted at a small angle to the motor shaft. With the motor operating at its normal speed of 400 rps, the point image of the light source emerging from the end of the fiber appears as a circular scan pattern, which is centered on the subject's optic disk. That is, the scanning circle is about 17 degrees off the visual

(continued overleaf)

axis, and is some 6 degrees in diameter. The scan pattern is caused to track by deflecting the output end of the fiber. This is done by two electromechanical driver units (modified loudspeakers) that are mounted at right angles to each other. In turn, these are driven by the X- and Y-servo outputs of an electronic signal processor.

By toothed wheels and magnetic pickups, the scanning motor is also made to provide a single frame sync pulse and 512 minor sync pulses per revolution. The signal processor is thus effectively locked onto the position of the spot, and minor variations in motor speed cannot distort the wave form of the video signal obtained from the photomultiplier tube (PMT) shown in the diagram. The focus lamp shown in the diagram is used in setting up the apparatus, and ensures that the scanning spot is in sharp focus on the subject's retina.

As the scanning spot moves in a circle about the optic disc, the amount of light that is reflected to the photomultiplier is determined by the fundus pattern, that is, discontinuities such as veins and the color of the cellular material. Thus, if the eye remained perfectly still, the pattern of the video signal obtained from the photomultiplier would be the same for each revolution of the flying spot. As the eye moves, however, the pattern of the video signal changes slightly.

The amount the eye moved is determined essentially as follows: (1) The first video signal pattern after pushing the start button is stored in the core memory and used as a reference or master frame. (2) Every succeeding video signal pattern is compared with the stored reference. (3) A noise-suppressing algorithm developed expressly for this application converts the retinal-reflectance signals into position-error signals. (4) The position of the fiber is adjusted to regain the stored signal pattern. (5) The motion of the eye is recorded graphically.

The master frame selected as a reference pattern actually consists of the algebraic difference between the first video frame and a slightly delayed version of itself. Selection of this frame determines the location on the fundus to which the scanning circle will be locked in the closed-loop condition. The master difference frame is then stored and multiplied repeatedly by each new video frame, in real time. This product is integrated over the duration of one frame, yielding a cross-correlation value which is positive, negative, or zero, depending on whether the incoming video signal was earlier, later, or the same as the master frame (relative to the sync pulse). This calculation corresponds to a pure rotational component about the center of the scanning circle. The X and Y motion signals are obtained in the same way, except that before integrating, the video signal is also multiplied by a gating signal or weighting function, which consists of the sine or cosine of the angular position of the flying-spot.

Notes:

1. The following documentation may be obtained from:

   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)
   Reference:
   NASA CR-114307 (N71-24931), Research Study of a Fundus Tracker.

2. No additional documentation is available. Specific questions, however, may be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: B72-10220

Patent status:

No patent action is contemplated by NASA.

Source: Donald H. Kelly and Hewitt D. Crane of Stanford Research Institute under contract to Ames Research Center (ARC-10488)