THE DIGITIZED MICROSCOPE (or DM) - A MEASURING DEVICE FOR THE EVALUATION OF PHOTO EMULSIONS IN HIGH-ENERGY PHYSICS AT MPI IN MUNICH, GERMANY

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1. INTRODUCTION

The scanning and measuring of photo emulsions with a microscope is a time-consuming job. Carathanassis therefore made a proposal for a device which allows a fully automatic evaluation on-line to a large digital computer. A prototype has been constructed, measurements have been carried out, and data written on magnetic tapes. In the meantime, computer programs for the geometric reconstruction have been written and carefully checked.

2. SYSTEM (see Fig. 1)

The system as planned for on-line use consists of a microscope and its associated electronics, parts of the HPD electronics and data connections, a Digital Equipment PDP-8 computer, and an IBM 360/91.

The program in the 360/91 receives digitizings from the microscope, detects track elements, and follows tracks by giving commands to the stage control via the PDP-8.

Because a direct data connection to the 360/91 does not yet exist, data are transmitted via the DDC to the IBM 7090 where they are written onto magnetic tapes which are then used as input to the 360/91 program. For the same reason, computer-controlled track-following is not possible at present.

3. LAYOUT

The microscope was specially constructed by W. Süss, Munich. The precision-measuring stage and the optics were delivered by Leitz, Wetzlar. Motion of the stage and microscope tube is achieved by spindles driven from Slo-syn stepmotors. Motor-drives were manufactured by Omni Ray, Zürich. Displacements in the directions X_m, Y_m, and Z_m are sensed to an accuracy of 1 μm, by linear Heidenhain gratings and associated electronics. The television system is an Image-Orthikon-Camera System Televisor from Fernseh G.m.b.H., Darmstadt. The electronics are home-made and use Digital Equipment M-Series modules and circuits, which we designed ourselves. (It was not considered necessary to describe the HPD electronics in this paper.)

4. OPERATION

The photo emulsion lies on the measuring stage which can be moved in X_m and Y_m directions under computer control. The television camera observes, through the microscope, dark points on a bright area of 93 × 77 μm (magnification of the microscope ≈ 1000). The depth of focus is in the region of some microns. The tube of the microscope is raised by a motor-driven spindle until the top surface of the emulsion is in focus. The spindle rotates quickly back to its original position and the microscope follows slowly, its motion controlled by a hydraulic brake (see Fig. 2). During this motion the TV makes a raster scan, using the CCIR standard: the camera takes 50 pictures every second, each with 312 lines. Every second picture and every second scan line are suppressed later in the digital circuits in order to avoid getting more information than is needed. The time corresponding to several lines is needed for the retrace; thus the effective raster becomes 144 lines/picture. The time needed for one picture scan is 20 msec; this is followed by a pause of at least 20 msec. The analogue signals being picked up are filtered, amplified, and squared. The filters had to be carefully designed to avoid distortion of the signals, because noise and signal frequencies are near together and the signal-to-noise ratio is very poor. We found that a TBT-Filter (Transitional-Butterworth-Thomson) suited best. The dark period of the TV and low frequency distortions are eliminated by a special clamp circuit with an adjustable time constant. The squaring is done by a Schmitt-Trigger. Its level is controlled by computer program. The squared signals are compared with reference pulses from a crystal clock to determine the position in the TV picture (X_t, Y_t). These data are transmitted, together with the stage and tube coordinates (X_m, Y_m, Z_m), to a fast intermediate buffer in the HPD which has a capacity of 64 18-bit words and a cycle time of about 850 nsec. The data flow is under control of the 7090 and PDP-8 programs, enabling transmission of a TV picture when a specified Z_m position has been reached by the microscope tube. Usually a picture is taken every 3 μm, but a minimum distance of 1 μm can be programmed. The 7090 reads the content of the intermediate buffer at regular intervals and writes the data onto magnetic tapes to be used by the 360/91. (Figure 3 shows a plot of one TV picture from this tape.) As soon as the DDC between the HPD and the 360/91 is complete, all calculations will be done during the time the microscope is scanning and the generation of data tapes will not be necessary. The program will determine the direction of tracks and give commands via the PDP-8 to the stage control for track-following.

The measuring time is about 10 seconds for a volume of 93 × 77 × 400 μm including stage motion between measurements.

5. PROGRAMS

For each volume element of emulsion scanned, the (X,Y,Z) coordinates for each grain (digitization) are measured and stored. X is the line number of the television picture, Y is the distance along the line, and Z is the Z of the microscope stage. The tracks are to be followed in roughly the X-direction.

The following procedure is used to find a track. First, the desired slice of the scanned volume is made by selecting all grains having (X,Z) coordinates lying within a given distance ΔZ of the plane

$$Z = B + N \cdot X \ .$$

(See Fig. 4.) (Which slice is "desired", i.e. which parameters B, N, and ΔZ are used, is defined by the physics involved.) Then, the (X,Y) coordinates of the selected grains are considered.

A track will consist of a constellation of grains lying along a straight line of the form

$$X = A + M \cdot Y \ .$$

A matrix of all possible A and M values is set up, whereby the rows correspond to the A values and the columns correspond to the M values.

Naturally, the possible A and M values are accumulated, the number of A values being equal to the number of lines of the TV picture, and the number and magnitude of the M values being given by the physics of the situation. At the start of each slice, all matrix elements are zero. Then the (X_i,Y_i) coordinates for the i^{th} grain are used to calculate the possible values of $A = A_j$ for this grain from

$$A_j = X_i - M_j \cdot Y_i ,$$

where all possible values of $M = M_j$ are substituted sequentially. The corresponding matrix element for each A_j and M_j thus computed is increased by one. This procedure is repeated for all grains of the slice. The resulting matrix is then examined for maxima among the matrix elements. A matrix element which exceeds a given minimum value (given by the physics, the density of background grains, the quality of the emulsion, etc.) and which is greater than its eight immediately neighbouring elements, represents a track. The digitizations (grains) used to form this element are collected and a straight line is fitted to their (X,Y,Z) coordinates. Provided this fit fulfils certain criteria, the track is accepted. This fit is used to follow the track to the next scanned volume element.

6. CONCLUSION

The DM can be said to fulfil the special purpose for which it was designed. In our opinion it would be possible, with some trivial changes in the electronic circuits, to use this system in other fields, e.g. biology, cancer research, etc.

Remark

More detailed information about the DM will be given soon in an MPI internal report.

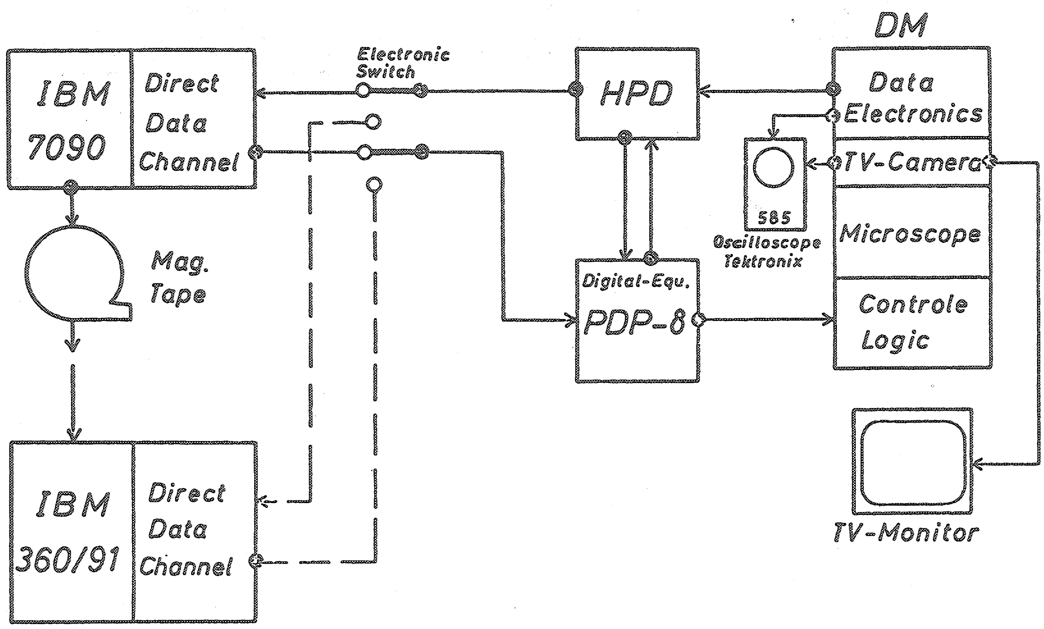

FIGURE 1

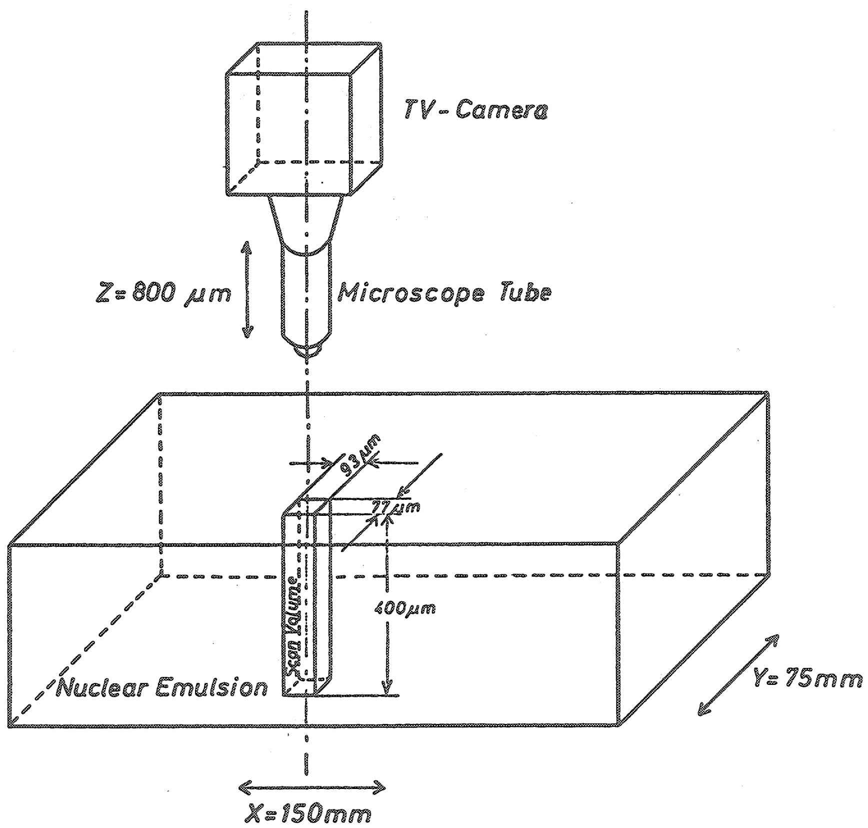

FIGURE 2

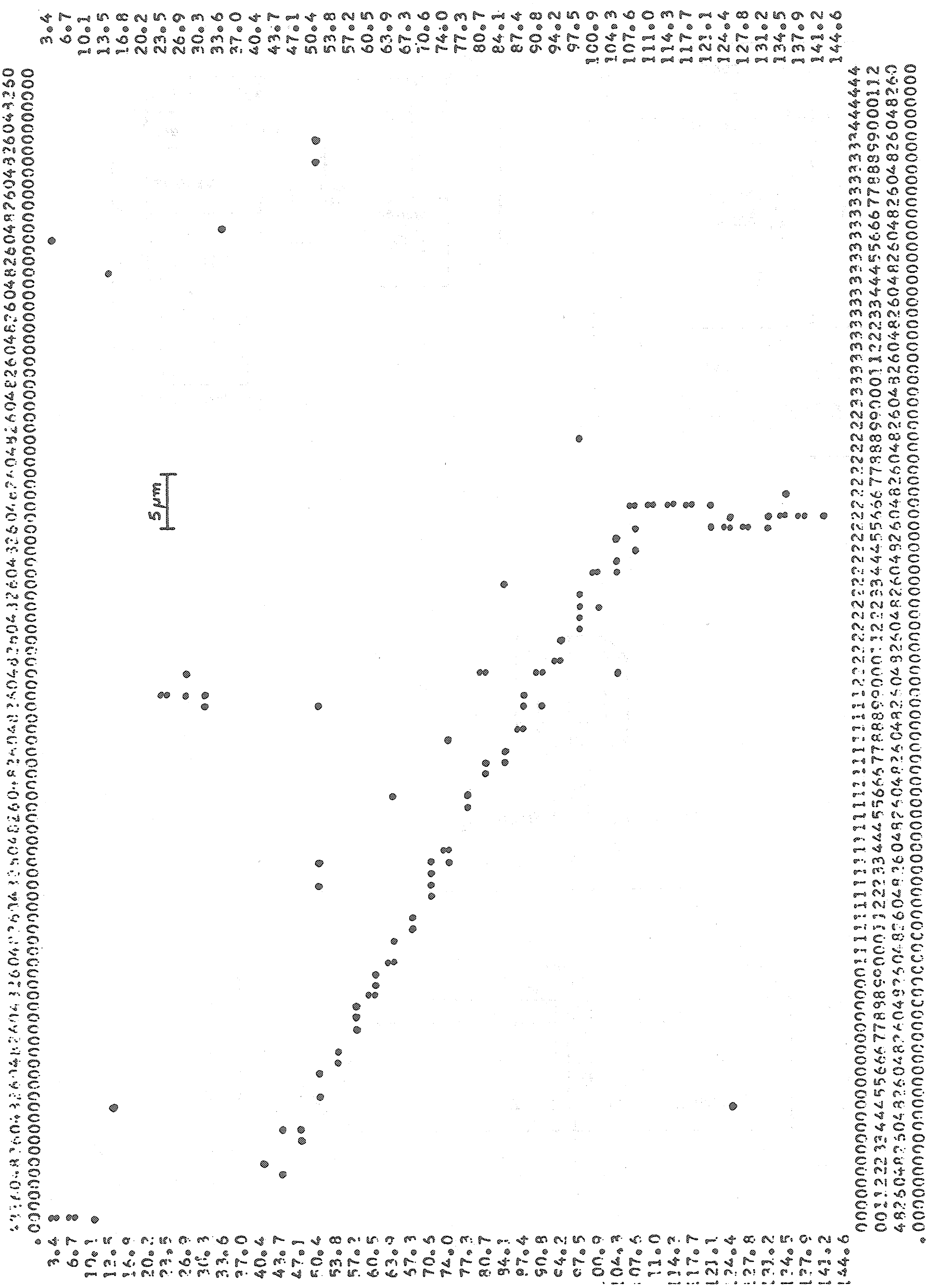

FIGURE 3

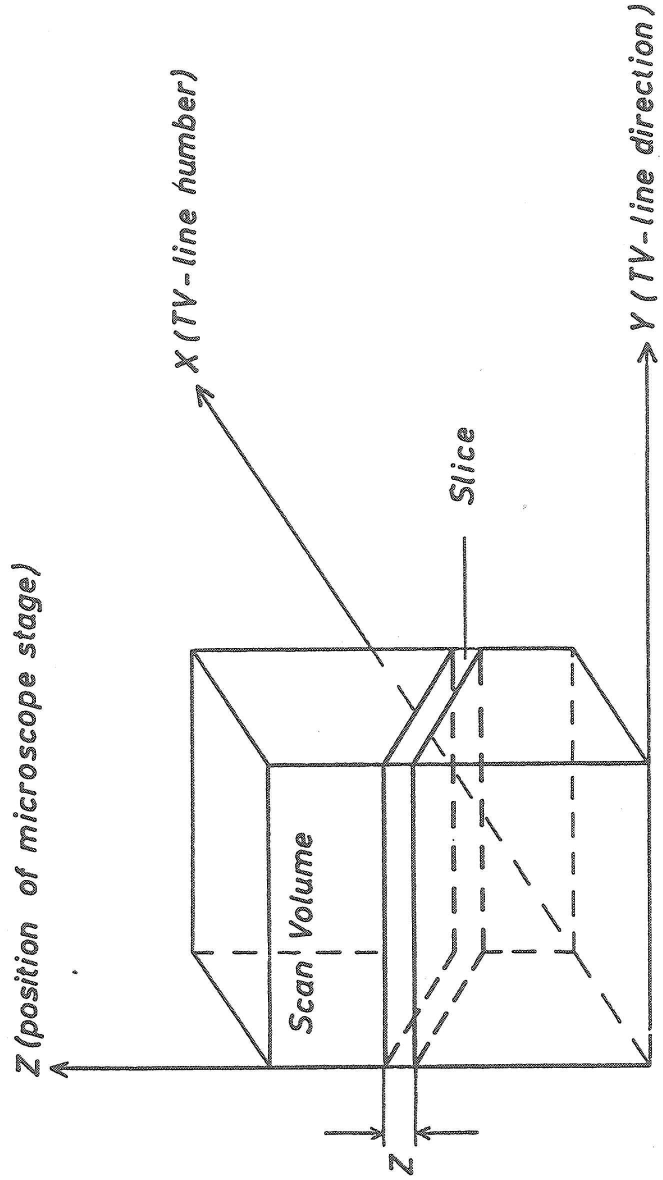
Z (position of microscope stage)
X (TV-line number)
Y (TV-line direction)
Slice
Scan Volume
2ΔZ

FIGURE 4