LUCIOLE

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1. Introduction

Luciole is an on-line flying spot scanning device designed for the analysis of spark chamber photographs. The first on-line tests using the IBM 7090 are due to take place in October 1963. The device uses a high resolution CRT to produce a continuously running TV-like scan with a spot size on the film not exceeding 30 μm diameter over 36 x 36 mm^2.

2. Approach

Luciole is, according to Kowarski's terminology, an example of the "tricky software solution" to the automatic processing of spark chamber pictures. It has evolved from the HPD and is thought to be better adapted to the particular problem of spark chamber pictures. While less precise than the HPD, the time to scan a picture is less and the cost is relatively low. Particular attention has been devoted to the stability and reliability of the device [1].

3. The flying spot generator

A Ferranti type 5/71 AM CRT is used together with CELCO focusing and deflection coils (fig.1). The raster is produced over a 60 x 60 mm^2 area within which the spot size is always less than 50 μm diameter *. This is demagnified by 1 : 0.6 onto the film by means of a pair of lenses face to face (Schneider Xenar and Componon).

The time for the complete scan is 1.14 sec and this is followed by a flyback time of 0.38 sec. A scan contains a total of 768 lines approximately 50 μm apart. The least count along the scan time is 22.5 μm.

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* A much finer spot can be obtained at the center of the screen; even over the whole scanning area, a more stringent requirement could be met. We have preferred to chose a value that can be maintained over several hours without re-adjustment.

The pin cushion distortion has been roughly corrected for by an array of permanent magnets. The residual distortion will then be corrected for by the computer on the basis of a calibration made every few hours by scanning a suitable test pattern.

A reproducibility has been obtained in the "fast" direction (F) along the scan lines of better than $\pm 10^{-4}$ rms and in the "slow" direction (X) perpendicular to the scan lines of better than $\pm 3.10^{-4}$ rms. Slow general shifts of the raster in either the F or X direction do not affect the measurement process.

4. The digitising process

A method of digitising ("Sampled Analog Digitising") has been chosen which does not necessitate a large buffer memory. At regular intervals (corresponding to the least event in F) the photomultiplier signal corresponding to the scan across the film is sampled A sequence of zeros and ones is generated where the ones correspond to opaque regions on the film. This sequence is fed into a shift register of 17 bits.

After every 17 clock pulses, its contents are transferred into the lower half of a one word buffer provided that the register does not contain only zeros (figure 2). Subsequent half words go alternately into the upper and the lower halves of the word. Such a sequence of half words ends when an upper half containing only zeros occurs. Then this is replaced by the true F-coordinate of the last sampled point expressed as the total number of clock pulses counted from the beginning of that scan-line. The X-coordinate (number of the scan line) is read out at the end of each scan-line (except when this has been completely blank).

The timing of the load-unload procedure of the buffer is such that each completed word can be read into the 7090 before the next load operation is due.

5. Speed

The speed of the device is limited essentially by the maximum rate of the DDC (estimated to be one transfer every 17.6 μsec. for our operating conditions and by the film transport (about 0,12 sec. actual advance time plus settling time). Because the raster runs continuously, the maximum speed will not be reached unless the computer can complete its processing before the scan of the next picture starts. If it should fail to do this, no data is read in and that picture will be scanned again by the following scan. In a later version of the device, this loss can be eliminated.

6. Programming

Programming for Luciole falls basically into two categories :

a) programs designed to test hardware,
b) programs to process experimental photographs

The present programming effort is concentrated on the category a), for which programs are already well advanced.

It is the aim of the programs in the latter category to read in Luciole information from one frame, write out processed data from a frame two previous and process the previous frame simultaneously, the complete cycle taking a maximum of 1.5 sec. It is proposed to process each frame in two passes of the input data. Pass (1) to locate the fiducial marks (and hence the chambers), and pass (2) to locate sparks and associate them into tracks, possibly in space coordinates. Data from each frame will be written on tape with a record to identify it, and it is hoped to apply some simple criteria to eliminate frames which are of no interest.

For this work the experience gained on the HPD is useful, although the existing programs are not directly applicable due to the format of the data. In the computer the data appears as a string of binary digits representing dark and light areas on the frame; in other words a bit pattern is assembled in the machine, and it is proposed to utilise this information directly by means of pattern recognition programs. The object of such programs is to "mask-out" the binary digits corresponding to a cross for example, and then to test on the remainder of the search area for zero. In figure 3 an area of memory has been depicted as an array on which the program will operate, a perfect fiducial cross may appear as indicated. If a mask is found which will zero the outlined word, then this mask will predict the masks necessary for the two words immediately below and to the right of this word. The complete area will then be scanned and a check on the number of zero words made. Background noise may be dealt with by accepting a number of non-zero words. For example, consider a cross that has been detected by twelve consecutive scan lines, if twelve lines were found to be initially non-zero, and after masking, three or four lines still remained non-zero, then it may be accepted as a cross. Such criteria can only be established by experimentation - a stage that the present programs have not yet attained. It is intended to convert information to coordinates only when the necessary pattern has been recognised, thus conserving computing time.

Considerable effort is being concentrated on the problems associated with crosses; it is essential that this work precedes work

on spark recognition since the sparks are located from data derived from the fiducial marks. Clearly the method of pattern recognition described above may be extended for use with sparks, but it is probable that simpler methods will be devised in this case.

7. Further development

A new version of Luciole will be developed when the first one, described above, is successfully put into operation. It will incorporate one or several of the following improvements :

a) triggering of the beginning of the frame scan by the computer,
b) preset switching to select one or several scan line densities, corresponding to the information density on the picture,
c) positioning of the scan line, under computer control,
d) computer controlled selection of "active elements" on the scan line,
e) scanning in two perpendicular directions.

With these modifications the computer, the scanner and the experiment to be evaluated can be matched together most efficiently.

Reference :

1. H. Anders, D. Maeder and D. Wiskott, Nucl. Instr. and Methods 20 (1963) 414.

Figure captions

Fig. 1 Schematic block diagram of the Luciole system.

Fig. 2 Format of data transferred to the IBM 7090.

Fig. 3 Schematic information array in the core store of the computer, derived from a perfect fiducial cross and prepared for application of the pattern recognition program.

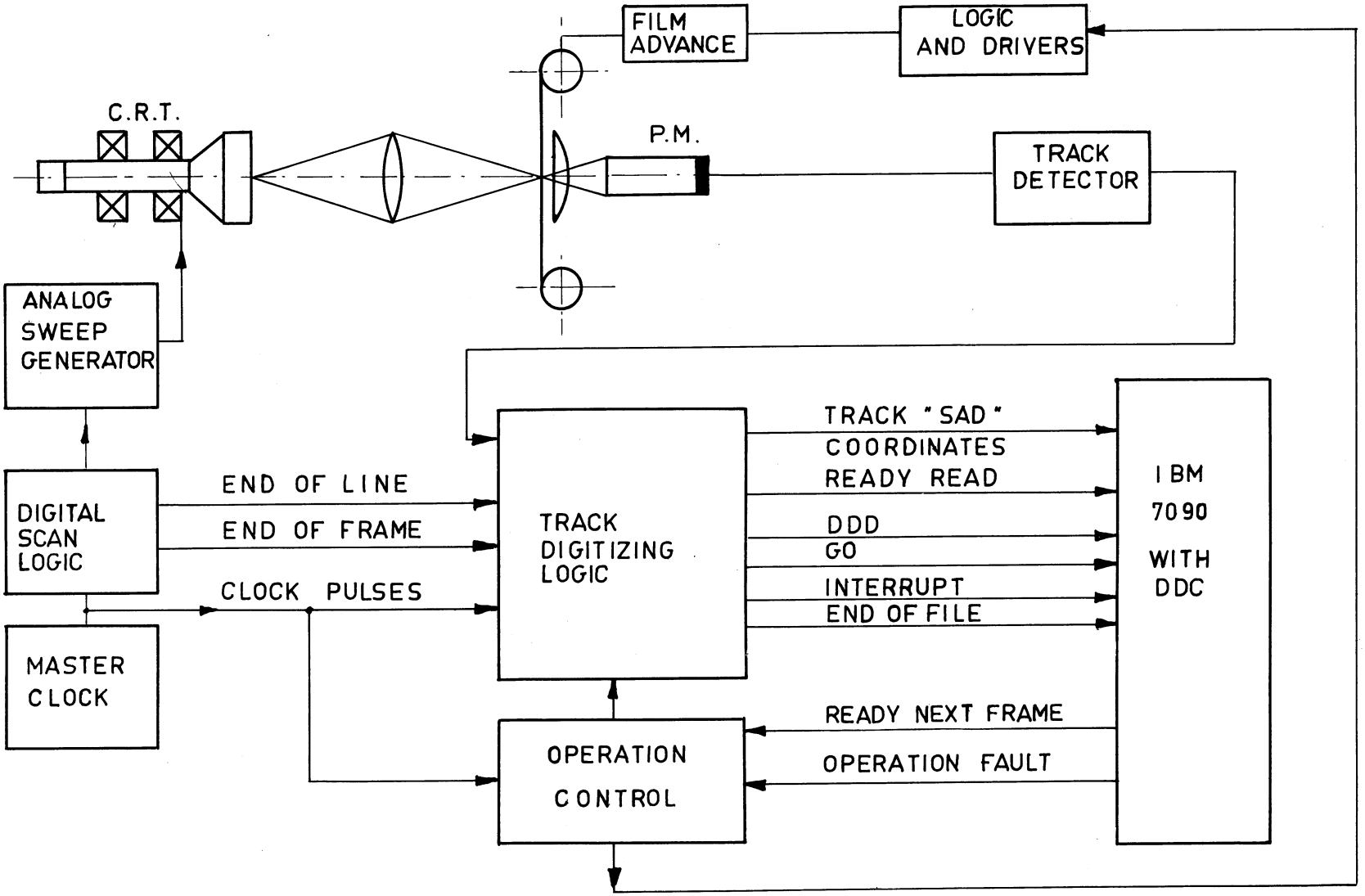
FILM ADVANCE
LOGIC AND DRIVERS
C.R.T.
P.M.
TRACK DETECTOR
ANALOG SWEEP GENERATOR
DIGITAL SCAN LOGIC
MASTER CLOCK
END OF LINE
END OF FRAME
CLOCK PULSES
TRACK DIGITIZING LOGIC
TRACK "SAD" COORDINATES
READY READ
DDD
GO
INTERRUPT
END OF FILE
IBM 7090 WITH DDC
READY NEXT FRAME
OPERATION FAULT
OPERATION CONTROL

Figure 1

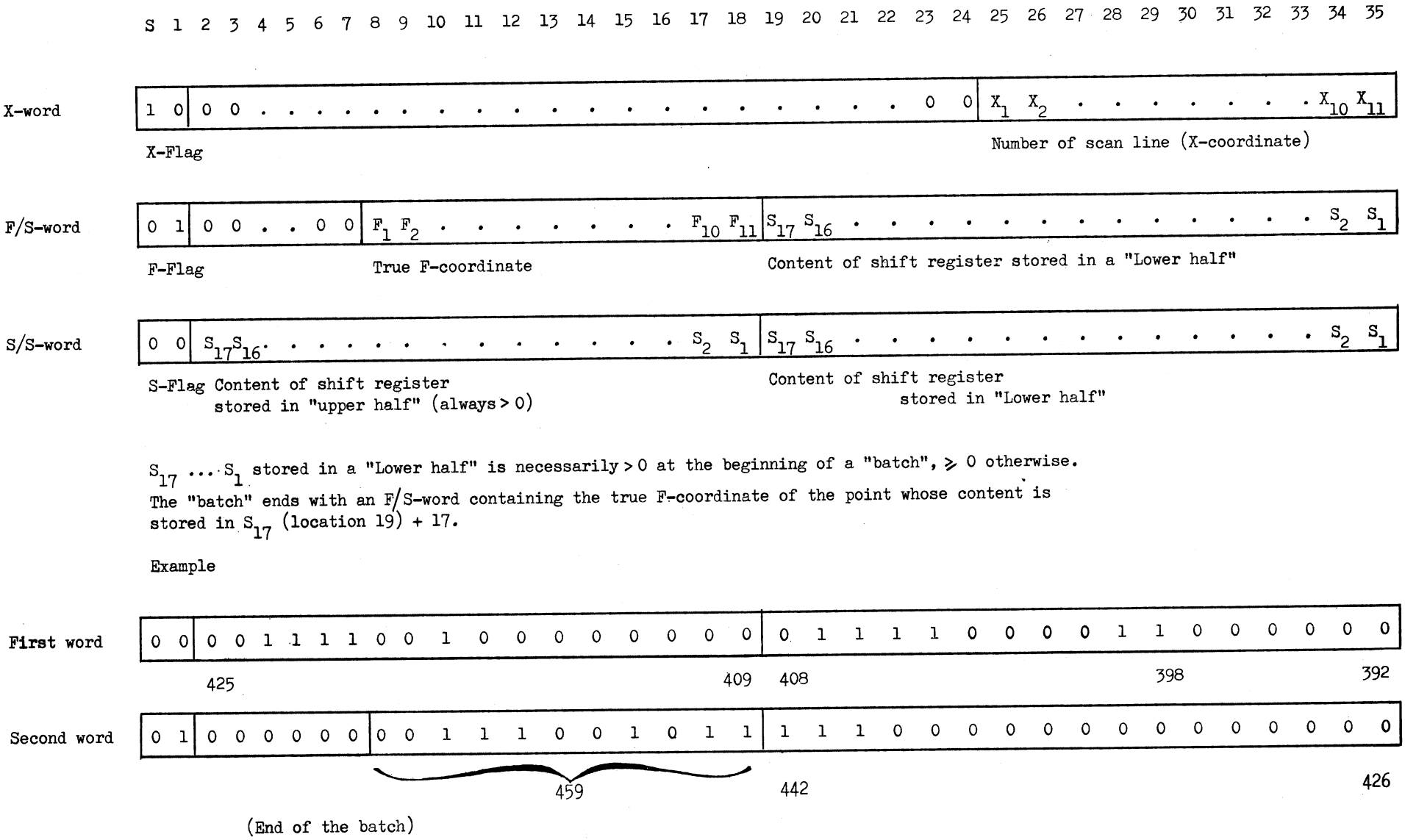
S 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
X-word
1 0 0 0 . . . . . 0 0 X1 X2 . . . . . X10 X11
X-Flag
Number of scan line (X-coordinate)
F/S-word
0 1 0 0 . . 0 0 F1 F2 . . . . . F10 F11 S17 S16 . . . . . S2 S1
F-Flag
True F-coordinate
Content of shift register stored in a "Lower half"
S/S-word
0 0 S17 S16 . . . . . S2 S1 S17 S16 . . . . . S2 S1
S-Flag Content of shift register stored in "upper half" (always > 0)
Content of shift register stored in "Lower half"
S17 ... S1 stored in a "Lower half" is necessarily > 0 at the beginning of a "batch", ≥ 0 otherwise.
The "batch" ends with an F/S-word containing the true F-coordinate of the point whose content is stored in S17 (location 19) + 17.
Example
First word
0 0 0 0 1 1 1 1 0 0 1 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 1 1 0 0 0 0 0 0
425
409
408
398
392
Second word
0 1 0 0 0 0 0 0 0 1 1 1 0 0 1 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
459
442
426
(End of the batch)

Figure 2

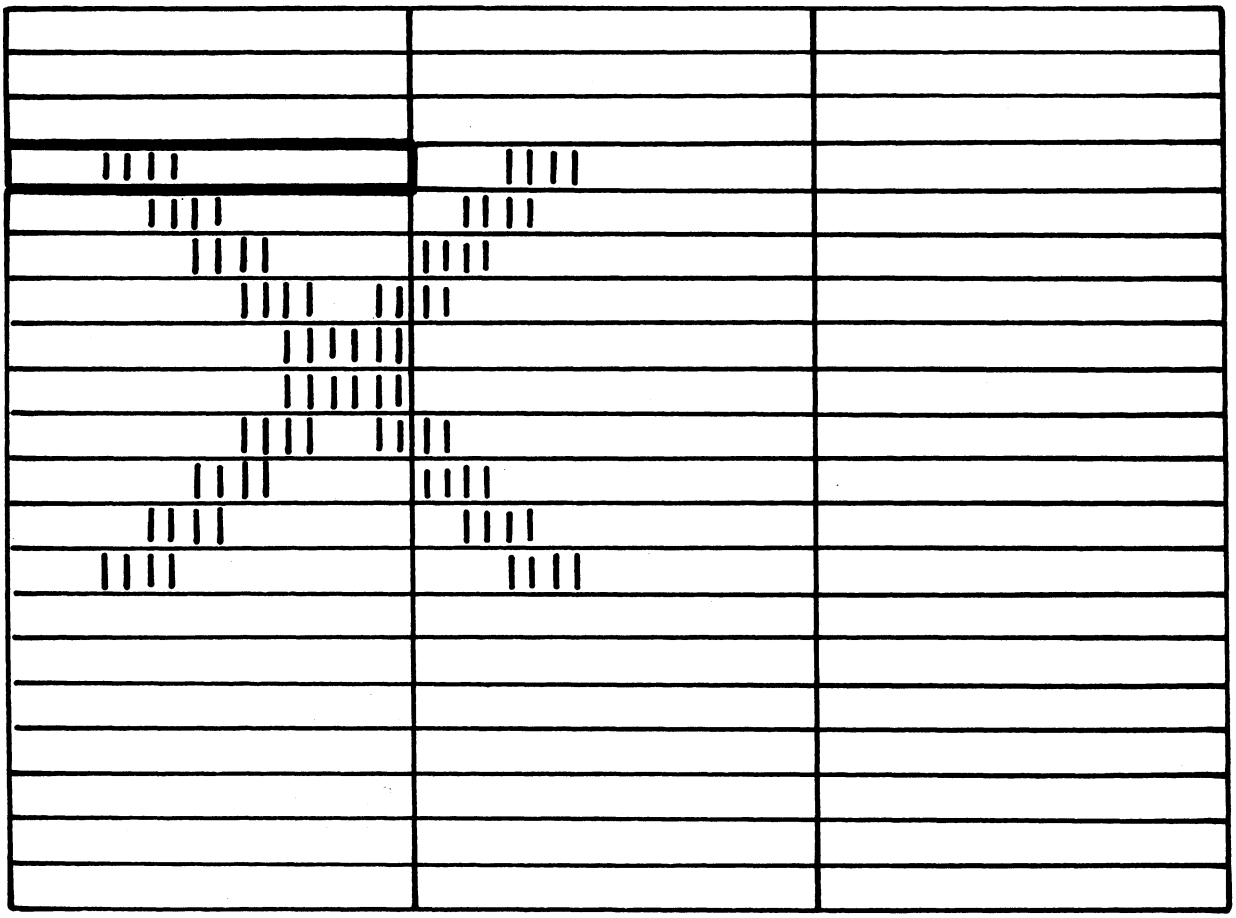

Figure 3