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"CHLOE"

A SYSTEM FOR THE AUTOMATIC HANDLING OF
SPARK PICTURES

by

J. W. Butler, D. Hodges, and R. Royston

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"CHLOE"

A System for the Automatic Handling of Spark Pictures*

by

J. W. Butler, D. Hodges, and R. Royston

I. FOREWORD

The system to be described was conceived by Donald Hodges and myself in the early part of 1961, and has since been designed and constructed by an engineering group led by Hodges, with software assistance by Richard Royston. Substantial support and encouragement were provided by the High Energy Physics Division of the Laboratory, particularly by Roger Hildebrand. The equipment is now operating but has not been put through the usual tidying up and debugging process necessary to produce a productive system.

II. INTRODUCTION

The evolution of this particular design was guided by three circumstances which obtained at about mid-1961.

Firstly, advances in cathode ray tube and fiber optics technology were occurring at a rate such that we could confidently expect suitable tubes to be available by the time they were needed. A firm decision was therefore made to concentrate our efforts in this area and avoid consideration of various types of mechanical scanning schemes. The correctness of this decision has been borne out, since good tubes are now obtainable from several manufacturers.

The second circumstance was the appearance on the commercial market of a number of small but fast digital computers of rather moderate cost. These machines are ideally suited for use as general system components, and will generally add a great deal of flexibility over that provided by a corresponding amount of custom electronics.

Finally, during 1961 the spark chamber steadily gained in popularity among high energy physicists and emerged as a competitor to the bubble chamber in volume production of data.⁽¹⁾ This had a strong effect on our course of action, since, as is now generally recognized, spark chamber experiments lend themselves more easily to complete automation than do comparable bubble chamber experiments. Our decision was to concentrate initial effort on the production of a working spark data analysis system, since this would be a worthwhile objective in itself and, at the same time, would furnish valuable experience bearing on the next step of automating bubble chamber analysis.

The chosen system configuration was intended to realize two general points of design philosophy. Only commercially available or state-of-the-art components should be used and the system should be flexible enough to accept information from various types of experiments involving photographic data acquisition.

*Presented by J.W. Butler at Informal Meeting on Track Data Processing, CERN (Geneva) July 19, 1962.

Both of these features were realized by incorporating into the system a mass-produced general purpose digital computer as the principal control and information handling unit, with external custom electronics held to a minimum amount.

III. GENERAL SYSTEM DESCRIPTION

A functional block diagram of the overall system is shown in Figure 1. The equipment consists of two main elements, a digital computer and an optical scanner, the latter being under control of the computer. The computer is the commercially available ASI-210, (2) while the cathode ray tube (CRT) scanner was built by the Applied Mathematics Division at ANL.

When the entire system is fully operational, operation will be quite simple. The programs corresponding to a given experiment are loaded into the main computer and the ASI-210, after which the operator merely keeps the scanner supplied with film. Every frame is scanned, but only those pictures which pass through a selection program in the ASI are transmitted to the main computer for further analysis. The typewriter is used to write out any comments which may be helpful during the course of the calculation.

While only one scanner is presently in place, the other one shown in Figure 1 will be added as soon as the system is checked out. The second tube is very useful for experiments utilizing separate film strips for different views of the same events. The boxes in Figure 1 relating to the main computer are not physically in existence, since we do not yet have a large computer with a suitable direct data channel.

A general view of the present set-up is shown in Figure 2. Figures 3 and 4 show the scanning position with the CRT and film transport.

IV. DETAILED DESCRIPTION AND OPERATION SEQUENCING

A. Film Handling.

Since rapid frame finding is not necessary, a rather simple mechanism is adequate for the purpose. This consists of a transport for 35 mm. perforated film, driven by printed circuit stepping motors under computer control. The film may be moved forward or backward through an integral number of 1/4 sprocket holes as instructed by the computer program. Searching for a particular frame may be accomplished by instructing the scanner to look for identifying information on the film, although this will be rather slow since no rapid transport mechanism is provided.

B. Scanner Operation.

Figure 5 is a block diagram of the scanner with its associated electronics. The tube used is a three inch fiber optics CRT manufactured by Ferranti Electric. The faceplate is made of five micron fibers and the tube is capable of a twenty micron spot diameter.

FIGURE 1

FIGURE 2

FIGURE 3

FIGURE 4

FIGURE 5

For operation, a spot of light from the CRT is projected onto the film and the light transmitted through the film is viewed by a photomultiplier. The light spot is positioned on the face of the CRT by a magnetic deflection signal derived from the two digital registers X and Y, a method suggested in this connection by L. Leipuner.⁽³⁾ To avoid having to transmit an instruction from the computer to interrogate each point, the X and Y registers are actually counters which cause the spot of light to be advanced sequentially from point to point independently of the computer. During the time when the current is being changed in the deflection coils, the CRT beam is switched off. There is then a pause to allow the deflection system to settle down, after which the beam is switched on and the photomultiplier output is sampled. If the point is of no interest, the counters advance and the cycle is repeated. If the point is of interest, the oscillator is halted and the current contents of the counters is read into the computer.

The meaning of the term "interest" in this connection calls for some definition. The scanner control unit contains two toggles for this purpose, the current point toggle (CPT) and the previous point toggle (PPT). At the beginning of each line scan, the PPT is reset to the same state, which may be "white" or "black" as instructed by the computer program. As each point is sampled, the contents of the CPT are transferred to the PPT and the CPT is then set to black or white according as the photomultiplier output pulse is below or above a preset reference level. The two toggles are then compared and, if they are in different states, the contents of the X and Y registers are sent to the computer memory. If the initial setting of the PPT is white, this is referred to as a "black-on-white" (BOW) mode, and the white-to-black and black-to-white X values are tagged "positive" and "negative" respectively. The tags are reversed in the other (WOB) mode. This comparison scheme obviously lowers the data rate into the computer by suppressing redundant information.

It is apt to be quite convenient in many experiments to use film formats which do not require scanning of the total field of view. To permit scanning of rectangular sub-areas, the X and Y counters are provided with lower and upper limit numbers which are set under program control. In addition, there is provision made for either horizontal or vertical scanning, also under control of the computer program.

C. Computer Control.

The ASI-210 is a solid state binary computer with a 21 bit word length and a parallel arithmetic unit. It is provided with a 4096 word randomly addressable core memory with a 2 microsecond total cycle time. A normal complement of single-address instructions is built in, each of which may involve indexing and indirect addressing. The three index registers are distinguished locations in the core memory. Two buffered input/output channels permit transmission of data to and from memory in the form of 6 bit characters (3-1/2 characters per word) or as full 21 bit words. After initiation of a data transfer, the actual transmission proceeds with only a slight effect on the speed of the central processor. Versatile program interrupt features, including two levels of interrupt priority, enable the computer to control and communicate with various external devices, including other computers.

The philosophy of external device operation is that once the operation of an external device (ED) has been initiated by the computer, it is then responsible for its own control and for communication with the central computer. The computer is provided with means for communicating with up to a maximum of 64 external devices. It does this by placing the address of the appropriate ED on 6 output lines. The ED which recognizes that it is being addressed can reply in two different ways, NOT BUSY or INTERRUPT REQUIRED. The ED address lines are activated by the interrupt scanner or by execution of an external device instruction in the computer. Normally, the interrupt scanner continuously cycles through all the ED addresses while the computer monitors the INTERRUPT REQUIRED line from the external devices. However, if an external device instruction is executed by the computer, the ED address lines are energized in accordance with the six most significant bits of an external device control word (EDCW) previously stored in memory. At the same time, the interrupt scanner is halted at this address for a time to allow the addressed ED to respond via the ED NOT BUSY line. If this response is received, the computer sends a start signal to the ED and restores normal operation of the interrupt scanner. If desired, a busy interrupt may be executed in case the ED fails to respond.

Computer control of the system is implemented by assigning a unique ED address to each function which must be under program control. As applied to the optical scanner unit, the names of these functions are:

Start scanning	Scanner functions
Film transport 0	Film transport 1
X low	X high
Y low	Y high
X and Y coordinates to computer	

Most of these terms have obvious meanings. As an example, the EDCW corresponding to "Film transport 0" addresses this component in accordance with the 6 most significant bits in the word, while the 13 least significant bits contain the number of 1/4 sprocket holes ($\pm$) through which the film is to be moved. "Scanner functions" is a register which controls the various modes of scanning; BOW or WOB, lateral or longitudinal, and normal or reversed. As indicated in Figure 1, other ED addresses are assigned to the main computer data channel and to normal peripheral equipment such as the paper tape reader.

D. Timing and Quantitative Characteristics.

The operating speed of the system is determined primarily by the frequency of the oscillator which drives the X and Y counters in the scanner control unit (Figure 5). This is set at 100 kc, the limitation being the response time of the magnetic deflection system for the CRT. The scanning time for the entire 1024×1024 spot raster is therefore about 10 sec, which compares reasonably well with the expected analysis time for a spark picture. At this rate, data transfer is not computer limited, since the ASI-210 I/O channel is capable of a 62.5 kc word rate and the coordinates are transmitted in packed form with the two 10 bit X and Y coordinates in a single 21 bit word. The scanner therefore has to wait only if the coordinates of two adjacent points must be measured, an exceedingly rare event with a reasonable picture.

It is a simple matter to modify the present equipment to employ a mixed analogue and digital scan, thereby reducing the scanning time for a normal picture to one or two seconds. This will be done if it is found necessary after actual operating experience. An attempt will be made to achieve a 4096 x 4096 spot raster, although it is not clear that this can be done at present without undue elaboration of the CRT control circuitry.

V. PROGRAMMING AND APPLICATION

General features of the existing central program are shown in flow chart form in Figure 6, prepared by Richard Royston. This is sufficiently detailed to be more or less self-explanatory, and gives a reasonably good picture of how the interrupt features of the computer are used to activate different program blocks as necessary.

The ASI 210 is capable of accepting data from the scanner on one input/output channel, performing computations and putting out results on the other input/output channel, all simultaneously. This means that it is possible to process the photographs at a speed which is limited only by whichever single one of these three processes is the slowest. In order to realize this speed one must work with two buffer areas in the memory for each of the input/output devices. Then, while data is being read into one of the input buffer areas (the scanner buffer areas or SBA in the flow diagram), previously processed data is being simultaneously read out of the corresponding output buffer area (the OBA in the flow diagram). At the same time, the data in the other input buffer area, which had been read in previously, is being processed and then placed in the other corresponding output buffer area. This is accomplished in practice by having special interrupt routines associated with the completion of input or output from the buffer areas which check to see whether the processing of data in the other buffer areas is completed. The main program must also check whether the input and output processes have been completed each time it finishes the processing of the data in one of the buffer areas.

In the present program, the box labelled "Process" merely transmits the coordinate information and formats it appropriately for punching out on paper tape. For testing purposes, these tapes are fed into the computer GEORGE, which has been programmed to reconstruct and photographically record the scanned pictures on a CRT output device. Three pictures which have been scanned and reproduced in this way are shown as Figures 7, 8, and 9.

We are now writing a program which will enable us to attempt the processing of data from an actual spark chamber experiment, but not enough has been done to justify discussion at this time.

VI. ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the contributions of Robert Vonderohe to the CRT circuit development and the able assistance of Richard Wehmann in design and construction of the entire system.

FIGURE 6

(Original)

(Reproduced)

FIGURE 7

(Original)

(Reproduced)

FIGURE 8

(Original)

(Reproduced)

FIGURE 9

VII. REFERENCES

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