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ANL BUBBLE CHAMBER AND SPARK CHAMBER
DATA HANDLING SYSTEM

by

J. Butler and D. Hodges

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ANL BUBBLE CHAMBER AND SPARK CHAMBER
DATA HANDLING SYSTEM

J. W. Butler and D. Hodges

I. INTRODUCTION

The purpose of this memorandum is to describe a data handling and interpretation system capable of dealing with the rather large flow of information from bubble chamber experiments to be carried out at ANL in conjunction with the ZGS accelerator. The total information output from these experiments is estimated to be 1,000,000 bits/sec. or about 3×10^{13} bits/year.

The overall system configuration is intended to realize three points of general design philosophy:

- a. Only commercially available or "state-of-the-art" components should be utilized. Due to the short time scale involved, it is not desirable to rely on the availability of items requiring significant developmental work.
- b. The information capacity of the system is maximized by the use of special purpose devices external to the main general purpose computer installation. In general, the use of a special purpose data handling device is economically justifiable if it is operated near its own maximum information capacity and if it can be constructed in accordance with existing engineering practices.
- c. The system should be flexible enough to accept information from other types of physics experiments similar in concept to bubble chamber experiments. Information of this general character may be generated by spark chambers, counter arrays, or other apparatus not now in existence.

II. GENERAL SYSTEM DESCRIPTION

The basic approach is the same as that used by Hough and Powell⁽¹⁾ but with certain modifications to better realize the above design philosophy and remove some minor operational difficulties present in their scheme.

The equipment to be described incorporates two principal departures from the basic Hough-Powell design as it has been described. Two separate on-line computers are used to optimize the flow of information and to bring about the required system flexibility. In addition, an interlaced scanning pattern inclined at 45° to the film axis is used in the precision digitizer to facilitate measurement of tracks in any direction on the film. This feature obviates the necessity for providing lateral film motion as in the "original" Hough-Powell system. Although not stressed in the present description, it is hoped that the mechanical digitizer may at some time be replaced by a purely electrical system such as a cathode-ray tube scanner. The presence of an on-line computer will facilitate this modification and result in a very attractive system.

A block diagram of the proposed equipment is shown in Fig. 1. The film is first viewed by a human at a Rough Digitizing Table (RDT). Here any of the triad of photographs of the same chamber exposure may be viewed on command and a decision made as to whether an interesting event is present and if so of what type. This event type number will be referred to as the Assignment Request (AR) number later in this discussion. Once an interesting triad is found, its frame number, event type, view number and other relevant book-keeping details such as the number of the table, date, etc., are punched out on a paper tape unit attached to the RDT. A number of rough co-ordinates of the interesting tracks are then punched out, the process being repeated for each of the three views.

At the completion of the viewing of a reel of film on the RDT, it, together with the punched paper tape associated with the interesting triads are taken to the Automatic Precision Digitizer (APD). The film is mounted on the film handling equipment and the paper tape is fed into the computer. The computer now calls for the first picture to be measured, and while the film is advanced to that picture, the computer "constructs" the tracks it is to view from the rough digitized information. It is then able to calculate "roads" about these tracks and feed this information to the Road Gating Computer (RGC). This computer uses fast circuitry and is a special purpose device in that it can only perform certain calculations as described later. The small fast buffer accepts co-ordinates that satisfy the RGC. At the end of each line of scan by the mechanical scanner, the generated co-ordinates that have satisfied the Road Gating Computer are present in the fast buffer and are then transferred into the computer. The computer then issues new road information to the RGC before the next line scan commences. While this line scan proceeds, the computer organizes the co-ordinate data it has received and records it on the magnetic drum. The drum is of such a size as to be able to contain all the generated co-ordinate information from a complete triad, and its rotation speed, hence the word reading rate, is matched to the capacity of the input channel to the main computer. Thus at the end

FIG. 1. SYSTEM DIAGRAM

of the measurement of a complete triad, the whole of the information on the drum is passed to the main computer in one revolution. The computer now calls for the next triad to be measured and while waiting, calculates the tracks it is to view on these photographs. Once the film handling equipment has found the required photograph, the action proceeds as previously described. Between each drum load of data the main computer performs the necessary spatial reconstruction and kinematic fitting operations on the data received from the last drum load.

Reduction of spark chamber data proceeds in an essentially similar manner except that a large share of the operations can be bypassed, as indicated on the block diagram. It is felt that present CRT technology permits the construction of a purely electronic system for reduction of data received in the form of photographic film from spark chamber experiments. In this case, the on-line computer and the main computer can be programmed to perform the entire recognition job with very little human assistance. Of course, if bubble chamber and spark chamber data are to be processed simultaneously, the on-line computer must have sufficient capacity and versatility to handle the information flow from both sources.

III. DETAILED DESCRIPTION AND OPERATION TIMING

A. Film Handling Equipment

This consists of a film transport system for 70 mm unperforated film with several modes of operation. The first is a fast advance for use in searching for the reference number of the next triad to be measured. Recognition equipment looking for these numbers on the film is located ahead of the film gate (the scanner viewing aperture) and as soon as the required information is detected the fast advance system ceases operation and a slow advance mechanism takes over. This latter, by taking note of various fiducial marks at the side of the film, advances the film slowly until it is positioned correctly in the film gate. Scanning now proceeds and the film is advanced at a slow, constant rate so that the position of the film is accurately known at all times during the scanning phase. To the rear of the film gate is the photomultiplier system which looks at the light intensity transmitted through the film.

B. Automatic Precision Digitizer (APD)

In order to obtain an accurately positioned spot of light with which to view the film, the optical and mechanical system shown in Fig. 2a is used. As can be seen from Fig. 2b, the moving spot of light is obtained by translating a slit on a rotating disc in front of a fixed slit and shining a light through their intersection, essentially as in the Hough-Powell scheme. Notice that there are two fixed slits so that two sequentially interlaced line scans are produced by the passage of a slit on the rotating disc. These two scans are arranged to be at right angles to each other and each is at 45° to the normal axes of the film as shown in Fig. 2c. The purpose of this type of scanning is to allow for the measurement of tracks in all directions. If, for example, a single scanning line is used, then tracks parallel to the scan (or within say 30° of the scan direction) are very difficult to digitize accurately. With the proposed double scanning system, no scanning line has to measure tracks at angles greater than 45° from the scanning direction. The computer decides which of the two scans to accept information from by using previously calculated road parameters. The position of the spot on the film is accurately digitized by the use of a shaft position encoder mounted on the same shaft as the rotating disc.

C. Road Gating Computer

This unit is made necessary by the high data rate from the APD. Running the APD at 2400 rpm results in a peak word rate of one ~ 14 bit co-ordinate/ μ sec. The on-line computer is used to calculate new information for the Road Gating Computer during every line scan. This information is in the form of "roads" which are simply a fixed plus or minus tolerance on track positions computed from the rough digitized measurements received for the photograph being scanned. A block diagram is shown in Fig. 3. The high and low co-ordinates are the information provided by the on-line computer. The Road Gating Computer decides whether the track co-ordinates received from the digitizer lie inside the high and low co-ordinates given.

a) Schematic of complete precision digitizer

b) Method of deriving the flying spot

c) Scanning pattern produced on the film

FIG. 2. MECHANICAL SCANNER

FIG. 3. ROAD GATING COMPUTER AND FAST BUFFER

If so, the co-ordinate is passed on to the high speed buffer. Only one of the four possible tracks can be measured at one time, so that the buffer can be shared by all four track units.

D. On-line Computer

Considerations of economy and versatility point to the use of a commercially available mass-produced general purpose computer for this component. However, more detailed programming studies must be made before the machine can be definitely specified. Necessary requirements are direct data input and output at fairly fast rates but only for a small number of words, word length greater than 14 bits, and paper tape input facilities. A reference design is being prepared incorporating the Packard Bell PB250 in the hope that a machine of this size will turn out to have adequate capacity. Some other possibilities are: Control Data 160, RW AN/UYK-1, Computer Control DDP, and the DEC PDP-1. Because of the speed and size requirements for the drum, it will likely have to be acquired from a different manufacturer.

E. Drum

The word length of the co-ordinates used in the on-line computer is between 12 and 16 bits, whereas the main computer to be acquired by ANL will have a word length of at least 48 bits. Therefore, at least three co-ordinates can be stored in one main machine or drum word, and it is one of the functions of the on-line computer to organize the data onto the drum in this way so that the time occupied in unloading the drum into the main machine is as small as possible.

F. Main Computer

This item is not properly a part of the system being described, but some general requirements may be observed. The main general purpose computer must be of sufficient capacity to perform the complete analysis and interpretation of the information from one stereo triad during the 90 seconds when the next triad is being scanned by the APD. Current practices seem to indicate a figure of about one minute for this analysis. If other than bubble chamber data is being processed the available time is, of course, correspondingly reduced. In addition, future program refinements such as the use of more accurate statistical techniques and the shifting of more of the recognition functions into the computer will undoubtedly cause this 90 seconds to look very short indeed.

G. Rough Digitizing Tables

The function of these tables is to prepare the "rough" track information for use by the Road Gate Computer. A detailed design description would fall outside the scope of this report, but some necessary features may be noted:

1. Automatic advancement from triad to triad on command.
2. Immediate availability of the three views projected in such a way as to register on the viewing plane.

3. The image viewed by the human operator should be between one-quarter and full size relative to the bubble chamber itself.
4. A rapid method of measuring the co-ordinates of any point on the viewed image.
5. A method of entry of fixed data onto the paper tape such as the date, operator's initials or code number, and other similar information.
6. Characters corresponding to film reel reference numbers, triad reference numbers, view numbers, etc., should be punched automatically. Actually, most of the information in item 5 could also be punched automatically or semi-automatically.
7. The operator should have the facility for labelling the characteristics of the co-ordinates being measured, such as vertex, middle of track or end of track. These are recorded as extra characters on the punched paper tape.

With reference to item 3, it would be very desirable to have available several steps of variable magnification. However, this requires a certain amount of development work and may not be realizable on the present system.

One method of accomplishing item 4 is by relative movement of the image with respect to a cross hair or other reference mark. Other methods are also being considered. F. Salter suggests that co-ordinates might be read off the image by means of a resistive coating applied to the viewing surface. Application, for example, of electrical potentials in space-time quadrature across this surface would enable the operator to read the co-ordinates with a contact pointer attached to a flexible cable.

The design of the Rough Digitizing Tables is really a problem in industrial engineering, and it is suggested that a consultant in this field be retained for a time to make time and motion studies before the design is frozen.

H. Timing Schedule

A diagram is shown in Fig. 4. The times are derived as follows: It is assumed that the APD disc is rotating at 2400 rpm. Thus, if the total picture is scanned with 2400 lines on each of the right-angled scans, the time for this is 30 seconds. A time of 1 second is allowed for the movement of the film from one view to the next, hence a total of 92 seconds per complete triad digitizing. The time between triads is variable but the minimum value is 1 second, this is for successive triads to be measured. Allowing for this variable time, down time, and film changing time, the figure of 2 minutes per digitizing or 30 per hour may be arrived at. This is 720 per day or approximately 1/4 million per year. What now is the amount of film generated per year? For the ZGS being built at Argonne, an average rate of 1 triad every 5 seconds may be assumed. This is 12 per minute, 720 per hour, 1700 per day

a) Sequence of measurements on one reel of film.

b) Sequence during scanning of one triad

c) Line scanning organization

FIG. 4. TIMING CHART

or approximately 5 million per year. Hence the digitizer can keep pace with the ZGS working 24 hours a day, 7 days a week, provided that only 5% of the pictures taken need to be accurately measured.

The number of Rough Digitizing Tables required to keep the APD busy may be found as follows: If a reel of film contains 300 triads, it will take about 4 hours to process it on the RDT. Assuming the 5% figure used above for the fraction of pictures to be accurately measured, the number of pictures to be measured is 15 per reel. Therefore about half an hour per reel should be allowed on the APD. Consequently, 8 RDT's are needed on a 3-shift basis, 12 on a 2-shift basis, and 24 for single-shift operation to keep the APD fully loaded.

Assuming 8000 main computer words being sent from the drum to the main computer core memory, this transfer takes about 33 milliseconds. As mentioned above, the main computer has about 90 seconds between each of these data dumps to perform all necessary calculations.

IV. SPARK CHAMBER FILM MEASURING EQUIPMENT

The form of this equipment follows a suggestion by L. Leipuner⁽²⁾ of Brookhaven, and a block diagram is shown in Fig. 5. In this system the scanning light source (a CRT) moves in two dimensions so that the film is stationary during the scanning time. Since the film has not been pre-processed by a human the whole of the film must be viewed by the system. With the CRT as the light source, the digitizing becomes a simple process. As the CRT beam is positioned, the beam is switched on and a decision is made whether or not a spark exists at that point. If it is decided that a spark is present, the co-ordinates given by counters causing the deflection of the CRT are noted. Both counters start off at zero and are advanced at a constant rate, the filling of one counter advancing the other counter by one place. Either the on-line computer or the main computer program decides where the "tracks" and fiducial marks are by making use of the received information from the digitizer. Provided that the on-line computer is used to receive the co-ordinate information, it should be possible to view each picture in about 1 second. If a paper punch output is used this time is increased to about 5 seconds.

FIG. 5. SPARK CHAMBER DIGITIZER

V. OTHER FEATURES

By reprogramming the on-line computer, the system as described can be easily adapted to accept data from associated physics equipment such as entrance hodoscopes for bubble chambers and various counter arrays. Probable future changes in methods of obtaining fiducial information in bubble and spark chamber experiments can also be accommodated without necessity for redesign of the system.

VI. REFERENCES

1. Paul V. C. Hough and Brian W. Powell, A Method for Faster Analysis of Bubble Chamber Photographs, Proceedings of an International Conference on Instrumentation for High-Energy Physics, Interscience Publishers, Inc. (1961) p. 242.
2. Private communication from L. Leipuner (BNL) to Arthur Roberts (ANL).