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REAL TIME MONITORING SYSTEM FOR TRACK CHAMBER MEASUREMENTS (*)

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ABSTRACT - A system for monitoring track chamber measurements by using an on-line computer has been developed and realized in Pisa.

The system consists of:

1) up to seven measuring machines (MM), each provided with a console for displaying messages from the computer.
2) a buffer memory (BM) between MM and the computer.
3) the general purpose computer CEP (1) of the Centro Studi Calcolatrici Elettroniche.
4) a control unit (CU).
5) a program which coordinates the measuring process and checks measurements for acceptability.

The system has become operational a year ago whith 3 MM's connected, and has been used for measuring $\sim 10^3$ events of elastic scattering of K-mesons on protons (2) with constantly good results.

1. Introduction.

In track chambers, ionizing particles lay a « track » as either a string of vapour bubble in bubble chambers or of localized electrical discharges in spark chambers. Stereo photographs are taken to provide information about nuclear interactions.

The main drawback in the use of such devices lies in the difficulty of analyzing the large sample of photographs required for statistical results to be significant. In a typical bubble chamber experiment some 10^5 photographs

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are taken and their analysis requires above one year work of a medium size laboratory.

The standard analysis of track chamber photographs is carried out in three steps ;

1) measurements by means of MM's of the coordinates of several points of the tracks of particles taking part to the nuclear interactions. Measures are punched on tape or cards. A conventional MM can measure tracks of particles taking part to, or created in, the nuclear interaction (i. e. the « event ») at a rate between 4 and 10 events per hour per machine depending on the number of measured tracks and on the required precision.

2) reconstruction of the tracks in space by means of a computer that processes information provided by step 1).

3) fitting the kinematics of the event to some physical hypothesis on the nuclear interaction to be studied.

A number of errors are produced by the MM's itself due to electronic and mechanical failures, and by the human operator. A drawback of the standard procedure is that the quality of the measurements is tested only at the second (or perhaps at the third) step of the analysis. These errors cause about 10 to 20$^0/_0$ of measured events to be rejected. Now, discarding altogether the rejected events might bias the experiment being performed, therefore one is forced to measure and analyze them again, which involves a heavy book-keeping.

Owing to the large number of events in the experiment this is not an easy task, and the amount of time lost in these operations is much more than 20$^0/_0$.

More advanced, less conventional analysis systems, such as the Flying Spot Digitizer (FSD), are being developed in various laboratories [3,4]. The FSD system is still not fully automatic, as rough measurements with conventional MM's are required before the accurate one with FSD [0]. In any case, even where these devices are operating, considerable attention is paid to improvements of the traditional techniques.

A good saving of time can be obtained by monitoring the measurements with a real time operating computer, so that any failure can immediately be detected. In such a way the book-keeping is reduced to a minimum as : i) there is no need to keep track of the failed events ; ii) there is no need to place films on the MM for measuring again rejected events ; iii) machine or human failures are recognized and corrected at once. Moreover, relying

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[0] The italian FSD has a production rate of about 100 events/hour with a reject rate of about 15$^0/_0$ (M. Masetti private communication).

on a computer for early spotting of mistakes is a help for the human operator in reducing his tension, which usually means a shorter measuring time.

Generally, a control system can be realized in various ways; for example by simply checking the format of the input data or by reconstructing the geometry of the points in space, or both by reconstructing the geometry and the kinematics of the event. Each solution requires various computer performances, hence a particular solution is conditioned by the over-all efficiency.

Taking into account the experience gained from a system operating at the University of Yale [5] and the computer here available, we have adopted an inexpensive solution which allowed us to estimate how useful a control system of such a kind could be for routine track chamber work.

2. The control Unit.

In our case, measuring an event is divided into a series of steps; fiducial marks (FM) measurement on one view, measurement of a track on one view, and so on. At the end of each block the operator sends a block-end signal (BE), stops and waits for the response (either OK or error message) from the computer about the measurement block he has completed.

The control unit (CU) [6] operates as follows.

Each MM has a small 12 BCD-character buffer (2 alphanumeric labels plus 10 numerical characters corresponding to a pair of coordinates or to a code signal). When a buffer is filled, a « ready » signal (RS) is set up. The CU searches in turn the various MM's for the RS. If a RS is found, the corresponding buffer content is transmitted to the CU central buffer and then shifted into the computer memory. At present the central buffer is a band of tape punched at 60 characters/sec. This was chosen on the ground of its very low cost and compatibility with the actual rate of data production from seven or less MM's. However it is foreseen to replace the punched tape memory with some other kind of memory in order to increase the speed of the system, if needed.

Due to the fact that the buffer memory is realized by means of a punched tape and that tape puncher and tape reader are at some distance from each other it may happen that a BE is punched and no RS are coming from MM's, in which case the block just completed cannot be transferred into computer memory, causing a halt in computer operation. To obviate that, the CU incorporates a circuit generating enough blank characters to permit transfer. Data coming out randomly from various MM's are being mixed when punched. An input program is provided for the CEP to sort all the data by means of a character that labels each measure as it comes out from the originating MM. The response from the computer consists of a 36-bit word : 5 bits give the message type (up to 32 messages) 3 and bits give the MM address.

The block diagram of the system in shown in fig.1.

3. The Program.

The program is coded in Fortran CEP (except for those routines dealing with input, output, decoding and sorting of the data written in symbolic language) and takes 15.000 words of storage. Besides all the required checks, it performs the complete stereo-reconstruction of events in space. Efforts have been made to select, with suitable checks, events that are not only properly but also well measured, in order to prevent any possible failure in the third step of analysis. In fact this step, due to the complexity of the job, cannot be performed on line.

The mean processing time is about 9 sec.s per event, each consisting of three tracks. The program is quite flexible to allow, with little changes, the simultaneous monitoring of measurements from photographs in two experiments as well as the insertion of any experiment dependent test.

Reconstructing the geometry of an event yields the geometrical parameters of the tracks that reveal the event in a reference frame fixed with respect to the track chamber. These parameters are the interaction or decay points of the particles, the directions of the particles in these points, the radii of curvature in the magnetic field. To perform this reconstruction one measure the position on the film of particular reference marks (Fiducial Marks) engraven on the windows of the chamber, and of points on the tracks as viewed on at least two stereo photographs taken by a few cameras of known position with respect to the chamber. The mathematical methods used are those described in ref. ([7]).

Our program is not sophisticated as the standard ones used at CERN, never the less it yields fairly reliable results if used chiefly to monitor measurements. The final event testing routine has been useful in rejecting poor measurements.

Iuput data consist of the following blocks of information:

1) Event identification and fiducial marks (FM) measurement on a first view.

2) FM measurement on a second view.

3) FM measurement on a third view.

4) Measuremeut of a track on a view.

5) Measurement of points of the same track on another view (0).
Blocks 4) and 5) are repated for each track.
6) End of event.
7) RESET control.

Program processes blocks from 1) to 6) produced randomly by different MM's in the right sequence for each MM. A list of error messages (table I, third column) is displayed on a board at each MM console, so that when an error is detected, the corresponding message lights up at the originating MM, warning that the error carrying block has to be repeated.

The blocks have been chosen in such a way as to reduce to a minimum the amount of measurements to be repeated without weighting down excessively the program. A reset option is available to operators for resetting the program at the initial conditions (block 1).

Table I shows the tests and the operations performed by the program and the error messages for warning operators. If no error is found in a given block an OK message is displayed. Each recognized error is immediately printed out and recorded on a magnetic tape for subsequent statistical analysis. The results obtained from each event which has passed successfully all the tests, are recorded on magnetic tape for further analysis (kinematical fit) by a 7090 IBM computer.

How the program handles input data can be understood from fig. 2. When data are redundant, input errors are simply ignored by the input program, provided that the machine label can be properly identified.

When a BE or an error that can not be ignored is recognized from data, control is transferred to the main program. The program is divided into sections. Section *A*, that constitutes the main program, controls the data flow from the various MM's and supervises the operation of the other sections that are called to perform the specific operations and tests required at that moment from a particular MM. This is done by using the vector JK (NOP), where NOP is the MM label, whose value specifies the section required. In addition it handles error return conditions from various tests, and includes a sub-section where the acceptability of FM measurements is checked.

Section I takes care of all the operations required for job start or end. Section B tests the quality of the measurements on a single view by a fitting precedure. Section C reconstructs in space the points measured on two views, and fits geometrical parameters. Section D carries out final computations and global checks on the entire event. Sections I, B, C, D are

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(0) A version of the program exists permitting track measurement in three views.

stored in the magnetic drum and trasferred into the fast memory when needed. The drum is also used for an easier sorting of output data.

5. Results.

Part of the $K^- p$ elastic scattering experiment performed by the bubblie chamber group of Pisa University in collaboration with the Brookhaven National Laboratories was analyzed by the described system. A thousand events were measured and processed for kinematical analysis; $4\,^0/_0$ of them were classified only after further measurements, so that we can define the efficiency of the on-line system to be about $96\,^0/_0$ (for the event-type concerned).

As for what concerns the measuring rate, this turned out to be some $25^0/_0$ higher than that obtained in the same conditions by the standard measuring system. It is to be pointed out that by using three MM's connected on-line this result alone is enough to defray computer expenses for the time needed. Unfortunately, in the extremely varying conditions in which this kind of experiment is ordinarily performed, it is not possible to assign a number to the time saving alluded to in the introduction: what can be said is that, in our case, we have experienced a great relief in the painstaking task of organizing the analysis work. We must note that our comparison has been carried out in the most unfavourable conditions, i. e. that of topologically simple events involving few charged non-decaying particles: for more complex events the monitor of the computer at the measuring stage is undoubtedly even more useful.

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TABLE I (1)

	FROM MM	COMPUTER OPER. TESTS	MESSAGE FROM COMPUTER
SECTION A	Event identification and FM measurem.		
		a) is the event number missing? b) is the FM measurem. order wrong? c) is the distance between FM wrong?	Message N⁰ 2: RM (remeasure from beginn.) » » 18: RM FM (pay att. to the order) » » 22: RM FM
	FM measurem. on second view		
		d) is this view the same as before? b) as above c) as above	Message N⁰ 3: RM FM (change view) » » 18: as above » » 22: as above
	FM measurem. on third view		
		as for FM measurem. on second view.	as for FM measurem. on second view.
SECTIONS	Track measurem. on one view		
		e) is section A terminated? f) too many tracks? g) » » points? h) is the second order parabolic fit unsatisfactory?	Message N⁰ 7: RM FM on another view or reset. » » 8: Reset and RM ev. » » 19: RM (too many points). » » 15: RM this block.

TABLE I (2)

	Track measur. on second view		
B and C		e) as above	as above
		i) is the view the some as before?	Message N^0 10: RM changing view
		f) as above	as above
		g) as above	as above
		h) as above	as above
		j) is the track code different from the one in previous views?	Message N^0 11: RM track in the 2 views (pay attent. to track code)
		k) does the geometrical reconstruction fail?	Message N^0 16: RM track in the 2 views.
		Geometrical parameters of tracks are fitted	
		l) is the order of measurem. of the track wrong?	Message N^0 23: RM track, correcting order (if possible) or res. and RM. event.
	THE LAST TWO BLOCKS ARE REPEATED FOR ALL TRACKS IN THE EVENT		
SECTION D	End event		
		m) too few tracks?	Message N^0 20: RM event (vrong number of tracks)
		n) has been the last track been measured on one a view only?	Message N^0 21: Track not complete. Complete or reset and RM ev.
		Event type recognition	
		q) is the event type in the list?	Message N^0 12: RM event

TABLE I (3)

		Completes the analysis of the event and writes results into magn. tape	
	ERRORS DUE TO THE APPARATUS ARE DETECTED ACCORDING TO THE FOLLOWING SCHEME		
		p) Input data can not be properly read	Message N⁰ 30: Stop and wait for N⁰ 31 to be lighted (continue)
		q) Apparatus failure has been detected and recognized	Message N⁰ 4: RM block (faulty view number)
			Message N⁰ 5: RM block (coordinates aut of the encoder range)
			Message N⁰ 13: RM block (faulty end of block machine label identified).
		r) Unrecognizable error detected	Message N⁰ 14: RM block (faulty end of block; machine label unidentified).
			Messages: 1, 6, 9 according to the type: RM last block

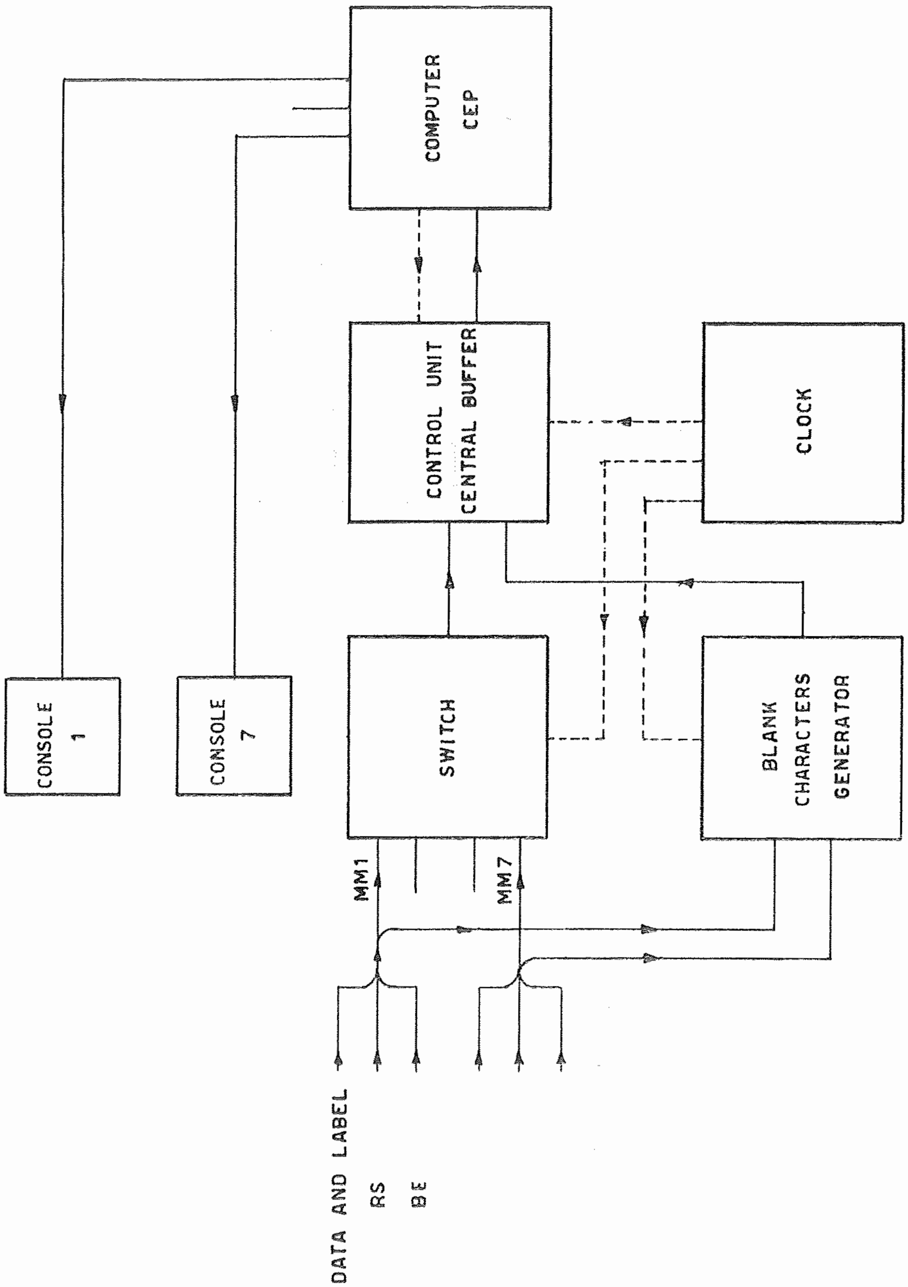

Fig. 1 - Block diagram of the track chamber monitoring system.

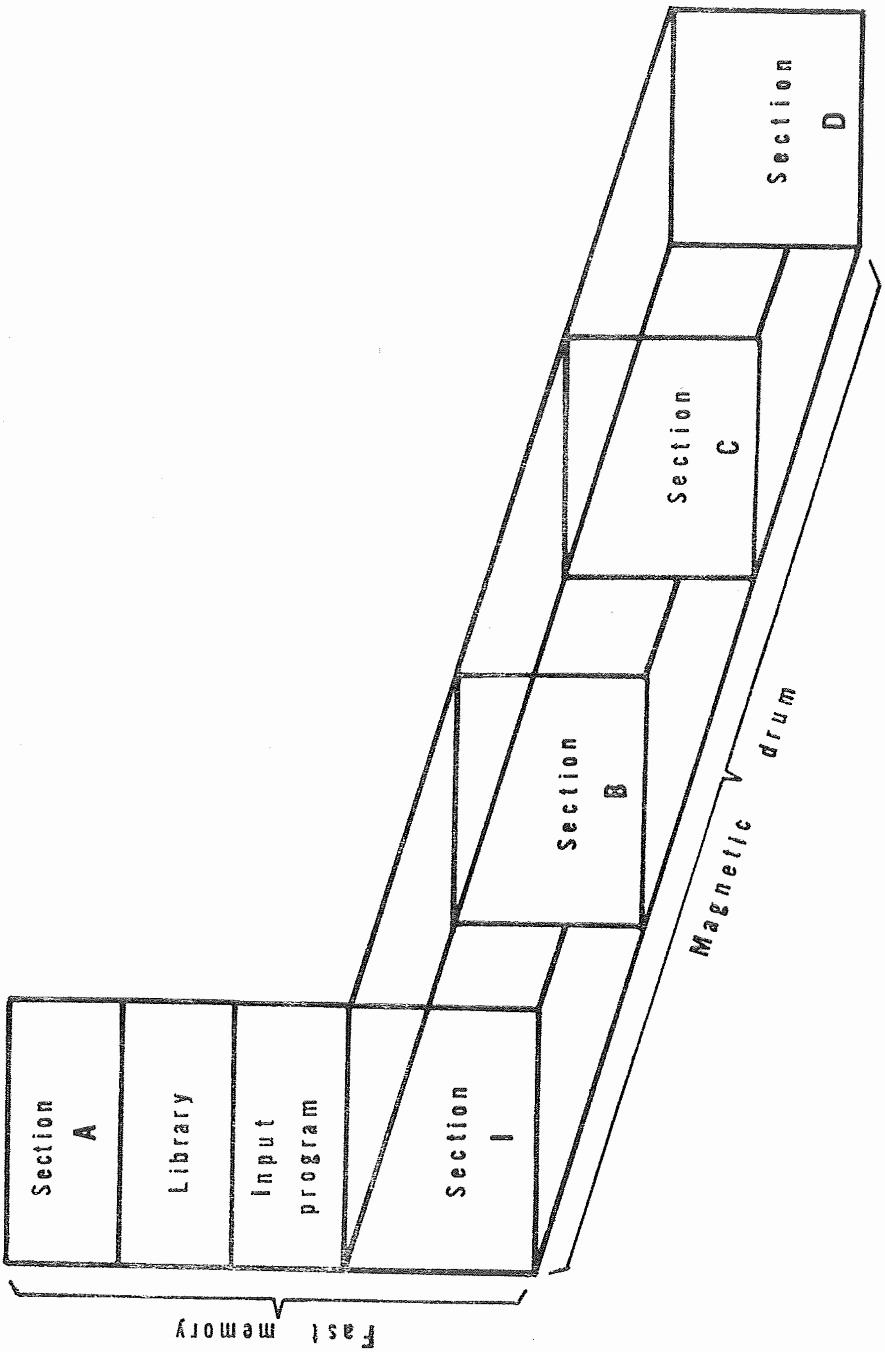

Fig. 2 - Program organization in the CEP memories.

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