REMARKS ON ON-LINE COMPUTER USE

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The on-line projects described so far in this conference have represented large commitments of equipment, money and manpower. They have also relied on extensive engineering capability. The advantages of on-line computers should be available to more modest programmes. I encourage all of you to think about how a computer could help in your experiment, and hope some possibilities have occurred to you.

At the Institute for Computer Research of the University of Chicago, we have active programmes directed toward developing on-line use of computers in experiments, as do some of our good neighbours at Argonne and at the Digital Computer Laboratory of the University of Illinois. It is noteworthy that most of the current on-line computer use has been developed by laboratories that have home-made computers. Among these, the SMP, Chloe, PEPR, Hough-Powell and Lindenbaum's experiments are outstanding examples. The reason for this probably lies with the existence of engineering capability that accompanies these home-built machines. At the Institute for Computer Research, we have such a home-built machine - Maniac III, that is crudely equivalent in vocabulary to a 7090 at about 1/4 the speed. Our main programme directed toward on-line experiments has been the spark chamber work reported yesterday, but our interests spread over many fields, of which high-energy physics is only one. Our experimental data links can move data about 1/10 of the computer's internal transfer speed.

There are various levels to which a computer may be used on-line with an experiment. In discussing this point, one may easily become involved in semantic questions as to just what is a computer. In a sense, the devices that encode the output of vidicons or of acoustic chambers for transcription onto magnetic tape are special purpose computers. I do not want to become involved in those semantic questions, so I will simply ignore them. Further, it is not clear just what is to be regarded as on-line use, or how much use should be made of a computer. The computer could be used to facilitate calculations to be made during an experiment; or, if it is to be part of the data-logging system, it could simply provide a buffer storage to smooth out tape unit use; it could multiplex the output to several tape units; or it could carry the reduction all the way to the final numerical results before producing any output. Between these, there is almost a continuum of possibilities. It is largely a matter of taste how far one goes - influenced by the degree to which one wants to become involved with the computer technology and to which one wants to handle the data at intermediate stages. I rather incline to the view that the on-line reduction at the time of the experiment should be to a "Minimum-redundancy" form, with individual events being transcribed on a permanent medium at that point, for subsequent tallying of the results. Whether the "minimum-redundancy" form should include checks of legality of the events (i.e. whether a scattering event occurred within the target) is again a matter of taste. Under these conditions, the computer may limit the data rate, and events that you have not been clever enough to allow for in the programme will be lost. This last is probably the only significant loss of events. However used, it may be advisable to regard the computer as part of the experimental apparatus, rather than the other way around, or as some mysterious black box that you are, by some divine grace, permitted to use.

There is some question about whether a special purpose or a general purpose computer should be used for these on-line applications. I am undecided about this at present, and I have heard arguments among computer people on both sides. The circumstances will determine which is best. In general, if cost is not important, a general purpose computer will provide more flexibility. In many cases, suitable general purpose machines are surprisingly inexpensive. Lindenbaum's data handler is part of any general purpose machine, and it is possible that a general purpose computer might be competitive in <u>real</u> cost. Alternatively, there may be problems (e.g. pattern recognition) for which any general purpose computer is too slow, and then a special purpose machine is definitely indicated.

Not all experiments are suitable for on-line computer use. In principle, any experiment may benefit from an on-line computer, but certain kinds of experiments will benefit in a more obvious way, and perhaps the exploration should begin with them. Experiments in which many similar events are expected are particularly suitable, but it would seem inadvisable to attempt experiments in which the event sought is particularly rare or unusually difficult to analyse. A computer and spark chamber combination will not, in my opinion, compete with bubble chambers for many applications - single event studies, for example. If a computer is used along with automatic data transcription, there is danger of missing discoveries because one has not been clever enough <u>a priori</u> to write a programme to handle that kind of event, and the programme may throw it out. Such events will be lost, unless there is also a permanent record of all events prior to the analysis stage.

With the ambiguity problem in chambers, it had been pointed out that there is little difficulty of principle in analysing multi-track events. However, extra computation time will be required to analyse the events. The human eye is exceptionally good at "pattern recognition", and an event that is difficult to disentangle by eye will certainly give a computer a lot of trouble.

As a strong protagonist of on-line computer use, it feels strange to me to find myself in the position of urging some caution following what I regard as some flamboyant promises about the potentialities of on-line computer use.

A few admonitions in closing :

1) A lot of homework is necessary before the experiment. Lindenbaum's experiment is a good example of this, and its historical development is an example of what may be expected if that degree of involvement is anticipated.

2) The availability of results during the experiment allows some freedom in modifying the course of the experiment, but not complete freedom. The large investment in both hardware and software required limits any changes to those that are consistent with the advance preparation. In particular, unexpected discoveries may be very difficult to pursue, and may require planning a new experiment.

3) Experimenters may be reluctant to change their equipment or programmes. This is noticeable to some extent with ordinary experiments, but is likely to be aggravated by the additional investment of time and effort involved in most on-line experiments.

4) A computer in the system cannot prevent mistakes of judgment by the experimenter.

5) The data rate must be balanced against the load at the computation centres and the reduction time per event, to avoid obtaining more data than can be handled in the existing facilities.

DISCUSSION

MACLEOD: If I may open the discussion on this paper by asking Dr. Miller exactly what he is questioning about on-line computers. As Maglič explained the other day, in 0.5 to 0.9 sec he has the momentum and scattering angle computed and available in the experimental area. This seems to me to have the essence of on-line operation.

R.H. MILLER: There is a matter of degree here. On-line operation may involve a very low rate of data transfer, but then the full advantage of on-line operation is not realized. I want to address myself to the higher data rates, but certainly some advantages can be obtained also at low rates.

MACLEOD: Does this imply that you do not regard the other aspects of on-line use - which is the sample computation - as of equal importance with the data acquisition ? I can understand your remarks in terms of high data acquisition rates, but I think equally important is the means of having some feed back of computed information.

R.H. MILLER: My whole contribution was full of hedges and you have perhaps, picked up some of the more obvious ones. These are all matters of degree, and I mention only the extreme examples of simple data acquisition up to and through writing the paper. Carrying out sample calculations is one of the stages between these extremes, but I think the farther you can go towards writing the paper in the computer the more you are taking advantage of on-line operation. But you'll find yourself computer limited at some point. I don't think you can really say very much in general about this. Each application has to be decided on its own merits. My own inclination is to go rather far in having the computer do a lot of the work.

PEREZ-MENDEZ: Since in every experiment you have to accumulate a certain number of events for you to see what is happening in the experiment, I would like to know what the particular advantages would be of being on-line continuously as distinct from having access to the computer every 10 minutes or every hour to compute the number of events you have accumulated and then monitor the experiment that way.

R.H. MILLER: This depends on the particular experiment. I can imagine experiments in which you get events once an hour in which there is not much advantage to having the computer full-time, but you might want to see what that event was immediately.

PEREZ-MENDEZ: If you only get one event an hour you don't want to tie up the computer for that hour, you just want to have access to it once an hour.

R.H. MILLER: I am assuming that a computer of this type has interrupt facilities, and any intelligent use of it has it doing other things when it is not tied up with the experiment.

PEREZ-MENDEZ: But if you require to interrupt the computer and it is not immediately available it implies that you must have some form of temporary storage for information until you can use the computer.

R.H. MILLER: This depends to a certain extent on monitors and so on. Normally, it would be available in a fraction of a second, and if you only get one event an hour you can't complain about the loss of a few seconds providing you don't lose the event in the process. Most of the automatic retrieval devices have their own storage. For example, the acoustic chambers seem to load up a set of scalers which may be retrieved at any later time.

HINE: I think there is one unambiguous criterian as to whether you want an on-line computer or not. If you want to get an answer back from it before you have forgotten what the question was, you need an on-line computer. If you don't mind that you have forgotten what the question was then you can put the results on tape. That is true however small the data rate may be.

MAGLIC: We heard yesterday that a slow on-line computer at Columbia University was helping a physicist inside a magnet to adjust the chamber. It was very slow communication, of the order of a second, but this didn't matter since he could only move the chamber a few centimetres per second. I would say that the generality obtained in a bubble chamber cannot be repeated in a spark chamber; but we need a knowledge of what type of physics is going to be done in the future. For instance at very high energies the momenta cannot be measured even in a bubble chamber with normal magnetic fields. Therefore it may become sufficient to do angular correlations and indeed recently it has been suggested in some papers that much physics can be done from angular correlation only, without measuring particle momenta.

R.H. MILLER: I would like to make 2 points; the first being that I was asked to outrage the populace - in which I seem to have succeeded. The second point is, I would ask you to repeat the omega minus experiment in your spark chamber.

WEINSTEIN: In 1958 some very good physicists said that all future work would come from bubble chamber analysis and they were wrong. I think we are equally as wrong in that the techniques we will be using 10 years from now have not been invented yet. And to say that the bubble chamber, because of its high density of data and magnificent angular resolution, is the instrument, is to say that spark chambers are only 3 years old. If you have a wide gap spark chamber and you took a picture of it and put it on PEPR how do you distinguish between this and a bubble chamber, other than it's a low density medium and has a high repetition rate ?

R.H. MILLER: You can do something with a single event in a bubble chamber and I will not argue that you can't do it in a spark chamber, particularly if you photograph the spark chamber, but if you transmit the spark chamber contents to a computer and do some processing on them without transcribing the raw events onto magnetic tape, you do not have much chance of handling that event.

FESSEL: You said earlier in your talk that this project required extensive engineering back up, and I personally would say that it is not true. We have built up the system I described with very little engineering support, by using knowledge which is available to most engineers in the open literature.