multiples) consist mostly of uninteresting tracks left by particles which have passed through the chamber unaffected (although perhaps deflected in one direction or the other, according to their charge, by the external magnetic field of a magnet). Traditionally, the analysis of such photographs, like the analysis of tracks in photographic emulsions, has been carried out in high-energy physics laboratories by small armies of part-time workers, usually women. Pressure to computerize the task of analysis has arisen not merely for economic but also for managerial reasons. A complete analysis of all the interactions recorded on a single bubble chamber image is too great to be attempted except in exceptional circumstances. The first attempts at simplifying the task required that the human operator should follow only tracks judged to be interesting with some device whose position in two directions could be recorded automatically, by pressing a button perhaps, stored in digital form and analysed to give a 3-dimensional reconstruction of the track.

In the past 15 years, however, the analysis of the complicated sets of images of which only some are interesting has been further simplified by the development of the so-called Hough-Powell device, essentially a means of scanning a plate or of scanning an image photometrically with a flying laser spot constrained on a predetermined raster. A digital output is thus provided in a simple form — each spot on the image is either black or white.

Limitations

In principle, appropriate analysis of two stereoscopic photographs of this kind can reconstruct the tracks of all charged particles passing through a bubble chamber. In practice, even with the use of computer hardware, the task is too slow and too demanding of storage space. Accordingly, it is still standard procedure for somebody, by means of visual inspection, to select those particular tracks in an image which are interesting enough to justify detailed analysis. One by-product of these computer systems is that they yield not merely a detailed geometrical reconstruction of a track but also a kinematical analysis of those particles involved. Whether they will ever be capable of operating entirely automatically, ignoring uninteresting tracks and singling out those which, by predefined criteria, are especially interesting or significant is another matter — and a problem in pattern recognition.

The development of these systems has been to an encouraging extent a collaborative business, in which the large high-energy accelerator laboratories have played a central part. In Europe, for example, one direct result of this collaboration has been the development of a set of standards (called CAMAC) intended to ensure compatibility of information processing equipment. □

Logic circuits before computers

When nobody was especially well supplied with equipment, but when nuclear physicists were better supplied than anybody — in the late 1940s and early 1950s — it was relatively easy to predict who the first users of computers would be. It is tempting to think, at least where the nuclear physicists are concerned, that they learned their habits during the Manhattan Project. In truth, the search for ways of applying computational techniques to the task of observing what you want to observe and not some tedious background signal came two decades earlier, in 1931.

Then, for practical purposes, there were merely a handful of techniques for observing the effects of energetic charged particles, one of which consisted simply of measuring the rate at which a charged electroscope would lose its charge. The most interesting technique was C.T.R. Wilson's cloud chamber, which had for the first time made it possible to visualize the tracks of charged particles travelling through its confined volume, but which to begin with could take snapshots of the flux of charged particles through it only at randomly chosen intervals. The chance of finding something interesting cannot have been much greater than that of finding a needle in a haystack.

Geiger counters, also widely used in the 1920s, were more discriminating than cloud chambers in that they would produce an electrical discharge only if the energy of the charged particle traversing them was greater than a certain amount determined by the quantity of precise composition of the gas with which the vacuum was filled — so much argon, so much nitrogen and so on. The snag with a Geiger counter (1930s vintage) is that it was simply a device for answering "yes" or "no" to the question "Where (and when) did a charged particle with more than the threshold energy pass by?"

But what more natural than to couple a layer of Geiger counters connected in parallel to the expansion mechanism of a cloud chamber so as to ensure that the cloud chamber photographs would include the track of at least one charged particle whose energy was greater than the threshold energy? This, in 1930, is what P.M.S. Blackett and G. Occialini (then at the Cavendish Laboratory) set out to do. Blackett used ruefully to complain that if Occialini had not taken a long holiday, they would have found the positron before P.W. Anderson.

From that point on, the use of elementary logic circuits, answering "yes" or "no" to questions such as "Has such and such a kind of charged particle passed through?", was inevitable. Arrays of Geiger counters working in coincidence ("A charged particle went in and another came out the other side") or in anti-coincidence ("It went in, but nothing came out") were all the fashion. Chadwick proved the existence of the neutron by such a technique.

By the outbreak of the Second World War, people's ambitions had grown, while detection techniques had become more complicated — sophisticated is hardly the word. By encasing cloud chambers in magnetic fields, and arranging that the chamber would not be triggered into action unless a charged particle "went in" and emerged virtually unchanged in direction (indicating that its energy was very large), it was possible to ensure that all cloud chamber photographs included at least one track of an energetic particle (which is how the "strange" particles of matter were eventually discovered, in 1948).

Long before then, however, logic circuits and the development of detecting devices had made it possible not merely to

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record the arrival of a charged particle but to assign it to some range of energy. The outputs from the devices used for such purposes were essentially digital, so why should they not be accumulated in digital form? This is how it came about that nuclear physics laboratories in the 1950s, but especially those connected with semi-secret enterprises, were the first to be blessed not merely with huge racks of electronics fitted out with tube-driven logic circuits but with slave electric typewriters as well, recording the data the detectors generated. (Most secretaries in those same laboratories still used manual machines.)

Frivolity apart, the outcome has been important. The high-energy physicists have been among the leaders in the use of computers for the control of experimental equipment. Most of the detection equipment now run in connection with high-energy particle accelerators consists of an elaboration of the counter-controlled cloud chamber now exactly half a century old. The difference is that the primitive logic circuits of the old devices have been replaced by computing machinery. □

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