EXPERIENCES WITH COUPLED COMPUTERS TO CONTROL AN HPD

H.J. Mück, H.-H. Nagel and F. Selonke,
Physikalisches Institut, Bonn, Germany.

V. Blobel, B. Hellwig, D. Mönkemeyer and E. Raubold,
DESY and II. Institut für Experimentalphysik, Hamburg, Germany.

Usually one of the following three modes to operate an HPD is encountered:

- The HPD is directly connected to a dedicated medium-size computer
- The HPD is directly connected to a shared large computer which gates in real-time but filters off-line
- The HPD is connected to a small computer which gates the digitisings onto magnetic tapes later to be filtered at another, larger computer.

The BONN-HAMBURG collaboration chose a different approach. The HPD is controlled by a small computer[§] which is directly connected to the large central computer[§§] at DESY via a 1.2 Mbyte/sec data channel and a separate Direct Control Feature (DCF). The DCF enables both computers to interrupt each other in order to transmit an 8-bit Byte of control information.

The satellite computer serves a threefold purpose:

1. DIGITISING BUFFER
   The small latency of 1-4 μsec and the high transfer rate of up to 1 Mword/sec of the Direct Memory Access to the satellite computer made a separate thin-film memory buffer unnecessary. A fast 8-word shift-register constructed of ICs is sufficient as buffer between the track detection circuit and the satellite computer memory even for 8-10 parallel tracks separated by not more than a bubble size.
2. PROCESS CONTROLLER
   The large computer transmits to the satellite information completely specifying the next scan. Film transport, carriage positioning and start of the digitising scan are then performed by the satellite computer which also routinely checks all incoming HPD-data for consistency.

[§] PDP-9 with 16K (18 bits) 1 μsec memory, Automatic Priority Interrupt System and Extended Arithmetic Element

[§§] IBM/360-75 with 1 Mbyte (8 bits) 750 nsec main core memory , 2 Mbyte 8 μsec Large Core Storage, 16 disc drives capable of storing 25 Mbyte each, etc.

These data are sent to the large computer in blocks of approximately 1000 words where they are transformed into the format required by the FORTRAN programs and stored into the Large Core Storage (LCS). No gating or filtering take place in the central computer during the scan. Carriage positioning and film transport by the satellite computer, however, are overlapped with filtering the digitisings of the preceding scan in the central computer.

The hardware design of the satellite computer and the negligible systems overhead allow it to react more rapidly than a large or even a medium size computer. Therefore the entire decision logic necessary to control the HPD was transferred to the satellite programs. This approach reduced the interface hardware considerably with the additional bonus of more flexibility. Special hardware-testing and trouble-shooting routines in the satellite computer substitute for the test- and simulation electronics required whenever an HPD is directly connected to a complex large computer. Thus program-supported trouble-shooting is possible without interfering with other users of the large central computer.

3. OPERATOR TERMINAL

The satellite computer uses a teletype and a fast, random access display with character generator, increment mode, vector mode and light pen in conjunction with 6K of satellite memory to support the communication between the operator and the programs in the large computer. Utility routines in the satellite computer allow one to display and modify text, display digitisings, select and enlarge areas of interest in the digitisings display, move symbols of rough digitiser measurements relative to the simultaneously displayed HPD-digitisings and to delete Master Points superimposed on the displayed road plot. The operator communication routines in the central computer are all written in Fortran, to a large extent according to standardised rules.

The final control concerning all HPD operations rests within the central computer programs. The HPD-operator cannot directly influence the HPD-routines in the satellite computer. He has to communicate his intentions to the central computer programs using the light pen to select one of several options offered to him in clear text on the display. Through this feature the operator may guide the programs in all major decisions. During production, however, logical flags changeable at execution time can be set to suppress most or all of the decision requests. The central computer programs then branch according to a standard choice.

The decision requests - if offered to the operator - are supplemented by the optional display of information necessary for a proper analysis of the situation. This includes a complete survey of the input to a program step: the display of all relevant program parameters by Fortran name and value, the scan and rough digitiser information, the HPD-digitisings as decimal numbers or as pictorial display. In addition the operator may request or suppress at execution time a varying amount of intermediate and final results for each program step. The speed and ease of information presentation on a display is essential for this kind of approach. The linkage editor used to build the overlay structure of the central computer programs allows the definition of more than one "region" - the overlays in one region being completely independent of those in another region. This feature was used to pack a large number of routines all in parallel into a small second region. Most of these routines display a section of a COMMON block containing parameters, data or working variables. The operator may request displays by these routines without modifying the program status in the main working region. The possibility to request displays of the same working variables at successive stop points in the program logic reduced the necessity for voluminous and usually not very intelligibly formatted on-line diagnostics encountered in lineprinter oriented program tracing.

Direct access to datasets residing on disks and the use of the new CERN geometry input format simplify the data management. A normal off-line batchprocessed job copies the filter results of a finished roll of film onto magnetic tape and then transfers the scan- and premeasurement information of a new roll onto the same permanent dataset. The amount of physical records in this dataset reserved for each event is determined from the number of tracks to be measured. There are actually two of these datasets which are used alternatively. The HPD-programs are fully controlled by the HPD-operator and need no special intervention by the central computer operators since no tape units are used by the on-line programs. To measure an event, the corresponding records of the direct access dataset are read by the on-line program, the fiducial and filter results are appended to the existing information and the combined data are written back onto the same place within the direct access dataset. This approach adapted from RHEL renders a separate SMOG-run unnecessary. In addition it allows repeat measurements of random events without any organisational difficulties and offers a good security against loss of events due to incorrect operator intervention, malfunction of hardware or central computer stops and restarts.

Adapting the CERN and RHEL Full Guidance Programs we attempted to implement the following concepts:

- Everything that depends on HPD-parameters is run on-line to the HPD. One common set of parameters is accessible to all routines. Conflicting parameter assignments in the course of hardware or software modifications should thus be avoidable.
- At every stage tests check the consistency of the results transmitted to the next step. Difficulties should be identified at the earliest possible stage before they accumulate and intermix at later stages rendering a proper error analysis time consuming if not impossible.
- The operator is able to immediately correct as far as possible any troubles detected by the program checks. This should reduce the book-keeping and other data management efforts necessary to bring recoverable events back into the main stream of processing. Unrecoverable errors are identified and flagged in order to pass them through all following members of the processing chain. This facilitates the easy accumulation of statistics about how many events are lost, for which reasons and in which part of the chain.

To realise this goal we incorporated the MIST, GATE, FILTER and SMOG programs into one overlay structure utilising the 120 Kbyte (12%) main core storage permanently allotted to the HPD-programs. In addition we use about 370 Kbyte (18,5%) of LCS for I/O-buffers and for saving the stage coordinates, the pointers to the digitisings and all digitisings for the normal and up to one abnormal scan.

As an example some of the tests are given that are applied in HAZE on top of the usual processing after a segment is filtered:

- Make sure a large fraction of the road is covered with Master Points
- Check the distance between the first or the last Master Point and the corresponding rough digitised point
- Check the distance between successive Master Points and its variance to insure an approximately even spacing of Master Points along the segment
- Check for subsidiaries in the roads of low momentum tracks for which larger tolerances must be admitted. Under these conditions incorrect subsidiaries are occasionally accepted by the program.

If the segment fails any of these tests the road plot together with superimposed symbols for Master Points and rough digitiser measurements is displayed. Depending upon the quality of the premeasurements about 5-8 % of the track segments are presented to the operator. About 2/3 of these are nevertheless acceptable and the operator chooses 'NORMAL CONTINUE'. Otherwise the operator may modify the road width, change the position of critical premeasurement points or shorten the road in case of discernible scatters. Since all digitisings are kept in the LCS, he may even correct completely wrong premeasurements where the track of interest leaves the road. Then the filter process is repeated. The operator may also force the acceptance of a subsidiary if the program choice is unsatisfactory or he may force filtering of the road in the opposite direction. Incorrect Master Points e.g. in the vicinity of small angle crossing tracks or confused regions may be deleted by the operator.

Under these conditions about 88-89 % of the events (12 GeV/c pp exposure in the CERN 200 HBC, all event types are measured) are successfully reconstructed by THRESH in the first pass. On a sample roll we redigitised those events that did not pass THRESH and scrutinised all tracks on the display that were not successfully reconstructed after the first pass. A number of small-angle kinks, rough digitiser errors and incorrect filter results could be identified and corrected that were not detected by the post-filter tests of the first pass. About 95 % of the 430 events on this sample roll were successfully reconstructed in THRESH after the second pass through the HPD.

One roll was processed by the HPD without any operator intervention. 82 % of the events passed THRESH. Thus the on-line operator intervention seems to gain us 6-8 % of the events. We are currently installing the following system: during the first pass no operator intervention is requested by the programs. As soon as all three views are measured on the HPD, THRESH will be run on a first direct access dataset containing both the premeasurements and the filter results. The THRESH-results will be written onto a second direct access dataset. In a separate step following the THRESH-run the geometry output on the second dataset will be inspected and the premeasurements of all tracks that failed in THRESH will be flagged in the first dataset. Only events with failed tracks will then be redigitised during another HPD-pass and the failed tracks presented to the operator. In a second pass through THRESH these remeasured events will be reconstructed and the THRESH output inserted in the proper place of the second direct access dataset. Only then will both direct access datasets be copied onto magnetic tapes for further processing.

Based on our experience this approach is expected to yield well over 90 % of the events successfully reconstructed for GRIND without a second pass on the rough digitiser tables which constitute the bottleneck within our system. The number of tapes and the corresponding book-keeping problems should be kept to a minimum. The geometry program is only run once on the good events which represent over 80 % of the sample. Since all segments are filtered by the same routines the recovery procedure should not introduce any bias with respect to precision or ionisation information.
We are just starting to adapt the CERN Minimum Guidance programs to our installation. Within our framework no large amounts of digitisings tapes will have to be handled since all digitisings of a scan are retained in the LCS, immediately processed by the Minimum Guidance routines and then discarded. The organisation developed to cope with the Full Guidance rejects is equally well applicable to Minimum Guidance rejects. Finally the methods developed to keep a complex program under close operator or physicist control are expected to be advantageous during the transfer and adaptation of the Minimum Guidance system to our HPD and our experiments.

DISCUSSION

J. RUSHBROOKE *(Cambridge)*: Did tracks with small-angle kinks not detected previously show up as tracks with large helix-fit errors in geometry, or at the filtering stage?

H. NAGEL: These small angle kinks were usually rejected by THRESH as having too large an error (> 17 μm THRESH residual). The kink, however, was not large enough to be detected by the FILTER test and was therefore not presented to the operator at the first pass.

J. RUSHBROOKE *(Cambridge)*: Down to what angle could an angle-change be detected by your FILTER program, with a view to segmenting long tracks having small angle changes in direction (Coulomb Scatters) on BEBC film?

H. NAGEL: We have not made any investigation as to whether we could be able to find small kinks automatically, (as is intended at Amsterdam, for instance) using the well known feature that a road plot compresses a track in its length and expands it in its width. So I cannot give you an exact figure.

J. RUSHBROOKE *(Cambridge)*: May I therefore put this question to Dr. van Leeuwen?

W. van LEEUWEN *(Amsterdam)*: The minimum angle, which can be detected during track following by MG FILTER is about 1°.

J.W. BURREN *(RHEL)*: Suppose that you compress the length of the track to fit it onto your display and then you blow it up sideways so that the width of the screen corresponds to say 300 to 400 microns. Then, you know that you can detect by eye a kink of a few degrees - certainly less than 5. When the track is non-circular the sensitivity of the eye of course will be lower. Even so one comes to remarkably small detectable angles ($\sim 0.05^{\circ}$) for a manual system using HPD digitizings.