SOFTWARE DEVELOPMENT IN THE TRISTAN CONTROL

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This paper describes the TRISTAN control system from the view point of application program development. The program production started in 1983 and at present 35 man-years have been supplied.

Introduction

TRISTAN, the 30 GeV X 30 GeV electron-positron colliding beam facility at KEK, was commissioned successfully in November 1986. A highly computerized distributed control system contribted significantly to the fast commissioning. The problem before us was how to develop necessary application softwares before the commissioning under the condition of limited manpower. Our answer is to make the efficiency of program development high and to increase the number of people who can write application programs. To this end we adopted the NODAL system with improved program development facility.

The TRISTAN Control System

Twenty-four minicomputers (Hitachi HIDIC 80-E's and HIDIC 80-M's) are distributed around the accelerators. These computers are linked by optical-fiber cables to form an N-to-N token ring network. The HIDIC 80-E's and HIDIC 80-M's are 16-bit minicomputers with 1-Mips computing power. Each minicomputer is equiped with 256-Kword memory, a magnetic disk drive, a console typewriter, a serial printer and one or two CRT terminals (DEC VT100 or equivalents). On the HIDIC 80-M a 4-Mbyte RAM is installed and is used as an additional "disk" device.

The minicomputers are classified into two groups: the system computers and the device-control computers. Each of the nine system computers supports one of the central-control functions such as servicing an operator console (OP0-OP4), alarm-processing (AL0 and AL1), library (LB0), etc. The fifteen device-control computers control hardware equipment such as magnets and power supplies (MG0-MG4), radio-frequency equipment (RF0-RF2), beam transport equipment (BT0 and BT1), vacuum equipment (VA0 and VA1), beam monitor equipment (BM0 and BM1). Figure 1 shows the overall configuration of the TRISTAN control system. The details of the system is given elsewhere [1].

The software system of the TRISTAN control is based on KEK NODAL language [2]. Nodal was first devised at the CERN SPS as an interpretive language for accelerator control [3]. The KEK version of NODAL has been enhanced over the original NODAL at the following points:

(1) High execution speed due to the compiler-interprter metod,
(2) It has a multi-computer file system,
(3) It has a full-screen editing facility, and
(4) External subroutines are dynamically linked to NODAL at run time.

The KEK NODAL is constructed on a real-time multitasking operating system, PMS, on HIDIC 80's.

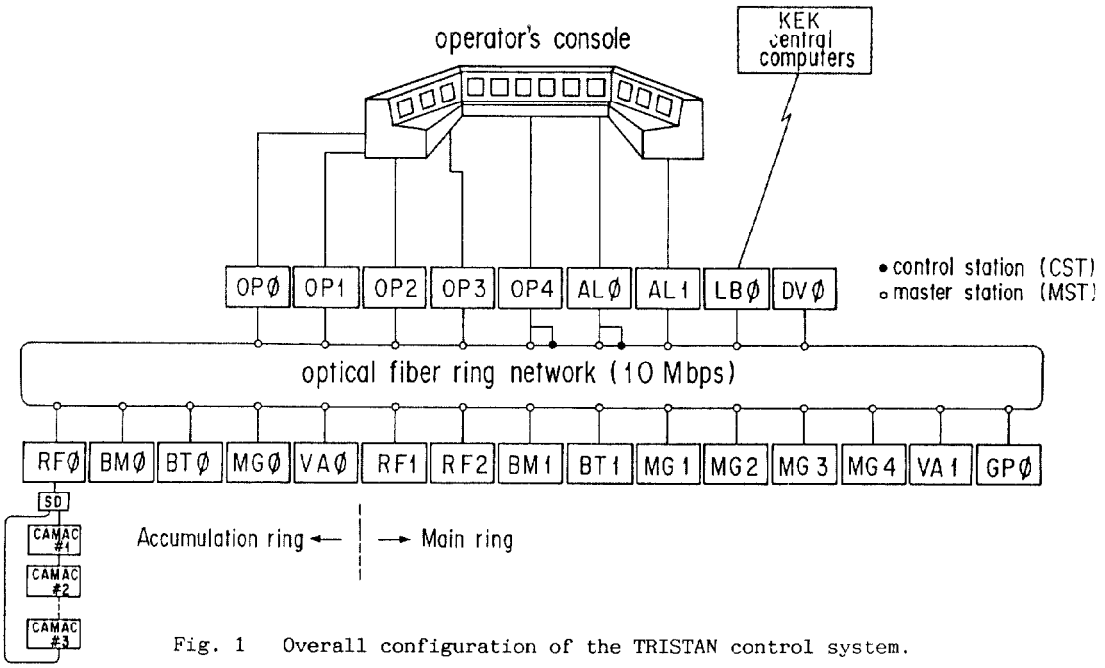

Fig. 1 Overall configuration of the TRISTAN control system.

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Categories of the Application Programs

In this paper, the term "application program" means programs written by the users of the control system. They are divided in two categories: (1) external subroutines and (2) NODAL programs.

External Subroutines

External subroutines are subroutines which are referenced from NODAL programs. There are two types of them. The first one is data modules which are divice handlers for accelerator equipment. The second one is functions, which performs some particular sevices. In the TRISTAN control, these external subroutines are coded in PCL, a real-time FORTRAN running on HIDIC 80's. The programs in this category must be designed, coded and installed before the accelerator commissioning. After the commissioning, they are not frequently modified. Of course there are many functions which are not written by the users, for example, mathematical functions such as SIN and COS, functions for graphic displys, CAMAC functions ,etc. These functions must be considered as parts of NODAL system and are not dealt with in this paper.

NODAL Programs

In the TRISTAN control system, programs for operation and beam study are written in NODAL. In addition to them, there are many NODAL programs for diagnosis of accelerator equipment and for meitenance of the control system itself. The programs of this category have unique features that they are modified and replaced by new one continuously even after the accelerator commissioning. Also according to the change of operation style of accelerators, which is frequent in modern accelerators, new programs must be created. Therefore, for the early stage of the accelerator life cycle, the burden of making data modules and functions is high, it becomes quickly that main efforts are devoted to making NODAL programs.

Application Program Development System

NODAL Program Development

As is stated before, eventually it becomes that the main efforts are bent to the production of NODAL programs. This is the reason why we adopted NODAL system at the TRISTAN control. The advantages of NODAL from the view point of software development is two fold: (1) NODAL is an interpreter languge. This means that we can develop NODAL programs interactively, and that the interpretive nature of NODAL makes the system more hermetic, that is the system is strong against bugs of user programs. These reduce the barriers for the programers of NODAL. (2) NODAL is a multi-computer language. In distributed control system, the most difficult task is to make programs which relate pieces of equipment on more than two minicomputers. We must inevitably write this kind of programs, since this is the very nature of operation programs. A NODAL program can be composed of subprograms which can be sent to other computers and are interpreted there. The programer, therfore, can write a multi-computer program on a single computer, leaving the complicated networking process to the NODAL system; thus enhancing the efficiency of programing under the multi-computer environment.

In addition to the above points, the KEK NODAL system has the following features: (1) a full-screen editing facility, and (2) multi-computer file system. The full-screen editing facility of KEK NODAL uses the cursor-control capability of DEC VT100. A user can edit his program by moving a cursor on the screen, inserting, deleting, or changing characters. The muti-computer file system of the KEK NODAL enables us to transmit program files freely between computers; thus, it enhances the flexibilty of the program development.

PCL Program Development

Even if the frequency of modification of PCL programs is not high at the TRISTAN control, we must not overlook them, since in this case we must use compiler language instead of NODAL interpreter and the efficiency of program development is very low compared with NODAL program development.

Moreover, HIDIC 80's are minicomputers for industrial control, where it is not frequent that application programs are modified after the system is completed; the program development system of HIDIC 80 is poor. Therefore, in the TRISTAN control we enhanced the program development facility of HIDIC 80 at the following points.

Full-Screen PCL Editor

We made a full-screen editor for PCL programs in addition to the line editor of the HIDIC 80. The mode of opeartion of this editor is nearly the same as that of the NODAL full-screen editor in order to maintain the same enviroment for the programers.

Remote Loading of External Subroutines

Every HIDIC 80 has a disk drive and the facility of program development in PCL. In this sense, in the TRISTAN control system there is no special minicomputer for program development purpose.

Even if every minicomputer has its program development facility, there occur some cases where we want to load external subroutines to remote minicomputers, because some minicomputers are more than 1 km aprt from the control room. Unfortunately original program development system of HIDIC 80 has no network facility; therefore we devised a scheme where files that contain PCL programs (IPS file) are tranferred between computers and remotely submitted.

(1) A NODAL function LBSAVE transfer a IPS file to LBO computer where it is saved as a file under NODAL file system (we call this file as PCL file).
(2) A NODAL function LBOLD transfer a PCL file on LBO to an IPS file.
(3) A NODAL function ISBMIT submits an IPS file.

Using these NODAL functions and the multi-computer facility of NODAL, we can manage the PCL program development over the minicomputer network (see Fig. 2).

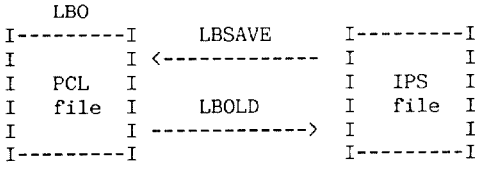

Fig. 2 Function LBSAVE and LBOLD

Dynamic Linkage of External Subroutines

Another device which makes the program development easy at the TRISTAN control is the dynamic linkage scheme of external subroutines. The names, the address of the load modules, the number and types of the arguments of data modules and functions are contained in a table (EFUN table). When the NODAL interpreter call a function or a data module, it gets the necessary information for linking from the EFUN table. By this scheme we can compile, link and load a new function or a new data module independently of the rest of the NODAL system. The only requirement for entering a function or data module into the NODAL system is to set the relevant parameters into the EFUN table. Lengthy procedure of re-compiling and re-linking of NODAL interpreter is not necessary. The independence of external subroutines greatly enhances the efficiency of debugging programs written in PCL.

Organization of Program Development

In the TRISTAN control there are no full-time professional programers; instead, hardware engineers, machine operation engineers, and beam physicists makes programs necessary for their jobs. This makes the number of people who can make programs large, which is the one of the objectives of the intruduction of NODAL to the TRISTAN control. The speed of program development is mainly determined by number of persons who can make programs times the efficiency of program production. Therefore, in addition to increase the efficiency of the program development, the increase of number of persons who can make programs are also inevitable.

The data modules are written by linkmen who are the member of hardware group. In the TRISTAN, there are five hardware groups: namely, vacuum, beam monitor, magnet, radio-frequency equipment, and beam transport. The device control computers exactly correspond to the division of groups. That is, every group has its device control computer(s). This scheme is suitable for the rapid commissioning, because each group can use their device control computer for his own purpose without interference between other groups, even before these computers are connected to the network. Number of linkmen per group is one or two. These linkmen also wrote necessary NODAL programs for diagnosis of the equipment.

The main part of the application NODAL programs are programs for accelerator operation. These programs were written by the member of the operation groups, who are responsible to the overall operation of the accelerators. They also make some functions necessary for opeartion in PCL. The number of members of the operation group is about fifteen.

The development of application programs began in 1983. At present (March 1987), nearly 900 NODAL operation programs, 100 data modules and 100 utility functions have been developed. The total manpower supplied for these programs are estimated to be 30 man-years for the NODAL programs and utility functions and 5 man-years for the data modules. The number of NODAL programs are continuously increasing.

Acknowledgement

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