CONTROL SYSTEM FOR THE FREE ELECTRON LASER BEAM LINE BASED ON PERSONAL COMPUTERS

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Abstract

We have developed a computer control system composed of personal computers (PCs) for the free-electron laser (FEL) beam line at the Institute of Scientific and Industrial Research (ISIR), Osaka University. The PCs are connected with Ethernet together and used to control magnets in the FEL beam line. The control software is composed of three hierarchical layers with a database residing on the middle layer, so that programs in each layer can be developed and maintained independently. To simplify development and maintain further, we adopted commercially available software for developing the programs. An overview of the control system is presented and upgrades of the control software to improve performance are described.

1 INTRODUCTION

We have been developing a far-infrared free electron laser (FEL) and self-amplified spontaneous emission (SASE) in the infrared region using the L-band linac at the Institute of Scientific and Industrial Research (ISIR), Osaka University. The FEL beam line had been operated with a manual control system and an operator had to be skilful, because the FEL and SASE are sensitive to operational conditions of the beam line as well as those of the linac. We therefore have introduced a computer control system using PCs to adjust parameters of the FEL beam line quickly and precisely[1]. The control system consists of four PCs linked with Ethernet. Components in the FEL beam line are connected to the PCs and remotely controlled through the network. The control software has three layers, and thereby programs on each layer are independent of those on other layers. The software has been upgraded two times after its commissioning; structure of the database has been modified to make response faster and a utility to recall previous settings has been added to operate the beam line more quickly[2]. In this paper, we will report on the control system for the FEL beam line, including the concept of development, the outline of hardware and software, and the modifications of the software.

2 CONCEPT OF DEVELOPMENT

We developed a computer control system based on the

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following concepts:

1. The control system should be simple and cost effective.
2. Programming of the control software should be easy.
3. The control system should be flexible for future modifications and extensions.

To meet the first requirement, we adopted PCs for control computers and also for interface controllers. PCs for device control have analog I/O and digital I/O boards in extension slots, which are connected to controlled devices. Following the second requirement, we use Microsoft Windows for operating system of the PCs, and commercially available, widely used software for development of the control software, such as Visual Basic and Microsoft Access. We adopted a layered structure for the control software to simplify the software and to make development easy. Such a structure also facilitates modifications and extensions of the software.

2.1 Hardware

The hardware structure of the control system is shown schematically in Figure 1. The FEL beam line consists of three bending magnets (BM), five quadrupole magnets (QM), and eight steering coils (STR). They are connected to power supplies in the control room. Each power supply has a 0~10 V analog input for controlling the output current and a 0~10 V analog output for monitoring it. The power supplies are connected to the device control PCs through analog I/O boards. Relays for switching polarities
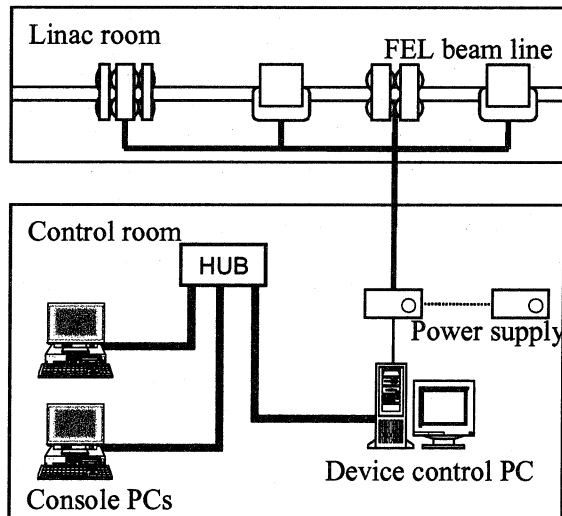

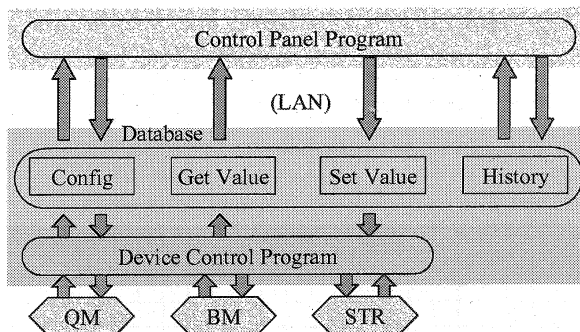Figure 1: Schematic drawing of hardware.

Figure 2: Schematic diagram of the structure of the control software and the data flow in the control system.

of the STRs are connected to digital I/O boards in the PCs. The device control PCs are connected to the PCs for operator terminals with Ethernet (100 base-T) and the devices in the FEL beam line are operated from the consol PCs.

2.2 Software

The control software has the layered structure composed of three layers as shown in Figure 2 and programs on each layers run independently of those on the other layers. The top layer is for user interface and a control panel program runs on this layer to provide a man-machine interface. This program communicates with the database on the middle layer to read output values of the devices in the FEL beam line and to write setting values to the devices via the database. The bottom layer is for device control and a device control program runs on this layer to read data and write setting values and commands to interface boards. We use Microsoft Visual Basic to develop these two programs. The middle layer is for the database, which has all the parameters of the devices under control read periodically and all the setting data sent to them. The database is made with Microsoft Access. Database files named generally as *.mdb are shared by all the PCs in a Windows workgroup, which makes it possible to control a device under one of the device control PCs from a console PC. The database contains four tables named Config, History, Get Value and Set Value, as shown in Figure 2. Config keeps setting parameters of the control software and History keeps accumulated operational parameters of the FEL beam line. Set Value and Get Value are used for communication between the top and the bottom layers. Data flows between the two layers are separated in two one-way traffics using two tables, Set Value and Get Value, in

Table 1: Access speed to the database.

	Original	New
MS Access	0.6 s	0.06 s
MS SQL Server	0.32 s	0.06 s

order to avoid conflict due to simultaneous access to the table by two programs.

3 SYSTEM UPGRADE

3.1 Access speed to the database

When the control software was designed, the response time was expected to be less than 0.1 s, which is defined as time to display a new value on the control panel after setting it. This value was estimated from the access speed of the device control PC to an interface board in it and the data transfer speed of LAN. We think that the response time of this order is necessary for quick and comfortable operation in FEL and SASE experiments. The response time, however, was measured in the actual operation to be 0.1 ~ 1 s or longer. Since the response time measured using a test program without the database was less than 0.1 s, we thought that the delay was due to the database. Thus we measured the access speed to the database using a test program, which writes data for the 16 devices under control in the database and then read them to measure the elapsed time. The measured time is 0.6 s, which is given in the cell of Table 1, specified by the row MS Access and the column Original, and consequently it was concluded that the slow response time of the control system was due to the database. In order to know whether this problem is specific to Microsoft Access, we made a similar measurement using another database, Microsoft SQL Server 7.0. It took 0.32 s as given in the Table 1, which is approximately a half of the response time measured with Microsoft Access but still not fast enough.

3.2 Modification of the database structure

We have modified the structure of the database to make the access speed faster. In practice, we exchanged columns and rows of the two tables for communication, Set Value and Get Value, in the database, as shown in Figure 3. A table in the database is composed of a set of records, and access to the table is made for each record. There is a virtual cursor in the table pointing a record as shown in Figure 4 and only data in the record pointed by cursor, which is called the current record, can be read or written. When data in another record are read or written, the cursor has to move to the record before reading or writing. This action imposes the heavy load on CPU because only one record in the table is loaded in the memory at a time. To read or write data in a new record, all the data in the record have to be loaded in the memory from the database in a hard disk, while data in the same record can be read and written quickly because they have been loaded in the memory. In the original database, a table is composed of a series of records and each record contains only one datum, as shown in Figure 3. To read all the data in the table, the cursor has to move many times. This problem can be solved by interchanging rows and columns in the table, so that a record contains all the data, as shown in Figure 3. As a result, the access speed has become ten times faster, as shown in the cell in Table

Original design

	SetValue
1	1.0
2	1.0
3	1.0
...	...

New design

	1	2	3	...
SetValue	1.0	1.0	1.0	...
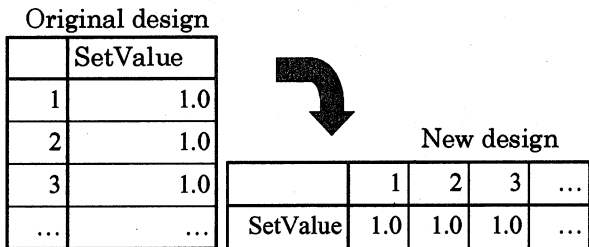
Figure 3: Modification of the table structure.

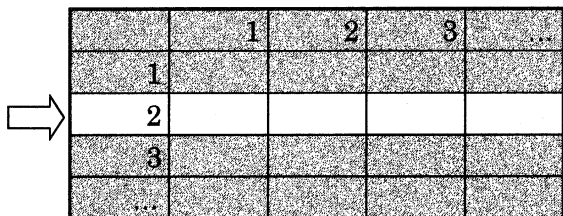|	1	2	3	...
1				
2				
3				
...				

Figure 4: Records and a cursor.

1, specified by the column New and the row MS Access. With the new database structure, the response of the control system has become quick enough to operate the FEL beam line comfortably in the experiments.

We have also measured the access time with SQL Server 7.0 for reference and it is given in the cell of Table 1, specified by the column New and the row MS SQL Server. When many records are read, the access speed with SQL Server 7.0 is two times faster than the access speed with Microsoft Access, while they are same for a single record. In our operational conditions, Microsoft Access is as fast as SQL Server 7.0,while the former is much easier to use than the latter. We therefore continue to use Microsoft Access as the database software. A simple method to make the access speed faster is to use a text file for communication in the middle layer. We have measured the access time of less than 1 ms in the same conditions. It might be difficult to use a simple text files for a database, because such a database has no access control. We will further study on this subject.

4 SUMMARY AND CONCLUSION

We developed the computer control system for the FEL beam line at ISIR, Osaka University in 1999. The system consists of four PCs connected with Ethernet. The components in the FEL beam line can be remotely controlled with a console PC. The control software has the layered structure and the programs in each layer could be developed independently. The control system cost approximately a million yen, which is much lower than an estimated cost of the system composed of UNIX servers and VME interface. The control software was improved to make response of the system faster by changing the table structure in the database.

The control system has been used to operate the FEL beam line for 90 days in total. Almost all the experiments were SASE experiments using the electron beam of energies 11.5 ~ 12 MeV. Setting values of the FEL beam line are not much different if the energy of the electron beam is in the same energy region, so that the utility for recalling previous operational settings is very useful and we can adjust the beam line parameters quickly for the SASE experiments.

7 REFERENCES

[1] T. Igo, et al, Proceedings of the 24th Linear Accelerator Meeting in Japan, (1999) 89.

[2] T. Igo, et al, Proceedings of PCaPAC 2000, (2000) ID64.