A VME/X-WINDOWS BASED CONTROL SYSTEM FOR A CLINICAL NEUTRON MACHINE

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Abstract

A control program has been developed for use with an existing radiation therapy machine used to treat cancer patients with neutrons. The system is safety-critical, multitasking, meets real-time deadlines and replaces existing control system hardware and software in use since 1984. The program allows therapists to treat patients in a safe and timely manner. The system controls various wedges, filters, and a collimator that shape the therapy beam dose distribution. It checks the actual machine state against a database of prescribed machine setups, and records accumulating dose for each patient across multiple treatment sessions, and updates logs used for patient record keeping and machine quality assurance. Development involved both formal and traditional methods, including extensive use of the Z formal specification language. Since the therapy equipment is in daily clinical use with the original control system, access to real machine hardware is very limited. This limited access necessitated the use of portable components such as X windows and ANSI C to allow for most development and testing to be done on a general purpose workstation and operating system. The program was written only in ANSI C using minimal support (X Windows, the real time operating system, and ANSI C libraries) to reduce the dependence on other third party products and software. This was done to ensure stability over the lifespan of the system and for quality control of safety critical functions. Experiences with testing the program and actual clinical use is reported.

1 INTRODUCTION

The University of Washington Clinical Cyclotron is a Scanditronix MC50 with an isocentric neutron therapy gantry, various wedges and filters, a multi-leaf collimator, and a movable therapy couch. Using these components together allow the therapists to deliver the correct dose and shaped beam to the target. The original therapy control system consisted of a Digital Equipment Corporation PDP-11 and a VT-100 terminal. The cyclotron has been in routine operation since 1984. [1]

The decision was made that the old control system needed to be replaced to allow for more efficient treatment cycles, safer treatment, and less reliance on out dated equipment.[2]

It was decided to take advantage of the newest technology and use a VME based single board computer to replace the PDP-11 and an X-Windows terminal for the operator interface. This decision was made to allow for easier migration as newer technologies become available.

2 CONTROL SYSTEM HARDWARE

2.1Existing Hardware

The old control system was comprised of a DEC PDP-11 communicating over 4 RS-232 serial communication lines to stand alone controllers. These controllers are :

1)Therapy Motion Controller (TMC)

This runs the all of the motions in the treatment room including the gantry, wedges, filters, and the room door.

2)Leaf Collimator Controller (LCC)

This runs the multi leaf collimator which shapes the neutron beam to match the tumor shape.

3)Dose Monitor Controller(DMC)

This monitors the amount of dose delivered on the target and terminates the treatment.

4)Modicon PLC

This monitors all the of the digital I/O points on the system, including door switches, push buttons, and beamline components.

Because of the specialized functions of the Scanditronix controllers (the TMC, DMC, LCC), the decision was made to continue to use these devices.

2.2 New Hardware

The PDP-11 has been replaced by a Motorola MVME 167 single board computer residing in a VME crate communicating with the local network via ethernet. The serial communication ports available via the Motorola transition board are used for the RS-232 communications to the various controllers.

3 CONTROL SYSTEM SOFTWARE

3.1 Existing Software

The only software that is carried over from the old control system is the Modicon PLC programming.

3.2 New Software

Extensive use of the Z formal specification language allowed for both formal and traditional modeling techniques.[3]

The new program was written only in ANSI C using minimal support applications such as X Windows, the real time operating system VxWorks from Wind River, and the ANSI C libraries. This reduces the dependence on third party products and software. This insures the reliability of safety critical functions and the stability of the system over the life of the project.

The operator interface runs on a Tektronix X windows terminal that is not running a window manager system. This way the control system cannot be minimized or hidden anywhere on the screen.

4 CONTROL SYSTEM OPERATIONS

4.1 Program Startup and Initialization

The VxWorks boot parameters are set so that the control system will start up automatically. Upon startup the program loads many constants and factors into resident memory. These factors are in multiple text files that reside on the Hewlett Packard UNIX machines that are clustered on the department network. If there is an error with reading any of these files, the program will alert the operator and will not be able to deliver any dose.

The program also reads files that define the keypad keys for operational use. Because a window manager is not used, there is no mouse available. In order to change windows and enter information, the keypad keys are mapped to functions to bring up different windows and change settings.

Upon startup, the program also reads in font and color values and defines X window graphics contexts and saves them in memory. This allows for faster operation and redrawing of X window items.

4.2 Operational Startup

Before the system is ready to treat patients it is necessary for the cyclotron operator to setup the system for the day. To do this, the operator is required to log into the control system and enter in the temperature and air pressure, which is read by hand in the therapy room. These readings are then used by the program to generate the daily calibration reading, which is used to monitor the dose delivered. This number is used to correct the ion chamber readings, which determine the dose and which are pressure and temperature dependent. Once the number has been calculated, the cyclotron operator logs off and the system is ready for treatment of patients. The program will not allow treatment unless the numbers entered are within a specific range. The program also monitors the temperature and pressure during the treatments and will give an error if they drift out of a specified range.

4.3 Therapy Sequence

The therapists each log in under their own login names. This allows for easier record keeping and lets us to know which therapists treat which patients.

Once logged in, the therapists see a listing of the current patients. This list is loading from the HP cluster and is generated by the therapists using a treatment planning program developed in house called PRISM. This program creates the treatment prescription and generates the settings needed by the therapy machine to deliver the correct dosage. Each patient is identified by name and patient I.D. number.

Once a patient is selected, the therapists then goes to the SELECT_FIELD screen. This shows a list of the prescribed fields and give the therapists the status of each field. It shows the number of treatments that have been given to date and the total number of treatments, and the dose per treatment and the total number of dose delivered to date. Both the patients name, I.D. number, and selected field are always present at the top of the display.

After a field is chosen, the therapist is then free to begin making machine subsystems ready for treatment. These subsystems consist of gantry/couch, filter/wedge, leaf collimator, dosimetry, room interlocks, and proton beam. These are represented along the top of the display, above the field and patient display, with boxes which display either red, green, or yellow. Green means that the subsystem has been cleared and is ready for treatment. Red means that the subsystem has not been cleared and must be cleared before treatment can start. Yellow means that the subsystem has been overridden. As a general rule, the machine is not to run with settings overridden.

To clear the various subsystems, the therapist must select the appropriate subsystem display. Once the display is selected, the therapist can hit the AUTO_SETUP key to start the serial communications to the controllers to clear the subsystem. Some of the control points must be set by hand by the therapists. These include the gantry angle, the collimator angle, and the opening and closing of the therapy room door.

For the DMC, the AUTO_SETUP command will begin sending the string of RS-232 commands that will load the dose numbers into the DMC.

For the LCC, the AUTO_SETUP will load the calibration factors into the LCC, and then will move the leafs to match the field prescription. This is displayed to the therapist by a graphical representation at the operator's display.

Because of the multi-tasking aspects of the system, it is also possible for the therapists to select a screen which shows a summary of the machine setup and start the AUTO_SETUP. Hitting AUTO_SETUP from this screen will cause the program to start the setup sequence for all non-ready subsystems.

Once all the subsystems are cleared, the machine is ready to deliver the dosage. A prompt will appear at the operators interface, instructing the therapists to press the START button. This then starts a sequence in the PLC which will retract the faraday cup and allow for proton beam to hit the target and deliver neutrons to the patient

4.4 Safety Interlocks

During the treatment sequence, there are multiple safety interlocks that can interrupt the treatment. These can be internal interlocks in the program or external interlocks monitored by the PLC.

If an interlock is tripped during the treatment, the faraday cup will interrupt the beam and stop the delivery of dose to the patient. Interlocks override the software and act directly on the machine. A message box will then appear on the operator console and will alert the therapists to the problem, and inform the therapists as to the steps that should be taken to remedy the situation. Once the interlock has been cleared, it is possible to for the therapists to continue with the treatment.

4.5 Record Keeping

One of the advantages of the new control system is the easier tracking of patients records. As a patient finishes treatment for a specified field, a text file containing all pertinent data is written to the network computers. This allows for verification of patient treatments.

A text file is also written that notes all of the log messages that have been written to the operator screen. This allows for the review of the daily operation of the therapy machine.

These files are both kept on a daily basis, which lets us reconstruct the history of therapy treatments in the past.

There is also the option to write out files for the serial communications to the various machine controllers. These are not written out on a daily basis, but must instead be written by pressing the WRITE_FILE button. These files have proven to be very helpful in troubleshooting any problems involving the controllers.

5 OPERATIONAL EXPERIENCE

5.1 System Testing

Much of the testing of the new control system was not done on the actual machine hardware. The machine is used 4 days a week for clinical use, with one maintenance day scheduled per week. Because of this schedule, we made use of a testbed environment that simulated the serial communications to the various controllers using UNIX text files. This allowed us to have testing procedures in place that let us make more efficient use of our actual machine access time.

5.2 Clinical Use

The new control system has been in clinical operation since June of 1999. To date, there have been some bugs discovered, most having to do with the reading and writing of files to the network computers. However, these bugs have been quickly fixed and no down time has resulted from them. The therapists have been enthusiastic about the ease of use of the new system, as well as the quickness with which they can treat patients. Also, the extensive record keeping that is now being done has allowed us to pinpoint some operational oddities with the controllers that were previously hidden by the old control system.

6 SUMMARY

The new control system for the University of Washington Medical Center Clinical Cyclotron has been operational for 3 months. By making use of low level applications and extensive formal and informal modeling, we were able to make a successful transition from the old system to the new. This transition has made for more efficient patient treatments, without compromising on any safety concerns.

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8 REFERENCES

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