Paper Session II-B - Accurate Depiction of Electrocardiogram Data in a General Purpose Computer

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Accurate Depiction of Electrocardiogram Data in a General Purpose Computer

by

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Abstract

Two conventional methods are currently used to produce an Electrocardiogram (ECG) waveform display. The first uses analog input to a strip chart recorder or oscilloscope. The second uses a digital input to specialized digital display equipment. A third alternative now exists which involves the display of digital ECG data on a non-dedicated general purpose workstation. This requires that the ECG display process coexist with other applications contending for processor resources. Accurate emulation of the standard ECG display requires balancing of processor speed, display refresh rate, screen resolution and strip chart recorder emulation.

Introduction

The Launch Processing System (LPS) is used to support the Space Shuttle operations at the Kennedy Space Center. A large part the LPS is the Control, Check-out and Monitor Sub-system (CCMS), which includes all the user interfaces for shuttle processing. The Biomed Console (BMC), located in Firing Rooms 1 and 3 of the Launch Control Center, is the primary interface that the LPS medical staff uses to monitor the condition of the astronauts and the shuttle cabin environment during launch operations.

In 1990, the decision was made to replace the BMC as part of the ongoing CCMS Survivability Project. This replacement effort required finding suitable replacements for all of the components that make up the BMC. These components included an Electrocardiogram, a local medical strip chart recorder, and a Shuttle Cabin Environmental cathode ray tube display.

The justification for replacement was driven by the fact that this equipment is obsolete and no longer supported by medical vendors. This condition imposed serious maintenance concerns involving reliability issues of the aging equipment and the lack of adequate spares.

Design Concepts

At the beginning of the project several guidelines were established to ensure that the needs of the Biomedical staff and the maintenance community were met in conjunction with the overall project schedule and budget. It was a necessity to have a method of rapid prototyping using the medical expertise of
the user community as design requirements. An emphasis was placed on the new equipment's graphical interface design to be flexible enough to incorporate user inputs throughout the design process. The ability to build up a prototype, demonstrated it's capability, and refine it accordingly in a timely manner was central to the design activity.

The Vehicle Safing/Biomed Front End Processor was also being replaced as part of the CCMS Survivability Project. It provides the external interface for the BMC to the LPS. This allowed an enormous amount of flexibility in the design of the external interfaces.

The design team's initial approach was to replace the BMC components with industry accepted medical equipment. Upon investigation this approach was rejected for a variety of reasons. The first reason was the incompatibility of this type of equipment with the standard way that telemetry is processed in the LPS. Development costs, to build vendor unique interfaces, were prohibitive. The second reason was the high cost of this type of equipment was prohibitive under the survivability budget.

A next approach was to work with medical equipment industry to come up with a system that would meet the needs of the BMC. Unfortunately the same issue of cost became apparent as well as the condition of using a proprietary architecture.

The final and selected approach was to implement the BMC design using standard open system architecture. With the user community's requirements for the new BMC crystallized, it became obvious that the BMC could be implemented using standard commercial off-the-shelf hardware and software. Interfaces which are industry standards, such as ethernet, SCSI, and RS232 could be used to satisfy all BMC data processing requirements. Also, using an off-the-shelf graphical user interface allowed user inputs to be incorporated very rapidly.
BMC Operational Overview

The BMC receives its data from instrumentation located on the Shuttle which is transmitted through the LPS communications network. A telemetry processor converts the signal to standard ethernet packets and re-transmits to the BMC. The data is manipulated and displayed by the BMC platform during shuttle support operations.
BMC Hardware Design

The BMC hardware consists of a SPARC 10 UNIX workstation, touch screen, and a thermal array recorder. The SPARC 10 is a model 41 with 32MB RAM, a 1 gigabyte hard drive, 2 serial ports, 1 ethernet IEEE 802.3 interface, and a GX+ Video Card. The touch screen is a 20" Intecolor CRT capable of high resolution display with a capacitive touch overlay interfaced to the workstation through a RS232 port. The Thermal Array Recorder is a 200 dot per inch thermal printer that accepts digital data for control and display. The recorder has a paper pickup with slip clutch. All components are housed in a console which has standard 19" rails.

Software Design

The BMC operating system consists of UNIX and Solaris. This provides the capability to bring the BMC up to an operational state, initiate communications, perform an orderly shutdown of the BMC, and perform health and status checks. In addition, Solaris comes with "C" compiler, X-windows, and Motif software as part of the standard package. This suite of software tools
provides the services common to applications which meet open systems standards for Commercial-Off-The-Shelf (COTS) packages.

**User Interface (X-windows)**

![Diagram of User Interface](image)

**Operational Software (Biomed User Interface)**

The Operational Software provides the capability to monitor and display at the Biomed console in the firing room certain biomedical and cabin environmental data and control the Thermal Array Recorder. The measurements and events that are monitored are Greenwich Mean Time (GMT), Mission Elapse Time (MET), O₂ partial pressure at three locations, CO₂ partial pressure, cabin pressure, cabin pressure rate-of-change, cabin Humidity, cabin temperature, cabin fan delta pressure, and two channels of ECG data at either flight deck, mid-deck or External Vehicle Activity (EVA) locations.

The ECG data display requirements were refined through rapid prototyping. The Biomedical staff provided medical expertise to determine that display would provide wave forms at a simulated chart speed that emulated the output of a standard medical strip chart. The heart rate is calculated using a running average of 6 beats. Beats are identified from the iso electric line followed by a peak. The display simulates chart speeds of 5, 25, and 50mm/s.

The ECG display update algorithm uses the SPARC system time to generate signal interrupts to produce a smooth display. The SPARC is limited
in the consistency and the resolution of the system timers. The best scrolling requires a balance between the number of pixels moved, the scrolling distance, and the timer ticks. The optimum balance was achieved through real time inputs from the medical staff during rapid prototyping to produce acceptable ECG displays while not overburdening the CPU. Copy screen functions were used instead of line erase and redraw to avoid screen flicker during scrolling.

The cabin environmental display measurement were interpreted and manipulated to the appropriate resolution and unit measure.

**Thermal Array Recorder (C')**

![Thermal Array Control Display](image)

Thermal Array Control Display

The Thermal Array Recorder driver provides the software interface from the workstation. The driver outputs to the two (2) channel Thermal Array Recorder using standard RS232 interface. The figure above is an example of the display output format. The display has control to change output speeds between 5, 25 and 50mm/s.

**Technology Transfer**

Standard, low cost, powerful real-time software development tools and high speed standard computing equipment are now available. The cost of such systems makes the tools available to even the smallest project. The prevalence of these tools in the computer science industry will make collaboration on real time data processing tasks, using input from several hosts, a reality on a standard platform.

This combination of design methodology and platform standards can be used as a model for future development of specialized monitor and control systems. Anywhere a specialized display is currently used to monitor a sensor or group of sensors, a consolidated display can be developed to facilitate a given enterprise. Through this technology, multiple displays can be accessed quickly as circumstances change during operations. The ability to rapidly prototype these screens and interfaces makes near real time development possible.

Using standards with sufficient performance depth makes developed systems extendible. Emerging VME, real-time operating systems, and software
development environments standards have enabled collection, manipulation, conversion, and rebroadcast of instrumentation data in a variety of formats. Ethernet and FDDI provide commercial development tools for networking with sufficient bandwidth to manage instrumentation monitoring hitherto restricted to analog techniques. Adherence to information systems standards enables concurrent development of libraries for monitoring and control algorithms. These software routines would be available to users and developers around the world. Enabling specialized monitoring and control applications to coexist, with other automated data processing applications on a standard general purpose computer, opens a new world of possibilities for information dissemination and use. Video conferencing, accounting, documentation access can now be coupled with remote real time monitoring.

For example, the medical community could develop specialized displays to monitor and control a myriad of sensors. These displays could be held in an on-line library available and configurable at the touch of a finger from the bedside or around the world. These displays could access any pertinent data on a given patient. The patient's current condition, medical history, medication, insurance, family members, as well as a library of professional consultants, and collected medical opinions can be displayed side by side with real-time instrumentation data or recorded data. These multi-media displays would be invaluable during diagnosis. An appropriate source for developers and physicians might be a standard library sponsored by the American Medical Association on the world wide web.

Conclusions

Open systems standards in the past were limiting to design and made software development costs prohibitive. Now viable standard alternatives to specialized hardware and software for monitoring and control of specialized systems are available. Computer and digital technology has evolved to the point where specialized instrumentation can be monitored and controlled by standard general purpose hardware and software. By minimizing the reliance on proprietary resources, we have maximized the probability that our equipment will be expandable and maintainable in the future. In our example, we used a SPARC 10 workstation, ethernet, and X Designer, but the selection could have been any workstation that runs standard UNIX, and standard protocol, with X / Motif interface software.

Before investing in proprietary specialized hardware and software that are not integratable and expandable using standard techniques decision makers should consider developing applications using standard tools.