Range Commanders Council

DATA REDUCTION AND COMPUTER GROUP

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GUIDELINES FOR INTERRANGE GRAPHICS CAPABILITIES

Special Report
A Common Real-Time Grahics Environment

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GUIDELINES FOR INTERRANGE GRAPHICS CAPABILITIES

Special Report
A Common Real-Time Graphics Environment

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A COMMON REAL-TIME GRAPHICS ENVIRONMENT

INTRODUCTION

Individual government test and training ranges from the Department of Defense, Department of Energy, and National Aeronautics and Space Administration are working on a large base of dedicated, imbedded real-time graphics equipment. Recent initiatives within many sponsoring activities have generated the need for test and evaluation (T&E) and training ranges to develop and upgrade systems which are common across the Major Range and Test Facility Base (MRTFB) and training ranges. These initiatives are driven by decreasing funding in research and development (R&D), procurement and operation and maintenance (O&M), and by the advent of technologies capable of attaining common systems architectures. In the area of range computation and display systems, commonality can be achieved by employing open real-time computing systems. Understanding the rapid changes in technology and recognizing industry trends towards universal computing standards will allow the ranges to plan ahead, adapting their current and future activities to lower budgets while still providing high quality products for their customers. By adopting this trend of openness and commonality in hardware and software systems, government ranges will save millions of dollars over the long term. Range graphics capabilities and upgrades can be enhanced by following a set of guidelines that detail a recommended common graphics environment. These guidelines are developed to promote improved range commonality and interoperability for graphical display of test and training data at all ranges, independent of where the test and training data were acquired. Goals include hardware and operating system independence to allow the exchange of applications software, incrementally upgrade paths to protect past investment, and to streamline acquisition procedures.

By specifying a common graphics environment, government ranges will be able to exchange application software source code and eliminate redundant software development efforts which would not only reduce development costs but would minimize the lead time required to implement software changes. To the extent possible, real-time applications software should be developed independent of hardware platforms with the expectation that it will be a shared resource. Using accepted industry standards for a portable operating system environment will eliminate system-dependent calls. When range requirements change and new technologies become available, only minor changes will be required to the existing software. Additional dollar savings can be achieved by developing a unified procurement process to acquire graphics equipment for ranges using similar requirements.

This document defines a common graphics environment for the development of graphics display systems which will promote commonality and interoperability between government test and training ranges. This environment is described as a set of functional components contained in a typical graphics system and the associated guidelines to consider when acquiring or developing each component. This approach provides the means for incremental upgrades and a way of taking advantage of new technology. To develop these guidelines, a graphical system has been divided into six components: operating system, graphics libraries, programming languages, communication architecture (data distribution to display devices), workstation characteristics, and hard-copy characteristics.

OPERATING SYSTEM

The operating system (OS) used should be based on industry standards for open systems. Currently, POSIX is the most widely supported real-time standard for workstations, and compliance is recommended. Using a POSIX-compliant OS will allow real-time applications to be ported between platforms from different vendors. While a POSIX-compliant OS could introduce computational overhead when compared to "native" system service calls, the speed of currently available processors would make the impact minimal. The selected OS should support a large address space to make full use of available memory. Experience has shown that a 32-bit addressing scheme should be a minimum requirement. The OS should support multithreaded multiprocessing to promote modular software development and to ensure high-priority tasks can react to real-time events. Sharing of data between processes is also required.

The POSIX 1003.13 defines real-time Application Event Profiles (AEPs) which describe different levels of real-time support including minimal, dedicated, and multipurpose. It is recommended that the operating system support the multipurpose real-time system profile which is intended for both real-time and nonreal-time tasks. This profile includes standards addressing the operating system interface (1003.1), real-time OS extensions (1003.4), execution threads (1003.4-a), performance metrics, and real-time OS performance monitoring tools. The POSIX 1003.4 (real-time extensions) is still in the draft stage but is close to becoming an accepted standard, and many vendors are providing functional support. Although POSIX 1003.4 does not currently address device drivers, the following real-time extensions are included:

- counting semaphores - allow processes to synchronize to a shared resource;
- memory locking - locks or unlocks all or a range of process pages in memory;
- shared memory - allows processes to share data by mapping to areas in memory, and mapping to files (with protection) and to shared memory objects if specified;

- scheduling - a combination of priority-driven first-in-first-out (FIFO), and time-slice round-robin scheduling;

- real-time signals - queued signals which inform processes of asynchronous events;

- clocks and timers - get or set system time, generate a signal at a relative or absolute time, suspend process for a period of time with high-resolution timers;

- interprocess communication - creates or opens message queues, sends messages, receives highest priority message, requests notification when message queue becomes nonempty; and

- input/output (I/O) - supports both synchronous and asynchronous. The process does not have to wait for I/O completion.

GRAPHICS LIBRARIES

Graphics libraries provide the interface between the application software and the display hardware. A set of standardized graphics libraries for open-system implementations will be necessary. To ensure portability, the use of any vendor-specific extensions to the adopted standard libraries must be avoided. Current open systems computing philosophies are built on a windowing system. The system can be divided into three areas: the window manager, the Graphical User Interface (GUI), and drawing libraries.

Windows Managers

The X-Windows is by far the most widely used and supported workstation windowing system across the industry and is therefore recommended. It is a network-transparent system. Users can access application programs running locally or on any machine connected to the network and can run multiple applications on the same workstation display. The X-Windows provides facilities for generating multifont text and two-dimensional (2-D) graphics in a hierarchy of rectangular windows. The applications and the workstation operate in a client-server relationship with X-application programs being the clients. Each X-Windows server includes one or more screens, a keyboard, and a pointing device. The X-Windows is fundamentally defined by a network protocol and includes a standard library (Xlib) that handles the details of network protocol and communication. Toolkits, higher-level graphics libraries, and window managers use Xlib to implement graphics user interfaces and to provide application graphics libraries. The Xlib is designed to be called by routines written in C-language.

Graphical User Interfaces

Graphical User Interfaces (GUIs) should be designed to ensure generalized and uniform appearance of window structures across display devices. The GUI libraries will enhance the appearance and user accessibility of the window manager. They typically include a user interface language and a toolkit for developing window displays. Two industry standard GUIs are widely available: OSF/Motif and Open Look. The OSF/Motif was developed by the Open Software Foundation, while Open Look was developed by Sun Microsystems and AT&T. Both of these standards are based on X-Windows and are hardware independent. In addition, both systems support several commercially available toolkits further enhancing the application development environment. However, Open Look and Motif are incompatible on the same platform, but Motif is supported on most all workstation platforms, while Open Look is not. Therefore, the use of Motif is recommended.

Drawing Libraries

Drawing libraries contain a set of graphics primitives used for definition, modification, and hierarchical graphics data display. An open, well supported drawing library is essential, and support for multiple libraries is preferred. The library used for each application should have sufficient features and performance to meet the needs of the application. Benchmarking the library/workstation combination before beginning applications development is highly recommended. The following common drawing libraries are recommended for use.

- Programmer's Hierarchical Interactive Graphics System (PHIGS) is a functional specification of the interface between an application and its graphics support system. Functional capabilities include structure definition, editing, display operations, and device control functions. The PHIGS+ adds rendering capabilities. The PHIGS Extension on X (PEX) is an extension of the X-Windows system to support three-dimensional (3-D) graphics using PHIGS.

- Open GL is a graphics library recently released by Silicon Graphics, Inc. as another proposed standard and has been ported to all major high performance workstations. Adding a GL extension to X-Windows (XGL) has also been proposed.

- Graphical Kernel System (GKS) is a basic graphics system for applications that produce 2-D pictures. Basic functions for graphical input and picture segmentation support operator interaction. The GKS-3-D extends GKS to include definition and display of 3-D wireframe objects including 3-D locator and stroke inputs. No rendering techniques are included.

It is recognized that a layered approach to implementing real-time graphics libraries, toolkits, and the X-Windows system could exact performance penalties. Intelligent software design and graphics accelerators should minimize this problem. Today's high-speed workstations take less graphics processing time.

PROGRAMMING LANGUAGES

The government has designated Ada as the language of choice for new systems development. Compliance with the government directives concerning the use of Ada is an important issue. Suggestions made concerning the development of graphics applications in Ada follow.

- The ranges must continue to support existing application programs, most of which are written in FORTRAN. There is no requirement to convert existing application programs to Ada. As the opportunity arises, however, the algorithms contained in these programs should be converted to equivalent Ada software components. The essence of these algorithms must be captured and expressed in a way that takes advantage of Ada's natural support for software engineering practices. Computer programs that convert FORTRAN programs to Ada should not be used because they tend to produce poor code.

- Newly developed Ada graphics programs should use Ada bindings to the standard graphical libraries specified elsewhere in this report.

- Since Ada is such a strongly typed language, standardization of common data types is vital for software sharing. If each range develops Ada software using their own local data types, it will be impossible to share routines without modification; therefore, the ranges should agree upon a series of fundamental data types - a common "data dictionary."

- Test and training ranges need special widgets not supplied with standard X-Windows tool kits. The ranges should develop standard widgets that can be shared.

COMMUNICATION ARCHITECTURE

A communication architecture will be needed that provides for distributed open systems implementations. It is difficult to discuss these architectures without mentioning "brand names"; however, this will become less of a concern as more products become available. Equally important is the selection of industry-standard network protocols to ensure platform and device independence. Connectivity to existing systems can be accomplished by using compatible multiple protocols on the same networking hardware. A list of current communications hardware standards follows.

- Ethernet (IEEE 802.3) is the standard communications system for the workstation industry. Although Ethernet is advertised to perform at 10 megabits (Mbits) per second, experiments have suggested a true maximum throughput of about 4 Mbits per second with a single broadcasting node, and a 2.7 Mbit throughput when multiple workstations are broadcasting. Workstations with multiple Ethernet adapters would be effective in separating a data acquisition network from one used for interworkstation communication such as hard-copy spooling and messaging. Ethernet is recommended for connectivity to existing systems and for nonreal-time communications.

- Fiber Distributed Data Interface (FDDI) consists of a set of standards that define a 100 Mbits per second timed token passing Local Area Network (LAN) that uses fiber optic media to transmit data between attached devices. A token ring network is deterministic, which makes it more suitable for real-time use than Ethernet. Adding more devices to an FDDI network increases latency; the token takes longer to circulate around the ring. The standard allows up to 500 stations depending on the network topology. One manufacturer recommends that an FDDI LAN generally be limited to 100 stations and 20 concentrators because of the performance and reliability characteristics of large rings. This is the networking standard recommended for real-time applications.

- IBM's 4/16 Mbit token ring is used for low-end applications and functions like FDDI.

- Replicated Shared Memory is a communications technique which uses an extremely high-speed data transfer system to update a section of memo shared by all systems on the network. Use of this technique is extremely application dependent. Synchronization between the interconnected processors must be considered. Sampled data must not be overwritten while another processor is using that data for calculation or display generation.

- The Digital Equipment Corporation (DEC) DR-11W interface is a defacto industry standard interface which is supported across many platforms for parallel communications.

- Synchronous Data Link Communications (SDLC) is an inexpensive industry standard interface for high speed (512 Kbits) serial data transfer.

- RS-232/422 is another established industry standard serial communications interface which is thoroughly supported and has excellent applications for limited data rates.

- Small Computer Serial Interface (SCSI) is primarily used for connecting multiple external devices such as disk and tape drives. There are three types of SCSI implementations: standard SCSI which limits the total cable length to 5 meters, differential SCSI which is balanced and can be used to connect remote systems, and SCSI-II which provides data rates of up to 32 MBps (SCSI-II "wide").

- IEEE-488 is used to interface to instrumentation and strip-chart recorders.

The current industry standard networking protocol is Transport Control Protocol/Internet Protocol (TCP/IP). Currently being developed is the Open Systems Interconnect (OSI) protocol. Both of these protocols are recommended for use in future systems, but support for protocols such as DECnet, Local Area Transport (LAT), and High-Level Data Link Control (HDLC) will be required.

Another way to achieve interoperability is through standard procurement requirements. The Government Open Systems Interconnection Profile (GOSIP) is a set of procurement-oriented standard profiles specifying how ISO standards will be used for U.S. Government computing. The GOSIPs specify certain implementors' agreements that must be met to qualify for government procurement bids. If one vendor supports a particular GOSIP such as U.S. GOSIP, then that vendor's product should be able to operate with the same type of product from any other vendor supporting the same GOSIP. The GOSIPs specify how applications communicate on OSI networks; their relevance to real-time is uncertain.

WORKSTATION CHARACTERISTICS

The workstation market has grown tremendously over the last few years. With computer graphics systems performance doubling every 18 months, it is imperative that government ranges maintain as much hardware independence as possible, so they can take advantage of new hardware with increased performance as it becomes available, regardless of the manufacturer.

Most high-performance graphics workstations have an internal graphics engine, separate from the Central Processing Unit (CPU). Functions such as clipping, viewing transformations, zoom and pan, and windowing are often performed in hardware to maximize graphics performance. Therefore, standard published CPU performance parameters such as a million instructions per second (MIPS), a million floating point operations per second (MFLOPS), and

SPECMARKS do not necessarily correlate directly with graphics performance; both computational speed and graphics drawing speed parameters must be considered. The ratings should be supported by meaningful range application specific benchmarks whenever possible. The best benchmark is running a program typical of a local application program on the range's current system.

Because of the importance of performing valid benchmarking to verify graphics workstation performance in the test and training range environment, a separate task DR-24, "Range Graphics Benchmark," was established within the DR&CG to define a common set of range graphics benchmarks. The results of task DR-24 are being published as document 166-95 which is available from the RCC Secretariat.

Experiments at ranges such as those at Naval Air Warfare Center Weapons Division (NAWCWPNS) Point Mugu, California, and Naval Air Warfare Center Aircraft Division (NAWCAD) Patuxent River, Maryland, have demonstrated satisfactory performance for T&E and training applications on workstations with the following capabilities. These capabilities are recommended as minimum characteristics for workstations procured for T&E and training range applications.

- A CPU rated at least 30 MIPS and 5 MFLOPS to provide the processing power required for 2-D and 3-D graphics computations.

- Drawing speeds of at least 100,000 independent solid-filled 10-pixel-per-side polygons per second and 750,000 randomly oriented 10-pixel vectors per second.

- At Least 32 MBytes of random-access memory (RAM), expandable, with cache memory of at least 256 KBytes.

- Double buffering and display of 8-bit planes of color selectable from a large color palette (16.7 million).

- Minimum visible resolution of 1280 x 1024 pixels.

- Noninterlaced screen refresh rate of no less than 60 Hz.

- A minimum of four independent graphics windows displayed on a single screen with 2-D and 3-D applications in any window. Workstations should be capable of supporting both 2-D and 3-D displays either initially or through incremental upgrades. Although 3-D capability may not be a requirement at some ranges, requirements for 3-D applications in the near future appear inevitable and would not be supported if only 2-D hardware is purchased.

- Multiple industry standard network interface connections available as options. Examples include Ethernet, FDDI, replicated shared memory, RS-232/422, IEEE 488, VME, and SCSI. Support of multiple networks allows the separation of the primary real-time data network from others used for interdevice communications. Each network must be independently supported.

- As a minimum, a keyboard and a pointing device for interactive input and support for devices such as dials, button boxes, programmable touch panels, digitizing tablets, and function keys. These peripheral devices should be connected via industry standard protocols such as RS-232.

- A scan conversion capability from high-resolution red-green-blue (RGB) video to lower resolution RGB, SVHS, National Television System Committee (NTSC), and digital video for real-time recording.

- A multimedia applications support capability (if required by application).

HARD-COPY CHARACTERISTICS

Experience in real-time operations has identified several important requirements which should be addressed in the acquisition of a hard-copy device. The most significant problems to date include excessive freezing of the screen during image capture, slow data interface to the device, inability to spool captured images, inability to multiplex the device to a number of sources, and the excessive cost of thermal transfer and other color imaging media. In acquiring a hard-copy device suitable for real-time graphics purposes, the following capabilities are recommended:

- A minimum displayable resolution of 300 dots per inch in both axes including full color for capable printers.

- Selective image capture and printing from at least four display sources.

- Spooling of multiple images, that is; the user should be able to capture a number of images successively without impacting the display device or waiting for the current print job to complete.

- An image capture operation that does not degrade or freeze the selected display for more than 0.5 seconds.

- The ability to capture an image either to a disk file or to a print device selectively.

- The ability to accept RGB sync-on-green signals at any commercial scan rate, either automatically or as specified by the user. Ideally, it should also accept other data formats such as Postscript.
- At least one high-speed, nonserial data interface, preferably a network interface such a Ethernet.
- Maximum total print times of 90 seconds for full color images, and 30 seconds for monochromatic (black and white) images. The printer should use standard copier paper as a consumable.