A High Performance Multi-Protocol Network-Based Application For Video Beam Diagnostics

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Abstract

The precision, cost and simplicity of operation make TV-based accelerator diagnostics very useful. The authors present a client-server video processing system including real-time jpeg compression-decompression code for a 20x reduction in network traffic. The product is developed using Object Oriented Design. The server supports both TINE and DCOM protocols and the TINE and DCOM clients have the same functionality and are built from the same components. Transparent multi-client control is provided. Video acquisition is based on the Data Translation Inc. frame grabbers DT3155, DT313X and the matching provided Data Translation SDK library. Image processing functions include light spot position and size calculations, visualization, image loading/saving, scaling, comparison, other useful procedures. It is optimized for beam measurement purposes. Operation at up to 10 Hz has been reached using 10 Mbps Ethernet and 500 MHz Pentium III workstations with 768x576 8bit grayscale images.

1 INTRODUCTION

TV-based measurement and control tools are very common for accelerators and other hi-tech applications. They have big information capabilities with moderate precision and speed. The hardware for such systems consists mainly of commercially available TV-cameras, lenses and frame grabbers. The growth of commercial TV applications results in a continuous decrease in prices and increase in quality. Another important advantage of imaging technology is the simplicity of maintenance.

The high information density peculiar to TV data becomes the limiting factor in its processing and transfer over networks. One digitized 8bit 768x576 CCIR (European black and white TV standard) image occupies approximately 0.44 MB and at 25 Hz operation 10 MB of data are produced each second. Theoretically the most common 10 Mbps Ethernet can transmit about 1 MB per second, but in practice in a control-room environment an application should not consume more than 20-30% of the network capability. Only modern PCs capable of live-image processing can be used and optimized programming is required. Most commercial imaging libraries deal with object recognition, edge contrast enhancement and filtering. Applications are directed toward binary logic transformations and work well with high quality images. The long analog video signal cables due to radiation problems and the large size of modern accelerators make video images noisy. Beam diagnostic applications generally need real-time measurement of normal distribution, size and position with subtraction of the background image.

A video data processing program previously created at DESY [1] includes many useful features for beam measurement purposes. It has the base functionality included in this project. The requirement of continuous viewing of SR TV-monitors in the HERA Lumi-Ugrade Project directed the features of designed application. The problem of network traffic defined the use of JPEG compression-decompression. The speed-optimized algorithm provides a 20-fold decrease in the amount of transferred data without remarkable loss of quality. Operation at up to 10 Hz has been achieved using 10 Mbps Ethernet and 500 MHz Pentium III computers with CCIR images, and live (50 Hz) for local clients. The supported video acquisition boards are Data Translation Inc. PCI frame grabbers DT3155 and DT313X [2]. Object oriented development allows expansion to other types without difficulty.

The Windows NT platform with X86 workstations was chosen as a general solution. The main part of the programming is done on VISUAL BASIC. Some time-critical subroutines are written on C and the JPEG code uses inline MMX ASSEMBLER.

2 ARCHITECTURE

The Component Object Model (COM) is a common technology for Windows. It was used for the architecture design. The software complex consists of a server application and Distributed COM (DCOM) or TINE [3] clients. Both client and server use the same compression-decompression module for the JPEG conversion.

2.1 COM-based architecture

Figure 1 shows the COM part of the application design. The server application includes image acquisition modules (classes), one per frame grabber board. The acquisition module performs the management of the board and contains all board peculiarities. Public access is made through its Interface for Board Control (IBC) which provides complete frame grabber control. DCOM clients direct the board through the IBC.

The server-to-client data transfer is based on two client interfaces: Interface for Frame Notification (IFN) for the video data refresh and Interface for Control Notification (ICN) for the acquisition parameters. ICN ensures control transparency – clients request an action through the IBC and the server notifies all existing clients about this through the ICN.

The subdivision of the client interface into two independent parts is done for traffic reduction only. The acquisition board can have several video inputs and it is convenient to have separate clients for each TV camera which execute both IFN and ICN and a central client managing general board settings which uses only ICN. In this case there is no need to supply the central client with the huge amount of TV data.

The main disadvantage of the DCOM part of the application is the need for registration and configuration. The ICN, IFN, and IBC interfaces and the server application itself have to be registered on all server and client workstations. The proper launch, access and security permissions have to be set. The limited VISUAL BASIC DCOM security control results in very open for corrupting influence workstations.

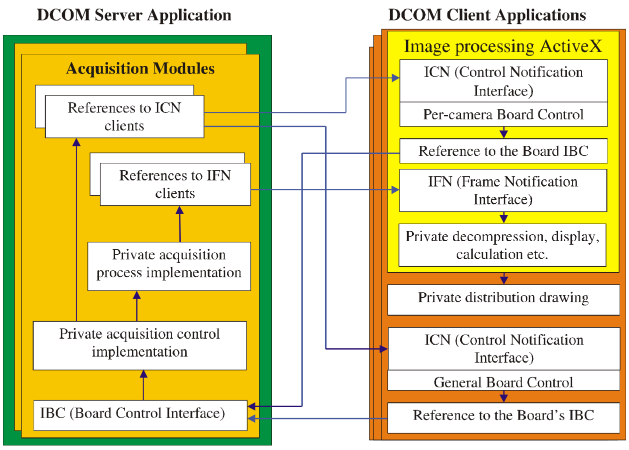

Figure 1: DCOM client-server flow chart.

2.2 *TINE-based architecture*

The Object Oriented Design makes the exchange of the DCOM network protocol for TINE very organic. This is done using ACOP and SRV controls. The rest of the server and client applications remain nearly the same. The flow chart is shown on Figure 2.

The TINE VBasic SRV ActiveX server is located in the DCOM server process. Its containing Visual Basic Form constructs the bridge between the protocols. This form contains references to the IBC's for the controlled grabbers and implements public client interfaces ICN and IFN. IBC allows translation of remote TINE management to the native board functions. The subscription of this form using ICN and IFN to the server's client list ensures delivery of both video and control data between server and client.

The TINE client is done using the existing COM client and a bridge between both protocols. This bridge is constructed by Virtual Board Servers (VBS).

VBS is the COM module representing the imaginary board server. For their clients it grants the whole board functionality. It carries out IBC and refreshes the list of its ICN and IFN clients. The particular IBC operation is provided by ACOP ActiveX controlling real remote board throughout above discussed SRV control. Another set of ACOPs is used for refreshing image data and controlling hardware settings. VBS fires matching notifications for its IFN and ICN clients receiving new pictures and parameter changes.

The use of the VBS-based bridge makes it unnecessary to change the DCOM clients. But there is no need to put VBS in the different NT process. This makes a difference between clients. TINE uses an in-process server dramatically reducing CPU overhead. An additional advantage of the local COM server is that it can be compiled as private and needs no registration. This was performed including the same IBC, IFN and ICN interface classes to the project and making them private.

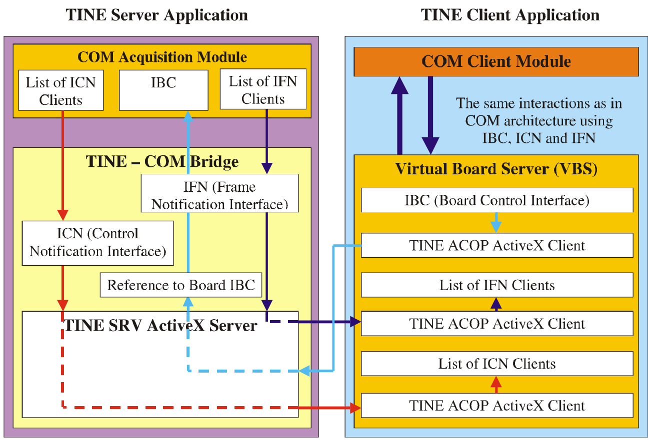

Figure 2: TINE client-server flow chart.

2.3 *JPEG Compression/Decompression*

The JPEG conversion is based on IJG code [4] with improved performance. The primary UNIX program was ported to an ActiveX control. The UNIX-style error handling was replaced with standard COM-style handling. The most consuming procedures were rewritten on MMX ASSEMBLER. The module has methods for compression, decompression and the property JPEG compression quality equivalent to that in the JPEG manual. The input-output data types are COM lovely VARIANT. The subtypes of input and output data define whether an action works with memory arrays or with files. Usual quality 768x576x8bit TV images are processed with 75% quality in less than 40 ms, which meets our real time requirements.

There is a possibility to switch off the compression. This is useful if both server and client reside on the same workstation.

2.4 Image acquisition

The currently supported frame grabbers include Data Translation Inc. DT3155 and DT313X. The acquisition modules residing in the server application are designed as classes executing IBC. They perform hardware control through the provided Data Translation SDK library. The public IBC allows clients to manage board operation. The acquisition class transmits TV image and board management data to the clients accomplishing appropriate interfaces via server callback method. It keeps the list of subscribed clients and refreshes them after successful acquisition or control action.

Server callbacks were preferred to raising events as they give more control over data flow and allow better error handling for dead clients.

As stated earlier, video images are normally compressed before network transmission. This is done by a JPEG conversion ActiveX control.

2.5 Common client architecture

Image processing is done on the client side of the application. Each client receives video data independently and performs its own handling. This gives the desired flexibility.

The basic client component is an ActiveX control class carrying out both client public interfaces ICN and IFN. This includes image receiving, decompression if necessary, display, calculations, storage and board control for the chosen TV input and the reception of corresponding control notifications. It provides the container (Visual Basic Form) with the results of calculated beam parameters.

The form includes graphs with user interface elements for the time development of the measured beam position and size. It also implements ICN for the common board parameter management.

2.6 TV processing ActiveX control.

The basic image treatment is performed by a previously designed ActiveX control. The addition of interfaces rearranges code but its essential job remains intact. It receives TV images and controls grabber operation for the chosen TV camera. The same JPEG module is used for the necessary decompression. The processing is based on fast routines integrated in a C DLL. These include grayscale or false-color displays with arbitrary zoom and automated stretched contrast, 2D histogram, profile computation and Gauss distribution fitting, mean and rank filtering. Very important for measurements is the allowance for background images. An interactively chosen rectangular Region of Interest (ROI) is used for the basis of the calculations.

The control displays the acquired 2D distribution with calculated beam position mark, optional horizontal and vertical profiles and corresponding data values. It is possible to store the current state in additional window as a reference for future comparison. The Graphical User Interface (GUI) allows the display and ROI change, image loading/saving, corresponding board control etc.

2.7 System configuration

To store and load current working parameters a Microsoft Jet Database (.MDB file) is used. It can be read or changed using MS Access and loaded/restored by the application using Data Access Objects (DAO). Both server and client applications load the last working set during start up and save the settings in the database file before termination. The common items affecting board operation are saved on the server workstation. The processing related part is located on the client side. The independent handing of each client permits individual client configurations, including desired filtering, background, ROI, scaling etc.

2.8 Error handling

Careful attention was paid to error handling based on COM rules. Some server exceptions are transmitted to the clients and are displayed using a specially constructed self-destructing message box control, but most are processed internally. The application performs logging of critical errors to a file for analysis. The goal was to build application that can’t break down despite incorrect external conditions.

2.9 Finding

The wide use of virtual classes (interfaces) enables hardware and software flexibility. To include additional board support we need only to build corresponding acquisition COM objects to carry out IBC and have IFN and ICN clients. Most of the system debugging becomes possible without hardware by means of an appropriate stub class.

The COM is the Microsoft method of object oriented programming and developing distributed applications. The authors tried to follow the standards as much as possible and the former local version of the application was written initially using COM and ActiveX. The implementation of JPEG compression/decompression extends it to DCOM client-server version.

The TINE protocol has a lot of advantages in a big heterogeneous control environment – it is easier to maintain and configure, is faster, has broadcast capabilities and is standard in DESY accelerator control. TINE doesn’t need to register and configure each server class on each workstation which makes use of DCOM and version upgrades a nightmare for system administrators. So, the coexistence of 2 network protocols in the program has mainly historical reasons for DESY and our planned installation will use TINE. The advantage of DCOM is its presence on Microsoft platforms which allows for its installation without TINE.

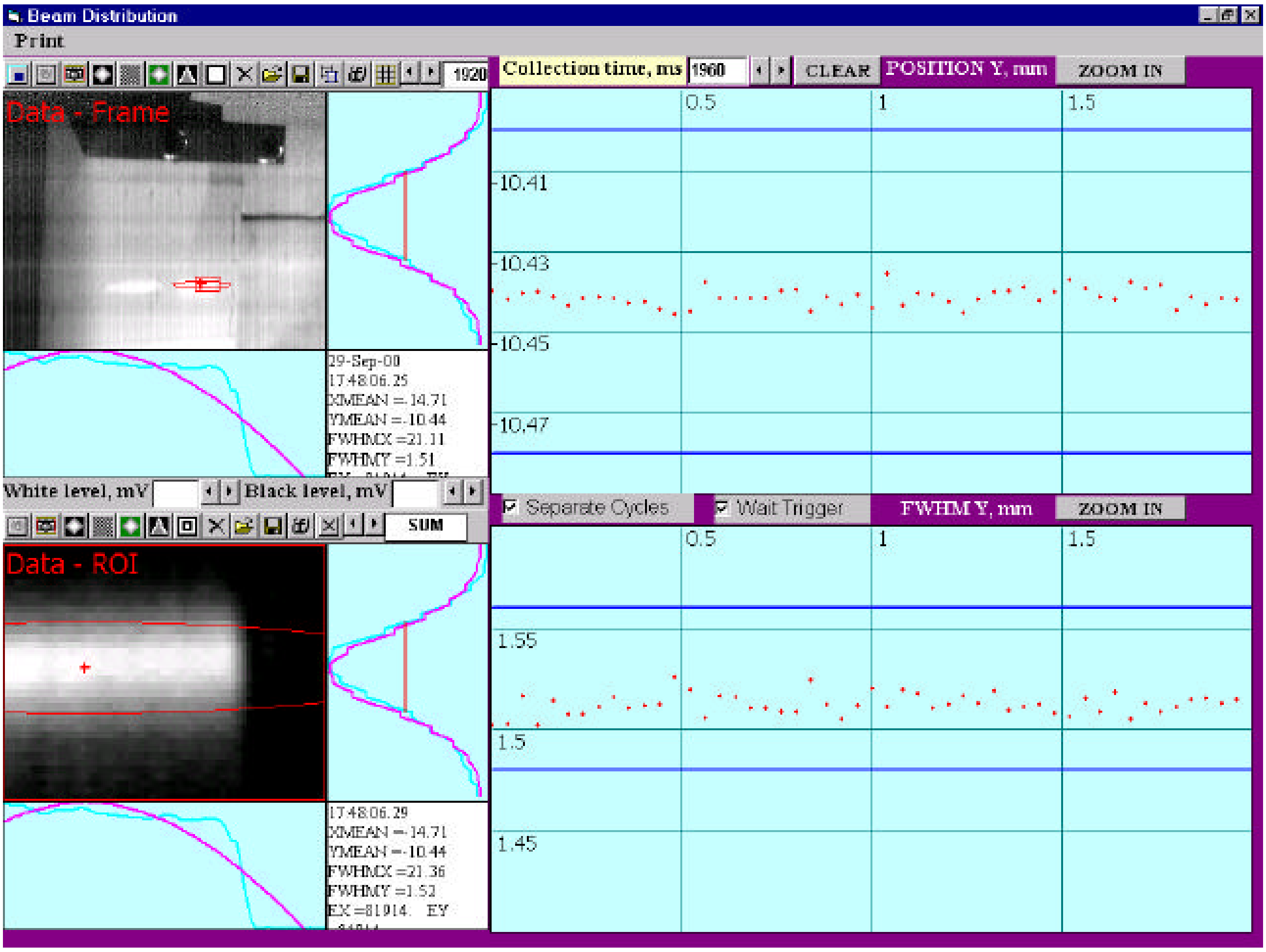

Figure 3: DORIS synchrotron radiation distribution. Vertical position and size vs. time.

3 RESULTS

Our experience in using the system for measurement of light distributions produced by different physical phenomena reveals some common tips. It was stated, that one often needs continuous real time TV registration for fast process observation. This is performed by the server acquiring images to the host memory live and transmitting these images to the clients as possible. The Figure 3a shows measurements done in such way of the synchrotron radiation distribution produced in the DORIS storage ring.

The common dynamic range of frame grabbers is 8 bit, but this precision can be achieved only in perfect conditions in which the TV camera is not more than 2 meters from the ADC. The radiation damage of CCD cameras also affects signal quality. A very important factor in image processing becomes correct background subtraction. It is necessary to achieve good results under varied conditions.

The human eye is very sensitive, but has a logarithmic response. This makes simultaneous measurement and observation problematic: An operator might consider a light spot as hardly visible and try to increase its intensity, but for the ADC the intensity is perfect and the human-pleasant picture is actually a saturated distribution with flat top. The general solution could be the wide use of false-color displays, showing levels of intensity using different colors.

The automatic gain control included in most available CCD cameras can produce problems when observing fast flashes in dark environments. There are many aspects of TV measurements, but the following statement summarizes our experience: TV methods are capable of providing excellent measurement precision. But it is necessary to carefully choose adequate hardware including controllable lenses, apertures, lights etc.

4 PROPOSALS

The constructed application has many general features, but additional capabilities are sometimes required. The main goal was to design a readout for the HERA Lumi-Upgrade SR monitor. That requires one to resolve multiple light sources in a single image. This can be done in the existing system using several clients calculating different spots independently, but such an approach is not optimal. In fact we need to establish multiple ROI support. Another important task could be the measurement of skewed distributions as this is commonplace. The measuring equipment (TV camera) is not always perfectly adjusted and a proper computation would improve the results.

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REFERENCES

[1] K. Wittenburg, V. Seleznev, F. Solodovnik etc., “Processing the information received by matrix beam detectors”, ICALEPCS’99, Trieste, Italy, 1999

[2] Data Translation Inc. home page, www.datx.com

[3] P. Duval, "TINE: An Integrated Control System for HERA", PCaPAC '99

[4] T. G. Lane, "Independent JPEG Group's software", www.ijg.org