

# PROCESSING THE INFORMATION RECEIVED BY MATRIX BEAM DETECTORS.

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Matrix detectors are widely used to measure beam distribution. This paper discusses real-time information processing, under the constraint of limited calculation resources.

## 1 INTRODUCTION

The use of TV image acquisition and processing systems is continuously growing at charged particles accelerators [1]. These have high information density, are simple to maintain, and are inexpensive due to use of commercial components and software. Generally hardware for such a system consists of a TV camera (recording primary radiation or radiation produced by interaction of beam particles with some target) and a frame grabber — the specialized for standard TV signals. DT3155 of Data Translation Inc a 4-input 8-bit grayscale frame grabber, was chosen as an image acquisition board. Many image processing software packages are available, but most of them do not satisfy beam diagnostics requirements. Their main disadvantages are inadequate support of real-time measurements and lack of appropriate display and calculation modes. The authors of this paper developed a PC Windows NT 4.0 image processing system for beam diagnostics based on our experience and using existing commercial hardware. Most of the application is written in Visual Basic and time-critical sections in Visual C.

## 2 DESCRIPTION

We started using image processing for beam diagnostics more than 10 years ago. The first system was realized in CAMAC [2], using self-developed electronics for the image acquisition. Data processing was done on an 8-bit I8080 computer. Of course it was not comparable with the modern version, but it had reasonable performance. Optimized computation and visualization algorithms and operational experience resulted in a high-speed system with a convenient GUI and functionality adequate for the beam diagnostics tasks.

A low-cost Data Translation DT3155 frame grabber was chosen for the modern system because it is supplied with an SDK providing full control of the board. The DT3155 is a PCI card capable of real-time 8-bit digitizing of standard CCITT (50 Hz, 768x576) or RS-170 (60 Hz,

640x480) TV signals with four multiplexed monochrome inputs. It can digitize 768x576 images at 4 Hz on a 200 MHz Pentium MMX. This includes calculation of distribution width and center (the main geometric characteristics) using gauss fitting and simultaneous display of 2-D and two integrated 1-D distributions. For the faster measurements it is necessary to store successively digitized images in RAM so that processing can be overlapped with acquisition. When this is done the maximum speed and capacity depend only on the computer system.

For flexibility and reusability the beam diagnostics program for TV-image processing was developed using OOP. Frame grabber control is localized in a class-module and the data for each TV-camera is managed via an ActiveX control. The main form acts as a container for objects and also is used for displaying time distributions of measured parameters and for printing.

The frame grabber class-module is implemented via the Data Translation SDK. It provides all necessary DT3155 card management.

The most significant program element is the TV camera ActiveX control, that includes conversion, display, computation, comparison, scaling, file saving and loading of digitized image utilities. It acquires images from the frame grabber module and displays acquired pictures together with calculated parameters. The GUI is provides a toolbar, popup-menu and the mouse interface. The last state of the ActiveX control can be saved in a separate window for future comparison or analysis.

Since during any physical measurement it is necessary to take into account the background conditions, all computations are performed on the difference of two images; one with and one without beam. The domain of definition is interactively limited to an arbitrary rectangular ROI (Region of Interest) in order to restrict reflection and other parasitic light sources. The simultaneous display of profiles integrated over ROI and 2-D distributions is convenient for diagnostics applications. Users can choose different modes of 2-D visualizations; grayscale black-and-white, automatic

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contrast stretch, zoom (ROI or Whole Frame), subtraction of background image, false color display of two beam distributions difference, which is useful for instability or drift observation. The ActiveX control contains three different images, which are interpreted as current data, background and reference. The user can acquire new images or load images that were previously acquired and stored in files.

It was found during testing that a gaussian of the integral distribution gives the most stable and reliable estimation of its center and width. This is more time-consuming and takes most of CPU time, but results in the spread of fitted peak of only a few pixels at the different ROI. The straight calculation of center of gravity results in an inequality of hundreds of pixels. This is very important if the TV camera is saturated or there is a lot of reflected or other parasitic light. Even under this conditions the gaussian fitting still gives good results. Often during an experiment it is hard or impossible to adjust the sensitivity of the camera to the signal range. The same dependence is observed during the distribution size computation.

The convenient interactive method of selecting the ROI (standard for Windows applications) of helps determine saturation by comparing the size of partial distributions with minimal and maximal intensity. This is significant for TV systems because of their small dynamic range. The 1-D and 2-D histogram display also allows checking for saturation via the distribution shape.

Negative image processing can be done by inverting the frame grabber data via its Look up Table. Figure 1 shows graphical program output from film exposed by channeled proton beam from the U-70 accelerator. The upper image is a grayscale display of the entire frame with maximized contrast and the lower is a 2-D histogram of ROI. Both cases are the difference of images with and without beam. Since the channeled beam has only a few percents intensity of the main beam it is nearly impossible to observe it and its structure on the grayscale display, but the 2-D histogram clearly displayed it. The 1-D histogram together with the calculated Gaussian distribution indicates the presence of a small additional peak. The fitting calculation "ignores" it and gives the parameters for the main distribution. The adjustment of ROI allows an estimate of the extra peak.

### 3 ALGORITHMS

Since high performance is one of the most important requirements, the gaussian fit and 2-D distribution display routines are written in C. The fit uses a known standard algorithm based on peak detection by means of calculation of first and second derivatives. It looks for such gaussian coefficients, that give zero first derivatives of the integrated squared difference between measured and supposed gaussian distribution and with positive second derivatives. Special display regimes, such as

displaying image differences, zoom with arbitrary gain and automatic contrasts stretch, require bitmap display routines. A special algorithm is provided to achieve optimal 2-D display zoom performance. It uses only integer calculations, without any use of floating point.

The most distinctive algorithm is for 2-D histogram creation. The most complicated thing in any 3-D graphics task is removing hidden image parts. This is done with the help of two techniques:

1. The sequence of drawing histogram bins is chosen, so that already drawn bins can't be hidden by any drawn later. A back row is unable to hide a front row regardless of its height because of the histogram has a regular structure and any bin of the back row is "back" to the front one. This means when a front line is drawn first — it only needs to be compared it with previously drawn lines but it isn't necessary to remove its invisible parts in the future.
2. The current shadow upper bound (line below the portion of the image already drawn and freshly created there parts should be invisible) is constructed in a linear array of size equal to the window width in pixels. The current histogram bin is compared with the shadow level and only portions in front are placed in the bin.

The image is created in PC memory and visualized only once. This improves performance.

## 4 CONCLUSIONS

The current Windows NT system consists of cheap industrial hardware components. It has high measurement accuracy based on background subtraction and computes geometric parameters by fitting via a Gauss distribution. The carefully optimized display and computation procedures provide a program refresh rate of 4 Hz that is sufficient for many real-time applications. The visualization is appropriate for data analysis and allows not only observing the calculated geometrical values, but also controlling the whole measurement path. The special regimes of instability and monitor drift can be observed via the storage of base state in a separate window and false color display of differences between two distributions. The program is adequate for beam diagnostics tasks. The Windows style GUI contributes to personnel self-teaching during operation. It can be used for processing exposed films. OOP technology allows easy system reconfiguration such as including or excluding additional TV cameras or frame grabbers. It is possible to build others applications by means of the existing ActiveX controls and classes. An example is to supplement the magnet element control with geometric parameter measurement for the feedback. In the future we will add a sophisticated utility for beam slope calculation, since this is necessary for the proposed application.

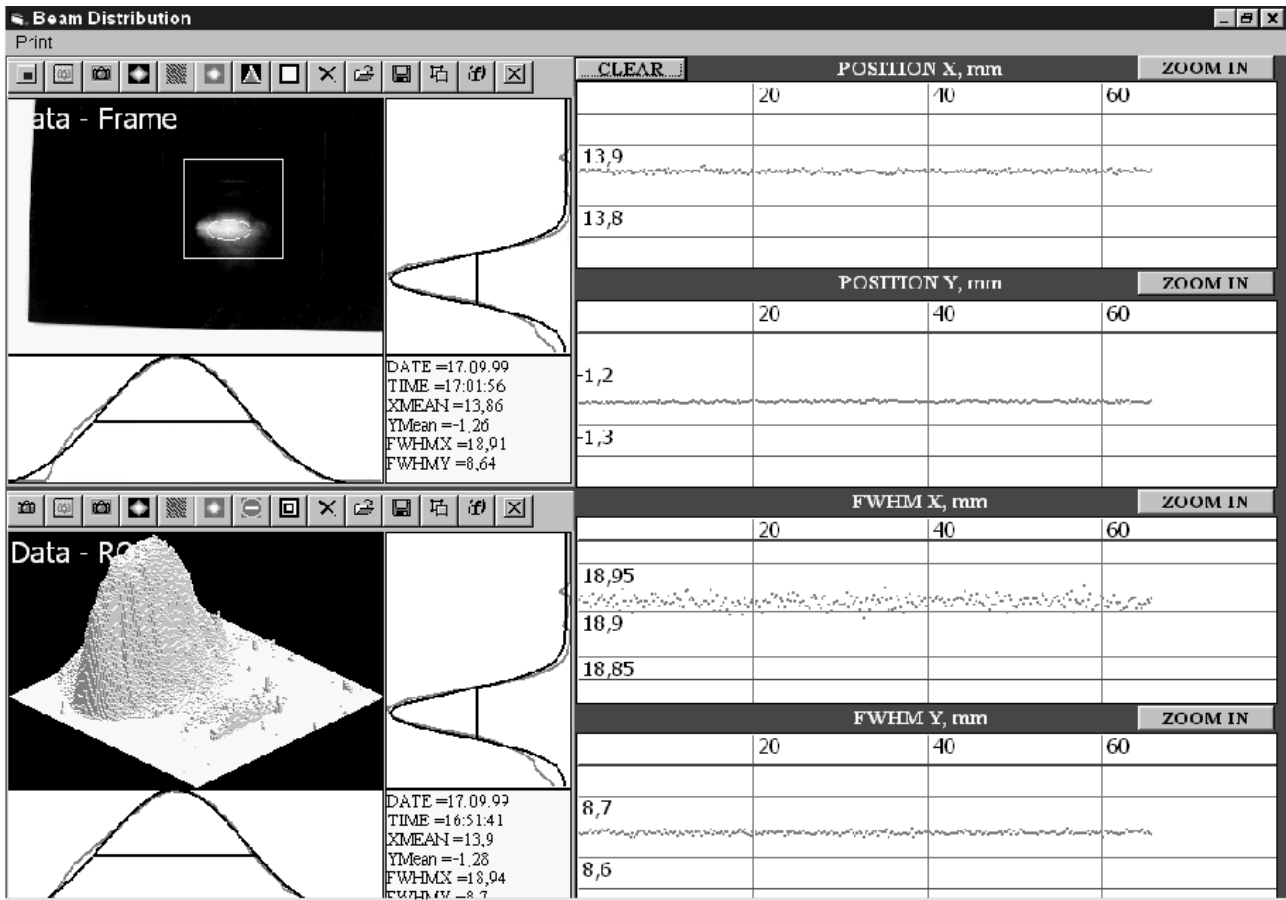


Figure 1. Example of the application screen.

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