BROOKHAVEN
NATIONAL LABORATORY

BNL-82244-2009-CP

Using an IIDC/DCAM camera for beam display and analysis

R.H. Olsen, D. Gassner, L.T. Hoff

Presented at the 12th International Conference on Accelerators and Large Experimental Physics Controls Systems (ICALEPCS 2009)
Kobe International Conference Center
Kobe, Japan
October 12-16, 2009

September 2009

Collider-Accelerator Department

Brookhaven National Laboratory
P.O. Box 5000
Upton, NY 11973-5000
www.bnl.gov

Notice: This manuscript has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. Department of Energy. The publisher by accepting the manuscript for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

This preprint is intended for publication in a journal or proceedings. Since changes may be made before publication, it may not be cited or reproduced without the author's permission.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Printed on recycled paper

USING AN IIDC/DCAM CAMERA FOR BEAM DISPLAY AND ANALYSIS *

R.H.Olsen#, D.Gassner, L.T.Hoff, BNL, Upton, NY 11973, U.S.A.

Abstract

An IIDC/DCAM camera is used to image the RHIC beams as they pass through a hydrogen jet. The data is transferred over a 1394 bus to a computer with a Linux operating system. A software process on that computer collects the individual frames and packages them into parameters within the RHIC control system's framework. This information is packaged to continuously update two primary types of clients: One type is responsible for near-real-time display of the images; useful in comfort displays, etc. The second is responsible for collecting data used in analysis of beam dynamics and properties like luminosity.

IIDC/DCAM CAMERAS AND LIBDC1394

Various Imaging applications in the Collider Accelerator Department (C-AD) at Brookhaven National Laboratory (BNL) use 1394 cameras. 1394 is a high-performance serial bus which can be found on many devices from laptop computers, through camcorders to time-critical controls instrumentation like the system under discussion here, which is in operation at the Relativistic Heavy Ion Collider (RHIC). The cameras we are using at C-AD differ from typical consumer camcorders, which often also use a 1394 connection, in that they implement a specification defined by the Imaging and Instrumentation Digital Camera (IIDC) working group, digital camera (DCAM) sub-working group, of the 1394 Trade Association. This specification provides a protocol which allows high speed transmission of uncompressed video data (without audio). An open source library called libdc1394[1] implements this protocol for computers that use the linux operating system.

The software we developed at BNL which is under discussion here makes use of this library. It has been used with lower-end SONY DFW-D500 cameras, Allied Vision Technologies Pike and Stingray models, and a high end Hamamatsu model in operation at the NASA Space Radiation Laboratory (NSRL)[2], also at BNL.

HYDROGEN JET IMAGING

One camera is focused on a hydrogen jet at RHIC, where particle beams travel around two rings named Blue and Yellow. The primary purpose of this hydrogen jet is to provide a means for proton beam polarization measurement. The visual characteristics of the beam when it hits the jet are interesting and additional information is gained from using the camera as a tool for beam diagnostics such as luminescence monitoring, and for comfort displays.

Network Topology

We have configured our network to allow for the efficient transfer of this H-Jet camera data throughout the complex, as shown in figure 1.

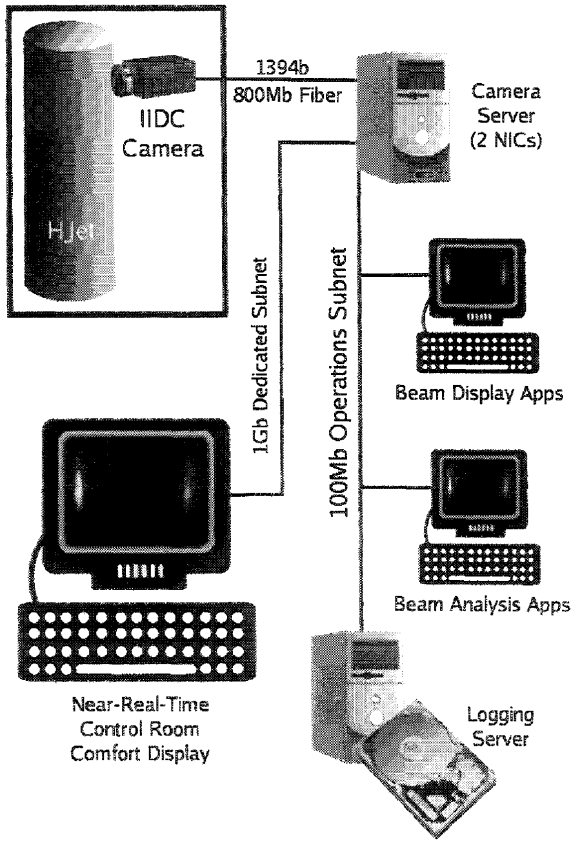

Figure 1: Network Topology for Hydrogen Jet Imaging

The images from the camera in the RHIC ring are transmitted over 1394 to a computer in a nearby service building where they are captured, packaged and made available throughout the system.

* Work supported by Brookhaven Science Associates, LLC under contract no. DE-AC02-98CH10886 with the U.S. Department of Energy.
# olsen@bnl.gov

H-JET IMAGE CLIENTS

The hardware configuration is designed to allow responsive servicing of two different categories of clients for the Hydrogen Jet images:

- The first category of client is interested in getting complete image data at a rapid rate. An example of this type of client is a comfort display in the Main Control Room which displays images of the beam in near-real-time, and at about 15 frames per second. For this client we have a dedicated path to the control room via 1 gigabit fiber through a separate Network Interface Card (NIC) in the camera server computer.
- A second category of client can get the information it needs from lower resolution images delivered at a slower rate. For example, we have a script which gathers images at different stages in the accelerator cycle for packaging together into movies. These clients can run on any of the computers attached through a second NIC to the operations network.

CONTROLS INFRASTRUCTURE AT BNL'S C-AD

Linux is the primary operating system in use at C-AD for operator consoles, file servers and servers where processes called "managers" run. These managers are Linux processes which serve as collections of Accelerator Device Objects (ADOs) [3], which are themselves collections of control points. A manager is well-suited to the task of controlling and coordinating access to these cameras, which are single-user resources. It becomes the gatekeeper to the camera controls and the image data being returned from the camera, and is responsible for publishing the information to a dynamic list of possible subscribers, or other clients, which may have different requirements for how much data they need and how often they need it.

The cameras on each 1394 bus are managed by one instance of a beam imaging camera (BIC) manager process which provides access to each camera and the image data it gathers to various applications throughout the C-AD complex.

BIC MANAGER

The manager needs to serve the image data up to several different types of clients, so it provides different control points to manipulate capture and processing, and several different ways of viewing the data.

- Camera Settings – The DCAM specification includes a number of parameters which the camera manufacturer may implement, including: exposure, brightness, gain, shutter, gamma, sharpness, etc. The manager allows clients to view these values and change them within the camera's limits.
- Triggering – 1394 cameras typically accept hardware triggers. The manager can switch between hardware triggering, triggering on demand and triggering using the C-AD controls software event subsystem.
- Area of Interest (AOI) – The width and height of captured data can be decreased from the maximum delivered by the camera. In practice, for the H-Jet instance of this manager, we are often able to decrease the width of images from 1080 down to 700 and the height from 810 down to 700 pixels, which substantially reduces bandwidth and storage requirements.
- Image Characterization – The manager provides information about images such as horizontal and vertical projections and centroids.
- Image Enhancement – The manager can take and subtract backgrounds, it can also perform software averaging over a specified interval.
- Image Repackaging – In addition to providing a full-sized, full-speed image, the manager maintains a second copy of the image which can be scaled to a smaller size and can update at a slower rate. It also provides a capability to repackage portions of the image; at RHIC this is used to allow separate views of the beam in the Blue and Yellow rings.

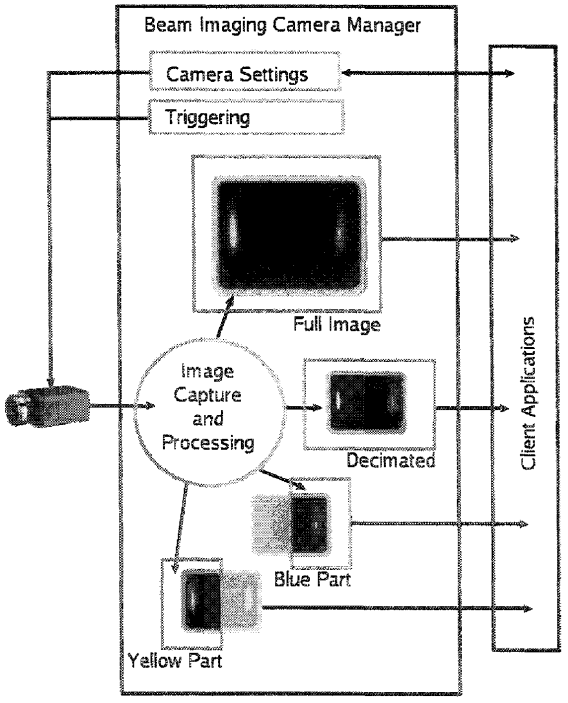

Figure 2: Beam Imaging Camera Manager Flowchart

BIC MANAGER CLIENTS

As in the specific case of the H-Jet above, in general a BIC manager instance will have different types of clients.

General Purpose Viewing Client

We have developed a simple image viewing application called bicview which can function in either of the two client modes, depending on how it is invoked. In the default mode of operation the user specifies a camera of interest and a connection is made to the appropriate manager, which will provide decimated versions of images received from the camera at a fraction of the rate at which they are acquired. The images are transferred using the standard C-AD controls infrastructure interface, called AdoIf[4]. For certain large images the display could not keep up with the rate at which the images were delivered. In this situation, rather than buffering images and allowing the display to fall behind, bicview drops intermediate frames to remain as current as possible.

Beam Analysis Client

C-AD has a general purpose application originally developed for using flags as profile monitors, which is used to analyze the images acquired by these cameras. This application also connects to the manager using the AdoIf interface. When used at RHIC it takes advantage of the manager's ability to repackage the image into parts to allow the blue and yellow beam to be considered separately.

PERFORMANCE

Dividing the clients according to bandwidth requirements and setting up the network to address their needs was successful. The client with a dedicated 1gigabit path was able to keep up with the roughly 200 megabit per second rate needed for full sized images at 15 frames per second (which we subsequently reduced by using the AOI feature of the manager). The display clients on the slower network benefited from being coded to drop frames so that the most current frames were displayed. This worked well for comfort displays.

SUMMARY

Libdc1394 provides access to industry-standard IIDC/DCAM cameras for Linux processes. We developed a manager and defined a network topology which successfully makes images from these cameras accessible to several different types of clients with very different bandwidth requirements using the C-AD controls infrastructure.

REFERENCES

[1] Douxchamps, Damien, Libdc1394: The API for IEEE1394/Firewire cameras, http://damien.douxchamps.net/ieee1394/libdc1394/.

[2] K.A.Brown, et.al. IEEE 1394 Camera Imaging System for Brookhaven's Booster Application Facility Beam, Proceedings of EPAC 2002, Paris, France, p.551

[3] L.T. Hoff, J.F. Skelly, Accelerator devices as persistent software objects, Proceedings of the ICALEPCS '93, Berlin, Nucl. Instr. and Meth. A 352 (1994) 185.

[4] S. Sathe, L. Hoff, T. Clifford, Client server design and implementation issues in the accelerator control systems environment, Proceedings of the ICALEPCS '95, Chicago, p. 142