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Design and performance of the data acquisition and control system of the TACTIC gamma-ray telescope

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The TACTIC gamma-ray telescope uses an interrupt-driven data acquisition and control system designed around a multi-node computer network, runing the QNX real time kernel. Apart from acquiring data from the 349-pixel imaging camera in real time, the system provides continuous monitoring and control of several vital parameters of the telescope to ensure its stable operation. With 10 concurrent processes running across the network, the system provides single-point control with elaborate GUI facilities for operating the multi-pixel camera of the telescope. A platform independent web based system is also being developed for the remote control and monitoring of the telescope. Quasi on-line analysis of the data recorded by the telescope is performed on a separate node to evaluate the data quality and to look for the presence of a gamma-ray signal on a nightly basis. The design and performance details of the system are described in the paper.

1. Introduction

The TACTIC (TeV Atmospheric Cherenkov Telescope with Imaging Camera) telescope[1] has been setup at Mt.Abu (24.6°N, 72.7°E, 1300m asl), a hill resort in western India for the study of cosmic gamma ray sources in the TeV (10^{12}eV) energy range. The altitude azimuth mounted telescope deploys a tracking light collector of $\sim$9.5m^2 area with photomultiplier tube (PMT) based 349-pixel imaging camera at the focal plane covering a field of view of $\sim 6°$x$6°$ with a uniform pixel resolution of $\sim 0.3°$. Each pixel comprises a 19mm diameter PMT (ETL make 9083 UVA) coupled to a light concentrator to enhance the sensitive area of the pixel. A hybrid zener based voltage divider network is used for each pixel to ensure its linear operation with a wide range of amplitudes of the Cherenkov flashes. A custom built multichannel computer programmable high voltage system is used for the online control of the gain of the individual pixels of the camera.

2. Signal processing

NIM based back-end signal processing hardware is used for amplification of the low amplitude PMT pulses and their subsequent amplitude discrimination. The threshold selected pulses are fed to a CAMAC based programmable trigger unit[2] for generating a trigger as per a user defined topological configuration. The trigger selected analog pulses are digitized by 12-bit CAMAC based Charge to Digital Converters (CDC) with a full scale range of 600 pC. The PMTs are operated at different high voltages to ensure their operation in a predefined single channel rate band which ensures the stability of the energy threshold of the telescope and also allows the use of the stable chance coincidence rate as a system health monitor[3]. The topological trigger generator looks for a coincidence among two or three nearest neighbour pixels within a coincidence gate width of $\sim$15 ns to signal the occurance of an Atmospheric Cherenkov Event (ACE). A high intensity fast LED located at a distance of about 1.5m from the camera face is used for the purpose of relative gain monitoring of the pixels. Four pixels located at the periphery of the camera have radio isotope (Am^{241}) based light pulsars fixed on them for monitoring the absolute gain of the camera. These pixels are operated at a fixed high voltage during all the observation runs and any variations recorded by their CDC channels are used as a measure of their absolute gain stability which is also periodically monitored by determining their single photoelectron peaks[4].

3. Data acquisition

As depicted in Fig.1 the data acquisition system of the TACTIC is designed around a network of PCs running a real time operating system QNX[5]. While one PC referred to as a gain control node is used to control the high voltages of the PMTs based on their scaler rates, the other PC referred to as the data acquisition node acquires the event and calibration data and also configures the trigger generators. These two front-end nodes along with the master node form the multinode data acquisition system of the telescope. The master node has elaborate GUI facilities and functions as a single point control console for the telescope and also stores all the acquired data. Two other nodes used for on-line data pre-processing are also linked to the same network. The Event Handler (EH) module is an interface between the CAMAC hardware and the inhouse developed application software. It accepts the various type of triggers generated by the TTG modules and provides three synchronous outputs for interrupting the data acquisition node, latching a real time clock and providing a 20 ns wide gate to the CDC. The system acquires the CDC data for the trigger selected ACE, calibration flashes, random sky noise and the absolute calibration data. The ACE is handled at interrupt level 3 while the relative calibration and sky noise data are acquired using interrupt level 4. The switching of the interrupts is managed by the EH under software control.

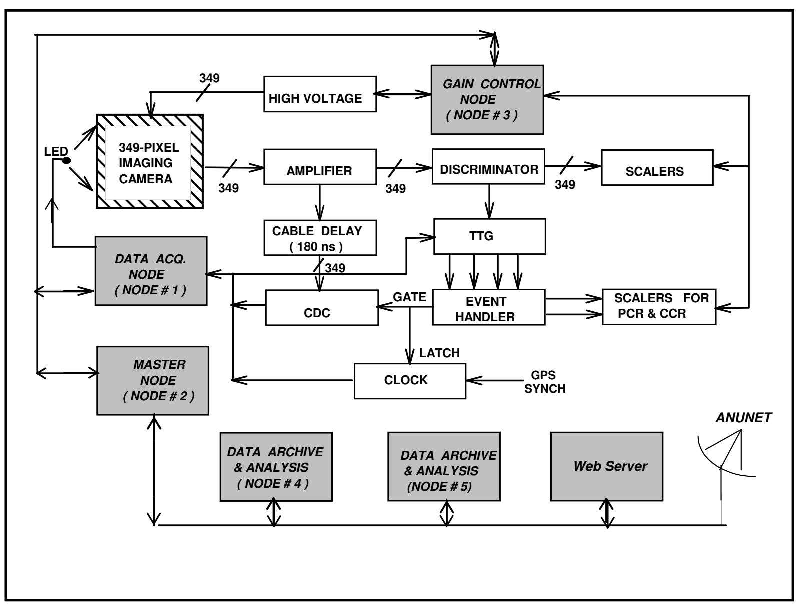

Figure 1. Block diagram of the back-end signal processing electronics used in the TACTIC imaging element; TTG:TACTIC Trigger Generator; PCR: Prompt Coincidence Rate; CCR: Chance Coincidence Rate.

3.1 Software

TACTIC data acquisition and control software is designed for the real time acquisition of event and calibration data and on-line display of telescope status in terms of prompt and chance coincidence rates and the shot noise rate of each of the 349-pixels of the camera. The software comprises around fifteen priority driven routines and device drivers stored on the master node which are spawned onto the front-end nodes as and when required. The main process called 'st_tactic' runs with highest priority on the master node and controls the execution of all other processes. This process is responsible for checking the network integrity and synchronising the network clocks at the beginning of observations. This master process communicates with other processes running on remote nodes to coordinate their execution by making use of interprocess communication facilities offered by the operating system.

A 'semaphore' has been developed under QNX to coordinate the functioning of multiple processes in the TACTIC software which are running on the same node and access common hardware. Prompt and chance coincidence rate processes which generate scrolling displays of these rates on the master node use the semaphore as they are running on the same node as the gain control process and use the same CAMAC bus.

The gain control process running on the gain control node controls the gain of PMTs by changing their high voltages on the basis of their single channel rates resulting from the ambient light induced shot noise fluctuations[3]. Since TACTIC does not have anode current monitoring hardware, single channel rate is used as an indirect method to keep track of the anode current of the PMTs to ensure their safe operation.

The data control process which runs on the data acquisition node controls two other processes running with the same priority on the local node. These processes acquire event and calibration data along with GPS referenced time informaton. The data control process makes available the real time clock data with microsecond resolution to all the processes which need it, by making use of shared memory. The data acquisition and control system generates $\sim$15 files at the start of the observation and adds 5 new files to it every hour. These hourly files contain information regarding Cherenkov events, relative calibration of pixels, sky noise values, single channel rate values and absolute calibration data. The size of each event is $\sim$708 bytes which results in 100 MB of data collection during a typical observation spell lasting five hours.

4. Remote operation

A platform independent web based system using the concept of 'virtual instrumentation console' is being developed to provide interactive control of the telescope from Trombay which is about 800 Kms away from the Mt. Abu observatory. The remote control system will provide location independent access to the data acquisition, control and analysis resources at the observatory using a dedicated 64Kbps ANUNET (Satellite based network) link. The system has two layers with the bottom layer having QNX based telescope data acquisition system linked to WinNT based web server using TCP/IP socket programming. The top layer has java client-server application using servlet communication to provide a rich user interface through standard internet browser. A remote daemon running in the background of the master node will accept connection requests from the web server and once the connection is established it will transmit current status information of the observation run to the remote client. X.509 certification will be used for server and client authentication. The web-server machine will use two network cards and a proxy server installation for internal network security from the outside world. In order to ensure effective utilization of the satellite network bandwidth the data and commands entered by the user on the virtual console will be transmitted to the remote site using very small data volume. Apart from the telescope control the system can also be used for audio-video interactions among the scientists at the two locations.

5. Performance evaluation

The data acquisition and control system of the TACTIC telescope has been working satisfactorily for the last few years and has detected few of the potential $\gamma-$ray sources including the standard gamma ray candle Crab Nebula whose energy spectrum in the 1.5-16 Trev energy band has also been determined accurately[6]. The data acquisition system can sustain an event trigger rate of $\sim$400 Hz corresponding to a system dead time of $\sim$2.5 ms which has been experimentally measured by collecting the relative calibration data along with the absolute time information. This finite dead time results in 1.23% loss of actual Cherenkov events while considering the event rate of $\sim$5 events s^{-1}. The gain control system which is a unique feature of the telescope has been recently updated to minimize the single channel rate stabilization time. It takes $\sim$7 minutes to bring the single channel rate of all the 349 pixels in a predefined band at the begining of an observation run while the subsequent stabilizations take only a minute or so and therefore allows the optimum use of the actual observation time for collecting data on a candidate $\gamma-$ray source.

6. Conclusions

A multinode interrupt driven data acquisition and control system has been developed for the TACTIC gamma ray telescope. The software for this system is distributed over 15 routines of C-code and runs on multiple nodes under the real time operating system QNX. The system provides GUI based single point monitoring and control from a dedicated node. The quality of the recorded data is evaluated on the data analysis nodes of the network and we also look for the presence of a γ-ray signal in the data on a nightly basis. The development of web based remote control and monitoring system will improve accessibility to the telescope resources. Preliminary tests have been conducted for the remote control of the telescope and a number of input forms and display screens of the master node have been transferred online to a work station at Trombay.

References

[1] A.K.Tickoo et al., Exp. Astron., 9 (1999), 81.
[2] S.R.Kaul et al., Nucl. Instr. and Meth. A, 496 (2003), 400.
[3] N. Bhatt et al., Meas. Sci. Technol., 12 (2001),167.
[4] A.K. Tickoo et al., Bull. Astr. Soc. India., 30 (2002), 381.
[5] QNX System Architecture by QNX Software Systems Ltd., www.qnx.com
[6] V.K. Dhar et al.,this conference.