BART: an intelligent GRB and sky monitoring telescope (2000-2004)

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Introduction

BART is a small intelligent robotic CCD telescope, devoted to rapid observation of prompt gamma ray burst transients. During its operation since early 2001, it had several prompt observations with world-competitive response time. The constraints to object magnitude were estimated and published in GCN circulars.

Telescope is located in Astronomical Institute of the Czech Academy of Sciences in Ondřejov. This poster describes also its new control system, named RTS2, which is in service since February 2003.

Automatic operation of the telescope includes observing, dark and flat field obtaining, roof operation, basic image analysis, creation of the archive and also camera temperature maintenance, device switch-offs during non-observing periods or heating the optics for dew prevention when needed.

There are four separate optical systems used for detection of an optical emission with CCD: Main tube, 25 cm Schmidt Cassegrain equipped with filter wheel and field of view 22 arc minutes; two identical WF (7°x5°) cameras using different filters (I,R) and a 300 mm lens with field of view about 2 degrees.

BART is well suited to provide follow-up optical observations of GRBs detected by INTEGRAL and other satellites. The experiment is also capable to provide simultaneous and quasisimultaneous optical data for selected targets observed by INTEGRAL.

History

BART was observing in Ondřejov since April 2001, using it's old software called RTS until February 2003, when the new, completely rewritten version came into service. Majority of it's errors have have been tracked down. System is running there in semi-automatic mode, with staff available to check it 24 hours a day. The restriction is given by the lack of weather sensors, thus the need of person to watch the weather nightly.

The instrumentation also develops slightly: the original setup consisted of one wide-field lens on top of the main tube, the second WF with I filter has been added together with new version of software. A 300mm lens with large format CCD has been added recently and is under testing.

GRB receiving

Primary GRB receiving is done through a dedicated client. It connects through socket to a GCN server in NASA-GSFC. If it gets a GRB event, which is currently visible, it asks central server for priority, moves the mount and after it finishes, it asks for camera exposures. Pictures from cameras are downloaded during readout through network to computer running the GRB client. There they are stored, get WCS, and stay in database.

In case of socket connection failure, backup system uses reliable e-mail receiving. GRB event is then observed from main scheduler. Main scheduler also takes care of observing GRB error box, which were below horizon when they occurred, or which were received when system wasn't operational due to bad weather conditions.

Derived instruments

Although nearly all the possible time observing, BART system is intended especially as a developing device for it's 24/7 staff availability. There are several derived experiments based on software developed on this platform including BOOTES and BOOTES2 which already showed their possibilities while observing GRB optical transients. There's close collaboration between BART and BOOTES people.

Some results

Several GRB events were followed, the more important for us shows the following table. There were several others alerts which were followed, but those have had much worse delay.

Of these events the most unlucky and exceptional is the first event of 11 November, when the telescope really followed the GRB within 30s after burst, but the very nearby moonlight destroyed most of the images. the only usable are images from the second phase of observing where the limits might be finally set.

GRB #	BART delay	Total delay	limits	notes
GRB 020124	10h	11.5h	R>14	long HETE delay
GRB 020305	30m	10.5h	R>14.3	30 minutes waiting for night
GRB 020317	90s	58m	R>13.5	dark GRB
GRB 020331	4.8h	5.5h	R>12.5	daytime GRB, bad weather
GRB 030824	30m	10.5h	R>14.3	
GRB 031111A	15s	30s	I>13	overexposed, limit for T=4h
GRB 031111B	16s	1.2h	R>14.5, I>14.2	close to the Moon
GRB 031216	11m	11.2m	R>15.0, I>14.6	

RTS2 - the operating software

RTS2, the operating software, is designed as a networked system for driving robotic telescopes. It is composed of several device servers, central server and various observational clients cooperating over a TCP network. Observation entries, requests and results are kept in database. Positions of GRBs are received from the Internet and observed either in prompt mode, or added to list of observation targets, depending on weather and other conditions influencing the observation. The idle time, when there is not any request for GRB observations, spends the telescope monitoring various active galaxies. The database lookup entry point is accessible at http://lascaux.asu.cas.cz/bartdb.

System code

The system consists of three kinds of programs:

central server
server/client programs for accessing and controlling devices like cameras, telescope or weather controller paired with dome/roof controller
client programs to control an observation - currently there is scheduler client for regular observations, gamma ray burst client for prompt observations of GRB optical transients, console based monitoring client, stream based monitoring client and focus client for camera focusing

Central server holds list of all connected devices and clients. Every new device register to central server in order to be accessible to clients, and every client connect and authorise itself to central server in order to be able to access devices.

Access to devices is priority-based - only client with the highest priority can access state-changing functions of a device - such as mount moving, or exposing and readout of camera. During a long-running operation, if a client loses priority, the operation is cancelled and devices are able to serve a new request of a client having higher priority. That is important for GRB observing, where the lowest response time is the most tentative criteria.

Priority requests are being sent from clients to the central server. It holds a list of priorities of all connected clients. If it finds that the priority has to be changed, it informs all connected devices about such change.

We are able to control whole family of SBIG parallel port based CCD cameras. We work on USB based SBIG, Apogee and FLIcam CCDs. We are able to control LX200 family of telescopes by Meade, and we have an alpha level driver for the Paramount.

Implementing a driver-layer of nearly any device daemon should be relatively easy thanks to a well-elaborated design of the upper layers.

System operation

Main scheduler takes care of obtaining pictures for flat-fields during dusk and dawn. It also obtains dark-frames at predefined time interval.

Composition of system can be at best understand from an example. On Figures 2 and 3 is described current configuration of Ondřejov BART.

Lascaux is an 2GHz Intel Celeron PC compatible computer running Debian GNU Linux. There resides central server, database, web server for database access and from there observations clients are usually run.

Other PCs are low-end Pentium or 486 class computers. They run stripped-down Debian, which occupies vast majority of theirs hard-drive.

Documentation

The whole RTS2 package is available on request to download, with complete source code included. There is slow progress on manual pages for whole system, but we expect to improve manuals as we don't have to track any errors now.

The code is covered by GNU license, which enables anybody under modify it, if certain conditions are being held.

The system development is tracked in CVS versioning system. RTS2 uses GNU automake and autoconf tools for Makefile creation.

Addresses

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BART database http://lascaux.asu.cas.cz/bartdb
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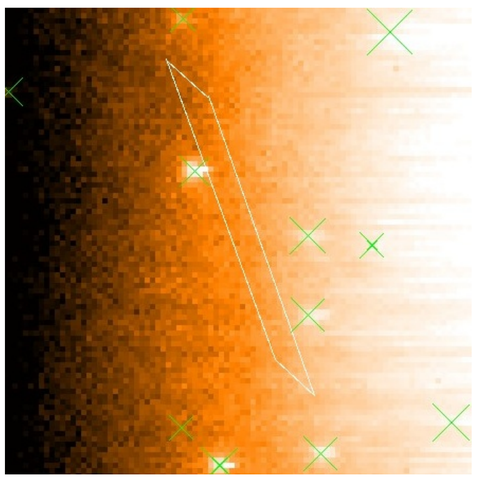
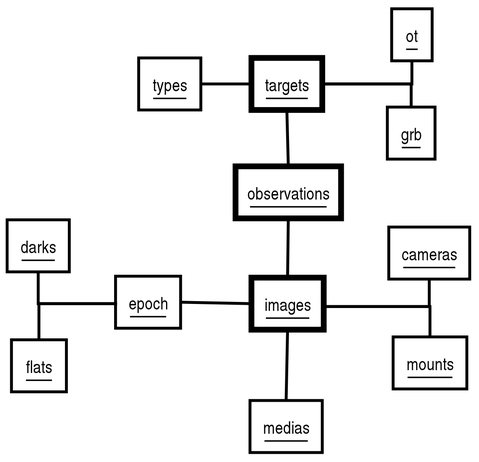
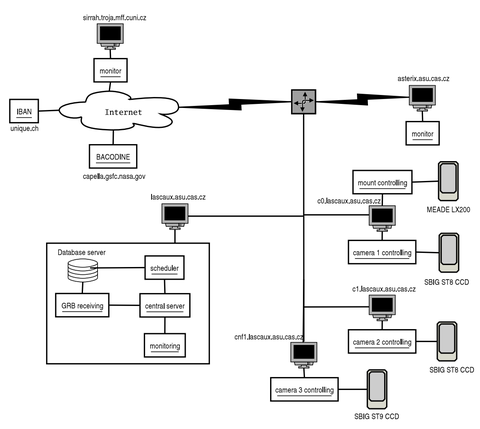
BART - telescope picture



GRB031111A I filter image 25'×25'



Database structure overview



BART - system structure