Software design for the TAIGA-IACT telescope pointing and control system

Dmitry Zhurav, Oleg Grez (for the TAIGA Collaboration)

1. Introduction

The TAIGA observatory (TuRkA Advanced Instrument for cosmic ray physics and Gamma Astronomy) is located in TuRkA valley at a distance of 50 km from Lake Baikal. The TAIGA observatory is a complex system of ground-based extensive air showers detectors. It consists of various types of detectors, including wide-angle detectors of Cherenkov light, radio antennas, detectors of electrons and muons of EAS. In December 2016, the First Image Atmospheric Cherenkov Telescope TAIGA-IACT was installed in the TuRkA valley. On the 2016-2017 data taking season only 6 of the 34 reflector segments is installed on the telescope.

2. Telescope Hardware

- Reflectors: 547 PMTs
- each PMT in a Winston cone
- FoV 10° x 10°
- angular res. 0.36° per pixel
- 8 LEDs around the perimeter

3. CCD-camera

- Proscica GC1380
- Computer 16nm Camera
- Camera Lenses 1:1.4 2/3" 04K
- 1360 x 1024 pixels
- 12-bit ADC
- FoV 30.8x23.4°
- 16-bit ADC 16 bit/pixel
- Exposure time 1 µs – 1 min
- Controlled over Ethernet

4. Drive system

- Phyron stepper motors
- 2 gearboxes
- Gear ratio 2000
- Axis res. 0.001° per step
- Micro step mode up to 1/152
- Controlled over Ethernet
- 2 limit switches on each axis

The first TAIGA-IACT Telescope installed in TuRkA valley. Picture taken in April 2017.

3. Software used for development

The following software is used for telescope pointing and control system development:
- EPICS – Experimental Physics and Industrial Control System
- SOFA – Standards of Fundamental Astronomy
- Astrometry.net software
- As framework for development of the telescope control system a set of software tools EPICS is used.

4. CCD-camera Image Processing

To accurately determine the direction of the telescope in celestial coordinates using the CCD-camera images a number of calculations should be performed.
1. To determine the position of the Cherenkov camera center eight LEDs are used, each of which is equidistant from the camera center. The position of the LEDs is estimated as the center of gravity of their light distribution taking into calculation the pixels exceeded the existing threshold above the background.
2. To mapping the obtained positions of the Cherenkov camera to the celestial region of the image in the pixel coordinates a transformation is used, that parameters are determined experimentally.

3. World Coordinate System (WCS) transformation parameters can be determined through astrometry.net software and index files based on the astronomical catalogue Tycho-2.
4. Using the transformed camera center position and WCS parameters the direction of the telescope in the RA-Dec coordinates is calculated.
5. The SOFA software libraries are used to determine the azimuth and altitude angles of the source.

5. Conclusion

The first Image Atmospheric Cherenkov Telescope TAIGA-IACT was installed in the TuRkA valley in December 2016. The Proscica GC1380 CCD-Camera is installed on the telescope for the pointing calibration and it’s position allows capturing both the Cherenkov camera and the observed source. A set of software tools EPICS was used to development the control system for the drive system and the CCD-camera control. The image processing software allows to determine the telescope position on-the-fly. Tracking with feedback from the CCD-camera was implemented. After commissioning the first TAIGA-IACT telescope it will operate using the shield encoders feedback and a pointing model. By 2019, it is planned to install 2 more IACT telescopes distanced at a distance of about 600 m from each other.

6. References

[1] N. Budnev et al. (TAIGA Collaboration) The TAIGA observatory - a hybrid detector complex for high energy gamma ray astronomy and cosmic ray physics in the TuRkA valley. These conference
[2] L. Sveshnikova et al. (TAIGA Collaboration) Commissioning the joint operation of the wide angle high energy IACT Cherenkov array with the first IACT of the TAIGA experiment. These conference
[5] L. Sveshnikova et al. (TAIGA Collaboration) The Search for gamma emission above 50 TeV from Crab Nebula in the TAIGA observatory. These conference