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GLORIA - Global Robotic Telescope Intelligent Array

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Abstract: GLORIA is the first free and open access network of robotic telescopes in the world. Using a dedicated Web 2.0 environment GLORIA users will soon be able to do research in astronomy by observing with robotic telescopes, and/or by analysing data that other users have acquired with GLORIA, or from other free access databases, like the European Virtual Observatory.
GLORIA project will define free standards, protocols and methodologies for doing observations with robotic telescopes and analysis of astronomical data. Free software packages, guidelines and support will be offered to users doing observations (on-line experiments) and data analysis (off-line experiments) within the network. Dedicated analysis environment LUIZA has been created for flexible analysis of astronomical images.
GLORIA research-level off-line demonstrator experiment is presented, based on the selected data from the Pi of the Sky telescope in Chile. Thanks to the wide field of view of the telescope the image sample allows for variability analysis of bright objects of different kind. Analysis is done using the LUIZA framework, designed within GLORIA for efficient analysis of astronomical data.

Keywords: Robotic telescopes, Research network, Web 2.0, Citizen science

1 Introduction

GLORIA stands for "GLObal Robotic-telescopes Intelligent Array" and will be the first free and open-access network of robotic telescopes in the world. It will provide a Web 2.0 environment where users can do astronomical research by observing with robotic telescopes, and/or analyzing data that other users have acquired with GLORIA, or from other free access databases, such as the European Virtual Observatory.

2 Benefits of network

Users with no telescopes will have access to a large number of robotic instruments in the network with dedicated web applications. During the three years of the project, at least 17 telescopes will be integrated into the network, with 12 of them currently being operational.

Telescope owners will be able to use software tools provided by GLORIA to robotize their telescopes, to do observations and analyse the data. They will be also invited to join the network, dedicating some of their observation time for other users and gaining wider access to network resources.

GLORIA project will define free standards, protocols and methodologies to allow citizen and professional scientists for controlling Robotic Telescopes and related instrumentation (cameras, filter wheels, domes etc) and incorporating them into the network. Dedicated tools will be developed for conducting so called on-line experiments by scheduling observations in the telescope network, and for conducting so-called off-line experiments based on the analysis of astronomical meta-data produced by GLORIA or other databases. All standards, software and documentation developed by GLORIA will be offered to the community under free licence to use, distribute and modify.

3 On-line experiments

GLORIA provides the mechanism for users to access and control the telescopes remotely and make observations. Web authoring tools will enable users to create their own online experiments. Two types of experiments will be available:

Interactive – with users getting direct remote control of the telescope functions,

Batch – when users send requests for target observations via the web interface and the network performs them automatically.

Batch mode of operation results in much more effective usage of network resources. Dedicated Observation Time Scheduler will be developed to prepare optimal observation schedules for all telescopes in the network. This is a highly non-trivial task for a network of heterogeneous telescopes.

The TAD (Telescopio Abierto Divulgacin) robotic telescope at Observatorio del Teide in Tenerife (Canary Islands)

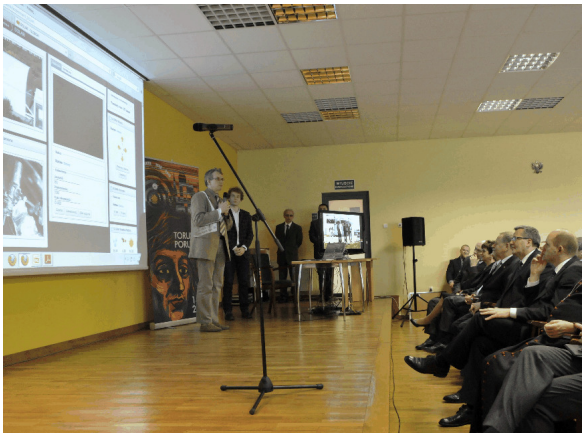

Figure 1: Symbolic opening of the GLORIA Network to users in the presence of the President of Poland. Toruń, April 25, 2013.

was the first GLORIA telescope made available to users. Symbolic opening of the GLORIA Network to users took place on April 25, 2013, in the presence of Bronislaw Komorowski, the President of Poland (see figure 1)

An important aspect of GLORIA's operation will be the capability to respond autonomously to alerts regarding new astrophysical events such as supernovae and gamma-ray bursts. A standard Alert programming interface will be designed for GLORIA's scheduler to allow the network to respond to these events. The message carrying the observational request is sent to one or more participating robotic telescopes to optimise the follow up observations by the network.

4 Off-line experiments

Off-line experiments are the experiments which are based on the analysis of existing astronomical data and do not require new, dedicated observations (no observing time is used). GLORIA's archival and other public data-bases can be used to carry out various astronomical research by professional, amateur and citizen scientists. Dedicated analysis framework LUIZA[3] has been developed for efficient data analysis in GLORIA. GLORIA will also offer a web environment for analysing meta-data similar to the European Virtual Observatory and Galaxy Zoo.

One of the challenges we have to face in designing environment for GLORIA off-line experiments is dealing with huge amounts of data and large variety of analysis tasks. We need an analysis framework which would be both very efficient and very flexible. These are requirements new to astronomy, however high energy physics experiments deal with enormous amounts of data and complicated analysis tasks since many years. LUIZA framework for GLORIA was based on the Marlin[2] package developed for the International Linear Collider (ILC), data analysis. Dedicated data classes, compliant with FITS (Flexible Image Transport System)[4] data file format, were developed for internal storage of images and data processing results. Within LUIZA, data analysis is divided into small, well defined steps, which are implemented as the so called processors. The main advantage of this solution is its flexibility. The idea is to develop a large number of processors in GLORIA, doing many different tasks, so user is always able to find a set which matches his needs. He is then able to define the whole analysis chain at run time, while LUIZA secures consistent data flow between processors. Possible types of offline experiments which could be implemented in GLORIA include:

- Classification of variable stars
- Evolution of variable stars with time
- Optical transient searches
- Occultations of stars by solar system objects

As with online experiments, we plan to develope web authoring tools, which will allow users to create their own offline experiments.

5 Off-line demonstrator experiment

Demonstrator experiments are implemented in GLORIA to present the capabilities of the analysis and web tools developed within the project. GLORIA research-level off-line demonstrator experiment is based on the selected data from the Pi of the Sky telescope in Chile. Thanks to the wide field of view of the telescope the image sample allows for variability analysis of bright variable objects of different kind. Analysis is done using the LUIZA framework.

Image analysis in the proposed demonstrator experiment is done in two steps: image preprocessing, which includes object finding and astrometry, and object light curve reconstruction. Preprocessing is done only once, while setting up the experiment (or whenever new data are added), and the object light curve reconstruction is run in response to each user request submitted via the web interface.

To trigger light curve reconstruction, user has to specify position of the object in the sky, as well as reference star selection and calibration parameters. As a response, server will send the light curve table with 3 columns: time (HJD), reconstructed magnitudo and estimated magnitudo uncertainty. Uncertainty estimate, calculated from comparison of multiple reference stars, can be used to remove bad quality measurements (eg. due to bad weather conditions or strong background). This is demonstrated in figure 2, where the distribution of the estimated uncertainty and the influence of the cut on the estimated uncertainty are demonstrated for the selected constant star. An example of the phased light curve of a variable star (RS Ori - classical Cepheid, delta Cep type), as reconstructed in the described demonstrator experiment, is shown in figure 3.

6 Outreach and education

In order to awaken interest in astronomy and publicise the GLORIA network, GLORIA carries out Internet live web broadcasts of most important astronomical events. Three such broadcasts were organized so far:

- Transit of Venus, June 6, 2012,
- Aurora borealis, August 24-28, 2012,
- Total Solar Eclipse, November 13, 2012.

In addition, all partners of the GLORIA network organized educational activities in their countries, providing additional

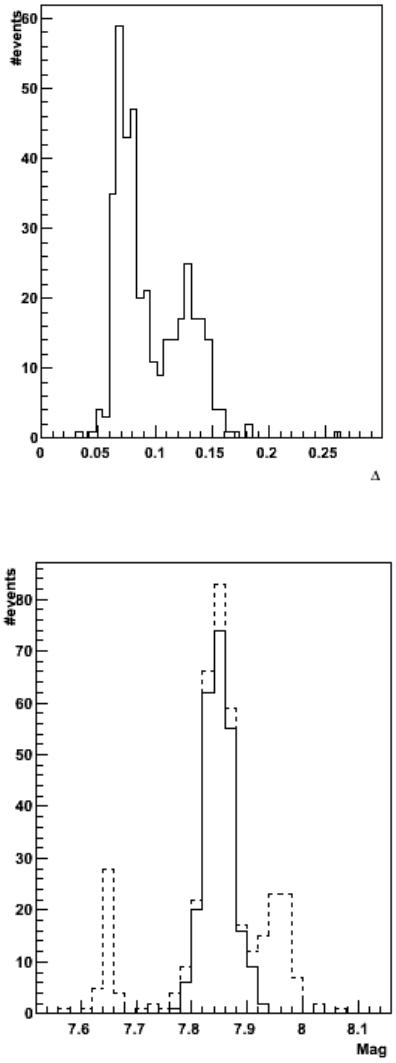

Figure 2: Top: distribution of the estimated calibration uncertainty Δ for selected constant star. Bottom: magnitudo distribution for selected star before (dashed line) and after (solid line) the quality cut $\Delta < 0.1$.

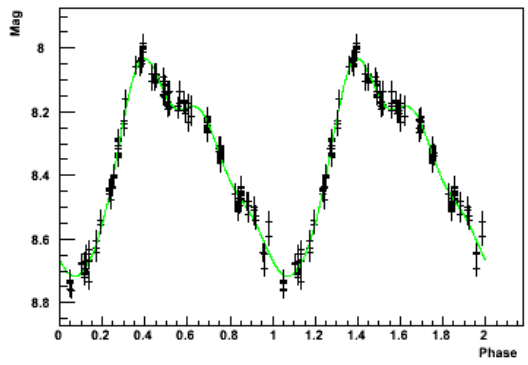

Figure 3: Phased light curve of RS Ori, classical Cepheid (delta Cep type), as reconstructed in the GLORIA off-line demonstrator experiment.

educational resources and support during the events. Amateur astronomers were also invited to contribute to the collected resources. As an example, about 500 photos from users all over the world were collected in an Venus-Transit outreach action. Two major events are still to be broadcasted by GLORIA:

- Total Solar Eclipse, November 3, 2013,
- Total Lunar Eclipse, April 15, 2014.

7 Conclusions

GLORIA is the first free and open-access network of robotic telescopes in the world. Using a Web 2.0 environment users can do astronomical research by observing with robotic telescopes, and/or analyzing data that other users have acquired with GLORIA, or from other free access databases. GLORIA project defines free standards, protocols and methodology for controlling Robotic Telescopes and related instrumentation and for conducting on-line and off-line experiments.

An efficient and flexible analysis framework for GLORIA has beed developed based on the concept taken from the high energy physics. Basic data classes, framework structure and data processing functionality are implemented, as well as selected data processing algorithms. The framework was used to set up the research-level off-line demonstrator experiment focusing on light curve reconstruction and classification of variable objects, based on the preselected data from the Pi of the Sky telescope in Chile.

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