



The Kyiv internet telescope project

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Abstract. We present a description both of the hardware and of several software packages that have been developed. The system uses a Celestron -1400XLT optical tube installed on a WS240GT mount. Images are taken with a fast 14-bit 512*512 pixels Rolera MG CCD camera, and the telescope is equipped with UBVRI filters and GPS timing. The whole system can be operated fully automatically during a defined observational task or during an entire night according to a schedule.

Keywords : automatized telescope – hardware – software – observations

1. Introduction

More than 120 telescopes have registered at the Robotic Telescope Projects website¹. There are telescopes with different levels of robotic control for various astronomical tasks. Astronomical observatories with a robotic control are widely described by (Strassmeier et al. 2004). The realization of such projects in the last decade of the 20th century is connected with the progress in CCD detector technology. Thanks to the Science Technology Center of Ukraine and the National Academy of Sciences we purchased basic equipment for the robotic telescope project of the Kyiv Internet Telescope (KIT). The telescope is capable of making previously scheduled observations of the targeted objects during a night. It is equipped with both stock-produced items and self-designed hardware and software.

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¹At <http://www.uni-sw.gwdg.de/hessman/MONET/links.html>

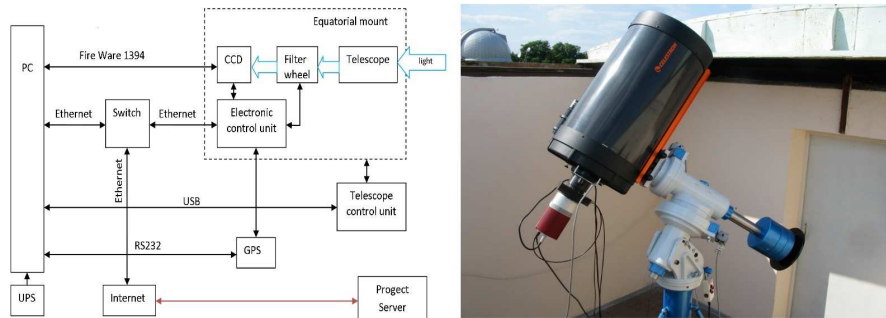


Figure 1. Block diagram and view of the Kyiv Internet Telescope.

2. Hardware

The 14-inch Schmidt–Cassegrain tube (356 mm) is a Celestron–1400XLT on a WS240GT equatorial mount, manufactured in the Ukraine and controlled by an ASCOM driver. The telescope is equipped with a QImaging Rolera MG_i CCD camera, which uses a 512×512, 16 μm pixel L3Vision Frame-Transfer EMCCD from e2v Technologies. This back-illuminated detector combines >90% QE in the 500–650 nm range and is capable of capturing 300+ frames per second with binning and ROI. The system has a field of view of either 7.2×7.2 arcmin with a scale of 0.8438 arcsec per pixel or 10.65×10.65 arcmin (scale of 1.2475 arcsec per pixel) with a focal reducer f/6.3 and it requires accurate pointing. The filter block has a filter wheel for 8 positions: the standard UBVRI Johnson–Cousins system, a clear glass filter, a dark and an empty window. The optical tube has been equipped with a homemade focuser, and an Acutime 2000 GPS receiver allows us to fix the UTC time of each exposure to an accuracy of 1 μsec .

We would like to locate our telescope at a site with good astronomical climate after the modules tests are finished. During the project development, the telescope facilities were located at the Holosiiv Observatory in the south of Kyiv. It is well known that a drawback to observations near large cities is the very high level of light pollution. The poor weather conditions of our climatic zone (about 60–70 clear nights without Moon per year) do not give us possibilities to obtain rich and accurate observational data, but does allow us to develop and test both new necessary components and operational software.

3. Software of the KIT

The telescope mount can be controlled in two ways. The first uses a hand control, connected to a PC by a custom RS-232 cable, and allows aiming the telescope and checking state. This allows initial mount alignment to be done manually, and was implemented only for the CGE mounting. The second way is full control of the tele-

scope with the help of a special ASCOM driver² and its command library. The last variant provides more universality and supports various mounts.

The software complex consists of the main control module (MCM) and separate device modules. Information about the telescope state and observation results is dispatched in real time to a remote server by a built-in web server. We decided to make each module as a separate fully-functioning program under the Windows operating system, for convenience during development, for the ability to replace devices, and for the ability to operate the system without all parts running. Each module has the ability to work in an autonomous mode without interaction with other modules or in a complex regime administered by the MCM. Mixed control variants are also possible, under which modules are partly automatic and partly under manual control. This structure turns out to be more error resistant. The basic information of the system's complex operations and individual module configuration is saved in the Windows registry, giving us necessary flexibility. Replacing individual modules is simply a matter of changing the registry information such that different modules are loaded. This approach makes it easy to obtain module service information in order to organize the data exchange between individual programs.

3.1 The operating algorithm of the telescope program-apparatus complex

The operating principles of the program complex took into account the main features of the robotic telescope. The Program administration ability of the total complex and separate devices manual control, semiautomatic and automatic regimes belong to these features. On the other hand there is intensive data exchange with the Web-server. The schedule of the telescope operation is received from the Web-server by the remote access and results of the observation and information about status of the telescope are sent to the server data base (Kleshchonok et.al. 2008). Interface to the individual telescope devices are established during module initialization. The operating schedule can be received either from the web-server or a local file according to an operator command. Each task in turn is selected automatically, splitted into sub-tasks which are sent to the separate devices by the central module. After the preparatory operations (telescope pointing, filter setting) are complete, an exposure start command is sent with all the necessary parameters (duration, number of frames, binning, etc.) To speed up the operation, it is possible to take a series of frames with identical parameters. When the camera module signals the MCM that the observation is complete, the MCM selects the next task from the schedule, and the cycle continues in this manner until the schedule is finished. Module state information and overall telescope state is transmitted during task execution. An observer may select some modules for manual control, at the same as other modules are operating under the automatic control of the MCM.

²At <http://ascom-standards.org>

3.2 The main control module (MCM)

The MCM program is named *ccenter.exe* and is written using the Delphi language. It has the following functions: (1) it loads other modules, (2) it follows the total observation schedule execution as well as the execution stages of individual observing tasks, (3) send commands to the separate modules and receives information from them, (4) keeps the protocol of the schedule execution and the technical protocol of the complex operation. The MCM displays the state of the individual devices, information that the web-server transmitted and the most recent CCD camera image. The MCM provides numerous schedule manipulation possibilities: to edit the task schedule, to combine several schedules, to clear a schedule, to change a task order, to insert tasks, and to initiate special cycle tasks with termination conditions such as time or cycle number.

3.3 The telescope module (TM)

The telescope module can be loaded automatically by the MCM or manually by the observer. The MCM transmits to the TM information about object coordinates and coordinate epoch. The TM returns information about the telescope state, real telescope coordinates and messages about termination of the aim process. Once the telescope is aimed, the TM automatically starts sidereal tracking. In order to improve the accuracy of the telescope coordinates one can use the '*Synchronize*' command with the help of objects in the field of view. The TM has a list of the bright stars for the initial alignment procedure which is important at the beginning of the telescope's operation. The information about connection status of the telescope and MCM, local sidereal time, horizontal and equatorial coordinates and telescope state is shown in the program window.

3.4 ROLERA MG*i* camera module (RCM)

QImaging's digital cameras are equipped with a programming interface, which allows users to create their own software. The inner structure of the hardware and software is inaccessible thus we have to use the QCam API which is available for Windows and Mac OS X systems. We developed our own software under Windows XP using the QCamDriver DLL and QImaging SDK. The QImaging corporation recommends the use of either C or C++ languages, and a C/C++ header file is included in the SDK. Our program module RCM is written in C++. The RCM can automatically find any QImaging digital camera and tries to set up a connection with them. RCM allows two different operating regimes: - independent from the MCM, in which the RCM requires all camera parameters, such as exposure, gain etc. to be manually set - interacting with the MCM, when RCM receives all exposure parameters from the control Center. MCM sends to the RCM following parameters: (1) exposure, (2) camera gain, (3) the

number of frames one wants to capture, (4) the region of interest (ROI), (5) start. In addition to these, the following parameters (displayed in the image file header) are sent: (1) a unique number that is used as the image file name, (2) the coordinates of the celestial object (3) the name of the celestial object, (4) the UTC system time, (5) the type of the filter, (6) the nick-name of the observer. After image capture, the RCM creates an image in the predefined format (usually FITS), then sends a message to the MCM to say that the exposure is accomplished. The RCM also writes to the FITS file the parameters of the telescope focal distance and aperture and some parameters of the Rolera MG camera.

3.5 Filter block module (FBM)

The filter block software manages the filter unit according to the instructions received from the MCM. The FBM is written using the C++ program language and uses the standard UDP protocol for communicating with the Elexol micro-controller that manages the filter device. The FBM regularly checks the status of the network connection to the Elexol notifies the user immediately if the connection is lost. The FBM has the same two operating regions as the RCM: independent and interacting with MCM. In the independent mode user may set any filter manually. Usually the FBM receives a filter name from the MCM and sets the corresponding filter. The FBM also tests the network connection (and monitors the Elexol micro-controller) by sending special echo signals to the Elexol micro-controller. On shutdown, the FBM sets the opaque filter, to reduce the possibility of mechanical damage or filter contamination.

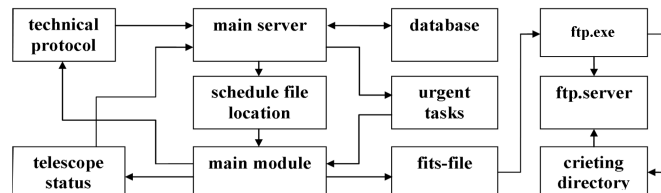


Figure 2. Communication module perform scheme.

3.6 Communication module (CM)

The communication module, entitled '*netd*', (Fig. 2) provides data exchange with the Main Project Server (MPS). The CM is a part of the software complex, installed on the computer which operates the telescope. Tasks performed by CM: (1) communicating with the MPS, (2) connecting to the MPS in order to receive the night's observing schedule, (3) recording such schedule to the local hard disk, (4) receiving technical information from the main module and recording it to the database, (5)

receiving information about the current telescope state from the MCM and recording it to the database, (6) uploading the observation FITS files to the ftp-server, (7) periodic revision of the schedule (new urgent tasks, for example, gamma-ray bursts, etc.), (8) informing the MCM about such changes. The CM consists of two programs: *ftp.exe* and *netd.exe*. The *Ftp.exe* program is responsible for transferring files to the project ftp-server, performs the above mentioned tasks and manages the work of *ftp.exe* work.

4. Server

The project server is designed and implemented as an Internet robotic telescope. The main functions of the project server (Kleshchonok et.al. 2008) are to provide information to Internet users, to connect with the telescope, to store and retrieve observation data and to grant access to the schedule parameters. The server provides the website <http://unit.univ.kiev.ua>, which consists of two parts: public - for all Internet users and private – for the registered users. The public part contains information about UNIT and the Kyiv Internet telescope project and useful astronomical data. The project server allows us to solve the following additional problems: the editing and displaying of observation schedule for the current night; access to the observational data at the FTP server; recording various pieces of information received from the telescope to a database; and organizing data exchange with the telescope. We use PostgreSQL as the database. Results of the observations are stored on the authorized FTP server.

5. Conclusions

The Kyiv Internet Telescope will be dedicated to monitor extra-solar planets and stellar variability, although it could also be used for research on selected objects and short-lived events. Many series of observations confirmed it. KIT also provides a promising approach in astronomical education. The line of future development will be in the combination of new devices with the basic KIT.

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