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Inside/Outside dome monitoring video system of the 6 m optical telescope BTA

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Abstract. A system for distant video monitoring observations with the 6 m telescope has been created. It allows real-time check of the telescope position and illumination inside the dome along with estimating weather conditions at the BTA site from any computer connected to the Internet.

Key words: telescope — techniques: camera — site testing

1. Introduction

The control of the position of the 6 m optical telescope during observations and also at any time the telescope moves is performed by a group of operators on duty. Since the operators were moved to another location from which the visual inspection of the telescope is impossible, it became necessary to apply systems of video monitoring of the telescope inside the dome and transmit the video signal to the BTA operator on duty. This was difficult to implement because the serial video cameras of Closed Circuit Television (CCTV) systems have low sensitivity. The position of the telescope needs to be controlled day and night. The difference of illumination between the daytime condition, when the dome shutter is open, and the night time condition, when it is dark inside the dome, is not less than 6 orders (10^6). The overwhelming majority of CCTV cameras have no such a dynamical range and are not sensitive in the darkness without IR illumination. The problem was solved with the aid of a special CCD camera. The description of this TV guide is presented below.

Another visual checking, which is necessary not only for the BTA operators but also for the astronomers during observations, is the monitoring weather conditions at the telescope site. By the present time this kind of monitoring has been executed by circular external sky viewing above the BTA based on the SIT television camera (Komarov et al., 2002a). This camera allow one to see the night sky above the BTA. By day time the camera was switched off since, because of the high sensitivity, its photocathode could be burnt out. For the round-the-clock monitoring of the astronomical climate in the vicinity of BTA it was necessary to use a TV guide operating in a wide range of illumination, but in contrast to the former version of the inside TV guide, such a camera must be of still higher sensitivity to see the night cloudiness and stars up to 6 stellar magnitudes. Thus, to solve this problem, a CCD video camera with a dynamical range up to 8 orders (10^8) is needed (Komarov et al., 2002b).

The authors solved this problem by creation of a video channel described below in section "Outside". This channel made it possible to carry out round-the-clock monitoring of the BTA outdoors. Such an external viewing of cloudiness permits the observer to select a sky region knowing the data on weather conditions, and promptly solve the problem of pointing the telescope to cloudless sky regions (Balega et al., 2002).

2. Night sky monitoring with world's optical telescopes

Similar systems, but only for the night monitoring of the sky are used at the following observatories (Komarov et al., 2002c):

- Kitt Peak National Observatory in Arizona, USA;
- Mauna Kea Observatory in Hawaii, USA;
- Rosemary Hill Observatory in Florida, USA;
- Mt.Wilson Observatory in California, USA;
- Wise Observatory in Israel;
- European Northern Observatory in the Canary Island, Spain, off the coast of Africa.

The night sky images transmitted from them are unified into Internet and a common net CONCAM (Nemiroff & Rafert, 1999). The images can be seen on the web site "The Night Sky Live" — http://www.concam.net.

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3. Remote mode of observations with the BTA video server "sky"

The system of remote video observations of the 6 m telescope and the round-the-clock monitoring of astronomical climate at its site is based on the BTA digital television complex (Vitkovskij et al., 2000a). This video net digitizes television signals from all the TV guides of the telescope. The video server "sky" is located in the BTA operating room, where all the main lines from the 3 foci come to.

At the present time the video server "sky" is processing the images from the following TV guides at the BTA foci (Komarov et al., 2002d):

- TV cameras at the prime focus (PF);
- TV guide of the field at the Nasmyth 1 focus (N 1);
- TV guide of the field at the Nasmyth 2 focus (N 2);
- TV guide of the slit at the focus N 1;
- TV guide of the slit at the focus N 2.

For service support and for monitoring the telescope position and weather conditions in its location additional channels were required:

- television camera of the TV-Guider;
- video cameras of observation and communication in the operating rooms;
- outside dome camera for monitoring of the day/night sky;
- inside dome camera for monitoring of the telescope operation.

The television signal in the video server "sky" is digitized by a video controller VS60 produced by the company "Videoscan" (Komarov et al., 2002a).

The frame grabber VS60 is a video controller for digitizing a black-and-white or coloured television signal with input of the obtained images into the computer.

The controller VS60, in contrast to the grabber VS56 used earlier, operates with bus PCI, which makes it possible to increase the speed of digitizing the TV frames (up to 12 frames per second with a resolution of 768×576). The operation of the frame grabber within the digital television complex of BTA and its basic parameters are described in detail in the paper by Vitkovskij et al. (2001).

The frame grabber supports the function of a window which permits opening of a part of an image which is of interest, but not the whole one. This makes it possible to decrease the volume of input data and increase the processing speed of digitizing the television frames (up to 25 frames per second with a resolution of the frame 320×240).

The software includes the library of functions under the OS Windows and DOS with the initial texts, descriptions and a demonstration programme which controls all the main functions of VS60. For operation of the frame grabber as part of the BTA video server, programmes were written for system control and processing of television information. The programmes are written to run under the OS Linux. This enables connection to the video server from any computer in local network and independent processing of observed images.

4. Remote mode of video observations with the BTA server "tb"

Remote access to the monitoring television channels of the telescope proved to be a great load for operation of the video server "sky". The round-the-clock condition of processing of television signals of the service channels began to decrease the processing speed of the digitizing of images from the main TV guides. For this reason, another controller in the other server was mounted for digitizing the data of the viewing cameras. Different models of video controllers were discussed. As a result, the authors concentrated attention on the analogous scheme of operation of the frame grabber VS60, but of serial model based on the video processor Bt878 installed under the OS Linux.

The service television channels came to be processed in the server "tb" with the aid of the television card AverMedia TV Phone "AverTV Studio" (PCI) of the company AverMedia. The programmes of processing the television signals under the Linux realized high speed digitizing of the video signal (up to 25 frames per second) and video image input into the local network of SAO RAS.

The controller with the video processor Bt878 offers very wide possibilities. Being fast-acting, it allows, besides grabbing individual frames, looking through video series with a speed of 30 frames per second on the display with a direct access to the video adapter of the computer without applying for the processor time. It permits simultaneous reading of the video series with recording of information on a hard disk (up to 15 frames per second with a resolution of 320×240).

It turned out possible to control this video controller under the OS Linux. So, the BTA video server "sky" was alleviated by switching the monitoring cameras to another computer equipped with "AverTV Studio" in the operating room.

At the present time, the server "tb" digitizes the images from the following TV systems:

- panoramic monitoring of sky above the BTA with a view angle of 50° (CCD accumulation);
- television system for monitoring of the telescope position and illumination inside the dome with a view angle of 90° (CCD with addition of frames).

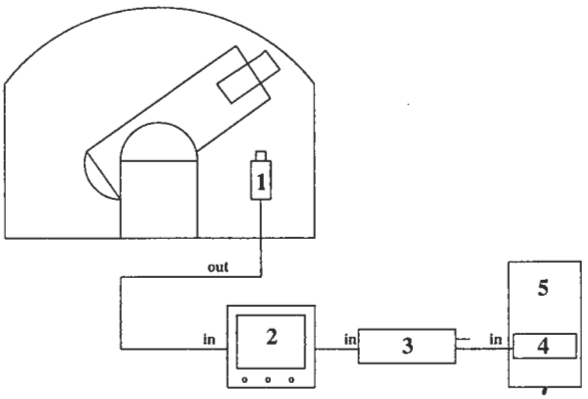

Figure 1: *The scheme of the digital TV system "Inside".*
1 — TV camera of the round-the-clock monitoring inside the dome;
2 — video control monitor of checking the telescope position (is located in the room of operators on duty);
3 — switcher of the television signals;
4 — video controller AverMedia TV Phone "AverTV Studio" (PCI);
5 — server "tb".

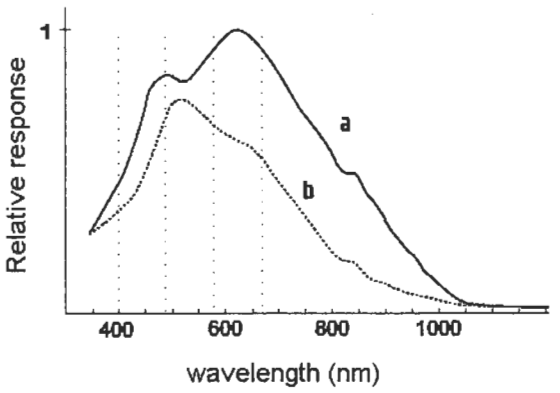

Figure 2: *Spectral sensitivity of CCD "Inside" (SONY CCD Camera System. Semiconductor Selection Guide).*
a — CCD used in the system "Inside",
b — standard CCD for the CCTV systems.

5. System "Inside"

To provide round-the-clock monitoring of the telescope position and illumination inside the BTA dome a television system "Inside" has been created.

It includes (Fig. 1):

- television camera of round-the-clock monitoring inside the dome;
- communication lines;
- video controller with the chip Bt878 in the server "tb";
- programme control of the controller;
- web application for output of the images being read to the web page of SAO.

The television camera was created on the basis of 1/2″ CCD chip produced by the company SONY. This chip has a high sensitivity and is able to ensure a pure image in dark of hardly illuminated places (a minimum illumination for an object is 0.001 lux with an objective F1.2. The sensitivity of the CCD chip is increased in the infrared range and exceeds the highest sensitivity in the IR range of the standard CCD at a wavelength of 800 nm by 10 dB (Fig. 2).

The parameters of the TV camera are presented in Table 1. The resolution of this camera, 560 TV lines secures a high image quality even at low illumination in the BTA dome during observations.

The built-in digital signal processor (DSP) performs the processing of signals, which improves the image quality by reducing noises, adjust of the sharpness of the contours and backlight compensation. The image is characterized by a high signal/noise ratio up to 46 dB (with the system of automatic gain control being off). The electronic shutter reduces automatically the accumulation time of the CCD when the illumination is increased. And in conjunction with the electronic diaphragm (Auto Iris) the television camera provides a quality image of the telescope position inside the dome in a wide range of illuminations from the solar brilliancy to the night condition.

The television output signal from the camera inside the BTA dome comes to the operating room to the controller AverMedia TV Phone "AverTV Studio" (with the chip Bt878) located in the server "tb". Every 20 seconds the server programme "webcam" (original — (C) 1999 Gerd Knorr) transmits digital images of the TV camera inside the dome to the web site of SAO by means of the card AverMedia.

The original programme "webcam" was supplemented with:

- the mode of operation with the black-and-white signal;
- the algorithm of automatic adjustment of contrast and brightness;
- the algorithm of summation of frames with decreasing of illumination (down to 200 frames, i.e. 8 seconds);
- the algorithm of robust statistics over the accumulated image to define the upper and lower image intensity before the formation of the JPEG file;
- the algorithm of removing line-column structures to equalize the background at the limiting accumulation;
- preparing and transmission to the web site of SAO of a diminished copy (icon) together with the full format image.

Table 1: *Parameters of the cameras of Inside/Outside dome monitoring video system*

Parameter	Inside dome camera	Outside dome camera
Sensitive image sensor	1/2″ (EX-View CCD)	1/3″ (EX-View HAD)
The number of effective pixels of CCD (H×V)	752 × 582	500×582
Unit cell size, μm (H×V)	8.6 × 8.3	9.8 × 6.3
Signal standard	625 lines/25 frames (CCIR)	
Signal scanning	interlace	
Video signal output	1.0 V (R 75 Ohm)	up to 10 V
Resolution	570 TV lines	420 TV lines
Minimum scene illumination with the objective F1.2	0.001 lux	0.0003 lux
Automatic gain control (AGC)	yes	
S/N with the full signal amplitude, dB	46 (AGC off)	
Gamma correction	0.45(on) or 1(off)	
Shutter	1/60(1/50)...,1/10000 s	2/3,...,1/100000 s
Objective	Ernitec CA0314NA F1.4, f=3.5 mm	Avenir SSE0612 F1.2, f=6 mm
View angle	90°	48° (H)
Ambient temperature	−10°C ~ +50°C	−30°C ~ +40°C
Relative humidity (free of condensate)	0%~96%	0%~90%

For viewing the image of the telescope position at a given moment one has to enter the web page of the SAO site (http://www.sao.ru/). Using the BTA icon "BTA online" open the web page, where the information about the current state of the parameters of the telescope including the video image of its position inside the dome is presented. For viewing the full format image (324 × 243), it is necessary to display the image in a separate window using the icon "WebCam".

6. System "Outside"

To ensure the round-the-clock monitoring of the weather conditions at the BTA site a television system "Outside" has been created.

It includes (Fig. 3):

— CCD camera for a day/night panoramic viewing of the sky above the BTA;

— thermal housing for all-year-round operation of the TV camera out of doors;

— support-slewing device (SSD) controlled from the BTA operating room;

— communication lines;

— remote control desk of the SSD;

— video control monitor (VCM) for checking the sky observations;

— video controller "Aver TV card" with the chip Bt878 in the server "tb";

— programme control of the controller;

— web application for display of the readout images onto the web-page of SAO.

The TV camera AVC-232 was created by the company "ACTIVISION security systems". It has a 1/3″ CCD SONY with a limiting sensitivity of 0.0003 lux under the condition "night exposure". The CCD chip SONY ICX-255 was made for sensitive systems for

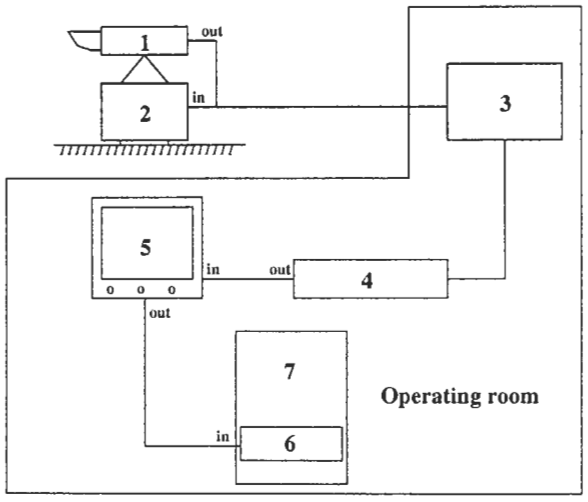

Figure 3: *The scheme of the digital TV system "Outside".*
1 — TV camera of the round-the-clock monitoring outside the dome;
2 — support-slewing device (SSD);
3 — remote switcher;
4 — control desk;
5 — video control monitor of checking the sky observations;
6 — video controller AverMedia TV Phone "AverTV Studio" (PCI);
7 — server "tb".

which high resolution is not necessary. It was made according to the technology "EXview HAD CCD" and has a sensitivity by 200 % higher in the visible region of the spectrum and by 500 % in the infrared one as compared to the similar CCD chips of TV standard.

In the mode "night exposure" the TV camera selects automatically an optimum time of accumulation on the CCD chip up to 2/3 s. This enables reaching an ultimately possible sensitivity for the CCTV video cameras.

The characteristics of the outside dome camera are given in Table 1.

The operation of the camera for a communication line 300 m long is provided by a special corrector of sharpness. The corrector has a function of smooth automatic disconnection when the illumination drops and ensures a maximum sharpness of stars on the image. On a dark moonless night the camera permits to see stars up to 7 stellar magnitudes. The system "Outside" operates 24 hours (day & night). "Night exposure" is realized automatically. The electronic shutter operating automatically provides exposures up to 10^{-5} s, which makes it possible to see the images in the light of solar illumination (excluding the direct fall of the light on the objective).

Thus, the system "Outside" gives the observer a possibility of a day/night monitoring of the sky at the BTA site. To exclude the direct falling of the Sun light on the CCD camera of the panoramic monitoring, an automatic shutter is used in front of the objective of the camera (Auto Iris). The thermal housing ensures the all-season round-the-clock operation of the system "Outside".

The video signal from the camera comes through communication line 300 m long to the BTA operating room video-control monitor (VCM). There is also located the remote control panel of the support-slewing device (SSD). A two-coordinate SSD makes it possible:

- to scan the sky in azimuth (A): from 0 to 360°, in elevation (Z): $(-10... + 65)°$;
- to point in azimuth at a speed: $6°/s$, in Z: $4.5°/s$.

The video signal from the VCM arrives to the server "tb" to the second input of the video controller AverMedia TV Phone "AverTV Studio". The digital processing programme of video images from the panoramic sky monitoring is similar to the version of processing for the system "Inside". The same is realized for web application. To check the weather conditions at a given moment, it is necessary to enter the web page of the SAO site (http://www.sao.ru/). Using the BTA icon "BTA online" open the web page with BTA control interface. Further one needs to use the icon "WebCam" to load it in a separate window of the full-format images (324×243) of the two systems "Inside" and "Outside".

7. Conclusions

The created systems helped the operators solve the problem of visual inspection inside/outside BTA dome. Besides, the digital video monitoring gives additional information in observations. With the aid of a panoramic sky view one can evaluate the weather condition during observations, that is at night, since this TV camera can see the night cloudiness owing to the mode "night exposure". So, the observer, knowing the results of the sky monitoring, can promptly solve the problem of repointing the telescope to more transparent regions of the sky. Images of the telescope position and its location are also accessible to remote users.

Output of this information to the SAO web page is not of only advertising character. Work on the organization of TV-access to the telescopes BTA and RATAN-600 still go on at SAO (Vitkovskij et al., 2000b). A dynamically renovated web-portal is being created for external users: students and teachers of astronomical departments of Russia's Universities, who

take part in the educational process of the shared research centre on the basis of SAO (Vitkovskij et al., 2002). The authors hope that the systems "Inside" and "Outside" described in the paper will form an integral part of systems of prompt obtaining of information about the 6 m optical telescope.

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