Remote Observing: Equipment, Methods and Experiences at the Dark Sky Observatory

D. B. Caton and R. L. Hawkins

Appalachian State University, Boone, North Carolina

Abstract

Over the last few years we have experimented with remote observing with the 32-inch telescope at our Dark Sky Observatory. We have used relatively inexpensive X10 control modules and software to control many electrical and electronic circuits and devices. User access is via a combination of Microsoft Remote Desktop and RealVNC. X10's ActiveHome Pro software provides the interface for device control.

Data acquisition has been with a Photometrics CH250 CCD camera under control of PMIS. Our new imaging camera is an Apogee U42 controlled by MaximDL. In both cases the control over the Internet is by the RD/VNC interface. All of this goes through an ordinary DSL connection at the observatory and provides surprisingly good performance even with the user having only DSL access at home as well.

Field acquisition for cases of telescope misalignment with the sky after an instrument changeover are provided by an ImagingSource DMK 41AU02-USB camera on a Vixen 80mm f/5 auxiliary telescope. In some cases, to prevent crashing PMIS due to buffer overrun/interrupt issues, the field alignment is monitored using a streaming Linksys webcam that looks at the data-acquisition PC's monitor. Autoguiding uses an SBIG ST-402 camera and either CCDOPS or MaximDL. While we have only done imaging via remote use, we are working to develop control of the spectrograph as well.

Weather conditions are monitored with a combination of a Davis Vantage Pro weather station, a Boltwood cloud/precipitation detector, daytime webcams and an infrared-sensitive SBIG Meteor camera for night views of the sky.

We are grateful for support for this work from National Science Foundation grants AST-0520812 and AST-0722491.

Introduction

At Appalachian State University's Dark Sky Observatory (DSO), we utilize a number of commercial products for remote control of the telescope, dome, and instrumentation. In addition, we use a set of daylight skycams and an infrared sensitive night-time skycam, along with a cloud/rain sensor and a Davis weather station to monitor local site conditions. We are in the process of mounting a seeing monitor on-site to allow us to make real-time measurements of the seeing at DSO. The methods discussed below are in use at the DSO 14- and 32-inch telescopes, and are currently being expanded to the DSO 18-inch telescope and the 16-inch telescope on campus.

Control of the 32-inch Telescope and Instrumentation

While we have variations of this system running on four telescopes, for the purposes of this paper we will use our 32-inch DFM Engineering telescope in an 8-meter Observa-Dome as an example.

The 32-inch telescope is controlled via DFM's WinTCS, which we in turn control using TheSky from Software Bisque. The computers running WinTCS and TheSky are connected via a serial connection. Dome rotation is automatically controlled via WinTCS, while the dome shutter and the telescope mirror doors are opened from within WinTCS. WinTCS also controls telescope focus and Guide-Acquire Module (GAM) axis positions: south port filter wheel for high speed photometer, and rotating mirror position (North, South, East, or West port or straight through). In the future this system will also control grating selection and grating tilt on a spectrograph currently under construction.

Both the autoguiding CCD (an SBIG ST-402) and the imaging CCD (an Apogee U42) are controlled by MaxIm DL. The autoguider can also be controlled by CCDOps. Autoguider outputs from the autoguider CCD interface directly to the DFM control system. The DFM FW-82 eight position filter wheel is also controlled by MaxIm DL. MaxIm DL for the imaging CCD is set up to run in "TheSky Controlled Telescope" mode, which allows MaxIm DL to get telescope coordinates from WinTCS via TheSky for image headers. The ImagingSource finder CCD is mounted on a wide field Vixen 80mm F/5 finder. This finder allows the observer to do remote rough centering in the event the telescope was disturbed since the last use (Figure 1).

Figure 1: ImagingSource Finder Camera on Vixen Finder Scope

Remote Access Software/Hardware

DSO is connected to the outside world via a DSL connection leased from the local phone company. This is necessary because DSO is some 20 miles from the ASU campus, and DSL is the only cost effective option for Internet access.

In order to access DSO remotely, we use a combination of Microsoft Remote Desktop and VNC. The observer first connects to a gateway machine running Remote Desktop, then connects from that machine to the telescope control computer, CCD control computer, and the X10 control computer via separate VNC sessions. Once connected, the observer can use the telescope and instrumentation just as they would if they were sitting in the control room.

X10 Control of On/Off Switches

X10 ActiveHome Pro controls power to most of the instruments and the dome, allowing the observer to remotely power items on and off as needed. X10 is a home control system developed in 1975 to allow simple control of light switches by sending signals to a module over the home AC wiring. In the years since, X10 has evolved into a number of different modules, both plug in and hard wired, for controlling lighting, outlets, and even heavy loads such as air conditioners. The modules below control power for our filter wheel, imaging CCD, and autoguiding CCD:

Figure 2: Several X10 Modules

X10 works by sending a one millisecond 120 kHz burst at the zero crossing point of the AC waveform followed by the absence of a burst for a logical 1. A logical 0 is an absence of the burst followed by a burst. An X10 data frame consists of a start code of 1110 followed by a four bit "house code" followed by a four bit "unit code" followed by a four bit command. This gives 256 possible devices in a given building, and 16 possible unique commands (on, off, brighten, dim, etc). There also exist extended commands, but these are used by very few modules.

A disadvantage of X10 is that it was never intended to be used in the electronics-rich environment of the current home, to say nothing of a modern observatory. The 120 kHz signals that are transmitted by the X10 hardware over the AC wiring appear as unwanted noise to and are mostly absorbed or greatly attenuated by the filter circuits in desktop computers, UPSs, and other electronics. There are two solutions to these problems. If the unit that is filtering the X10 signals does not itself need to be controlled by X10, a line bypass filter can be inserted between the outlet powering the device and the device's power cord. This will keep the X10 signals from "seeing" the filter circuitry in the attached device.

Bypassing devices that do not need to be controlled by X10 helps some, but in any large X10 installation, signal boosters are necessary. Our installation at DSO has two signal boosters produced by SmartHome.com along with a combination 220VAC switch/signal booster/repeater made by Elk (but no longer in production) used to control our dome air conditioner. This keeps our signal level high enough to allow us to also be able to switch a few computers on and off with X10 modules. JV Digital Engineering produces a much more robust signal booster which we will probably move to in the future, as we still occasionally have signal attenuation problems in our current setup.

At DSO, we control a number of devices via X10. Among them are the dome air conditioner, dome vent fan, dome power (for rotation and slit opening), dome lighting, several computers (to allow remote reboots in the event of a computer hang), an SBIG ST-402 guide camera, an ImagingSource finder camera, our Photometrics imaging CCD, and our Apogee imaging CCD. In addition to these devices, we interfaced two X10 modules to a pair of DPDT relays to allow us to switch telescope tracking on/off and to switch power to the telescope motors on/off (Figure 3).

Figure 3: X10 Module-Controlled AC Relays

Software control of X10

The X10 modules themselves are controlled by ActiveHome Pro software running on a computer in the telescope control room. Modules are switched on and off by simply clicking the corresponding switch icon in the program:

Figure 4: 32-Inch ActiveHome Pro Screen

We chose X10 based on cost and previous experience. However, SmartHome distributes a more robust system under the trade name Insteon. Insteon has built-in signal boosters can address over 16 million separate devices on one network, and has many more possible commands than X10, giving a potentially more flexible system. However, we could not justify the added expense in our installation.

Weather Monitoring At DSO

The remote use of an observatory requires flawless monitoring of the current weather conditions at the site. Any other strategy is sure to eventually lead to a wet telescope and likely much damage to exposed electronics mounted on and around the telescope. At DSO, we have several independent ways for the remote observer to monitor the current weather conditions at the site (see figure 5)..

For basic weather information, we have a NIST-certified Davis wireless VantagePro weather station which is integrated into a regional weather forecasting network. This station provides temperature, relative humidity, barometric pressure, wind speed and direction, cumulative precipitation, dew point, and solar irradiance. These data are archived in order to keep track of long-term trends at the site. The sensors for this unit are mounted at NOAA/NWS standard heights on a 10 meter tower. This unit has two base stations, one used for the weather network, the other dedicated to various software (including SkyNet) which makes decisions on whether to open or close the domes automatically. A wireless version of the station was chosen to avoid problems with lighting strikes.

For instantaneous cloud cover and precipitation monitoring, we use a Boltwood Cloud Sensor. This unit is attached to the South side of our 14-inch dome. The automatic shutdown contact of the cloud sensor is connected directly to the Observa-Dome dome automation hardware used in this dome to ensure the dome closes if rain or snow develops and the SkyNet software fails to shut down. This unit will likely be upgraded soon to a Boltwood Cloud Sensor II, which will also allow automatic shutdown on high wind and humidity conditions. Finally, we plan to install cloud sensors at the 32-inch & 18-inch domes at DSO and at the 16-inch dome on campus.

For daytime sky monitoring, we use four Logitech QuickCam Pro cameras looking northeast, northwest, southeast, and southwest. These are mounted on platforms of our design. The cameras are protected from the weather by an acrylic dome. The entire housing is sealed with o-rings and RTV. We have had no problems with moisture intrusion using this setup.

For nighttime cloud monitoring, we use a second-generation SBIG Meteor Cam, which covers a 90° x 140° patch of sky. On nights when observing is taking place, this camera runs continuously taking 30 second exposures one after another. High clouds that are impossible to detect with the naked eye are easily seen by this camera. This unit is no longer in production, but will soon be replaced in the SBIG product line by a much more capable unit which will cover a full 180° "fisheye" view of the sky.

Figure 5: (Left to Right): SE and SW SkyCams, Cloud Sensor, and IR SkyCam. Right photo: Davis weather station and tower.

Variations on a Theme:

While our 14-, 16-, 18-, and 32-inch telescopes operate similarly from a remote perspective, the actual hardware is slightly different. As an example, the 14-inch uses a bank of two batteries, four solar panels, and an inverter to power the dome shutter motor, and the dome shutter and dome rotation are controlled by a remote control system from Observa-Dome Labs running with AutomaDome in TheSky (Figure 6).

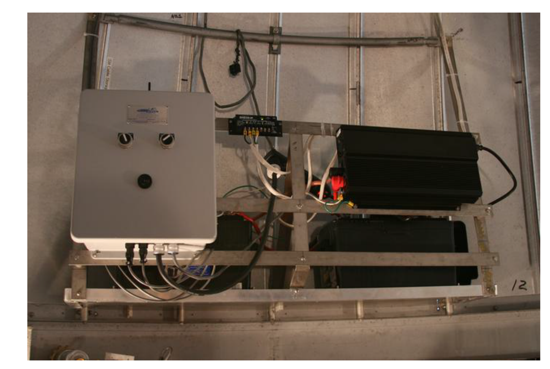

Figure 6. Left: solar panels on 14-inch telescope's dome. Right: controller, batteries and inverter to power its slit door motor.

The 16-, 18-, and 32-inch telescopes all get their dome opening/closing and rotation commands from DFM WinTCS. The 32-inch has full power rails for AC power and open/close signals, allowing the dome to be opened or closed at any position, while the 16- and 18-inch telescope domes have only 4-foot segments of (heavily modified) power rail (Figure 7) supplying only AC power to the dome shutter motor and an RF relay module, over which the actual open/close commands are sent. These latter two systems only allow the dome shutter to be opened or closed within about 15° either side of the dome home position.

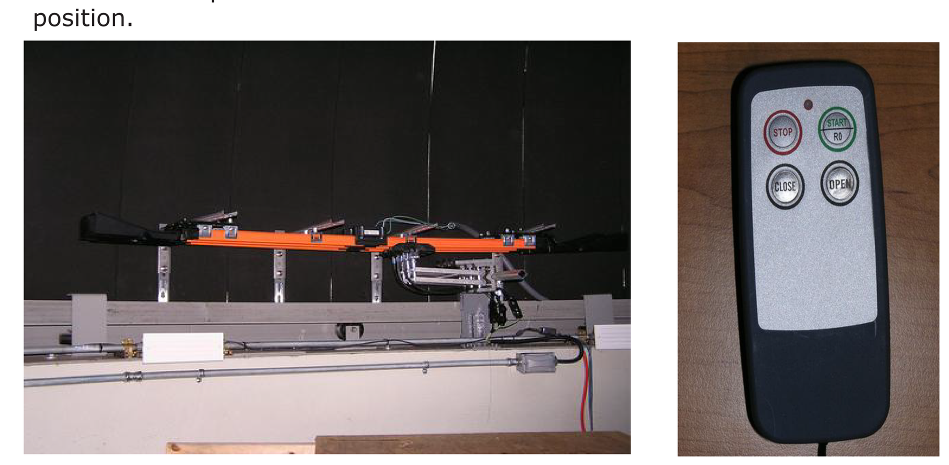

Figure 8: Left: 16-Inch Dome Shutter Control Box with Conductix Protean RF Module Mounted. Right: remote control paddle.

Conclusions

As can be seen, while it takes quite a bit of hardware and software to be able to run a telescope remotely, it is, in the end, just a matter of getting the right pieces installed and working together. We have been successfully operating our 32-inch telescope remotely for two years, with several dozen runs made from home or campus. This has saved time and commuting expenses as well as providing opportunities for running jobs while having other personal activities to attend to. Our 14-inch telescope has been operating successfully on the UNC SkyNet network in autonomous mode for several months.

Suppliers

Ash Dome (www.ashdome.com): Dome azimuth encoder mount
Conductix (www.conductix.com): Protean Dome RF Shutter Control
Davis Weather: (www.davisnet.com): VantagePro weather station
DFM Engineering (www.dfmengineering.com): Telescopes, filter wheels, & control systems.
Diffraction Limited (www.cyanogen.com): Data acquisition software & cloud sensors.
Duct-O-Wire (www.duct-o-wire.com): Power rails
Imaging Source: (www.imagingsource.com): DMK 41AU02 finder camera
Logitech (www.logitech.com): QuickCam Pro SkyCams
Observa-Dome Labs (www.observa-dome.com): Domes and dome automation
SBIG (www.sbig.com): IR SkyCam & autoguider CCD.
SkyNet (www.skynet.unc.edu): Automated observing network
SmartHome: (www.smarthome.com): AC power line control modules
Software Bisque (www.bisque.com): TheSky
VNC (www.realvnc.com): Remote access software
Vixen Optics (www.vixenoptics.com): A80SS Finder Telescope
X10 ActiveHome Pro (www.activehomepro.com): AC power line control modules and software.

Acknowledgements

We are grateful for support for this work from National Science Foundation grants AST-0520812 and AST-0722491.

We wish to thank the North Carolina Space Grant for a New Initiatives grant for some of the equipment for this project. The Appalachian State University Research Council also provided instrumentation funding for which we are grateful.