Automated Observing – Plug and Play approach

Abstract

The dream of many amateurs (and probably a few professionals) is a cheap and reliable means of setting up a remotely controllable and automated observatory. However, until recently, this has been a pipe dream with seemingly too many hurdles to overcome. Well now we have the means and you don't have to be a millionaire or have exquisite programming talents or highly modified hardware to achieve it. Today you can put together an entire package – off the shelf – no modifications required that will handle your most difficult observing needs.

Now I should point out that this is an automated image acquisition system. This paper does not describe a system whereby you press start at the beginning of the night and at the end of the night a list of new supernovae or Minor Planet discoveries get sent off to the Central Bureau – you will still have to process your own images and extract the data that you need though there is plenty of software that will semi automate these tasks.

Remote and automated observing

Many astronomers have achieved various stages of Remote and automated observing. So what do I mean?

Remote

Simply put this means that you do not have to be sitting in the observatory but be situated somewhere else. For the purposes of this paper it assumes that you have ready access to the observatory but can, if necessary operate hands off for the duration of the observing period.

Automated

This means that the equipment will automatically slew to, identify, correct pointing, automatically focus and automatically acquire a guide star, track and guide any target that you identified. It will then take a preplanned number of images each with a preplanned integration time and filter and when necessary move onto the next target without any intervention by the observer.

As an extension to this, one might also like the observatory to keep an eye out on the sky and automatically shut down the telescope and close the observatory if the sky clouds over or the winds reach a certain speed.

Off the Shelf

All the hardware and software can be purchased readily and is supported at least via the internet without the need for any modification at all.

Lets put something together

You should be aware that the option I am describing here is not the only option – it just happens to be the option that I use. Note that the solution that I am describing here is Windows Based. There may be Unix/Linux solutions but not using the software/.brands described here.

Hardware needs

Observatory – optionally automated but a roll top roof is perhaps the best option if automation is not a requirement. In my case I converted a metal garden shed and gave it a roll off roof. The observatory needs to be manually opened and manually closed but given that the observatory is located in my back yard only 5 metres from my back door this was not a significant issue. An automated dome is by far the best option – but it also costs an arm and a leg.

Telescope – must be goto capable with software support via ASCOM. I have only ever used Meade's range of Goto scopes starting with the 8" LX-90, moving to the 10" LX200 GPS then onto the 14" LX200 GPS. The optics in these scopes are fantastic but for imaging purposes the mounts leave a little to be desired – but I have probably the worst mount Meade has ever made (110 arcsec PE) but my off the shelf observatory setup still copes without the need to modify the scope. Guiding is performed with the use of a guide scope and camera attached to the main tube. In my case I use a Meade 102mm f/10 SCT.

Camera – must be optically suited to your telescope/optical train with support via ASCOM and MAXIM DL/CCD. I have used several cameras ranging from the Starlight Xpress MX516 and MX716 to the SBIG ST-8E and ST-9E. The former 2 are USB and the latter 2 are parallel. Use whatever suits the type of imaging you need and the optical train setup you have. In my case I operated the ST-8E at f/4 and the ST-9E at f/5.7 to give me around 2"/pixel resolution.
An electronic focuser with support via ASCOM. The Meade LX200 GPS scopes come fitted with the Microfocuser unit which can be operated remotely and via software.

Other - Optionally electronic weather station. I use a LaCrosse 3600. These are low end units but provide suitable accuracy for what my observatory needs. As yet I do not have a cloud sensor.

Software

ACP4 - This is the main package BUT it doesn't do anything by itself. It requires MaxIm DL/CCD as a minimum but works best with MaxIm, Pinpoint and FocusMax. This software comes in many flavours from the high end incorporating web server and access to the observatory to run sessions via the internet to the basic single user license allowing me simple control from a single PC.

Pinpoint 4 - Pinpoint is the astrometric reduction engine that plate solves images for pointing corrections.

MaxIm DL/CCD 4 - This is the CCD control version of the MaxIm suite. It controls the CCD image taking and guiding processes.

FocusMax - FocusMax works off ASCOM, and MaxIm to link to both the CCD Camera and Telescope Focuser. It automatically refocuses the scope.

ASCOM - Is the framework/support structure for this software suite

VNC - VNC is freeware that allows em to access and control one PC from another PC via a LAN connection.

A typical Session

Rather than go into the intricacies of how it all works let me just describe a Use Case (the assumption is that the hardware and software has been set up for use) for a typical session.

1. User prepares an Observing Plan
2. User opens the Observatory
3. User powers up the Telescope, Computers and Cameras and Observing Script selected
4. The Plan is loaded
5. The Telescope is aligned (pointing updated)
6. Optionally ACP automatically takes Sky Flats
7. Optionally ACP automatically takes darks
8. FocusMax used to Autofocus the scope
9. ACP issues a slew command to the first target
10. ACP instructs MaxIm to take a pointing image
11. MaxIm downloads the Image and ACP plate solves the image using Pinpoint
12. If the Pointing is outside the predetermined limit then ACP re-slews the scope to centre
13. ACP reads the imaging attributes. If the Integration time is longer than the minimum unguided image duration then ACP instructs MAXIM to take a Guide Camera Image.
14. Optionally ACP instructs MaxIm to change filter where required/fitted
15. Maxim downloads the image and is instructed to choose a guide star
16. MaxIm commences guiding
17. After a predefined settle time, ACP waits for the guide errors to be within predefined parameters before instructing Maxim to take the required image.
18. MaxIm downloads and saves image and ACP plate solves the image.
19. The ACP/MaxIm dance continues changing filters, pointing correcting, refocussing, changing targets etc for as long as the targets are visible or as long as the session lasts.
20. Optionally take dawn flats and darks
21. In the morning I power down the scope and the camera, close the observatory roof; download my images and power down the observatory.
22. I process my images.

Everything between steps 5 and 21 is automatically handled by the system – i.e. no human intervention. I do, however, monitor how things are going via VNC from

inside my house and fix any problems that may arise though problems are rare (see the Limitations section later in this paper). I should point out that the software can take care of step 5 as well – I just do it myself as a matter of course since the setup needs time to settle into the evening air.

I have been using my automation facilities to:
1. Track and image up to 3 Minor planet targets all night for photometric work
2. Track and image up to 20 NEOCP's a night for Astrometric work (typically these are magnitude 19.5 – 21.5 targets that require multiple short images tracked and stacked)

I have plans to undertake Variable stars photometry of AAVSO bulletin 66 targets once a month and an SN Search once or twice a month. Since these are secondary targets I would only invoke these plans if there were no suitable Minor Planet targets (rare) or conditions were not suited to Minor Planet Photometry (i.e. a bright/poorly placed moon)

I'd like to point out the difference between Observation Plan and the Observing Scripts at this juncture. The scripts that I use are predefined VB scripts supplied with the ACP software. The plans are written using a very basic command language and are used to define what targets are to be observed, where they are and how you want to image them. The Observing Plans are read and interpreted by the Observing Scripts. Users have the flexibility to write their own scripts if they so choose. To date I have not had the need.

Limitations

So this sounds all too good to be true doesn't it? Well it's all true and to date I have only encountered one limitation based on the work I perform or intend to perform. While imaging, if the setup cannot select a guide star for any target in the list the plan will stop. Generally this is a good thing as it often means that the sky has clouded over BUT there will be the occasion if following a single target that a large enough cloud will pass through the FOV preventing guiding and thus stop the session even though within minutes the cloud has passed. This perhaps is not a limitation of the system/setup but a limitation of the default observing scripts that are supplied with the ACP software. If you like (and many do) you can write your own scripts for your own purposes and this limitation can be tested for and overcome.

Although the setup is reliable, like anything electronic/mechanical you need to keep an eye on it and sometimes there are failures. In my case the Starlight Xpress Cameras, the USB drivers and MaxIm DL/CCD can get out of synch and result in a operational lockup of the computer ending the session but leaving the scope to track unstopped. The result can be a scope collision with something in the observatory as there is no function to stop tracking or park the scope before it heads below the observatory horizon. Fortunately MaxIm has come up with some reliable drivers and this occurrence is very rare (happened once in 6 months of continuous operation)

Lets put it all together

The shin bone's connected to the thigh bone and the thigh bone's connected to the …… Well it really is that simple – no kidding. Let me show you using my own equipment as an example (see figure 1).

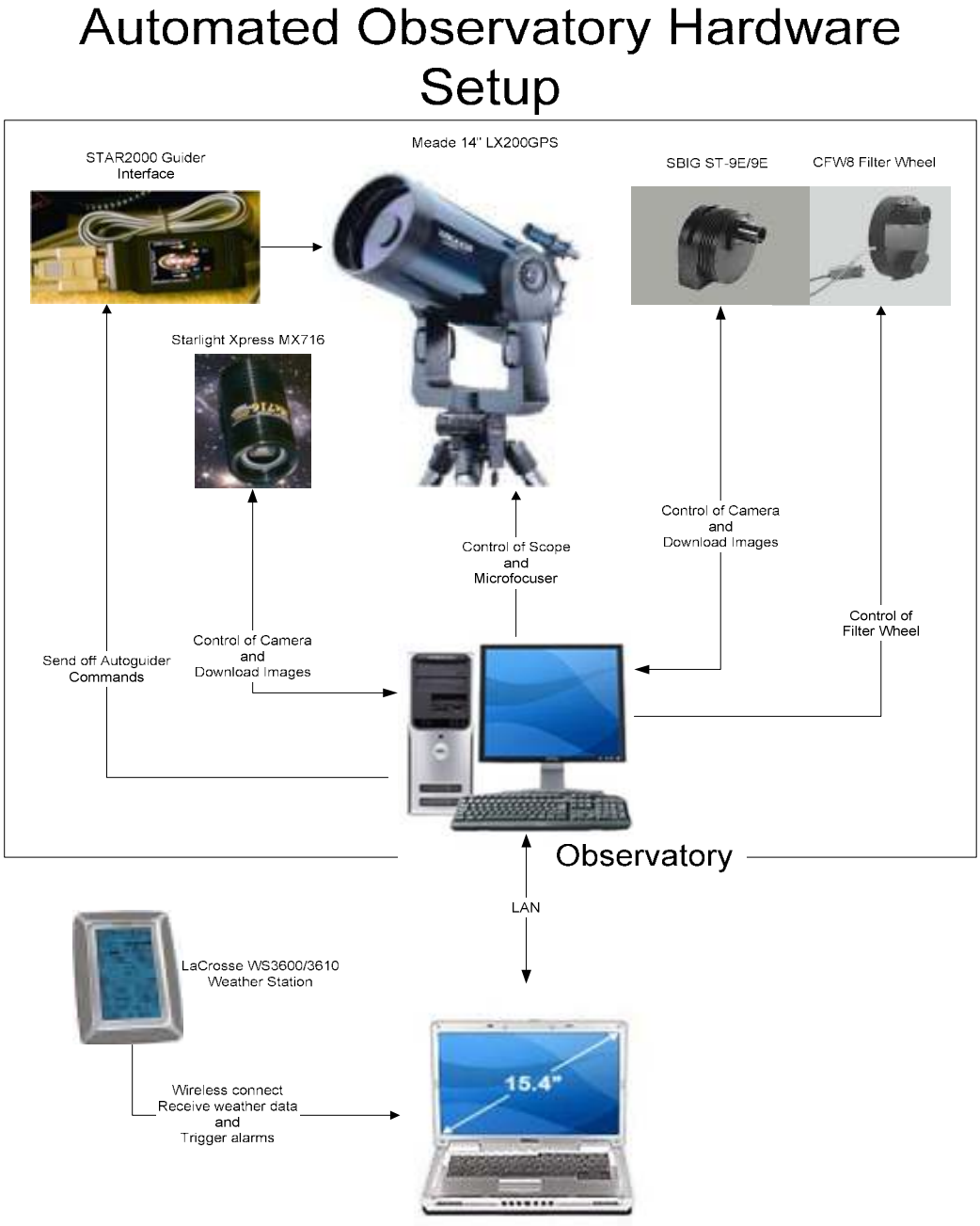

Figure 1

The LX200GPS scope is fitted with an f/3.3 Focal reducer providing f/4 for the ST-8E (with CFW8 Filter wheel attached) or f/5.6 for the ST-9E (without filter wheel) - focal lengths of 1420mm and 1970mm respectively. A guide scope is mounted on top of the LX200GPS (any suitable telescope that allows matching of the imaging resolution of the main scope will suffice). In my case I use a Meade 102mm SCT at f/10 fitted

with a Starlight Xpress MX716. I have also used this guide scope with f/6.3 focal reducer to give it a slightly wider FOV to "guarrantee"[1] picking up a guide star in every field.

[1] I have not yet encountered a field that could not produce a guide star. If one were to occur then there would be little point in imaging the main field as all the stars would be too faint for photometry purposes. Although the SBIG cameras are fitted with guide chips, I have chosen to rely on the larger field guide scope. You will have problems reliably finding a guide star if you only rely on the secondary guiding chips.

The SBIG camera is connected to the Observatory PC via Parallel cable. USB would be better and later, down the track I may fork out the money to pay for the camera upgrade. The Starlight Xpress MX716 is attached to the Observatory PC via USB 1.1 connectors. The Cameras are software connected/run by MaxIm DL/CCD which in turn controls the telescope via the Star2000 Autoguider box connected to the Observatory PC's serial connector and the other end to the LX200GPS Autoguider connector.

A second Serial connection from the Observatory PC connects to the Scopes RS-232 port to allow ACP4 to communicate with the telescope.

The Bottom Line

Of course all this is fine but I hear you ask "What does it cost?" Table 1 contains indicative costs as at March 2006 in both $AU and $US.

Table 1: Indicative costs associated with setting up an automated observatory

LX200GPS 14"	$ 9,995 AU	$ 5,649 US
Guide scope	$ 350 AU	$ 250 US
SBIG ST-9E	$ 4,000 AU	$ 2,895 US
SX MX716/SBIG ME402	$ 2,400 AU	$ 1,295 US
STAR2000	$ 350 AU	$ 245 US
LaCrosse WS3600	$ 600 AU	$ 340 US
Computer	$ 995 AU	$ 299 US
Modified Roll Top Obs	$ 800 AU	$ 500 US
ACP4 Single User Basic	$ 700 AU	$ 495 US
MaxIm DL/CCL	$ 650 AU	$ 449 US
Pinpoint	$ 250 AU	$ 149 US
FocusMax	$FREE	$FREE
ASCOM	$FREE	$FREE
VNC	$FREE	$FREE
Total	$21,090 AU	$12,566 US

It looks like a lot of money if you were doing it all from scratch but many of you will already have some of the components and you can certainly build up to it rather than getting it all at once. You can also change the configuration – larger or smaller scope, different camera combinations even go with or without the weather station or even

upgrade to an automated Dome observatory (at an extra $14,000 AU). Similarly you may be able to get away without a guide scope and second CCD Camera if you used a precision mount such as the Paramount ME or equivalent – but of course this would depend on the type of imaging you were performing.

Suppliers

Where do you get it? Well here are some current contacts:

Meade LX200GPS Scopes	http://www.meade.com
SBIG Cameras	http://www.sbig.com
Starlight Xpress Cameras	http://www.starlight-xpress.co.uk/
ACP4	http://www.dc3.com
Pinpoint 4	http://www.dc3.com
MaxIm DL/CCD	http://www.cyanogen.com
ASCOM	http://ascom-standards.org/
FocusMax	http://users.bsdwebsolutions.com/~larryweber/
VNC	http://www.tightvnc.com/

Other tools

There are other tools that will make the observers job a little easier. Astroplanner is a good example. This package allows you to build and visualise an observing plan (though the generated plan cann't be used by ACP). At $20 US – the price is hard to beat. Obviously a planetarium package could be used but they tend to be cluttered with tools for viewing rather than planning a session.

Post processing your images is dependant on what you want to do. "Pretty Pictures" can be processed via MaxIm Dl/CCD direct. MaxIm can also perform astrometric and photometric reduction as well but I prefer the ease of use of more dedicated packages such as Astrometric for Astrometry (pretty much the 'Industry Standard"