The Baker Observatory Robotic Autonomous Telescope

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ABSTRACT

The objective of our project is to have an autonomous observatory to obtain long duration time-series observations of pulsating stars. Budget constraints dictate an inexpensive facility. In this paper, we discuss our solution.

Keywords: robotic telescope, Baker Observatory

1. INTRODUCTION

Our research focuses on understanding stars by using their pulsations to discern their interior structure (asteroseismology). Asteroseismological techniques have, in some cases, been successfully applied to measure the mass and luminosity of isolated pulsators to great accuracy and identify the location of structural or compositional changes within their interiors (Bradley, & Winget 1994, Kawaler & Bradley 1994; Wolff et al. 2002; Metcalfe, Montgomery & Kawaler 2003). It is even possible to discern the rate of evolution, internal rotation, subsurface magnetic fields, and possible binary companions through pulsations (Kawaler, Sekii, & Gough 1999; Mukadam et al. 2002, Reed et al. 2004). Via pulsations, a planet was discovered orbiting an evolved star, which allows us to examine solar system evolution through the red giant phase (Silvotti et al. 2007).

Yet Missouri State University is not a research institution. Our focus is on teaching and our teaching loads reflect this commitment. In practice, this means that we teach classes most weekdays and do not have a doctoral program. We do have capable and eager undergraduate student researchers, yet they also have classes most weekdays. As such, for most of the year we cannot observe five nights of the week as we have daytime commitments. However, Missouri State University owns and operates Baker Observatory. Located near Marshfield, Missouri, about 30 miles from campus. This observatory has moderately dark skies, typical seeing of 2-3", high humidity about half the time, and around 200 clear nights per year. It is equipped with a 16" telescope (the original sight testing telescope for Kitt Peak National Observatory), a 14" Celestron telescope, and several 8" telescopes for student courses. Though our facility is small and our skies not the best, our equipment has obtained useful and necessary data which have contributed to many projects (recently including Pakstiene et al. 2011; Baran et al. 2011; Østensen et al. 2011; Saeson et al. 2010; Baran et al. 2010; Østensen et al. 2010; Reed et al. 2009; among others). Our observatory is surrounded by rural farm land and while not very populous, it is not isolated.

The solution to our dilemma was proposed by our colleague A. Baran; put a telescope on our site that can obtain data autonomously. As we found our current 16" telescope scientifically useful, we decided to keep that size aperture as budget constraints would not allow us to purchase a larger one. Our initial budget was in the area of $25,000 and we thought we could work within that constraint. Over time, we realized this was unrealistic, yet our goal remained to spend as little as possible while creating a dependable system. While a remote location in Arizona or New Mexico would provide better skies and place the responsibility for opening and closing decisions on someone else (a site manager type of person who rents telescope space), it is prohibitively expensive as one service trip would roughly equal our annual budget. So we would be far short of money to install, commission, and debug the telescope.

We began researching equipment in the winter of 2010. The telescope arrived in May, 2010 and the dome in July of the same year. As of May, 2011, we have yet to obtain first light, but anticipate the system will be operational prior to fall 2011.

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2. HARDWARE AND SOFTWARE

Choosing software to run the telescope is probably the most important component. Out of naivité , we were originally going to do all the programming ourselves. Fortunately, we had programmer issues that curtailed this plan and so we searched the internet for a solution. We found XmTel* and were going to use that, but at this conference, we were introduced to RTS2†, which we are using now. We have already interfaced rts2 with our telescope, CCD, filter wheel, and weather station. Obviously there are other options and others have found working solutions within the Windows operating system. However, we are most familiar with Linux and find it to be more robust. As such, RTS2 is a good fit for us.

In searching for hardware, we tried to be fiscally responsible (i.e. cheap) while getting equipment we can use. Each item is discussed below and shown schematically in Figure 1.

- Meade 16" LX200 GPS telescope ($14,000). We are using the fork mount that came it. We have heard mixed reviews its quality but have a local contact who has rebuilt the motors and internal wiring, and so we are confident it will satisfy our needs.
- Custom focuser ($200). We decided that rather than purchasing an in-line focuser unit, which are fairly expensive to hold the weight we need, that we would turn the focus and mirror lock knobs ourselves. So we built a custom system using stepper motors and belts. This custom system also allowed us the flexibility to be incorporated into our custom mount for the Apogee filter wheel.
- Pier ($500). We built a custom, heavy-duty short pier to mount the telescope fork equatorially.
- AstroHaven 7' clamshell dome ($19,000). This is mounted directly onto a cement pad on the ground. We have two 12" base rings (one produced locally).
- Dome fans ($100). We wanted to have fans in the dome that were capable of changing the air every ~ 5 minutes. Our building is about $800\,ft^3$ and we bought two high-speed computer case fans which are capable of moving $2750\,ft^3 m^{-1}$. We control these via a Tbalancer bigNG 4-channel controller board which interfaces to our computer via USB.
- Apogee U47 CCD and 9 position filter wheel and Bessell U,B,V,R,I filters ($16,400). The CCD is a high-speed USB CCD that we use at Kitt Peak National Observatory, so we had it on hand. The filter wheel was for another project that did not end up using it, and so we had it available. So the only real expense was the set of filters from Omega Optical. Eventually we will purchase a new Apogee CCD specifically for the robotic system.
- Boltwood 2 cloud sensor ($1,500). Our only source for weather information.
- 220 V and 110V uninterruptible power supplies (UPS; $1,500). We have (an expensive) one for 220 V to run the dome and a 110 V one for everything else. These also supply spike and surge protection and can be externally interfaced.
- Security ($$\sim 2,000$). The main expense is a wood privacy fence around the cement pad, which has not been built yet. The privacy fence should allow us to isolate the environment from the outside world (animals mostly). Inside the fence we will have a series of motion sensors and webcams. Our motion sensors will not view the ground, so detecting animals is less likely, but just the fence (and the top of the fence, where intruders would enter). When a motion detector is set off, the plan is to have our smartphones alerted, flood lights turned on, and an audio warning that the area is under serveillance. Hopefully that will deter any would-be intruder. Via our smartphones, we can access the webcams and assess the situation, and notify police if necessary, and the webcams will also record any intruders for later prosecution (if necessary). We also have a dome sensor that patches directly into the alarm system of the main observatory building. If an unauthorized dome opening occurs, campus security will be notified.
- Miscellaneous ($500). We have purchased switchable power supplies (remotely accessible and computer controllable), USB hubs, ethernet switches, and webcams specifically to look at the telescope, dome and other critical equipment so we can remotely assess any issues.
- Computer ($2,000). Currently we are using a surpluss computer provided by the university during our testing phase. Soon we will purchase a computer power enough to operate all components without lagging.

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*http://www.astronomy.net/forums/software/messages/43.shtml

†www.rts2.org

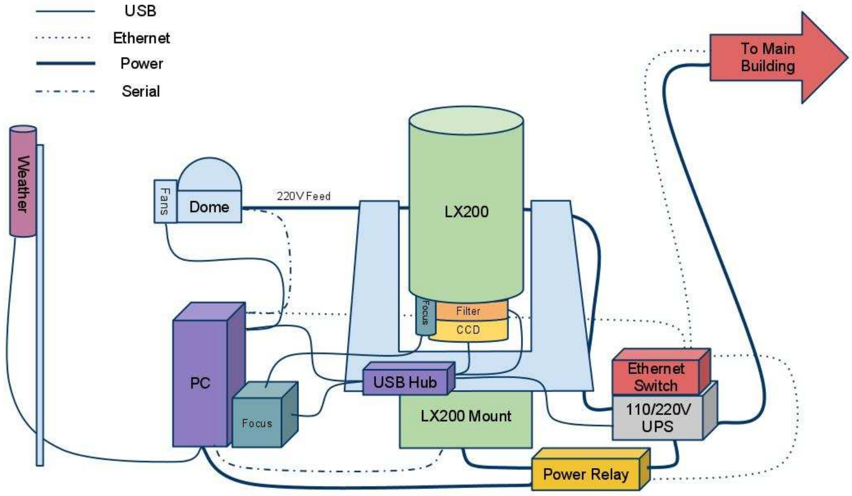

Figure 1. Schematic of our robotic telescope setup.

3. DISCUSSION

To date, we have spent about $42,000 and have yet to acheive first light. We anticipate any remaining costs to be under $5,000. Our hesitancy is based on security; we will not install the telescope into the dome until a fence is built and we can depend on our sensors to alert us of intruders. Our programmers (Lee Hicks and Matt Thompson) have written some RTS2 drivers for equipment we have which were previously unsupported and we believe the system should function without too many bugs.

In our next phase, we will begin testing all of the equipment on-site as an integrated unit though the telescope will not be inside the dome. We will use the telescope just outside of the dome, so we can test all the equipment as one unit. We anticipate having a working facility before fall 2011.

This conference was particularly beneficial for us. Currently, there is no centralized on-line repository of robotic telescope information. A Google search for robotic telescopes or robotic observatories finds mainly individual robotic telescopes (sometimes with useful information, but most often just a description of what they have) or commercially available telescope time. A central repository of hardware/software options, problems, solutions, and recommendations is greatly needed. So for us, this conference was that chance to exchange knowledge and ideas and to learn from others who are doing (or have done!) similar projects.

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