

The Lowell Telescope Scheduler: A system to provide non-professional access to large automatic telescopes

Kim Binsted^{1,3}, Nicholas Bradley¹, Marc Buie², Scott Ibara¹, Mary Kadooka³, Derek Shirae¹

Abstract

Here we describe the Lowell Telescope Scheduler (LTS), a system which allows high-school students and other non-professional users to propose research projects and request observations on a 31-inch telescope at Lowell Observatory. At the heart of the system is an automatic scheduler, which allows the principal investigator at the telescope to quickly and easily integrate outside observation requests into his nightly viewing schedule. The system also has a web-based interface which allows inexperienced telescope users to make reasonably sophisticated observation requests. The system is currently being used by students at Oregon Episcopal School who are particularly interested in observing the comet Tempel One, which is soon to be examined in the Deep Impact mission.

Keywords: astronomy, education, scheduling, telescope, web-based interface

Introduction

Amateur astronomy is enjoying a boom, thanks in part to the availability of relatively low-cost, high-quality telescopes on the consumer market. Non-professional astronomers have made significant discoveries, and skilled enthusiasts have taken and published very impressive astronomical images. It would seem that the barrier to entry is finally low enough that real astronomy can be a routine part of our educational system.

However, the situation is not quite as rosy as it may seem. Operating a telescope successfully still requires knowledge and experience beyond that of many high school teachers and most high school students. Moreover, observing many interesting objects (such as the comet Tempel One) requires larger and more expensive telescopes than most high schools could afford. Finally, many high schools are in well-lit urban or suburban areas, where successful observations would be difficult or impossible.

Nonetheless, students learn best through direct experience, and it is hard to overestimate the excitement and engagement of a student who has managed to see, for example, Saturn's rings through a telescope for the first time. An image a student has taken herself has a much greater educational impact than one found in a textbook or downloaded from the Internet. So, the question is: can we provide students with inexpensive access to high-quality telescopes?

Most large telescopes are devoted to research. Of those available for educational purposes, most are small – the Faulkes Telescope Project [Faulkes, 2005] uses the largest. However, there are many medium-sized, computer-controlled research telescopes that are not used all the time. The telescope we are focusing on in this paper is typical of this group. It is a 31-inch

¹ Information and Computer Science Department, University of Hawaii. Contact: binsted@hawaii.edu

² Lowell Observatory, Flagstaff, Arizona. Contact: buie@lowell.edu

³ NASA-UH Astrobiology Institute, University of Hawaii. Contact: binsted@hawaii.edu

telescope at Lowell Observatory in Flagstaff, Arizona, and is used primarily for observations of Pluto. However, Pluto can only be observed when it is visible from the Lowell Observatory, and when sky conditions are photometric. So, it is only being used for its primary purpose a small percentage of the time. The remaining time could be productively used by other researchers and amateur astronomers, including students.

However, the task of analyzing, selecting, debugging and scheduling large numbers of observation requests is extremely onerous. Even if the primary investigator (PI) were willing in principle to let others use the telescope, the time cost to the PI would make this unfeasible.

On the other hand, if we can automate some or all of these tasks, giving amateur and student astronomers access to a telescope will no longer be a burden to the PI, and much more telescope time may become available. The most difficult problem is automating the task of efficiently scheduling the requested observations, taking into account the constraints on, and priority of, each request.

Another problem is that of giving inexperienced student observers the support they need to make effective observations. Large telescopes and high schools are rarely located near each other, so the observations will necessarily be remote. Also, in the maximally automated scenario, there will be no direct interaction with the PI, who knows the most about the capabilities and limitations of the telescope. For students to make effective observations, they must:

- Know what they want to observe, and when it is observable with the telescope.
- Be able to specify desirable conditions for an observation. Students are often tempted to give hard times rather than qualitative constraints (e.g. airmass, local

sidereal time (LST) etc), which usually results in fewer, less effective, observations.

- Request observations that are practical given the telescope's capabilities and priorities. For example, a request for an all-night observation under photometric conditions when Pluto is observable will never be granted, given the primary mission of the Lowell telescope.
- Use the telescope's capabilities, such as filters, effectively.

Related Work

The Faulkes Project [Faulkes, 2005] is the most ambitious program to allow access by non-professionals to large telescopes. It uses two telescopes: Faulkes North, on Haleakela in Hawaii, and Faulkes South, at Siding Springs Observatory in New South Wales, Australia. Schools can buy time on either telescope at a relatively low price. The user controls the telescope in real time via a web interface. Because they are sophisticated pieces of equipment, the Faulkes telescopes require a significant amount of training and practice to use effectively. The TOPS program [Bedient *et al*, 2003] sought to train math and science educators in using Faulkes and incorporating astronomy into their curricula.

The Faulkes Project is a fantastic resource for teaching astronomy; however, it is aimed at a different educational scenario than our project is. Faulkes is ideal for giving a class of students, led by an experienced astronomy instructor, real-time access to a specified time-slot on a high-quality telescope. Our project, on the other hand, seeks to give individual students or groups of students the opportunity to plan and carry out a significant research project over time, with minimal guidance from an experienced astronomer.

There are several other examples of teachers getting time on large telescopes, but as with Faulkes, the necessity of working with a fixed time-slot means that individual students are not likely to be able to carry out their own independent research projects.

At the heart of our system is the telescope scheduler. There are several other schedulers for automated telescopes, including one that applies “just in time” planning to the problem [Swanson *et al.*, 1994]. These schedulers, however, are typically attempting to schedule highly constrained professional research demands over an entire observation season, rather than amateur observation requests over the course of a night.

Our Approach

As discussed above, our goal is to give students access to automated research telescopes during their ‘down time’ (i.e. when the PI is not making observations). To achieve this, we have built a system which combines a nightly observation scheduler, an observation request database and a web-based interface that allows students to enter their observation requests.

One important feature of this system is that students need not specify a particular time slot for their observation; instead, they are encouraged to specify the conditions (LST, airmass, etc) under which the observation should occur. This gives the system the opportunity to schedule the requests as efficiently as possible, allowing more requests overall to be fulfilled.

Another important feature is that the scheduling of all observations (including those of the PI) are done automatically. By reducing the workload on telescope PIs, we hope to increase the number of PIs willing to let students use their telescopes.

Scheduler

Our scheduler must operate under a number of constraints. It must:

- Prioritize the PI’s observations.
- Schedule as many observations as possible, taking into account project priorities (set by the PI) and observation priorities and constraints (set by the observer).
- Ensure that background tasks (calibrations, filter changes, etc.) are accomplished when necessary.
- Ensure that no requests that may damage the telescope are scheduled.
- Avoid partial observations (e.g. a subset of a series in which all images are required) where possible.
- Minimize periods in which the telescope is unused.
- Run quickly, so that the PI can evaluate current conditions and run the scheduler immediately before the nightly observation period.

The scheduler algorithm is outlined in Figure 1, and given in more detail below.

1. **Determine initial conditions.** These are either specified by the PI or calculated. Initial conditions include whether or not conditions are photometric (specified by PI), which filters are available (specified by PI), the Julian date and time for the start (t_i) and end (t_f) of the observation period (calculated), the focus interval (specified by PI), and the set of available calibration points (calculated, based on information from the standard stars database).
2. **Build a list of candidate requests (L).** This is done by querying the database of requests, and filtering out those that do not meet the following conditions:
 - a. The observation has not already been successfully taken

- b. The observation requires only filters that are available in the observation period
 - c. The request matches current photometric conditions
 - d. The request is associated with a project that is currently active
 - e. The requested field is up at some point during the observation period
 - f. The observed object will be sufficiently far from the Moon to be observable (as specified in the request) at some point during the observation period
 - g. The current lunar phase matches the request
3. **The main loop:** Schedule a focus and/or a calibration if necessary. Then, choose and schedule the highest priority doable request R from L. A request is ‘doable’ if, at the time the scheduler is currently considering, the requested airmass, LST, phase and contamination constraints will hold over the length of the observation. If a request is for a series of observations, the remaining observations in the series are given a high priority (at the level just below that of the PI’s observation requests), so that the scheduler avoids breaking up a series. If the request is for a single ‘as long as possible’ observation, then it should be scheduled until a higher priority task is requested, or a necessary system event (e.g. a focus) is required. Repeat until the observing period is over, or there are no more requests.

Given a database of typical observation requests, this algorithm performs adequately, producing a schedule that meets our design requirements. However, it does not necessarily produce the *optimal* schedule. Moreover, some requests – for the planet Pluto (the PI’s primary target), for example

– will never be honored. This problem can only be avoided by educating the users so that they do not make requests that are difficult or impossible to fulfill.

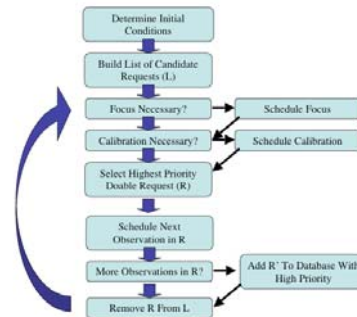


Figure 1: The scheduler algorithm

The Database Interface

The goals of the interface to the observation request database is to gather the information necessary for the scheduler to function, while minimizing the amount of technical and astronomical expertise required to make effective observations. It must also provide enough information about practical considerations (e.g. the telescope’s priorities, other demands, etc.) to allow students to make requests that are likely to be granted and scheduled.

The first version of the database interface was developed in consultation with the teachers, researchers and students involved in the TOPS project [Bedient *et al*, 2003]. We are currently evaluating the interface, as students attempt to use it to make observations. Many of the students are interested in observing the comet Tempel 1, at least in part because of the imminent (July 4, 2005) arrival of the Deep Impact probe, which will investigate the composition of the comet by hitting it with a projectile and observing the results.⁴

⁴ If this paper is accepted, we plan to present the results of our evaluation at the conference.



Figure 2: Deep Impact approaching Tempel One (Image courtesy of P Rawlings)

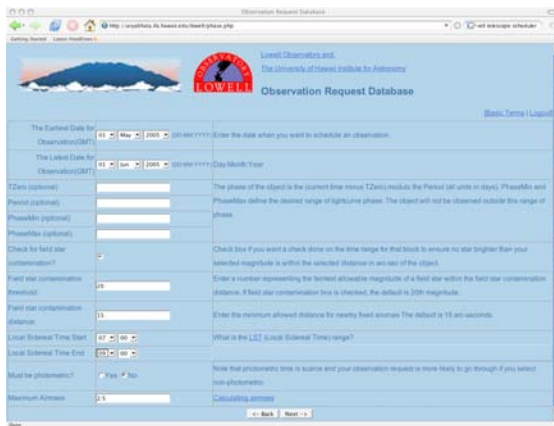


Figure 3: One screen from the interface to the observation request database.

Discussion and Future Work

As mentioned above, the scheduler as it stands is not perfect. It only performs minimal look-ahead, which limits the efficiency of the resulting schedule, particularly if ‘awkward’ (i.e. overlong or clashing with high-priority requests) observations are requested. Also, it is not able to reschedule in the middle of the observation period in the case of a failed observation. Finally, it is entirely focused on a single observation period, and does not take into account, for example, whether or not a given observation could be done on another night.

To address some of these problems, we are currently investigating the possibility of using a genetic algorithm to improve the efficiency of the scheduler. Genetic algorithms have long been applied

successfully to highly constrained scheduling problems (see, for example, [Davis, 1985]). Our initial experiments suggest that this approach is promising; however, we have yet to build a full-scale scheduler using this approach.⁵

Conclusion

In conclusion, we have built a system that allows students and other non-professionals to request observations at a large research telescope. Users are encouraged to submit observation constraints, rather than request for a particular time-slot. By providing an easy-to-use interface and an automatic scheduler, we have reduced the PI workload associated with non-professional observers to the extent that, we hope, many more partially-used research telescopes will become available to high-school astronomy students.

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⁵ We expect to have built and tested one by mid-summer, and hope to present the results at the conference, if accepted.

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