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A New Graphical User Interface for Observatory Control

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ABSTRACT

The Hobby-Eberly Telescope has identified a number of problems with the current observatory control interface used by operators to run the telescope and associated equipment. We consider the applicability of a purely graphical interface to replace the existing interface and explore the pros and cons of a graphical interface. The design decisions for a new interface are discussed and the process by which we plan to create the new interface is described. An initial prototype interface has been developed and discussed with the telescope operators. The prototype interface and the reasoning behind some of the decisions are discussed.

Keywords: User interface, GUI, graphical user interface, telescope control, observatory control

1. INTRODUCTION

The Hobby-Eberly Telescope (HET) (Figure 1) is a 9.2-meter tilted Arecibo-style telescope with a segmented primary mirror and moving star tracker at prime focus. Its design was a prototypical approach to the construction of a large, low-cost, telescope optimized for spectroscopy. Following construction, shakedown, and initial commissioning, the telescope is now in full-time science operation[1].

The HET was funded and built by a consortium of five universities, the University of Texas at Austin, the Pennsylvania State University, the Ludwig-Maxmilians Universität München, the Georg-August-Universität Göttingen, and Stanford University. Descriptions of the telescope[2], its operation[3], scientific instrumentation[4,5,6,7], commissioning experience[8,9], and early science results[10,11] may be found at the indicated references, but a brief description of its operation and history is included here for the reader's convenience.

Figure 1 The HET mirror, structure, and tracker.

The fixed-elevation telescope employs a spherical segmented primary mirror supported by a steel truss as an essential part of the telescope's low-cost, Arecibo-style design concept. All 91 segments are identical regular hexagons. The unique design of the HET allows the primary mirror to remain stationary during an observation; it can be repositioned in azimuth between observations to access different areas of the sky. The mirror has a constant zenith angle of 35 degrees, and thus

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always has the same orientation with respect to gravity. Images of astronomical objects are acquired and followed across the mirror array at prime focus for up to 2.5 hours by means of a tracking device mounted atop the telescope structure.

2. OPERATION

The unique nature of the HET means that the usual method of telescope operations, i.e., a principal investigator or student coming out to the telescope for several nights of observations, is not efficient. The telescope can view only a limited portion of the sky on any particular night although it can see 70% of the observable night sky at McDonald over the course of the year. In order to make effective and productive use of the telescope, the HET was designed from the outset to be used exclusively for queue observing.

Two operators are required to run the telescope during science observations. Together, the Resident Astronomer (RA) and Telescope Operator (TO) are responsible for telescope safety, operation, and data acquisition. We use two operators for safety reasons, although the software could be written to allow operation by one person. The Resident Astronomer is responsible for all instrument operation and science data acquisition. He or she chooses which targets to observe, operates the science instruments, and verifies that the science image meets the data quality criteria specified by the Principal Investigator, e.g., signal to noise or wavelength coverage. The Telescope Operator is responsible for the safe and efficient operation of the remainder of the observatory and telescope. He or she must monitor the many systems used during observations, keep an eye on the weather, operate the telescope, and deal with any diagnostic or warning messages that may occur. The TO is responsible for the safety of the telescope along with the associated systems and has the sole authority to terminate observing because of problems or conditions that threaten the telescope.

We distinguish here between a Telescope Control System (TCS) and an Observatory Control System (OCS). A Telescope Control System is responsible only for moving and pointing a telescope and possibly the dome or enclosure. It may also be responsible for moving objects that are part of the telescope itself, e.g. tertiary mirrors for a Nasymyth focus. An Observatory Control System on the other hand monitors or controls all facets of the observatory required for science observations. These may include weather or environmental monitoring, control of an active mirror, dome louvers and ventilation equipment, air conditioning equipment, and calibration equipment. These terms tend to be used interchangeably and the software developed at many observatories may do some or all of these activities. For example, at the HET we have software called the Telescope Control System while in reality it is designed to be the central interface for the telescope operator and present all relevant information to the operator and thus is really an Observatory Control System.

Observatories utilize numerous systems that must operate in conjunction to make science possible. The Telescope Operator must be able to monitor these numerous systems and have diagnostic or warning messages presented in a timely and accessible manner so that the telescope can be safely reconfigured or shut down if a problem arises. An integrated control system provides a central interface that presents this information to the operator. In many cases the observatory systems operate with out any trouble, however, the operator must be able to trust that if a problem crops up notification will occur and the proper response can be identified. Many observatories claim to have an integrated control system while in reality the operators keep additional terminals or screens open to monitor the engineering portions of the system so that they can catch errors or additional diagnostic information when problems occur.

3. SOME PROBLEMS

The HET was designed from the start to be an extremely inexpensive telescope. In order to keep costs down the project utilized a very small programming staff during construction. This, coupled with an initial lack of knowledge about how to operate a telescope like the Hobby-Eberly, meant that the original software was incomplete. In particular, the inter-process communications software did not work and many communication links were simply turned off to achieve basic functionality. Without a fully integrated control system the HET software is simply a collection of individual systems. This means that the TO must monitor multiple GUIs in order to get a complete picture of what is going on with the entire system. These multiple interfaces in turn mean that the TO must make numerous mouse clicks and key strokes in order to get an observation underway, increasing the observing overhead and reducing the time available for science.

Because of the complex design of the HET, the TO and RA need additional information over and above that which is normally required at more traditional observatories in order to insure that the telescope is behaving correctly. Trajectories are of limited duration and the TO an RA need to know how long the trajectories will be and how much time remains in the trajectory in order to properly estimate the observing time available. In addition the pupil of the tracker falls off the primary mirror except for the center of a trajectory. Thus the exposure time is a function of the trajectory path across the primary mirror. Trajectories that pass through the center of the primary gather the greatest flux of photons. The operators need to know the path of the trajectory in order to set the correct exposure time and this is best presented as a graphical display rather than as a numerical value. While not complicated in principal the HET interface requires more than just the usual RA/DEC display of more traditional telescopes.

The initial HET TCS interface developed during construction was strictly an engineering interface. It provided hooks to all the internals of the software and it performed the basic functionality that the construction staff thought was required. However, while this software could move the telescope and associated systems, it was incapable of operating the telescope for any sort of science operations. Soon after the operations staff took over it was decided that this system should be replaced. Work was in progress on a new user interface for the Harlan J. Smith telescope at this time so the two programs were combined and a common interface was developed for both telescopes with specialty code for the unique functions of each telescope. After nine months of development this system was successfully deployed at the telescope and has been in use for nine years at both the HET and at the Harlan J. Smith Telescope[12]. The interface is shown in figure 2.

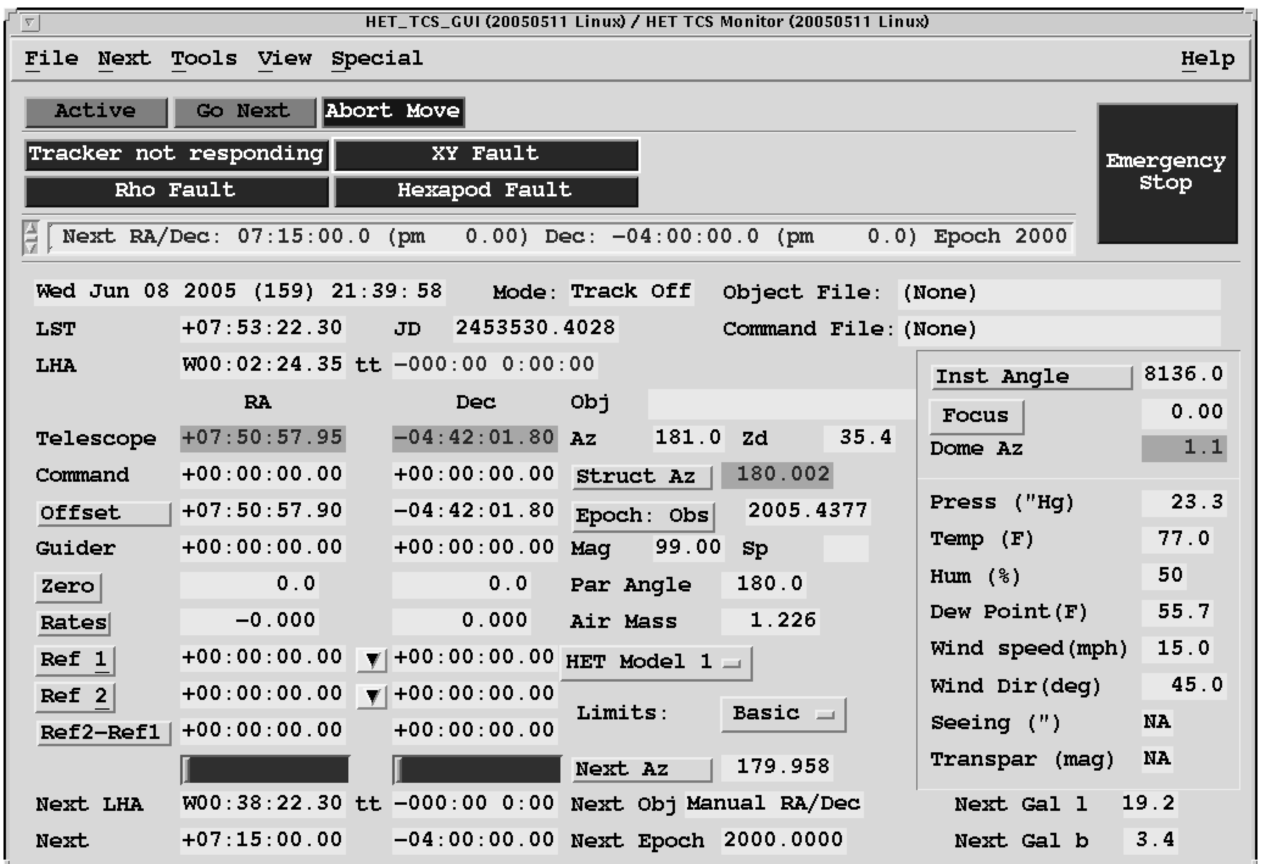

Figure 2. The current Telescope Control System interface used at the Hobby-Eberly Telescope. Note the extensive use of numerical data as the presentation model.

While this TCS has been very successful, it still suffers from some problems that are annoying to the operators and that cause operation to be more inefficient than necessary. Because the interface was developed quickly with the goal of getting on the sky and tracking an object, some of the functionality deemed less critical was omitted from the system. In particular, because of the rush to get a new interface in place, much of the inter-process communication was incomplete. Thus the operator is still left with numerous GUIs, one for each subsystem, with numerous mouse clicks and keystrokes required to initiate a coordinated action. Additionally, because the interface was designed for both the Harlan J. Smith telescope, a classical equatorial telescope, and the HET, a unique alt-az telescope, the information presented to the operator is not always relevant. The HET portion of the software was added on top of the software for the Smith telescope. Thus, while the operator gets the information required to operate the HET telescope there is much information presented that is not relevant to HET operations. The GUI itself takes up quite a lot of screen real estate and we have had to provide five monitors with multiple virtual screens to the telescope operator in order to display all the interfaces required for night time operations. In short the operator is presented with a lot of information that is not useful and which distracts from the information that is.

4. A NEW USER INTERFACE

4.1. Motivation

A few years ago I was watching my teenage son playing a space adventure and flight simulator game on his computer. Looking at the display and the speed of his play it became clear that quite a bit of information was being presented and assimilated very quickly. How was it that he could rapidly navigate and win this game while our operators struggled to diagnose problems and were frightened of actually trying to change or improve a procedure? Could a purely graphical display with minimal text content provide the relevant information that a telescope operator needed to run an observatory while solving many of the problems described above? With no background in user interface design and no mandate to produce a new interface we began looking into what might be required to create a new paradigm for our operators and whether it was a worthwhile effort.

4.2. Design

In order to design a new user interface for our Telescope Operators, we first considered what sort of decisions the operators need to make at night and what information is required to make those decisions. The primary activity, of course, is to make the telescope go to the right place on the sky, insure that it has reached the correct object, and to make sure that it is tracking that object correctly. Operators must also be warned when an abnormal condition exists in a piece of equipment or if a closure criterion has been met. Warning and notifications are easily handled with dialog boxes or pop-up window; however, it is also useful if the operator can have access to trend data, e.g. weather data. Then the operator can estimate how long a good seeing period will last or when a closure criteria will be meet and how long the Resident Astronomer has to continue observations. Such information aids in efficiently scheduling the telescope during the night and allows the operators to take maximum advantage of the conditions at hand.

Once we identified the information required by the operator, we identify where that information comes from and how it gets to the operator. The HET uses multiple server modules, each controlling a different system, so we require well-defined communication semantics between processes and systems. Of course such communication semantics are not unique to the HET or to a new GUI. They are an important part of any well-designed control system.

Once we know the information that needs to be presented, we ask if there are any common properties of the information that can be utilized to create common presentation formats. For example, wind direction, dome position, and telescope azimuth are all azimuthal numbers and could be presented as lines on a heading circle; the dust count, air temperature, and wind speed are numeric with closure limits and can be presented as a bar graph that changes colors a we get close to a limit. The HET has louvers encircling the enclosure walls that can be opened at night. Anemometers and wind vanes are installed in each opening. The vector direction and speed can be displayed on the heading circle and can be either length or color encoded.

Images can be a powerful part of any graphical presentation system and astronomy lends itself to images quite readily. Our operators already monitor the guider images as well as satellite based water vapor images and local cloud cameras. Images can be presented as a background to a text or vector based drawing plane or may be the primary graphical object displayed.

Finally we considered what the advantages and disadvantages of a graphical interface might be compared to the text-based display currently in use. The primary advantage of a graphical interface is the ability to present a large amount of information in a compact format. If presented correctly, such an interface will be easier to use, thereby reducing operator fatigue during long nights. However, such an interface requires a lot of pre-planning in order to match the user's model to the programmer's model. With out such a match the user's expectation of program behavior will not follow the programmer's expectation[13] and the user will not or can not perform proper corrective actions in the event of a problem. Finally, a graphical interface is more complex to design, write and maintain which raises the cost of development and operations.

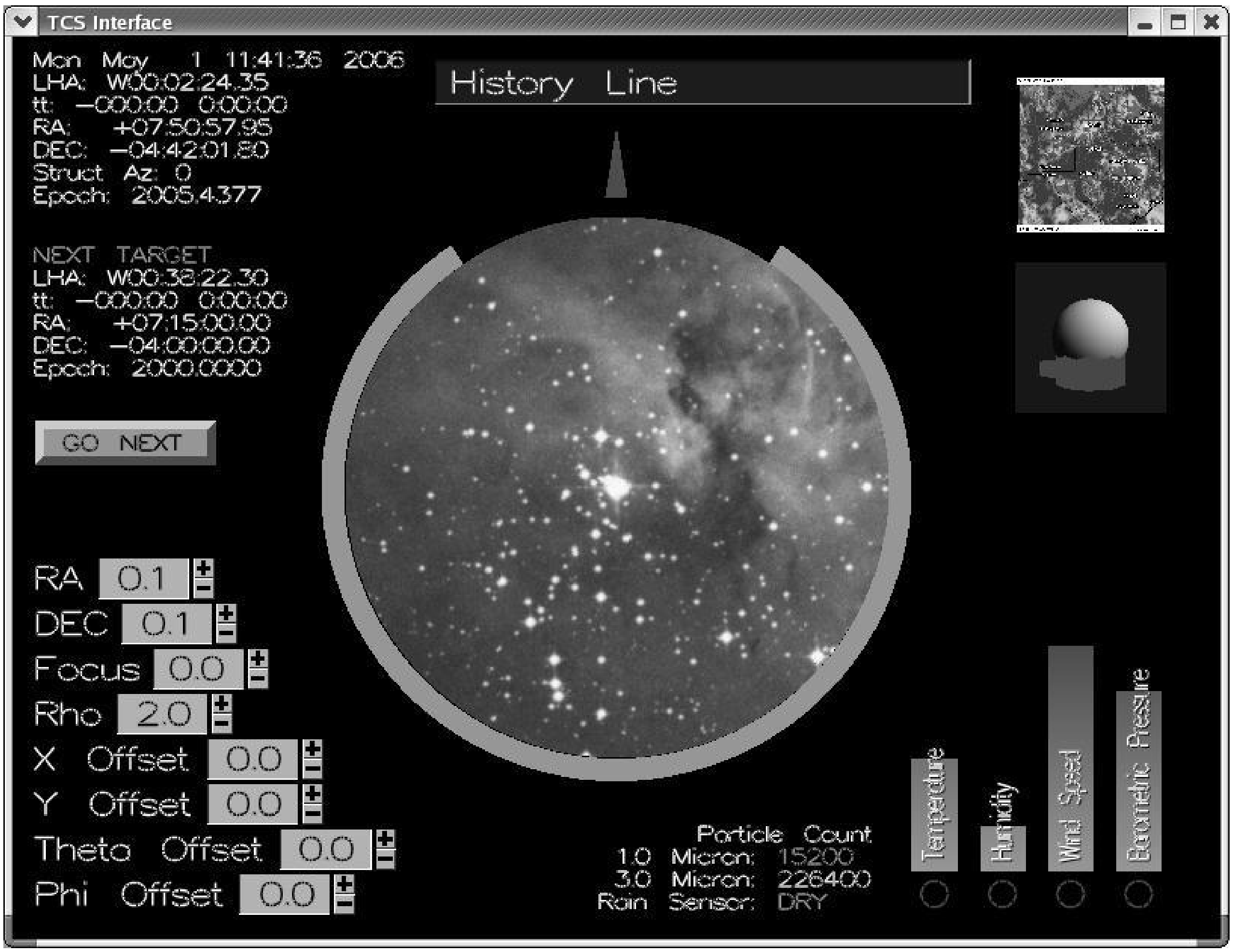

Figure 3. The prototype user interface for the HET. Note the extensive use of graphical elements as compared to the old interface.

One of the advantages of the HET is that we have a small pool of Resident Astronomers and Telescope Operators who are the only ones who use the telescope control system. Furthermore, they are using the system almost every night. They therefore have the time to deal with a long learning curve and can learn the system intimately. We do not have to deal with visiting astronomers who may use the interface only a few times a year and require a very simple interface in order to get back in operation again. Even so, our operators still have a different mental model of the telescope behavior than the programmers do.

4.3. Development Program

With the above ideas in mind we began exploring designs and concepts for a new interface in the summer of 2005 through the auspices of the McDonald Observatory's Research Experiences for Undergraduates (REU) program. Because the REU program was only ten weeks long we rather quickly defined preliminary data requirements and developed a mockup interface that we could present to the operators for comment. We chose the OpenGL Application Programming Interface (API) as our graphics platform because it is the most widely used and supported API in the industry.

Our initial efforts were spent in the design phase described in Section 4.2. We learned about OpenGL as well as basic User Interface design issues. Then we created a mockup program that consisted of just the display portion of the code. This interface was presented to the telescope operators for comment as well as to explore their expectations about what happens, for example, when they click on an area or when an alarm turns red. These comments were then incorporated into a redesign of the interface.

When designing a new user interface one is tempted to make extensive use of color information, however, one of our current telescope operators is almost completely color-blind and we have had other color-blind operators in the past. We deal with this by insuring that color is not the only factor indicating information to the operator. One way to insure that color is not a determining factor in the design is to create the interface first in black-and-white or in grayscale. Once the design is complete we add color to enhance the display. The prototype interface is shown in Figure 3.

The prototype is very incomplete but has a number of the graphical elements discussed above. The central area shows a heading circle. The arrow at the top shows the telescope azimuth direction, while the opening in the circle is the dome position and an indication that the dome is open. The stars in the center may come from a real time guider image, a section of a digital sky chart, or an online finder chart provide by the investigator. Wind direction arrows are planned as are vectors showing the status and flow through the enclosure louvers. The central area may also be used to display the tracker trajectory as this falls within a circular area. A trajectory arc would immediately show the operator how much time is left in the trajectory and hence the available exposure time. The bar charts in the lower right corner show the current weather values from the external weather tower. We plan to include seeing values from our Differential Image Motion Monitor (DIMM) telescope as well.

The upper right corner contains a real time image from the National Weather Service satellite or radar services. Clicking on the image to expands it to fill the display. This image has a transparency level set so we can still see the main display through the image. The image just below it is a place holder. We had room on the display and thought that the images were a neat idea but have not yet come up with an image that we find useful.

Each area of the display supports mouse-clickable actions although none are active at this time. We have not fully defined what should happen yet.

The left hand area of the display still contains a lot of text information although the operators rarely use this information. They do not really care what the Right Ascension and Declination of the telescope are unless they are unable to match the finder chart with the current star field. They do care about the current and next azimuth of the telescope because this determines how long it will take to move to the next target. As we develop the prototype and transition to a more functional interface we will further refine the use of text and graphics with in the display.

5. FUTURE WORK

This year's REU student will complete the data flow requirements and create a list of all relevant data, data source and data format. Proper definition of the relevant data also includes a better definition of the behavior of the interface including the definition of all mouse click and keystroke activities. Once we define the data requirements, the communications paths required to get the data to the telescope operator will also be defined.

As we identify the data sources for the interface we will create the actual data channels at the telescope so that we can get live data to the interface. During this entire process we need to keep the Telescope Operators in the loop so that they can make comments on whether a particular graphical element or mouse action is a useful feature for their nighttime activities. Finally we need to support engineering modes for the daytime engineers as well as to allow the operators to identify and resolve problems at night.

6. SUMMARY

The Hobby-Eberly Telescope has begun a program to explore whether a completely graphical user interface can provide relevant information to a telescope operator more efficiently and with fewer displays than the current multi-window user interface does. We began by exploring the pros and cons of graphical interfaces. After identifying problems with the current user interface we explored what decisions the operators must make during observations and what information was required to make these decisions. The relevant data sources were identified. We have developed a prototype interface and begun discussions with the operators to determine the functionality desired. Additional work will continue to refine this process and the requirements for the new interface.

7. ACKNOWLEDGEMENTS

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