P60 Control Software Design Specification

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Purpose

The purpose of this document is to describe the design goals for the control software of the robotic 60-inch telescope at Palomar.

1 Introduction

The complete software aspects of the Palomar 60-inch telescope upgrade and roboticization are illustrated in an overview fashion in Figure 1. Palomar Operations is responsible for upgrades to the Telescope Control System (TCS) which will put it in direct command of all mechanical systems associated with the telescope; the TCS will have ultimate responsibility for the safety of the observatory. Caltech Optical Observatories (COO) will be responsible for the direct control and readout of the camera and will also control the attached filter wheel; in addition, COO will provide a GUI interface to the Instrument Control System (ICS). SRL and Astronomy will collaborate on the higher-level control software.

In this document we will be describing the design characteristics of this control software, specifically, the Observatory Control System (OCS), Observation Scheduling Software (OSS), and Image Analysis Pipeline (IAP). The design of the Data Reduction Pipeline will be addressed in a separate document.

In the context of the overall system, these high-level control components are responsible for directing observations in real-time and gathering scientifically useful data, based on the prioritized target list and observation requests of the human operator(s). As such, the software systems are responsible for deciding:

1. What targets to observe
2. How and when to observe them
3. How and when to gather relevant calibration data
4. Whether a given observation has been successfully executed

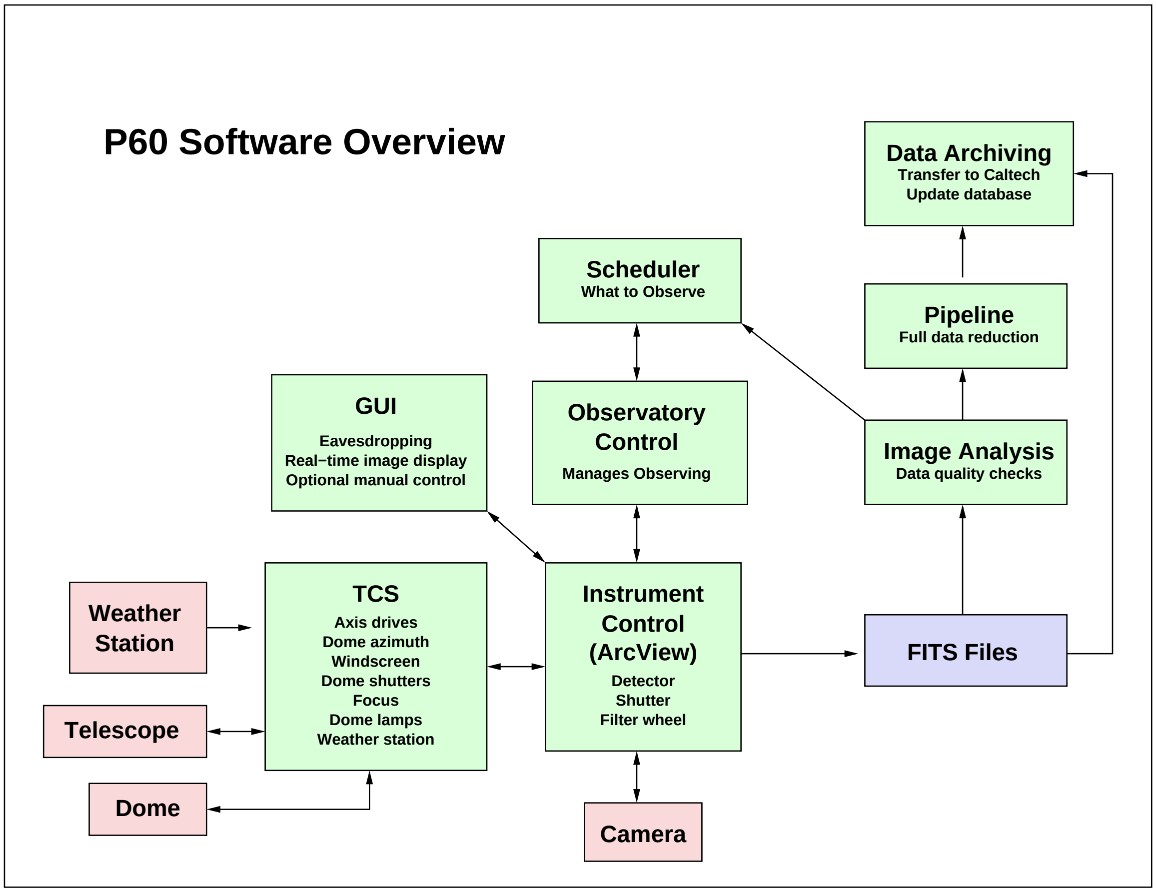

Figure 1: Overview of software systems associated with the Palomar 60-inch upgrade and roboticization; see text for details. Arrows indicate lines of communication and/or data transfer between the various components of the system.

This responsibility set may be summarized as "meeting the operators' goals," that is, the control software should act as an intelligent and adaptive proxy for a human observer.

We have divided up these responsibilities in a modular fashion that we hope makes sense from a logistical and programming as well as a logical perspective. These separate components will each be discussed in turn below.

2 Observatory Control System

The Observatory Control System, or OCS, is the direct interface between the control software and the telescope and instrument control systems. It will be responsible for communicating with both of these systems, although we note that all communication with the TCS will be carried out with the ICS as an intermediary (Fig. 1). The OCS will monitor the progress of individual observation requests, and should be capable of recognizing and reacting appropriately to most error conditions that are anticipated in the TCS and ICS, for example, shutter failure or filter wheel malfunctions. The OCS should also be able to coordinate its requests appropriately so that, for example, telescope motion and dome movement are complete prior to the initiation of a science exposure.

The intent is for the OCS to be devoted to executing "one observation at a time." This single observation is likely to consist of a single exposure in many cases. However, in at least some cases it will consist of multiple exposures: for example, the multiple exposures of a single focus-loop or the multiple observations of a single field of photometric standards. It is important for scheduling control purposes that the OCS return control to the OSS frequently, so it is not clear to what extent multiple science exposures of a single field will be packaged as a single observation for the OCS. Currently it seems likely that each science exposure will be treated as a separate observation in the OCS, with the OSS coordinating multiple observations of science fields as appropriate.

3 Observation Scheduling Software

The OSS is intended to serve as "the brains of the operation." Beginning with the prioritized target list that is provided by the human operators, and taking as input the continuing stream of data provided by the instruments and the parallel image-analysis pipeline (IAP), the OSS should manage the observations so as to gather the requested data, in scientifically useful form.

In addition to managing the target queue, the OSS is responsible for gathering appropriate calibration data, including (at least potentially) dome flats, sky flats, pointing checks, focus runs, and photometric standard fields. These calibration activities will, to some extent, be interleaved with science observations. However, to the greatest extent possible, they should take place during the afternoon and evening/morning twilight so as to leave most of the night for science observations. If, at some point during the night, observing conditions are acceptable but no targets are available, additional calibrations may be scheduled.

Design of the OSS must address two important subsidiary goals, target prioritization and observation specification. We will now discuss each of these aspects of the software separately.

3.1 Target Prioritization

The Target Prioritization subsystem is responsible for negotiating among the various targets in the operator's queue, and among the various standard calibration sequences, in order to decide what "the next target" of observation should be. The goal is for the target prioritization subsystem to be a multivariable system that is (eventually) sensitive to all relevant aspects of the observatory's operation. To begin with, we anticipate being sensitive to the target elevation/airmass, relative visibility (as a fraction of the night), and to the sky brightness, moon distance, seeing, and atmospheric extinction conditions. This component of the software should be capable of ready modification so that the sophistication of the system can be improved with time. However, it is not anticipated that it will perform any sort of a global optimization on the overall target queue (as, for example, is performed by the HST scheduling system).

As an important part of the target prioritization process, the system will have to be aware of past observations of a particular target if these observations are intended to form a coherent scientific whole. For example, photometric time series, image mosaics, or multiband observations will all require a memory on the part of the OSS. In particular, we intend for the system initially to have the capability of periodic or logarithmic monitoring of a target. These concerns therefore play a role in the specification of observations, as discussed below.

Finally, the target prioritization system will be responsible for sensing and responding appropriately to burst alerts, in a fully interruptible fashion.

3.2 Observation Specification

Within the context of the 60-inch control software, the question "What is an observation?" will have at least two different answers. As discussed above, for the purposes of the OCS we plan to take a very low-level view and identify *an observation* with a single science exposure or a brief sequence of calibration (or possibly science) exposures. For the purposes of the OSS, however, we plan to take an expansive definition of an observation which will hopefully make the observatory flexible and easy to use for the human operators.

Thus, an observation may be specified as exposure to a given depth (specified in seconds) over a given field of view. Mosaicking of the field will be automatic, and in some or most cases, all parts of the requested region will be covered by multiple exposures (per requested filter). If the time series of the observations is important, either to achieve a regular cadence or to maintain a logarithmic monitoring of the region, then this too will be achieved automatically via the target prioritization system.

As noted in the previous section, this will require the system to have a per-observation memory of which aspects of the observation have been executed in the past, in order to bring the full desired sequence to a successful conclusion.

4 Image Analysis Pipeline

The purpose of the IAP is to provide rapid feedback to the other components of the control software on the success and relative quality of the data as they are gathered. As such, the IAP will be an abbreviated or truncated version of the data reduction pipeline (which will be described in more detail elsewhere).

Specifically, it is intended (eventually) for the IAP to:

1. Debias and flatfield data frames
2. Measure the sky level
3. Detect objects and measure the seeing
4. Determine best focus from each focus-loop

5. Perform astrometric registration and check the pointing
6. Perform photometry and measure atmospheric extinction

All of these capabilities may not be present in the first generation of the software; they are given in estimated order of difficulty and are likely to be implemented in this sequence. Once calculated or measured, these data will be made available to the OCS so that it may confirm that the exposure was successfully executed, and to the OSS so that it may appropriately prioritize the next observation.

In order to make the best use of these data within the OSS, it will be important to have models for the telescope performance and sky properties so that, for example, a measurement of the seeing in one band may be used to estimate the seeing in other bands. As another example, we hope to construct focus and pointing models of sufficient accuracy that in-night calibrations and corrections to these models are minimal. It is worth noting that a rudimentary, operational IAP will be useful, for these purposes, at an early stage of the telescope operations.