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ObsTac: automated execution of Dark Energy Survey observing tactics

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Abstract. The Dark Energy Survey is a multi-filter survey of the southern galactic cap with two components: a wide component which visits many fields, each ten times over the course of five years; and a time-domain component of ten fields revisited on a regular cadence in each of four filters through the survey. Optimal selection of an observation for any particular time depends on many factors, including weather (including seeing), moon position and phase, image quality of already collected exposures, and others. ObsTac is the component of the observing software system that automates selection of observations based on current conditions. It integrates with the observing software through an observing queue, supporting interactive intervention by observers. It has a modular structure that simplifies replacement of different components of the system, including the implementation of the tactics algorithms themselves and interfaces with data sources that supply, for example, weather and progress data. In addition to its use in observing, obsTac may also be used to run simulations to evaluate strategic and tactical algorithms based on archival weather data.

1. The Dark Energy Survey

The Dark Energy Survey (DES) (The Dark Energy Survey Collaboration 2005) is an ongoing astronomical survey collecting data using the DECam instrument (Flaugher et al. 2012) on the Blanco telescope at the Cerro Tololo Inter-American Observatory (CTIO). The survey will provide data for four complementary probes of dark energy: type Ia supernova, baryon acoustic oscillations, galaxy clusters, and weak lensing. It consists of two components: a wide survey covering a footprint of 5000 square degrees with ten exposures in each of five filters (g, r, i, z, and Y), and a time-domain survey that will observe ten fields on a regular cadence in each of four filters (g, r, i, and z).

Several factors determined the footprint of the wide survey, including: overlap with existing surveys; avoidance of the high extinction and high stellar density areas of the sky (the galactic plane); a large enclosed contiguous survey area; and accessibly from CTIO on the survey calendar.

2. DES observing tactics

Over the course of the allocated nights, the survey will receive time in a variety of weather conditions, at a range of sidereal times. To maximize the useful survey area covered, the survey must make effective use of each set of conditions as they occur. Major factors are

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position Different areas of the survey are accessible at different times of the year. The western edge of the footprint can only be observed in the beginning of each season, and there are times late in each observing season when only the eastern edge is accessible. If the survey does not collect data in the west early in each year, it will never be able to. If it observes the eastern edge earlier than it needs to, there will be observing time at the end of the year when none of the uncompleted areas of the footprint can be observed. At any given time, therefore, fields that set earlier are given priority over fields that set later.

sky brightness Scattered light from the sun (during twilight) and moon affects shorter wavelengths of light much more strongly than longer ones. All wide-survey exposures in g and r must be taken when the moon is below the horizon (dark time). To ensure that there is enough total dark time to complete the survey in g and r, exposures in z and Y are taken only in bright time. Exposures in i may be taken in either dark or bright time, depending on completion of the survey in i relative to the other filters.

seeing The scientific usefulness of wide-survey exposures depends on the delivered point spread function. This is critical in r, i, and z, which will used for weak lensing ellipticity measurements. When seeing is poor, exposures in these filters need be avoided because any taken in poor conditions will need to be repeated.

Finally, measurement of supernova light curves requires revisits to the time-domain fields on a regular cadence: if it has been longer than seven days since the last visit to a time-domain field, it needs to be observed as soon as it can be.

A simplified schematic of the DES tactics designed to achieve this is as follows:

1. If there are time-domain fields that have not been observed in the last seven days, and they can be observed usefully under the current conditions, observe them.

2. If the seeing is good and the moon is down, select a wide-survey exposure in g, r, or i. Give priority to fields that set earliest.

3. If the seeing is good and the moon is up, select a wide exposure in i, z, or Y. Give priority to fields that set earliest.

4. Observe the time-domiain survey exposure sequence completed least recently.

The survey will collect data under all seeing conditions, with the expectation that particularly poor data will be retaken.

3. ObsTac itself

ObsTac is a python module that implements DES survey tactics. ObsTac has three fundamental architectural elements:

actions An action object describes an action that can be taken. An action can either be a single exposure, a sequence of exposures, or “wait”. (A “wait” action may be chosen, for example, if obsTac is called for a time the sun is above the horizon.)

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circumstances A circumstance object is a composite object used to represent the state of the survey and environment at a given time. A circumstance object includes the time, extrapolated or actual seeing and sky brightness, telescope position, survey footprint, and other information needed to select an action. A circumstance object may represent either a real or hypothetical set of parameters, and a given instance of an obsTac application may instantiate several instances representing different extrapolated future times.

tacticians A tactician is a callable object that accepts a circumstance object as its only parameter, and returns a prioritized list of actions that may be taken.

An application using the obsTac module generates a circumstance object for the time for which an action is needed, calls a tactician object with the circumstance object as its only parameter, and receives prioritized list of actions in return. (A prioritized list is returned rather than a single action to support complex composition of tacticians using other tacticians.)

4. Observing with ObsTac

SISPI (Honscheid et al. 2012), the DECam control system, consists of a collection of applications that interact with each other through remote procedure calls. Among these is the Observation Control System (OCS), which includes an observing queue. During observing, SISPI executes exposures starting from the head of the queue. The SISPI user interface provides displays and controls for human observers to examine and edit the observing queue. (The queue may be edited during observing.)

ObsTac supplies an additional SISPI application that, when enabled, also adds exposures to the queue. When the obsTac SISPI application is enabled, it selects new exposures and adds them to the queue until the estimated duration of the queue reaches a configurable target, typically 15 minutes. A callback triggers this process each time the contents of the queue changes, for example because SISPI has taken an exposure off of the queue because it has begun to observe it. As a result, when enabled, obsTac maintains the length of the queue at the desired duration. The finite duration of the queue provides an opportunity for the human observing staff review obsTac's selections before they are executed by SISPI. Because obsTac examines the contents of the queue and the table of exposures each time it selects a new exposure, it natually accommodates interventions by humans, including manual observation of DES observing fields and intermixing of non-DES science exposures (for engineering and testing, for example) with DES exposures.

In production, obsTac uses an implementation of the `circumstances` object that incorporates interfaces to other observing systems, thereby providing obsTac with recently updated information. For example, it provides data on the seeing based on automatic assessment of recent exposures, the table of completed exposures, the current contents of the queue, and what exposure is actively in progress.

5. ObsTac in simulation

The performance of realistic algorithms for selecting exposures depends on a long list of tunable parameters. These parameters determine, for example, under what conditions

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time-domain fields are selected instead of wide survey fields: if these conditions occur too often, the wide-survey will not have enough time to complete its footprint. If they occur too rarely, the time-domain cadence may be missed, or time with very good seeing (essential to some wide survey exposures but less critical to time-domain ones) may need to be used for time-domain exposures to maintain the time-domain survey cadence. Similarly, the schedule, data quality requirements, airmass limits, area of sky covered by the wide survey, and other parameters also have a strong effect on the completeness and data quality of the survey.

ObsTac simulations can be run to estimate the consequences of different combinations of parameters. In these simulations, the implementations of the `tactician` and `action` classes are the same as used in production, but several members of the `circumstance` class are replaced by implementations that return seeing and cloud-cover values based on historical data from CTIO.

A simulation driver application uses the obsTac `tactician` to select exposures over the course of a survey schedule, for a given set of parameters, mimicking the behavior of SISPI and DES data processing (which can declare exposures that do not meet quality standards "bad", and in need of repetition) as it does so. Repeated over many years of historical data, these simulations indicate what results can be expected from a given set of parameters in a typical year, and the range of results that can be expected based on year-to-year variations in conditions.

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