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Science Goal Driven Observing

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Abstract. In the coming decade, we will be forced to automate many of the scientific tasks that are done manually today because observatories will have to be managed in a fiscally tight environment. Thus, spacecraft autonomy will become a part of mission operations. In such an environment, observing campaigns of inherently variable targets and targets of opportunity will need flexible scheduling to focus observing time and data download on exposures that are scientifically interesting and useful. The ability to quickly recognize and react to such events by re-prioritizing the observing schedule will be an essential characteristic for maximizing scientific returns from the observatory.

The science goal monitoring (SGM) system is a proof-of-concept effort to address these challenges. The SGM will have an interface to help capture higher level science goals from the scientists and translate them into a flexible observing strategy that SGM can execute and monitor. We are developing an interactive distributed system that will use onboard processing and storage combined with event-driven interfaces with ground-based processing and operations, to enable fast re-prioritization of observing schedules, and to minimize time spent on non-optimized observations.

1. Introduction

In the last fifteen years astronomers have come to depend on software tools to operate observatories/missions, and also to obtain, analyze, archive and reanalyze data. In the coming decade due to limited funding, observatories must work with smaller and smaller operations staff, even as instrument complexities and data volumes are increasing. Many of the scientific tasks that have traditionally been manually overseen will have to be automated. In such an environment, software tools are an essential component for increasing scientific productivity and developing cost-effective techniques for obtaining and assimilating data.

Thus, spacecraft autonomy will become an even greater part of mission operations. While recent missions have made great strides in the ability to autonomously monitor and react to changing health and physical status of spacecraft, little progress has been made in responding quickly to science driven events.

The current spacecraft operations are reasonable for simple pointed observations. For observations of inherently variable targets, monitoring projects and targets of opportunity, the ability to recognize early if an observation will meet the science goals, and react accordingly, can have a major positive impact on the overall scientific returns of an observatory and on its operational costs. Thus, for at least a class of targets there is a need for flexible scheduling to capture quality data to achieve science goals.

2. The Science Goal Monitor Project

The Science Goal Monitor (SGM) project is a research effort funded by NASA Code R to determine if it is feasible to "get the eye back to the telescope" and to develop prototype software that will enable this. In the first phase of our study, we have determined that there is a subset of space science problems that are conducive to the philosophy of science goal driven observing. These problems are related to objects that are time variable and are often monitored for long periods. Using these problems as test cases for our prototype, we are in the process of designing and developing the SGM system which is a set of tools that have the ability to capture the underlying science goals of an observation, translate them into a machine interpretable format, and then autonomously recognize and react in a timely fashion when goals are met. SGM will provide astronomers with visual tools to capture their scientific goals in terms of measurable objectives and be able to autonomously monitor the data stream in near-real time to see if these goals are being met. Our prototype is designed for use in a distributed environment where some analysis can be performed onboard a spacecraft, while other analyses can be performed on the ground.

To testbed our proof-of-concept prototype, we have determined that an observatory that has the following conditions would get the most benefit from an SGM-like system: a typical target is intrinsically variable, targets are monitored for long periods of time, and spacecraft are designed for scheduling flexibility.

2.1. The Science Goal Monitor (SGM) Project Overview

The Science Goal Monitor (SGM) system will interact with not only the data processing pipeline for a mission, but when used on board the spacecraft, it will also interact with the raw data from the detector. Figure 1 shows the high-level concept of the SGM. At present, we are concentrating on designing the Science Goal Capture Tool (SGCT). We hope to design and develop an underlying architecture and framework for the SGM system (see Figure 1). The three key modules include:

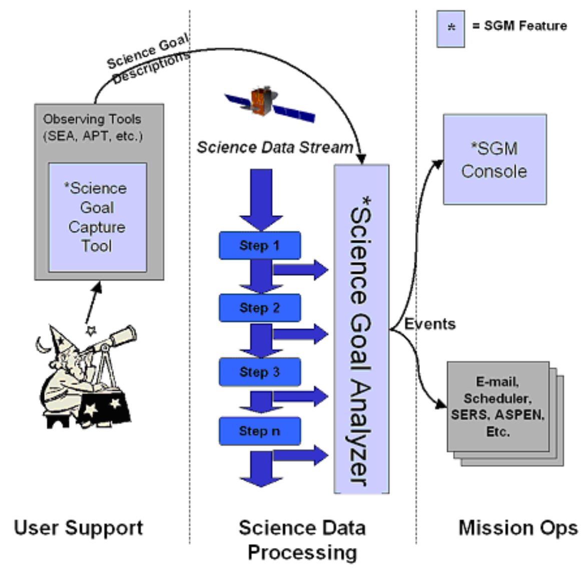

Figure 1. SGM System Overview (ground-based)

- The Science Goal Capture Tool (SGCT) will capture the user's science goals in an intuitive and easily understandable manner while simultaneously storing them in a format for easy machine processing. To achieve this mix of capabilities we are modeling the SGCT after "state diagrams" commonly used in computer science. An example of an early design overview of the SGCT interface is shown in Figure 2.
- The Science Goal Analyzer (SGA) will interpret the science data stream from the observatory and interact with its processing pipeline to analyze whether or not a set of science goals are being satisfied. When goals are met, the SGA will fire events notifying any registered observer of the event and provide access to the details. While usability will be the key in the capture tool, the analyzer will place a premium on efficiency and speed. We anticipate that the SGA will work in cooperation with an onboard scheduler. The SGA will also monitor messages and data from the spacecraft flight software and update the status of its monitored campaigns accordingly. This partnership will allow the SGM to introduce progressive autonomy and dynamic behavior while the instrument and flight software continue to provide their traditional safety and control checks.
- The Science Goal Monitor Console (SGMC) will provide a visual interface and console for mission operations to query, monitor, and interact with the SGA. We currently anticipate that this feature will be used primarily as a testing module to observe and validate the workings of the SGA and also as the "reference implementation" of an event monitor.

An important component of the SGM will be the ability to send alerts to interested scientists and operations managers, alerting them when SGM has recognized an interesting event. There are already several event notification systems in development or operation. We propose to provide an interface to one

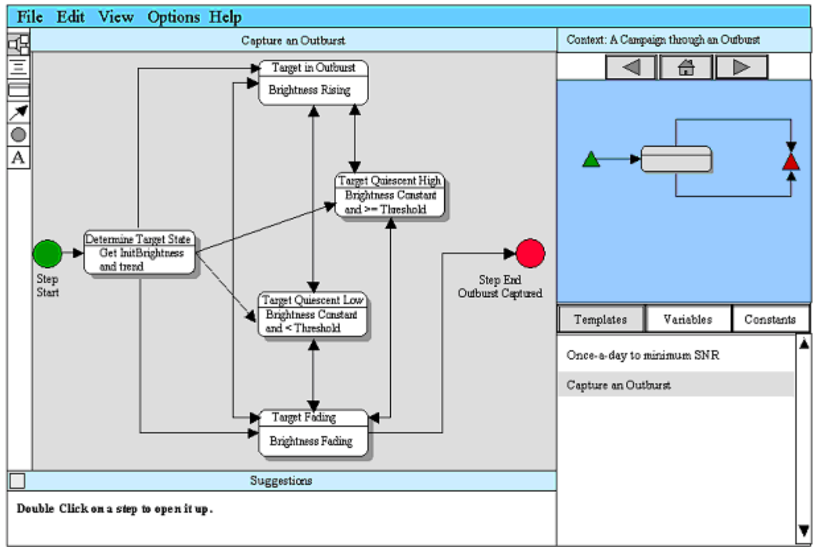

Figure 2. SGM Science Goal Capture Tool

or more of these systems, but do not plan to develop one specifically for the SGM.

2.2. The Science Goal Monitor (SGM) Project Future Plans

We are currently prototyping user interfaces to capture science goals in a fashion that the scientist can use and understand. We are also evaluating existing and emerging software to dynamically evaluate science data on board the spacecraft. The prototype will be used to evaluate the effectiveness of an SGM and to understand the risks involved for such a system to be implemented. We plan to implement and test the prototype using the Small and Medium ApertuRe TelescopeS (SMARTS) project.

3. Conclusions

Introduction of flexible scheduling and autonomously reacting to science driven events inherently infuses automation technologies into mission operations. Missions, especially complex high-profile missions, are more culturally and politically averse to risk when it comes to automation. Clearly, the capture of science goals rather than the mechanics of an observation while developing observing programs, and the subsequent automatic analysis of the data stream to determine if goals are met, represents not just a leap forward in automation, but a large change in the operations paradigm. We are in the early stages of the Science Goal Monitor project to develop prototypes, evaluate their effectiveness, and understand the risks.

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