DYNAMIC SCHEDULING FOR THE BIMA ARRAY

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ABSTRACT

In order to make the best use of varying weather conditions we propose to to implement dynamic scheduling for BIMA array observations. The schedule is determined in real time from a prioritized list of observations and the system status including the weather conditions. We briefly discuss the relative merits and problems of flexible scheduling.

1. Introduction

There are two traditional methods for scheduling observations. 1) **interactive** observations give control of the telescope to a user. 2) **fixed queue** observations proceed in a linear fashion through a previously prepared schedule. Interactive observing is appropriate for observations where the observer looks at the data and then decides what to do next on the basis of the results. A fixed queue is more appropriate for long observations where the observer does not need to look at the observations in real time. In order to make best use of the instrument we need to change the observing schedule according to the system status and the weather conditions. For example, if a project needs all antennas in order to obtain the required uv-coverage, then if one or more antennas is out of service, it is better to observe a project that does not need all the antennas. Similarly if the weather is not good enough for the current project to succeed, then we make better use of the array by scheduling a project which can make use of the current conditions. This issue will become more obvious with 1 mm receivers on the BIMA array. **Flexible scheduling** uses the weather and system monitors to select from the queue the project which makes best use of the telescope under the current conditions. Flexible scheduling is being implemented at several observatories and is proposed for the MMA (MMA memo 164). The following sections further develop these ideas.

2. Time Allocation

The TAC makes a prioritized list of the projects according to the scientific goals and policies of the BIMA board. Each project has certain requirements in order to succeed: rms noise, seeing, uv-coverage, polarization etc. The actual observing schedule is best determined in real time from this list and the system status including the weather conditions. Each project is assigned a priority and a maximum allocated telescope time by the TAC. The priority for several projects may all be the same, for example, there can be 3 top rated projects with all the rest as second priority. Other requirements for each project such as rms noise level, seeing, LST or UT time range, can be specified either by the proposer, or by the TAC.

3. Scheduling Program

The scheduling program determines the observing schedule from the current status of the observations, the system status and the calendar. The scheduling program will monitor the weather and switch projects if the weather is no longer suitable for the current project. If the weather turns favorable for a higher priority project in the middle of the night, the scheduling program can stop the current project gracefully and start a new one. Clearly, one does not want to jump in and out of a project too often. The scheduling program is guided by **decision thresholds** which control when to start and stop a project. These decision thresholds form a set of parameters which can be tuned to produce the best performance. The decision thresholds really determine the behaviour of the scheduling program. If the highest weight is given to completing the current project, then the behaviour is like a fixed queue. If high weight is given to high priority projects and low weight to completing the current project, then switching is more likely. The thresholds also control the ordering of the queue. How large a change in seeing, mmh2o, or priority will trigger a change in the schedule ? How much weight do we give to filling the schedule with the next available project ? What is the minimum time to stay inside a project ? These are all parameters which we can tune to obtain the desired behaviour.

A flexible schedule can accommodate both fixed queue and interactive observing. Time critical observations can be scheduled by giving them high priority at the appointed time. For interactive observing, the user takes control of the telescope for a time interval after which control is returned to the scheduling program to determine the best project to observe. Interactive observing can be made more productive and less stressful. The interactive user who wants more time to evaluate his data can return control to the scheduling program, and come back (hours or days) later to continue.

The scheduling program must also maintain a list of the current status of the observations for each project, the scientific requirements, and maximum time allocation. A project can be terminated when it has met its requirements, or when it would exceed its maximum time allocation. For many projects, uv-coverage is important. Simply repeating the same HA range during suitable weather conditions may not satisfy the scientific requirements, so the scheduling program must keep track of the HA ranges which have been observed.

4. Schedule Planning

The scheduling program can also be run off-line with the real system status replaced by model inputs and weather statistics. A template schedule such as is produced for a fixed queue would assume perfect weather. A more realistic schedule would allow for better weather conditions at night, and schedule projects which can be self-calibrated during periods likely to have poor seeing, such as summer afternoons. The scheduling program can thus be used for planning how much time it is realistic to schedule for projects which require better weather.

The program can be run on different lists of possible observations. For example we can run the program on a list comprised only of 3mm projects, or a combined list of 3mm and 1mm projects, in order to see how the projected schedule is likely to work out under different assumptions of system status or weather. We can use a record of rms seeing available from 12 GHz phase monitors, or other weather statistics to make realistic projections for a future schedule.

5. Implementation at BIMA

The scheduling program will replace the current formatted schedule and the fixed queue. The scheduling program has as its input the prioritized list of the projects, the current status of the observations, and the system status. The output from the scheduling program is a log of the completed observations, system status and weather, and a projected schedule for future observations. At any time, the system manager and the users can see a summary of what has been done, the current status, and the projected schedule for completion of the projects. The future schedule, as in the planning phase, can assume various weather projections to assist in planning the completion date for the current list of projects. Since the same scheduling program can be run off-line we can check out and tune the decision thresholds before it is installed on the telescope. We can start very simply, so that a project will run to completion unless there is very substantial change in the system status or weather.

6. Impact on user

The observer prepares an observing control file, as at present, specifying which sources and calibrators are to be observed. This minimises the impact on the observers. System control of the calibration sources and calibration interval depending on the weather and system parameters is also desirable, but this can be implemented in a later phase of the development. The user specifies certain requirements for his project to be run. Currently these are the LST range, and in some cases the UT (solar, VLBI, comets etc.). These parameters are part of the requirements for the project to run. Obviously, as the user specifies more requirements, the project is harder to schedule. The user can run the scheduling program off-line on his project with model system and weather inputs to see the effect of the specified requirements on the scheduling of his project. The requirements might then be adjusted to make the project more likely to be scheduled.

7. User tools

The BIMA observing proposals also include a required rms noise level. The programs OBSTAU and OBSRMS allow the user to estimate how much integration time is required to achieve a specified rms noise in the specified angular and velocity resolution. Not much help is offered to estimate the system temperature.

There are some loaded questions on the proposal cover sheet about whether the project can be self-calibrated, or is conducive to fast-switching. These questions should be formatted so that they are more obviously related to the proposer's scientific objectives. We need tools which translates these scientific objectives (source, field of view, angular resolution, spectral resolution, sensitivity, dynamic range etc) into instrumental parameters (LST range, mosaic fields, array configurations, correlator configuration, integration time, uv-coverage etc). Such tools serve to make the telescope more available to non-specialists, and to educate the user as to what it is possible to achieve. The program XCORF is a good example of such a tool. The user starts with a spectral line and velocity resolution which he would like to observe. XCORF relates these scientific requirements to the instrumental parameters of the BIMA correlator, and reveals that it may be possible to observe other spectral lines simultaneously. The user can interactively modify his requirements which are translated into the instrumental parameters.

8. Impact on data archiving

The data will be more fragmented than it is now. Instead of 8-hr tracks, evaluated by a "quality" code, the archive should only consist of data which meets the specified quality requirements. The systemp, weather monitor data and rms pointing will continue to be stored with the uv-data, so that the observer can select subsets of the data as at present. The current data archive has the capability of locating and retrieving multiple data sets. "filler" projects are being successfully archived and retrieved.

9. Conclusions

* Implementation of a more flexible observing schedule is essential to make best use of the BIMA array.

* The telescope is treated as a valuable resource. We try to avoid scheduling observations which will be discarded because they do not meet their requirements.

* BIMA can play a major role in developing a dynamic scheduling program which is well adapted

for scheduling the MMA.

* The impact on the observers is minimized by keeping the existing project format.

* The scheduling program is a new piece of software which determines when to start and stop each project. It maintains a summary of the observations done and the future queue of observations.

* The scheduling program can be run off-line to produce a template schedule, this makes the job of the TAC and system manager easier.

* The behaviour of the scheduling program is determined by decision thresholds which we can tune to obtain the desired performance.

* We can start quite simply with a program which gives high weight to completing the current project, and build on our experience. Since the program can be run off-line we can test it before it is installed on the telescope.