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GMRT Observation Scheduling : the *repair* and *web display* scripts and usage

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Abstract: The Giant Metre-wave Radio Telescope (GMRT) is the world's largest low frequency radio telescope. Observing time is allocated by a GMRT Time Allocation Committee and scheduled by the Observatory personnel. Currently observations scheduling is implemented in two main steps (1) a scheduler software developed by TRDDC in collaboration with NCRA called GSCHED (see Gharote et al. 2009 for more details) and (2) a 'repair' and 'web display' software developed at NCRA which is described here. These two pieces of software together with the human scheduler are able to achieve efficient and optimal scheduling of GMRT time. In this note, we describe the second step in the scheduling procedure. The first step has been discussed in the paper.

Introduction: The Giant Metre-wave Radio Telescope (GMRT), located 80km north of Pune in India, is the world's largest radio telescopes at meter wavelengths. It is operated by the National Centre for Radio Astrophysics (NCRA), a part of the Tata Institute of Fundamental Research (TIFR). There are fourteen antennas randomly arranged in the central square, with a further sixteen arranged in three arms of a nearly "Y"-shaped array giving the longest interferometric baseline of about 25 km. Each antenna is 45 meters in diameter and operates at five frequency bands between 150 MHz to 1420 MHz. The GMRT is an interferometer which uses a technique known as aperture synthesis to make images of radio sources. Astronomers from all over the world regularly use this telescope to observe many different astronomical objects such as HII regions, galaxies, pulsars, supernovae, sun and solar winds.

GMRT was dedicated to the international astronomical community in 2002. Since then a time allocation committee has been reviewing and allocating GMRT time to observing proposals. On the average about 65 observing proposals are received by the committee for each observing cycle. While initially the cycle length varied from four to six months, since around mid-2004 (observing cycle 6), GMRT has been operating in two five month observing cycles in a year and two months of maintenance activities. The observing cycles start in April or May and September or October of every year. Proposals are invited in January and July for the two cycles.

Between 2002 and 2008, the observing schedule was generated manually by Observatory personnel. This was fairly laborious and involved a fair bit of preparation and time. Moreover it also made scheduling of GMRT observations fairly person-specific. Since optimization of constraints was top priority, it involved a fair amount of learning and iterating before arriving at a schedule which was optimal. However from the experience gained from scheduling GMRT observations, it was clear that we should explore ways to automate the scheduling procedure as far as possible such that the constraints violation is minimized within the available time.

In 2006, a MoU was signed between NCRA and TRDDC (research wing of TCS) and optimizing GMRT scheduling was taken up as one of the collaborative projects. In 2008, TRDDC was ready with an algorithm which could be used to generate an observing schedule. The algorithm was designed to optimize the constraints violation and not only available telescope time. The scheduler software GSCHED which resulted from the above exercise has been used to generate the first cut of observing schedule for GMRT since end-2008 ie Observing cycle 15. More details on this software can be found in Gharote et al. (2009). The schedule generated by GSCHED has two major drawbacks – firstly the observations get broken up into smaller chunks and scheduled on different days and observations of one proposal are not scheduled contiguously. Resolving this at the optimization routine level has not been possible and hence we have been exploring heuristic approaches. In the meantime, we have developed the 'repair' and 'display' part of the software which requires manual interaction to generate the observing schedule which are discussed in this short note. In the final scenario, we do imagine that a all-encompassing software will aid the scheduling process of GMRT observations.

GTAC cycle and Scheduling. GMRT has two five months observing cycles every year, starting around 1st of April and 1st of October. The months of March and September are used for maintenance/upgrade work. Each GTAC cycle length is ~ 22 weeks (154 days i.e. 3700 hours). Weekly maintenance days start on each Wednesday at 09h and end on Thursday around 17h. This also includes time for post-maintenance quality checks (PMQC) which are conducted from 07h to 11h on Thursday. Thus, we can summarize a typical observing cycle as consisting of the following breakup:

Total observing cycle time = 3700 hours.
Total maintenance + PMQC time = 750 hours.
Net GMRT time available = 2950 hours
Total time allocated by GTAC = 1800 to 2000 hours.
Free GMRT Time = 1150 to 950 hours

Free telescope time is used for the following purposes during an observing cycle:

1. Feed rotation: Feeds are mounted on four sides of a turret at GMRT and depending on the observation frequency, the appropriate band is brought to focus. This procedure which consists of rotating the feed and making a pointing measurement takes approximately two hours.
2. Target of Opportunity(ToO) and Director's Discretionary Time (DDT).
3. Makeup observations especially for system failures.
4. System tests
5. Maintenance activities

The rest of the note discusses the post-GSCHED software which we have developed. This software is divided into two main parts:
A) mkformat.pl: Representing the GSCHED output which is in ASCII format in a graphical format using Perl scripts. Also convert the schedule into an user-friendly spreadsheet format which can be used to edit the schedule.
B) mkhtml.pl: Converting the observing schedule into HTML format for display on the web page. This step also uses Perl scripts and Javascript libraries for its implementation.

A) Convert GSCHED output to graphical format + enable manual editing of schedule:

GSCHED generates several output files which contain the schedule and several other useful utilities. The file "15Output_GraphicInterface.txt" generated by GSCHED is used as input to the perl script: mkformat.pl

The perl script mkformat.pl requires the following files as input:

1. GSCHED output file containing the schedule: "15Output_GraphicInterface.txt".
This file has the following format.

Date	Code	Slot	Time in the slot	Total Time	RA	Dec	Wave band	Type
8-4-2010	18_031(S1)	[18-24]	6.00	77.0	247.50	40.00	200	C

The first column gives the date on which the observation is scheduled, the second column lists the proposal code and observation number, the third column shows the IST of the slot in which it is scheduled, fourth column lists the time within the slot scheduled for the proposal, fifth column details the total time to be scheduled for the particular observation, sixth and seventh columns give the RA and declination of the source in degrees, eight column gives the waveband it is scheduled in and the last column shows the type of the observation (C for continuum, L for line and P for pulsar).

2. The second input file given to GSCHED and which contains all the information relevant to an observation: "Input2_ProposalData.txt".

!Status	Prop_Id	Prop_Code	Observer_Type	Type Object	Actual_Time	AllotedTime	Band(cm)	Rise_Time	Set_Time	RA	Dec	Start_Day	Start_Month	Start_Year	End_Day	End_Month	End_Year	Start_Day	Start_Month	Start_Year	End_Day	End_Month	End_Year
0	1	19_004(S1)	0	L	12	12	21	30366	61134	198.85	-16.39	10	10	2010	11	10	2010	0	0	0	0	0	0
0	2	19_005(S1)	0	L	8	8	21	9236	45343	121.71	12.06	0	0	0	0	0	0	12	11	2010	30	11	2010

The first column gives the status of scheduling whether to go through the scheduling algorithm or it is a prefixed time slot. second one is just proposal ID, third one is proposal code, fourth one is whether the user is foreigner of Indian, fifth one is observation type (C for continuum, L for line and P for pulsar), sixth one is actual time, seventh one is allotted time, eighth one is wavelength, ninth one is rise time and tenth one is set time. Column eleventh is RA and twelfth is Dec. Column no 13th to 18th describes the preferred time slots and 19th to 24th describes non preferred time slots for the user.

3. Equatorial Co-ordinates of the Sun relevant to the observing cycle being scheduled are in the file: sun_cord.txt
(Ref.: "http://ssd.jpl.nasa.gov./horizons.cgi#top")
The format of this file is:

date	time	RA	Dec
2010-Oct-01	00:00	12 27 47.65	-03 00 07.2
2010-Oct-01	01:00	12 27 56.69	-03 01 05.4

The first column is the date and second column is the time in IST. The last next three columns give the right ascension and the last three columns gives the declination of the sun on that particular day and time.

4. The script also requires the first input file taken by GSCHED namely
Input1_ModelParameters.txt. The script reads the start date and end date of the observing cycle from this file.

```
161                 !       Number of Observations
6                   !       Size of each time slot used for a allocation (hours)
!-------------------------------------------------------------------------!
08 10 2010          ! Planning cycle start date (DD:MM:YYYY)
10 03 2011          ! Planning cycle end date (DD:MM:YYYY)
```

5. The master perl script also requires the following perl scripts: format.pl, remove_overlaps.pl, fill_all.pl. modi_proposal_data.pl and table.pl - these scripts are developed for implementing different tasks such as formatting and making a editable schedule and so on.

Once the files listed above have been made available in the same directory, then the perl script mkformat.pl can be run as follows:
./mkformat.pl

On a successful execution of this script the following output files are generated. A few other files are also generated but since they are not used in the subsequent steps we do not mention them here:

1.1. "sch.txt" – the editable schedule file with the following format:

Date	IST	OBS Code	LST
Sun-10Oct10	19	19_043(S1)	19.7
Sun-10Oct10	20	19_043(S1)	20.7
Sun-10Oct10	21	19_043(S1)	21.7

In this file, the first column gives the day-date, second column lists the IST, third column lists the observation scheduled in that hour and the fourth column lists the LST corresponding to that IST on that day. This file can be manually edited using Open Office spreadsheet. This can be invoked by typing 'oocalc' at the prompt. Thus the syntax for editing the file is:

> oocalc sch.txt

Another method of editting this file is given at the end of this section.

2. "table.txt" – the file which lists the equatorial coordinates of the sun, the LST and IST for each hour of the observing cycle and has the following format:

Date	Day	IST	LST	RA	Dec	IST	LST	Day
08Oct10	Friday	00	0.5	12.89	-5.70	1	1.5	Fri
08Oct10	Friday	01	1.5	12.89	-5.72	2	2.5	Fri
08Oct10	Friday	02	2.5	12.89	-5.73	3	3.5	Fri
08Oct10	Friday	03	3.5	12.90	-5.75	4	4.5	Fri

first column is date then day, IST, next is LST then sun RA, then sun DEC, then end IST, end LST and day name in short.

3. "input2.txt" – a modified version of the "Input2_ProposalData.txt" file containing information on all the observations to be scheduled. The format of the file is as follows:

Status	Prop_Id	Prop_Code	Observer_Type	Type_Object	Actual_Time	AllotedTime	Band(cm)	Rise_Time	Set_Time	RA	Dec	prf_date	nonprf_date
0	1	19_004(S1)	0	L	12	12	21	9.01	17.5	13.26	-16.39	10Oct10-11Oct10	NA-NA
0	2	19_005(S1)	0	L	8	8	21	3.12	13.11	8.11	12.06	NA-NA	12Nov10-30Nov10

Editing the schedule: The observing schedule ("sch.txt") can be edited by two ways. This file can be edited either by the OpenOffice utility 'oocalc' or by an editor named 'edit.pl' that is developed in perl-Tk. Edit.pl can be used to edit the schedule for one day at a time and has the following syntax:

./edit.pl -d 30nov2009

This utility is developed so that small changes in the schedule such as test observations etc can be done without having to edit the entire file sch.txt. This editor then saves the changes in sch.txt and also runs mkhtml.pl (detailed in the next section) and generates the schedule file gtac.html

If sch.txt is edited manually, then after saving the changes, mkhtml.pl should be run on the file to generate the schedule.

B) Converting the observing schedule into HTML format for display on the webpage

In this step, the schedule file sch.txt generated in the previous step is converted into html format file which can then be uploaded onto the NCRA webpage. This step also uses Java tool tips. The programme also has a few more useful utlities : 1) Schedule with error flags, if source is below horizon ie. the '-e' . this is useful while scheduling the observation. 2) Schedule with highlited proposal code, this is useful when checking the schedule for different propolsals. This step also had a facility to generate a schedule with an error flag in the cells when the object being observed is not above the horizon. thus helping the scheduler visualize problem slots subsequently edit them.

The perl script "mkhtml.pl" is to be run to generate the HTML schedule file.

Syntax: mkhtml.pl -h for help (it will dilsplay the help message)

```
-h                      # This help message.
-e                      # Error if source is below horizon
-d <ddmmmyy>            # start date.
-D <ddmmmyy>            # end date.
-i <input>  sch.txt     # input file
-o <output> gtac.html   # output file
-c <code>   nnn         # gtac code , to highlight the particular observation.
Example
./mkhtml.pl  -i  sch.txt  -o  gtac.html  -d  08oct2010 -D 09mar2011 -e  -c 043
```

The input files required by mkhtml.pl are listed below: Most of them are generated in the previous step.

1. "sch.txt" (Observing schedule)

2. "input2.txt" (details of the scheduled observations)

3. "table.txt" (LST, IST and equatorial coordinates of the Sun)

The above files are generated from step A.

The following files are also required by mkhtml.pl are generated manually and then given to the perl script.

4. "colors.txt" (list of colours which will be used for generating the online schedule). The format of this file is:

Colour name in HEX code
#FA8072
#F4A460
#2E8B57

5. "pi_names.txt" - list of names of the Principal Investigators (PI) of the various proposals. The format of the file is:

"19_004"	"Ming Sun"
"19_005"	"S K Sirothia"

This file also contains the following useful coding where various strings are defined for different functions such as:

"NA"	"ERROR"
"PMQ"	"Post Maintenance Quality Checks"

6. "top_note.txt" - note which will be displayed at top of the schedule.
The most important use of this note is to indicate the date of the latest update to the schedule and its version.

7. "bot_note.txt" - note which will be displayed at the bottom of the schedule.
The major use of this is to indicate any new symbols used in the schedule and to acknowledge the joint efforts of TRDDC and NCRA in generating the software used for the schedule.

This step also uses a Java tool tips library "wz_tooltip.js" which is freely available on the internet for use. This utility allows the display of pop-up windows in the html file. This is an useful feature since the information related to any observation can be listed in the pop-up window. The script "mkhtml.pl" reads the above-mentioned seven files and produces the html file named "gtac.html" which contains the schedule listed in sch.txt in a format which can now be displayed on the web. A sample of the final schedule is shown in the figure below.

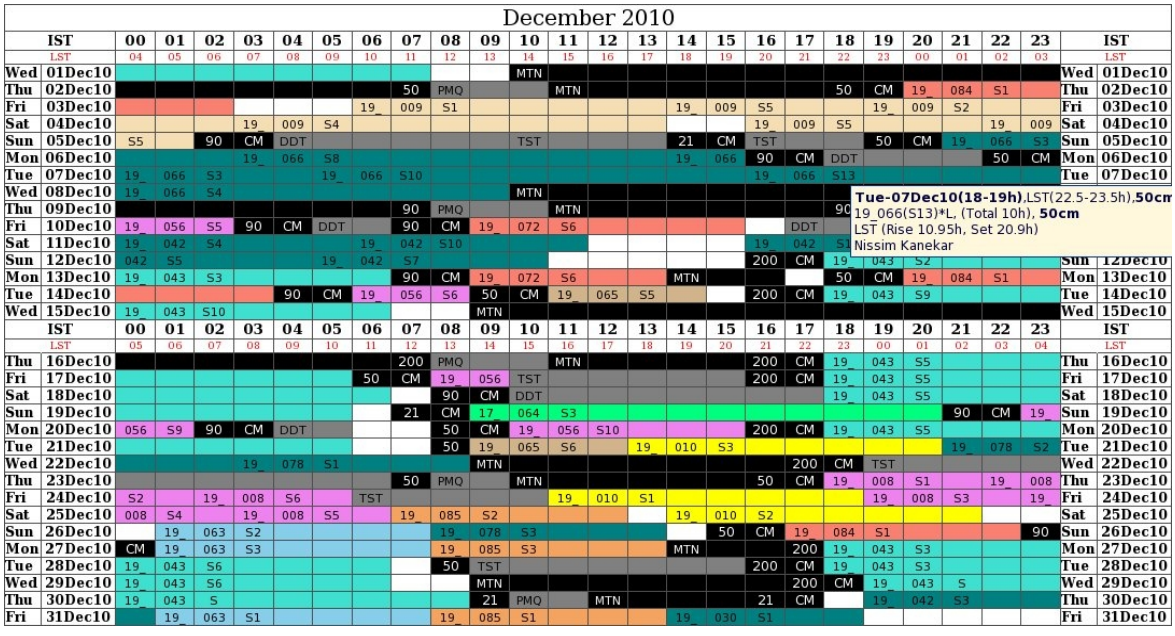

Fig 1. A section of Web based GMRT observing schedule generated by mkhtml.pl

Fig 2. Popup window shows the Information related to the observations.

The notations which are used in the online schedule are:

* blank(WWW) - White slot
* TST - Test observation.
* TOO - TOO observation
* DDT - DDT observation
* PMQ - Post Maintenance Quality Checks.
* TOO - TOO observation
* STP - Stow position checks
* MTN - Maintenance
* HOL - Holiday
* 90CM - 90 cm feed
* 200CM - 200 cm feed
* 50CM - 50 cm feed
* 21CM - 21 cm feed
* xx_nnn - GTAC code

Input file "color.txt" defines the colours that can be used to show the scheduled GTAC observations.
Other than GTAC observations there are specific reserved colors for non GTAC things in the schedule.
Below we list the specific colours alongwith their function:

* white - white slot
* black - Maintenance and Feed rotation.
* Red - Blinking the running time hour cell.
* blue - Error.
* gray - TST/DDT/TOO/PMQ/STP

The online observing schedule shown in the above figure (Fig 1.) colour-codes each proposal and using the above format where each hour is labelled, uses that colour to specify the start and end times of the particular observation. Additionally the feed rotation, feed in focus, maintainence time etc are appropriately labelled in the schedule. At GMRT we have been scheduling a minimum of one hour so each hour is depicted by a box in the graphical display of the schedule. IST is kept constant along columns whereas LST varies with epoch. IST is labelled in black and LST in red colour. The online display file shows some basic information along with the observation related information. At the top it displays the current date, time in IST and LST at GMRT. This time is continuously updated by client side java script and it uses the time reference from the client machine i.e the local machine of the user. The left and right extreme columns show the date and when the cursor is moved onto them, the Tooltip shows the sun coordinates for that date. Notes are displayed at the top and bottom. Month (e.g. May 2010) is displayed in bigger fonts at the beginning of the schedule for that month. IST and LST lines are inserted at the interval of 15 days. Each hour cell displays the tooltip when the cursor is moved onto it. The white slots display the date, IST, LST and frequency band. The hour cells which have observations scheduled show details of that observation such as name of PI, frequency band of observation, rise and set times of the source and so on. As shown in the Fig. 2 the first three cells show the information about the proposal code and source number. No text is displayed from cell 4 onwards but same color shown up to the end of the observation. For time scheduled for other purposes such as DDT or test, only the first one or two cells show the relevant code. The rest of the cells are blank but show the same colour. The current hour is shown in blinking red. The times in the pop-up Javascript tooltips and the blinking red are based on the time in the client machine and will be incorrect if the client machine has a wrong time setting.

Displaying the schedule: The file gtac.html contains the observing schedule. This can be displayed on the web for users to access. Note that the Javascript Tooltips library i.e. the file 'wz_tooltip.js' should be present in the same directory as gtac.html so that the tooltips are enabled.

Summary: In this note (in which the development of software to aid the scheduling of GMRT observations are detailed), we describe the 'repair' and 'display' scripts that have been developed by us and are being used to generate the observing schedule. The schedule generated by GSCHED, the linear optimization routine is used as input to this part of the scheduling process and the schedule edited as required and the final display generated. In the future, we expect that the collaborative project with TRDDC can be furthered and the experience gained by the team can be put to use to generate an all-encompassing scheduling software.

Acknowledgments: We thank the initiators of the world wide web (www) which has enabled us to get quick and easy access to literature on scheduling software, display routines and other useful information. We also acknowledge use of the Javascript Tooltips library which we could download over the www and use in our html application. We gratefully acknowledge inputs from our colleagues in improving the software.

References:

1. "Automated Telescope Scheduling."
M S Gharote, A M Deshpande, S P Lodha, N G Kantharia, Y G Wadadekar, S N Katore, A Pramesh, 2009, in The Low-Frequency Radio Universe ASP Conference Series, Vol. 407, Proceedings of the conference held 8-12 December 2008, at National Centre for Radio Astrophysics (NCRA), TIFR, Pune, India. Edited by D. J. Saikia, D. A. Green, Y. Gupta, and T. Venturi. San Francisco: Astronomical Society of the Pacific, p.438