DACH Operation Center Biennial Report 2019/2020

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Abstract The newly founded DACH Operation Center is a joint cooperation between the Federal Agency for Cartography and Geodesy in Germany (BKG), ETH Zurich (ETHZ) and Technische Universität Wien (TU Wien). The main motivation to establish a new Operation Center (OC) was to bring together the scheduling expertise at TU Wien and ETHZ and the technical and operational expertise at BKG. Together, it was possible to develop a fully automated scheduling procedure that is currently used for various IVS observation programs such as AUA, OHG, T2, INT2, INT3, EUVGOS, VGOS-B and more. Within the cooperation, BKG is responsible for the technical aspects and is ensuring the long-term stability of the OC, while ETHZ and TU Wien are focusing on scientific studies and potential improvements to VLBI scheduling such as the newly developed scheduling parameter optimization based on Artificial Intelligence.

1 General Information

With the retirement of Arno Müskens, who had maintained the scheduling activities at the University of Bonn (IGG) for the last 30 years, the official IVS sessions supervised at Bonn had to be transmitted to another OC. Around the same time, a new VLBI scheduling software, VieSched++[1] [1], was developed at TU Wien. To test the new scheduling software and to ensure a smooth transition of the scheduling activities at Bonn to a suitable successor, first tests were started in late 2018 by using the new scheduling software supervised at TU Wien. First, the work focused on improving scheduling for the T2 sessions but soon other observation programs followed.

Meanwhile, it was decided that Wettzell should be designated as a new Operation Center and continue the work of Arno Müskens to ensure the long-term stability of the scheduling activities. Since there was evidence of significant improvement gained by using VieSched++ and by following the scheduling approaches developed at TU Wien, VieSched++ was selected as the scheduling software run by the Wettzell OC operationally. To ensure a generation of high-quality schedules and to benefit from the scheduling experience gained with the first tests of VieSched++, a cooperation between TU Wien and BKG was founded in 2019. With the move of Matthias Schartner, the main developer of the VieSched++ software package, from TU Wien to ETH Zürich, a third institution joined the cooperation, so that the BKG, the ETH Zürich, and the TU Wien jointly performed the assigned scheduling tasks in the context of the Operation Center Wettzell. In late 2020, it was decided to bundle the current activities as a joint Operation Center called "DACH"[2] to streamline the activities and reduce the confusion about official responsibilities.

1. ETH Zürich
2. Federal Agency for Cartography and Geodesy
3. Technische Universität Wien

DACH Operation Center

IVS 2019+2020 Biennial Report

[1] https://github.com/TUW-VieVS/VieSchedpp

[2] https://www.bkg.bund.de/DE/Observatorium-Wettzell/IVS-VLBI-Operations_Center/IVS-VLBI-Operations_Center.html

2 Activities during the Past Year

In the last year, the main focus was on the establishment of the new OC. Right from the beginning, it was planned to aim for a fully automated approach. Therefore, VieSched++ was extended by VieSched++ AUTO[3], an automated scheduling framework written in Python. In this regard, VieSched++ AUTO can be seen as a frontend to VieSched++. The automated scheduling routines are controlled by the session master files. Based on a daily cronjob, the schedule master files are checked and upcoming sessions are identified. These sessions are then scheduled and notification E-Mails are distributed to responsible persons for human quality control as described in Section 3. Additionally, the schedule files are automatically uploaded to the IVS servers in case no human intervention is necessary. Since VieSched++ AUTO is written in the very popular and easily accessible programming language Python and is completely decoupled from the complex VieSched++ algorithms, maintaining and customizing VieSched++ AUTO is a fairly simple process. Thus, special treatments of individual observation programs is possible and it is possible to include custom steps in the scheduling process, such as making custom changes to the VEX files required by the VLBA stations or custom changes to the SKD files required for VGOS sessions.

Simultaneously, new hardware facilities at Wettzell were provided for the automatic scheduling to ensure a long-term oriented environment for all of the necessary IT infrastructure with hardware redundancy and data backup procedures. These aspects are especially emphasized at the Geodetic Observatory Wettzell to provide a robust infrastructure concerning a potential failure analysis to reach quality-oriented requirements as OC.

From a scientific point of view, the main focus was on improving the automation through an Artificial Intelligence powered parameter optimization [2]. This approach mimics evolutionary processes such as selection, crossover and mutation to iteratively explore the scheduling parameter space to find an optimal solution for any given session. In particular, it optimizes the individual station weights and the weight-factors of the different optimization criteria [1]. Drawback of this approach is the excessive computation cost. This drawback is diminished by the fact that the software runs automatically as a daily cronjob and can produce all schedules over night.

[3] https://github.com/TUW-VieVS/VieSchedpp_AUTO

Table 1 List of automatically generated schedules per observation program. The first block lists IVS Intensive sessions assigned to the DACH OC. The second block lists IVS 24-hour sessions assigned to the DACH OC. The third block lists other IVS sessions not assigned to the DACH OC but automatically scheduled for testing purposes. The final block lists non-IVS sessions scheduled at the DACH OC. Column "#sessions" lists the number of automatically scheduled sessions (as of 2021-11-02) while column "first" lists the first session of the observation program that is automatically scheduled.

Name	#sessions	first session	(date)
INT2	62	Q20200	(2020-07-18)
INT3	24	Q20188	(2020-07-06)
VGOS-B	10	B20329	(2020-11-24)
AUA	7	AUA066	(2020-07-15)
CRDS	4	CRD108	(2020-08-04)
CRF	3	CRF120	(2020-09-07)
T2	3	T2141	(2020-09-15)
OHG	3	OHG126	(2020-07-28)
INT1	148	I20188	(2020-07-06)
R1	29	R1957	(2020-07-27)
R4	30	R4956	(2020-07-23)
VGOS	14	VO0219	(2020-08-06)
GOW08	5	WD344I	(2020-12-09)
GOW16	24	WD212Q	(2020-07-30)
GOW17	1	WD287R	(2020-10-13)
INT9	5	WD233Q	(2020-08-20)
SI	31	SI0181	(2020-06-29)

3 Current Status

In the following, the main staff members contributing to the DACH OC are listed together with their related tasks.

Table 2 Contributors to DACH OC and their tasks

Matthias Schartner	main software developer, quality control
Christian Plötz	technical support, coordination
Walter Schwarz	lead technical support
Torben Schüler	head of observatory Wettzell
Lisa Kern	quality control
Johannes Böhm	head of VLBI group at TU Wien
Benedikt Soja	head of Space Geodesy group at ETHZ

As of right now, the official IVS Intensive observing programs, INT2, INT3, VGOS-B and 24-hour observing programs AUA, CRDS, CRF, EU-VGOS (only partly and scheduled by hand), T2 and OHG are scheduled within the DACH OC. Furthermore, the INT1, R1, R4 and VGOS sessions are also automatically scheduled for testing purposes but without uploading them to the IVS servers. However, their results can also be found on our web-page. Additionally, other non official IVS sessions are scheduled as well, for example the Southern Intensives (SI), local baseline sessions at Wettzell (GOW08) and BKG internal Intensives between Wettzell and AGGO (INT9, GOW16), and Wettzell, AGGO and O'Higgins (GOW17). Table 1 list the different observation programs as well as the number of automatically generated schedules (as of 2021-11-02) and the name of the first automatically generated session. In total, over 400 sessions have already been automatically scheduled.

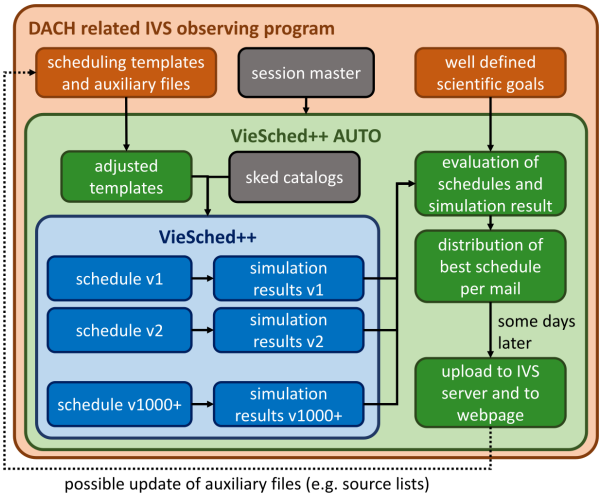

Fig. 1 High-level flowchart for the automated DACH scheduling procedure. Orange boxes represent files/metrics defined for every observation program. Green boxes are tasks executed by VieSched++ AUTO. Blue boxes depicts scheduling results of VieSched++. Gray boxes represent external data sources.

Figure 1 provides a high-level flowchart of the automated DACH scheduling procedure. For every VLBI observing program, some schedule template files are provided and a dedicated scientific goal was defined. In the most simple case, the scientific goal can be defined as a mixture of achieving the best mean formal errors and/or repeatability values for the Earth orientation parameters and/or station coordinates. However, in principle more complex and more sophisticated goals are possible as well. To simplify the generation of a scientific goal and its implementation within VieSched++ AUTO, hundreds of pre-defined statistics are available.

The schedule template files serve as a start point and contain information about the proper observing mode to use and the scheduling boundary conditions that are necessary. For every session, these template files are adjusted and further serve as input for the scheduling software VieSched++. For example, within the template files the station network and start and stop times are adjusted and necessary down- and tag-along times are assigned. If general changes to the scheduling approach are necessary, for example, if the target observation signal to noise ratios need to be adjusted or the minimum observation time needs to be changed, it is mostly sufficient to do these adjustments in the template files directly. Since they are human-readable and the file format is the very popular and standardized Extensible Markup Language (XML), no programming skills are required to perform these adjustments. Additionally, it is possible to use the VieSched++ graphical user interface to change the template files or to produce new ones.

Defining a dedicated scientific goal is necessary for several reasons. First, the concept of VieSched++ is that it will not only generate one schedule per session but a multitude of different schedules using different observation strategies and approaches. Often more than one thousand different schedules are generated per session. Every session is further simulated at least one thousand times to receive reliable repeatability estimates, leading to over one million simulation runs per session. Based on the dedicated scientific goals the best schedule is selected. This approach further ensures a transparent decision making without any human bias solely based on Monte-Carlo simulations.

The best schedule, together with meaningful statistics and comparison graphs, is distributed per E-Mail to some responsible persons for human quality control. Here, great care was taken that it is possible to quickly judge solely based on the notification E-Mail and attached figures if the schedule is good or not. This approach is reducing the human workload significantly since no additional software packages need to be used to inspect the scheduling result and the quality control can be done on every computer. In case that there is

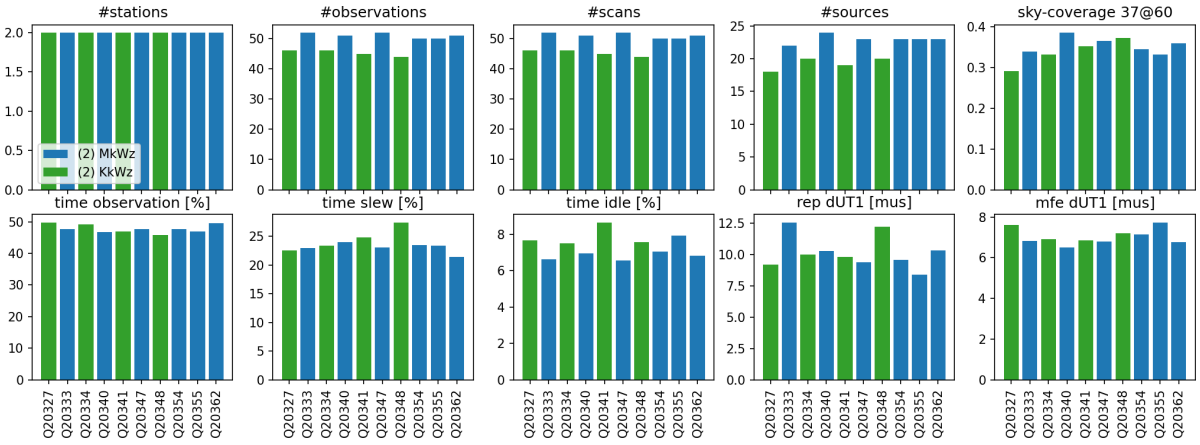

Fig. 2 Statistics of the INT2 observing program as attached to the scheduling E-Mails for human quality control. Besides general statistics, the simulated dUT1 mean formal errors (mfe) and repeatability values (rep) are listed as well as information about the sky-coverage.

no human intervention necessary, the schedule is automatically uploaded to the IVS servers some days after the scheduling was done. It is to note that the automated scheduling process is very robust. Within the last month, no human interaction was necessary. Furthermore, VieSched++ AUTO automatically distributes error notifications per E-Mail in case problems arose and log-files are stored for inspection.

Figure 2 depicts a summary plot of the INT2 statistics. Every time a new INT2 session is scheduled the statistics figure gets updated. It is also attached to the notification E-Mails for human quality control. In the figures, various interesting and meaningful statistics of the last 10 sessions of this observation program are visualized. Therefore, it is possible to quickly compare the scheduling performance with the one of previous sessions to identify potential problems. Depending on the observation program and the session goal, the displayed statistics vary.

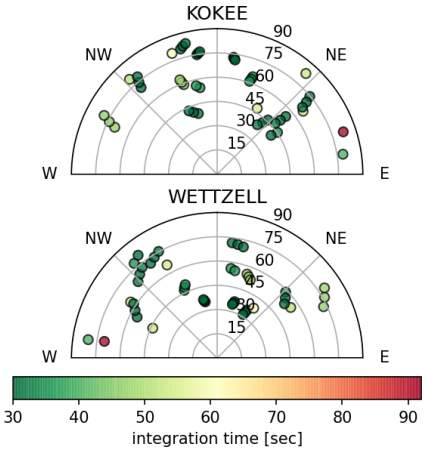

Fig. 3 Sky-coverage of session Q20348 with color-coded integration time. These plots are attached to the automatically generated notification E-Mails distributed by VieSched++ AUTO and are uploaded to our webpage.

As an example, Figure 3 displays the sky-coverage of session Q20348 (IN220-348) observed on 2020-12-13 and scheduled by the DACH OC in a stereographic projection (only the northern half). This kind of graphics are automatically distributed by E-Mail for human inspection and for quality control. Here, the integration time is color-coded but similar plots with a color-coded observation start time with respect to the session start time exist and are distributed as well.

4 Future Plans

As a next step, the idea would be to incorporate actual analysis results into the statistics and decision making process. One could think about automatically analyzing the correlation and analysis reports looking for anomalies. Based on this information it would be possible to temporarily discard poorly performing sources form the source list or to put unreliable stations temporarily into tag-along mode. Additionally, we belief that the responsibility of an OC does not finish with

the distribution of schedule files but should also include quality control of the actual results.

Within the development of VieSched++ and its scheduling logic, a main focus will be laid on the inclusion of VLBI observations to satellites and spacecraft since this will enable some interesting science cases. First steps in this regard are already taken and a new VieSched++ version will be released soon.

Another major point in the future will be the changes due to the new upcoming data formats. With the readopting of the work on the VEX2 format, which will hopefully result in a final version soon, adjustments in the scheduling software are necessary to support the new format. The same holds for the newly proposed scheduling catalogs and the resulting changes in scheduling models (such as slew-time, telescope sensitivity and source flux density models). Although we do not plan to contribute to the development of these models, we will ensure that necessary adjustments in the scheduling software VieSched++ are performed in case that the IVS agrees to use the new formats and models.

Besides these operational and scientific points we would like to discuss our approaches with other OC as well and motivate them to test and establish our routines themselves. Therefore, we offer full support in the installation and utilization of our software products, which are all publicly available on GitHub.

Acknowledgements

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References

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2. M. Schartner, C. Plötz, B. Soja, Automated VLBI scheduling using AI based parameter optimization, *Journal of Geodesy*, submitted, 2020.