

Improved VLBI scheduling through evolutionary strategies

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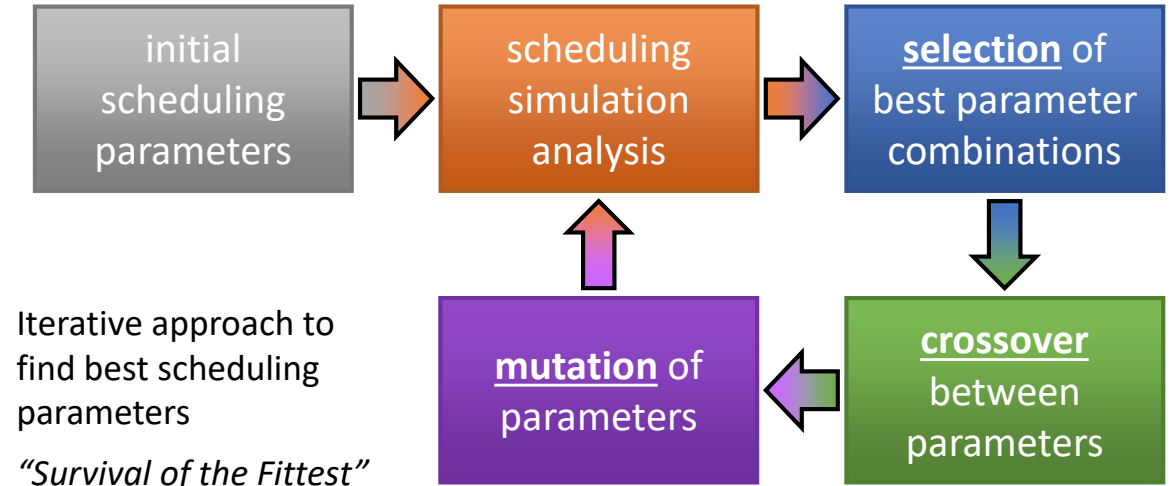
²Bundesamt für Kartographie und Geodäsie, Germany

Aim of this study:

- Improve VLBI scheduling based on efficient sampling of scheduling parameter space
- Automate process of VLBI scheduling

Presented approach is currently operational in use for various IVS programs: INT2, INT3, VGOS-B, VGOS-C, AUA, T2, OHG

2 Concept of evolutionary strategy

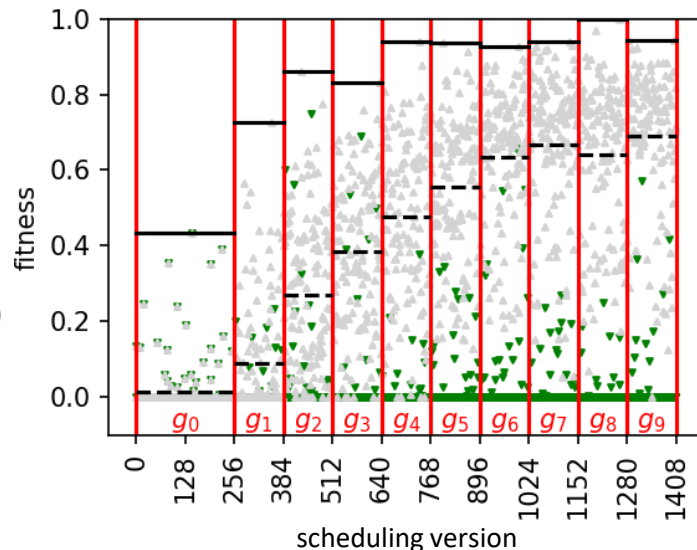


3 Example of scheduling performance evolution with time

"fitness" quantity on how good schedule is

- △ evolutionary strategy
- ▲ classical approach
- max fitness (iteration)
- - - mean fitness (iteration)
- iteration steps

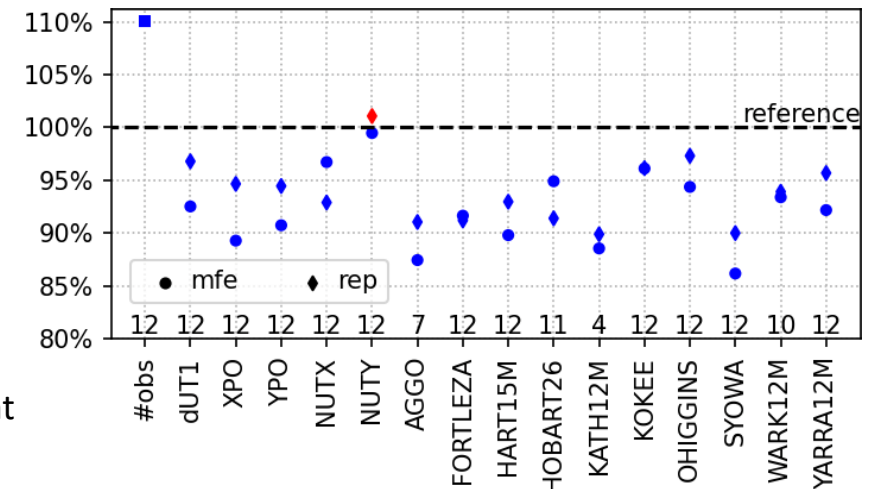
→ scheduling quality increased over time



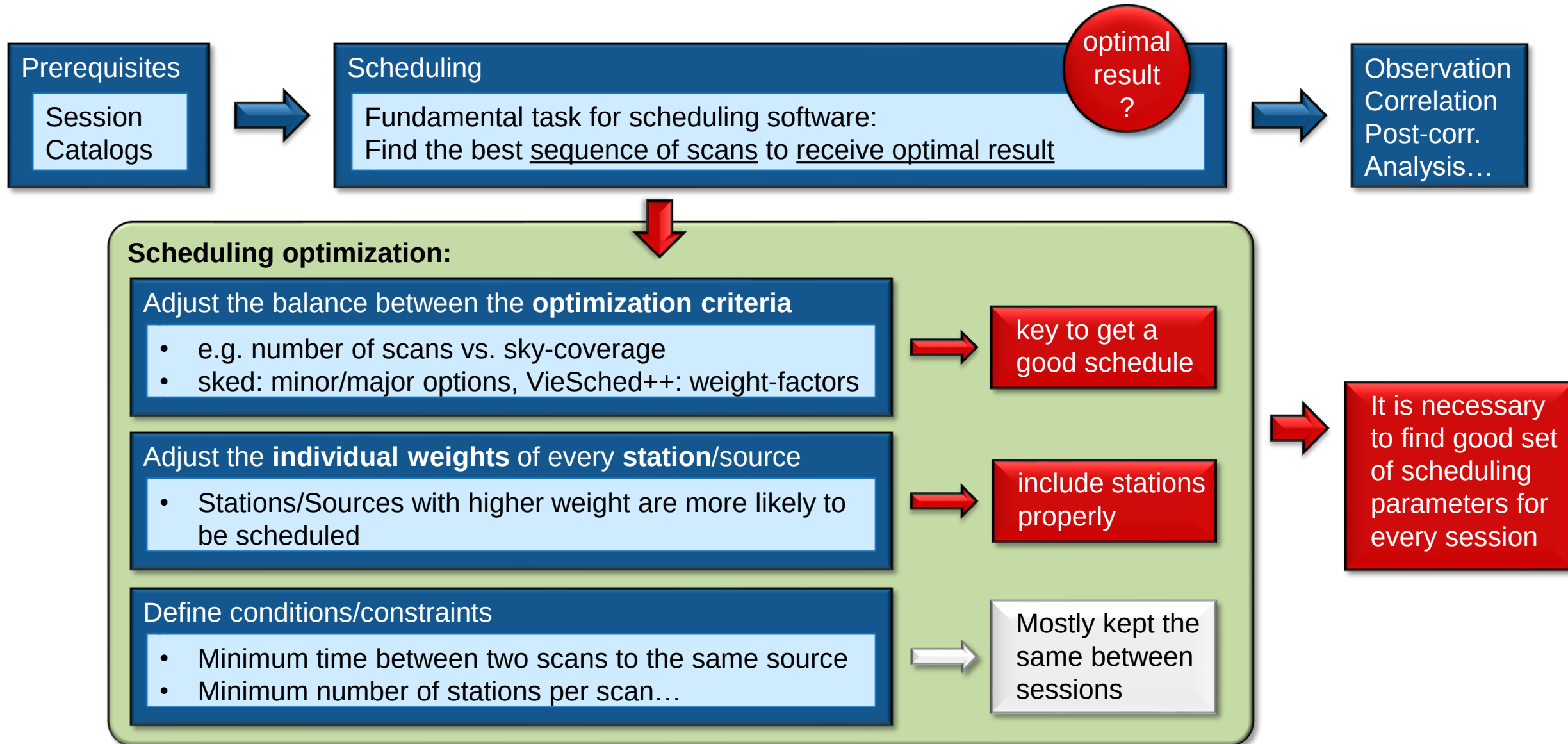
4 Simulated improvement in geodetic parameter precision

simulations from 12 OHG sessions
reference = classical scheduling approach

rep: repeatability
mfe: mean formal errors
Blue → improvement
Red → degradation



VLBI scheduling optimization



Challenges and goals for scheduling optimization

Find a set of scheduling parameters for providing “optimal results”

1. We have to define a proper session goal and a “fitness” function (high fitness = good schedule) → **tricky**
 - E.g. OHG sessions:
 - Most important: high precision for station coordinates (special focus on O’Higgins)
 - Important: high number of observations (special focus on O’Higgins)
 - Less important: EOP precision
2. We have to define which scheduling parameters should be adjusted
 - weight factors (4 parameters)
 - Individual station weight (n parameters for n -station network)
3. We have to come up with a novel approach for efficient sampling of the scheduling parameter space
 - high dimensional (see 2.) → brute-force selection or grid-search does not work well
 - AI approaches, in particular an **evolutionary strategy** → **this study**

Evolutionary Strategy

Task is to find a good set of parameters within the scheduling parameter space

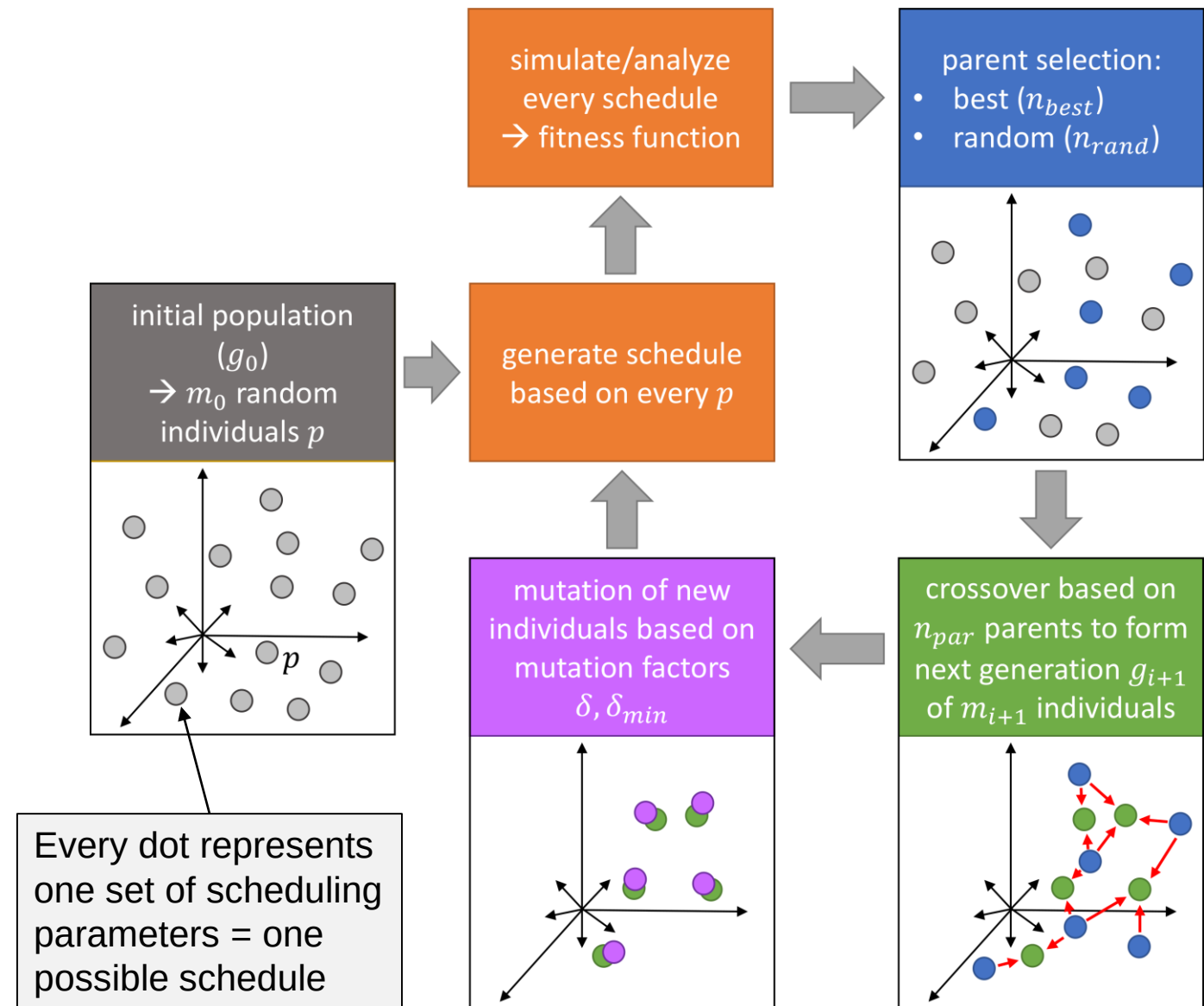
Inspired by biological evolution

“Survival of the fittest”

Fitness is calculated based on simulation results and session goals (fitness function)

Iterative approach based on

- **Selection**
- **Crossover**
- **Mutation**



More details: Schartner et al. (2021)

Parameter evolution 24-hour R1 session

12 dimensional parameter space

- 4 weight factors ω_{sky} , $\omega_{\#obs}$, ω_{dur} , ω_{idle}
- 8 station weights $\omega_{station}$

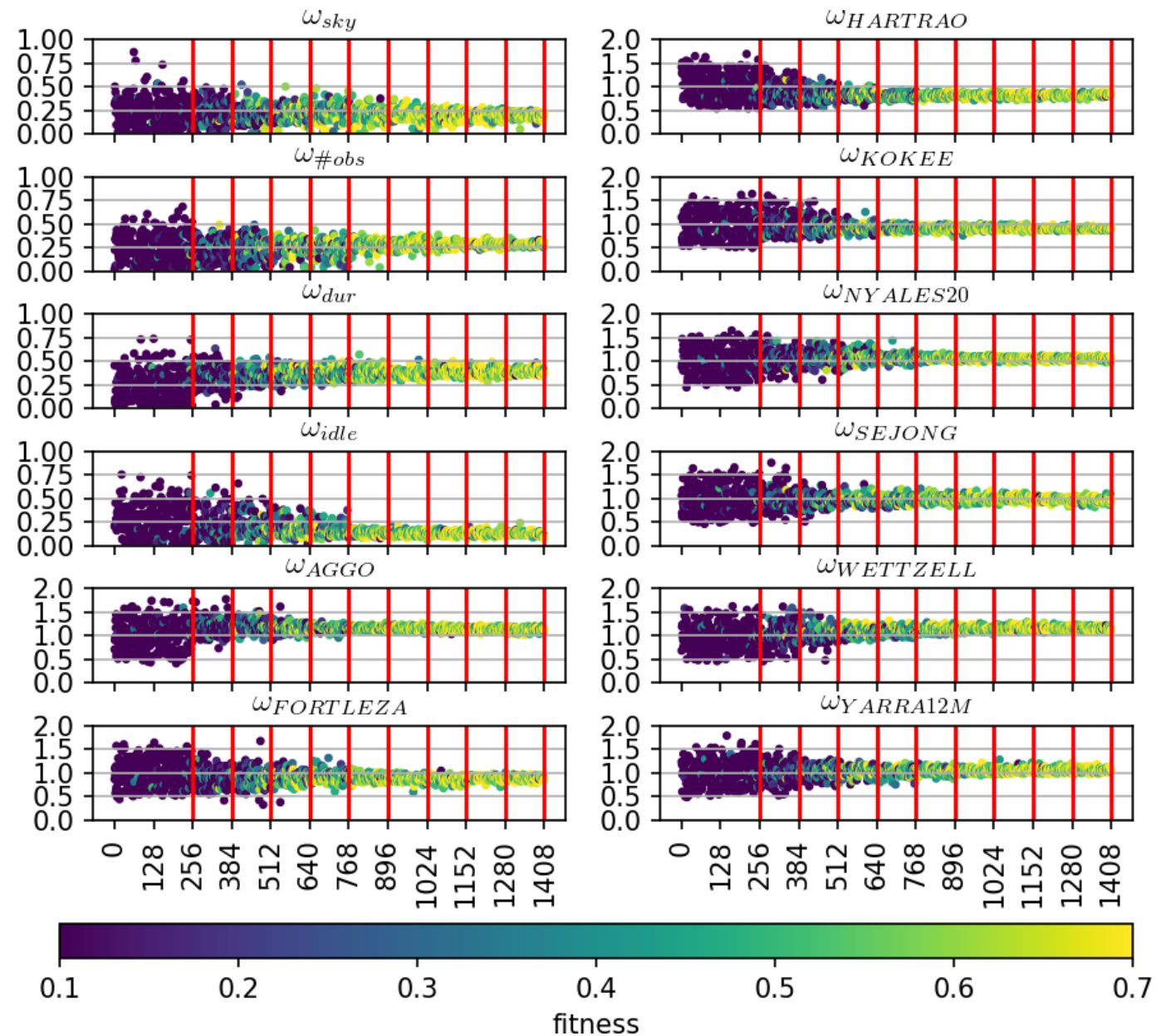
10 generations (delimited by red lines)

- Initial generation 256 individuals
 - Following generation 128 individuals
- 1408 schedules (abscissa)

Displayed are slices from the twelve dimensional parameter space

Things to note:

- fitness of ES increases with time



More details: Schartner et al. (2021)

Parameter evolution

Intensive session

3 dimensional parameter space

- 2 weight factors $\omega_{sky}, \omega_{dur}$
- 1 additional scheduling parameter t_c

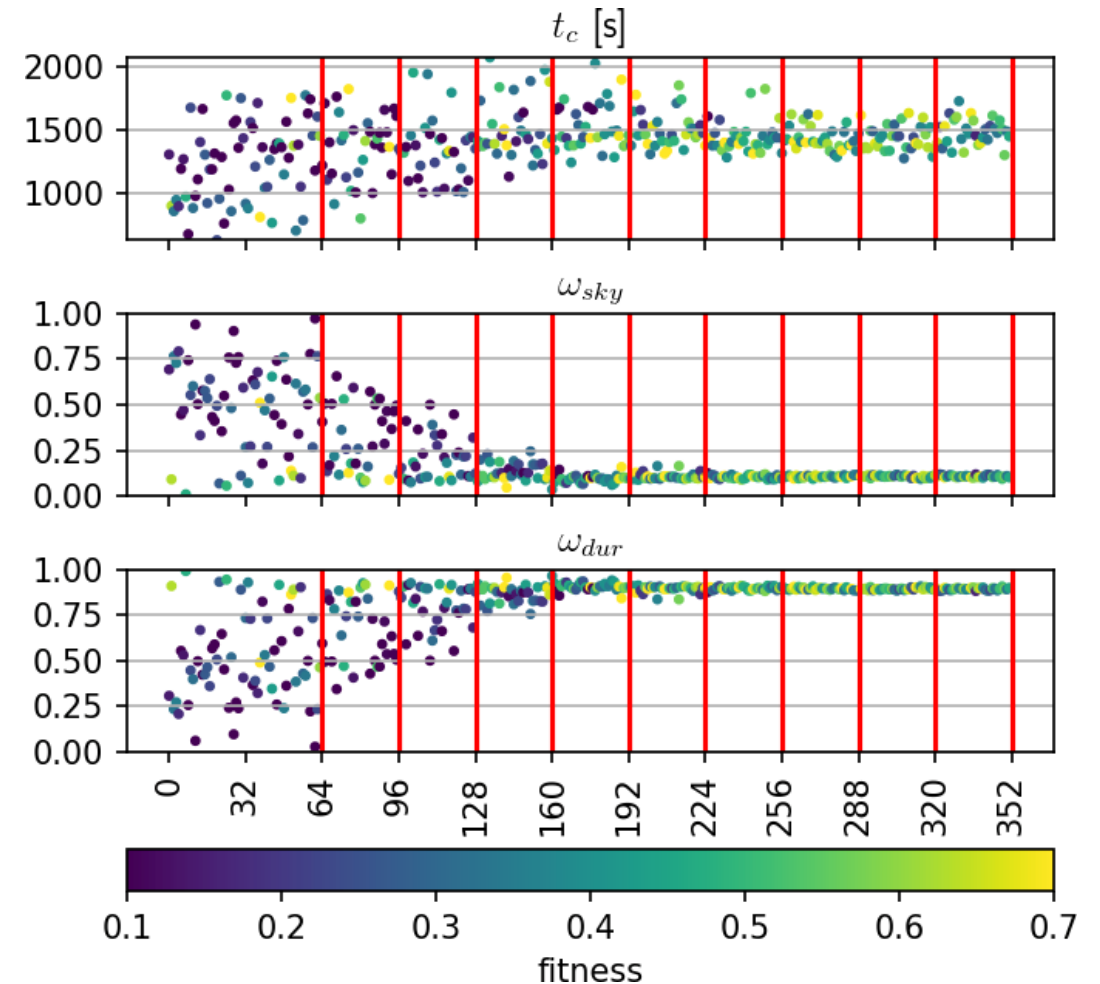
10 generations (delimited by red lines)

- Initial generation 64 individuals
 - Following generation 32 individuals
- 352 schedules (abscissa)

Displayed are slices from the twelve dimensional parameter space

Things to note:

- **fitness of ES increases with time**
- **optimal solution is found at the edge of the parameter space**



More details: Schartner et al. (2021)

Improvement of geodetic parameters based on ES (simulations)

Example: average improvement based on 12 OHG sessions

Relative improvement of simulated

- ◆ repeatability (rep)
 - mean formal errors (mfe)
- of geodetic parameters and
- number of observations based on 12 OHG sessions

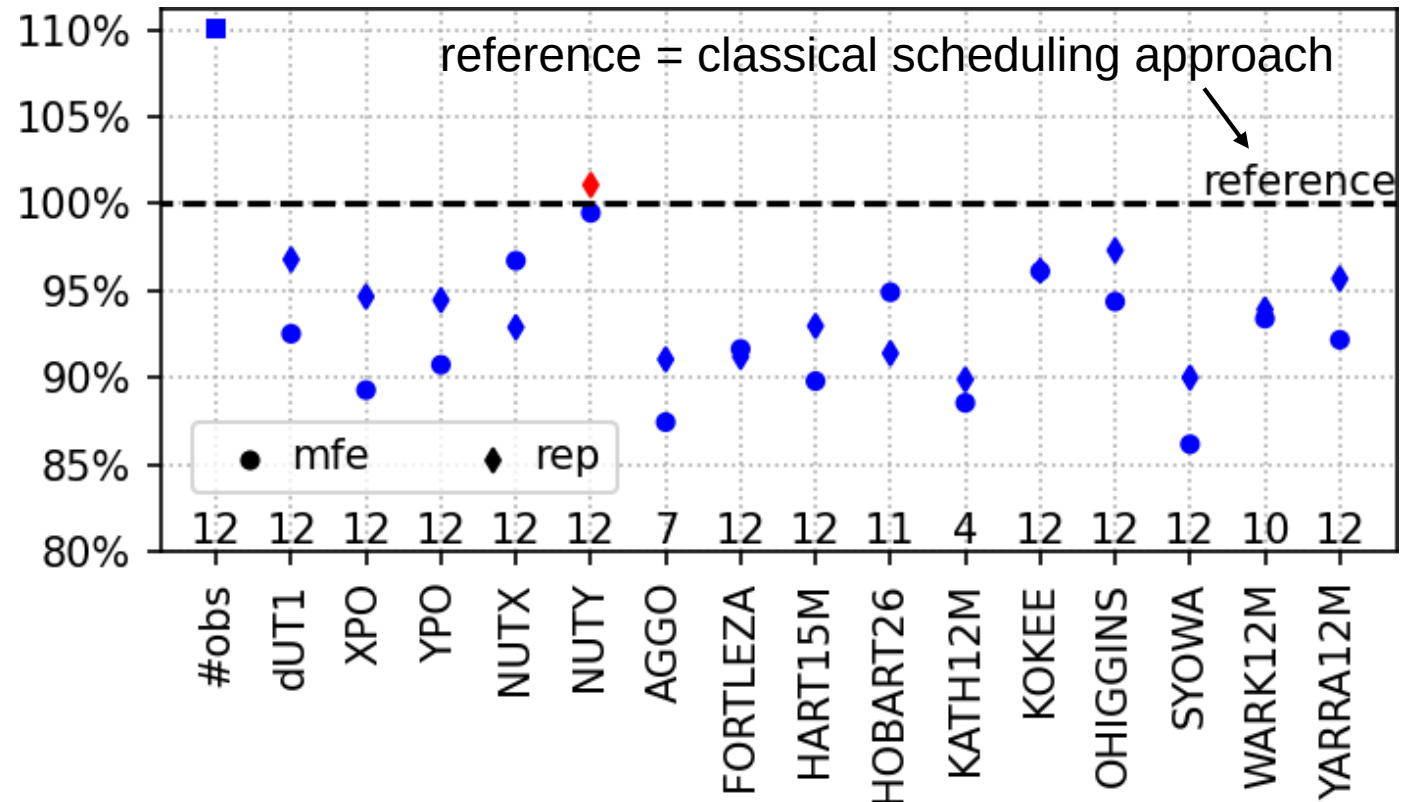
Reference (100%): results gained by using classical scheduling approaches

Blue → better performance

Red → worse performance

Things to note:

- On average 10% more observations
- On average, station coordinates precision improved by 8%



More details: Schartner et al. (2021)

Conclusion

Evolutionary Strategy (ES)

- 👍 **Transparent** scheduling
 - Based on **well defined goals**
 - Based on **Monte-Carlo simulations**
 - **Reduced human bias** in scheduling
- 👍 **Reduced human workload**
- 👍 **Highly optimized scheduling**
- 👍 Benefit is highest for complex schedules
 - OHG, T2...

IVS programs currently scheduled utilizing ES

- | | |
|----------|----------|
| — AUA | — INT2 |
| — INT3 | — INT9 |
| — OHG | — T2 |
| — VGOS-B | — VGOS-C |

Non-IVS program currently scheduled utilizing ES

- GOW08 (BKG)
- GOW16 (BKG)
- GOW17 (BKG)
- SI (Southern Hemisphere Intensives)

→ Approach works well for all session types

References

Schartner, M., Plötz, C. & Soja, B. Automated VLBI scheduling using AI-based parameter optimization. *J Geod* **95**, 58 (2021). <https://doi.org/10.1007/s00190-021-01512-w>

VieSched++: <https://github.com/TUW-VieVS/VieSchedpp>

VieSched++ reference: <https://iopscience.iop.org/article/10.1088/1538-3873/ab1820>

Manuals: <https://n.ethz.ch/~mschartner/download/>

YouTube tutorials:

<https://www.youtube.com/watch?v=rFEBkVEvlh0&list=PLxSgY16KcDTuH3QBSN-gnS5HKtrSagksx>

The screenshot shows a YouTube video player interface. The video title is "Introduction to VLBI scheduling with VieSched++" by Matthias Schartner, Institute of Geodesy and Photogrammetry, ETH Zürich. The video is part of a playlist titled "01 VLBI scheduling with VieSched++ - basics". The video player shows a thumbnail of a cityscape with a large blue overlay containing the title and author information. The video progress bar is at 0:00 / 57:02. The right sidebar shows a list of videos in the playlist, including "01 VLBI scheduling with VieSched++ - basics", "02 VieSched++ observing mode", "03 VieSched++ parameterization", "04 VieSched++ Analyzer", "05 VieSched++ statistics viewer", "06 VieSched++ Intensive sessions", and "07 VieSched++ add artificial station".