Minimization of the UT1 Formal Error Through A Minimization Algorithm

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Introduction

Suppose that we could put our observations anywhere. Where would we put them to minimize UT1? Of course the resulting schedules would be unrealistic, but maybe we could learn something that will help us in writing realistic schedules.

In this poster we report on our approach to this question and also describe scheduling principles to minimize UT1 formal errors. We also report on insight gained into IVS schedules based on tools we developed to answer our initial question. We focused on the IVS INT10 series which uses the Kokee-Wettzell baseline.

Our Approach

We used the Conjugate Gradient method as implemented in Numerical Recipes to minimize the UT1 formal error. This method uses the Fletcher-Reeves-Polak-Ribiere method to minimize a function provided that you know how to calculate the function and its gradient. We developed the following subroutines for use in this algorithm:

\[ \sigma_{\text{UT1}} = \sum_{i=1}^{n} \left( \sigma_{\text{CI}} + \sigma_{\text{AI}} + \sigma_{\text{SI}} \right) \]

\[ \sigma_{\text{CI}} = \sum_{i=1}^{n} \left( \sigma_{\text{Cl}} + \sigma_{\text{Acl}} + \sigma_{\text{Scl}} \right) \]

\[ \sigma_{\text{AI}} = \sum_{i=1}^{n} \left( \sigma_{\text{Ael}} + \sigma_{\text{Aaz}} + \sigma_{\text{Aaz}} \right) \]

\[ \sigma_{\text{SI}} = \sum_{i=1}^{n} \left( \sigma_{\text{Scl}} + \sigma_{\text{Saz}} + \sigma_{\text{Saz}} \right) \]

Using Gradients to Evaluate Intensive Schedules

The gradient tells us the sensitivity of UT1 to small changes in the position of the observations:

\[ \sigma_{\text{UT1}}(\theta_1, \theta_2) = \nabla \sigma_{\text{UT1}} = \left( \frac{\partial \sigma_{\text{UT1}}}{\partial \theta_1}, \frac{\partial \sigma_{\text{UT1}}}{\partial \theta_2} \right) \]

If the gradient is large, then small changes in position will result in large changes in the UT1 formal error. If the gradient is small, then small changes in position will have little effect.

Conclusions

• Conjugate gradient minimization identifies sources near the "corners" of mutual visibility as best for minimizing \( \sigma_{\text{UT1}} \). Evaluation dependent observation signatures identify positions near a small area of the sky at ~20 degrees elevation, and 30 ps sigmas identify positions near the horizon and over a wider part of the sky.

Approach: We made manual schedules that used two new approaches suggested by the minimization results and compared them to the operational MSS (formerly US) observing strategy. This is the strategy in which Sked has available all sources that are mutually visible on the Kokee-Wettzell baseline and tries to make schedules with good sky coverage. We made schedules for October 1, a time of the year with fewer strong sources, and December 16, a more normal time of the year.

• Cluster approach: We tried to observe from 66 to 75 degrees azimuth and 301 to 310 degrees azimuth, near 20 degrees elevation. This is analogous to the results from the elevation dependent observation signature minimization case.

• Cone: We tried to observe as close to 90 or 270 degrees azimuth as possible, going no further than 45 or 315 degrees azimuth. We used no elevation restrictions. This is analogous to the 30 ps observation signature minimization case.

I. Cluster (note: UT1 formal errors were calculated using elevation dependent observation sigmas)

<table>
<thead>
<tr>
<th>Date</th>
<th>Error</th>
<th>Minimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSS Oct 1</td>
<td>7.89 μs</td>
<td></td>
</tr>
<tr>
<td>Cluster Oct 1</td>
<td>17.11 μs</td>
<td></td>
</tr>
</tbody>
</table>

The target scheduling area is too small, and it is too hard to find sources near that area, especially for October 1. Sources must be repeated too frequently. This approach does not seem viable.

II. Cone (note: UT1 formal errors were calculated using 30 ps observation sigmas)

<table>
<thead>
<tr>
<th>Date</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSS Dec 16</td>
<td>8.18 μs</td>
</tr>
<tr>
<td>Cluster Dec 16</td>
<td>6.91 μs</td>
</tr>
</tbody>
</table>

The target scheduling area is much larger, and it is easier to find sources there. This lessens the repetition of sources. This approach is potentially viable, depending on further testing.

References
