On the Selection of Core Sources

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Abstract In earlier work [3, 4], we had suggested a method of ranking source sets in order to select the list of sources that better define the orientation parameters of rigid rotation transformation from one system to another. The transformation parameters' formal errors were selected as a characteristic of the source set. For all catalogs, IVS WG2 selected a special order for the source lists and obtained an accuracy for the transformation parameters as a function of the number of sources. For all catalogs with a minimum between 300 and 400 sources, adding sources after the minimum leads to increasing formal errors of the orientation parameters. After that, we selected the common sources which were selected before the minimum, and we obtained the "optimal set". Source position time series were obtained and analyzed for the optimal set of sources. It was shown that some of the core sources have unstable positions and need to be excluded from the optimal set. Nevertheless, the time series show that the stable sources compose a mainly optimal source set.

1 Introduction

We try to select the set of sources that minimizes formal errors of the orientation parameters of the rigid rotation transformation model.

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2 List Characteristic Definition

We do not use ranking of sources. Instead, we construct ranking parameters that can characterize the list of sources. Then we can compare not individual sources, but instead a set of them. The main advantage of our method is that it takes into account both geometrical distribution of the sources in the set and source position accuracy.

Let's say we have two catalogs (RA, DE) and (ra, de); we can then represent the differences

$$dRA = RA - ra$$

$$dDE = DE - de$$

between them and form

$$dRA = A1\tan(DE)\cos(RA) + A2\tan(DE)\sin(RA) - A3$$

$$dDE = A1\sin(RA) + A2\cos(RA),$$

where A_1, A_2, and A_3 are the transformation parameters. If we select the set of common sources in the two catalogs then we can calculate parameters $\mathbf{A} = (A1, A2, A3)$ and formal errors σ_{A1}, σ_{A2}, and σ_{A3} by the Least Square method:

$$\mathbf{A} = \mathbf{N}^{-1}\mathbf{b}$$

$$\sigma_{A1} = \sigma_0\mathbf{N}^{-1}[0,0]$$
$$\sigma_{A2} = \sigma_0\mathbf{N}^{-1}[1,1]$$
$$\sigma_{A3} = \sigma_0\mathbf{N}^{-1}[2,2].$$

We form normal equation matrix $\mathbf{N} = \mathbf{C}^{\mathbf{T}}\mathbf{PC}$ where $\mathbf{C} = \partial(dRA, dDE)/\partial A$ with the $\mathbf{P} = \mathbf{E}$ unitary matrix. The diagonal elements of inverted normal matrix

$\mathbf{N}^{-1}[0,0]$, $\mathbf{N}^{-1}[1,1]$, $\mathbf{N}^{-1}[2,2]$ are not affected by the differences between the two catalogs and depend only on the set of sources. For the calculation of σ_0, we use the formal errors of the selected set of sources

$$\sigma_0 = \frac{\sum(\sigma_{RA})^2 + \sum(\sigma_{DE})^2}{N-3} \qquad (1)$$

Thus we calculate σ_{A1}, σ_{A2}, and σ_{A3}, which are not affected by the differences between the two catalogs and depend only on the geometrical distribution of the sources in the set and formal errors of source coordinates.

We do not use σ_0 for the standard formula

$$\hat{\sigma_0} = \frac{\sum(r_{RA})^2 + \sum(r_{DE})^2}{N-3} \qquad (2)$$

where r_{RA} and r_{DE} are the residuals after transformation, because all CRF catalogs are obtained from the same data, and using σ_{RA} and σ_{DE} gives more adequate results.

For source list ranking parameter q, we select the maximum of the orientation parameter formal errors:

$$q = MAX(\sigma_{A1}, \sigma_{A2}, \sigma_{A3}). \qquad (3)$$

3 Optimized List Construction

If we want to define the orientation of the catalog in the best way, we need to select the set of sources that minimizes parameter q. The obtained set of sources can be considered as a set of "defining" sources.

We take into account only sources that are presented in the ICRF-ext.2 catalog [1] and have more than 10 session in the gsf008a catalog.

We use the next algorithm for the selection of the set of sources:

- Triple loop over all sources to select three sources that give a minimum value of q. At this step, we have the optimal set for $N_{sources} = 3$.
- Search over all remaining sources in order to minimize q for N+1 sources Remove the identified source from the list of remaining sources and add it to the final set.
- Repeat Step 2 for all remaining sources.

After that, we have a sequence of the lists that contains the optimal set of sources for a given $N_{sources}$ (see the

red line on the Figure 2). We obtained for all catalogs $MAX(\sigma_{A1}, \sigma_{A2}, \sigma_{A3})$ as a function of the number of sources (Figure 1). All of the catalogs have a minimum between 300 and 400 sources. Adding sources after the minimum leads to increasing formal errors of orientation parameters.

The first three sources in the set after step 1 are $0851 + 202$, $0955 + 476$, and $2037 + 511$.
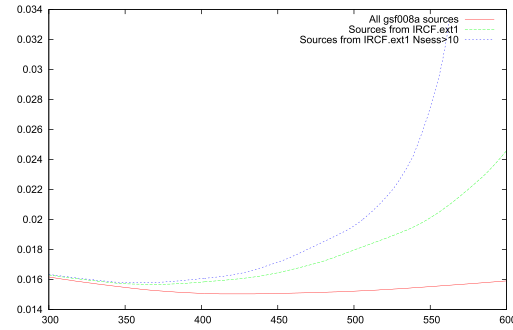

Fig. 1 Normalized $MAX(\sigma_{A1}, \sigma_{A2}, \sigma_{A3})$ vs. the number of sources for different catalogs.

4 Comparison of Our Optimized List and the OPA-ranked List

We have compared our optimized list with the OPA-ranked list. Also we calculated parameter q for the ICRF 212 defining list and for some lists of common sources. The results are presented in Figure 2.

The $\sqrt{q}$ plotted on the graph can be considered as the maximum formal error of the orientation parameters for the given set of sources. One can see that the ICRF 212 defining list gives worse results than the subset of the first sources from the OPA or IAA lists. Excluding from it seven sources not presented in the OPA list gives significant improvement. The first 380 sources from the OPA list recommended by Sebastien and Anne-Marie Gontier [2] show much better results than the 205 ICRF defining sources. But if we take common sources from the first 380 sources of the OPA list and the first 380 of the IAA list, we obtain almost two times better results by our criteria. The common set contains 288 sources.
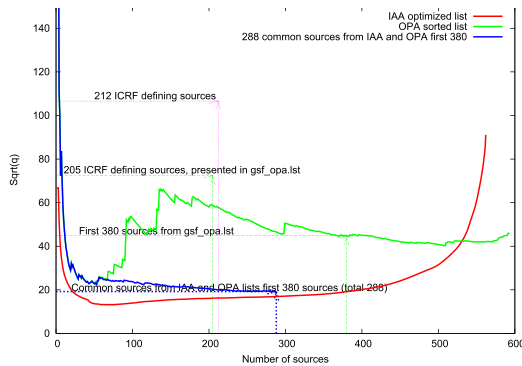
Fig. 2 MAX(σ_{A1}, σ_{A2}, σ_{A3}) vs. the number of sources for different subsets of the gsf2008a catalog.

5 Conclusion

It seems that transformation parameters for ICRF2 by the first 380 sources of the OPA-ranked list will not be estimated with the best accuracy. We suppose it would be better to use part of our optimized list or the common part of the N sources from our OPA list for the calculation of the transformation parameters. The function $q(N)$ for our optimized list rapidly increases only after N=400 sources. Thus if one takes the common part of any list of sources with our list for N⩽400, it will increase the accuracy of the transformation parameters.

The presented algorithm can be used for the selection of core sources for new catalogs. We plan to use selected sources for the actual computation of the transformation parameters between catalogs for ICRF3. The algorithm needs to be reviewed in the case of upcoming of multi wavelength reference frame.

References

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