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Source Selection for NNR Constraints from Source Position Time Series

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Abstract. Time series for more than 600 sources were calculated using the QUASAR software for VLBI data processing. Source positions for every source were obtained from single series analysis by fixing the coordinates of all other sources. A priori source positions were used from the ICRF-Ext.2 radio source position catalog. Time series analysis is performed with covariation analysis technique. The global solutions with different sets of sources for NNR constraints were obtained. Transformation parameters between obtained source catalogs were calculated and compared.

1. Introduction

The main goal of this study is to propose the parameter which can be used for selecting stable and unstable sources from the analysis of source position time series. We calculate the covariance function for the time series and try to use its second point as the characteristic parameter. Its value shows how much the time series was correlated independent of the way it was correlated (random walk, piece-wise linear, or any other technique).

The source position time series iaa000b, iaa000c were calculated using the QUASAR software [1, 4]. Most available VLBI observations (excluding DSN and VCS sessions) between Aug. 1979 and May 2007 were used. The time series were generated from a single session solution for each source: one source for the session with the coordinates of all other sources fixed. The station positions were not estimated for both series. The TRF was fixed to ITRF2005, the CRF was fixed to ICRF-Ext.2. The following parameters were estimated in these solutions: position of one source, EOP (X_p, Y_p, $UT1 - UTC$, X_c, Y_c) (only for iaa000b solution), WZD (linear trend and stochastic), troposphere gradient east and north, station clock offset (quadratic trend and stochastic).

We use the covariance functions from the time series analysis. Because there are no standard algorithms for obtaining covariance functions of non-equidistant time series, we use the following two methods.

First method.

For non-equidistant time series:

$$\{x_i\}_{i=1}^{N},\ x_i = x(t_i),\ t_1 < t_2 < ... < t_N,\ i = 1, ..., N. \quad (1)$$

Estimation of the covariance function for equidistant time shifts:

$$\tau_k = \Delta\tau \cdot k,\ \Delta\tau = \frac{t_N - t_1}{M}, k = 0, ..., M-1,\ M < N,$$

was calculated by formula

$$q(\tau_k) = \frac{M-k}{M}\left(\sum_{i,j:\tau_k<|\gamma_{ij}|<\tau_{k+1}} x_i x_j\right)/m_k, k = 0, 1, ..., M-1.$$

Here $\gamma_{ij} = t_i - t_j$ and m_k — the number of γ_{ij} in the range from τ_k to τ_{k+1}. The $\Delta\tau$ was chosen to 14 days.

Second method.

Estimation of the covariance function q_k for non-equidistant averaged time shifts τ_k:

$$q_k = \frac{\sum_{j=k+1}^{N-k} x_{k+j}x_j}{N},\ \ \tau_k = \frac{\sum_{j=k+1}^{N-k}(t_{k+j} - t_j)}{N-k},\ k = 0, 1, 2, ..., N-1. \quad (2)$$

Using these methods we obtained covariance functions for all time series of all analysis centers (the data are available on the ftp server of the WG on ICRF-2). The covariance functions for long time series are similar and in further computations we use the first one.

In the further analysis, we use the values of q_1 — the second point of the covariance function. The first point q_0 is the variance of the time series. But the second point characterizes the variance of the correlated part in the time series.

The second point of the covariance function shows how much the time series are correlated independent of the origin of the correlation (random walk, piecewise linear, or any other technique).

We calculated the coefficient $k = Max(q_1^{RA*cos(DE)}, q_1^{DE})$ for each time series with more than 75 sessions and used it to estimate how stable the sources are. The list of 140 sources was obtained and sorted by our stability criteria. In Tabl. 1 the most stable sources are shown ($k < 0.1$) and in Tabl. 2 most unstable sources are shown ($k > 0.5$). 15 sources from Tabl. 1 are contained in M. Feissel's list of stable sources and four sources from Tabl. 2 are in the unstable list.

2. Global solutions

In order to test our stability criteria described above, we calculated 15 VLBI global solutions using various sets of sources from our list of NNR constraints the origin of the Celestial Reference Frame.

A short description of these solutions is as follows:

Table 1. First 20 most stable sources ($k < 0.1$)

Source	N_{sess}	k	Source	N_{sess}	k	Source	N_{sess}	k
1351-018	489	0.040	1255-316	121	0.078	1908-201	386	0.096
0111+021	109	0.048	1606+106	1854	0.082	0743+259	400	0.096
1128+385	955	0.049	1652+398	218	0.087	0642+449	937	0.096
2318+049	426	0.060	0556+238	385	0.089	0804+499	1115	0.096
0201+113	378	0.065	1417+385	173	0.091	0602+673	328	0.097
2209+236	139	0.068	1144+402	93	0.093	0749+540	630	0.098
0133+476	1027	0.076	0657+172	112	0.095			

Table 2. Last 11 most unstable sources ($k > 0.5$)

Source	N_{sess}	k	Source	N_{sess}	k	Source	N_{sess}	k
0355+508	269	0.556	1354+195	78	0.688	1642+690	96	0.852
2128-123	558	0.573	1053+815	351	0.725	1253-055	140	1.212
1641+399	813	0.575	2007+777	224	0.777	0316+413	96	1.305
1226+023	709	0.581	1313-333	99	0.835			

- celestial reference frame: ICRF-Ext.2,
- terrestrial reference frame: VTRF2005,
- IAU2000A precession-nutation model,
- definition of the origin TRF by NNR/NNT constraints for 11 stations,
- estimated parameters: celestial frame: right ascension, declination (global), terrestrial frame: X, Y, Z, rates (global), Earth orientation: X_p, Y_p, $UT1 - TAI$, X_c, Y_c (local), zenith troposphere delay: linear+stochastic signal (local), troposphere gradient: east and north (local), station clocks: quadratic+stochastic signal (local).

Definition of the origin CRF.

- In the solutions $q55_1$ through $q55_5$ for NNR constraints, 55 sources were used from the first 65 most stable sources excluding the first 10 for $q55_1$, excluding the second 10 sources for $q55_2$, etc.
- In the solutions q65 through q140 for NNR constraints between 65 and 140 sources were used from our list correspondingly.
- Solution q212 used 212 ICRF defining sources for NNR constraints.

3. Comparison of Obtained CRF Catalogues

The 15 catalogs obtained were compared with the ICRF original catalog. Transformation parameters for M. Feissel's list of 199 stable sources were calculated using the standard IERS transformation model with 6 parameters:

$$\Delta\alpha = A_1 \tan\delta \cos\alpha + A_2 \tan\delta \sin\alpha - A_3 + D_\alpha(\delta - \delta_0),$$

$$\Delta\delta = -A_1 \sin\alpha + A_2 \cos\alpha + D_\delta(\delta - \delta_0) + B_\delta,$$

here parameters A_1, A_2, A_3 represent the rotation angles between two catalogs and $D_\alpha, D_\delta, B_\delta$ the deformations. Transformation parameters are shown in Tabl. 3 and 4.

Table 3. Transformation parameters (rotation angles) between obtained solutions and ICRF-Ext.2

Sol. ID	$A_1, \mu as$	$A_2, \mu as$	$A_3, \mu as$
$q55_1$	-7.1 ± 10.4	19.1 ± 9.7	-1.6 ± 11.6
$q55_2$	-7.1 ± 10.4	30.8 ± 9.8	-7.5 ± 11.7
$q55_3$	-16.2 ± 10.3	17.3 ± 9.7	-6.0 ± 11.5
$q55_4$	-9.6 ± 10.4	18.3 ± 9.7	-6.0 ± 11.6
$q55_5$	3.5 ± 10.3	16.1 ± 9.7	-14.1 ± 11.5
q65	-7.8 ± 10.4	20.6 ± 9.7	-8.4 ± 11.6
q75	-1.5 ± 10.3	22.9 ± 9.7	-12.6 ± 11.5
q85	-4.0 ± 10.4	26.4 ± 9.7	-14.5 ± 11.6
q95	-6.4 ± 10.4	28.1 ± 9.7	-15.7 ± 11.6
q105	-9.7 ± 10.4	25.7 ± 9.7	-20.4 ± 11.6
q115	-9.0 ± 10.4	25.0 ± 9.7	-21.3 ± 11.6
q125	-8.2 ± 10.4	29.1 ± 9.7	-26.4 ± 11.6
q135	-5.5 ± 10.4	25.9 ± 9.7	-27.3 ± 11.6
q140	-2.9 ± 10.4	23.7 ± 9.7	-25.6 ± 11.6
q212	-4.1 ± 10.4	-41.4 ± 9.7	23.2 ± 11.6

4. Discusson

We try to use our stability criteria based on covariation analysis for forming the best set of sources for NNR constraints for global solutions. When we used the sets of most stable sources (first part of Tabl. 3) for the constraints, the obtained catalogs had different rotation angles (A2 from 16 μas to 30 μas with formal errors of 10 μas). However, the analysis shows the difference between the rotation angles of q212 catalog and all others. We can surmise that this is due to the presence of sources with short observation history in the list of defining sources, because even most unstable sources in our list have more than 75 sessions of observations. This conclusion needs to be tested.

Table 4. Transformation parameters (deformations) between obtained solutions and ICRF-Ext.2

Sol. ID	$D_\alpha, \mu as$	$D_\delta, \mu as$	$B_\delta, \mu as$
$q55_1$	0.0±0.4	-0.2 ± 0.3	-1.7 ± 11.3
$q55_2$	0.2±0.4	-0.3 ± 0.3	2.0 ± 11.4
$q55_3$	0.1±0.4	-0.3 ± 0.3	1.9 ± 11.3
$q55_4$	0.0±0.4	-0.1 ± 0.3	-9.4 ± 11.3
$q55_5$	0.0±0.4	-0.1 ± 0.3	-10.6 ± 11.3
q65	-0.1 ± 0.4	-0.2 ± 0.3	-4.9 ± 11.3
q75	0.4±0.4	-0.2 ± 0.3	-0.5 ± 11.3
q85	0.6±0.4	-0.2 ± 0.3	-7.1 ± 11.3
q95	0.6±0.4	-0.1 ± 0.3	-13.0 ± 11.3
q105	0.6±0.4	-0.2 ± 0.3	-8.9 ± 11.3
q115	0.6±0.4	-0.2 ± 0.3	-6.2 ± 11.3
q125	0.6±0.4	-0.2 ± 0.3	-4.6 ± 11.3
q135	0.6±0.4	-0.2 ± 0.3	-3.4 ± 11.3
q140	0.6±0.4	-0.2 ± 0.3	-0.7 ± 11.3
q212	0.6±0.4	-0.5 ± 0.3	22.3 ± 11.3

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