THE USE OF THE NONROTATING ORIGIN IN THE COMPUTATION OF APPARENT PLACES OF STARS FOR ESTIMATING EARTH ROTATION PARAMETERS

N. CAPITAINE and F. CHOLLET
Observatoire de Paris - URA 1125/CNRS
61, Avenue de l'Observatoire
75014 - Paris
FRANCE

ABSTRACT. A new procedure has been devised for computing apparent places of stars in the intermediate frame (Capitaine 1990) linked to the nonrotating origin (Guinot 1979) for estimating the Earth rotation parameters (ERP) from astrometric observations. The latitude and time parameters as derived by this procedure have been compared to the parameters as derived from the classical procedure used for the reduction of Paris astrolabe observations (Chollet 1984). The consistency between the two procedures has been found to be of the order of a few 10^{-4}", which is under the order of precision of the computations in the classical procedure. The new procedure, which is more directly related to the Earth rotation, is proposed to be used for the derivation of the ERP in the Hipparcos frame from existing astrometric observations, which is planned for the near future (IAU WG on "Earth Rotation in the Hipparcos Reference Frame").

1. INTRODUCTION

The latitude and time parameters are clasically derived from astrolabe observations of one group of stars by comparing the computed apparent places of the stars in an intermediate frame linked to the Celestial Ephemeris Pole (CEP) and true equinox with their corresponding observed places.

The use of the nonrotating origin (NRO) as proposed by Guinot (1979) instead of the equinox, for reckoning the Earth's angle of rotation, associated with the use of the celestial coordinates of the Celestial Ephemeris Pole to account for the effects of precession and nutation, instead of the classical precession and nutation parameters, provides an intermediate frame which is more directly related to the observation of Earth rotation.

A new procedure has thus been devised for computing the instantaneous latitude and time parameters from Paris astrolabe observations referred to such an intermediate frame. This procedure is based on the matrix transformation of vector components (denoted by [ ]) between the geocentric celestial and terrestrial reference systems (denoted by CRS and TRS, respectively) which can be written (Capitaine 1990) as:

$$[TRS] = W(t).\,R(t).\,NP(t)\,[CRS], \qquad (1)$$

W(t) being for the terrestrial displacement of the CEP (i.e. "polar motion"), R(t) for the celestial Earth's angle of rotation (i.e. "stellar angle") and NP(t) for the celestial displacement of the CEP (i.e. precession/nutation) from the epoch t_0 to the date t.

2. PROCEDURE FOR COMPUTING APPARENT POSITIONS OF STARS REFERRED TO THE NRO

The new procedure, compiled from the classical procedure for computing apparent positions of stars for astrolabe reductions (Chollet 1984), uses the following steps:

- expression, in rectangular coordinates, of the unit vector determined by the standard mean place of the star in the FK5 (epoch J2000.0),

- correction for proper motion and normalization of the resulting vector,

- rotation (ε_o) of the vector from the mean equator of epoch to the ecliptic of epoch,

- correction for annual parallax and aberration using the position and velocity of the Earth, with respect to the solar system barycenter, referred to the ecliptic and mean equinox of J2000.0 and normalization of the resulting vector,

- rotation ($-\varepsilon_o$) of the vector from the ecliptic of epoch to the mean equator of epoch,

- rotation of the vector from the mean equatorial frame of epoch to the celestial intermediate frame of date, t, linked to the CEP and the NRO, using the matrix transformation (Capitaine 1990) (see Figure 1): $NP(t) = R_3(s).R_3(-E).R_2(d).R_3(E)$. (2)

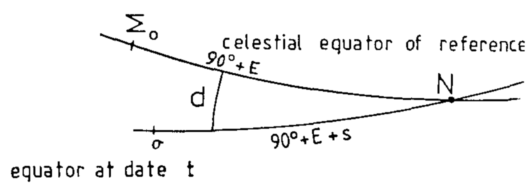

Figure 1: *The angular parameters for the transformation in the new procedure*

3. PROCEDURE FOR DERIVING LATITUDE AND TIME PARAMETERS REFERRED TO THE NRO

The new procedure uses the following steps:

- rotation of the vector from the intermediate celestial frame of date to the local terrestrial frame linked to the CEP and to the local meridian, using the rotation matrix $R_3(\theta+\lambda)$, where $\theta = \theta_0 + k\,(UT1 - UT1_0)$ is the stellar angle (Guinot 1979, Capitaine *et al.* 1986) and λ is the longitude of the station,

- computation of the spherical coordinates of the resulting apparent direction to be compared with the observed spherical coordinates of the star,

- least squares adjustment of latitude and time parameters: φ and UT1 -UTC for each group of stars.

4. NUMERICAL CHECKS

Numerical checks of this procedure were performed for the derivation of the latitude and time parameters from Paris astrolabe observations spanning several months (see example).

https://doi.org/10.1017/S0252921100063831 Published online by Cambridge University Press

(i) Classical procedure

N° 226 PARIS Latitude 48 50 8.5000
FK 5 Longitude 0 9 21.0453
Groupe 2
Lam γ
19901009

Date	Gr	Obs.	UT0 UTC	Pds.UT	UT Moy.	UT0 TAI	UT Ref.	dΦ	Pds.Φ	Rayon	Nb.*	Pds.Gr
19901009	2	19	0.19564	4.3	24.600	25.19560	24.00	0.9145	3.1	15.9701	26	3.6
Sigmas correspondants				0.0044					0.051	0.033		0.168

Rang	N°FK	Résidu	CLI	UT Calculé	Val.Obs	A(x)	Cts.	dh	SinZ	CosZ	Refr
1	851	0.135	0.000	85809.4014	9.8670	0.0	1	1.7118	0.35771	0.93383	0.0203
2	165	0.324	0.000	86113.6947	13.8713	0.0	0	1.5661	0.88061	0.47384	0.0234
3	2336	0.105	0.000	86232.0380	12.1353	0.0	0	0.6522	0.65505	0.75558	0.0246
4	3794	0.287	0.000	86430.5889	31.0333	0.0	0	2.0212	0.46137	0.88721	0.0267
5	1600	0.099	0.000	86698.0323	58.2107	0.0	0	1.7073	0.98858	0.15090	0.0294
6	89	0.139	0.000	86929.1566	49.4731	0.0	1	1.6364	0.53286	0.84620	0.0318
7	844	0.169	0.000	87093.3840	33.6487	0.0	0	2.3408	0.90775	0.41952	0.0335
8	1613	0.295	0.000	87361.4125	1.5494	0.0	0	1.2193	0.93468	0.35549	0.0363
9	178	0.066	0.000	87481.8031	1.8533	0.0	0	0.3281	0.59760	0.80179	0.0376
10	182	0.026	0.000	87726.3025	6.4036	0.0	0	0.7906	0.74976	0.66171	0.0401
11	869	0.175	0.000	88105.0381	25.2301	0.0	0	1.8451	0.99800	0.06329	0.0440
12	3891	0.054	0.000	88235.3128	35.4936	0.0	0	1.6481	0.95204	0.30598	0.0454
13	158	0.247	0.000	88402.4695	22.6548	0.0	0	1.8294	0.96620	0.25779	0.0471
14	863	0.053	0.000	88758.3189	18.6467	0.0	1	1.9797	0.60246	0.79815	0.0508
15	2348	0.119	0.000	88866.3719	6.5556	0.0	0	1.8692	0.99507	0.09917	0.0519
16	1032	0.258	0.000	89046.8787	6.9544	0.0	1	0.3460	0.45130	0.89237	0.0538
17	203	0.111	0.000	89381.3768	41.4890	0.0	1	0.7439	0.68586	0.72773	0.0572
18	27	0.032	0.000	89487.5161	27.6195	0.0	1	0.7049	0.67892	0.73422	0.0583
19	193	0.035	0.000	89640.5470	0.7171	0.0	0	1.7136	0.97889	0.20439	0.0599
20	139	0.147	0.000	89867.0846	47.4008	0.0	1	2.0951	0.67145	0.74105	0.0623
21	1094	0.044	0.000	90017.5692	17.9442	0.0	1	1.7221	0.46359	0.88605	0.0638
22	875	0.031	0.000	90393.5972	33.8732	0.0	0	2.1734	0.82107	0.57083	0.0677
23	1619	0.030	0.000	90726.9163	7.1331	0.0	0	2.0462	0.99005	0.14073	0.0712
24	19	(0.000)	0.000	90878.7614	38.8306	0.0	1	0.5920	0.86866	0.49542	0.0728
25	173	0.165	0.000	91005.0263	44.9364	0.0	1	0.2492	0.25771	0.96622	0.0741
26	1126	0.080	0.000	91318.9675	59.1965	0.0	0	2.0178	0.85028	0.52633	0.0774
27	66	0.168	0.000	91455.1823	15.1552	0.0	1	0.1334	0.42878	0.90341	0.0788

UTC H 0.0000 TAI UTC 25. m H/UTC 0.0000 m UT/UTC 0.0015
CHR H 0.0000 DTC 0.0 R approché 16.000

N° 226
FK 5
Groupe 2
Lam
PARIS
19901009

(ii) New procedure

N° 226 PARIS Latitude 48 50 8.5000
FK 5 Longitude 0 9 21.0453
Groupe 2
Lam NRO
19901009

Date	Gr	Obs.	UT0 UTC	Pds.UT	UT Moy.	UT0 TAI	UT Ref.	dΦ	Pds.Φ	Rayon	Nb.*	Pds.Gr
19901009	2	19	0.19567	4.3	24.600	25.19563	24.00	0.9140	3.1	15.9703	26	3.6
Sigmas correspondants				0.0044					0.051	0.033		0.168

Rang	N°FK	Résidu	CLI	UT Calculé	Val.Obs	A(x)	Cts.	dh	SinZ	CosZ	Refr
1	851	0.135	0.000	85809.4016	9.8670	0.0	1	1.7112	0.35771	0.93383	0.0202
2	165	0.324	0.000	86113.6947	13.8713	0.0	0	1.5666	0.88061	0.47384	0.0233
3	2336	0.105	0.000	86232.0379	12.1353	0.0	0	0.6529	0.65505	0.75558	0.0245
4	3794	0.286	0.000	86430.5890	31.0333	0.0	0	2.0206	0.46137	0.88721	0.0266
5	1600	0.099	0.000	86698.0323	58.2107	0.0	0	1.7073	0.98855	0.15090	0.0294
6	89	0.139	0.000	86929.1566	49.4731	0.0	1	1.6363	0.53286	0.84620	0.0318
7	844	0.169	0.000	87093.3841	33.6487	0.0	0	2.3406	0.90775	0.41952	0.0335
8	1613	0.295	0.000	87361.4125	1.5494	0.0	0	1.2195	0.93468	0.35549	0.0362
9	178	0.066	0.000	87481.8029	1.8533	0.0	0	0.3288	0.59760	0.80179	0.0375
10	182	0.026	0.000	87726.3024	6.4036	0.0	0	0.7913	0.74976	0.66171	0.0400
11	869	0.175	0.000	88105.0382	25.2301	0.0	0	1.8451	0.99800	0.06329	0.0439
12	3891	0.054	0.000	88235.3128	35.4936	0.0	0	1.6483	0.95204	0.30598	0.0453
13	158	0.247	0.000	88402.4694	22.6548	0.0	0	1.8297	0.96620	0.25779	0.0470
14	863	0.053	0.000	88758.3190	18.6467	0.0	1	1.9793	0.60246	0.79815	0.0507
15	2348	0.118	0.000	88866.3719	6.5556	0.0	0	1.8696	0.99507	0.09917	0.0518
16	1032	0.258	0.000	89046.8787	6.9544	0.0	1	0.3463	0.45130	0.89237	0.0537
17	203	0.111	0.000	89381.3767	41.4890	0.0	1	0.7446	0.68586	0.72773	0.0572
18	27	0.032	0.000	89487.5160	27.6195	0.0	1	0.7052	0.67892	0.73422	0.0583
19	193	0.035	0.000	89640.5470	0.7171	0.0	0	1.7142	0.97889	0.20439	0.0598
20	139	0.147	0.000	89867.0846	47.4008	0.0	1	2.0982	0.67145	0.74105	0.0622
21	1094	0.044	0.000	90017.5692	17.9442	0.0	1	1.7221	0.46359	0.88605	0.0638
22	875	0.032	0.000	90393.5972	33.8732	0.0	0	2.1732	0.82107	0.57083	0.0677
23	1619	0.029	0.000	90726.9163	7.1331	0.0	0	2.0463	0.99005	0.14073	0.0711
24	19	0.000	0.000	90878.7614	38.8306	0.0	1	0.5924	0.86866	0.49542	0.0727
25	173	0.165	0.000	91005.0260	44.9364	0.0	1	0.2485	0.25771	0.96622	0.0740
26	1126	0.080	0.000	91318.9675	59.1965	0.0	0	2.0181	0.85028	0.52633	0.0773
27	66	0.167	0.000	91455.1822	15.1552	0.0	1	0.1331	0.42878	0.90341	0.0787

UTC H 0.0000 TAI UTC 25. m H/UTC 0.0000 m UT/UTC 0.0018
CHR H 0.0000 DTC 0.0 R approché 16.000

N° 226
FK 5
Groupe 2
Lam
PARIS

Table 1: Example of the estimated parameters φ and UT0-UTC using the two procedures

These checks show our procedure referred to the NRO to give results consistent to a few 10^{-4} arcseconds with the estimations of the same parameters from the classical procedure referred to the true equinox and using the Sidereal Time computed with the complete equation of the equinoxes (Aoki and Kinoshita 1983). Such a consistency is under the order of precision of the computations in the classical procedure.

The practical advantages of this new procedure for deriving variations of latitude and time from astrometric data are that the calculations are simpler and that the derived quantities are more directly linked to the kinematic parameters representing Earth Rotation.

5. CONCLUSION

The present study shows that the computation of the apparent places of stars referred to the nonrotating origin provides latitude and time parameters which are consistent with those derived from the classical method with an accuracy of a few 10^{-4} arcseconds. Such a procedure, which is more directly related to the Earth rotation, can be used with advantage for the estimation of the Earth Rotation Parameters (ERP) from astrometric observations. It is proposed to be used for the computation of the ERP in the Hipparcos frame from existing astrometric observations, which is planned for the near future (IAU WG on Earth Rotation in the Hipparcos Reference Frame).

6. REFERENCES

Aoki, S. and Kinoshita, H., 1983, 'Note on the relation between the equinox and Guinot's non-rotating origin', *Astron. Astrophys.* **105**, 335-360.

Capitaine, N., 1990, 'The celestial Pole coordinates',*Celest.Mech Dyn.Astr* **48**, 127-143.

Capitaine, N., Guinot, B., Souchay, J., 1986, 'A nonrotating origin on the instantaneous equator: definition, properties and use', *Celest.Mech* **39**, 283-307.

Chollet, F., 1984, 'Calcul des positions apparentes et recommandations de l'UAI', *Astron.Astrophys.* **132**, 296-300.

Guinot, B. 1979, 'Basic problems in the kinematics of the rotation of the Earth', in *Time and the Earth's Rotation* , D.D. Mc Carthy and J. D. Pilkington (eds), D. Reidel Publishing Company.