METHODS OF USE AND PRESENTATION OF THE ACCURATE ASTROMETRIC DATA BASED ON THE MODERN TERRESTRIAL AND CELESTIAL REFERENCE SYSTEMS

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ABSTRACT. The increasing precision of the modern astrometric data as well as changes from the introduction of a new paradigm for the relations of terrestrial and celestial systems, forces the changes in methods of the usage and presentation of the data. The paper presents the efforts undertaken to satisfy these needs in the "Rocznik Astronomiczny". Among the issues under consideration are: 1) identification and analysis of the sources of problems with interpolation of the high accuracy data; 2) reviewing the used interpolation methods; 3) development of the new methods of presenting of the high accuracy data, allowing their proper interpolation; 4) research on the need and the possibility to redefine the "Besselian Numbers" algorithm in calculations of the "apparent places", to the form in which it could be used in the new paradigm (CIP/CIO).

1. INTERPOLATION OF APPARENT POSITIONS OF STARS

Apparent positions of stars are usually published with an interval of 1 or 10 days (Krynski, Sekowski, 2003–2010). For interpolation the most important are the factors which cause the highest amplitude changes of apparent position of a star in a short time.

Annual aberration of light — the effect within a single day slightly differs from a linear one. In the extreme case, the linear interpolation errors for 24 hours interval shall not exceed 1 mas. In the case of 10-days intervals, linear interpolation errors can reach values of 70÷80 mas; in this case a quadratic interpolation gives compliance at 1 mas (Sekowski, 2006).

Precession and nutation — nutation of the pole of the Intermediate Reference System is the major factor affecting the variability of the apparent position of stars (Krynski, 2004a, 2004b). All nutation theories IAU80, IAU2000 and IAU2006 are represented by the series of periodic terms (sine, cosine) of fundamental arguments. Quality of interpolation of the tabulated apparent position of stars is mostly affected by the amplitudes of short-periodic terms of the series. Among the long-periodic nutation terms, both in longitude and obliquity, the most dynamic variability shows the terms of periods of 186.2, 6798.4, 121.7 and 365.3 days. The dynamics of their variability, reaches in longitude/obliquity: 45.3/19.7, 15.9/8.5, 2.7/1.2, and 2.5/0.1 mas/day, respectively (Sekowski, 2006). Amplitudes of short-periodic terms achieve much smaller absolute values. They show, however, much higher dynamic variability. The short-periodic nutation component exhibiting highest dynamics that determines its practical potential in the context of interpolation, is a term of the period of 13.7 days. Its dynamics of variability reaches 104.7 mas/day and 45.0 mas/day in longitude and obliquity, respectively (Sekowski, 2006).

Interpolation methods — there are three basic methods typically used for interpolation of the astrometric data: 1) Stirling interpolation — giving good results in the nearest vicinity of the main node u_0 (not further then 30% of the interpolation interval), its linear variant is spanned on three nodes (one backward and one forward; 2) Newton interpolation — giving good results on both ends of the interpolation interval, identical with the Bessel method in their linear variants; 3) Bessel interpolation — giving the best results in the middle of interpolation interval, in its second order variant symmetrical with respect to the interval, constructed on two backward and two forward nodes.

In case of linear interpolation Newton and Bessel methods give identical results, which are much better then those from Stirling scheme everywhere within the interpolation interval. In case of second order interpolation Bessel interpolation method shows much less errors then two other methods investigated.

2. TABULATION OF THE INCREASED PRECISION DATA

Data published in the astronomical almanacs are presented in tabulated form. This refers to the majority of data being published as they are time dependent. These are, in particular, solar and lunar ephemerides, sidereal time data, the apparent positions of stars, and all other data related with them, e.g. Besselian Numbers, precession-nutation matrix coefficients etc.

The increasing precision of the fundamental catalogue data, the accuracy of modelling of location and movement of the Earth and Solar System bodies, and the contemporary definitions of the reference systems cause, that the data published in astronomical almanacs could potentially reach much higher quality. In many cases, however, the accuracy is lost as a result of inappropriate form of presentation.

The manner in which data appear in the data tables is closely associated with the terms of their interpolation. The appropriate step of the data tabulation as well as the interpolation algorithm used are strongly associated with the potential to achieve the expected accuracy. There is data, e.g. precession-nutation matrix coefficients, which accuracy is far higher then it is possible to be achieved from interpolation between the exact values, with even as short as 1-day interpolation step. In such cases completely new ways of tabulation are needed (e.g. based on Tchebyshev polynomials) in order to maintain the current non-electronic forms of data publishing.

3. RIGOROUS AND SIMPLIFIED APPARENT POSITION ALGORITHMS

Precession-nutation matrix — today's algorithm for calculating apparent positions of the celestial bodies is based on a rigorous vector algebra and the precession-nutation is given in a form of the rotation matrix. Therefore astronomical almanacs usually contain the tables listing a sequence of nine element sets of precession-nutation matrix. The matrix elements are numbers from 0 to 1, having up to 12 significant digits. A large number of matrix elements and their significant digits makes the use of precession-nutation data in this form inconvenient. The presentation of data also poses problems with the interpolation, since the matrix elements contain all components of short-periodic nutation terms. Thus the search for alternative ways of presenting precession-nutation data, without loss of accuracy of interpolated data, under the largest possible interpolation interval is required.

Besselian Numbers — current, simplified algorithm for calculating an apparent position on the basis of the Besselian Numbers does not meet the criterion of possible to achieve nowadays accuracy. Developing a new algorithm that uses the current theory of nutation, with increased accuracy, is furthermore hampered by the apparent lack of separation between long- and short-periodic terms of nutation. The new simplified algorithm should also be in line with the new paradigm of astronomy, in which the sidereal time is replaced by the Earth Rotation Angle.

4. FINAL REMARKS

Examination of the presented problems will be a methodological basis for practical solutions, the development of a modernized form of data presentation in printed form, and finally sharing the almanac data via the Internet.

Creation of the web version of the almanac is a further objective of this project, significant for a practical applications in geodetic astronomy as well as for education and popularization.

Acknowledgements. The work presented is a subject of research grant N526 154737 awarded to the Institute Geodesy and Cartography, Warsaw by the Ministry of Science and Higher Education of Poland.

5. REFERENCES

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