ASTRONOMICAL COORDINATES WITHOUT TABLES

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Introduction

THE RECENT advances in microcomputer technology have raised the question of whether reference to astronomical tables of apparent coordinates is actually required for determining the astronomical positions of the sun and other stars. In light of the almost exponential trend of power and compactness of microcomputers, it is now feasible to directly compute the various astronomical data from the same basic theories of motion of the earth that are used to prepare the tables. This means that one need not keep such tables on hand but instead simply supply the time and date to a computer program employing the necessary algorithms.

Previous Computational Methods

Many researchers have used a wide variety of techniques to approximate the data in astronomical tables. Among these are the methods that fit various functions to the data (e.g. algebraic and Chebychev polynomials, Fourier series, etc.). However, these are merely approximations and are invariably limited to the specific time period over which the data were approximated (e.g. 1 month for the Star Almanac's polynomials). As a result these functions must be continuously updated for new time periods.

The ideal method would involve computing the data directly from the basic theories of the motion of the earth and stars. For the sun the periods over which the algorithms are valid depend only on significant changes in the astronomical constants used in the theories. Although the algorithms for stars (e.g. Polaris) depend on the astronomical constants, they are affected to a greater degree by uncertainties in their motions with respect to our solar system (i.e. proper motion). However, for 1′ accuracy in azimuth determinations, the estimates for the proper motions are valid for periods of about 30 years.

Recently, Meeus [1962], Emerson [1978], Bennett [1980] and Craymer [1984] have derived algorithms for updating the sun's right ascension and declination using the theories of the motion of the earth around the sun. The precision resulting from Meeus [1962], Emerson [1978] and Bennett [1980], however, are limited. On the other hand, Craymer [1984] provides all of the necessary expressions necessary to compute exactly the values published in the Astronomical Almanac and K & E Ephemeris (actually reproduced from the former). In addition, Craymer [1984] also provides a more thorough review of the fundamental concepts involved.

Updating the Position of Stars

The astronomic position (i.e. right ascension and declination) of a star is readily obtained by simply updating its catalogued coordinates at one point in time (called the catalogued epoch) to that for the time of observation. These catalogued positions are currently available in the FK-4 star catalogue which will soon be followed by the updated version, the FK-5.

The procedures for updating catalogued star positions are readily available in many text books on positional astronomy (e.g. Mueller [1969]). Briefly, the following effects that must be applied to the catalogued positions are:

1. proper motion – the absolute motion of the star with respect to the earth,
2. precession – the long period motion of the earth's spin axis,
3. nutation – the short period motion of the earth's spin axis,
4. aberration – the effect of the finite velocity of light,
5. parallax – the effect of the displacement of the observer from the origin of the stellar coordinate system. This is negligible for most stars including Polaris.

Updating the Position of the Sun

The method of updating the astronomical position of the sun is not so readily available. However, the theory upon which the tables are based was developed almost a century ago by the famous Canadian astronomer Simon Newcomb [1898] for the American Ephemeris and Nautical Almanac. In this paper Newcomb develops expressions describing the motion of the sun as perceived from the earth.

Briefly, the procedure of updating the sun's astronomical position involves computing the following from Newcomb [1898]:

1. mean ecliptic coordinates (i.e. ecliptic longitude and latitude),
2. mean obliquity of the ecliptic
3. perturbing effects of the planets and moon on ecliptic longitude, latitude and obliquity,
4. effect of nutation on ecliptic longitude and obliquity,
5. aberration effect on ecliptic longitude,
6. transformation from ecliptic longitude and latitude to right ascension and declination using the obliquity of the ecliptic.

The results of such a computation may be further reduced for the effect of geocentric parallax given the approximate geographic latitude and longitude of the observer (cf. Mueller [1969]).

Practical Applications

These computations can be quite involved for manual solutions. The advent of the microcomputer, however, has now resolved this problem. Furthermore, it would be more efficient to combine the commonly employed routines for azimuth determination with those described above. Such a program could be used to directly compute the azimuth of the sun in the field.

A program has been developed by the first author under contract with the Ontario Ministry of Transportation and Communication and is available as a technical report from the Department of Survey Science, Erindale College [Craymer, 1984]. This contract was made possible through the efforts of J. T. Gourlay, O.L.S. and F. G. Lane, O.L.S. The program was written in a low level of FORTRAN in order to make it as transparent as possible for reasons of compatibility, customization and ease in converting to other languages. The authors and students of Survey Science have also developed programs in BASIC and for the HP-41CV.

A paper (Craymer and Gunn [1984]) giving the necessary algorithms for programming azimuth determinations for the sun and polaris may be obtained by writing to Survey Science, Erindale College, University of Toronto in Mississauga, Mississauga, Ontario L5L 1C6. •

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