Precision Sun Ephemeris

This MATLAB function computes a true-of-date geocentric ephemeris of the Sun based on the data and numerical methods described in the book, *Planetary Programs and Tables* by Pierre Bretagnon and Jean-Louis Simon. This book is available from Willmann-Bell at www.willbell.com.

The fundamental time argument of this method is the number of days relative to the Julian epoch January 1, 2000 normalized with respect to 3652500 Julian days. This value can be calculated for any Julian Ephemeris Date *JED* with the following expression

$$U = \frac{JED - 2451545}{3652500}$$

The geocentric, ecliptic *mean* longitude of the Sun is calculated with a trigonometric series of the form

$$\lambda_s^m = \lambda_0 + \lambda_1 U + \sum_{i=1}^{50} l_i \sin\left(\alpha_i + \nu_i U\right)$$

The geocentric distance of the Sun is calculated with another series of the form

$$r_s = r_0 + r_1 U + \sum_{i=1}^{50} r_i \cos\left(\alpha_i + \nu_i U\right)$$

The longitude of the Sun is corrected for the effect of *aberration* (in radians) with the following equation:

$$\Delta\lambda_s^a = 10^{-7}\left\{-993 + 17\cos\left(3.10 + 62830.14U\right)\right\}$$

The nutation in longitude (in radians) is calculated from

$$\Delta\psi = 10^{-7}\left(-834\sin A_1 - 64\sin A_2\right)$$

where

$$A_1 = 2.18 - 3375.70U + 0.36U^2$$
$$A_2 = 3.51 + 125666.39U + 0.10U^2$$

The apparent, geocentric ecliptic longitude of the Sun is determined as the combination of these three components with the next equation

$$\lambda_s = \lambda_s^m + \Delta\lambda_s^a + \Delta\psi$$

The three components of the geocentric, ecliptic position vector of the Sun are given by

$$x_s = r_s \cos\lambda_s$$
$$y_s = r_s \sin\lambda_s$$
$$z_s = 0$$

The apparent geocentric, equatorial right ascension α_s and declination δ_s of the Sun can be found from

$$\alpha_s = \tan^{-1}\left(\cos\lambda_s, \sin\varepsilon\sin\lambda_s\right)$$
$$\delta_s = \sin^{-1}\left(\sin\varepsilon\sin\lambda_s\right)$$

where ε is the true obliquity of the ecliptic. This number is calculated from the mean obliquity of the ecliptic ε_m and the nutation in obliquity $\Delta\varepsilon$ in this function with the following expressions:

$$\varepsilon = \varepsilon_m + \Delta\varepsilon$$
$$\varepsilon_m = 10^{-7}\left(4090928 + 446\cos A_1 + 28\cos A_2\right)$$
$$\Delta\varepsilon = 10^{-7}U\left(-226938 + U\left(-75 + U\left(96926 + U\left(-2491 - 12104U\right)\right)\right)\right)$$

Finally, we can compute the three components of the *apparent*, geocentric equatorial position vector of the Sun with the following three expressions:

$$r_x = r\cos\alpha_s\cos\delta_s$$
$$r_y = r\sin\alpha_s\cos\delta_s$$
$$r_z = r\sin\delta_s$$

where r is the geocentric distance of the Sun.

This function requires initialization the first time it is called. The following statement in the main MATLAB script will accomplish this:

```
suncoef = 1;
```

This variable should also be placed in a `global` statement at the beginning of the main script that calls this function.

The syntax of this MATLAB function is

```
function [rasc, decl, rsun] = sun2 (jdate)

% precision ephemeris of the Sun

% input

%  jdate = julian ephemeris date

% output

%  rasc = right ascension of the Sun (radians)
%         (0 <= rasc <= 2 pi)
%  decl = declination of the Sun (radians)
%         (-pi/2 <= decl <= pi/2)
%  rsun = eci position vector of the Sun (km)
```

This software suite includes a script called `demo_sun2.m` that demonstrates how to interact with this MATLAB function. The following is a typical user interaction with this script.

```
demo_sun2 - precision sun ephemeris

please input the calendar date
(1 <= month <= 12, 1 <= day <= 31, year = all digits!)
? 11,12,2012

please input the ephemeris time
(0 <= hours <= 24, 0 <= minutes <= 60, 0 <= seconds <= 60)
? 10,30,30
```

The following is the screen display for this example.

```
calendar date        12-Nov-2012

ephemeris time       10:30:30.000

right ascension      +15h 12m 1.8633s

declination          -17d 51m 29.13s

geocentric position vector and magnitude (kilometers)

rx    -94283839.07641500
ry    -104741350.27591196
rz    -45404118.00434278

rmag  148059875.38952234
```