Second Level of the Astronomical Calculations in GCAL

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Algorithms for calculation of tithi, naksatra etc are given in this document. All descriptions are given "as they are" in application, that means this document does not aim to define calculation algorithms for values like tithi, naksatra etc. rather it describes how these algorithms are implemented.

This documents is for certification of algorithms used in GCAL program.

Content

Mathematical operations

/	divide
*	multiple
floor	returns whole of part of real number
rmdr	return remainder after subtraction of whole part of number
put_in_360	puts given angle into range 0..360 degrees or equivalent 0..2*PI

Calculation of Tithi

input values:

m – tropical longitude of the Moon /real number/
s – tropical longitude of the Sun /real number/

output value:

tithi – number of tithi /integer/
tithi_elapsed – amount of elapsed time from tithi (in percents) /real number/

```
tithi = floor ( put_in_360(m – s – 180.0) / 12.0 )

tithi_elapsed = rmdr( put_in_360(m – s – 180.0) / 12.0 ) * 100.0
```

Paksa

input value:
tithi – moon's tithi /integer/

output value:
paksa – moon's paksa /integer/

value 0 is for Krsna Paksa
value 1 is for Gaura Paksa

```
paksa = floor( tithi / 15)
```

Naksatra

input values:
m – tropical longitude of the moon /real number/
a – ayanamsa value calculated for the same moment as longitude of the moon /real number/

output values:
naksatra – number of naksatra /integer/
naksatra_elapsed – elapsation of naksatra /real number/

We need convert range <0,360) to range <0,27). Therefore constant 3/40.0 is used.

naksatra_pos = (sidereal_moon_pos) * (3 / 40.0)
in other symbols:

```
naksatra_pos = put_in_360(m – a) * (3 / 40.0)



naksatra = floor( naksatra_pos )

naksatra_elapsed = rmdr ( naksatra_pos ) * 100.0
```

naksatra value 0 is for Asvini, value 26 is for Revati

Yoga

input values:
m – tropical longitude of the moon /real number/
s – tropical longitude of the Sun /real number/
a – ayanamsa value calculated for the same moment as longitude of the moon /real number/

output value:

yoga – number of yoga /integer/

yoga_pos = (sidereal_moon_pos + sidereal_sun_pos) * (3/40.0)
in other symbols:

yoga_pos = ((m – a) + (s – a)) * (3/40.0) = put_in_360(m + s – 2*a) * (3/40.0)

yoga = floor(yoga_pos)

Yoga value 0 is for Viskumba, value 26 is for Vaidhrti.

Rasi

input values:

s – tropical longitude of the Sun /real number/
a – ayanamsa value calculated for the same moment as longitude of the moon /real number/

output value:

rasi – integer number of rasi for sun in given position

sidereal_sun_pos equals **(s – a)**

rasi = floor (put_in_360(s – a) / 30.0)

rasi value 0 is for Mesa (Aries), value 11 is for Mina (Pisces)

Sankranti

Sankranti calculation is based on rasi.

1) If rasi is changing from one day (day1) to next day (day2), then exact time of change of rasi is calculated.

2a) If calculated time of sankranti is **before** noon for day1 for given location, then sankranti is mentioned in day1.

2b) If calculated time of sankranti is **after** noon for day1, then sankranti is mentioned in day2.

Masa

input values:

date – day, month, year
time of sunrise
tithi for given date

output values:

masa – calculated masa for given day
gyear – gaurabda year

Now we will calculate conjunctions of sun and moon, that is moment when sun and moon have the same longitude, in other words Gaura Pratipat Tithi begins.

Let us say that t1 is moment of sunrise for given day. Then we will calculate four previous conjunctions and two next conjunctions.

Ordered by time, we have values c0, c1, t1, c2, c3, c4, c5 where c0 < c1 < c2 < c3 < t1 < c4 < c5

step 1

We will calculate sun rasi for each conjuction and we get values rasi0, rasi1, rasi2 ... rasi5. We are not calculating rasi for t1 (sunrise of given date) since we dont need it.

For normal months, we will find [rasi(n+1)] equals [rasi(n)+1 modulo 12].

For adhika (extra) months, we will find [rasi(n+1)] equals [rasi(n) modulo 12].

For ksaya ("destroyed") months, we will find [rasi(n+1)] equals [rasi(n)+2 modulo 12].

We first look for any ksaya month within values c0...c5.

If we have found an index k such that [(rasi(k-1)+2) modulo 12] equals rasi(k)
then we need to look for a subsequent adhika masa.

If we have found an index ke, with ke >= k, such that rasi(ke+1) equals rasi(ke)
then the range of months to be corrected is from k up to ke
otherwise the range to be corrected is from k up to 5.

For each month in the range to be corrected we will decrement the rasi number by 1.

If we have found no such index k, then skip to test 2.

see examples below for step1 effect.

step 2 is performing evaluation for masa. Following is decision table which reads from top to bottom and is similar to decision tree.

<table>
<tr><td colspan="3">if rasi(3) equals rasi(4)
... note that time t1 is between rasi(3) and rasi(4) moments</td></tr>
<tr><td>yes, equals</td><td colspan="2">no, rasis are different</td></tr>
<tr><td rowspan="3">t1 belongs to adhika masa</td><td colspan="2">t1 does not belong to adhika masa</td></tr>
<tr><td>paksa is krsna</td><td>paksa is gaura</td></tr>
<tr><td>t1 belongs to masa according rasi(4), which is the next conjunction rasi</td><td>t1 belongs to masa according rasi(3), which is the previous conjunction rasi</td></tr>
<tr><td>rasi_g (see step 3 below) is set to rasi(3)</td><td>rasi_g set to rasi(4)</td><td>rasi_g set to rasi(3)</td></tr>
</table>

To determine the month:

Rasi	Month
Mina	Visnu
Mesa	Madhusudana
Vrsabha	Trivikrama
Mithuna	Vamana
Karka	Sridhara
Simha	Hrsikesa
Kanya	Padmanadbha
Tula	Damodara
Vrscika	Kesava
Dhanus	Narayana
Makara	Madhava
Kumbha	Govinda

step 3

After calculation of masa, we will calculate gaurabda year.

Basic formula is

GYprep = Gregorian Calendar Year – 1486

But this is not true for time interval from 1st January to Gaura Purnima. In that interval is valid formula GYprep = Year – 1487.

So test for Gaurabda Year is:

if masa_g is in the interval from Kesava to Govinda (that means before Gaura Purnima)and at the same time Gregorian month of given date is from interval January to June

then GaurabdaYear = GYprep – 1

otherwise GaurabdaYear = GYprep

Examples

Four Examples for STEP 1 of masa calculation algorithm.

Table 1 shows sequence of rasis for six consecutive conjunctions of the sun and the moon.

actual sequence						sequence to be used					
c0	c1	c2	c3	c4	c5	c0	c1	c2	c3	c4	c5
aries	aries	taurus	gemini	cancer	leo	aries	aries	taurus	gemini	cancer	leo
aries	aries	gemini	cancer	cancer	leo	aries	aries	taurus	gemini	cancer	leo
aries	aries	gemini	cancer	leo	leo	aries	aries	taurus	gemini	cancer	leo
aries	taurus	taurus	gemini	leo	leo	aries	taurus	taurus	gemini	cancer	leo
taurus	cancer	leo	virgo	virgo	libra	taurus	gemini	cancer	leo	virgo	libra

normal sequence is aries – taurus – gemini – cancer – leo – virgo – libra – ...

Table 2 gives representation of previous sequences given by ksaya/adhika notation:

actual sequence						sequence that will appear					
aries	**taurus**	**gemini**	**cancer**	**leo**	**virgo**	**aries**	**taurus**	**gemini**	**cancer**	**leo**	**virgo**
adhika	normal	normal	normal	normal	-	adhika	normal	normal	normal	normal	-
adhika	ksaya	normal	adhika	normal	-	adhika	normal	normal	normal	normal	-
adhika	ksaya	normal	normal	adhika	-	adhika	normal	normal	normal	normal	-
normal	adhika	normal	ksaya	adhika	-	normal	adhika	normal	normal	normal	-
-	normal	ksaya	normal	normal	adhika	-	normal	normal	normal	normal	normal

Table 3) STEP 1 is, in general, handling these cases of ksaya-adhika sequences:

Case	Sequence	No. of changes in rasi	No. of changes in masa
1	adhika-ksaya-adhika	1	2
2	adhika-normal-ksaya-adhika	1	2
3	adhika-ksaya-normal-adhika	2	3
4	adhika-normal-normal-ksaya-adhika	1	2
5	adhika-normal-ksaya-normal-adhika	2	3
6	adhika-ksaya-normal-normal-adhika	3	4

No adjustment of months is required BEFORE the ksaya month, only after.

Algorithm does not handle single ksaya month, since a ksaya month will be followed by an adhika month within a maximum of 3 months' time.

Revision History

Date	Description
May 2, 2008	Initial version.
May 9, 2008	Corrections of few small errors.
June 7, 2008	Changed algorithm for masa calculation.
June 9, 2008	Changed few words in description of the masa calculation. Changed title of this text.
June 20, 2008	Changed description of masa calculation. Added rasi/masa table.