Position Change of the Moon to showing the Lunar Mansion's Pattern

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Abstract. This research was conducted to find out the pattern of the lunar mansions from the position change of the Moon. These positions were called as the lunar mansions. The lunar mansions have 27 groups with important 27 fixed stars. The Moon's position was calculated from nearby stars by cosine formula. The smallest angular separation between the Moon and the fixed stars was the lunar mansion of the day. The graph relates with the date from 2011-2030 and the lunar mansions was showed the lunar mansion's pattern. It was found that the lunar mansion's pattern was a linear equation as $M = (0.9882x + 15.4192) \pm 0.6910$.

1. Introduction

The period of the Moon has two types, synodic period and sidereal period. The positions of the Moon on each nightfall were compared by nearby apparent fixed stars. These positions were called, Lunar mansions. The lunar mansions have 27 groups [1]. The extent of the lunar mansions was assigned by Right Ascension of the fixed stars according to each lunar mansion on the sky [2]. These stars have 27 stars such as in table 1.

Table 1. Lunar Mansions and Modern Stars [2].

Lunar Mansions	Star Names	Lunar Mansions	Star Names	Lunar Mansions	Star Names
1. *Asvini*	β-Ari	11. *Phalguni*	δ-Leo	21. *U.Asadha*	ζ-Sgr
2. *Bharani*	35-Ari	12. *U.Phalguni*	β-Leo	22. *Sravana*	α-Aql
3. *Krittika*	η-Tau	13. *Hasta*	δ-Crv	23. *Dhanistha*	β-Del
4. *Rhohini*	α-Tau	14. *Citra*	α-Vir	24. *Satabhisa*	λ-Aqr
5. *Mrgasira*	λ-Ori	15. *Svati*	α-Boo	25. *Bhadrapada*	α-Peg
6. *Ardra*	α-Ori	16. *Visakha*	α-Lib	26. *U.Bhadrapada*	γ-Peg
7. *Punarvasu*	β-Gem	17. *Anuradha*	δ-Sco	27. *Revati*	ζ-Psc
8. *Pusya*	δ-Cnc	18. *Jyestha*	α-Sco		
9. *Aslesa*	ε-Hya	19. *Mula*	λ-Sco		
10. *Magha*	α-Leo	20. *Asadha*	σ-Sgr		

An importance of the lunar mansions, the days of full moon in some lunar mansions were assigned to the Buddhist holy days such as *Magha Puja*, *Visakha Puja* and *Asadha Puja* [3]. It was found that the position of full moon may not match with the Buddhist holy days on the Thai Lunar calendar [2].

2. Searching to the Lunar Mansions

The daily positions of the Moon during 2011-2030 were the principal data of this research. We obtained the coordinate of the Moon at Bangkok (100°28′59.9″ E, 13°19′59.9″ N at 00:00 UT) from http:// ssd.jpl.nasa.gov/horizons.cgi and the coordinate of the fixed stars from http://simbad.u-strasbg.fr/simbad/. The position of the Moon and 27 fixed stars in each day, a smallest angular separation between the Moon and the fixed stars was imposed as the lunar mansion of the day. It was calculated by the cosine formula of spherical triangle [4] as

$$\cos \overline{AB} = (\cos \overline{AP} \times \cos \overline{BP}) + (\sin \overline{AP} \times \sin \overline{BP} \times \cos \angle APB) \tag{1}$$

and $\overline{AP} = 90° - \delta_A$, $\overline{BP} = 90° - \delta_B$ and $\angle APB = \alpha_B - \alpha_A$. Let A and B are the position of the Moon and the fixed stars respectively. P is the north celestial pole. δ is the Declination and α is the Right Ascension.

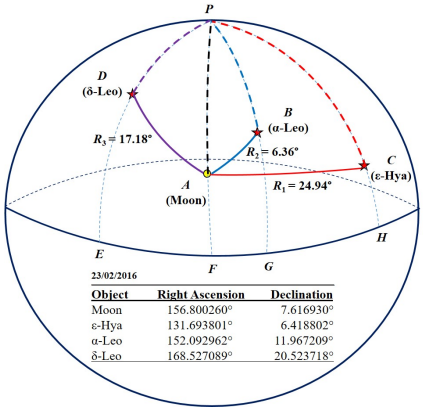

Figure 1. Nearby apparent stars of the Moon on 23rd February 2016, α-Leo is the smallest angular separation.

Figure 2 presents the example of three apparent stars that nearby the Moon on 23rd February 2016. Let R is an angular separation and A is the Moon's position. C, B and D are the position of the nearby apparent stars, ε-Hya, α-Leo and δ-Leo respectively. E, F, G and H are the position of the star on great circle (spherical equator). The nearest angular separation is calculated as

The angular separation between the Moon and ε-Hya.

$AP = 90° - 7.616930° = 82.383070°$
$CP = 90° - 6.418802° = 83.581198°$
$\angle APC = 156.800260° - 131.693801° = 25.106459°$
$\cos R_1 = (\cos AP \times \cos CP) + (\sin AP \times \sin CP \times \cos \angle APC)$
$\cos R_1 = (\cos 82.38° \times \cos 83.58°) + (\sin 82.38° \times \sin 83.58° \times \cos 25.11°)$
$\therefore R_1 = 24.943646°$

The angular separation between the Moon and α-Leo.

$AP = 90° - 7.616930° = 82.383070°$
$BP = 90° - 11.967209° = 78.032791°$
$\angle APB = 156.800260° - 152.092962° = 4.707298°$
$\cos R_2 = (\cos AP \times \cos BP) + (\sin AP \times \sin BP \times \cos \angle APB)$
$\cos R_2 = (\cos 82.38° \times \cos 78.03°) + (\sin 82.38° \times \sin 78.03° \times \cos 4.71°)$
$\therefore R_2 = 6.358540°$

The angular separation between the Moon and δ-Leo.

$AP = 90° - 7.616930° = 82.383070°$

$DP = 90° - 20.523718° = 69.476282°$

$\angle APD = 156.800260° - 168.527089° = -11.726829°$

$\cos R_3 = (\cos AP \times \cos DP) + (\sin AP \times \sin DP \times \cos \angle APD)$

$\cos R_3 = (\cos 82.38° \times \cos 69.48°) + (\sin 82.38° \times \sin 69.48° \times \cos -11.73°)$

$\therefore R_3 = 17.184217°$

3. Finding of the Lunar Mansion's Pattern

A smallest angular separation of the Moon with the fixed stars was the lunar mansion of the day. The relation between the lunar mansions and the number of the day (Date) was presented the lunar mansion's pattern.

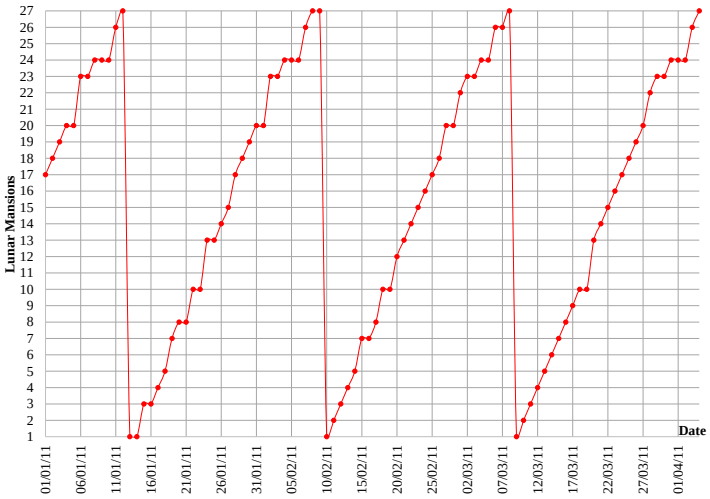

Figure 2. The example of the graph between the lunar mansion and the date since 1st January to 4th April 2011.

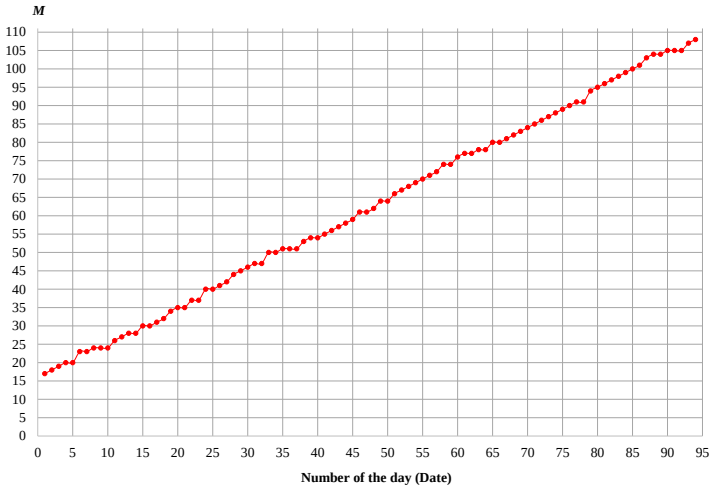

Figure 3. The continuous graph of the lunar mansions in each day.

Figure 2 is a plot between the lunar mansion and the date, starting from 1st January 2011. It has four datasets. Each dataset is the sequence of the lunar mansions from 1 (*Asvini*) to 27 (*Revati*). Datasets were adjusted to one dataset for easier analysis as in figure 3. The continuous graph was related by $M = L + (27 \times n)$ and the number of the day. Let L is the sequences of the lunar mansions, 27 is a number of the lunar mansions and n is the number of sidereal period of the Moon start from 0, 1, 2,..., n (integer). For example, the lunar mansion on 12th January 2011 is 27 (*Revati*), $L = 27$ and $n = 0$ (first period of the Moon). So, M is $27 + (27 \times 0) = 27$. The lunar mansion on 13th January 2011 is 1 (*Asvini*), $L = 1$ and $n = 1$. So, M is $1 + (27 \times 1) = 28$.

4. Result and Discussion

The position change of the Moon was compared with the position of the fixed stars, shows lunar mansions. The continuous graph between the lunar mansions by M and the number of the day throughout 20 years was showed the lunar mansion's pattern as

$$M = (0.9882x + 15.4192) \pm 0.6910. \quad (2)$$

Equation 2 is a linear equation when x is the number of the day, 0.9882 is a slope and 15.4192 is the interception of y axis. While a deviation error of an equation, $\pm$ 0.6910, was calculated from the Root Mean Square Error (RMSE) [5].

5. Conclusion and Further Work

The lunar mansion of the day was the smallest angular separation between the Moon and nearby apparent stars. The relation between M and the number of the day was indicated the lunar mansion's pattern. Hence, if we know the lunar mansion, we can adjust the rule in lunar calendar to match with the phenomena of the Moon.

In the future, we will improve the equation of lunar mansion's pattern to search the lunar mansion of the day instead of the formula of angular separation. After that, we have a plan to make the lunar calendar from the Moon's position related with the Moon's phase.

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