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DEVELOPMENT OF A PYTHON-BASED POSITION CALCULATION SYSTEM FOR THE MOON'S VISIBLE POSITION IN EQUATORIAL COORDINATES

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Abstract :
In the field of astronomy, it is important to know the position of the moon in equatorial coordinates. However, these calculations can be difficult to do manually. Therefore, a system for calculating the visible position of the moon in Python-based equatorial coordinates has been developed. This system uses a suitable algorithm to calculate the visible position of the moon in equatorial coordinates. The calculation results obtained from this system are then compared with the simulation results from the Stellarium software. System for calculating the visible position of the moon in equatorial coordinates with PythonRA values (alpha): 11h21m36.9s and declination (delta): 8° 28' 23" while the results from the Stellarium software simulation at the same time are RA (alpha): 11h18m0.33s and declination (delta): 8° 25' 18.2".The results of the comparison show that the system for calculating the visible position of the moon in Python-based equatorial coordinates has a difference in RA of 0h3m36s and declination of 0°3'4.8" from the Stellarium simulation. The error value for the comparison of python calculations with Stellarium is RA = 2% and Declination = 0.6%. This shows that the use of python can simplify calculations with difficult algorithms and the results obtained are quite accurate. Thus, this Python-based system for calculating the visible position of the moon in equatorial coordinates can be used as a tool in the field of astronomy.

Keywords: Equatorial, Position of the Moon, Python, Stellarium

INTRODUCTION

Astronomy is the science that studies or observes celestial bodies outside the Earth's atmosphere such as stars, planets, satellites, meteors, asteroids, and other phenomena that occur (Djamaluddin, 2011). Observation of stars and celestial bodies has been done since ancient times. The things studied include origins, physical properties, chemistry, mathematics, biology, and others (Akbar, 2017; Budiwati, 2019). The moon is one of the celestial objects closest to the earth and also a natural satellite of the earth. In the era of increasingly advanced technology, determining the visible position of the moon plays an important role in various fields, such as astronomy, navigation and environmental monitoring. Accurate information regarding the visible position of the moon is needed in observing and analyzing these areas (Djamaluddin, 2011). This needs to be done because of a misconception of lunar geometry calculations such as phases in the concept of lunar periods (Mulyadi, 2018; Ridhallah, 2020). The motion of celestial objects forms lines and angles that change at any time must be calculated with good geometry (N. Azmi & Ukhti, 2023).

It also helps in computational understanding, one of which is about algorithms (Susilayati et al., 2007). To simplify the process of calculating the visible position of the moon (Musfiroh & Hendri, 2018), a system for calculating the position of the moon based on Python has been developed (Ferrara, 2008). This system utilizes equatorial coordinates as a reference for calculating the visible position of the moon at a certain point in time. The use of the Python programming language allows this system to be developed easily and can be accessed by various users with various levels of ability (Pujani, 2014).

Python has many math libraries that can be used to perform the necessary calculations (Taruna & Prakoso, 2017). Apart from that, Python also has the ability to visualize the results of these calculations, so that it can help in visually understanding the position of the Moon (Standish & Williams, 2006). Python is distributed under several different licenses from several versions. However, in principle python can be obtained and used freely (Melinda et al., 2021). In this study, Jean Meeus' algorithm was used , which is a calculation based on the movement of the position of celestial bodies such as the sun and moon with a high level of accuracy from thousands of corrections (Andini et al., 2023). This research was helped by Python can be a useful programming language for calculating the position of the Moon (Mustari, 2015). In addition, this system will also be tested and compared with the simulation results from the Stellarium software as a reference for evaluating the accuracy of the calculation results. Where stellarium is an open source planetarium and can also show the validity of the presentation of the position of celestial object (Siti Anisa Hidayati & Yushardi, 2023).

RESEARCH METHOD

The waterfall method was chosen for the development of the lunar position calculation system because the project has a structured and stable nature, with requirements that have been clearly identified from the beginning (Maulana et al., 2023; Nur, 2019). Clarity regarding requirements, complexity of astronomical calculations, and the need for high precision in results make this sequential model suitable for ensuring every stage, such as requirements analysis, design, Code generation, and testing, can be meticulously completed before moving on to the next stage . The waterfall model is development process commonly used in software projects. Because this model has a flowing process or one stage to another (Budi, 2021)

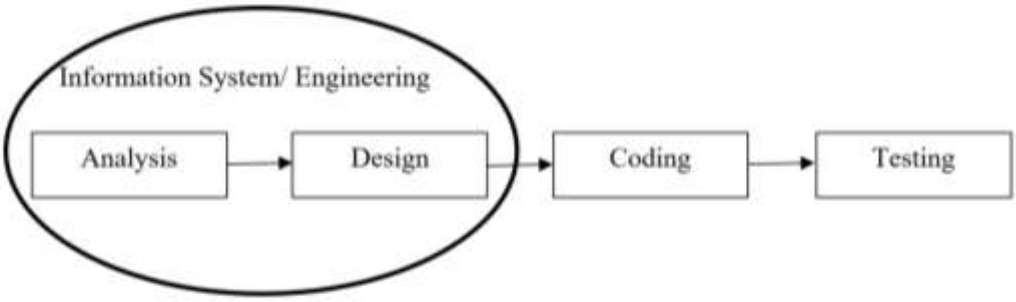


Figure 1. Waterfall Model illustration

The waterfall model provides a sequential software life-flow approach starting from the analysis, design, coding, testing, and support stages.

a. Requirements analysis: specifying python requirements according to what is required by the user in calculating the position of the Moon (Bachtiar, 2013).
b. Design: the calculation of the position of the Moon refers to Jean Meeus's book which will be processed into a coding program (Taruna & Prakoso, 2017)
c. Generating program code: entering all equations for calculating the position of the Moon with equatorial coordinates and obtaining the final results in the form of RA and Declination (Schwarz et al., 2021).
d. Testing: Calculation data will be processed by the program (input data in Julian days and output data in the form of moon position). By matching the calculation results in the program against the

reference book and comparing the results in the program with the results in the Stellarium software (Bachtiar, 2013).

Calculation of the position of the moon with reference to the coordinates used. In this study using equatorial coordinates (Right Ascension and Declination) (Siagian et al., 2023). The main step for calculating the position of the Moon is to calculate the time consisting of the date, month, and year. By converting that time to Julian Day which is the time used in astronomy (Kurniawan & Riyadi, 2021). To calculate the time in years of julian day (J) the formula is used:

$$T = \frac{J}{36525} \tag{1}$$

With T (time), J (Julian day), and uses the constant 36525, which is the number of days on 1st century Julian Day. Furthermore, to determine the visible position of the Moon at equatorial coordinates using Julian Day used the formula (Nursodik, 2018)

$$L' = 2,18 \times 10^2 + 4,81 \times 10^5 T - 1,32 \times 10^{-3} T^2 + \frac{T^3}{5.38 \times 10^5} - \frac{T^4}{6,51 \times 10^7} \tag{2}$$

Where L' is the lunar longitude and T is the julian day time

$$D = 2,97 \times 10^2 + 4,45 \times 10^2 T - 1.63 \times 10^{-3} T^2 + \frac{T^3}{5.45 \times 10^5} - \frac{T^4}{1,13 \times 10^8} \tag{3}$$

Where D is the mean elongation of the Moon

$$M = 3,5 \times 10^2 + 3,59 \times 10^4 T - 1,53 \times 10^{-4} T^2 + \frac{T^3}{2,45 \times 10^7} \tag{4}$$

Where M is the average anomaly of the sun

$$M' = 1,35 \times 10^2 + 4,77 \times 10^5 T + 8,99 \times 10^{-3} T^2 + \frac{T^3}{6,97 \times 10^4} - \frac{T^4}{1,47 \times 10^7} \tag{5}$$

Where M' is the average anomaly of the Moon

$$F = 9,32 \times 10^1 + 4,83 \times 10^5 T - 3,40 \times 10^{-3} T^2 - \frac{T^3}{3,52 \times 10^6} + \frac{T^4}{8,63 \times 10^8} \tag{6}$$

Where F is the argument lunar longitude (the mean distance of the Moon calculated from the point of intersection of the moon's trajectory with the ecliptic).

$$A1 = 1,19 \times 10^2 + 1,32 \times 10^2 T \tag{7}$$
$$A2 = 5,31 \times 10^1 + 4,79 \times 10^5 T \tag{8}$$
$$A3 = 3,13 \times 10^2 + 4,81 \times 10^5 T \tag{9}$$

Where A1, A2, and A3 are additional arguments for correction

$$E = 1 - 2,51 \times 10^{-3} T - 7,4 \times 10^{-6} T^2 \tag{10}$$

Where E is the eccentricity of Earth's orbit

$$\Sigma \mathrm{l} = 3,96 \times 10^3 \sin A1 + 1,96 \times 10^3 \sin(L' - F) + 318 \sin A2 \tag{11}$$
$$\Sigma \mathrm{b} = -2,23 \times 10^3 \sin L' + 3,82 \times 10^2 \sin A3 + 1,75 \times 10^2 \sin(A1 - F) + 1,75 \times 10^2 \sin(A1 + F) + 1,27 \times 10^2 \sin(L' - M') - 1,15 \times 10^2 \sin(L' + M') \tag{12}$$
$$\lambda = \mathrm{L}' + \frac{\Sigma \mathrm{l}}{1 \times 10^6} \tag{13}$$
$$\beta = \frac{\Sigma \mathrm{b}}{1 \times 10^6} \tag{14}$$
$$\Delta = 3,85 \times 10^5 + \frac{\Sigma \mathrm{r}}{1 \times 10^3} \tag{15}$$
$$\varepsilon = \varepsilon_0 + \Delta\varepsilon \tag{16}$$
$$\alpha = \arctan\left[\frac{\sin\lambda \cos\varepsilon - \tan\beta \sin\varepsilon}{\cos\lambda}\right] \tag{17}$$
$$\delta = arcsin[\sin\beta \cos\varepsilon + \cos\beta \sin\varepsilon \sin\lambda] \tag{18}$$

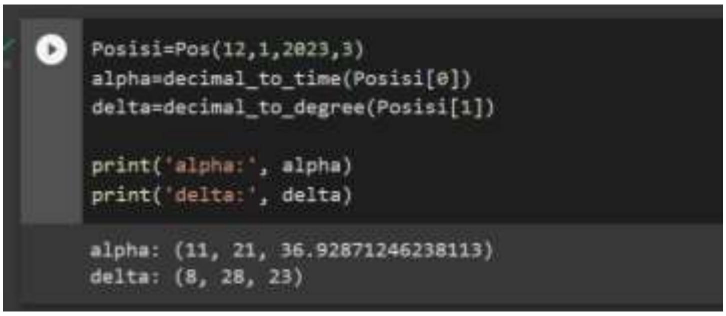
With λ (Lunar Longitude), β (Moon Latitude Correction), α (Right Lunar Ascension), and δ (Moon Declination). Calculations must be detailed and accurate so that errors do not occur. In stage (d) the test is carried out by calculating the reference error with equation (19). By getting the difference in error values, researchers can find out or analyze the quality of the program made.

$$Z = \left|\frac{X-Y}{Y}\right| 100\% \tag{19}$$

With discrepancies (Z) between experimental measurements X and other measurements (usually theoretical or standard measurements) Y. Deficiencies can be read when calculations show inaccurate results. With reference values obtained from stellarium software (Khusnani et al., 2022).

RESULTS AND DISCUSSION

Calculations with equatorial coordinates, namely using RA that is, an arc along the equatorial circle calculated from the point of Aries eastward to the point of intersection between the equatorial circle and the circle of declination through the celestial body (Muthmainnah, 2015; Nurmila, 2017; Mutmainnah, 2021;Khusnani et al., 2022; Diana et al., 2023;). And also and declination which is the distance of a celestial body to the celestial equator (Kamalludin, 2019) data as the position of the celestial object (moon). By taking an example on January 12, 2023 at 10.00 WIB. Calculation values obtained using python RA (alpha): 11h 21m 36,9s and Declination (delta): 8° 28' 23”



```
Posisi=Pos(12,1,2023,3)
alpha=decimal_to_time(Posisi[0])
delta=decimal_to_degree(Posisi[1])

print('alpha:', alpha)
print('delta:', delta)

alpha: (11, 21, 36.92871246238113)
delta: (8, 28, 23)
```

Figure 2. Calculation in Python

With Position variables containing date, month, year, hour. For hours on Julian Day, it must be changed to UT (Universal Time). While the results from the Stellarium software simulation at the same time are RA (alpha): 11h18m0.33s and Declination (delta): 8° 25' 18,2”

Moon
Type: moon
Magnitude: -11.75
Absolute Magnitude: 0.21
Mean Opposition Magnitude: -12.74
RA/Dec (J2000.0): 11h16m47.98s/+8°32'54.5"
RA/Dec (on date): 11h18m00.33s/+8°25'18.2"
HA/Dec: 5h42m04.83s/+8°25'18.2"
Az./Alt.: +278°09'22.2"/+4°56'56.5"

Figure 5. Stellarium Simulation

The results of the calculation have a difference between RA: 0h3m36s and Declination: 0°3'4.8”. there is a difference in the calculation comparison because the Jean Meeus algorithm for calculating the position of celestial objects uses a Geocentric reference frame at the center of the earth while Stellarium uses a Topocentric (Observer) reference frame (Moore & Series, 2008). Further research can expand its scope to explore other aspects that can affect the calculation of the position of celestial objects (Schwarz et al., 2021). The use of python in the calculation of the position of the Moon in astronomical geometry provides advantages through ease of programming with friendly syntax, flexibility and portability across platforms, and simplifies the calculation and visualization of results, providing an optimal environment for complex tasks in astronomy (Khusnani et al., 2022) In the development of this research, differences in calculation results emerged with Geocentric and Toposcentric models. It's just that the algorithm is too complex in calculating the position of the Moon, it takes resources and computing time long enough.

CONCLUSION

System for calculating the visible position of the moon in equatorial coordinates with PythonRA values (alpha): 11h21m36.9s and declination (delta): 8° 28' 23” while the results from the Stellarium software simulation at the same time are RA (alpha): 11h 18m 0.33s and declination (delta): 8° 25' 18.2”. So that calculations in Pythonhave a differenceRA: 0h 3m 36s and Declination: 0°3'4.8” for Stellarium simulation. The error value for the comparison of python calculations with Stellarium is RA = 2% and Declination = 0.6%.This shows that using python can simplify calculations with difficult algorithms (M. F. Azmi et al., 2018).

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