The Simulation of Comet Orbit in Solar System

Mr. Nattawat Chaitong (Grade 11)
[Prommanusorn Phetchaburi School, Phetchaburi, Thailand]

Abstract

In observing objects in the sky, the observer can determine the coordinates of that object, but could not know the orbit. The author is impressed by comet motion. As a result, the goal of this project is to develop a comet motion model using Python 3 programming and Euler's method to calculate comet movements, utilizing celestial equator velocity and coordinates of the comet as initial values, and then test the discrepancy. By using Comets as follow: Tempel 1, Holmes, and Ancke to test the model, which has an error of the eccentricity of 54.2%, 54.4%, and 68.7% respectively in comparison to the reference source, the results demonstrated that the model can be used to simulate comet motion. The errors in this simulation were brought on by the fact that the created model did not take Jovian planets into account.

Research background

Ice-covered space objects known as comets are thought to have their origins at the solar system's periphery. The comet becomes heated as it gets closer to the Sun, which causes the ice to vaporize from the sun and become the head and tail that are visible. Because comets' orbits differ from planets', they are more fascinating. A common numerical approach for estimating model solutions to different problems is the Euler's method. As a result, the researcher is interested in simulating comet motion using Python and Euler's method as a computer programming language.

Method

1. Programming a simulation with Python 3 in Visual Studio Code using libraries which includes
   1.1 NumPy, it is used as an arithmetic operator, and
   1.2 Matplotlib, it is used to plot graphs.
2. Determine the variables in the calculation by using the coordinates and velocity of the object solar system and the comet on January 1, 2021, from database of JPL's HORIZON respectively.
3. Create functions and equations used in calculation by using the following formulas and equations:
   3.1 Equations used to convert Horizontal coordinate to Cartesian coordinate.

$$\mathrm{X} = d \cdot \cos(\delta) \cdot \cos(\alpha) \quad (1)$$
$$Y = d \cdot \cos(\delta) \cdot \sin(\alpha) \quad (2)$$
$$Z = d \cdot \sin(\delta) \quad (3)$$

   Where X, Y and Z is the values of each axis in Cartesian coordinate.
   δ is declination.
   α is right ascension.

   3.2 Function for calculate acceleration to update the acceleration ($\vec{a}$) velocity ($\vec{v}$) and the change of position ($\vec{r}$) in a period (Δt), using 1 day to update each calculation. As shown in the equations below:

$$\vec{a}(t) = \frac{GM_1M_2}{r^3}\vec{r} \quad (4)$$
$$\vec{v}(t+\Delta t) = \vec{v}(t) + \vec{a}(t)\Delta t \quad (5)$$
$$\vec{r}(t+\Delta t) = \vec{r}(t) + \vec{v}(t+\Delta t)\Delta t \quad (6)$$

4. Simulate model as a 3D simulation.
5. Compare eccentricity from a simulation to database by calculate error percentage, as shown in equation (7)

$$\%Error = \frac{\left|r_{sim} - r_{ref}\right|}{r_{ref}} \times 100\% \quad (7)$$

Summary

As a result of the comet motion modeling study, the motions of comets which are Tempel 1, Holmes, and Encke are shown in Figure 1. The eccentricity in relation to the reference source and the error of the semi-major axis values are displayed in table 1.

Table 1 the comparison of the eccentricity for each comet.

		9P/ Tempel 1	17P/ Holmes	2P/ Encke
eccentricity	Simulation	0.237	0.031	0.283
	Reference	0.519	0.070	0.329
	%Error	54.2	54.4	13.9

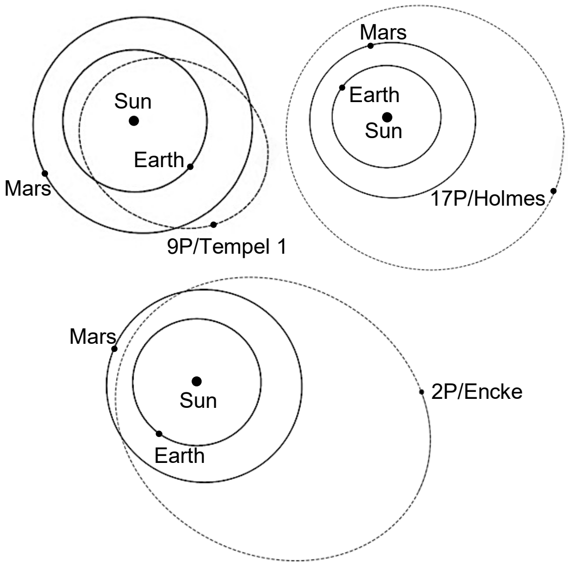

Figure 1 the simulated orbits while the first line represents the Earth's orbit, the second line represents Mars's orbit, and the dashed line refers to comet orbit.

According to the study, Euler's method and created programming in Python 3 can be used to simulate a comet's motion. Due to the created model didn't include Jovian planets, thus, it caused the errors of this simulation.

Acknowledgement

It will take a number of operations to complete this project. The project's planners received support and guidance from numerous sources throughout in a variety of areas. In this regard, I would like to express my gratitude to Mr. Taweerak Tunphuttha, who served as my advisor and offered guidance throughout the project. Finally, I'd like to express my gratitude to the National Astronomical Research Institute (Public Organization) for giving me the chance to conduct this research.

Reference

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