Planetary Orbit Simulator

Lab Report

December 10, 2015

Abstract

I have created a simple Planetary Orbit Simulator using GUI programming in Python 2.7. I have used the TkInter and Turtle packages to create the user interface and draw the orbits, respectively. I have also used matplotlib to plot velocity versus time graphs for the planets.

1 Introduction

1.1 Newton's Law of Gravitation

Newton's Universal Law of Gravitation states that two masses exert an attractive gravitational force on each other along the line joining the objects which is proportional to the product of the masses of the objects and inversely proportional to the square of the distance between them (Figure 1).

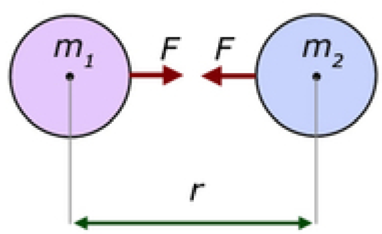

Figure 1: [1] Gravitational force between two masses

That is,

$$F = G\frac{m_1 * m_2}{r^2}$$

where $G = 6.67408 * 10^{-11} m^3 kg^{-1} s^{-2}$

1.2 Drawing Orbits with Euler's Method

I assume that there is a planet of mass m orbiting around the Sun. Therefore, from the previous section, the x and y components for the gravitational force acting on it can be written as $F_x = Fcos\theta$ and $F_y = Fsin\theta$. If M is the mass of the Sun, using Newton's Second Law equation $F = ma$, the acceleration becomes

$$a_x = \frac{GMcos\theta}{r^2}$$

$$a_y = \frac{GMsin\theta}{r^2}$$

But, since $x = rcos\theta$, $y = rsin\theta$ and $r^2 = x^2 + y^2$,

$$a_x = \frac{GMx}{(x^2 + y^2)^{3/2}}$$

$$a_y = \frac{GMy}{(x^2 + y^2)^{3/2}}$$

These two equations determine the path of the planet in its orbit around the Sun. We have to calculate the position of the planet after every time step Δt. Thus, from the Euler's Method, we get

$$x(t + \Delta t) \approx x(t) + v_x(t)\Delta t$$

$$y(t + \Delta t) \approx y(t) + v_y(t)\Delta t$$

We can also define equations with velocity as a function of acceleration-

$$v_x(t + \Delta t) \approx v_x(t) + a_x(t)\Delta t$$

$$v_y(t + \Delta t) \approx v_y(t) + a_y(t)\Delta t$$

Using these equations, I created loops in my program to find positions of planets after each time step and used Turtle to draw dots for them in a grid. Then, using the values for mass, initial velocity and initial position from NASA's website, I was able to generate orbits for Mercury, Venus, Earth and Mars.

2 User Interface

TkInter is used to create the first window (Figure 2). The text is a part of the background picture which I designed separately myself and embedded using PhotoImage. There is an image button which launches the second window and the Turtle animation using a function. There are also two other buttons which open the LaTeX report and quit the program.

In the second window (Figure 3), the legend for the planets and the text is already embedded in the background picture. The buttons use matplotlib to plot the graphs for each planet. I took the velocity values for 100 weeks from the Turtle animation by printing it and put it in numpy arrays. The quit button kills the Turtle animation and the second window.

The third window (Figure 4) is created by defining a new class in Turtle. The Turtle draws dots of different colours representing the orbits of different planets after every time step.

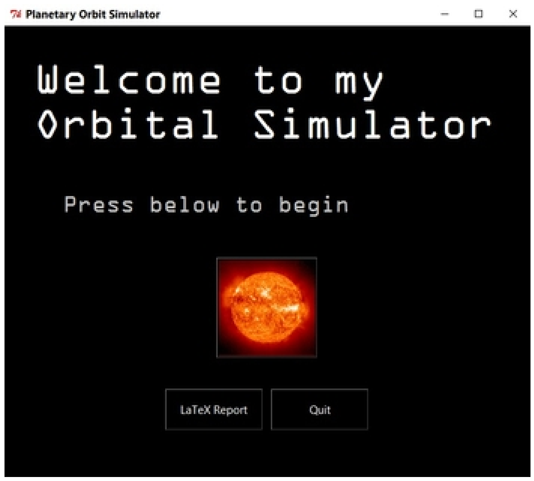

Figure 2: First Window

3 Observations and Conclusions

- I obtained circular orbits for all four planets. As the number of time steps increased, the orbits got more and more distorted. This can be attributed to my approximations with the Euler's Method because of which each revolution gave an orbit a little different from the previous one.

- Mercury's orbit was the least accurate and stopped looking like a circle just after a few revolutions. The reason for this can be that because of a smaller orbit, the effects produced by approximation errors were more profound. Also, since it is so close to the Sun, relativistic effects have a massive impact on Mercury's orbit but were completely ignored in this program.

- Finally, the velocity-time graphs for all four planets showed that their velocities peaked and dipped several times in 100 weeks. This is not surprising since the distance of the planets from the sun is changing at each point in their orbits. But, Mercury's change in velocity were too high to be just caused by a change in the magnitude of the gravitational force. They were most likely amplified by the approximations I made for my calculations.

4 References

[1] Alan J. Reed, A-level Physics Tutor, http://www.a-levelphysicstutor.com/field-gravit-1.php, 2011

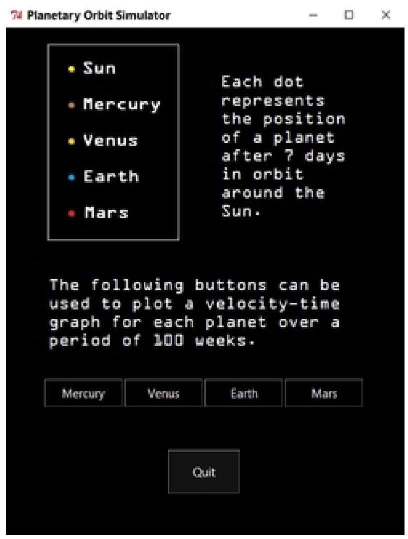

Figure 3: Second Window

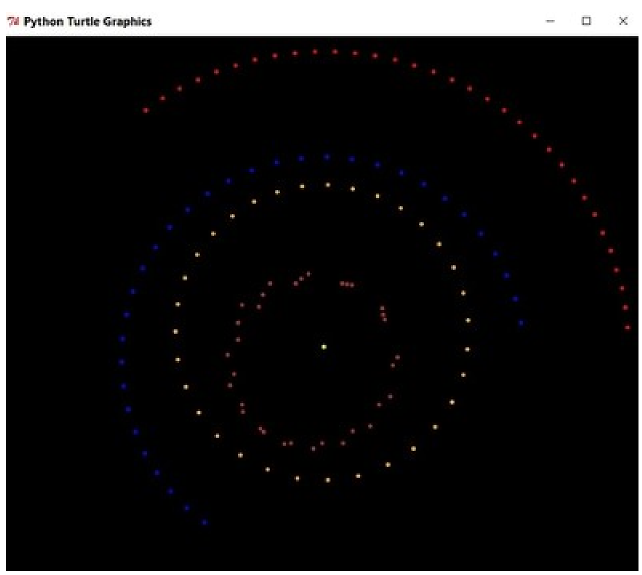

Figure 4: Turtle Window