Session 2 – Arrays and Functions

Objectives

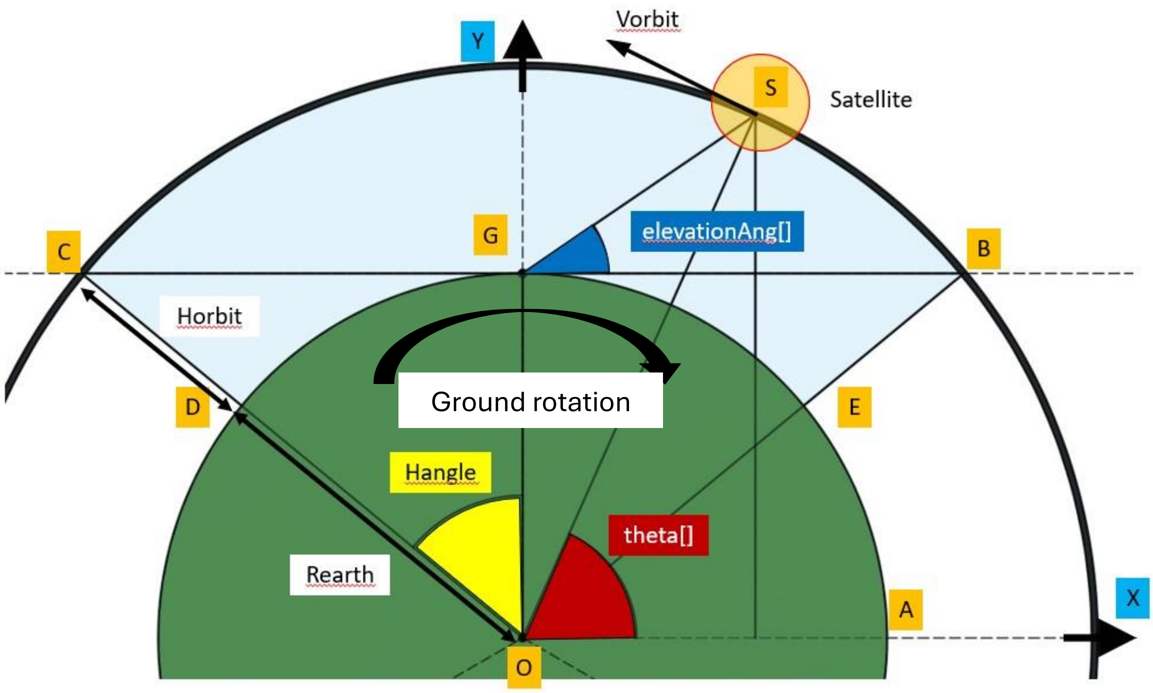
The objectives of this session are:

1. For a given height of orbit, calculate:
    a. Max angular acceleration
    b. Max angular speed
2. Input values of various heights and store in an array.
3. Output arrays of angular speed and acceleration. Make a function to write output values.
4. Plot values of various arrays.

Chapter 1: Assumptions and Equations

In the previous session, we got a time in horizon while only considering the speed of the orbit of the craft. However, the earth also rotates about its axis and the ground speed can have a significant impact on the actual time in horizon. Since an orbit can be in any orientation, we could say that the time calculated in the previous session is an average value.

However, to design parts of the satellite, we need to consider the worst case scenario. This is when the ground is moving in the opposite direction to the orbit and the relative speed of the craft w.r.t the ground is maximum.



Here, we see the black line, arc BSC as the orbit of the satellite. The satellite itself is at point S moving with velocity Vorbit. The height of the orbit above the earth determines this orbit's velocity. G is the ground station with which the satellite needs to maintain contact. The satellite is constantly pointing in the direction SG to maintain the lock with the ground station. The line BC is the line of the horizon. The satellite is only visible to the ground station if it is above BC. Thus, the satellite must be pointing in the direction BG before coming up to the horizon at point B and continue to point along SG (toward G) until it goes out of the horizon at point C. When this pointing starts, theta[0] is angle AOB which is π/2−Hangle.

Then it goes to pi/2 when S crosses the Y axis. The motion on the other side of the Y-axis is identical to the motion before so we only need to calculate until it hits the vertical. During this time, the elevationAng[] goes from 0 to π/2 radians as the craft goes from being just above the horizon to being directly overhead. In the worst-case scenario, the ground would be moving in the exact opposite direction to the craft giving us the minimum possible time in the horizon and consequently demanding the largest possible acceleration. That means that the craft is rotating in the arc BSC and the ground is rotation in the arc DGE. The sum of these angular velocities about the center point O and the Z axis in figure 1 gives us the net angular velocity for the craft so we know how quickly it passes from horizon to horizon. In the frame of the earth, we add the earth's angular velocity to the satellite and the diagram still holds.

Only the Vorbit is different, which is accounted for in the new angular velocity.

Angular speed of orbit and actual time in horizon

$$angular\ speed\ wrt\ center\ \left(\frac{rad}{s}\right) = \frac{Vorbit}{Rorbit}$$

$$angular\ speed\ wrt\ ground\ (Worbit)\left(\frac{rad}{s}\right) = \frac{Vorbit}{Rorbit} + \frac{2\pi}{day\ in\ seconds}$$

This is how many radians per second the craft moves with respect to the stationary frame of the earth. This is the effective angular speed. Thus, the actual time in horizon is:

$$Thorizon\ (s) = \frac{2 * Hangle}{Worbit}$$

Here, Hangle is the angle in horizon which remains the same as the previous session but Thorizon changes to account for the new angular speed.

We want 100 points for calculation, so we divide Thorizon into 101 points on each side, so 202 points in total. Thus, each time step is:

$$deltaT = \frac{Thorizon}{202}$$

Angular speed of the craft

The craft needs to maintain line of sight with the ground station G, throughout. As it goes along the orbit by changing its angular position, theta[], it needs to rotate about its own axis to maintain the elevation angle, elevationAng[] from the horizontal.

This gives:

$$elevationAng[i] = \arctan(\tan(theta[i]) - \sec(theta[i]) \cos(phi))$$

From this elevation angle, we just numerically get the rotation speed and angular acceleration of the craft by dividing by the deltaT. So:

$$Wcraft[i] = \frac{elevationAng[i] - elevatinoAng[i-1]}{deltaT}$$

$$alpha[i] = \frac{Wcraft[i] - Wcraft[i-1]}{deltaT}$$

Chapter 2: Inputs and outputs for code

Inputs

All the inputs from the previous file are needed. Those are the constant inputs.

The const_input.txt file will contain:

Rearth (km): 6378

Gconst (SI): 6.674E-11

Mearth (kg): 5.792E+24

Intermediate files/ variables

These files are both input and output. We first generate these text files as outputs and later use them as inputs. If it is not a lot of different values, we can just store them as variable arrays instead.

For this session, we only have intermediate variables in the form of an array of Horbit values.

Outputs

We need to get theta, elevation angle, wcraft, alpha, and maximum values of wcraft and alpha as outputs for each Horbit.

Conclusion and Key Learnings

- Understand the basics of arrays in python.
- Generate 2D plots.
- Understand the basics of functions in python.