Gliwice, 27-01-2025

Mathematical modelling and computer simulations in theory and practice

Documentation of lfinal project

Title: SATELITTE AND GROUND STATIONS

Author (Authors): Radosław Jędrzejczyk

Field of studies: Informatics (sem.V)

Project Objective:
Project objective is to visualise satelitte orbit around the earth, effective range of it's detector and its' visibility from ground stations.

Description:
We want to describe an unique orbit of a body orbiting the Earth. We can neglect the mas of the orbiting object, because as long as we're not considering objects size of a moon any difrences in trajectory aren't going to be noticable.

In order to describe unique orbit we will use traditional orbital elements – Keplerian elements, those are:

1. Eccentricity (e) – shape of the elipse.
2. Semi-major axis (a) – half the distance between the apoapsis and periapsis.
3. Inclination – tilt of the elipse with respect to reference plane.
4. Longitude of the ascending node – orientation of the ascending node (point at which orbit is crossing reference plane, while body is moving up).
5. Argument of periapsis – angle from the ascending node to the periapsis.
6. True anomaly at given moment – angle from periapsis to the object.

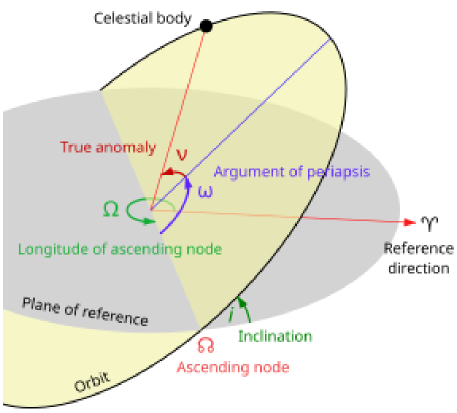

Figure 1: Keplerian orbit elements.

Knowing semi-major axis we can calculate semi-minor axis:

$$\sqrt{a^2(1-e^2)}$$

Knowing this values we can construct all posbile trajectories around the body. We will start by describing the trajectory on the XY Plane (our reference plane):

$$f(t)=\begin{cases} x=a(\cos(t)-e) \\ y=b\sin(t) \\ z=0 \end{cases}$$

In next step we're preparing rotation matrice using inclination, longitude of the ascending node and argument of periapsis, what will put orbit in the correct orientation. Knowing true anomaly at a given moment we can point current position of an object on the trajectory.

Additionally we will define values for hyphotetical detector on the sattelite:

- Range.
- View angle.
- Angle from nadir in the direction of movement.
- Angle from nadir perpendicular to the direction of movement.

Aforementioned inputs are given by sliders:

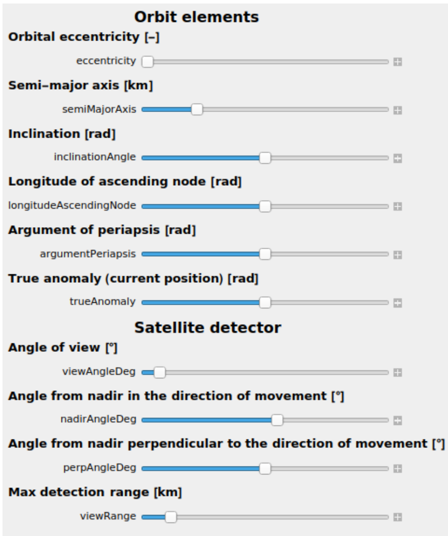

Figure 1: Inputs for satellite.

Additionally we can add ground stations and check altitude at which satelite is perceived for them. In order to define station we need to define:

1. Current date – position on Earth is defined by lattitude and longitude but position of the sattelite is based on celestial coordinates. We need to move lattitude and longitude in correct postion relative to sky.
2. ID – in order to recognise them.
3. Latitude.
4. Longitude.

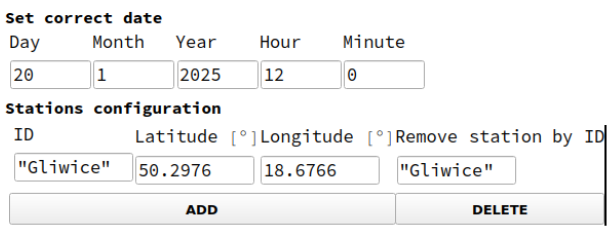

Figure 2: Inputs for ground stations.

Outputs:

As an output we get:

- Table presenting our stations positions, angle at which sattelite is visible relative to station, and visual information about it's visibility.
- Visualisation of sattelite position (red dot), its' orbit (black, dashed line), its detector field ov view (yelow cone), stations positions (green dots + IDs displayed).

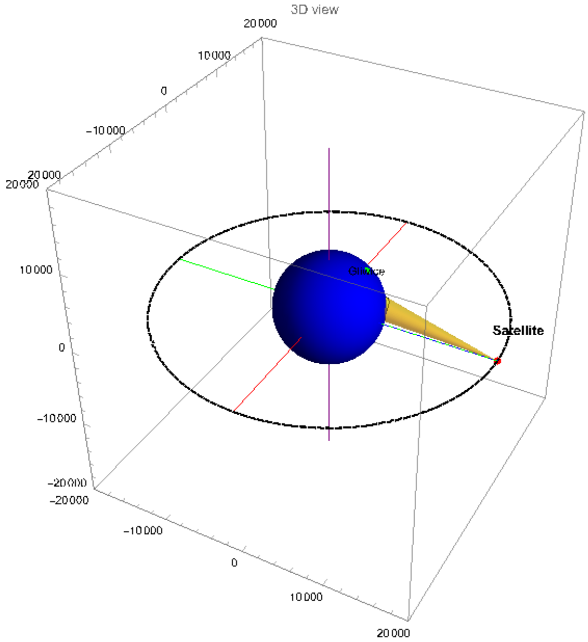

Figure 3: Example of visualisation.

We can define any orbit and detector field of view in this fashion.

List of stations

ID	Latitude [°]	Longitude [°]	Sat altitude [°]	Visibility
Gliwice	50.2976	18.6766	17.969	
another	-50.2976	18.6766	-73.6763	

REFRESH TABLE

Figure 4: Examplary table of stations.

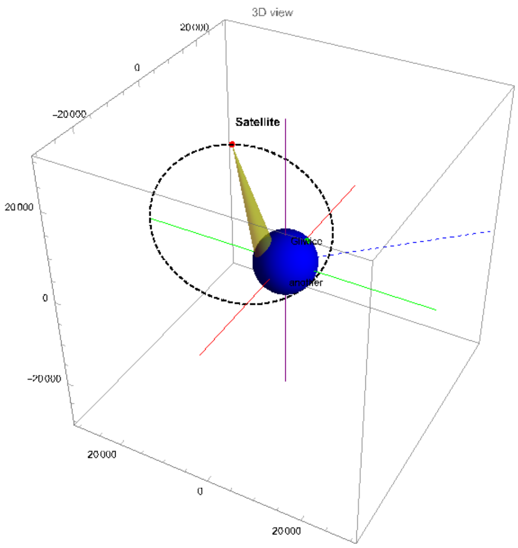

Figure 5: Sattelite in higly eliptical orbit.

Enclosures:

- ❑ File with the program (Jędrzejczyk_Radosław_project)