***Geoinformatics Project, 2021***

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# Abstract

The Clock, Ephemeris, Integrity (CEI) data set of a GNSS Satellite contain the essential parameters to use the satellite’s broadcast signals for positioning purposes. By reading the navigation message file of a GPS, a user can determine the approximate position and velocity of a satellite and correct for the propagation delay of the signal due to ionospheric effects.

The GNSS Data Processing Software (GDPS) has been developed, using Python, for determining the position and velocity of a satellite by reading its navigation message. By using the ionospheric error correction parameters in the file, GDPS determine the variation of the ionospheric effect on different positions of the Earth. A Graphical User Interface has been developed to enable a user to access GDPS.

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# 1.0 Introduction

GNSS Point positioning involves measurement of the signals emitted by a satellite for the determination of the position of a receiver on the surface of the Earth. The emitted signal contains information about the clock, ephemerides and integrity of the satellite. The signal propagation through the atmosphere is delayed by the presence of free electrons in the ionosphere (about 100 and 1000 km altitude) and the water vapour content of the troposphere. These delays affect the precision in the estimated position of a receiver. By reading the navigation message file, a user can determine the approximate position and velocity of a satellite and correct for the propagation delay of the signal due to ionospheric effects.

GDPS is a program for determining the position and velocity of a satellite by reading its navigation message. By using the ionospheric error correction parameters in the file, GDPS determine the variation of the ionospheric effect on different positions of the Earth. A simple Graphical User Interface has been developed to enable a user access GDPS. The algorithms implemented in the software are as defined in the IS-GPS-200L (Sections 20.3.3.4.3 and 20.3.3.5.2.5 for ephemeris determination and Ionospheric Model respectively).

## 1.1 Objectives

The objectives of the exercise has been to develop a software that

* computes the time varying position of the phase center of a satellite’s antenna
* computes the velocity of a satellite
* produces maps of the positions of a satellite
* produces a map showing time varying effects of the ionosphere on the propagated signal
* incorporates a Graphical User Interface for accessing the software

During the development some changes were made from the initial draft. It was decided to keep the core functionalities intact and replace the tropospheric and relativistic effect computations in favor to dedicating more importance to the graphical interface and presentation of the results.

## 1.2 Main features

GDPS has two main modules:

* Satellite orbit: this module tracks the position and velocity of a satellite vehicle over time. It allows to visualize the ground tracks of any chosen satellite vehicle over the surface of the earth, and to show the variation of azimuth and elevation that it would have with respect to an arbitrary position inserted by the user.
* Ionospheric error correction: This module shows the time varying effects of ionospheric delay on a GPS satellite emitted signal. It allows visualizing the ionospheric delay with respect to time across varying positions of the earth, elevation and azimuth of a GPS receiver with respect to satellite.

## 1.3 Prerequisites

### 1.3.1 Libraries

Python is the programming language used to develop the application

To run the GDPS program, the user is required to install the following packages

* Matplotlib ( 3.2.0 )
* Cartopy ( 0.18.0 )
* Astroplan ( 0.8 )
* wx ( 4.1.1 )
* Geopandas ( 0.9.0 )
* Numpy ( 1.18.1 )

### 1.3.2 Data types and formats

GDPS uses GPS RINEX legacy navigation (LNAV) message files up to version 3.05. The file has to contain the navigation message of one or more satellite. Versions later than this would not be recognized by the system. Future development will consider newer versions.

When accessing the respective modules, the elevation, azimuth, longitude and elevation parameters have to be of decimal degree formats. The heights value for producing the local map of the satellite orbit module has to be in meters. The time parameter for the ionosphere model is in the format HH:MM:SS

#### Running the application

To run the application, on the Comman Line Interface, navigate to the geoInfoProj folder and run using the command below

python Main.py

This will open the GUI OF GDPS

#### Installing the executable GUI

To install, download the executable file from here…………………………………. And run as follows

# 2.0 GDPS Interface

## 2.1 Menu items

The menu items of GDPS GUI are

### 2.1.1 Input



Figure 1 Input Menu Item

Open

This provides access to the file directory for opening an LNAV RINEX file to open. When the file is not of the GPS navigation type, an error message is printed to the user as shown in Figure ……….. defining the error and by closing the dialog, the user can select the required file type.



Figure 2 File Opening Dialog

On opening a file, when there are no ionospheric error correction parameters in the file (Figure ……………..), the user is informed of such.

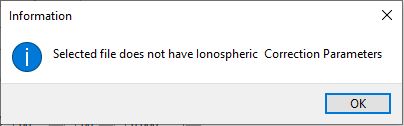


Figure 3 Ionospheric Correction Parameter Unavailablity Notice

Close

This exits the currently running window of the GUI.

### 2.1.2 Help



Figure 4 Help Menu Item

Help Content

This gives a brief documentation on how to use the software and the modules being used.



Figure 5 Help Content

About

This gives a brief description of GDPS.



Figure 6 About Page

To allow easier navigation, the menu items could be accessed using the ALT key and followed by the highlighted key on the item. Also, the key combinations defined in Table 1 can be used to access the respective items.

**Table 1**

|  |  |
| --- | --- |
| **Key short-cuts** | **Definition** |
| Ctrl + O | Open |
| Alt + F4 | Close |
| F1 | Help contents |

## 

## 2.2 Main windows

### 2.2.1 Satellite orbit

This is the Initial panel for the orbit visualization. From here the user can choose between 2 possibilities.

****

Figure 7 Satellite Orbit Panel

#### Global map

By selecting *Global Map*, the user can insert the number of the satellite he wants to visualize and click on the ‘proceed’ button. This will produce the map of the orbit.

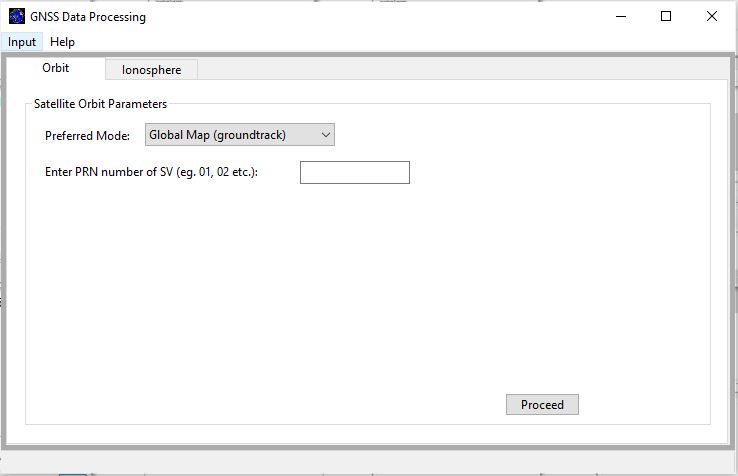
****

Figure 8 Satellite Orbit (Global Map Page)

#### Local Map

By switching to *Local Map*, the number of parameters to insert changes: in addition to the SV number, boxes to enter the position of the reference point in geodetic coordinates are added on the screen. From here it’s possible to produce the trend of the azimuth and elevation in time with respect to the inserted parameters.



Figure 9 Satellite Orbit (Local Map Page)

### 2.2.2 Ionosphere

On this panel (Figure ………………..), the user selects the preferred model (Global Map or Local Map).



Figure 10 Ionosphere Model Panel

#### Global Map

By selecting the Global Map, the panel is updated, exposing the buttons for inserting the required parameters (time, elevation and azimuth), Figure …………………. The default time values are zeros and the user can change the values. Also, only numerical values can be entered in each button. By clicking on the ‘Proceed’ button, an Ionospheric Error map is produced showing the variations in the ionospheric effects on the globe.



Figure 11 Ionosphere Model (Global Map) Page

#### Local Map

By selecting the Local Map, the panel is also updated (Figure ………..), exposing the buttons for inserting the parameters (time, longitude and latitude) required for the model. Also, the default time values are zeros and the user can change the values. By clicking on the ‘Proceed’ button, an Ionospheric Error map is produced showing the variations in the ionospheric effects on the globe.



Figure 12 Ionosphere Model (Local Map) Page

In both instances of Global Local Map analysis, when a GPS Navigation message file has not been selected, the user is informed of the unavailability of the Rinex file (Figure ……………..) and given a guide to select the file.



Figure 13 File Unavailability Error Notice

# 3.0 Graphical outputs and interpretation

## 3.1 Satellite orbit

The software computes position and velocity of satellites every 5 minutes, in a range of 2 hours, after every epoch (entry) in the data. With the available dataset a map is produced visualizing the shape of the orbit of the chosen vehicle.

### 3.1.1 Global map

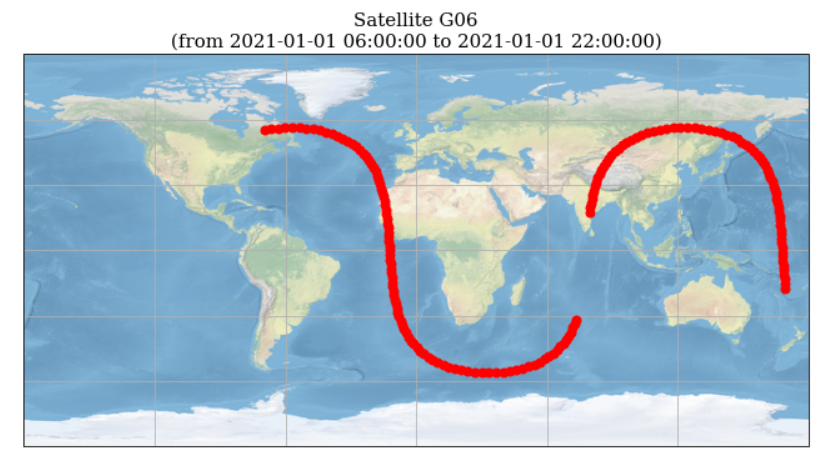
This functionality shows the ground track with respect to the Earth’s surface.

Figure 14 Global map: ground track

### 3.1.2 Local Map

This functionality displays the difference in time of the azimuth and elevation of a satellite, calculated with respect to an arbitrary position set by the user.

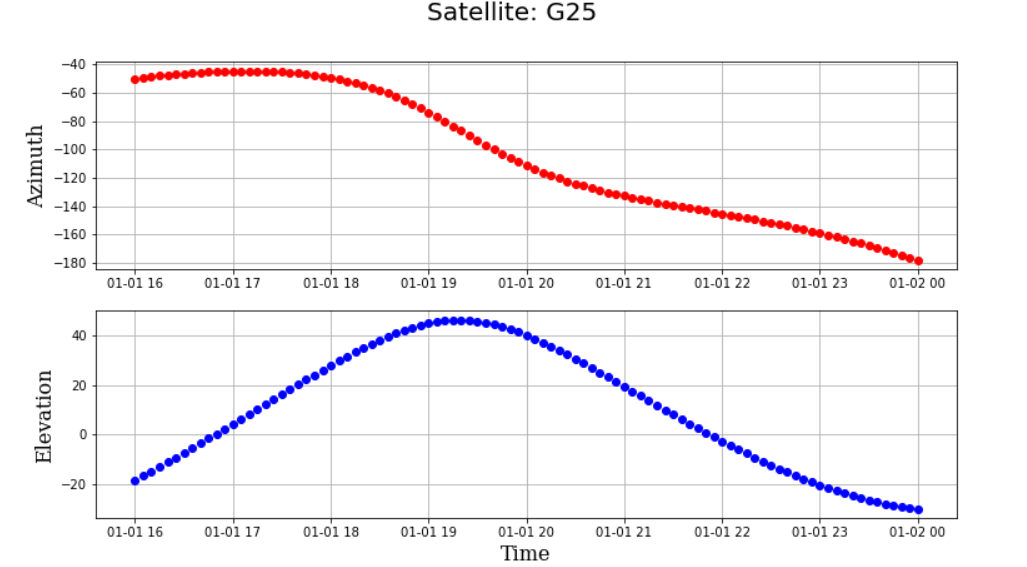


Figure 15 Local: azimuth & elevation plot

For all the displayed plots, a save button in the lower part of the panel will allow exporting them as image files.

## 

## 3.2 Ionosphere

### 3.2.1 Global map

Figure …………….. shows a sample output map for a global map of ionospheric effects with regions of higher ionospheric error at the time shaded red and regions of lower ionospheric effects shaded blue.

****

Figure 16 Ionospheric Effect (Global Map)

### 3.2.2 Local Map

Figure ………………………. Shows a sample output local map of ionospheric effect for varying elevation and azimuth. From the graph, it is clearer that the ionospheric error is higher for lower elevation of the station with respect to the satellite vehicle.



Figure 17 Ionospheric Effect (Local Map)

# 4.0 Conclusion

4.1 Testing

Immagine che contiene testo

Descrizione generata automaticamenteA script “differences.py” was developed for confronting the output of the software with the precise ephemerides (i. e. an historical archive where precise positions of satellites are stored). The script takes in input the produced file of positions and the precise ephemerides file (.sp3) and elaborates a text file of the differences.

After testing with thousands of results, the difference has always been in the range of some meters.

Immagine che contiene tavolo

Descrizione generata automaticamente

Immagine che contiene tavolo

Descrizione generata automaticamente

4.2 Scalability

For future development, the software can be upgraded to work also with newer versions of navigation message files.

Also, given the modular approach to the solution, other modules can be added for further processing satellite data, for example for computation of the tropospheric effect delay on the signals or for the relativistic effect correction.

4.3 References

#references to official documents