Instituto Superior Técnico

Fenómenos Interativos

Program Guide

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1 Program Guide

1.1 Installation instructions

In this section, we will briefly indicate the steps required to install and run our computational application, as well as its capabilities.

1. Click on the link indicated on the email (`https://drive.tecnico.ulisboa.pt/download/1414448696233759`). This will open a google tab and will start to download a .zip file called "multipole_G4.zip".
2. Go to Downloads and copy the .zip file you just transferred for the folder where you want to run the program in.
3. Right click on the file and select the option to "Unzip here". This will take a few seconds and in the end will create a new folder named "multipole_G4".
4. Open the command window and on it, type "python -m pip install –upgrade pip"and press enter. This will take a few seconds. You can now close the command window.
5. Go to the folder you extracted in step 3. There you will find a file named "setup"or "setup.bat", depending on your file explorer settings. Press this file twice. This will install all the packages needed to run this program in a python environment. This will take about **5 minutes**. During this process, do not interact with nor close any command windows that pop up. In the end of this program, you may get an error regarding the directory name (it varies from computer to computer, but you can ignore this error). You should get a message that says "Hit any key to exit....". You should press any key and close the window.
6. Go back to the folder extracted in step 3 and refresh the file explorer. If all went according to plan, you now have a shortcut in this folder with the name "Multipole".
7. Press this shortcut twice to open the program. It will initially open a command window. Wait about 30 seconds. Do not interact with the command window during this time. The main program GUI will then appear as follows:

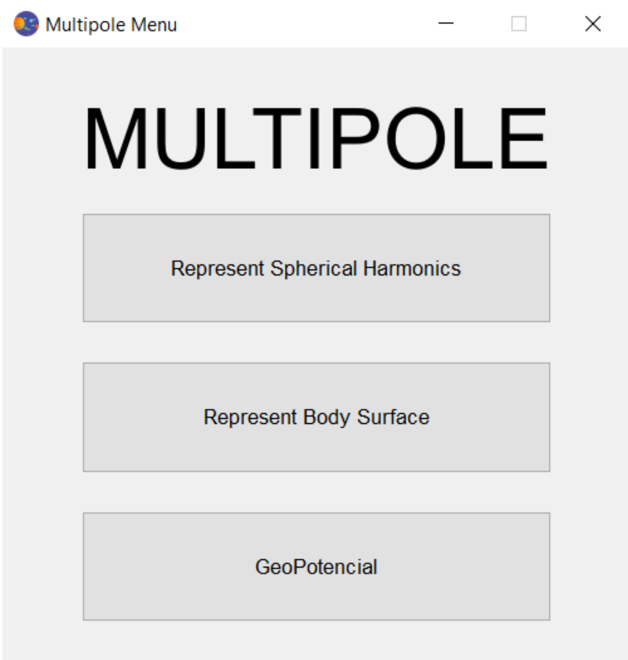

Figura 1: Program GUI.

If at any step of this process you encounter any problem or if the final GUI window doesn't appear, please contact us so we can help you with the installation.

To close the program, you can either close the command window or the GUI.

1.2 Features

The program's main window comes with the following options:

- Represent Spherical Harmonics
- Represent Body Surface
- GeoPotential

In order to select each of these options, just click once on them and a new window will show up. In case you want to select other options, just close recently opened tab because the main window will be left opened.

1.2.1 Represent Spherical Harmonics

This section of the program allows the user to visualize the shape of the spherical harmonics functions. According to Fig.2:

1. Degree and Order: (Allows the user to select every spherical harmonics functions up to degree and order of 50).
2. Type: (Allows the user to select three different parts of the spherical harmonics functions: Absolute, Real and Imaginary).
3. Representation:(The user can visualize the true shape of the spherical harmonics (with the Ylm option), as well as its influence on the unit sphere. The different colors represent the distance to the origin. In addition to that, the sum of the last two representations can be visualized with the option (Ylm+1))
4. View along the axes (X+ X- Y+ Y- Z+ Z-) and Isometric view.
5. Toggle Parallel Projection, Toggle Axes Indicator and Toggle Full Screen.
6. Save Representation as a Screenshot and more options.

The user can use the mouse to rotate the figure about the origin. Further options include:

- CRTL+MOUSE: to rotate about a selected point.
- SHIFT+MOUSE: to move the figure.
- SCROLL WHEEL: to zoom in and out.

As the user explores the options, it might be seen that the program doesn't respond when the Imaginary option is selected along with m=0. This happens because the zonal harmonics don't have an imaginary part. That can be confirmed by the fact that the absolute value representation corresponds to the real one.

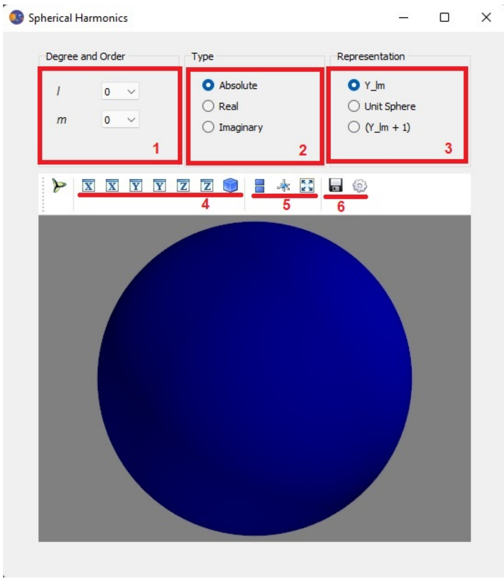

Figura 2: Interface of "Spherical Harmonics Representation"

1.2.2 Represent Body Surface

This section of the program allows the user to visualize the spherical harmonics representation of a given irregular body and compare it to the original one. According to Fig.3, the present options are:

1. Body and Max Degree: the user is able to select one out of four irregular bodies which represent asteroids. They have all been retrieved from NASA's archives. The user can also select one of the available maximum degrees in which the body can be represented that we have calculated beforehand for ease of use.

2. Add New Max Degree: In this tab, the user has the freedom to select any maximum degree. By clicking "Calculate", the program will take some time to perform the calculations (explained in section **??**) needed and then output the representation for the chosen degree. It should be noted that any new values of maximum degree that are calculated will be stored and these representations can be accessed in the "Max Degree"tab. **CAUTION**: the time taken to perform the calculations increases with the maximum degree for which we are approximating. Any input over 20 (depending on the machine) may cause the window to display "Non responding". If you wait long enough, it will eventually display the representation. Therefore, we do not recommend any input above 20.

3. Original Body: It shows the 3D representation of the original body extracted directly from the NASA archives.

4. Spherical Harmonic Representation: It shows the 3D representation of the body as a linear combination of all spherical harmonic coefficients up to degree and order L_{max}.

The user can use the MOUSE to rotate the body about the origin. It should be noted that both representations are affected by MOUSE operations. Further options include:

- CRTL+MOUSE: to rotate about the axis perpendicular to the screen.

- SHIFT+MOUSE: to move the figure.

- SCROLL WHEEL: to zoom in and out.

The program will not perform the calculations with invalid inputs such as letters or other special characters.

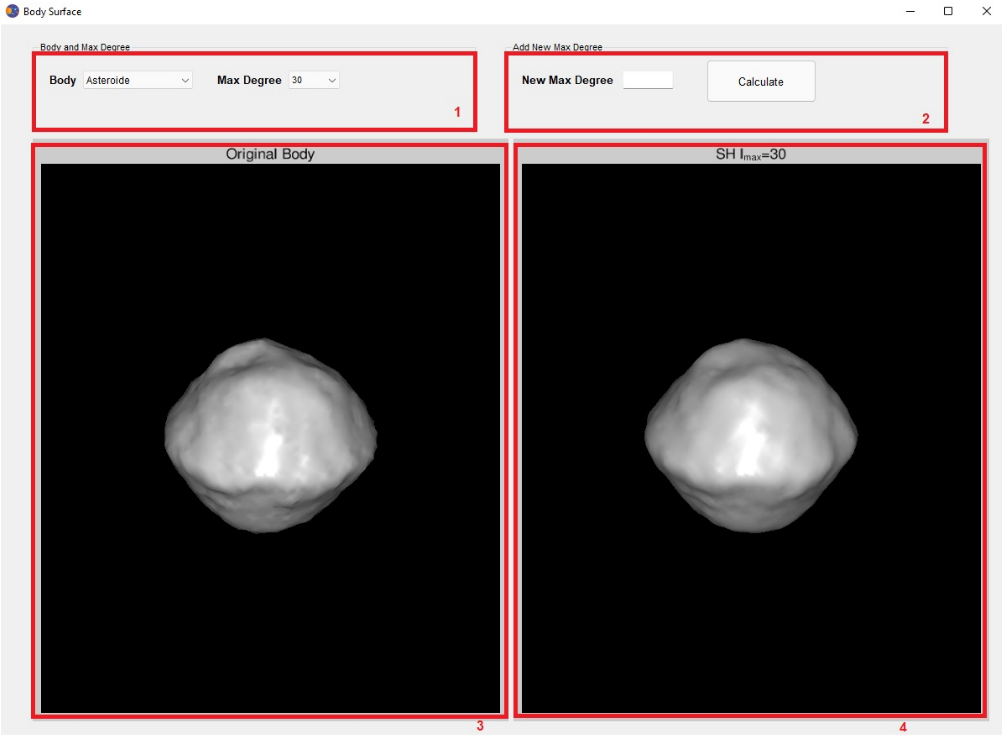

Figura 3: Interface of "Body Surface"

1.2.3 GeoPotential

This section of the program allows the user to visualize different parameters along the Earth's surface and throughout the space around the Earth. It comes with five different tabs which allow the visualization and calculation of different parameters. Some of these parameters, such as the geoid heights, are described in more detail in section **??**

- Geoid Here, we can visualize the geoid (also described in section**??**), as calculated from coefficients obtained by a mission such as GOCE's.

  1. It comes with a colormap along the surface of the Earth which represent the geoid heights.
  2. The scale is represented in a colorbar.
  3. 3D representation of the Earth's geoid

  The 3D body can be manipulated as follows:

  – View along the axes (X+ X- Y+ Y- Z+ Z-) and Isometric view.
  – Toggle Parallel Projection, Toggle Axes Indicator and Toggle Full Screen.
  – Save Representation as a Screenshot and more options.

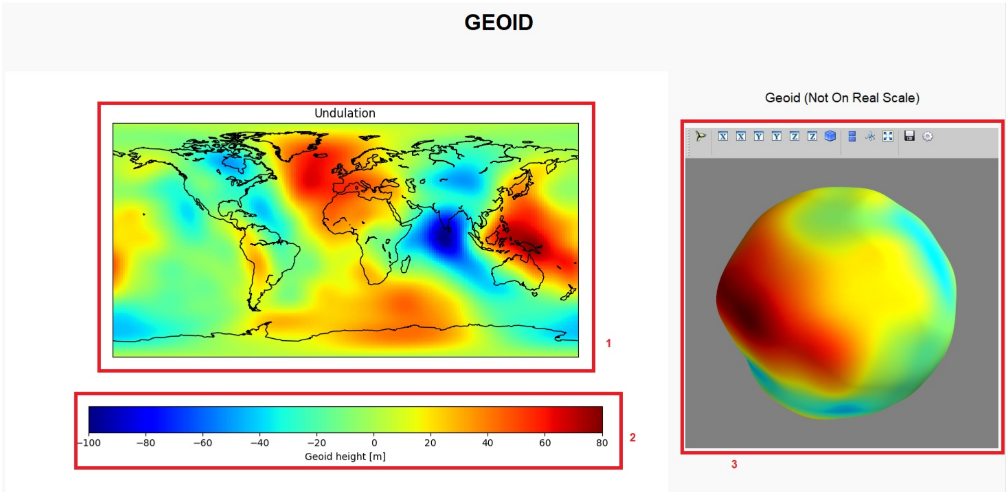

Figura 4: Interface of "Geoid"

- Coefficients Visualization

  In this part of the program, we display what the gravitational potential of the Earth would look like if the J2 coefficient was in a different position. In other words, we replace the actual value of the coefficient by the value that is usually in the J2 position. After sliding to the desired position and leaving it still, the image will change shortly.

  1. Colormap of the Gravitational Potential in a Sphere of Radius of 6378km along its colorbar with the respective scale.
  2. Colormap of the Gravitational Acceleration in a Sphere of Radius of 6378km along its colorbar with the respective scale.
  3. Replace J2 coefficient: the slider allows the user to replace the J2 coefficient by one of the ten available (C52 would refer to the coefficient of degree 5 and order 2).

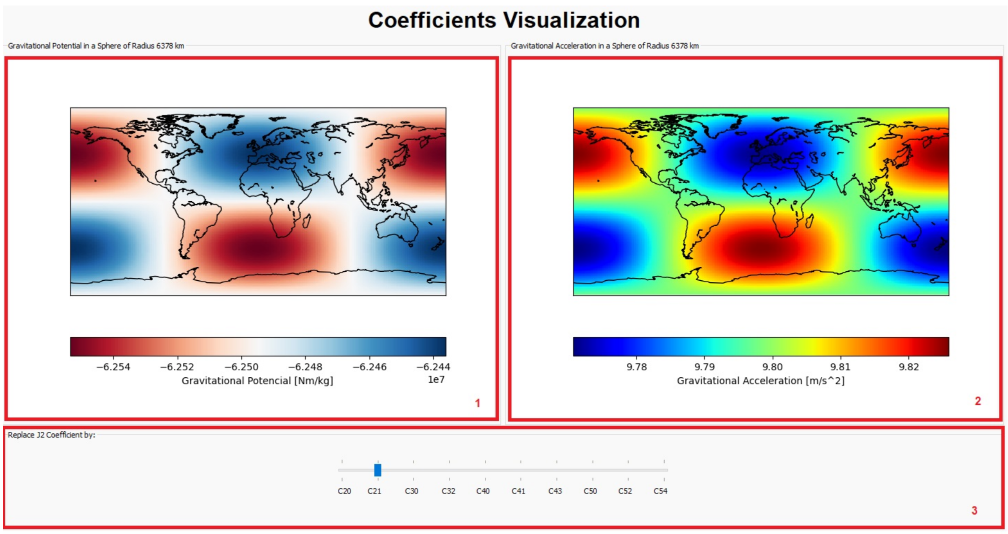

Figura 5: Interface of "Coefficients Visualization"

- Potential Visualization

  In this section, we perform an analysis of the potential field around the planet, both as a sphere around the Earth and in an equatorial cut.

1. Colormap of the Gravitational Potential on a Sphere of Radius of 6378km along with a colorbar which indicates the corresponding scale. This section also comes with a slider which allows the user to select different heights from 220km to 230km.
2. Colormap of the Gravitational Potential on a slice of Sphere of Radius of 6378km along its colorbar with the corresponding scale. This slice corresponds to the intersection of the sphere with a plane with polar angle of 0 degrees. Adjusting the slider allows the user to visualize the potential distribution from the Earth's radius to the selected height.

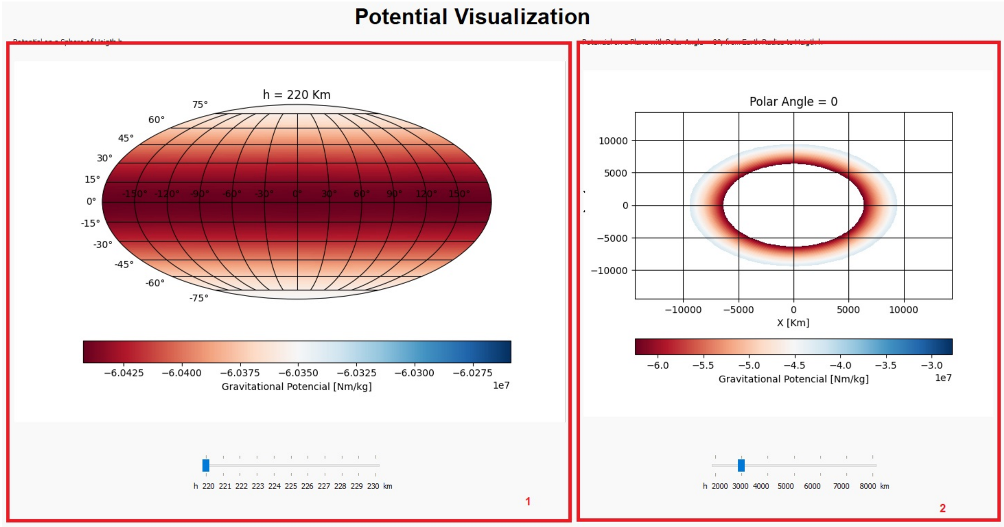

Figura 6: Interface of "Potential Visualization"

- Acceleration Visualization

  Similarly to the last section, here we plot the acceleration values around the planet.

  1. Colormap of the Gravitational Acceleration on a Sphere of Radius of 6378km along with a colorbar which indicates the corresponding scale. This section also comes with a slider which allows the user to select different heights from 220km to 230km
  2. Colormap of the Gravitational Acceleration on a slice of Sphere of Radius of 6378km along its colorbar with the corresponding scale. This slice corresponds to the intersection of the sphere with a plane with polar angle of 0.057 degrees due to a singularity at 0 degrees. Adjusting the slider allows the user to visualize the acceleration distribution from the Earth's radius to the selected height.

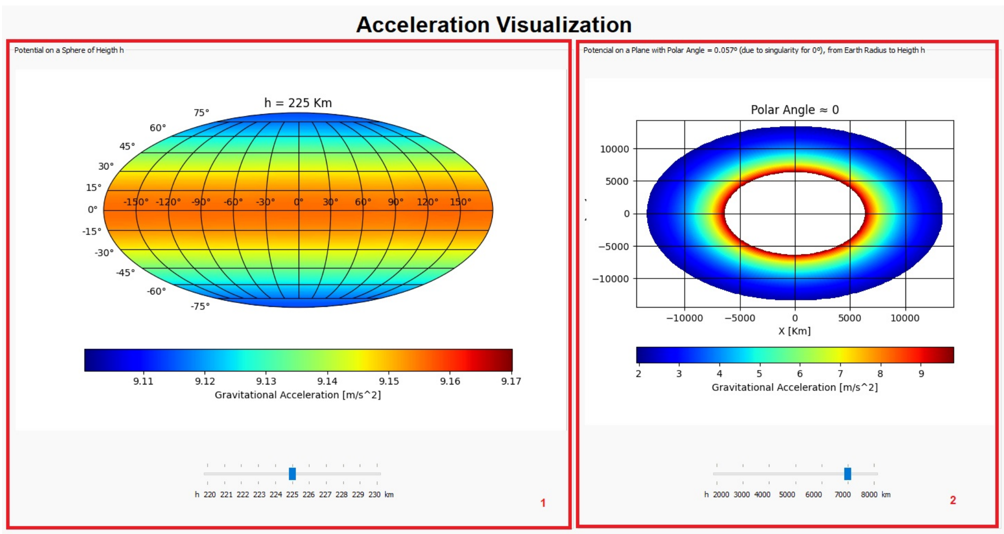

Figura 7: Interface of "Acceleration visualization"

- Calculate Gravitational Potential & Acceleration

  Here, we calculate the gravitational potential and acceleration for an individual point that is specified by polar and azimuth angles, as well as by the height above the perfect sphere of radius 6378.

  1. Colormap of the Gravitational Potential (left) and Gravitational Acceleration (right) on a perfect sphere of radius of 6378 + h km (h being the altitude input by the user) along with colorbars which indicate the corresponding scales. Notice that changing the altitude the figures themselves don't change, only the scales do (this is because we set the colorbar's limits to automatic).
  2. Coordinates of the point where the potential and acceleration are to be computed. These are represented in spherical coordinates: Height, Polar Angle and Azimuth Angle. Each parameter comes with an interval in which the calculations yield valid results. The program will not run with invalid inputs and the input will return to the last valid input (if an invalid input is entered).
  3. Results of the calculations performed by the program as a function of the selected inputs. The black dot in each graph indicates the selected coordinates.

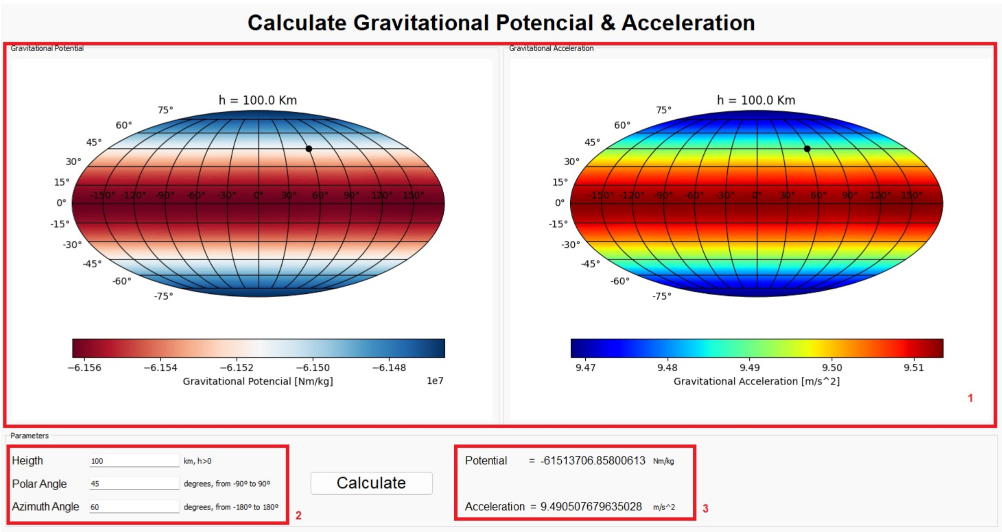

Figura 8: Interface of "Calculate Gravitational Potential & Acceleration"