Assessment: Graduate Student in Planetary Science

April 8, 2024

Introduction

The goal of this assessment is to find out if you are suited to join the University of Alabama Planetary and Near-Surface Geophysics Research Group. The most important skill as a graduate student is to independently solve problems for which you were not trained. Because of this, grades and reference letters are poor predictors for student success.

It is of paramount importance that you **solve the tasks by yourself**, without the help of a friend or teacher. Obtaining help for the tasks will skew the outcome and risk that you lose years of your life without getting a degree.

All of the assessment tasks can be solved with free open-source software. All you need is a computer and internet access. No commercial software is required.

Process

- Solve the tasks in Section "Tasks"
- Create a single document with the resolved tasks in their order. If you skip a task, please write "task skipped".
- Email that document to `amplattner@ua.edu`
- I will respond to your email and, if your assessment shows promise, will set up a video or phone meeting to discuss the assessment.

Important: Solving the tasks is no guarantee for admission to the program, even if you solve every task perfectly! But if you do solve the tasks well, our video/phone chat shows me that you have strong potential, and there is funding available, then you may be a high priority candidate for admission.

If you believe you found a mistake in the assessment, perhaps a link is dead or so, then please let me know. Also, if you almost solved a task but you are stuck in one detail, then please also let me know and perhaps I can help. However, if you send me many emails asking question that you could have solved yourself, then this is a sign that you are not an independent problem solver and hence not suited for graduate school.

Tasks

Task 1

- Download the data file "LonLatBr.txt" from `http://alainplattner.net/downloads/assessments/LonLatBr.txt`. This is an ASCII file containing three columns: Longitude (between 0 and 360), Latitude (between -90 and 90), and radial magnetic field (in nanoTesla).
- Use Matlab or Octave or Python or R or IDL to create a scatter plot of these data. Excell does not count. Describe what you observe. Your solution to this tasks needs to include: The figure, your code (Matlab/Python/R/IDL), your description of the observation.

Hint: If you have no programming experience and no access to Matlab, then I recommend using Octave (`https://www.gnu.org/software/octave/index`). I also highly recommend the free textbook "An Introduction to MATLAB for Geoscientists" by David Heslop. This Book is written for the proprietary software Matlab, but the free software Octave is virtually the same as Matlab, in particular for this task.

Task 2

The formula for the magnetic potential V, given the spherical-harmonic coefficients c_{lm}, and dependent on the spherical coordinate system r (radial coordinate), lon (longitudindal coordinate), lat (latitudinal coordinate) is

$$V(r, \mathrm{lon}, \mathrm{lat}) = \sum_{l=1}^{L_{\max}} \sum_{m=-l}^{l} \left(\frac{r}{a}\right)^{-l-1} c_{lm} Y_{lm}(\mathrm{lon}, \mathrm{lat}),$$

where Y_{lm} are spherical harmonics (see e.g. `https://en.wikipedia.org/wiki/Spherical_harmonics`) and a is the radius of the planet.

Task: Calculate the derivative of function V with respect to the radial coordinate r.

Hint: The spherical harmonics $Y_{lm}(\mathrm{lon}, \mathrm{lat})$, their coefficients c_{lm}, and the radius of the planet a do **not** depend on the radial coordinate and can hence be considered constants with respect to the radial coordinate.

Task 3

Download and install the planetary magnetic field research software "Slepian" from `https://github.com/Slepian/Slepian`. This software runs on Octave as well as on Matlab.

In the Slepian software folder, subfolder `edu`, subfolder `Ch_01_SphericalHarmonics`, read through the document `Ch_01_SphericalHarmonics_tut.pdf` and solve the exercises. This should get you ready to solve the task.

Task:

- From the data file `LonLatBr.txt` of task 1, calculate spherical-harmonic coefficients up to maximum spherical-harmonic degree 4 that fit the data points in a least-squares sense.
- Plot the resulting spherical-harmonic linear combination, plot the data points as a scatter plot, and plot the difference between the data points and the spherical-harmonic linear combination.
- Describe your observations. How well do the spherical-harmonic coefficients fit the data?

Your solution to this task needs to contain the figures, your Octave or Matlab code (the content of your m-file), and the description of your observation.

Hint: To solve a linear system of equations given in its matrix-vector formulation

$$Ax = b,$$

where A is the matrix, x are the unknown coefficients, and b is the right-hand-side vector, you can use Matlab / Octave's matrix solver simply by running

```
x = A\b
```

In your case, the matrix A will contain the spherical harmonics evaluated at the data locations, the right-hand-side vector b will contain the radial component values, and the vector x will give you the spherical-harmonic coefficients.

Key

If you solved all three Tasks independently and can explain them well in our phone or video chat, then you demonstrated that you may be suited for our graduate program in planetary physics. Please note that admission depends on availability of positions as well as competing candidates and other factors such as eligibility to work as a teaching assistant.