

A python code for numerically finding solutions to seismic surface waves

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Semester Report

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1 Background

The earth module consists of 2 modules of seismic code written in Fortran 77 which solves certain problems in seismology regarding solutions of seismic surface waves namely the **Love waves** and the **Rayleigh waves**.

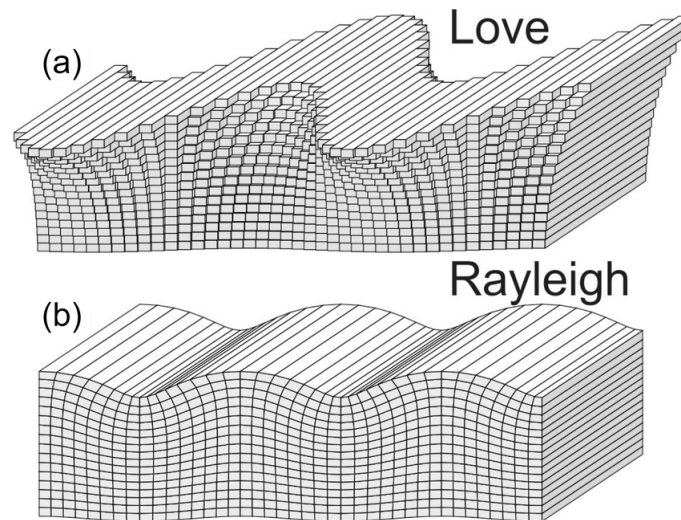


Figure 1: Love (a) and Rayleigh (b) surface-wave displacements for a horizontal propagation from left to right. Love waves are purely transverse motion, whereas Rayleigh waves contain both vertical and radial motion. After Shearer (2009).[3]

Love waves(Figure 1 (a)) have a horizontal motion that moves the surface from side to side perpendicular to the direction the wave is traveling. Of the two surface waves, Love waves move faster.

Rayleigh waves(Figure 1 (b)) cause the ground to shake in an elliptical pattern. This motion is similar to that observed in ocean waves. Of all the seismic waves, Rayleigh waves spread out the most, giving them a long duration on seismograph recordings.[1]

The two modules in earth as mentioned above are:

1.1 Srgramf

Srgramf is a program for computing seismic surface wave Green functions and synthetic seismogram in 1-D Earth models. It is designed to be compatible with the output of earthsr.

1.2 Earthsr

Earthsr is a program to compute Rayleigh and Love wave dispersion curves in a one-d medium for sources and receivers at specified depths. The output of this program is a table of dispersion and excitation information which then is passed to the srgramf program.

2 Objectives of the project

In the summer of 2021, I had worked on translating the earthsr module and had finished translating it to work for Love waves. For the semester project my objectives were:

- Finish the translation of earthsr module for Rayleigh waves.
- Parallelize the translated earthsr code to make its performance comparable to the original Fortran code.
- Translation of the srgramf module into python and make relevant changes to the code to improve performance and readability of the code.

3 Previous changes to srgramf

- Srgramf was initially called **srgram**. Srgram was rewritten to work in the frequency domain(hence the 'f')
- Srgram was a rewrite of **gram** by Steve Roecker to work with earthsr(which was also a rewrite of the original earth code by Steve Roecker) hence the 'sr'

4 Work done on earthsr

The following section describes the work done on translation and modifying the original code done during the timeline of the semester project:

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5 Working of earthsr(brief)

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6 Work done on srgramf

Entire working version of srgram was translated into python for the semester project. The following changes/additions were made to the code.

6.1 Used library methods to parse specs/config files

The original code wrote the whole code for parsing the input specs file which contained certain input parameters to the code. This original method of parsing the input file included ways to make comments in the file so that the parser would completely ignore the comment lines. This was modified to use '.ini' files which has built in functions in python to do the parsing. A number of other options were considered which were rejected due to various reasons.

Type of file considered	Reason rejected
.yaml	Need of complex data structures was not required
.json	Data was not being transmitted across a server and format was complex for easy modification
.cfg	Format was similar to .ini and I lacked familiarity with this type of file

In the original code, the parser was programmed in a file called parseprogs_mac.f which contained 254 lines of code and due to this decision, those many lines were omitted in the translated code.

6.2 Using standard/accurate values for constants

The original code contained values for various constants of nature. Since these values were never revised since the writing of the original code in the 1980's, I provided revision using accurate values from the various in built libraries in python. Some of those revisions were like using value of pi from numpy, using revised value of flatness of earth, using radius of earth from astropy, etc.

6.3 Appropriate replacement for common blocks

Fortran uses common blocks to share data between various files/modules. Since this functionality is not available in python, I used other solutions to replicate this behavior.

- Some of the variables were declared in a common file and this file was imported in all the files requiring the variables. This was done in accordance of the official python documentation's recommendation on creating global variables.[4]
- Some of the variables were packaged in a class and an object of the class was passed as a parameter. Since user defined objects are mutable, these were passed as

parameters and this method was used mostly in cases where it seemed appropriate to use call by reference

- Some variables were simply passed as parameters to functions to the calling files this was used as a last option and especially when it seemed appropriate to do so.

6.4 Using OOP principles

Python being fairly good in working with classes and objects, I incorporated the use of them wherever necessary to make the code less redundant and modular. For example, consider the code snippet in Figure 6.4

```
class mkhomogsrparams:
    def __init__(self,angle) -> None:
        self.angle = angle
        self.cos = math.cos(angle)
        self.sin = math.sin(angle)
        self.cos2 = math.cos(angle*2)
        self.sin2 = math.sin(angle*2)
        self.c2p1 = 0.5*(1+self.cos2)
        self.c2m1 = 0.5*(1 - self.cos2)
```

Figure 2: A Code Snippet of the translated code

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7 Working of srgramf

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8 Overcoming and Shortcomings of new code

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9 Future plans

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10 Conclusion

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References

- [1] *Britannica*
. URL: <https://www.britannica.com/video/181934/rock-vibrations-Earth-earthquake-waves-P-surface>.
- [2] Arjun Datta. *EC3144 course at IISER Pune*.
- [3] *Jens M. Turowski*. URL: https://www.researchgate.net/figure/Love-a-and-Rayleigh-b-surface-wave-displacements-for-a-horizontal-propagation-from_fig3_295863200.
- [4] *Official Python Documentation*
. URL: <https://docs.python.org/3/faq/programming.html#what-are-the-rules-for-local-and-global-variables-in-python>.

Code documentations

- [5] *Comments of the original code*.
- [6] *earth.doc*.
- [7] *gram.notes*.
- [8] Keith Priestly. *Notes*.
- [9] Steve Roecker. *README.example*.
- [10] Steve Roecker. *README.srgram*.
- [11] Steve Roecker. *README.srgram*.