SeidarT 1.0 Documentation

version 1.0

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Contents

SeidarT 1.0

https://github.com/ChristopherGerbi/SeidarT
Geophysical wave modeling through complex media
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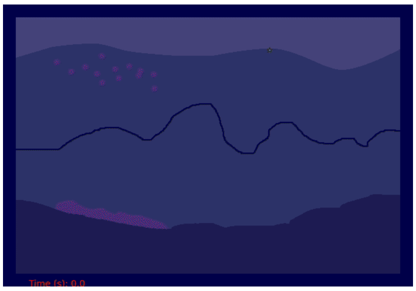
The Seismic and Radar Toolbox (SeidarT) is a collaboration between the Universities of Maine and Washington to provide an open source platform for forward modeling elastic (seismic) and electromagnetic (radar) wave propagation. The major objective of the project is to easily and quickly implement isotropic and anisotropic complex geometries and/or velocity structures to investigate, and plan field campaigns to image local and regional subsurface structure, particularly for the cryosphere. Larger problems require the curvature of the Earth to be taken into consideration.

Much of this code has been adopted from the SEISMIC_CPML software provided by Computational Infrastucture for Geophysics (CIG). Further details to the backend numerical code can be found in the References section.

About

SeidarT is a powerful numerical modeling tool to calculate englacial seismic and electromagnetic wave propagation. Though it grew out of a desire to simulate field surveys in glaciers and ice sheets, the code is general enough for any Earth material.



An example of model output calculated by SeidarT, showing wave propagation through multiple material types along the X-Z plane and complex geometry between the layers.

%%%%%%% This animation should be redone without background noise %%%%%%%

Statement of Purpose

Known issues

€ The volume around the source rings in the electromagnetic modeling.

Installation

The dynamical programming language of Python3 is used as a front end to run the more computationally extensive modeling schemes in Fortran. There are a number of ways to install this software depending on your desired level of control over the process. Most users should be fine with the •Auto-installation, in the section below.

If you are an advanced user and looking to take more in-depth control of the installation process, you can use the Manual installation instructions.

Below the installation instructions, we describe the Folder structure.

Note

Mac OS X users: you will have to install Homebrew prior to installing this software if you do not already have it.

Auto-installation

First, some background:

This method will install SeidarT on most Unix-based systems using a combination of Anaconda and Fortran compilation. It ſs not necessary to know or do much more than execute a few command line entries. However, it will help to know that the installer will create whatſs called a •virtual environment, or more specifically an •Anaconda environment,. Without getting into details, this conda environment is basically a way to create a virtual Python configuration that will let this software run but not affect your systemſs Python configuration, which is a fancy way of saying that conda will avoid causing cascading bad effects on your computer. In short: conda is nice because it plays nicely with various systems. Note well that you will have to activate this conda environment whenever you wish to run SeidarT. This is not hard but it is critical. Read on for instructions on how to both install and activate your SeidarT conda environment.

1. **First, make sure you have the proper prerequisites**

   On Mac OS X systems with Homebrew, copy/paste/enter the following two lines:

   ```
   brew update
   brew install gcc git parallel
   ```

   or on Debian/Ubuntu systems that use the `aptitude` package manager, do the following to get those prerequisites:

   ```
   sudo apt update
   sudo apt install gcc-9 gfortran git
   ```

2. **Get the software**

   Change to the directory where youſd like SeidarT to go, clone it from GitHub, and change into the SeidarT directory created by Git:

   ```
   cd /path/to/parent/directory
   git clone https://github.com/sbernsen/SeidarT
   cd SeidarT
   ```

3. **Install**

   Run the auto-installer script and follow the prompts:

   ```
   bash install.sh
   ```

   This script will first check if Anaconda or Miniconda already exists on your system. It will download and install Miniconda if necessary. It will also add conda to your `$PATH`, which is to say that it will tell your computer where to look to use the conda software. Then, it will use conda to create a SeidarT environment and install the rest of the requirements into that environment. Finally, it will compile the Fortran code in this repository.

You should now be able to move on to the Getting Started section.

Manual installation instructions

This is the more involved and less sure-fire installation method, probably best left for intermediate level Unix users and up. The following system dependencies are required:

Python3, Fortran95, GCC, pip, git, dos2unix, ghostscript, imageMagick

and additionally, these Python dependencies are also required: *numpy, scipy, matplotlib, mplstereonet* (optional for viewing fabric distributions).

1. **Get system prerequisites**

   First, install what you will need to compile the Fortran code. This can be with Homebrew (on OS X) using the commands:

   ```
   brew update
   brew install gcc git dos2unix ghostscript imagemagick numpy vtk python pip
   ```

   and via **apt** (on Linux) with:

   ```
   sudo apt update
   sudo apt install gcc-10 git dos2unix ghostscript imagemagick \
     python3.8 python3-numpy python3-vtk python3-pip
   ```

2. **Install Miniconda**

   Anaconda will work as well, but miniconda is a smaller initial installation, and will only install what you need.

3. **Get Python prerequisites**

   From a Terminal window in which the `conda` command is accessible, run the following commands:

   ```
   conda create -n seidart python=3 pip git ghostscript imagemagick \
     numpy matplotlib scipy pyevtk vtk
   conda activate seidart
   pip install mplstereonet
   ```

4. **Get the software**

   ```
   cd /path/to/parent/directory
   git clone git@github.com:sbernsen/SeidarT.git
   cd SeidarT
   ```

5. **Run the installer**

   ```
   bash manual_install.sh
   ```

6. **Update PATH**

   When the compilation is finished, we can add the folder to the path directory and the python path directory. Currently, this software is supported with bash so append the following lines to the `~/.bashrc` file if using Ubuntu:

   ```
   export PATH=$PATH:/path/to/SeidarT/bin

   export PYTHONPATH=$PYTHONPATH:/path/to/SeidarT/bin
   ```

   and if Python 2 is the default version, create an alias by adding this line to your aliases (either in `~/.bashrc` or `~/.bash_aliases`)

   ```
   alias python=python3
   ```

> ### *Note*
>
> Notes for Macintosh users:
>
> Depending on the OS release (El Capitan, High Sierra, Mojave, etc.) and whether you have Anaconda installed appending a path might be different. Anaconda may set aliases so troubleshooting on a Mac can be cumbersome. Before editing the `/etc/path`, `.bash_profile`, `.profile`, or `.bashrc` files, it is a good idea to create a backup especially if you are not familiar with either or any of those files. To do this copy the original to a new name. For example,
>
> ```
> cp <location/of/path/definitions> <location/of/path/definitions>_original
> ```
>
> that way you can always revert back to the working script.

There are a variety of ways to edit the documents but for simplicity change directories to the home folder:

```
cd ~
```

and input into the command line:

```
sudo nano .bashrc
```

and append the `export PATH=...` lines at the bottom. Save and close the file (*CTRL+X*, then *Y* and enter) then check to make sure it is included in the path:

```
. ~/.bashrc
echo $PATH
echo $PYTHONPATH
```

Folder structure

Here we describe the folders you may need to use while working with the software.

- **bin**

  Contains the active Python and Fortran codes used in calculating and displaying the wave propagation.
- **docs**

  Repository for html documentation.
- **EXAMPLES**

  Hosts images and other files used in the tutorial. Also contains a shell script that can help with bookkeeping.
- **materials**

  Library for definitions and subroutines.

- **`genindex`**
- **`search`**

Getting Started

General workflow

Using SeidarT follows a relatively simple workflow.

1. You need two or three files to start:

   - A 2D image saved in *png* format.
   - A *csv* file listing the X,Y,Z coordinates of receivers for your survey
   - If your material is anisotropic, you need a file in the format delimited file specifying the

   Euler angles for a number of crystals, with one triplet per line. See an example orientation file and/or generate one using the `orientation_tensor` function.

1. Generate a project file (using `prjbuild`) and edit that text file to set up your survey.
2. Create files describing the radar or seismic source (`sourcefunction`).
3. Choose the style of survey you want to do [single shot, common offset, common midpoint, or (in development) polarimetric] and run the calculations.

4. For single shot, you can create an animation of the wave propagation (`im2anim` for 2D or `vtkbuild` for 2.5D).
5. Display your results as radar- or seismograms, or wiggle plots. You can also save the timeseries-receiver data in a *csv* file for further processing in different software.

Output from the seismic model is m/s and from the radar model is

Files to generate or edit

€ *PNG image (.png)*

This defines the geometry of your model system. A good starting size is 50 to 500 pixels for each direction. Each RGB color represents a different material, so **the file must be saved with no antialiasing**. Typically each pixel represents the same distance in x and z (in meters). To get started on a new project create a new folder and save the image to the folder. From the command line, change directories to the project folder then enter the following:

```
prjbuild -i /path/to/geometry/image.png -p project_filename.prj
```

Below, we describe the *prj* file structure and how to edit it.

€ *receiver locations (text file, commonly receivers.xyz)*

A comma separated list of X,Y,Z coordinates (one set per line, with X,Y,Z as the first line) for receiver locations. Can use pixels, but more typically meters as the units.

€ *project file (.prj)*

This file is the heart of the software. It defines domain values, material properties, and survey conditions for electromagnetic and seismic runs. Here, we identify what each line means and which to edit. All lines with # are comments. Bold text indicates a line the user should edit.

Table: .prj File lines and their meanings

Line	Description
`I,fill2.png`	The image file associated with this *.prj* file.
`D,dim,2`	**Choose either 2D or 2.5D.** 2.5D is the 2D image extruded in the y-direction.
`D,nx,240`	Read from the image file. Do not change.
`D,ny,1`	**Number of pixels in the extruded direction if using 2.5D.**
`D,nz,50`	Read from the image file. Do not change.
`D,dx,1`	**Number of meters each pixel represents in the x direction.**
`D,dy,1`	**Number of meters each pixel represents in the y direction.**
`D,dz,1`	**Number of meters each pixel represents in the z direction.**
`D,cpml,20`	**Thickness of absorbing boundary layer. A typical value is 20.**
`D,nmats,3`	Read from the image file. Do not change.
`D,tfile,`	An attenuation processing value that is not yet implemented.

Line	Description
`M,1,ice1h,98/197/178,-10,2,910,0,0,TRUE,test.ang`	One comma-separated-values line per material (per color in the model image). **User should change/add the material name (see list), temperature (in degrees Celsius), density, porosity, water content, whether the material is anisotropic (TRUE or FALSE), and if anistropic, the name of the anisotropy file. Use a dummy value of 2 for attenuation, recognizing that attenuation is not yet incorporated in the calculations.** User should not change the material ID or R/G/B values. Note: Since large density gradients cause numerical instabilities, the density for air must be increased. A value of 400.0 works until a better formulation of the air-rock interface is implemented.
`S,dt,`	Timestep will be calculated automatically.
`S,time_steps,500`	**Decide how many timesteps you want the model to run.**
`S,x,100`	**x-coordinate of the seismic source**
`S,y,0`	**y-coordinate of the seismic source**
`S,z,0`	**z-coordinate of the seismic source**
`S,f0,60`	**Frequency of the seismic source**
`S,theta,0`	**Inclination of the seismic source (+ is down)**
`S,phi,0`	**Angle of seismic source from x-axis in the x-y plane (+ is counterclockwise when viewed from above)**
`C,0.0,`	Stiffness tensor for each material. User *can* enter or change this manually if desired. If blank, calculated from materials information in the earlier section.
`E,dt,`	Timestep will be calculated automatically.
`E,time_steps,500`	**Number of timesteps to run the model.**
`E,x,100`	**x-coordinate of the radar source**
`E,y,0`	**y-coordinate of the radar source**
`E,z,0`	**z-coordinate of the radar source**
`E,f0,1e8`	**Frequency of the radar source. 10-100MHz is a good range to start.**
`E,theta,0`	**Inclination of the radar source (+ is down)**
`E,phi,0`	**Angle of radar source from x-axis in the x-y plane (+ is counterclockwise when viewed from above)**
`P,0.0,`	Permittivity tensor for each material. User *can* enter or change this manually if desired. If blank, calculated from materials information in the earlier section.

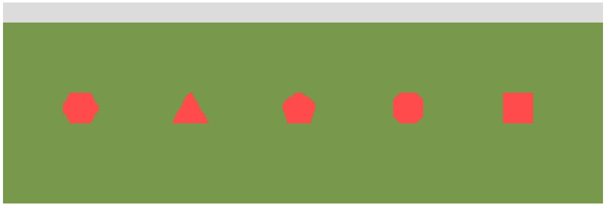
€ *orientation file*

A delimited file of one entry of Bunge notation Euler angles per line. A typical number of entries is 500 to ensure a smooth data field.

Examples

The following are small, simple models to introduce the routines.

Shapes model: create a 2.5D animation of wave propagation



The model domain for the €shapes• example.

1. Open a terminal and change directories into the EXAMPLES>shapes folder. Input into the command line:

```
prjbuild -i shapes.png -o shapes.prj
```

2. Using a text editor to modify shapes.prj, add values to the appropriate lines below the header to match the following:

```
I,shapes.png
D,dim,2.5
D,nx,300
D,ny,3
D,nz,100
D,dx,1
D,dy,1
D,dz,1
D,cpml,20
D,nmats,3
D,tfile,10

# Material definitions:
# number, id, R/G/B, Temperature, Attenuation, Density,
#       Porosity, Water_Content, Anisotropic, ANG_File
M,0,ice1h,120/152/76,-20,2,917,0,0,FALSE,
M,1,water,220/220/220,-20,2,1000,0,0,FALSE,
M,2,granite,255/75/75,-20,2,2700,0,0,FALSE,

# The source parameters for the seismic model
S,dt,
S,time_steps,400
S,x,150
S,y,1
S,z,0
S,f0,60
S,theta,0
S,phi,0

# id, C11, C12, C13, C22, C23, C33, C44, C55, C66, rho
C,0,,,,,,,,,,
C,1,,,,,,,,,,
C,2,,,,,,,,,,

# The source parameters for the electromagnetic model

E,dt,
E,time_steps,400
```

```
E,x,150
E,y,1
E,z,0
E,f0,1e8
E,theta,0
E,phi,0

# id, e11, e22, e33, s11, s22, s33
P,0,,,,,,,,,,
P,1,,,,,,,,,,
P,2,,,,,,,,,,
```

All lines that start with a # are commented lines. For reference, you can use the RGB values to identify the materials.

After filling in the domain and material values, save the .prj file, then run the command:

```
prjrun shapes.prj -m n
```

If you look at the prj file now, you will see that the dt lines and the stiffness and permittivity tensors are filled in. Even though we have all the required fields entered, the model didnƒt perform any wave propagation calculations because we used the `-m n` option. The `-m n` step is required to prepare the file to calculate the sourcefunction (next step).

Before we can do the wave propagation calculations, we need to generate a source function:

```
sourcefunction -p shapes.prj -S gaus0 -m b -a 10
```

Now you can run the model (both seismic and electromagnetic):

```
prjrun shapes.prj -m s
prjrun shapes.prj -m e
```

When that is finished letƒs build the vti files to view the wavefield. Starting with the seismic wavefield, enter:

```
vtkbuild -p shapes.prj -c Ex -n 20
```

This should produce a set of vti files identical to the ones in the folder •shapes_ex1_vti‚. This is a short animation, but the steps for a larger one are the same.

When that is finished letƒs build the GIF to view the wavefield. Starting with the seismic wavefield, enter:

```
im2anim dipping_bed.prj -c -n 10 Vx -f 30
```

then repeat when the command line returns but change the „-cƒ option to „Vzƒ, „Exƒ, or „Ezƒ. Alternatively, you could change the frame rate (-f) to a higher or smaller number to adjust the speed of the GIF. We specified the „D,writeƒ parameter to 10 which is a little undersampled to view seismograms or radargrams, but creating the GIF takes some time and we donƒt need that much resolution. If you would like to create the seismograms decrease the write parameter between 2-4.

Fill model: create a single shot seismogram and wiggleplot

The model domain for the €fill• example.

#. Open a terminal and change directories into the EXAMPLES>fill folder. We have already created and completed a .prj file for this example („fill.prjƒ). As you can see from the materials, we have set it up to be a granite bedrock (blue) overlain by a subglacial (teal for ice) lake (red for water). We have also created a file listing the locations of the source and receiver (spaced every 2 m along the surface) from x=50 to x=190 meters.

1. Run the model:

```
prjrun -p fill.prj -m s
```

2. Build the csv file containing the receiver timeseries:

```
arraybuild -p fill.prj -c Vx -r receivers.xyz
```

3. Display the results:

```
rcxdisplay -p fill.prj -f receiver_array.csv -g 700 -e 0.02
```

4. Play with the gain and exaggeration to vary the image to your liking.
5. To make a wiggleplot:

```
wiggleplot -p fill.prj -g 5 -r receiver_array.csv -c Vx -x 2 -d 1 -n 5
```

Fill model: create a common offset radar profile

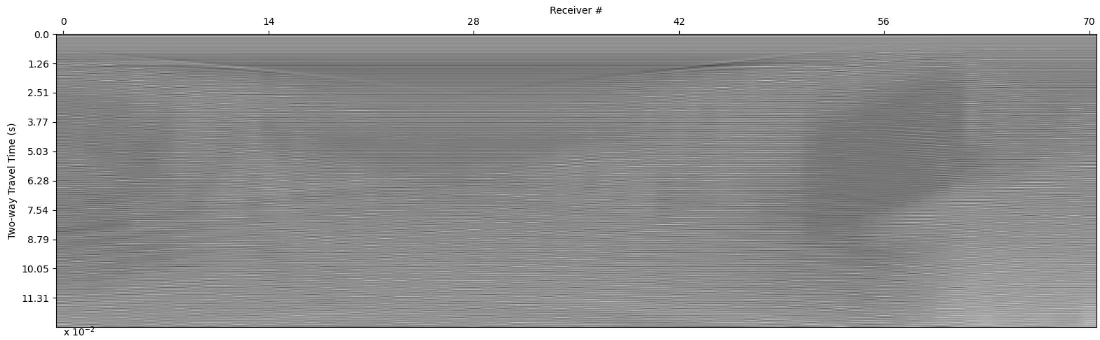
1. Using the same model as before, run it, this time with common offset:

```
common_offset -p fill.prj -o 1 0 0 -r receivers.xyz
```

2. The receiver timeseries are automatically generated, so you can directly display the results:

```
rcxdisplay -p fill.prj -f Ex.co.csv  -g 100 -e 0.02

You should get something like this:
```



A common offset survey across the ‚fill‘ example.

Play with the gain and exaggeration to vary the image to your liking.

Routines and wrappers

The following is a brief overview of the commands available in the SeidarT environment. More information is available in the Command reference.

Routines

prjbuild.py

Constructs a template and assigns default values from a PNG image. See prjbuild.

sourcefunction.py

Creates .dat files needed to define the source impulse. Does not need to be run if source function files are already present. See sourcefunction.

prjrun.py

Reads the project file assigns coefficients given that all the required fields are satisfied then runs the specified 2D forward model. You can suppress modeling and edit the stiffness and/or permittivity and conductivity coefficients. Once they are provided in the project file, they wonʃt be computed or overwritten from the material values. If you would like to change the material values and recompute the tensor coefficients, you need to delete the existing tensor coefficients if included in the project file. See prjrun.

im2anim.py

Create a animation from the model outputs. Currently, this takes some time to run which you can speed up by increasing the „writeʃ value in the project file. This only takes 2D models, and there are bugs with matplotlib that cause red/blue flashing. See im2anim.

arraybuild.py

Build the basis for plotting the seismograms or radargrams for the wide angle survey. You can suppress plotting which will return a .csv file. An auto-controlled gain function can be called for better visualization. The receiver locations are given by a text file with the header X,Y,Z. These locations can be given in meters relative to (0,0,0) or in indices. (0,0,0) is top left when viewing the image. See arraybuild.

rcxdisplay.py

> **Note**
>
> Originally •codisplay, in legacy code

Display the outputs of the common offset survey. This is also called to display the common midpoint survey. Similar to `arrayplot.py`, the gain function can be called. See rcxdisplay.

orientation_tensor.py

Compute the Euler angles and orientation tensor for a fabric defined by itʃs trend and plunge angles. The orientation tensor isnʃt required by the program but it provides useful quantitative information describing the orientation of the fabric. See orientation_tensor.

Wrappers

common_offset.sh

This is a wrapper that simulates a common offset survey. The receiver .xyz file is input to give the points of the survey and the source is offset from this location given the offsets for the x, y, and z directions. See common_offset.

common_midpoint.sh

This is similar to the common offset survey but it shifts the source and reciever away from a common midpoint. The midpoint is specified by the source location in the project file. By default the source will be to the viewer∫s right of the midpoint but to flip the location of the source and reciever, set the midpoint x-value to negative. See common_midpoint.

> **Note**
>
> The aspect ratio for the common offset and common midpoint surveys determines the axis exaggeration. This will be updated in the future to be easier to adjust but to change this value edit the line `ax.set_aspect(aspect=??)` in `arrayplot.py` and `codisplay.py` then run the plotting scripts individually not the wrapper scripts.

prjbuild

generates project text file template

Usage

```
prjbuild -i IMAGEFILE -p PROJECTFILE
```

Inputs

- `-i`: .png file of cross sectional view of study site
    - No antialiasing
    - Use pixels dimensions proportional to unit dimensions
    - Start with small dimensions (150x150, 200x500), as larger dimensions quickly become more time intensive
- `-p`: filename, including .prj extension

Outputs

- Project file to fill in based on site characteristics

sourcefunction

Creates .dat files needed to define the source impulse. Does not need to be run if files are already present.

Usage

```
sourcefunction [-h] -p PRJFILE -S SOURCETYPE -m [s e b] -a AMPLITUDE
```

Inputs

- `-p`: PRJFILE

  Path to the .prj file, which must have dt and permittivity and stiffness tensors completed (usually via the `-m n` option of `prjrun`).
- `-S`: Source type

  Specify the source type. Available wavelets are: gaus0, gaus1, gaus2 (gaussian n-th derivative), chirp, chirplet. (Default = gaus0)
- `-m`: Model type

  Specify whether to construct the source for an electromagnetic or seismic model. e: electromagnetic, s: seismic, b: both
- `-a`: Amplitude

Input the scalar actor for source amplification. (Default = 1.0)

- -h, --help

  show this help message and exit

Outputs

.dat files in x, y, z for each model type

prjrun

Performs single-shot wave propagation with receiver locations specified later in postprocessing.

Usage

```
prjrun -p PROJECTFILE -m [n e s] -a [0 1]
```

Inputs

- -p PROJECTFILE, --prjfile PROJECTFILE .prj file

  The file path for the project file, completely filled in for the model type used except for permittivity and stiffness coefficients, and dt

- -m [n e s] Which model to run

  - n calculates only timesteps and material tensors, necessary before running sourcefunction
  - e electromagnetic propagation
  - s seismic wave propagation

- -a [0 1] (optional)

  Append/recompute the coefficients to the permittivity and stiffness matrices; 1 = yes, 0 = no; default = 1. Do not recompute if you have made manual changes to the matrices in the prj file.

Outputs

.dat files equal in number to the number of time steps specified in the .prj file.

common_offset

A wrapper script to create a common offset survey. The survey is along the x-direction, but can be extended to other directions.

Usage

```
common_offset -p PROJECTFILE -o X Y Z -r RCXFILE -s [OPTIONAL] -c VALUE [optional]
```

Inputs

- -p PROJECTFILE, --project PROJECTFILE

  Project file path

- -o X Y Z, --offset X Y Z

  Source-receiver offset distance for all three directions (meters). Even in 2D calculations, you must enter three space-separated X Y Z values.

- -r RCXFILE, --receivers RCXFILE

  The coordinate locations of every survey point (meters). The file is comma-delimited in each row, with the first row required to by „X,Y,Zƒ

- -s, --seismic

  (OPTIONAL) Specifier to run seismic common offset. Default is electromagnetic.

€ -c, --cores

For parallel computation, specify the number of cores.

Outputs

Three CSV files, containing Ex, Ey, and Ez (or Vx, Vy, Vz) values, with time series in columns of the source locations.

common_midpoint

creates receiver setup by defining final and middle locations, and receiver spacing across surface

UNDER CONSTRUCTION

Usage

```
common_midpoint -p PROJECTFILE -t [X] -o [X] \
  -d [distance between each receiver] [-s] [-p]
```

Inputs

€ -p PROJECTFILE, --prjfile PROJECTFILE

The project file path

€ -t VALUE, --total VALUE

The terminal distance between the source and receiver

€ -o VALUE, --offset VALUE

The initial source and receiver offset from the midpoint given in (+/- meters). A negative value means that the source is left of the midpoint. The total source and reciever distance is 2*offset.

€ -d VALUE, --delta VALUE

Source and receiver step length (meters); total distance between the source and receiver is 2*delta*i + 2*offset.

€ -s, --seismic

(OPTIONAL) Specifier to run seismic common offset

€ -p, --plot

(OPTIONAL) Show plot. Default is none

Outputs

orientation_tensor

Wrapper to generate the Euler angles for the plunge and trend then plot the results

Usage

```
orientation_tensor -o ANGFILE -n VALUE -P VALUE -t VALUE -a VALUE -A VALUE -S
```

Inputs

€ -o, --outputfile

Specify the file to save the outputs

€ -n VALUE, --npts VALUE

Total number of grains in synthetic sample

€ -P VALUE, --plunge VALUE

Plunge angle in degrees for center of single pole

€ -t VALUE, --trend VALUE

Trend angle in degrees for center of single pole

- -a VALUE, --anglemin VALUE

  Minimum angle deviation from center of single pole

- -A VALUE, --anglemax VALUE

  Maximum angle deviation from center of single pole

- -S, --suppress_plotting

  (OPTIONAL) Suppress all plotting

Outputs

- -o FILE, --outputfile FILE

  This will produce a delimited file, the name of which you can enter on the materials line(s) in the prj file.

arraybuild

generates a csv file (receiver_array.csv) with the timeseries in columns by receiver

Usage

```
arraybuild [-h] -p PROJECTFILE -r RCXFILE [-i INDEX] -c CHANNEL
```

Inputs

- -h, --help

  show this help message and exit

- -p PROJECTFILE, --prjfile PROJECTFILE

  The project file path

- -r RCXFILE, --rcxfile RCXFILE

  The file path for the text file of receiver locations

- -i INDEX, --index INDEX

  Indicate whether the receiver file contains coordinate indices or if these are the locations in meters. Default (0 - meters)

- -c CHANNEL, --channel CHANNEL

  The channel to query.

  For radar: Ex, Ey, or Ez
  For seismic: Vx, Vy, Vz, S1, S2, S3, S4, S5, S6
  S# represents the stress tensor:

  - S1 - sigma_11
  - S2 - sigma_22
  - S3 - sigma_33
  - S4 - sigma_23
  - S5 - sigma_13
  - S6 - sigma_12

Outputs

CSV of amplitude values for all pixels surveyed (*receiver_array.csv*)

rcxdisplay

Plot the amplitude timeseries based on a csv matrix

Usage

```
rcxdisplay -p PROJECTFILE -f DATAFILE -g VALUE -e VALUE -s [OPTIONAL]
```

Inputs

- -p PROJECTFILE, --prjfile PROJECTFILE .prj file

  The file path for the project file.

- -f DATAFILE, --file DATAFILE

  Path to the csv file with receiver timeseries data, commonly receiver_array.csv or [Vx Vy Vz Ex Ey Ez].co.csv. See arraybuild for how to generate this file for single shots.

- -g VALUE, --gain VALUE

  Gain (smoothing length). Possible values are 1 through the number of timesteps.

- -e VALUE, --exaggeration VALUE

  Vertical exaggeration. Set the aspect ratio between the x and z axes for plotting. Default is 0.5

- -s VALUE, --seismic VALUE

  (OPTIONAL) Whether the model is seismic rather than electromagnetic

  - A nonzero value sets this flag to True (i.e. mark as a seismic model)
  - A value of 0 sets this (explicitly) to False (i.e. mark as an electromagnetic model, this is the default)

Outputs

Plot of amplitude across area surveyed.

wiggleplot

Plot single, and select handful of amplitudes at specified X locations and all Z locations

Usage

```
wiggleplot -p PROJECTFILE -r DATAFILE -g VALUE -x VALUE -d VALUE -n VALUE \
   -c [Ex Ey Ez Vx Vy Vz]
```

Input

- -p PROJECTFILE, --prjfile PROJECTFILE .prj file

  The file path for the project file.

- -r receiver_array.csv

  The file path for the receiver array data, typically receiver_array.csv

- -g VALUE, --gain VALUE

  The linear horizontal exaggeration of the amplitude values from the receiver array file.

- -x VALUE, --receiver_spacing

  The horizontal distance between receivers, in meters, to lable the x-axis properly.

- -d, --columns

  The frequency at which columns are pulled for plotting from the csv file

- -n VALUE, --single_plot_dist

  The receiver number (column) indicating amplitude values will be plotted in a single-wiggle plot

- -c [Ex Ey Ez Vx Vy Vz], --channel [Ex Ey Ez Vx Vy Vz]

  The channel to query (Vx for the seismic x direction, for example)

Output

- Plot of the amplitude value of each pixel in a column
- Plot of the amplitude value of every pixel in every nth column aligned across a graph

im2anim

Create animation of the propagation of waves across a 2-dimensional study area

Usage

```
im2anim -p PROJECTFILE -c [Ex Ez Vx Vz] -n [steps in time series] \
  -d [delay between frames]
```

Inputs

- `-p PROJECTFILE`, `--prjfile PROJECTFILE` .prj file

  The full file path for the project file
- `-c [Ex Ez Vx Vz]`, `--channel [Ex Ez Vx Vz]`

  Whether to plot the seismic or radar model in the X or Z direction
- `-n VALUE`, `--num_steps VALUE`

  Interval between time series steps used to create the animation
- `-d VALUE`, `--delay VALUE` OPTIONAL

  Delay between frames, default=1
- `-a VALUE`, `--alpha VALUE` OPTIONAL

  Change the transparency of the model plotted in the background; default = 0.3. Zero is full transparency, 1 is opaque.

Outputs

A GIF animation of the wave propagation.

vtkbuild

Creates a series of 3-dimensional vti files that can be imported into Paraview to generate an animation. (Directly building the animation is planned for a future release.)

Usage

```
vtkbuild [-h] -p PROJECTFILE -c [Ex Ey Ez Vx Vy Vz] -n NUM_STEPS
```

Inputs

- `-p PROJECTFILE`, `--prjfile PROJECTFILE` .prj file

  The full file path for the project file.
- `-c [Ex Ey Ez Vx Vy Vz]`, `--channel [Ex Ey Ez Vx Vy Vz]`

  Whether to plot the seismic or radar model in the X, Y, or Z direction
- `-n VALUE`, `--num_steps VALUE`

  The time step interval between the images that are going to be used. n=20 means that 1 out of every 20 images will be used, thus significantly reducing how long it takes to compile.

implot

Plot a snapshot of the wavefield in 2D

Usage

```
implot -p PROJECTFILE -v VELOCITYFILE
```

Inputs

- `-p PROJECTFILE, --prjfile PROJECTFILE` .prj file

    The full file path for the project file

- `-v VELOCITYFILE, --velocity VELOCITYFILE`

    The .dat file that corresponds to the velocity in either the x-direction or z-direction (e.g. Vx000400.dat). The corresponding orthogonal velocity file will be loaded as well.

Outputs

A png image of seismic or radar return of the selected timestep overlain on the model geometry

imvector

Plot a snapshot of the vector wavefield in 2D

Usage

```
imvector -p PROJECTFILE -v VELOCITYFILE
```

Inputs

- `-p PROJECTFILE, --prjfile PROJECTFILE` .prj file

    The full file path for the project file

- `-v VELOCITYFILE, --velocity VELOCITYFILE`

    The .dat file that corresponds to the velocity in either the x-direction or z-direction (e.g. Vx000400.dat). The corresponding orthogonal velocity file will be loaded as well.

Outputs

A png image of seismic or radar vector field of the selected timestep overlain on the model geometry

vectoranim

This program builds a gif from the set of image output of the FDTD modeling. The images can be in csv or unformatted Fortran binary, however, the program runs faster to use the latter. To use, ensure the project file is in the same directory as the output files.

Usage

```
vectoranim -p PROJECTFILE -n VALUE
```

Inputs

- `-p PROJECTFILE, --prjfile PROJECTFILE` .prj file

    The full file path for the project file

- `-n VALUE, --num_steps VALUE`

    The time step interval between the images that are going to be used. Every time step is written to file which means that we can take any equally spaced images to create the gif with an appropriate resolution, time to compute, and file size. For example, n=20 means that every 20 images will be used thus significantly reducing how long it takes to compile the gif.

Outputs

A GIF animation of the wave propagation.

Creating a png file

Geometries for the model domain within SeidarT are initiated with a PNG image. The program identifies unique RGB values, setting material properties for each. For example, if you wanted to define a geometry with ice overlying bedrock, you would create a .png image that is one color for the ice and another for the rock below. Everyone has their preferences to generate images but GIMP or Inkscape provide free and open software that are more than sufficient.

> **Note**
>
> When creating a PNG, anti-aliasing must be turned off to avoid color boundary gradients.

Building images in Inkscape has some advantages other than being free. Saving a .svg to pdf allows the user to change the number of pixels and the spatial resolution of the image quite easily. With ghostscript, the command

```
gs -q -dBATCH -dNOPAUSE -sDEVICE=png16m -sOutputFile=<file> -r96 <input_file>
```

will generate a PNG file from a PDF. The resolution `-r` can be varied to change the pixels. In Inkscape, the image pixels can be set in Document Properties. When saving the SVG as PDF, you will be prompted with options, and the value for Resolution for rasterization (dpi): will determine - in order to get the same pixel setting that you set in Inkscape - the value for the `-r` (resolution) option above. If you want to double the resolution, just double this number (i.e. `-r192`).

Building documentation

This documentation is built with Sphinx 3.5.4 and rst2pdf 0.98.

To build the documentation, ensure you are in the SeidarT conda environment, then install the requirements:

```
pip install sphinx==3.5.4 sphinx_rtd_theme rst2pdf
```

Then, change directory into `docsrc/`:

```
cd SeidarT/docsrc
```

Then, use the `make` command to direct Sphinx to build the documentation:

```
make github
```

This will build documentation (both HTML and PDF) and move these items to the folder where GitHub will look to render them (`docs/`). Additionally, you can specify which documentation is built by using the `make html` or `make pdf` in order to preview these. The outputs of these intermediary commands will be in `docsrc/_build/html` or `docsrc/_build/pdf`.

Additional information can be found here.

> **Note**
>
> Sphinx 4.0 and above depreciates a function that rst2pdf relies on to build the PDF file. At this time it is necessary to downgrade to Sphinx 3.5.4 in order to build documentation in PDF format.

Currently available materials

- air
- ice1h

- € soil
- € water
- € oil
- € dry_sand
- € wet_sand
- € granite
- € gneiss
- € basalt
- € limestone
- € anhydrite
- € coal
- € salt

Units

Units for seismic output are meters per second.

Units for electromagnetic output are volts per meter.

References

< references will go here >
< a reference list may look like the following >

1. Bernsen, Steven (2021). *SeidarT: seismic and radar toolbox* (unpublished). University of Washington.
2. Gerbi, Christopher (2021). *SeidarT: seismic and radar toolbox* (unpublished). University of Maine.

Search documentation

Need to look something up?

- € **search**