mttime

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CONTENTS

mttime is a python package developed for time domain inversion of complete seismic waveform data to obtain the seismic moment tensor. It supports deviatoric and full moment tensor inversions, and 1-D and 3-D basis Green's functions.

CHAPTER

ONE

GETTING STARTED

1.1 Requirements

The package was developed on python 3.7 and 3.8, and is running and tested on Mac OSX.

- ObsPy 1.0.* and its dependencies
- pandas 1.0.*

1.2 Installation

- Create a Python environment
- Install ObsPy and pandas
- Make sure you have cloned the repository
- Install mttime

I recommend installing Python via Miniconda or Anaconda. Choose Miniconda for a lower footprint. Then follow the instructions on their sites to install ObsPy and pandas for your given platform.

Download mttime and install it from source. If you installed Python via conda make sure you activate the environment where ObsPy and pandas are installed.

```
# Activate environment
conda activate your_environment

# Build and install mttime
git clone https://github.com/LLNL/mttime
cd mttime
python setup.py install
```

Finally, if you want to run the tutorials you will need to install Jupyter Notebook.

1.3 Usage

You can execute the package from the command line or run it interactively in the Python console. In either case you will need to provide an input file that contains information about the file structure and parameters to set up the inverse routine. If no file is given the code will look for a file named **mtinv.in** in the current working directory.

Executing the package from command line will launch the inversion, save and plot the result to file:

```
mttime-run mtinv.in
```

The equivalent in the Python console:

```
>>> import mttime
>>> config = mttime.Configure(path_to_file="mtinv.in")
>>> mt = mttime.Inversion(config=config)
>>> mt.invert()
>>> mt.write()
```

Refer to the *User Guide* for more details.

CHAPTER

TWO

USER GUIDE

The user guide covers the inverse routine and file structure. Users brand new to moment tensor inversion should check out the Jupyter Notebook tutorials for an complete example that includes data processing and synthetics calculation.

Further information on any specific method can be obtained in the *API Reference*.

2.1 Basics

The inverse routine is divided into three main parts:

1. Parsing an input file to get a set of parameters required to run the inversion.
2. Perform the inversion based on the parameters provided.
3. Write the results to file.

```
>>> # import the package
>>> import mttime

>>> # 1. read input file and set up the inversion
>>> config = mttime.Configure(path_to_file="mtinv.in")
>>> mt = mttime.Inversion(config=config)

>>> # 2. Run inversion and plot the result (if plotting function is turned on)
>>> mt.invert()

>>> # 3. Save result to file
>>> mt.write()
```

We will go over the details in the following sections.

2.2 Dataset

In this section we will introduce the file structure and input parameters using an example. The earthquake in this example occured near Byron, California on July 16, 2019. The raw data and instrument response were obtained from the IRIS DMC using ObsPy's mass_downloader functionality.

2.2.1 Directory and file structures

In this example all of the files (input, data and synthetics) are assumed to be located under a single root directory called **project**:

```
project
|    mtinv.in
|
|____40191336
|    |  BK.QRDG.00.z.dat
|    |  BK.RUSS.00.z.dat
|    |  ...
|
|____40191336/gil7
     |  BK.QRDG.00.12.0000.ZDD
     |  BK.QRDG.00.12.0000.ZDS
     |  ...
```

Under project there is the input parameter file **mtinv.in** which contains headers and a station table:

```
origin          2019-07-16T20:11:01.470000Z
longitude       -121.7568
latitude        37.8187
depth           10,12,20
path_to_data    40191336
path_to_green   40191336/gil7
green           herrmann
components      ZRT
degree          6
weight          distance
plot            1
correlate       0
    station  distance  azimuth  ts  npts   dt  used  longitude  latitude
 BK.QRDG.00     80.99   335.29  32   150 1.00     1    -122.14     38.48
 BK.RUSS.00     81.16   353.18  32   150 1.00     1    -121.87     38.54
  BK.CVS.00     84.88   313.73  31   150 1.00     1    -122.46     38.35
 BK.OAKV.00     88.89   320.02  31   150 1.00     1    -122.41     38.43
 BK.FARB.00    110.46   263.41  31   150 1.00     1    -123.00     37.70
  BK.SAO.00    120.23   166.71  31   150 1.00     1    -121.45     36.76
  BK.CMB.00    122.83    78.33  31   150 1.00     1    -120.39     38.03
 BK.MNRC.00    132.06   333.21  32   150 1.00     1    -122.44     38.88
```

Configure object will parse the input text file.

```
>>> config = mttime.Configure(path_to_file="mtinv.in")
```

The headers have two columns: a parameter name and its corresponding value. If the values are left blank, the default values will be used instead. A descrption of the parameters are shown here:

parameters	description
path_to_file	path to input file containing headers and station information. Directory will become the project root directory. Default is `"./mtinv.in"`.
datetime	event origin time, optional.
longitude	event longitude, optional.
latitude	event latitude, optional.
depth	source depths to invert.
path_to_data	path to data files, relative to root directory. Defaults is `"./"`.
path_to_green	path to Green's function files, relative to root directory. Defaults is `"./"`.
green	Green's function format, options are `"herrmann"` or `"tensor"`. Defaults to `"herrmann"`.
components	waveform components, options are `"Z"` for vertical component, or `"ZRT"` for three-component data in vertical, radial and transverse components. Defaults to `"ZRT"`.
degree	degrees of freedom allowed in the inversion, options are `5` for deviatoric or `6` for full. Defaults to `5`.
weight	data weights, options are `"none"`, `"distance"` or `"variance"` for no weights, inverse distance, or inverse variance, respectively. Defaults to `"none"`.
plot	If `True` will plot the solution and waveform fits. Default is `False`.
correlate	Flag to cross-correlate data and Green's functions for best time shift in time points. Default is `False`.

Station table

Lines 13 and onward in **mtinv.in** contain the station information, line 13 is the station header and should not be modified. A description of the headers is shown here:

headers	description
station	file names of data and synthetics
distance	source-receiver distance
azimuth	source-receiver azimuth
ts	shift data by the number of time points specified
npts	number of samples to invert
dt	sampling interval in seconds
used	components to invert, set 1 to invert and 0 for prediction only. For three component data you can set flags for individual components, ordered by ZRT. e.g. 110 will invert ZR components only
longitude	station longitude
latitude	station latitude

2.2.2 Waveform Data

mttime expects both observed and synthetic Green's functions to be fully processed. This means they are corrected for instrument response, filtered, and decimated, and saved as SAC binary files.

The data file names have the following format:

[station].[component].dat

- station: from the station column
- component: Z, R, or T (from the components parameter)

With the example above the data file names for station BK.CMB.00 are:

- BK.CMB.00.Z.dat
- BK.CMB.00.R.dat
- BK.CMB.00.T.dat

2.2.3 Synthetic Seismograms

The basis Green's functions can be combined to create three component time histories for an arbitrarily oriented point source. As mentioned previously two types of synthetic basis Green's functions are accepted: `herrmann` and `tensor`.

The tensor format is pretty straight forward, it consists of the six elementary tensor elements in cartesian space. north, east and down directions (x, y and z) in Aki and Richards (2002). The herrmann format is based on the formulation of Herrmann and Wang (1985), which consists of ten fundamental source types.

The synthetic file names have the following format:

[station].[depth].[green_function_name]

- station: from the station column
- depth: source depth with four significant digits
- component: Z, R, or T (from the components parameter)
- green_function_name: this depends on format of the Green's functions
  - `herrmann`: TSS, TDS, RSS, RDS, RDD, ZSS, ZDS, ZDD, REX, and ZEX (total of 10)
  - `tensor`: ZXX, ZYY, ZZZ, ZXY, ZXZ, ZYZ, RXX, etc. (total of 18)

With the example above the synthetic file names for station BK.CMB.00 are:

- BK.CMB.00.12.0000.TSS
- BK.CMB.00.12.0000.TDS
- and so on.

If we change the format to tensor (such that `green="tensor"`), the file names become:

- BK.CMB.00.12.0000.TXX
- BK.CMB.00.12.0000.TXY
- and so on.

2.3 Output Files

Running the inversion with the example above will generate the following outputs.

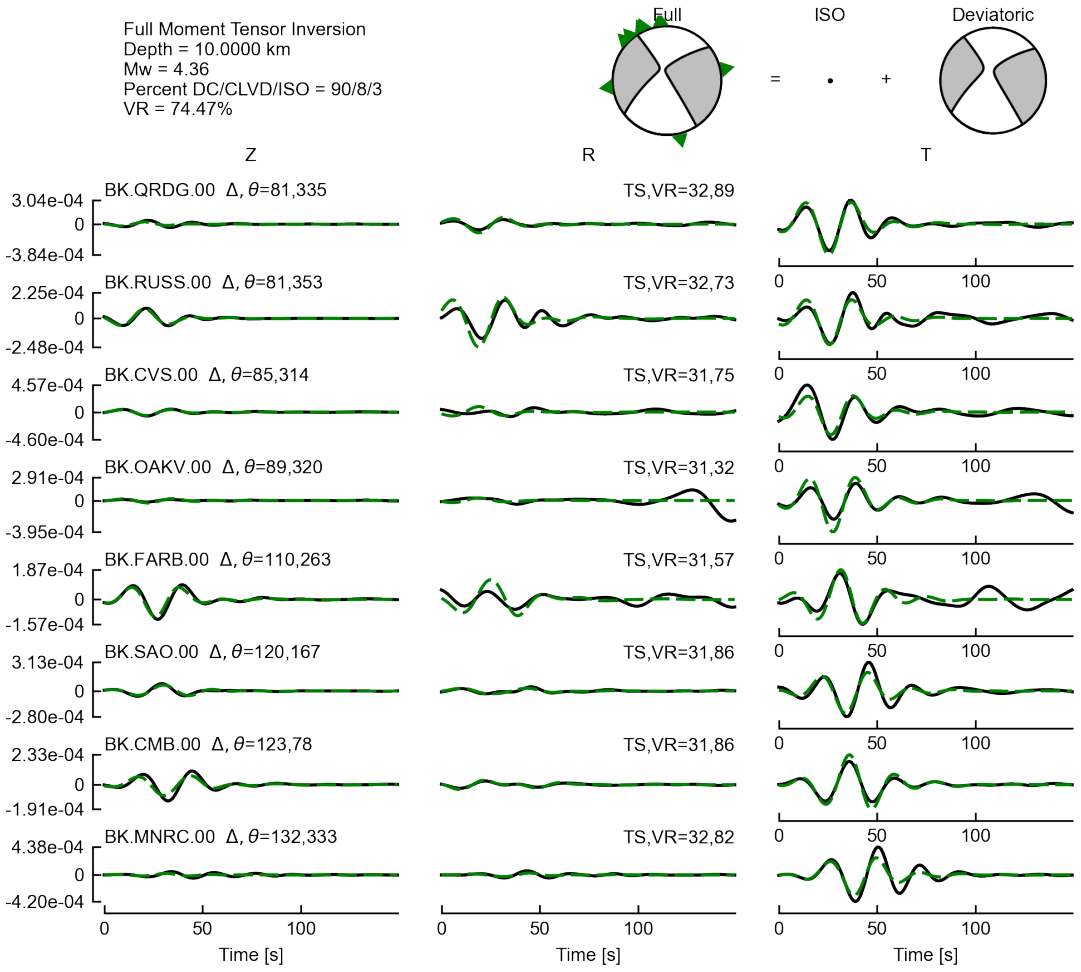
```
>>> mt = mttime.Inversion(config=config)
>>> mt.invert()
>>> mt.write()
```

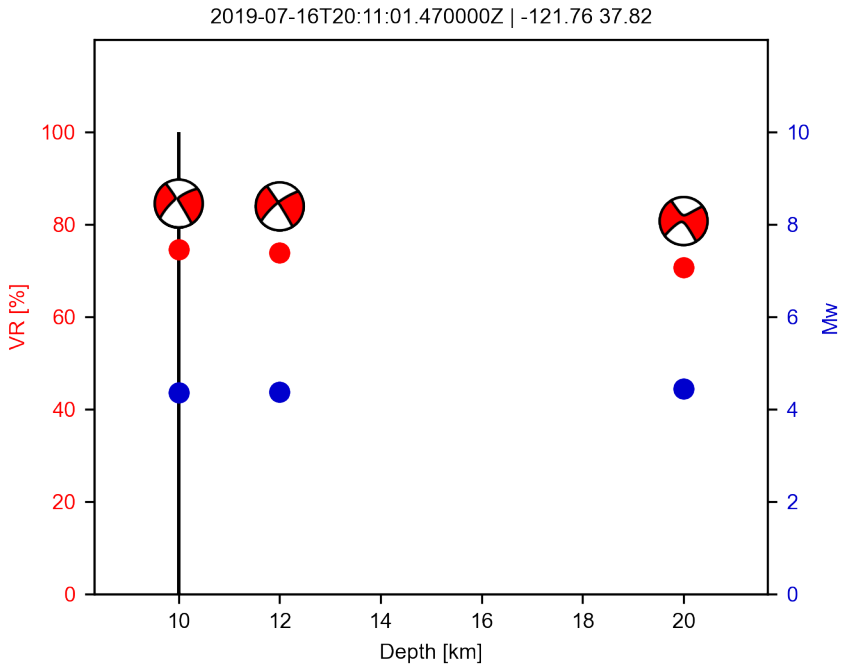
- Text files:
  - d10.0000.mtinv.out - moment tensor solution at 10 km depth
  - d12.0000.mtinv.out
  - d20.0000.mtinv.out

```
Full Moment Tensor Inversion
Depth = 10.0000 (km)
Mo = 3.833e+22 (dyne-cm)
Mw = 4.36
Percent DC    =  90
Percent CLVD =   8
Percent ISO  =   3
Fault Plane 1: Strike=233 Dip=66 Rake=-6
Fault Plane 2: Strike=326 Dip=84 Rake=-156
Percent Variance Reduction = 74.47

Moment Tensor Elements: Aki and Richards Cartesian Coordinates
Mxx         Myy         Mzz         Mxy         Mxz         Myz
-2.836e+22 3.458e+22  -3.037e+21 -1.067e+22 1.033e+22  1.066e+22

Harvard/CMT convention
Mrr         Mtt         Mpp         Mrt         Mrp         Mtp
-3.037e+21 -2.836e+22 3.458e+22  1.033e+22  -1.066e+22 1.067e+22

Eigenvalues: 3.833e+22 -3.790e+20 -3.477e+22
Lune Coordinates: -1.95  2.03
Station Information
    station distance azimuth  ts  npts   dt  Z  R  T weights    VR longitude latitude
 BK.QRDG.00    80.99  335.29  32   150 1.00  1  1  1    1.00 89.26  -122.140   38.480
 BK.RUSS.00    81.16  353.18  32   150 1.00  1  1  1    1.00 73.30  -121.870   38.540
  BK.CVS.00    84.88  313.73  31   150 1.00  1  1  1    1.05 74.81  -122.460   38.350
 BK.OAKV.00    88.89  320.02  31   150 1.00  1  1  1    1.10 32.40  -122.410   38.430
 BK.FARB.00   110.46  263.41  31   150 1.00  1  1  1    1.36 56.80  -123.000   37.700
  BK.SAO.00   120.23  166.71  31   150 1.00  1  1  1    1.48 86.32  -121.450   36.760
  BK.CMB.00   122.83   78.33  31   150 1.00  1  1  1    1.52 85.93  -120.390   38.030
 BK.MNRC.00   132.06  333.21  32   150 1.00  1  1  1    1.63 82.31  -122.440   38.880
```

- Figures:
  - bbwaves.d10.0000.00.eps - focal mechanism and waveform fits at 10 km depth
  - bbwaves.d12.0000.00.eps
  - bbwaves.d20.0000.00.eps
  - depth.bbmw.eps

Since we performed the inversion at multiple source depths, in addition to the standard focal mechanism and waveform figures, the plotting function will also generate a figure that shows the solution as function of source depth.


Full Moment Tensor Inversion
Depth = 10.0000 km
Mw = 4.36
Percent DC/CLVD/ISO = 90/8/3
VR = 74.47%
Full
ISO
Deviatoric
=
+
Z
R
T
BK.QRDG.00 Δ, θ=81,335
TS,VR=32,89
3.04e-04
0
-3.84e-04
BK.RUSS.00 Δ, θ=81,353
TS,VR=32,73
2.25e-04
0
-2.48e-04
BK.CVS.00 Δ, θ=85,314
TS,VR=31,75
4.57e-04
0
-4.60e-04
BK.OAKV.00 Δ, θ=89,320
TS,VR=31,32
2.91e-04
0
-3.95e-04
BK.FARB.00 Δ, θ=110,263
TS,VR=31,57
1.87e-04
0
-1.57e-04
BK.SAO.00 Δ, θ=120,167
TS,VR=31,86
3.13e-04
0
-2.80e-04
BK.CMB.00 Δ, θ=123,78
TS,VR=31,86
2.33e-04
0
-1.91e-04
BK.MNRC.00 Δ, θ=132,333
TS,VR=32,82
4.38e-04
0
-4.20e-04
0
50
100
Time [s]



2.4 Figure Options

There are more display options available in *mttime.core.inversion.Inversion.plot*.

- `view="waveform"` - MT solution and waveform fits.
- `view="depth"` - MT solution as a function of source depth.
- `view="map"` - map view.
- `view="lune"` - full MT source-type on the lune.

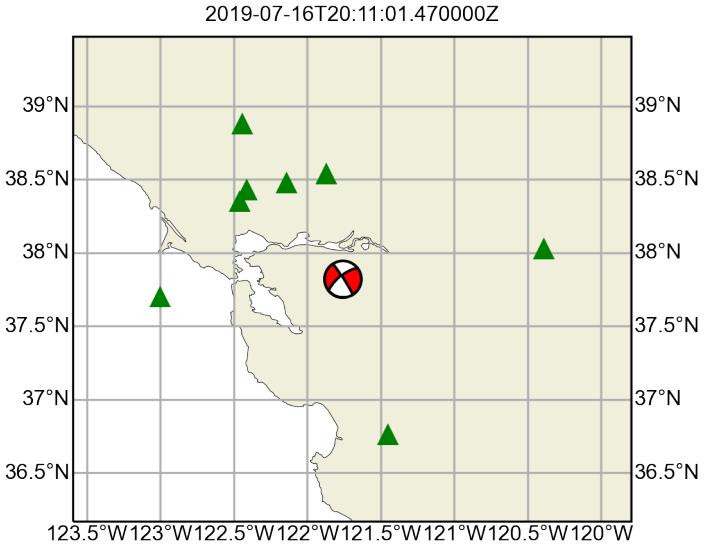
In the example above we set `mt.config.plot=True`, which is equivalent to:

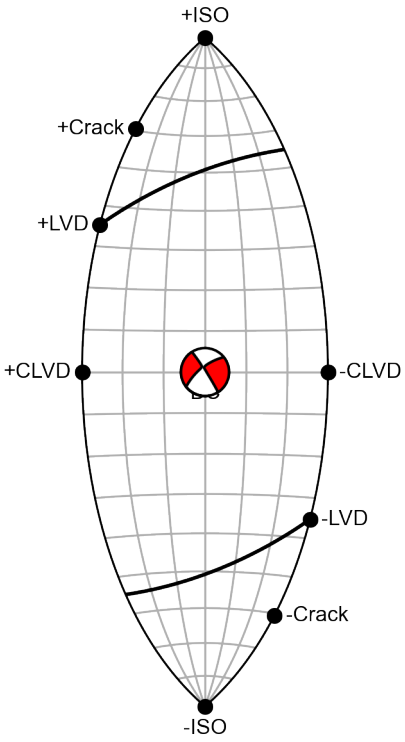
```
>>> mt.plot(view="waveform")
>>> mt.plot(view="depth") # if depth is not fixed
```

To plot the solution on a map or lune:

```
>>> mt.plot(view="map", show=True)
```

```
>>> mt.plot(view="lune", show=True)
```


2019-07-16T20:11:01.470000Z
39°N
38.5°N
38°N
37.5°N
37°N
36.5°N
123.5°W
123°W
122.5°W
122°W
121.5°W
121°W
120.5°W
120°W


+ISO
+Crack
+LVD
+CLVD
-CLVD
-LVD
-Crack
-ISO

CHAPTER

THREE

API REFERENCE

This page gives an overview of all public mttime objects, methods and functions.

3.1 Core Modules

mttime.core.configure	Set global mttime configuration
mttime.core.inversion	Time domain moment tensor inverse routines
mttime.core.tensor	Routines for handling inversion results
mttime.core.utils	Utility functionality for mttime

3.1.1 mttime.core.configure

Set global mttime configuration

Example

```
>>> import mttime
>>> # read input file mtinv.in
>>> config = mttime.Configure(path_to_file="mtinv.in")
```

Classes

Configure	Configure object for *Inversion*

mttime.core.configure.Configure

class Configure(*path_to_file=None*, *df=None*, ***kwargs*)

Bases: object

Configure object for *Inversion*

Sets up the moment tensor inverse routine. **kwargs can be provided either in path_to_file or during class instantiation. df and depth are required if not reading from a file. **kwargs will override the values in path_to_file and any missing keyword arguments will be set to their default values.

Parameters

- **path_to_file** (*str*) – path to input file containing headers and station information. Input file should be located in the project root directory.
- **df** (DataFrame) – station table, required if path_to_file=None.
- **datetime** (*str, optional*) – event origin time.
- **longitude** (*float, optional*) – event longitude.
- **latitude** (*float, optional*) – event latitude.
- **depth** (*float, int, list*) – source depths to invert, required if path_to_file=None
- **path_to_data** (*str*) – path to data files, relative to root directory. Defaults is ".".
- **path_to_green** (*str*) – path to Green's function files, relative to root directory. Default is ".".
- **green** (*str*) – Green's function format, options are "herrmann" or "tensor". Default is "herrmann".
- **components** (*str*) – waveform components, options are "Z" for vertical component, or "ZRT" for three-component data in vertical, radial and transverse components, and "ZNE" for vertical, north and east. Default is "ZRT".
- **degree** (*int*) – degrees of freedom allowed in the inversion, options are 5 for deviatoric or 6 for full. Default is 5.
- **weight** (*str*) – data weights, options are "none", "distance" or "variance" for no weights, inverse distance, or inverse variance, respectively. Default is "none".
- **plot** (*int, bool*) – If True will plot the solution and waveform fits. Default is False.
- **correlate** (*int, bool*) – Flag to cross-correlate data and Green's functions for best time shift (in time points). Default is False.

Methods

write	Function to write inversion configuration to a file

mttime.core.configure.Configure.write

Configure.**write**(*fileout='config.out'*)

Function to write inversion configuration to a file

Write inverse routine parameters and station table to a file.

Parameters **fileout** (*str*) – output file name. Default is "config.out".

Example

```
>>> config = Configure()
>>> config.write(fileout="configure.out")
```

3.1.2 mttime.core.inversion

Time domain moment tensor inverse routines

Example

```
>>> config = mttime.Configure(path_to_file="examples/synthetic/mtinv.in")
>>> tdmt = mttime.Inversion(config=config)
>>> print(tdmt)
     event: {'datetime': '2019-07-16T20:10:31.473', 'longitude': -121.757, 'latitude
↪': 37.8187}
     depth: [10.0, 20.0]
     green: herrmann
components: ['Z', 'R', 'T']
    degree: 5
    weight: distance
      plot: False
 correlate: False
| STATION TABLE |
    station  distance  azimuth  ts  npts   dt  Z  R  T  longitude  latitude filter
↪nc  np  lcrn  hcrn model
 BK.FARB.00    110.00   263.00  30   100 1.00  0  0  0    -123.00     37.70     bp
↪2   2  0.05  0.10  gil7
  BK.SAO.00    120.00   167.00  30   150 1.00  0  0  1    -121.45     36.76     bp
↪2   2  0.05  0.10  gil7
  BK.CMB.00    123.00    78.00  30   150 1.00  0  0  0    -120.39     38.03     bp
↪2   2  0.05  0.10  gil7
 BK.MNRC.00    132.00   333.00  30   150 1.00  1  1  1    -122.44     38.88     bp
↪2   2  0.05  0.10  gil7
| PREFERRED SOLUTION |
None
>>> tdmt.invert()
Deviatoric Moment Tensor Inversion
Depth = 10.0000 km
Mw = 3.97
Percent DC/CLVD/ISO = 100/0/0
VR = 100.00%%

Deviatoric Moment Tensor Inversion
Depth = 20.0000 km
Mw = 4.25
Percent DC/CLVD/ISO = 62/38/0
VR = 87.05%%
```

Classes

Inversion	A container for a single inverse routine

mttime.core.inversion.Inversion

class Inversion(*config=None*)

Bases: object

A container for a single inverse routine

Object contains the inversion parameters, data and synthetic files, and moment tensor solutions.

Parameters **config** (*Configure*) – object containing the necessary parameters for setting up the inverse routine

Variables

- **streams** (a list of Stream) – processed waveform data.
- **moment_tensors** (a list of *Tensor*) – moment tensor solutions.
- **preferred_tensor_id** (*int*) – index to the preferred moment tensor solution (maximum variance reduction).

Methods

get_preferred_tensor	Returns the preferred moment tensor solution
invert	Launch the inversion
plot	Plot inversion results
write	Write inversion results to file

mttime.core.inversion.Inversion.get_preferred_tensor

Inversion.**get_preferred_tensor**()

Returns the preferred moment tensor solution

A function that returns the solution with the highest variance reduction (goodness-of-fit between data and synthetic waveforms).

Returns the preferred moment tensor solution.

Return type a *Tensor* object.

mttime.core.inversion.Inversion.invert

Inversion.**invert**(*show=False*)
Launch the inversion

Will perform multiple inversions if more than one source depth provided, and plot the results if attribute `config.plot=True`

mttime.core.inversion.Inversion.plot

Inversion.**plot**(***kwargs*)
Plot inversion results

Various options available to display the results.

Parameters

- **view** (*str*) – type of figure to produce. Default `waveform` creates the standard figure with focal mechanisms and waveform fits. `depth` shows the focal mechanism and moment magnitude as a function of depth. `map` plots stations and focal mechanisms in map view. `lune` plots the moment tensor source-type on a lune.
- **show** (*bool*) – If `True` will display figure after plotting and not save image to file, default is `False`.
- **format** (*str*) – figure file format, default is `"eps"`.
- **option** (*str, optional*) – Optional parameter if view is set to `waveform`. The default plots all solutions. Set to `preferred` to plot only the preferred solution.

mttime.core.inversion.Inversion.write

Inversion.**write**(*option=None*)
Write inversion results to file

Save all solutions or only the preferred solution to file. The output file name format is `d[depth].mtinv.out`.

Parameters **option** (*str*) – option to write all solutions or only the preferred solution. Default is `None`. If set to `preferred` only the solution with the highest VR will be saved.

3.1.3 mttime.core.tensor

Routines for handling inversion results

Functions

eigen2lune	Calculate source-type parameters on a lune
find_fault_planes	Compute direction of slip and orientation of fault planes
find_strike_rake_dip	Compute strike,rake and dip
get_m_in_basis	Convert moment tensor between coordinate systems

mttime.core.tensor.eigen2lune

eigen2lune(*lam*)

Calculate source-type parameters on a lune

A function that calculates the source-type parameters gamma and delta based on the formulation of Tape and Tape, (2012).

Parameters **lam** (ndarray) – eigenvalues in descending order.

Returns lune coordinates gamma and delta.

Return type (float, float)

mttime.core.tensor.find_fault_planes

find_fault_planes(*M*, *M_dc*)

Compute direction of slip and orientation of fault planes

Function that returns slip direction and orientation of fault plane and auxiliary plane.

Parameters

- **M** (ndarray) – moment tensor in matrix form.
- **M_dc** (ndarray) – double-couple moment tensor in matrix form.

Returns direction of slip and orientation of the fault plane and auxiliary plane.

Return type list((float, float, float), (float, float, float))

mttime.core.tensor.find_strike_rake_dip

find_strike_rake_dip(*u*, *n*)

Compute strike,rake and dip

A function that returns the strike, rake and dip of given slip and fault normal vectors.

Parameters

- **u** (ndarray) – slip vector.
- **n** (ndarray) – fault normal vector.

Returns strike, rake and dip of a fault plane.

Return type (float, float, float)

mttime.core.tensor.get_m_in_basis

get_m_in_basis(*m*, *in_basis*, *out_basis*)
Convert moment tensor between coordinate systems

A function that returns the moment tensor in a new coordinate system. See supported coordinate systems below.

Parameters

- **m** (ndarray or list) – moment tensor elements (M11, M22, M33, M12, M13, M23) for a given coordinate system (1, 2, 3).
- **in_basis** (*str*) – input moment tensor coordinate system.
- **out_basis** (*str*) – output moment tensor coordinate system.

Returns moment tensor in a new coordinate system.

Return type ndarray

Supported coordinate systems:

basis	vectors	reference
"NED"	north, east, down	Jost and Herrmann, 1989
"XYZ"	north, east, down	Aki and Richard, 1980
"USE"	up, south, east	Larson et al., 2010
"RTP"	r, theta, phi	Harvard/Global CMT convention

Classes

Tensor	Object containing a single six-element moment tensor

mttime.core.tensor.Tensor

class Tensor(*m*, *basis='XYZ'*, ***kwargs*)
Bases: object

Object containing a single six-element moment tensor

A container for all things related to the moment tensor m. Optional **kwargs are used to write and plot inversion results. Moment tensor elements will be stored in XYZ coordinates. Use *get_tensor_elements* to convert between coordinate systems.

Parameters

- **m** (ndarray) – six independent moment tensor elements (M11, M22, M33, M12, M13, M23) in dyne-cm.
- **basis** (*str*) – moment tensor coordinate system. Default is "XYZ".
- **depth** (*float*) – source depth.
- **inversion_type** (*str*) – Deviatoric or Full.
- **component** (*list (str)*) – waveform components.

- **station_table** (DataFrame) – station table. Required header names are: station, distance, azimuth, ts, dt, weights, VR, [ZRTNE] (one column for each component in component), longitude, and latitude.
- **total_VR** (*float*) – total variance reduction.
- **dd** (ndarray) – observed data stored as a single vector, required for plotting.
- **ss** (ndarray) – synthetic seismograms stored as a single vector, required for plotting.

Methods

decompose	Moment tensor decomposition
get_decomposition	Get the decomposition of a moment tensor
get_tensor_elements	Retrieve the moment tensor elements
write	Write detailed solution to file

mttime.core.tensor.Tensor.decompose

Tensor.**decompose**()

Moment tensor decomposition

A function that decomposes the moment tensor from attribute m. Moment is in dyne-cm.

Attributes

iso: ndarray isotropic moment tensor elements.

dev: ndarray deviatoric moment tensor elements.

dc: ndarray double couple moment tensor elements.

clvd: ndarray CLVD moment tensor elements.

eigenvalues: ndarray eigenvalues.

mo: float total scalar seismic moment in Bowers and Hudson (1999) convention.

mw: float moment magnitude.

mw_dev: float deviatoric moment magnitude.

miso: float isotropic moment.

mdc: float double-couple moment.

mclvd: float CLVD moment.

pdc: float percentage of double-couple component.

pclvd: float percentage of CLVD component.

piso: float percentage of isotropic component.

fps: list of (float, float, float) strike, dip, and rake of the two fault planes.

lune: (float, float) gamma and delta in lune source-type space.

mttime.core.tensor.Tensor.get_decomposition

Tensor.**get_decomposition**()
Get the decomposition of a moment tensor

A function that returns the decomposed moment tensor in a dictionary. Refer to *decompose* for the complete list of decomposition attributes.

Returns moment tensor decomposition.

Return type dict

mttime.core.tensor.Tensor.get_tensor_elements

Tensor.**get_tensor_elements**(*basis='XYZ'*)
Retrieve the moment tensor elements

Function that returns the moment tensor in the specified system coordinates.

Parameters **basis** (*str*) – system coordinates, default is XYZ. Refer to *get_m_in_basis* for supported systems.

Returns a dictionary of moment tensor elements.

Return type dict

mttime.core.tensor.Tensor.write

Tensor.**write**()
Write detailed solution to file

A function that saves the detailed moment tensor solution to a file named d[depth].mtinv.out.

Attributes

m	Moment tensor elements

mttime.core.tensor.Tensor.m

property Tensor.**m**
Moment tensor elements

MXX, MYY, MZZ, MXY, MXZ, MYZ in dyne-cm.

3.1.4 mttime.core.utils

Utility functionality for mttime

Functions

RGF_from_SW4	Function to convert reciprocal Green's functions from SW4 to tensor format
az2baz	Azimuth to back-azimuth conversion
gaussj	Solves the linear matrix equation Ax = b
get_dependency_version	Get version information of a dependency package.
rotate_rt2ne	Rotate to the great circle path.
to_int_or_zero	Converts given value to an integer or returns 0 if it fails.
xcorr	Compute cross-correlation coefficient

mttime.core.utils.RGF_from_SW4

RGF_from_SW4(*path_to_green='.'*, *t0=0*, *file_name=None*, *origin_time=None*, *event_lat=None*, *event_lon=None*, *depth=None*, *station_name=None*, *station_lat=None*, *station_lon=None*, *output_directory='sw4out'*)

Function to convert reciprocal Green's functions from SW4 to tensor format

Reads the reciprocal Green's functions (displacement/unit force) from SW4 and performs the summation to get the Green's function tensor. RGFs from SW4 are oriented north, east and positive down by setting az=0.

Assumes the following file structure: f[x,y,z]/station_name/event_name.[x,y,z]

Parameters

- **path_to_green** (*str*) – path to RGFs.
- **t0** (*float*) – offset in time (>=0).
- **file_name** (*str*) – name of RGF sac files from SW4 (event name).
- **origin_time** – event origin time.
- **event_lat** (*float*) – event latitude.
- **event_lon** (*float*) – event longitude
- **depth** (*float*) – source depth
- **station_name** (*list of strings.*) – station names.
- **station_lat** (*list of floats*) – station latitudes.
- **station_lon** (*list of floats*) – station longitudes.
- **output_directory** (*str*) – output direcotry.

mttime.core.utils.az2baz

az2baz(*angle*)
Azimuth to back-azimuth conversion

Parameters **angle** (*float or int*) – azimuth value in degrees between 0 and 360.

Returns corresponding back-azimuth value in degrees.

Return type float

mttime.core.utils.gaussj

gaussj(*A*, *b*)
Solves the linear matrix equation Ax = b

Computes the solution of a well-determined linear matrix equation by performing Gaussian-Jordan elimination for a given matrix and transforming it to a reduced echelon form.

Parameters

- **A** (numpy.ndarray) – coefficient matrix.
- **b** (numpy.ndarray) – vector of dependent variables.

Returns solution vector x so that Ax = b.

Return type numpy.ndarray

mttime.core.utils.get_dependency_version

get_dependency_version(*package_name*, *raw_string=False*)
Get version information of a dependency package.

Parameters **package_name** (*str*) – Name of package to return version info for

Returns Package version as a list of three integers or None if import fails. With option raw_string=True returns raw version string instead (or None if import fails). The last version number can indicate different things like it being a version from the old svn trunk, the latest git repo, some release candidate version, ... If the last number cannot be converted to an integer it will be set to 0.

mttime.core.utils.rotate_rt2ne

rotate_rt2ne(*r*, *t*, *az*)
Rotate to the great circle path.

Rotates a pair of horizontal component data from north and east direction to radial and tangential direction.

Parameters

- **r** (ndarray) – radial component data.
- **t** (ndarray) – tangential component data.
- **az** (*float*) – The direction from a seismic source to the seismic station measured clockwise from north.

Returns rotated horizontal component data oriented in north and east direction.

Return type Tuple of ndarray

mttime.core.utils.to_int_or_zero

to_int_or_zero(*value*)
Converts given value to an integer or returns 0 if it fails.

Function taken from misc

Parameters **value** – arbitrary data type.

Returns

Return type int

mttime.core.utils.xcorr

xcorr(*data*, *template*, *normalize=True*)
Compute cross-correlation coefficient

Parameters

- **data** (numpy.ndarray) – first time series.
- **template** (numpy.ndarray) – second time series.
- **normalize** (*bool*) – If True normalizes correlations.

Returns cross-correlation function.

Return type numpy.ndarray

3.2 Plotting Modules

mttime.imaging.source	Plotting routines for mttime
mttime.imaging.beachball	Draws the beach ball diagram of a moment tensor

3.2.1 mttime.imaging.source

Plotting routines for mttime

Warning: This module should NOT be used directly instead use the class method *plot*.

Functions

beach_map	Plot beach ball on a map
beach_mw_depth	Plot depth search result
plot_lune	Plot source-type on a lune
plot_waveform_fits	Plot waveform fits and focal mechanisms

mttime.imaging.source.beach_map

beach_map(*m*, *event*, *longitude*, *latitude*, *distance*, *used*, *show*, *format*)
Plot beach ball on a map

Function to plot stations and focal mechanisms on a map.

Parameters

- **m** (*list*) – focal mechanism.
- **event** (*dict*) – event origin time, longitude and latitude.
- **longitude** (list or ndarray) – station longitudes.
- **latitude** (list or ndarray) – station latitudes.
- **distance** (list or ndarray) – source-receiver distance.
- **used** (list or ndarray) – inverted stations. Sets the station marker colors, `True` for green and `False` for gray.
- **show** (*bool*) – display image after plotting instead of saving it to file.
- **format** (*str*) – figure file format.

mttime.imaging.source.beach_mw_depth

beach_mw_depth(*tensors*, *event*, *show*, *format*)
Plot depth search result

A function that plots focal mechanism, variance reduction, and moment magnitude as a function of source depth.

Parameters

- **tensors** (a list of *Tensor*) – moment tensor solutions at various depths.
- **event** (*dict*) – event origin time, longitude and latitude.
- **show** (*bool*) – display image after plotting instead of saving it to file.
- **format** (*str*) – figure file format.

mttime.imaging.source.plot_lune

plot_lune(*m*, *gamma*, *delta*, *show*, *format*)
Plot source-type on a lune

Function to plot moment tensor source type on a lune based on the formulation of Tape and Tape (2012). Theoretical source types and source type arcs are also plotted.

Parameters

- **m** – moment tensor.
- **gamma** (*float*) – lune longitude.
- **delta** (*float*) – lune latitude.
- **show** (*bool*) – display image after plotting instead of saving it to file.
- **format** (*str*) – figure file format.

mttime.imaging.source.plot_waveform_fits

plot_waveform_fits (*tensor*, *show*, *format*, *nrows=10*)
Plot waveform fits and focal mechanisms

Parameters

- **tensor** (*Tensor*) – moment tensor solution.
- **show** (*bool*) – display image after plotting instead of saving it to file.
- **format** (*str*) – figure file format.
- **nrows** (*int*) – maximum stations per page. Default is `10`.

3.2.2 mttime.imaging.beachball

Draws the beach ball diagram of a moment tensor

Source codes are adapted from `mopad_wrapper`.

Functions

beach	Plot beach ball based on MoPaD

mttime.imaging.beachball.beach

beach (*fm*, *linewidth=1*, *facecolor='0.75'*, *bgcolor='w'*, *edgecolor='k'*, *alpha=1.0*, *xy=(0, 0)*, *width=200*, *size=100*, *nofill=False*, *zorder=100*, *mopad_basis='NED'*, *axes=None*, *show_iso=False*)
Plot beach ball based on MoPaD

Function that returns a beach ball as a collection and can be added to an existing `Axes`.

Parameters

- **fm** (*list*) – focal mechanism in (strike, dip, rake) or (M11,M22,M33,M12,M13,M23). The moment tensor elements are given for a coordinate system with axes pointing in three directions.
- **linewidth** (*float*) – width of nodal and border lines. Default is `0.8`.
- **facecolor** (*str*) – color or shade of the compressive quadrants. Default is `0.75` (gray).
- **bgcolor** (*str*) – background color, default is `w` (white).
- **edgecolor** (*str*) – color of nodal and border lines, default is `b` (black).
- **alpha** (*float*) – beach ball transparency, default is `1.0` (opaque).
- **xy** (*tuple*) – original position of the beach ball. Default is `(0, 0)`
- **width** (*float*) – width of the beach ball (aka symbol size). Default is `200`.
- **size** (*int*) – number of points interpolated to draw the curve. Default is `100`.
- **nofill** (*bool*) – no shading of the beach ball. Default is `False`.
- **zorder** (*float*) – set the zorder for the artist. Artists with lower zorder values are drawn first. Default is `100`.
- **mopad_basis** (*str*) – moment tensor coordinate system. Default is `"NED"`.

- **axes** (Axes) – figure axis for beach ball, this is used to ensure the aspect ratio is adjusted so that the beach ball is circular on non-scaled axes. When this option is used figure cannot be saved in vector format. Default is None.
- **show_iso** (*bool*) – flag to display the isotropic component, default is False.

Returns a collection of lines and polygons.

Return type PatchCollection

Warning: Set axes=None if you want to save the beach ball image in vector file formats.

3.3 Scripts

mttime.scripts.run	mttime command line utility

3.3.1 mttime.scripts.run

Note: This script automatically installs during the setup procedure with the name $ tdmtpy-run. For more info on the command line options, please run $ tdmtpy-run --help. Alternatively you can also execute $ python -m mttime.scripts.run.

mttime command line utility

CHAPTER

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Note: The code is still under development, your feedback is appreciated.

PYTHON MODULE INDEX

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