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MoPaD ‑ Moment tensor Plotting and Decomposition

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MoPaD – *Mo*ment tensor *P*lotting *a*nd *D*ecomposition

1 General information

MoPaD is a tool for graphical and numerical analysis of seismic moment tensors. It is a python script containing 4 methods. The main feature is the visualisation of a focal sphere diagram as graphical output in several formats. Alternatively an output string can be generated, which may be piped into *GMT's psxy* for directly plotting beachballs into *GMT* maps.

The other two features of *MoPaD* are decompostion and conversion of the moment tensor. The output is brought on the shell and can be either piped into further processing steps or just be used for human interpretation.

2 Setup

2.1 preconditions

The conditions for running *MoPaD* is mainly the existence of a valid *Python* installation on the system (Version 2.4 or higher). Within the latter, the modules

- *matplotlib* and *numpy*

must be found.

For graphical output, *pylab* with its generic setup is loaded, so it should work out of the box. If the option *save* is chosen, the matplotlib-renderers are set to the appropriate file format. If this fails due to the system's options, the backend *GTKCairo* is used as a backup solution for generating *.png files (*PyGTK* is required for this though).

2.2 Installation

MoPaD is a python script, wrapped around two basis classes. So for using it from a shell, there is no need for further installation, but it has to be made executable by typing

```
chmod a+x mopad
```

3 Conventions

3.1 Orientation

The standard basis within *MoPaD* is (North, East, Down) - in short `NED`; it is used, if not stated otherwise. Optionally one can choose betweeen the alternative bases `UNE`, `NWU`, and `XYZ` for input and output.

3.2 M

The moment tensor (source mechanism) in the call of *MoPaD* is a comma-separated list of one of the following lenghts

- 3 (strike,dip,rake)

- 4 (strike,dip,rake,moment)

- 6 (M11,M22,M33,M12,M13,M23)

- 7 (M11,M22,M33,M12,M13,M23,moment)

- 9 (full moment tensor)

The moment must be a strict positive value! Strike, dip, and slip-rake are in degrees and they are automatically restricted to meanigful ranges.

3.3 Options and Arguments

Options are given by a "-" directly followed by the specific letter (case-sensitive). Different arguments are separated with a white space, whereas argument-tuples are concatenated with a comma (and NO white spaces in-between). The list of possible options can be found, calling "-h" (see section 4).

3.4 Deviatoric ↔ Isotropic

As a standard, only the deviatoric part of **M** is plotted. If the isotropic part shall be taken into account, the option "-I" must be given. If the percentage of the isotropic part is larger than 50%, a uniformly coloured disk is shown.

3.5 Eigenvectors

The eigenvectors EV show up with the option "-e". They are marked with triangles, pointing upwards for positive axis of the respective EV, pointing downwards for the negative ones. The colour green denotes tehe tension axis, magenta can be seen at the pressure axis, blue is the neutral axis.

4   Usage

In general the tool is used by choosing a method and providing a valid
moment tensor **M** .

- mopad <method> <moment tensor> [<options>]

The methods in *MoPaD* are

- (p)lot – plotting the focal sphere diagram (FSD)

- (g)mt – yielding a string, describing the FSD - to be piped into psxy

- (d)ecompose – decomposing **M** into its possible partitions

- (c)onvert – converting **M** from/into (strike,dip,rake)-form or change
  basis representation

Information about the possible input options at any point shows up by using
the option -h

- mopad -h

or

- mopad <method> -h

4.1   first example

A simple plot of an FSD, belonging to a rupture with (strike,dip,rake)=(0,0,0)
can be made with

- mopad plot 0,0,0

or in moment tensor representation in the basis (North,East,Down):
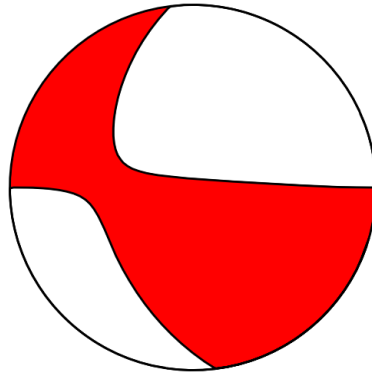
- mopad plot 0,0,0,0,-1,0

Figure 1: Standard FSD for $\mathbb{M}=[1,2,3,-4,-5,0]$

4.2 Method: `plot`

This ist the most important method, it returns a plot of a focal mechanism.

available options

- Saving
- Type of plot
- Quality
- colours
- Miscellanous
- Fault planes
- Geometry
- Appearance

Examples

In figure 1 a standard FSD without any additionals is shown as a first example of the handling of *MoPaD*. Simply use:

```
mopad plot 1,2,3,-4,-5,0
```

Assumingly very rare applications are demanding the effort of varying nearly all of the plot parametres for FSDs; nevertheless the possibility is given and the result is shown in figure 2; stemming from the following input:
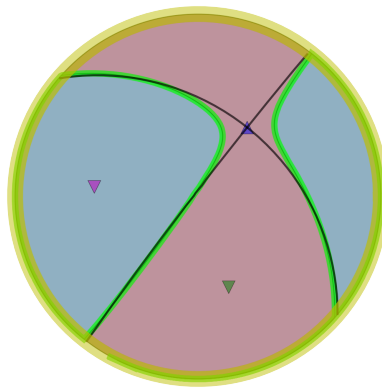
Figure 2: FSDs for M with variations in viewpoint, lines, colours, and shown features.
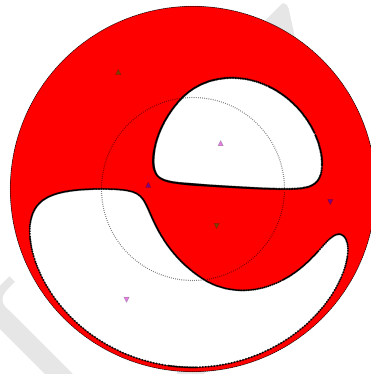

Figure 3: Full sphere FSD of M (lower hemisphere in inner circle).

```
mopad p 1,2,3,-4,-5,0 -D -r 123,34,56 -w 120,200,220 -V 45,45,45
-n 6 0,255,0 1 -l 15 yellow 1 -e 12 5 0.8 -a 0.8 -f examples_2_-
fullparameterrange.png
```

For a complete overview over the 3D-focal mechanism, one can choose the option to plot an extended projection, where the second hemisphere is brought to the $\mathbb{R}^2$, too. Although not highly intuitive, this provides a good control of results by giving a fast overview over positioning of eigenvectors and nodal lines, see figure 3:

```
mopad p 1,2,3,-4,-5,0 -A 10 5 0.5 -O -f examples_1_full_w_EV.png
```

If a direct output of the plot into a file is desired, the option -f is used

- mopad plot 1,2,3,-4,5,0 -s .svg
  ⇒ 'dummy_shortname.svg'

- mopad plot 1,2,3,-4,5,0 -f better_name.eps
  ⇒ 'better_name.eps'

- mopad plot 1,2,3,-4,5,0 -f right_name_wrong_format.tiff
  ⇒ 'right_name_wrong_format.tiff.svg'

4.3   Method: gmt

This method returns a string containing $\mathbb{R}^2$-coordinates in (x,y)-form, for further use to be piped into the psxy function of GMT. Again, the shape of all features is calculated internally and the returned coordinates define the different lines, in their combination describing the shape of the focal mechanism. For getting the full information into psxy though, one has to call this specific method twice, adding up the information about the different areas of the sphere on the one hand and the lines and eigenvector positions on the other hand.

Kinds of Options

- Output

- Appearance

- Geometry

Examples

Here we present our approach to generate flexible and stable FSDs for complex source mechanisms with GMT, omitting its psmeca-tool. *MoPaD* provides the final coordinates of the border lines as well as the eigenvectors. These are to be piped into the psxy-tool of GMT, there the defined areas can be filled with colours, set by an external *.cpt-file. The tension-areas of the bachball hold the colour-key '1' for the psxy-Z-option, the pressure areas the key '0'. If requesting only the border lines, the key is also set to '1'.
In figure 4, the generation of such a FSD via the combination of *MoPaD* and GMT is illustrated.
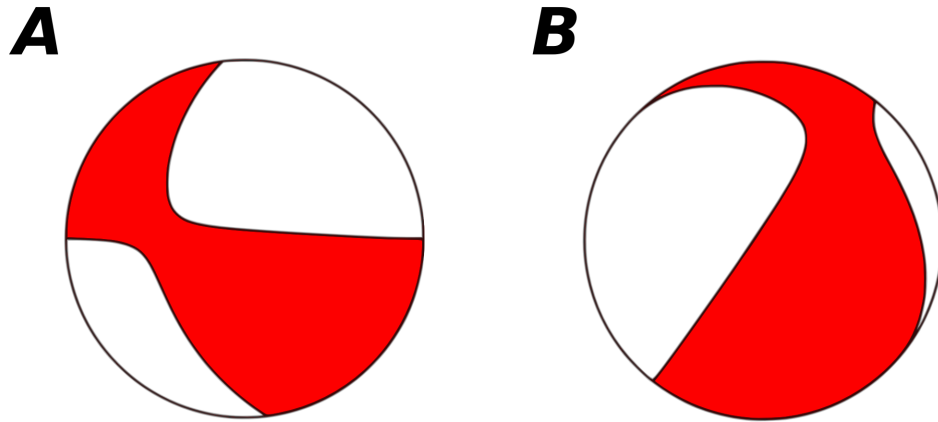
Figure 4: **A**: Standard focal-sphere-diagram plotted via a combination of *MoPaD* and `psxy`.
B: Rotated FSD, easily generated with options of the `gmt`-method.

The complete command for a standard output as shown in fig. 4-A is

```
mopad g 1,2,3,-4,-5,0 -t fill -p s | psxy -Jx4/4 -R-2/2/-2/2 -P
-Cpsxy_fill.cpt -M -K -L >BB1.ps && mopad g 1,2,3,-4,-5,0
-t lines -p s | psxy -Jx4/4 -R-2/2/-2/2 -W5 -P -Cpsxy_colours.cpt
-M -O >> BB1.ps
```

That seems to be rather complicated in the beginning, but the advantage of our new approach shows up, if one wants to handle focal mechanisms, not limited to the standard view and projection. Here the high flexibility comes at hand, using a command which is not more complex than in the standard case:

```
mopad g 1,2,3,-4,-5,0 -t fill -p o -V 45,45,45 | psxy -Jx4/4
-R-2/2/-2/2 -P -Cpsxy_fill.cpt -M -K -L > BB2.ps && mopad g
1,2,3,-4,-5,0 -t lines -p o -V 45,45,45 | psxy -Jx4/4
-R-2/2/-2/2 -W5 -P -Cpsxy_colours.cpt -M -O >> BB2.ps
```

yielding the rotated result in fig. 4-B using an orthographic projection.

4.4   Method: `decompose`

It returns strings, showing several information about the parts of the original source mechanism. Either get a full decomposition of the internally calcu-

lated seismic moment tensor or only parts, one is interested in. A variety of possible parts is provided, even in different basis systems.

Kinds of Options

- Fancy

- Type of decomposition

- Partial decomposition

- Basis systems

Examples

- `mopad d 1,2,3,-4,5,0 -c`
  Yields a complete decomposition.

- `mopad d 1,2,3,-4,5,0 -p in,out,type,full,`
  `iso,iso_perc,devi,devi_perc,dc,dc_perc,clvd,`
  `mom,mag,eigvals -y -i use -o xyz`
  Returns only parts of the decomposition. The input is interpreted in the basis system *USE*, where the results are shown in the system *XYZ*, all output is given in human readable form (`-y`):

  ```
   Basis system of the input:

  USE

   Basis system of the output:

  XYZ

   Decomposition type:

  ISO + DC + CLVD

    Full moment tensor in XYZ-coordinates:

    /  3.00  0.00  5.00 \
    |  0.00  2.00  4.00  |
    \  5.00  4.00  1.00 /


    Isotropic part in XYZ-coordinates:
  ```

8

```
/  2.00  0.00  0.00 \
|  0.00  2.00  0.00 |
\  0.00  0.00  2.00 /
```

Isotropic percentage:

23

Deviatoric part in XYZ-coordinates:

```
/  1.00  0.00  5.00 \
|  0.00  0.00  4.00  |
\  5.00  4.00 -1.00 /
```

Deviatoric percentage:

77

Double Couple part in XYZ-coordinates:

```
/  0.89  0.25  4.58 \
|  0.25 -0.15  3.61  |
\  4.58  3.61 -0.74 /
```

Double Couple percentage:

88.5259362938

CLVD part in XYZ-coordinates:

```
/  0.11 -0.25  0.42 \
| -0.25  0.15  0.39  |
\  0.42  0.39 -0.26 /
```

CLVD percentage:

11

```
 Seismic moment (in Nm) :

8.66342023913

 Moment magnitude Mw:

-5.40820707909

    Eigenvalues T N P :

[6.2811376975080657, 0.3822825416266778, -6.6634202391347426]
```

4.5 Method: `convert`

Using `convert`, one can EITHER turn the geometrical representation of a source (strike, dip, slip-rake) into a moment tensor and vice versa, OR change the basis system of a provided 3×3-matrix OR a 3D-vector.

Kinds of Options

- Fancy
- Type conversion
- M basis conversion
- Vector basis conversion

Examples

- `mopad c 1,2,3,-4,5,0 -b ned use`
  Converts the input from *NED* to *USE*:

  ```
  (3.0, 1.0, 2.0, 5.0, 0.0, 4.0)
  ```

- `mopad c 1,2,3,-4,5,0 -t sdr -f`
  The input is a moment tensor, whose DC part is represented as (strike, dip, slip-rake):

  ```
  Fault plane 1:
  strike = 354°, dip = 38°, slip-rake = 171°
  Fault plane 2:
  strike =  91°, dip = 84°, slip-rake =  52°
  ```

10

- `mopad c 1,2,3 -v ned xyz`

  By the option `-v`, the input is interpreted as an $\mathbb{R}^3$-vector. Its basis is transformed from *NED* to *XYZ*:

  ```
  (2.0, 1.0, -3.0)
  ```

5 Authors

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MoPaD is an open-source project and it is developed under the GNU LGPLv3. The development of *MoPaD* has been submitted to *Seismological Research Letters*. It contains the theoretical backbone of *MoPaD* and several references to other related tools.

After leaving the alpha-testing status, *MoPaD* will be downloadable from the authors' institute web address. Up to then, current versions can easiest be obtained by contacting the authors. Critics and suggestions are more than welcome!