MEPL2 – interactive-batch tool for full seismic MT plotting

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Introduction

Seismic source (“origin of earthquake”) can be, under some simplification, described either by seismic moment (3x3 symmetric tensor (MT)) or by its geometrical orientation (3 angles named strike, dip, rake and by amount of double couple (DC), compensated linear vector (CLVD) and volumetric (VOL) part); we use standard definition given by Aki and Richards (1980). So called “beach balls” are then popular and figurative ways of graphical presentation of seismic source orientation already for many decades – see Fig.1. The ball is divided by two nodal lines; theses lines are projection of *i*, plane in which occur movement which evoke the earthquake and *ii*, perpendicular plane. The nodal lines are often accompanied by colored areas which distinguish opposite signs of movement. If only pure double couple source (DC) is considered, the borders of differently colored areas are exactly the nodal lines. In case of more complex source (i.e. non-DC component are also incorporated) theses borders are generally shifted. Here, we present program MEPL2 - a semi-interactive tool for plotting of seismic source orientation: full moment tensor (MT) or strike/dip/rake representation is supported; many useful options are available. There is given brief description and several typical graphical outputs.

Brief description of basic features

Program MEPL2 was developed in MATALB platform, all the important graphical properties can be controlled interactively from main control window – see Fig. 1. Besides, this window can serve also as an input form for input data – i.e. seismic source orientation. The data (multiple MTs or source geometrical orientations) can be input not only from the program’s main window but alternatively also from a data file (then only control options are set in program’s main window). One, two or N sources can be plotted simultaneously which can be used for many different types of visualization.

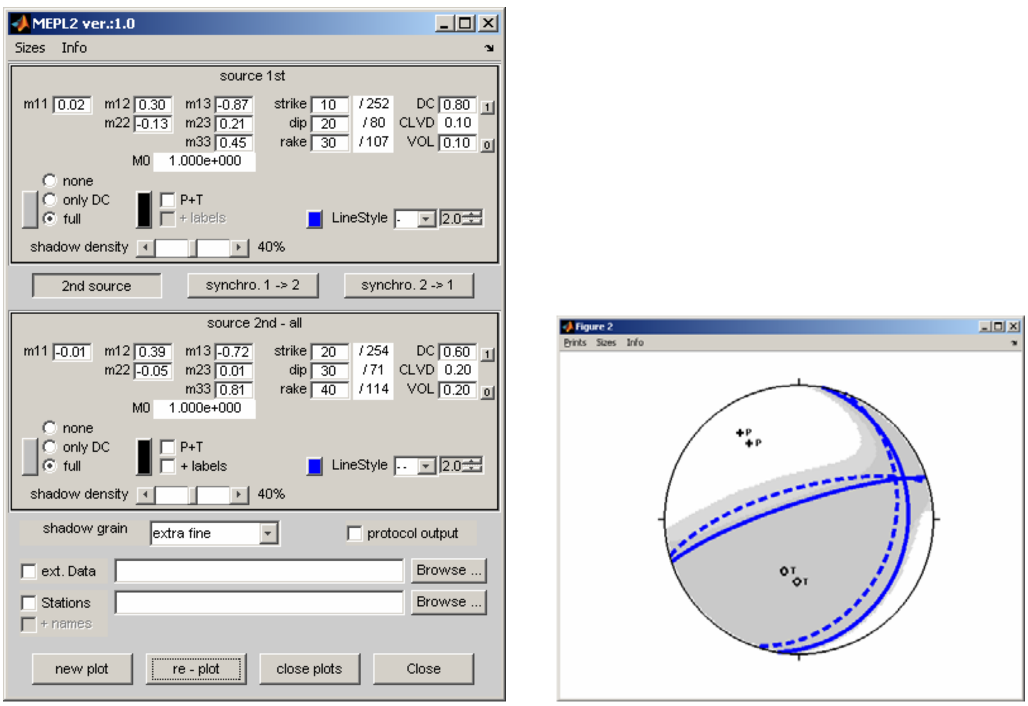

Figure 1: Screen shot of MEPL2 main control window (left) and corresponding graphical output (two slightly different sources are plotted).

Examples of created figures

We present some examples of typical graphical outputs (figures 2-7).

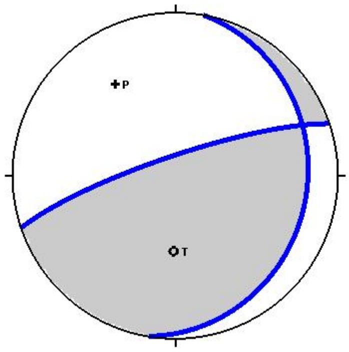

Figure 2: Simple pure DC mechanism.

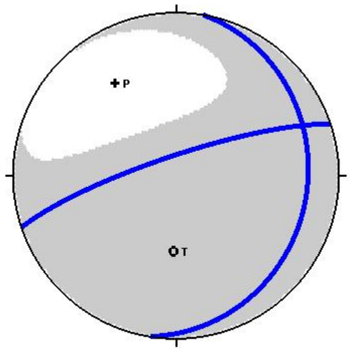

Figure 3: Source mechanism with non-DC component.

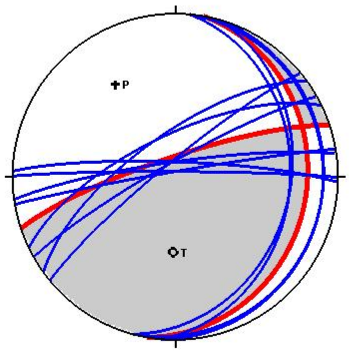

Figure 4: Source mechanism (red) and its errors (blue).

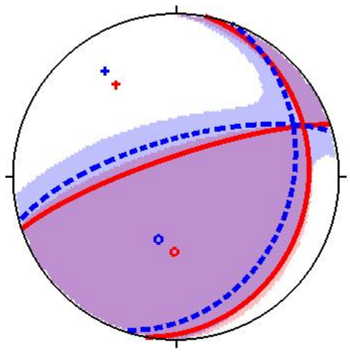

Figure 5: Comparison of two slightly different mechanisms.

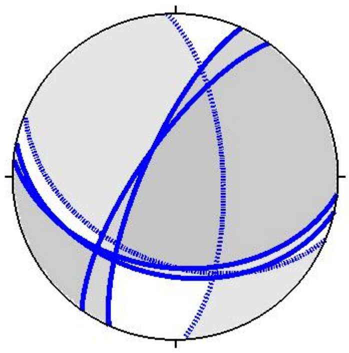

Figure 6: MT inversion of real data, 3 different inversion are presented (for more details see e.g. Baish et al., 2002, Kolář, 2007a,b or Vavryčuk, 2007).

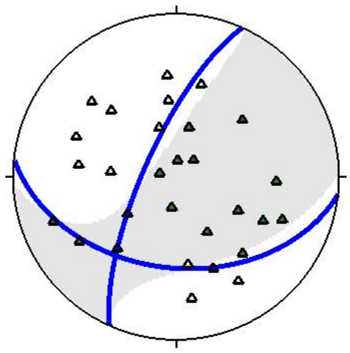

Figure 7: Source mechanism with non-DC component and used stations – the same data as in Fig. 6.

Some technical remarks

Projection definition

Beach ball figures are defined in a standard way, i.e. equal area (stereographic) projection on low hemisphere. The projection is given by relation

$$R = \sqrt{2}\sin\left(\mathrm{tof}/2\right)$$

where *tof* is take of angle, *R* distance form the origin; azimuth doesn't change .

Programming approach

Even if the projection definitions are relatively simple, the shape of final curves and/or areas might be rather complicated and in some cases difficult to plot. We decided exploited MATLAB's poverty in vectors and matrixes mathematical operations and all the necessary geometrical object are calculated as an approximation of points/areas when the sampling interval is chosen sufficiently small to produce "nice and smooth" figure. This is especially important for plotting of colored areas. N.B. that MATLAB doesn't posses any graphical function which can paint an area given by graphical representation of their borders (it is possible only if the borders are given in their numerical representation – however solving such problem would be rather inconvenient in our case). Therefore we use an approach when colored areas of the ball are "paved with colored hexagons". Despite of the MATLAB poverty this part is rather time consuming, therefore program MEPL2 is not fully interactive but only semi-interactive (i.e. figures are created after setting of all control parameters and changed options can be displayed only by re-drawing of the figure). The speed of the figure creation depends significantly on the size of the colored area tiles (parameter: *shadowing grain*). Raw tiles size can be used for quick overlook and figure tuning, tinny size tiles then for final figures construction.

MEPL2 in actual version has almost 2000 lines of MATAB code.

MT's decomposition

Both description of seismic source orientation are possible: either 6 components of MT or values of strike, dip, rake (standard definition - see e.g. Aki and Richards, 1980) accompanied possibly also with amount of volumetric component (VOL), compensated linear vector component (CLVD) and double couple component (DC). Note: the definition of VOL/CLVD/DC component given by different authors (slightly) varies; here we adopted definition given by Vavryčuk (2001), formulas (7) and (8):

$$\mathrm{VOL} = \frac{1}{3}\,\mathrm{trace}\,(\mathrm{MT})/\,M_{|max|}$$

$$\mathrm{CLVD} = -2\;M^{*}_{|min|}\,/\,M^{*}_{|max|}\left(1-|\mathrm{VOL}|\right)$$

$$\mathrm{DC}\;=1-|\mathrm{VOL}|-|\mathrm{CLVD}|\;,$$

where $M_{|max|}$ denotes that eigenvalue of MT which has the maximum absolute value (and analogously for $M_{|min|}$); symbol M^{*} denotes deviatoric part of MT; absolute values of VOL, CLVD and DC range in interval <0 ; 1>. This definition of MT decomposition has following basis features: the value of DC is always positive, and the ISO and CLVD are positive for tensile source, but negative for compressive one; the sum of all 3 absolute values is always a unit.

Transformation from MT to strike, dip, rake representation and vice verse is performed by programs developed by Kolář (2006).

Historical note

From historical point of view the "beach ball" formalism has been developed since 30's to 50's of the last century (see e.g. Litehiser, 1989). During this period it has been clear up the understanding of the nature of seismic source and consequently the way of graphical presentation of seismic source orientation was developed into present form. At least works of Byerly and Honda (Honda, 1962) should be mentioned here. Even if all the knowledge were already available (e.g. in the mentioned works), plot of beach ball could be rather difficult from technical point of view (namely plot of colored area of general shape). Despite of small historical research which the author has made, it is not know to him who plotted the first beach ball in now-days form and will be than grateful for any remarks on this topic.

Conclusion

We have developed useful tool for figurative graphical demonstration of different effects which can be considered in relation to seismic sources' orientation, namely: multiple solutions, one solution with errors, comparison of different sources, etc. Such presentation can be helpful when various practical tasks are solved[1].

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[1] The figures created by MEPL2 has been already used e.g. in Kolář (2007a,b,c).

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