EMOT v.1.0 - User guide

Type: Package
Title: Entropic Mouse Tracker (EMOT)
Version: 1.0 (beta)
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Matlab depends: Statistics Toolbox, Optimization Toolbox

Note: This version is built under Matlab version 8.0 (R2012b)
Description: Implementation of the EMOT method for spatial analysis of mouse-tracking data. This version includes: function for data modeling, estimating parameters, and performing graphical analyses of trajectories and extracted measures.

The EMOT method is described in:
Calcagnì A., Lombardi L., & Sulpizio S. (2016). Analysing spatial data from mouse tracker methodology: An entropic approach. *Behavior Research Methods*. In press.

Usage

The EMOT method is called by:

```
[results] = EMOT_main(X,Y,analysis,graphic,saveFileName,options)
```

where the input is as follows:

`X` $n \times p$ data matrix with n trials and p points of x-Cartesian coordinates

`Y` $n \times p$ data matrix with n trials and p points of y-Cartesian coordinates

`analysis` 1×2 cell array containing two arguments: (i) type of analysis (`'single'` or `'group'`) and (ii) id. trial. For instance, {`'single' 32`} calls EMOT method to work on the trial no. 32 which corresponds to the row no. 32 in the matrices `X` and `Y`. By contrast, {`'group' [1 101]`} calls EMOT to perform a group analysis from the first trial up to the trial no. 101.

`graphic` boolean `true`|`false` for the graphical output of the EMOT method. Note that this option is only available with the single-type analysis

`saveFileName` string containing the file name for the EMOT results (both in the .csv and .mat format). Use `' '` or `[ ]` will assign a default file name.

`options` a structure containing the optional parameters for the EMOT method:

- `options.thr`: y-Cartesian coordinate that represents the upper-bound of the set [0, `options.thr`] containing the recorded points to be removed from the original trajectories before running the analyses. This can be set to remove imperfections, tremors around the starting point, and other artifacts that may arise by inspecting the raw trajectories. If the field is empty, a predefined value will be assigned.
- `options.binHist`: parameter T to build the histogram models of the EMOT representation. This field can be: (i) any integer number (e.g., 20), (ii) the string `'auto'` for the automatic selection of T by using the Shimazaki method (for further details, see: Shimazaki H., & Shinomoto S. (2007). A method for selecting the bin size of a time histogram. *Neural Computation*, 19(6), 1503-1527), and (iii) the string `'sa'` for the selection of T with a dedicated sensitivity analysis. If the field is empty, a predefined value will be assigned.
- `options.F0iidtol`: the tolerance parameter for the computation of the zeroth-frequency of the vector θ (further details in the EMOT paper). The range of suggested values is $[0, 0.1]$ where 0 indicates no tolerance whereas 0.1 higher tolerance. If the field is empty, a predefined value will be assigned.
- `options.verbose`: boolean `true`|`false` for the textual output of the EMOT method.
- `options.maxFunEvals`: positive integer for the Maximum number of function evaluations allowed in the decomposition procedure (further details in the "Optimization Toolbox" documentation). If the field is empty, a predefined value will be assigned.
- `options.maxIter`: positive integer for the Maximum number of iterations allowed in the decomposition procedure (further details in the "Optimization Toolbox" documentation). If the field is empty, a predefined value will be assigned.
- `options.display`: string `'none'`|`'iter'`|`'final'` for the textual output of the decomposition procedure (further details in the "Optimization Toolbox" documentation). If the field is empty, a predefined value will be assigned.

`options.algorithm`: algorithm name for the decomposition procedure (further details in the "Optimization Toolbox" documentation, function `fmincon`). If the field is empty, the predefined interior-point algorithm will be assigned.

`options.sa_Tmin`: lower bound for the estimation of T via sensitivity analysis (if `options.binHist='sa'`). If the field is empty, a predefined value will be assigned.

`options.sa_Tmax`: upper bound for the estimation of T via sensitivity analysis (if `options.binHist='sa'`). If the field is empty, a predefined value will be assigned.

Note that `EMOT_main` requires `X` and `Y` matrices loaded in the Matlab workspace. These data matrices can contain trials with several lengths p. In this case, the $n \times 1$ vector `NUM_MVS` containing the lengths p's of each trial should also be provided as additional variable in the workspace. If not, EMOT computes this variable automatically. In addition, x-y Cartesian coordinates in `X` and `Y` matrices should be organized such that the end point of the movement path is always on the right-side of the screen (i.e., the category target must be on the right-side whereas competing target on the left side of the screen). If not, `X` and `Y` must be pre-processed and organized in this way before running EMOT.

The output `results` is a structure containing the following fields:

`fail`	boolean `1`|`0` indicating when EMOT fails to estimate the entropic measures on a given movement trajectory. The reasons are directly related with the quality of the original x-y path (e.g., number of sampled points)
`psi`	ψ measure
`csi`	ξ measure
`zeta1`	ζ_1 measure
`zeta2`	ζ_2 measure
`zeta`	ζ measure
`H_theta`	$\mathcal{H}$ histogram model
`H_theta0`	$\mathcal{H}_{\prime}$ histogram model
`U`	$\mathcal{U}$ histogram model
`U1`	$\mathcal{U}_1$ histogram model
`U2`	$\mathcal{U}_2$ histogram model
`tau`	τ estimated vector
`u1`	υ_1 estimated vector
`u2`	υ_2 vector
`pi`	π vector
`lambda1`	λ_1 vector
`lambda2`	λ_2 vector
`KL_output`	structure containing the output of the decomposition procedure (further details in the "Optimization Toolbox" documentation)
`xref`	original x-Cartesian coordinates
`yref`	original y-Cartesian coordinates
`theta`	θ vector of angles
`theta0`	θ_0 vector of angles

sa structure containing the output of the estimation of T via sensitivity analysis (if `options.binHist='sa'`):

- `T`: the estimated T parameter.
- `acc`: accuracy (0-100%) of the results.
- `data`: data generated during the sensitivity analysis (first column: values of T; third column: values of ψ; fourth columns: values of ξ; fifth column: values of ζ_1; sixth column: values of ζ_2).

Note also that when `'group'` analysis is called, the EMOT results are also saved into an external n (trials) $\times$ 4 (EMOT measures) .csv file, where the columns report ψ, ξ, ζ_1, and ζ_2, respectively.

Examples

The command `[results] = EMOT_main(X,Y,{'single' 98},true,'results',[])` calls EMOT on trial no. 98 with graphical results and predefined options. The string `'results'` indicates the file name of the output.

The command `[results] = EMOT_main(X,Y,{'group' [1 5]},[],[],[])` calls EMOT with the group-analysis modality on the trials 1-5 with predefined options.

The command `[results] = EMOT_main(X,Y,{'group' [104 107]},[],'group_results',opts)` calls EMOT with the group-analysis modality on the trials 104-107 with options declared in the structure `opts` (e.g., `opts.binHist='sa'`, `opts.sa_Tmin = 20`, `opts.sa_Tmin = 60`). Results will be saved in the `'group_results'` output file.

The command `[results] = EMOT_main(X,Y,{'single' 13},true,[],opts)` calls EMOT on trial no. 13 with graphical results and options declared in the structure `opts` (e.g., `opts.binHist='sa'`, `opts.sa_Tmin = 20`, `opts.sa_Tmin = 60`). Note that, in this case, only the fields `options.binHist`, `opts.sa_Tmin`, and `opts.sa_Tmax` are defined, the remaining fields are automatically set with their predefined values.

Example of output of the call `[res] = EMOT_main(X,Y,{'single' 16},false,[],[])` with no graphical output and default options:

```
==================== EMOT v.1.0 ==================================

@ Single trial analysis: Data id. 16
@ EMOT started
@@ e—Decomposition: Successfully executed!
@ EMOT finished

==================================================================

res =

         fail: 0
          psi: 0.5518
          tau: [23x1 double]
           u1: [11x1 double]
```

```
          u2: [11x1 double]
         csi: 0.1291
       zeta1: 0
       zeta2: 0.4227
        zeta: 0.4227
     H_theta: [23x1 double]
    H_theta0: [23x1 double]
       xHist: [1x23 double]
           U: [23x1 double]
          U1: [11x1 double]
          U2: [11x1 double]
          pi: [23x1 double]
     lambda1: [11x1 double]
     lambda2: [11x1 double]
         thr: 0.1000
   KL_output: [1x1 struct]
        xref: [1x67 double]
        yref: [1x67 double]
       theta: [59x1 double]
      theta0: [2x1 double]

res.KL_output =

         iterations: 69
          funcCount: 3273
    constrviolation: 2.4736e-13
           stepsize: 7.2274e-11
          algorithm: 'interior-point'
      firstorderopt: 0.0123
       cgiterations: 0
            message: Local minimum possible. Constraints satisfied.
             fmincon stopped because the size of the current step is less than
             the default value of the step size tolerance and constraints are
             satisfied to within the default value of the constraint tolerance.
```