# MFA User's Guide

**Version 1.1 for Windows platforms, May 2020**

This documentation explains how to use the computer program **MFA**, which performs multi-fractal analysis on the basis of the singularity spectrum and the Rényi spectrum, from: (A) a curve with equally-spaced data points (see below for characteristics of the data to be analyzed, when these are numerical) or (B) a stack of figure files, all of same size in terms of number of row pixels by number of column pixels (see below for characteristics of the basic data when graphical). The results can be saved as outputs in numerical and/or graphical format.

Reference:
Han, L., Srocke, F., Mašek, O., Smith, D. L., Lafond, J. A., Allaire, S., and Dutilleul, P. 2020. A Graphical-User-Interface application for multifractal analysis of soil and plant structures. *Computers and Electronics in Agriculture* 174:105454 (DOI: 10.1016/j.compag.2020.105454).

**MFA Installation**

1. Retrieve a copy of the zipped folder **MFA.zip** (Supplementary material of the above-captioned reference), and unzip it to your destination location on your computer.

2. Verify that the MATLAB runtime (version 8.5, R2015a) is installed on your computer. For this installation, run MyAppInstaller_mcr.exe, to be found inside the unzipped **MFA** folder, and follow the instructions until completion.

3. Launch the program by double-clicking on **MFA.exe**.

**How to Use MFA**

If the program **MFA** is successfully launched, a GUI (graphical user interface) window will appear waiting for "input" by the User.

1. Locating the input file

Once you click the *Locate input file* button, you can browse your file system, go to your source folder and choose the input file. If the input is a series of images (see 3-dimensional input, second option below), the one you choose will be the ending of image sequence for your input.

This application accepts the following types of input file:

a) One-dimensional numerical data contained in a text (ASCII) file or an Excel (Microsoft) file. The data in the text file should be ordered and delimited by a space, a comma, a tab, or a semi-colon; they are the quantitative values of interest. The data in the Excel file should be in one column without identifier.

b) Three-dimensional graphical data in the form of a sequence of binary images. Their names consist of same string plus the ordering number starting from 1, e.g. Biochar723. The 1s in each image represent the structure of the object of interest.

2. Loading the input file

The "Load file" button lets the input data read into the memory of the computer. It is referred as *original data* hereafter. When the input is three-dimensional graphical data, the program reads image from ordering number 1 to the image the User selected.

3. Initial graph

A data curve is first shown in the display panel. This curve represents either the distribution of the original data if numerical [see option a) above and Complementary Note 1 regarding interpolation below] or the distribution of the curve produced from a sequence of binary images [see option b) above and Complementary Note 1 regarding interpolation below].

4. Interpolated data

The User will choose the range from the *original data* (partially or wholly) on which the multi-fractal analysis is performed by entering the starting number and ending number into the respective boxes. A new dataset, hereafter referred to as *Interpolated data*, is generated whose length has been reset and the values are obtained by interpolation using the MATLAB function *SPLINE* (cubic spline data interpolation, 0.01 accuracy). The buttons of *Interpolated Data, Singularity Spectrum* and *Rényi Spectrum* show the graphical results obtained for interpolated data.

5. Exporting **MFA** results

In the "output" panel, an identifier is requested as prefix for the names of the output files. Then, the User can choose the desired output file by highlighting the item in the list box and save it by clicking the *output file* button. This procedure must be repeated for multiple outputs. The output file(s) will be saved in the same folder as the input file(s).

Seven output files are listed in the list box for exportation, giving the opportunity to the User to further explore and interpret the results. The content of these output files can be described as follows.

. *Interpolated Data Table*
*Userdefinedprefix*_interpolated_data.txt contains the interpolated data computed from the input data; interpolation is necessary when the number of input data is not a power of 2, which is a pre-requisite for the modeling and spectrum equations in multi-fractal analysis within a certain range from a finite number of data points. The delimiter is new-line, which is readable in Microsoft Word or simply WordPad in the Windows operating system.

. *Singularity Spectrum Estimates*
This Excel file contains 6 x 17 numerical entries concerning the estimated singularity spectrum. The first row contains the α-estimates, and the corresponding *f*(α)-estimates are given on the second row. The third and fourth rows contain the standard errors associated with the α- and *f*(α)-estimates, respectively. The $R^2$ values are reported on the fifth (α) and sixth [*f*(α)] rows.

. *Rényi Spectrum Estimates*
This Excel file contains 3 x 17 numerical entries concerning the estimated Rényi spectrum (estimates of the $D_q$ dimensions). The three rows respectively contain: the $D_q$ estimates (first row), the corresponding standard errors (second row), and the $R^2$ values associated with the estimation of the $D_q$ dimensions (third row).

. *Singularity Spectrum Figure*
One of the multi-fractal analysis figure outputs. In this figure, only the estimates of α and *f*(α) for which the $R^2$ value is greater than $(0.9)^2 = 0.81$ in their estimation are shown. The horizontal and vertical bars represent the standard errors.

. *Rényi Spectrum Figure*
This is also a typical graphical output of multi-fractal analysis. The range of *q*-values is set to be from –8 to +8, by increments of 1, for all multi-fractal analyses. The $D_q$-estimates are generally greater than 1.0 when *q* is negative, and smaller than 1.0 when *q* is positive. If you experience a situation in which this is not the case (i.e., an exception to the rule), especially when *q* is positive, please refer to the complementary notes of this guide.

. *Input Data Curve*
This is an image in TIFF format, which displays the input series with its real length (before any interpolation). When the input data are provided by a series of binary images, in which black pixels represent the structure of interest, the “length” will be the ending number that the User chooses. This curve is expected to help the User grab the characteristics of the input data.

. *Interpolated Data Curve*
This is an image in TIFF format as well, which displays the interpolated data curve from the chosen range of the original input by the User. The length of interpolated data is automatically categorized into 128, 256, 512 or 1024 to meet the requirement of multi-fractal analysis.

**Complementary Notes**

**1.** The current version of the **MFA** program accepts a length of *original input data* between 91 and 1448. With the rule of powers of 2 that applies to the statistical inference (estimation) in fractal analyses, interpolation may need to be performed from a chosen part of the *original input data*. Specifically, numerical input data with a length from 91–181 (182–362, 363–723,724–1448) will be interpolated into a new input curve with a length of 128 (256, 512, 1024) within the chosen range.

**2.** If the input is a series of binary images, the program will generate a curve representing the percentage of black pixels (structure of interest) on each image, then use this curve as *original input data* in **MFA**.

**3.** When the User experiences $D_q$-estimates are greater than 1.0 when $q$ is positive in the Rényi spectrum, these $D_q$-estimates will be replaced by 1.0 with zero standard error; likewise, all $D_q$-estimates will be replaced by 1.0 with zero standard error if $D_q$-estimates are less than 1.0 when $q$ is negative in the Rényi spectrum.