1D FSV Tool

User’s Guide

Version: **4**

December 2007

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1 Introduction to the 1D Feature Selective Validation (FSV) Theory

The **1D Feature Selective Validation (FSV) Tool** is a standalone application that implements the two dimensional (1D) FSV theory.

The **1D FSV Tool** is as a joint project between:

Applied Electromagnetics Group, De Monfort Univ., Leicester, UK http://www.eng.dmu.ac.uk/aeg/
UAq EMC Laboratory, Univ. of L'Aquila, L'Aquila, Italy http://www.diel.univaq.it/labs/emc/
UMR EMC Laboratory, Univ. of Missouri-Rolla, Rolla, USA http://www.emclab.umr.edu

The 1D Feature Selective Validation (FSV) algorithm has been developed to compare two sets of bidimensional (surface) data (not necessarily in the electrical engineering field) and put them in an objective and comprehensible form.

Several motivations form the basis of FSV:

- The need to control variations between visual assessment results;
- The reduction of cost (a skilled engineer is an expensive commodity);
- The desire to reduce ambiguities;
- The inability of humans to process and cache extremely large volumes of data.

The FSV theory was conceived as a technique to quantify the comparison of data sets by mirroring engineers' visual perceptions.

Furthermore, FSV allows automated comparisons of large volumes of complex data whilst reliably categorising the results into a common set of quality bands.

The FSV offers three figures of merit of the comparison of two data sets:

- ADM (Amplitude Difference Measure) and FDM (Feature Difference Measure). These are available as numerical values and can be converted to a natural language descriptor in a six level scale: excellent, very good, good, fair, poor, Very Poor. These combine to give the GDM.
- GDM (Global Difference Measure). An overall single figure goodness-of-fit between the two data sets being compared. This allows a simple decision to be made about the quality of a comparison. This may be numerical or converted to a natural language descriptor

These figures of merit can be further represented in three different ways in order to quantify the quality of the comparison performed:

- GDM_i, ADM_i and FDM_i. These are point-by-point comparisons of the amplitude differences, the feature differences and the global differences. This allows a user to analyze the resulting data in some detail, probably with the aim of understanding the origin of the contributors to poor comparisons.
- GDM_c, ADM_c, FDM_c. These give probability density functions which show the proportion of the point-by-point analyses of each of the components that falls into the six natural language

descriptor categories. This provides a measure of confidence in the single figure comparisons.

- GDM_{tot}, ADM_{tot}, FDM_{tot}, GDM_{conf}, ADM_{conf}, FDM_{conf}, GDM_{pw}, ADM_{pw}, FDM_{pw}. These are more synthetic figures of merits of the comparison and stem from an elaboration of the variables described in the previous points. They are described in the next Chapter.

Based on these figures of merit, the comparison of two data sets can be ranked. The ranking, useful for making a selection between multiple comparisons, is given by considering two quality factors for each figure of merit. The GRADE and the SPREAD.

- The GRADE is a direct indication of the quality of the comparison. The smaller it is, the better the comparison.
- The SPREAD indicates the level of reliability of the outputs. The smaller it is, the higher is the reliability of the results.
- GRADE and SPREAD are computed for each figure of merit (ADM, FDM, GDM) and reported on a GRADE-SPREAD chart.

1.1 The Feature Selective Validation (1D FSV) method

The structure of the 1D FSV involves reading the two data files to be compared and interpolating them over common domain so that the data-points to be compared are coincident. This approach ensures that like is being compared with like and will not affect the overall results unless the data are severely under-sampled. It must be remembered that the purpose of the FSV is to mimic a visual comparison and so long as any interpolation does not produce visually different results, this approach is perfectly acceptable.

The actual comparison is based on decomposing the original data into ‘trend’ and ‘feature’ information. This is done by applying 1D Fourier Transform to the data and to window the transformed data to separate out the lower and higher portions. The high and low portions are then inverse transformed back into the original domain. Combinations of these filtered data sets and their derivatives are used to compute the Amplitude Difference Measure (ADM) and the Feature Difference Measure (FDM): which can be combined into the Global Difference Measure (GDM).

More specifically, the procedure is:

1. *Read data, obtain the overlap window and interpolate the data, if necessary, in the overlap region to ensure coincident pairs of data points.* This ensures that the two data sets to be compared have the same number of data points located at the same positions on the independent (x) axes.
2. *Fourier Transform both data sets.* Depending on the number of samples a Fast or Discrete two dimensional transformation is used.
3. *Calculate the ‘low’ data sets using the transformed data.*
    a. Ignore the first four data points in the transformed set (in order to avoid DC and very low frequency components) and sum the intensities of the remaining data.
    b. Obtain a 40% location by summing the data from the DC+1 point (i.e. ignoring the near-DC data) until the total reaches 40% of the total value calculated in step 3a. The ‘40%’ location used by the FSV is the lowest of the two resulting numbers (from the two original data sets). A ‘break-point’ five data points above this is returned – a value that allows a comfortable transition window between the low and the high results.

   c. Window the transformed data for both data sets by taking a linearly decreasing envelope from two points below the break-point to two points above it. Essentially, low-pass filtering the transformed data.

   d. Inverse transform the windowed data to give the 'low region' data for both original data sets, they are named ($Lo_1(x,y)$ and $Lo_2(x,y)$.

4. *Calculate the 'high' data sets using the transformed data.* Repeat the process from 3c, by applying the opposite envelope to the transformed data: essentially high pass filtering it. These data is then inverse transformed to give the 'high region' data for both of the original data sets. They are named $Hi_1(x,y)$ and $Hi_2(x,y)$.

5. *Calculate the "DC" data sets using the transformed data.* The first four data points in the transformed set in step 3a. are inverse transformed and give the 'DC' data for both of the original data sets. They are named DC_1 and DC_2.

6. *Calculate the ADM on a point-by-point basis.* Each data set has N y points identified by the Cartesian coordinates (x_i) , i = 1,… , N. For sake of simplicity in the next it will be used the notation (x_i) = (i). At an arbitrary data point (i), the ADM is evaluated as in the following equation (1.1). This point-by-point variable is also abbreviated as ADM_i

$$ADM_i(i) = ADM_{old}(i) + \left(c_m \cdot ODM_i(i) \cdot e^{c_{m1} \cdot ODM_i(i)}\right) \tag{1.1}$$

where:

$$ADM_{old}(i) = \frac{\left\| Lo_1(i) \right| - \left| Lo_2(i) \right\|}{\frac{1}{N}\sum_{i=1}^{N}\left(\left| Lo_1(i) \right| + \left| Lo_2(i) \right|\right)} \tag{1.2}$$

$$ODM_i(i) = \frac{\left\| DC_1(i) \right| - \left| DC_2(i) \right\|}{\frac{1}{N}\sum_{i=1}^{N}\left(\left| DC_1(i) \right| + \left| DC_2(i) \right|\right)} \tag{1.3}$$

c_m and c_{m1} are weighting coefficients set equal to 1 (1.4)

$ODM_i(i)$ represents the contribution to $ADM_i(i)$ of the difference of offset between the two original signals.

7. *Calculate the single value of ADM.* A mean value of the ADM(x_i) = ADM(i) gives an overall, single figure, goodness-of-fit. It is obtained from the following equation

$$ADM = \frac{\sum_{i=1}^{N} ADM(i)}{N} \tag{1.5}$$

Note: a median value, rather than a mean value has demonstrated some improvements in agreement with visual interpretations for 1D data, although this has yet to be determined for 1D.

8. *Calculate the ADM confidence histogram.* The range of values for the ADM, and, in fact, the FDM and GDM can be divided into six categories, each with a natural language descriptor: Excellent, Very Good, Good, Fair, Poor, And Very Poor. These are the terms that are most often used in descriptions of the quality of comparisons. The confidence histogram, like a probability density function, provides some intelligence as to how much emphasis can be placed on the single figure of merit. There is some evidence to show that this mirrors the overall group assessment of any data pair by a number of engineers. The determination of the histogram is simply a case of counting the proportion of points that fall into one of the categories, according to the rule base in Table 1.1.

Table 1.1 - FSV INTERPRETATION SCALE

FSV value (quantitative)	FSV interpretation (qualitative)	FSV Visual six point scale
Less than 0.1	Excellent	1
Between 0.1 and 0.2	Very good	2
Between 0.2 and 0.4	Good	3
Between 0.4 and 0.8	Fair	4
Between 0.8 and 1.6	Poor	5
Greater than 1.6	Extremely Poor	6

9. *Calculate derivatives in preparation for the FDM calculation.* The following components need to be calculated: The first derivatives of the *Lo(x)* and *Hi(x)* data sets and the second derivatives of the *Hi(x)* data sets. The derivatives accentuate the high rate-of-change features in the original data and differences based on the derivatives are combined in the determination of the FDM.
   The first and second derivatives are currently obtained by a simple difference approach Lo’(i) = Lo(i+1) – Lo(i-1). At the edges of the domain is used a correction:
   for left edge of the domain:

$$\frac{dLo}{dx}(i)=\frac{Lo(i+1)-Lo(i)}{\Delta}$$

   where *i* represents the element of the vector and Δ is equal to 1.
   for right edge of the domain:

$$\frac{dLo}{dx}(i)=\frac{Lo(i)-Lo(i-1)}{\Delta}.$$

   for all internal point:

$$\frac{dLo}{dx}(i)=\frac{Lo(i+1)-Lo(i-1)}{\Delta}$$

10. *Calculate the point-by-point FDM.* The FDM is formed from three parts based on the derivatives calculated in step 9.

$$FD_I(x) = \frac{\left|Lo_1^{'}(x)\right| - \left|Lo_2^{'}(x)\right|}{\frac{2}{N}\sum_{\min}^{\max}\left|Lo_1^{'}(x)\right| + \left|Lo_2^{'}(x)\right|} \tag{1.6}$$

$$FD_{II}(x) = \frac{\left|Hi_1'(x)\right| - \left|Hi_2'(x)\right|}{\frac{6}{N}\sum_{\min}^{\max}\left|Hi_1'(x)\right| + \left|Hi_2'(x)\right|} \tag{1.7}$$

$$FD_{III}(x) = \frac{\left|Hi_1''(x)\right| - \left|Hi_2''(x)\right|}{\frac{7{,}2}{N*M}\sum_{\min}^{maz}\left|Hi_1''(x)\right| + \left|Hi_2''(x)\right|} \tag{1.8}$$

$$FDMi = 2*(FD_I + FD_{II} + FD_{III}) \tag{1.9}$$

Being *min* and *max* the lowest and highest components (x) in the data sets.

11. *Calculate the single value of FDM.* This is done in exactly the same way as for the ADM.

12. *Calculate the FDM confidence histogram.* This is done in exactly the same way as was done for the ADM.

13. *Obtain the point-by-point GDM value.*
    The GDM is premised on the ADM and FDM being largely independent, which means that:

$$GDM = \sum_{f_{\min}}^{f_{\max}} \sqrt{k_{ADMi\_cm} \cdot (ADM_i(x))^2 + k_{FDMi\_cm} \cdot (FDM_i(x))^2} \tag{1.10}$$

    the weighting coefficients k_{ADM_cm} and k_{FDM_cm} as at point 20.

14. *Calculate the overall GDM value and the GDM confidence histogram.* This follows the same procedure as the ADM and FDM.

15. *Determine the synthetic figures of merit ADM_{tot}, FDM_{tot}, GDM_{tot}.* These variables are the average of the point-by-point values of ADM, FDM and GDM respectively.

16. *Determine the synthetic figures of merit ADM_{conf}, FDM_{conf}, GDM_{conf}.* These values are computed by weighting the number of samples of the point-by-point corresponding variables falling in the six classes of Table 1.1 with the associated weight of the visual six points scale in the same Table.

$$xDM_{conf} = 1\cdot(\#EX) + 2\cdot(\#VG) + 3\cdot(\#G) + 4\cdot(\#F) + 5\cdot(\#P) + 6\cdot(\#EP) \quad \text{with } x = A, F, G \tag{1.11}$$

where # is the number of elements belonging to a class. The total value is then normalized to the length of the Low/High array.

17. *Determine the equivalent visual scale values* ADM_{pw}, FDM_{pw}, *and* GDM_{pw}. The FSV values can be scaled to the Visual six point scale in Table 1.1. The piece-wise visual conversion for this is given in Table 1.2, where y is ADM_{tot}, FDM_{tot} or GDM_{tot}.

Table 1.2 - Piece-wise visual conversion

If $y \le 0.1$ Then $V = 1 + 10y$
If $y > 0.1$ and $y \le 0.2$ Then $V = 2 + 10(y - 0.099)$
If $y > 0.2$ and $y \le 0.4$ Then $V = 3 + 5(y - 0.199)$
If $y > 0.4$ and $y \le 0.8$ Then $V = 4 + 2.5(y - 0.399)$
If $y > 0.8$ and $y \le 1.6$ Then $V = 5 + 1.25(y - 0.799)$
If $y > 1.6$ Then $V = 6$

The piece-wise conversion approach is represented by the graph in Fig. 1.1:

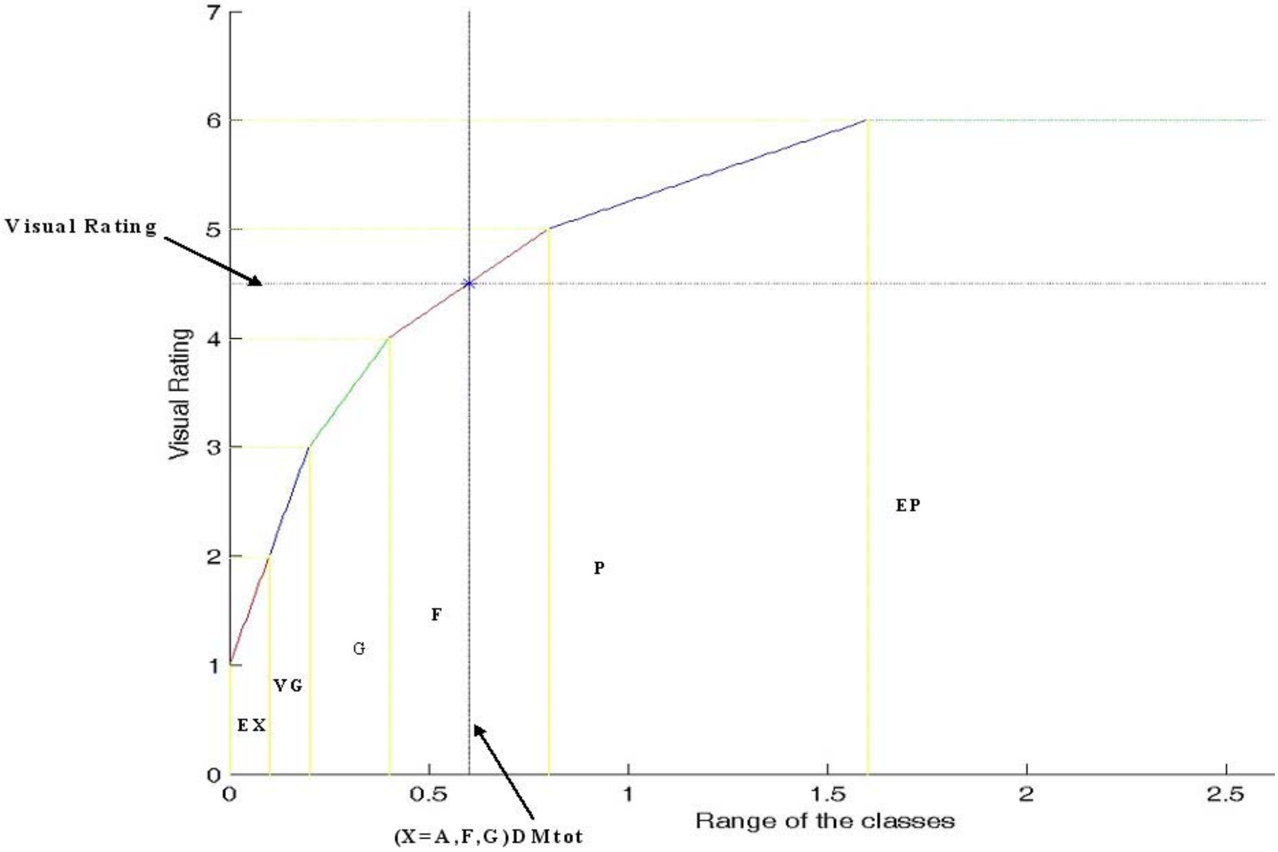


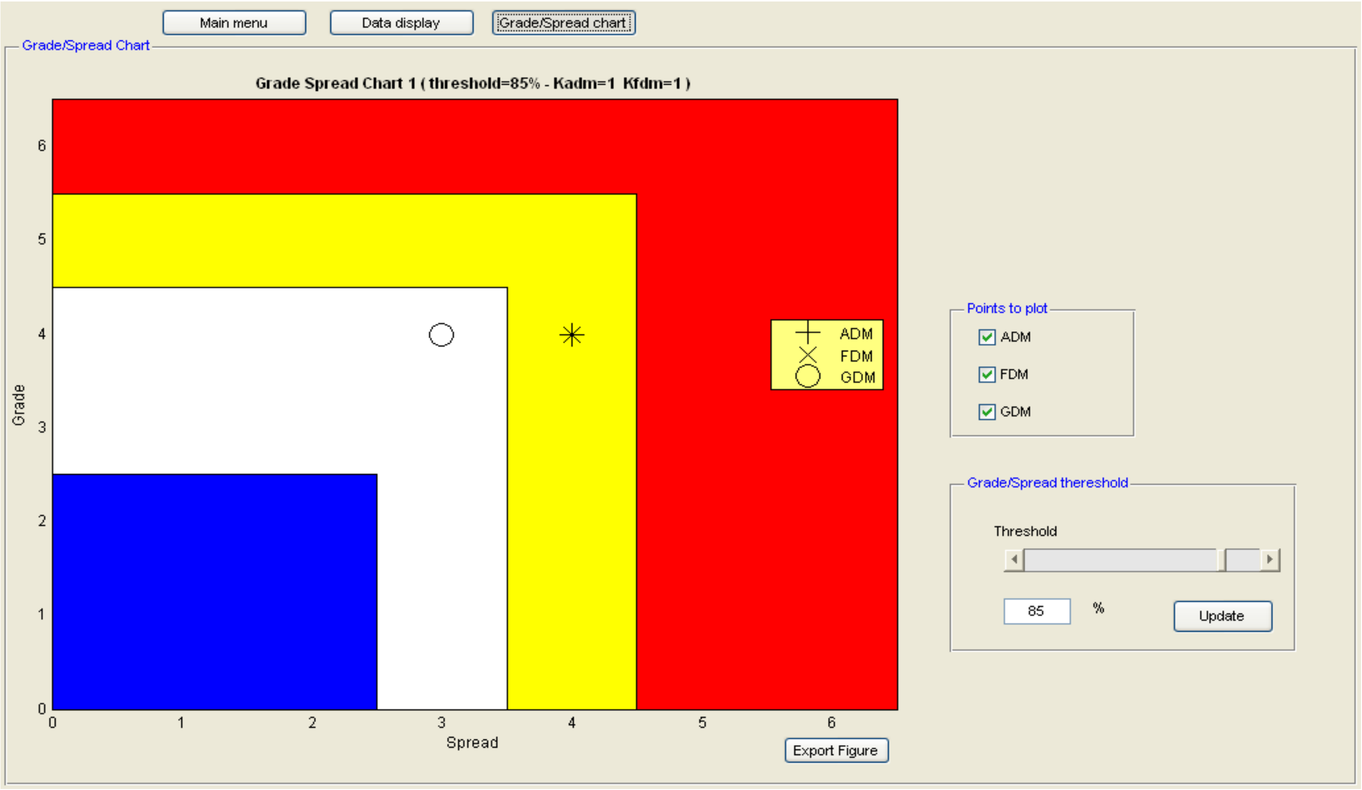
Fig. 1.1 - Piece-wise visual conversion graph.

17. *Determine the GRADE value and range*

The GRADE *value* is computed by taking the number of classes, starting from the best (Excellent) to the worst (Extremely Poor), which include a user defined amount (named "threshold" and set at 85 % by default) of the total samples of the data sets to be compared. GRADE *value* ranges from 1 (best quality) to 6 (worst quality). The GRADE *range* is given by considering the range of the classes included in the GRADE *value* computation.

18. *Determine the SPREAD value and range*
    The SPREAD is computed by taking the number of classes, starting from the most populated to the lowest one, which includes a user defined amount (named "threshold" and set at 85 % by default) of the total samples of the data sets to be compared. SPREAD ranges from 1 (best quality) to 6 (worst quality). The SPREAD *range* is given by considering the range of the classes included in the SPREAD *value* computation.

19. *Plot the GRADE-SPREAD chart*
    Each figure of merit (ADM, FDM, GDM) has associated with it a GRADE, SPREAD pair. This pair is plotted on the GRADE-SPREAD plane, named GRADE-SPREAD chart (Fig. 1.2). The chart has colored regions: different colors indicate different quality of the comparisons.



☑ ADM
☑ FDM
☑ GDM

Threshold

85 %

Fig. 1.2 - The GRADE-SPREAD coloured chart

20. *Compute k_{ADM_cm} and k_{FDM_cm}*

In forming GDM in (1.11) , the relative weight of ADM and FDM depends on their level of confidence or reliability. Higher is the reliability (that is to say smaller is the value of SPREAD) greater is the relative weight of one of them in GDM.
The following algorithm is used to compute the weighting factor k_{ADM} and k_{FDM} in (1.11):

```
If $Spread_{ADM} < Spread_{FDM}$
  then
      $K_{ADM} = 1$
      $K_{FDM} = Spread_{ADM} / Spread_{FDM}$
    Else if $Spread_{ADM} > Spread_{FDM}$
      Then
      $K_{FDM} = 1$
      $K_{ADM} = Spread_{FDM} / Spread_{ADM}$
      Else
        $K_{ADM} = 1$
        $K_{FDM} = 1$
```

1.2 The Combined Analysis for complex values

In the FSV 1D analysis the results of the comparisons of Magnitude and Phase can be combined and weighted. This is the so called “combined” analysis.
FSV treats magnitude and phase parts of the data to be compared, separately throughout and recombines them at the end. This way is as close a similarity as possible to the manner in which engineers would approach the analysis of the magnitude-phase data. In a similar manner to the way visual decomposition into amplitude and feature comparisons are combined into an overall conclusion, the magnitude and phase parts are considered separately and then weighted in the process of forming an overall opinion.

The FSV analysis is performed, as in points 1. to 11. of the previous section, on the magnitude and phase parts separately and recombined on a point-by-point (x,y) base (by using ADM and FDM functions) through the K weighting factors according to:

$$ADM_{combined}(x) = \sqrt{\mathrm{K}_{magnitude} \cdot ADM^2_{magnitude}(x) + \mathrm{K}_{phase} \cdot ADM^2_{phase}(x)} \tag{1.12}$$

$$FDM_{combined}(x) = \sqrt{\mathrm{K}_{magnitude} \cdot FDM^2_{magnitude}(x) + \mathrm{K}_{phase} \cdot FDM^2_{phase}(x)} \tag{1.13}$$

The K factors ranges from 0 to 1; they are related by the following constrain

$$\mathrm{K}_{phase} = 1 - \mathrm{K}_{magnitude} \tag{1.14}$$

The GDM will combine the ADM and FDM without the inclusion of a separate weighting factor (this has already been included in (1.13) and (1.14)):

$$GDM_{combined}(x) = \sqrt{ADM^2_{combined}(x) + \cdot FDM^2_{combined}(x)} \tag{1.15}$$

1.2.1 K weighting factor

$K_{magnitude}$, K_{phase} are the weighting factor ($0 \leq K_{magnitude}, K_{phase} \leq 1$) representing the relative subjective importance placed on the two terms. The selected values of K are also an important factor in communicating the comparison because it relies on the engineers involved in rationalizing their subjective decision. In certain applications, only the magnitude of the electromagnetic variable is required, in which case setting $K_{magnitude} = 1$ ($K_{phase} = 0$) reduces these equations to those previously described. In other applications both the magnitude and phase are equally as important. For example, a wrong equivalent circuit could result when there is perfect agreement in the magnitude but a small difference in the phase. In this case, it would be anticipated that $K_{magnitude}$,$K_{phase} = 0.5$ would be appropriate.

The FDM is treated in the same way using the same weighting factor. The GDM will combine the ADM and FDM as before without inclusion of a separate weighting factor (this has already been included in the component measures).

The output variables of the Combined analysis are the same than those illustrated in points 12. to 20. of the previous section.
Moreover the user can select more than one pair of K weighting factors for each analysis as is described in 3.4.2.1.

Based on this algorithm the **FSV Tool** has been developed as a standalone application for Windows OS.

2 How to Install

2.1 System Requirements

The **1D FSV Tool** is developed to run under WINDOWS 2000 or Windows XP, It has not yet been tested on WINDOWS VISTA.

2.2 Installation

The **1D_FSV*xxx*.zip** file (*xxx* indicates the number of the version) contains all the needed parts of the **1D FSV Tool**.

Method 1: users that have a version of MATLAB installed:

1. Check if a MATLAB compatible version is installed in your system:
   - type in matlab prompt: `version`
   - if the output is: “`7.1.0.246 (R14) Service Pack 3`” your machine is able to run 1D FSV. Otherwise see the Method 2.
2. Unzip the content of the .zip file **1D_FSV*xxx*.zip** in the installation directory (i.e. 1D_FSV”) and double click on *“fsv1D.exe”*.
3. In the zip package it is also provided an icon file (.ico) to create a desktop shortcut for the *“fsv1D.exe”* file according to the standard Windows’ procedure.

Method 2: users that do not have MATLAB installed or an earlier MATLAB version than from 7.1.0 :

To run 1D FSV to another development machine that does not have MATLAB 7.1.0 installed (including a machine that has MATLAB but it is a different version of MATLAB 7.1.0) the users must install the MCR (Matlab Component Runtime library) ver. 7.3 if it is not already installed on the user machine.

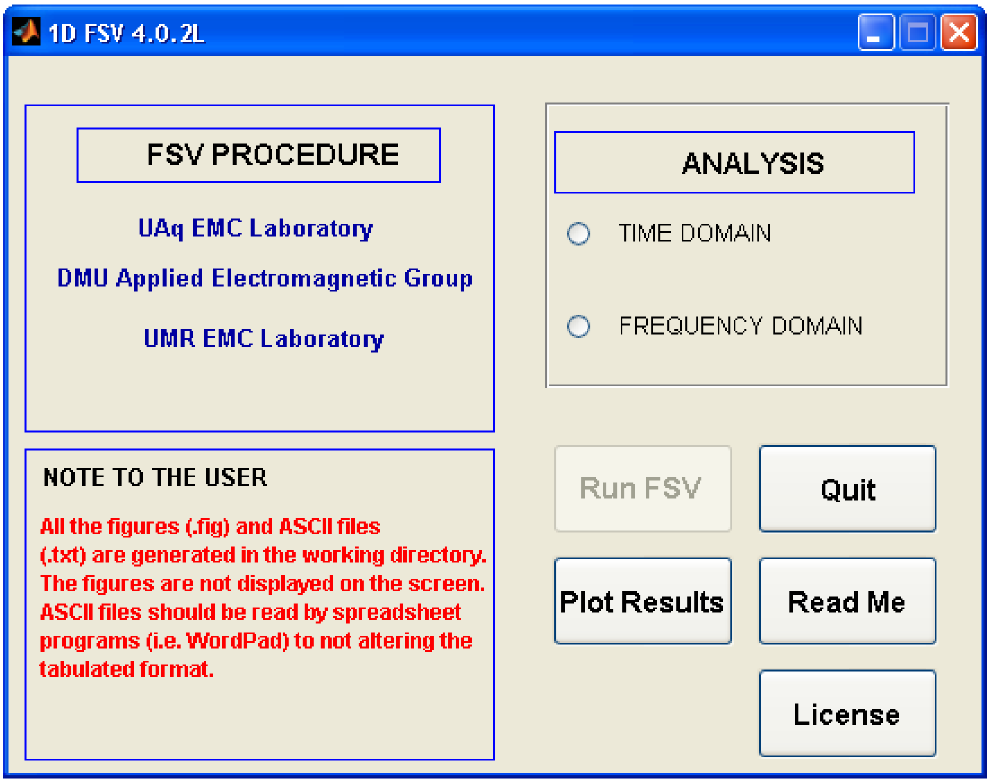
1. Get the package MCRInstaller.exe from http://ing.univaq.it/uaqemc/1D_FSV_2_0_0/, that is the MCR ver. 7.3 bundled with MATLAB 7.1.0.246 (R14 SP3).
2. Run MCRInstaller.exe once on the target machine, that is, the machine where you want to run the application. The MCRInstaller opens a command window and begins preparation for the installation. Then the MCR Installer wizard appears, click Next to begin the installation and follow the instructions on the GUI.
3. Unzip the content of the .zip file **1D_FSV*xxx*.zip** in the installation directory (i.e. "1D_FSV") and double click on *"fsv1D.exe"*.
4. In the zip package it is also provided an icon file (.ico) to create a desktop shortcut for the *"fsv1D.exe"* file according to the standard Windows' procedure.

Note for Windows Users: You must have administrative privileges to install the MCR on a target machine since it modifies both the system registry and the system path.
Running the 1D FSV after the MCR has been set up on the target machine requires only user-level privileges.

3 Run FSV Tool

3.1 Initial Window and analysis

Run the **FSV Tool** from the .exe in the installation directory or double-click on the desktop icon. When **FSV Tool** is started, an initial window appears (see Fig. 3.1). The user may choose any of the major functions desired.



NOTE TO THE USER

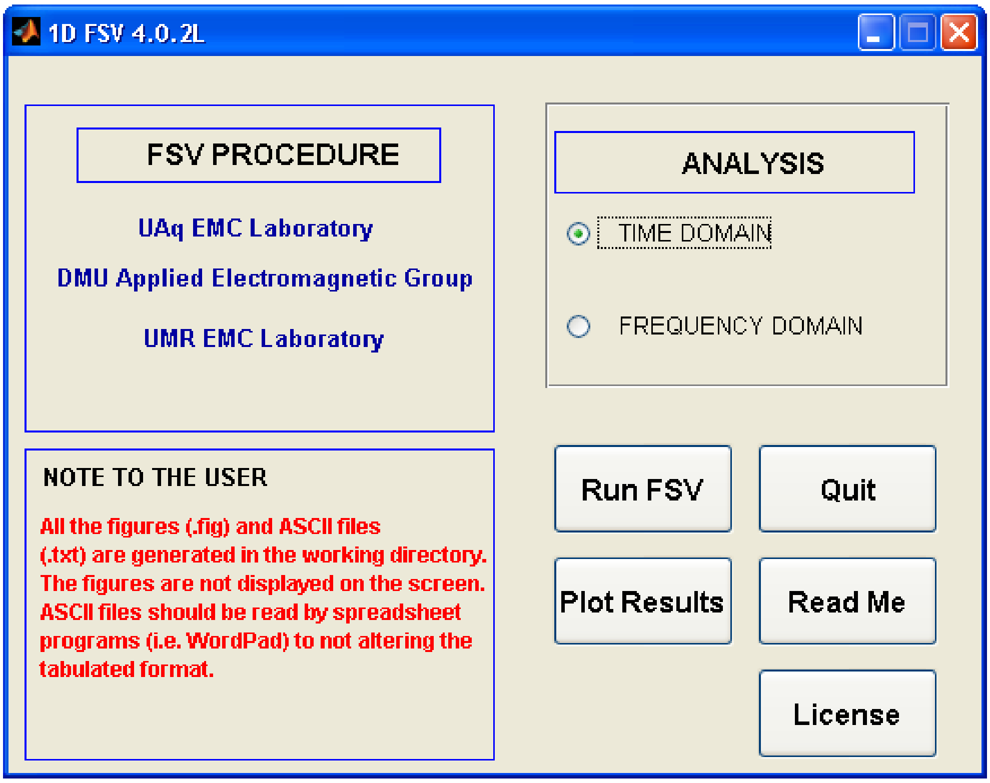
All the figures (.fig) and ASCII files (.txt) are generated in the working directory. The figures are not displayed on the screen. ASCII files should be read by spreadsheet programs (i.e. WordPad) to not altering the tabulated format.

Fig. 3.1 - Initial window (Main menu)

The major functions are:

1. Select the analysis mode in the **ANALYSIS** selection box
2. **Run FSV**: run an 1D FSV analysis (see Chapter 3)
3. **Quit**: exit the program
4. **Plot Results**: display results of previous analysis without running a new one (see Section 5.3)
5. **Read Me**: display this document

To run the first analysis the user has to select an analysis mode by using the radio button in the **ANALYSIS** selection box.



NOTE TO THE USER

All the figures (.fig) and ASCII files (.txt) are generated in the working directory. The figures are not displayed on the screen. ASCII files should be read by spreadsheet programs (i.e. WordPad) to not altering the tabulated format.

Fig. 3.2 - Selecting the Time Domain analysis

- ***TIME DOMAIN*:** time domain analysis is performed on two set of data that are generic Amplitude values.
- ***FREQUENCY DOMAIN*:** frequency domain analysis is performed. In this case FSV requests the type of frequency analysis to perform by the following dialog window:

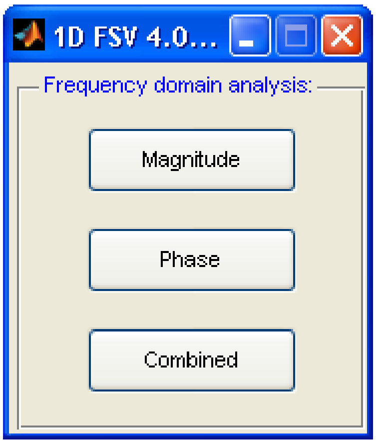


Fig. 3.3 - Frequency analysis menu

  - *Magnitude*: the data input are magnitude values.
  - *Phase*: the data input are phase values
  - *Combined*: the 1D FSV combined analysis performs two FSV analysis (magnitude and phase) and combines them in a unique result.

Note: though in the TIME DOMAIN – Amplitude analysis and in the FREQUENCY DOMAIN – magnitude and phase analysis 1D FSV applies an identical algorithm, the tool requests to specify the nature of the input data to be specified in order to use an appropriate terminology and graphic presentation.

3.2 Output data folder

Push the button **Run FSV**. Now **FSV Tool** requests the directory to select where the output data files will be saved.

Select Folder for OUTPUT Data

Fig. 3.4 - Window for selecting the destination directory

In the selected destination directory the **FSV Tool** will create a subdirectory named “Time Domain Analysis_x” (or “Frequency Domain Analysis_x”) in which the output files will be stored (see Chapter 7). ‘x’ is an incremental number to distinguish the subdirectories.

3.3 Input data loading

After that FSV requests the input data files to analyze according the analysis mode chosen in initial window.

FSV analyzes two set of data at a time in a normal computation and four set of combined data: i.e.a pair of Magnitude-Phase or real-imaginary set of data, in a combined analysis.

TIME DOMAIN:

- **Amplitude**. Two set of data at a time are analyzed: *Amplitude 1 – Amplitude 2*.

FREQUENCY DOMAIN

- **Magnitude**. two set of data at a time are analyzed: *Magnitude 1 – Magnitude 2*.
- **Phase**: two set of data at a time are analyzed: *Phase 1 – Phase 2*.
- **Combined**. four set of data at time are analyzed at a time. Each dataset is given by two components, Magnitude and Phase: (*Magnitude 1 and Phase 1) – (Magnitude 2 and Phase 2).*

As described in section 1.2, **1D FSV performs the comparison between the corresponding component**:

1) *Magnitude 1 – Magnitude 2*
2) *Phase 1 – Phase 2*

For each set of data FSV requests to specify the input format of the datasets by the GUI of Fig. 3.5. At the present time they are three: X-Y ASCII and Y-only ASCII (see Chapter 6):

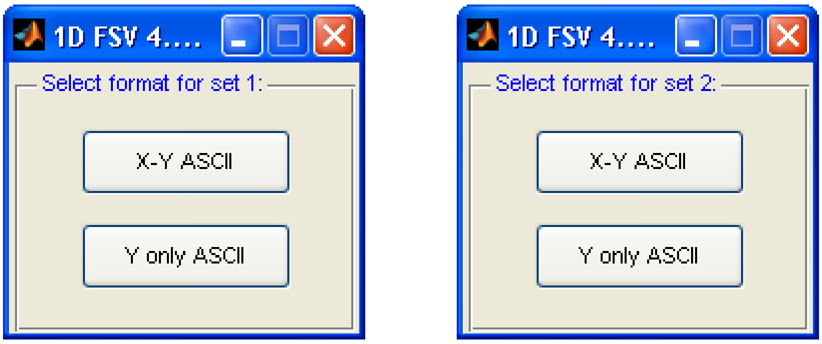


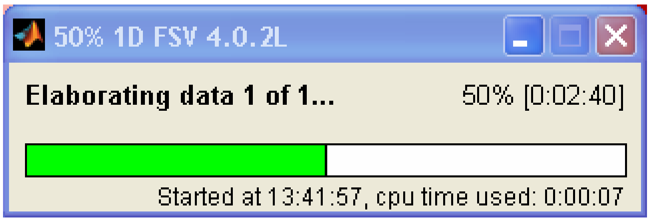
Fig. 3.5 – GUIs select input format for set 1 (left) and set 2 (right)

See Chapter 4 for detailed data loading procedure to follow for each analysis mode.

3.4 1D FSV Computation

3.4.1 Non combined data

The **FSV Tool** performs its calculations in the background.

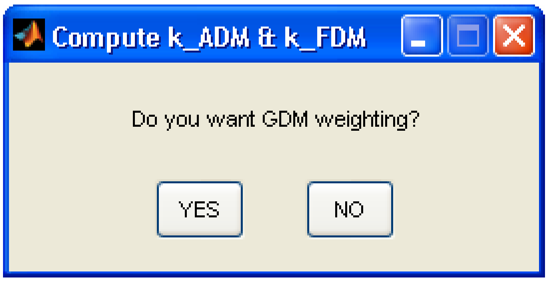


Elaborating data 1 of 1... 50% [0:02:40]

Started at 13:41:57, cpu time used: 0:00:07

Fig. 3.6 - 1D FSV progress bar

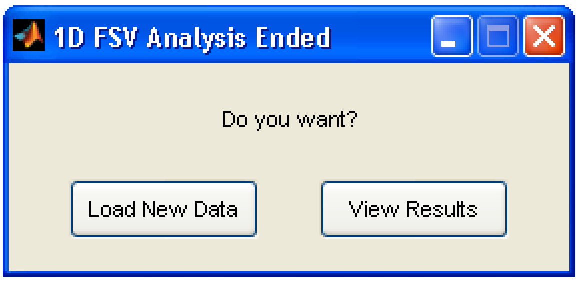
Once this has been completed, the user is prompted to use or decline the GDM weighting procedure (outlined in *point 20* of the Section 1.1) or not.



Do you want GDM weighting?

Fig. 3.7 - Window for selecting the GDM weighting.

At the end of the calculation a new question is issued, as in the next figure.



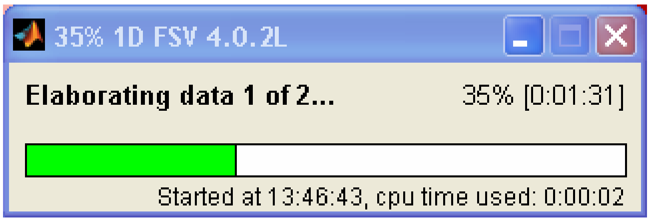
Do you want?

Fig. 3.8 - Window at the end of a complete 1D FSV analysis of a pair of data sets.

If it is answered **Load New Data,** then the **1D FSV Tool** back to Initial Window (Fig. 3.1) and is prepared for a new analysis.
If it is answered **View Results** the figures of the results are shown (see Section 5.2).

3.4.2 Combined data

The **FSV Tool** performs its calculations in background.

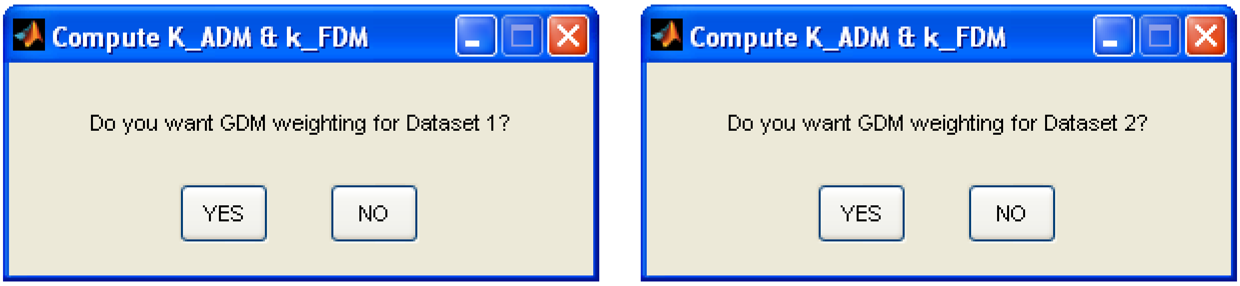


Elaborating data 1 of 2... 35% [0:01:31]

Started at 13:46:43, cpu time used: 0:00:02

Fig. 3.9 - Progress bar of combined analysis

In the case of combined analysis, for each component comparison, FSV calculates ADM, FDM, and GDM separately and for each one is issued to use the GDM weighting procedure:



Do you want GDM weighting for Dataset 1?

Do you want GDM weighting for Dataset 2?

Fig. 3.10 - Windows for selecting the GDM weighting in combined analysis

3.4.2.1 K weighting factor

After the GDM weighting procedures FSV requests to insert one or more $K_{magnitude}$, K_{phase} weighting factors (see section 1.2). The user can choose the value of the K factors by means of a GUI dialog:

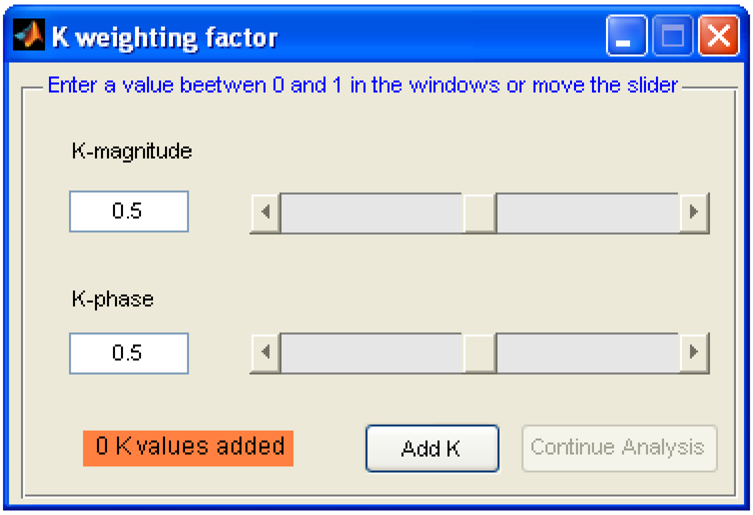


Fig. 3.11 - K weighting factor choice GUI

it can be directly inserted the value of $K_{magnitude}$ or K_{phase} and automatically the other one is computed according to (1.15). The default value for $K_{magnitude}$ and K_{phase} is 0.5.

Press **Add K** button to add a new pair of K weighting factors:

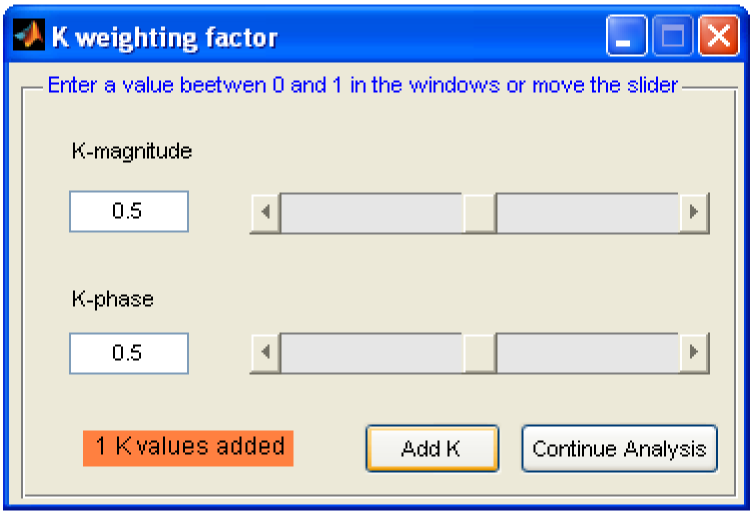
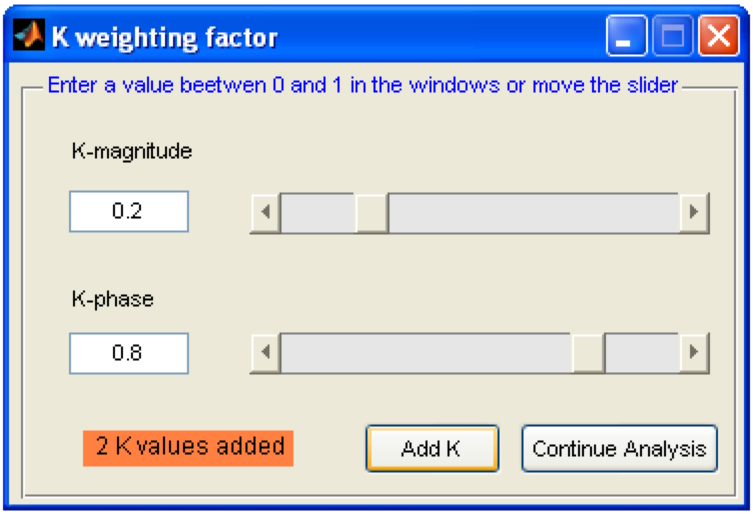


Fig. 3.12 – One value of K weighting factor added

At least one pair of K weighting factors must be entered in order to continue analysis, then the **Continue Analysis** button is enabled.
The counter in the bottom-left orange box gives the number of K weighting factors added:


K weighting factor

Enter a value beetwen 0 and 1 in the windows or move the slider

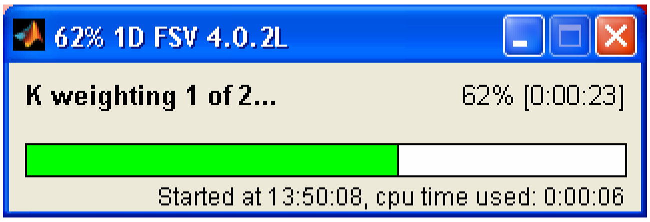
K-magnitude 0.2

K-phase 0.8

2 K values added

Fig. 3.13 - Two value of K weighting factor added

When all K are inserted is possible to run the analysis for each K by pressing **Continue Analysis** button:


62% 1D FSV 4.0.2L

K weighting 1 of 2... 62% [0:00:23]

Started at 13:50:08, cpu time used: 0:00:06

Fig. 3.14 - Progress bar of K weighting procedure

The GUI prevents the insertion of a pair of K weighting factors that have already been added, or where invalid values of K are being entered, ($0 \leq K_{magnitude}, K_{phase} \leq 1$), and displays these warnings:


Warning...

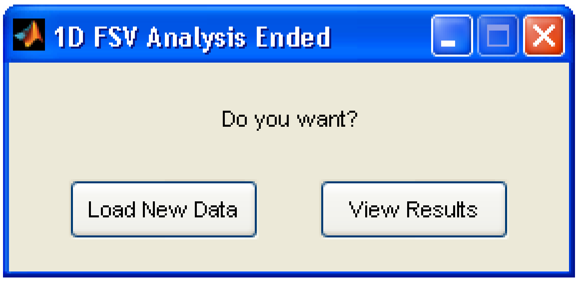
K value already present !

Warning...

K must be 0 <= K <= 1 !

Fig. 3.15 - K Warning Dialogs

At the end of the calculations a new prompt is issued as in the next figure.


1D FSV Analysis Ended

Do you want?

Fig. 3.16 - Window at the end of a complete 1D FSV analysis of a pair of data sets

If it is answered **Load New Data,** then the **1D FSV Tool** back to Initial Window (Fig. 3.1) and is prepared for a new analysis.
If it is answered **View Results** the figures of the results are shown (see Section 5.2).

4 Input Data Loading

The current 1D FSV release take can be chosen from X-Y ASCII and Y only ASCII formats. For the data structure of the input files see Chapter 6. In this examples we assume that input data are stored in X-Y ASCII structure. Then each set is given by one file.

4.1 Domain and data requirements

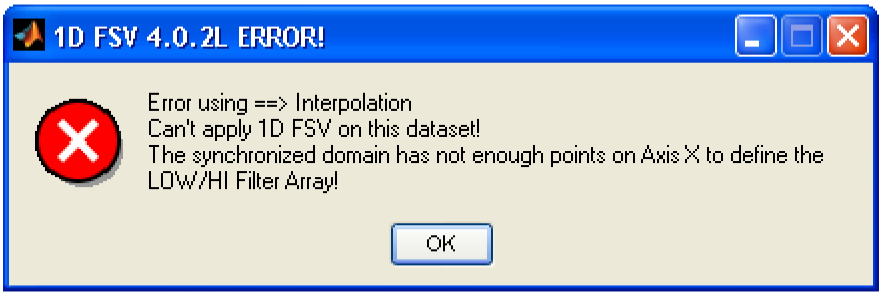
Consider a dataset with a domain on *x* axis of N points. In the non-combined analysis two data sets are compared: first of all 1D FSV calculates the overlay window of the input data by finding lower and upper bound of the two domains. If **the intersection of two domains isn't empty** the resulting domain values are interpolated using the minimum of the punctual steps of the two original domains. But there are two checks to perform:

1. **Condition 1: Absolute minimum size.** In order to correctly build the Low and High filter the data size is lower limited by a minimum value that depends by the DC cut-off radius. The total minimum size is given by:

   2*(DC + 12) - 1

   If *DC=4* the minimum data size for each dimension is **31 points**.

The error messages of the GUI are:

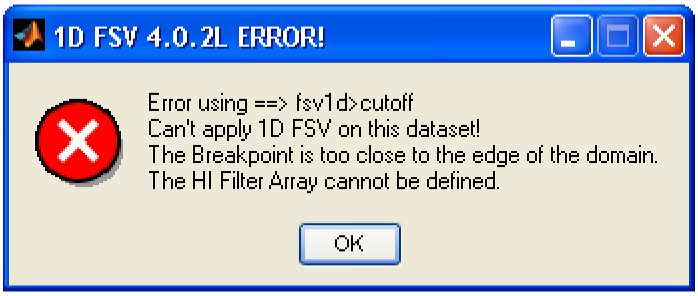


Error using ==> Interpolation
Can't apply 1D FSV on this dataset!
The synchronized domain has not enough points on Axis X to define the LOW/HI Filter Array!

Fig. 4.1 – Error Message GUI for insufficient points on *x* axis

2. **Condition 2: High filter realizability.** The breakpoint value cannot be greater than a certain value to allow the building of high filter.

   The error message of the GUI is:


1D FSV 4.0.2L ERROR!

Error using ==> fsv1d>cutoff
Can't apply 1D FSV on this dataset!
The Breakpoint is too close to the edge of the domain.
The HI Filter Array cannot be defined.

Fig. 4.2 - Error Message GUI for breakpoint greater than BK_{max}

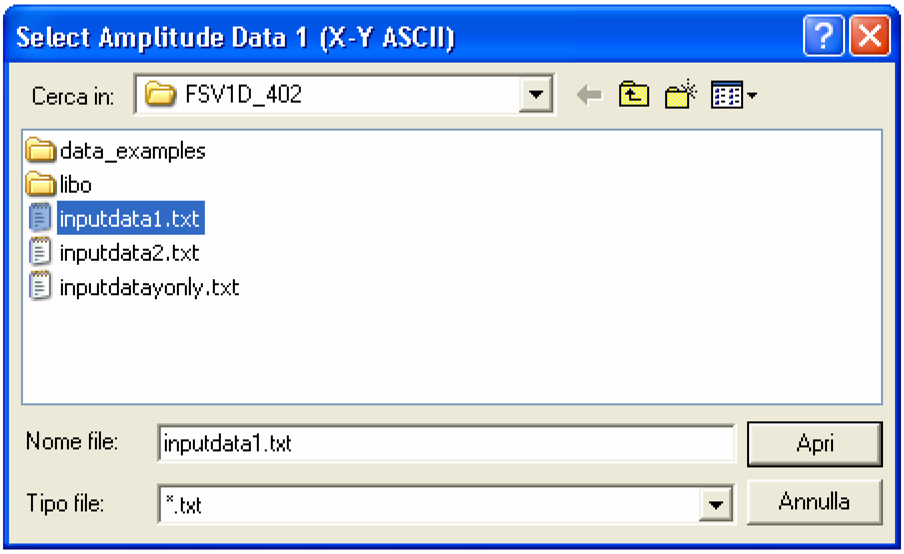
Only for the combined data:

In the combined analysis two pair of data sets are compared, i.e.:
1) Magnitude 1 – Magnitude 2
2) Phase 1 – Phase 2
For each pair of data sets, 1) and 2), the previous above two condition must be valid, in addition, to be correctly combined, **the domain of each Magnitude and Phase parts must be identical.** In the example Magnitude 1(2) domain must be identical to Phase 1(2) domain.

4.2 Loading X-Y ASCII format

This format can be used when data coming from different sources have to be compared. 1D FSV can import data stored in two column ASCII file (see Section 6.1).
An example of loading one set of data in X-Y ASCII format:

1. Select the file (i.e. *inputdata1.txt*) containing the data set 1 as in Fig. 4.3:


Select Amplitude Data 1 (X-Y ASCII)

Cerca in: FSV1D_402

Nome file: inputdata1.txt

Tipo file: *.txt

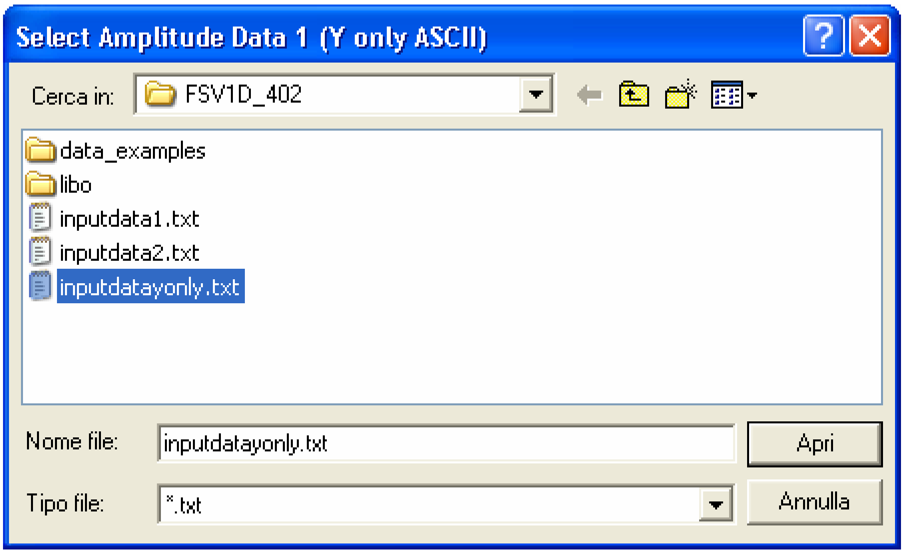
Fig. 4.3 - Window for domain files' selection

The same sequence of windows is proposed for the loading of the second set of data.

4.3 Loading Y onlyASCII format

1D FSV can import data stored in one column ASCII file (see Section 6.2).
An example of loading one CST ASCII set:

1. Select the Y only ASCII data file (i.e. *inputdata1yonly.dat*) containing the set as in Fig. 4.4:



Select Amplitude Data 1 (Y only ASCII)

Cerca in: FSV1D_402

data_examples
libo
inputdata1.txt
inputdata2.txt
inputdatayonly.txt

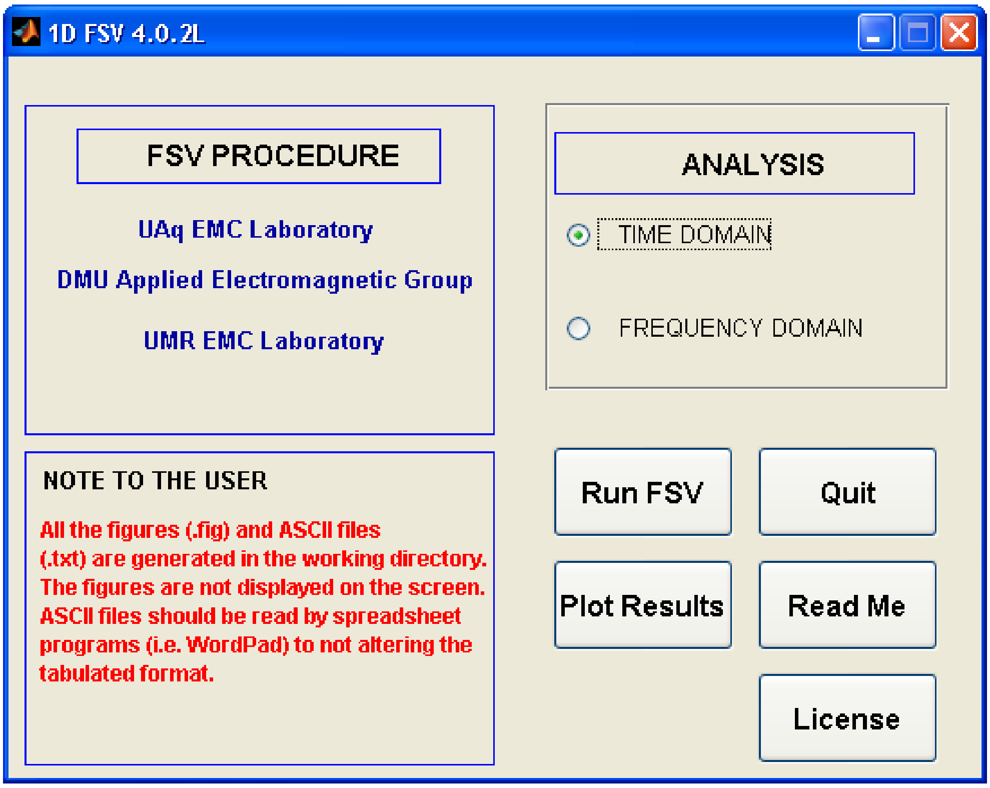
Nome file: inputdatayonly.txt

Tipo file: *.txt

Fig. 4.4 - Window for data files selection

The same sequence of windows is proposed for the loading of the second set of data.

4.4 Time domain analysis


1D FSV 4.0.2L

FSV PROCEDURE

UAq EMC Laboratory

DMU Applied Electromagnetic Group

UMR EMC Laboratory

ANALYSIS

● TIME DOMAIN

○ FREQUENCY DOMAIN

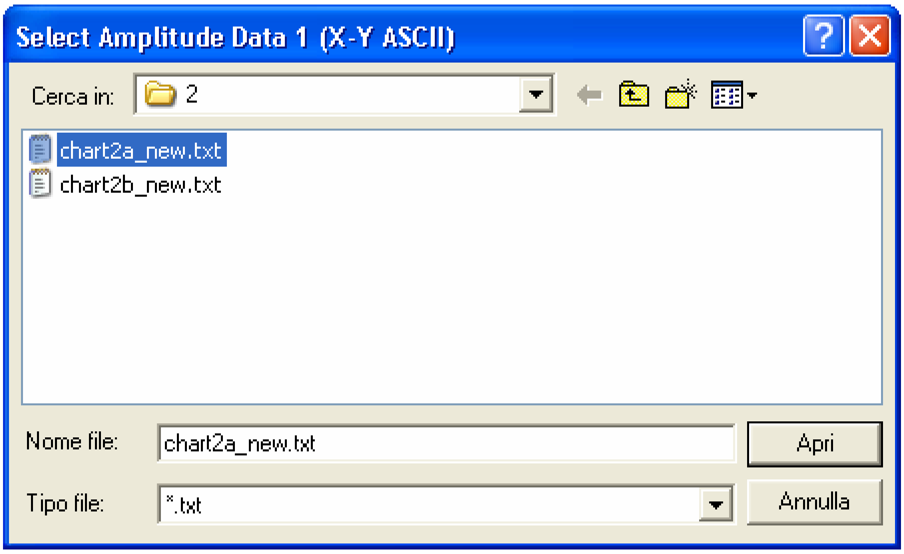
NOTE TO THE USER

All the figures (.fig) and ASCII files (.txt) are generated in the working directory. The figures are not displayed on the screen. ASCII files should be read by spreadsheet programs (i.e. WordPad) to not altering the tabulated format.

Fig. 4.5 - Selecting the Time Domain analysis

In the *TIME DOMAIN – Amplitude* analysis after the Output data folder is set **FSV Tool** requests the input data. In this example the input data files are in MATLAB FSV ASCII format.

1. Fig. 4.6 Select the directory in which your data are located. For test purposes it can be used the *data_examples/survey_data/2* directory that is located in same folder of the main program "*fsv1D.exe*". Select the file (i.e. *chart2a_new.txt*) containing the data and domain set as in Fig. 4.6:


Select Amplitude Data 1 (X-Y ASCII)

Cerca in: 2

chart2a_new.txt
chart2b_new.txt

Nome file: chart2a_new.txt

Tipo file: *.txt

Fig. 4.6 - Window for domain files' selection 1

2. Select the second file (i.e. *chart2b_new.txt*) containing the second set as in Fig. 4.7:

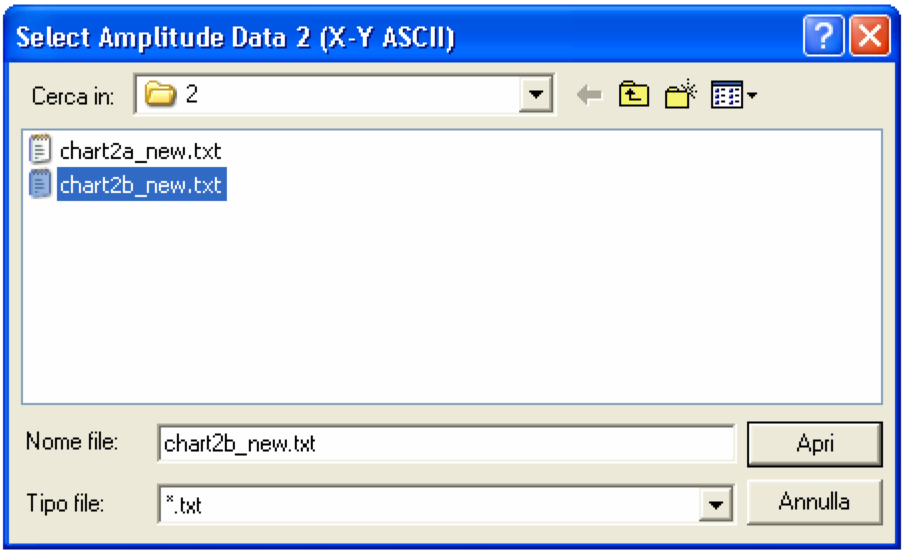


chart2a_new.txt
chart2b_new.txt

Nome file: chart2b_new.txt

Tipo file: *.txt

Fig. 4.7 - Window for data files' selection 1

4.5 Frequency domain analysis

Again in the following examples the input data files are in X-Y ASCII format:

4.5.1 Magnitude

In the *FREQUENCY DOMAIN – Magnitude* FSV Tool requests two input datasets to compare. Basically you can follow the same procedure as seen in *TIME DOMAIN – Amplitude* analysis:

1. Select the first file (i.e. *chart2a_new.txt*) containing the first magnitude set,
2. Select the second file (i.e. *chart2b_new).txt*) containing the second magnitude set.

4.5.2 Phase

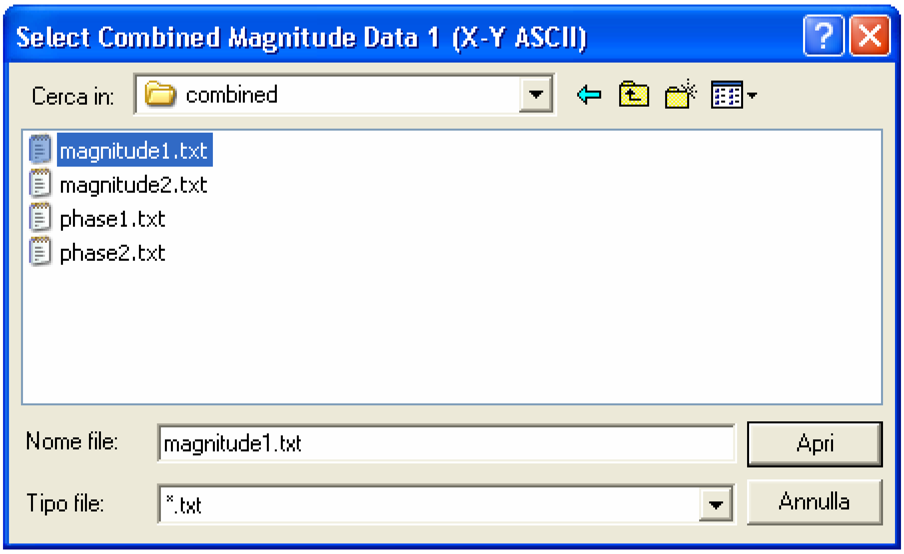
In the *FREQUENCY DOMAIN* –FSV Tool requests two input datasets to compare.

3. Select the first file (i.e. *chart2a_new.txt*) containing the first phase set,
4. Select the second file (i.e. *chart2b_new).txt*) containing the second phase set.

4.5.3 Combined

In the *FREQUENCY DOMAIN – Combined* analysis FSV Tool requests two combined input sets to compare.

1. Select the directory in which your data are located. For test purposes the *data_examples/combined* directory that is located in same folder of the main program *fsv1D.exe*" can be used. Select the first file (i.e. m*agnitude1.txt*) containing the data of component 1 of first combined set:



Select Combined Magnitude Data 1 (X-Y ASCII)

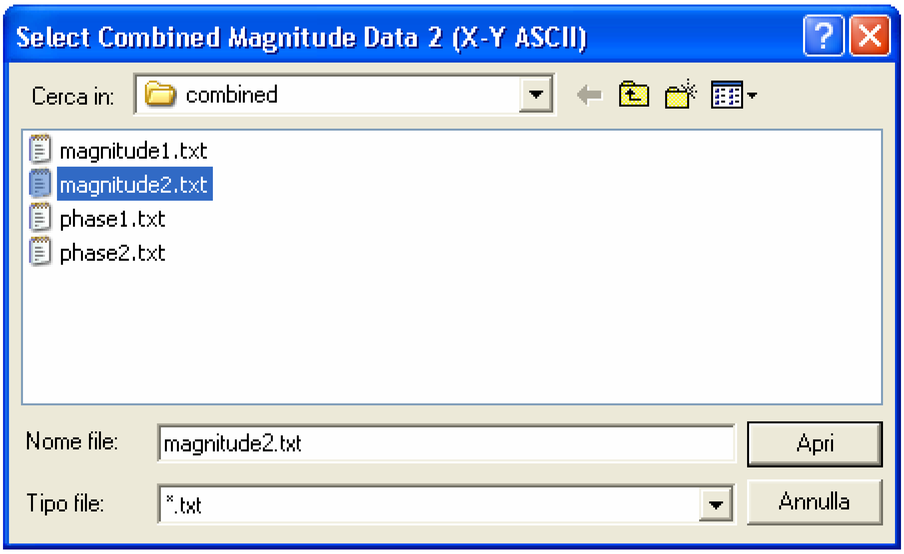
Cerca in: combined

Nome file: magnitude1.txt

Tipo file: *.txt

Fig. 4.8 - Window for magnitude files' selection 1

2. Select the second file (i.e. *magnitude2.txt*) containing the data of component 2 of first combined set:



Select Combined Magnitude Data 2 (X-Y ASCII)

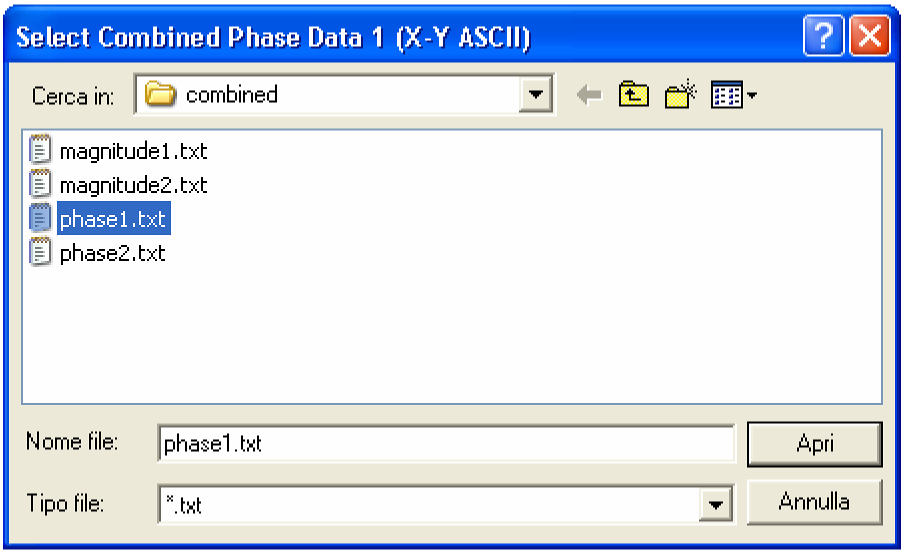
Cerca in: combined

Nome file: magnitude2.txt

Tipo file: *.txt

Fig. 4.9 - Window for magnitude files' selection 2

3. Select the third file (i.e. *phase1.txt*) containing the data of component 1 of second combined set:



Select Combined Phase Data 1 (X-Y ASCII)

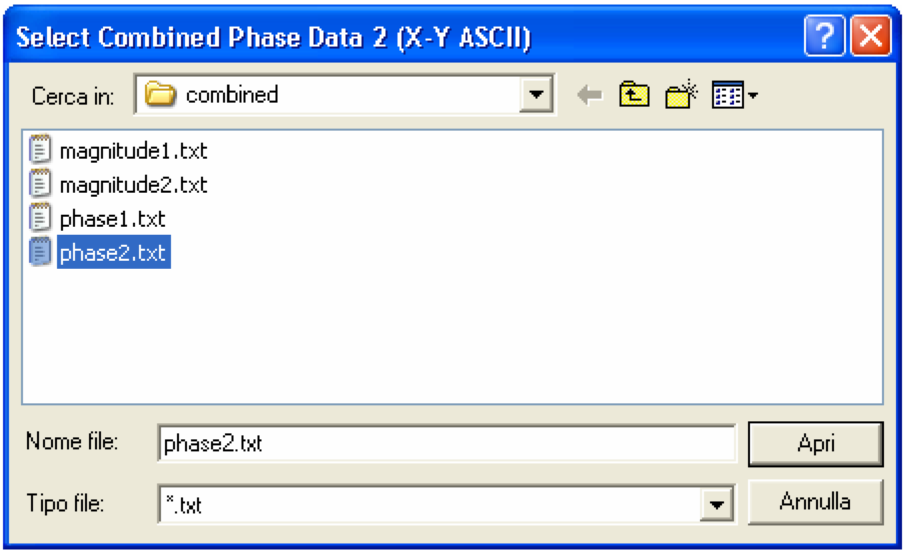
Cerca in: combined

Nome file: phase1.txt

Tipo file: *.txt

Fig. 4.10 - Window for phase files' selection 1

4. Select the fourth file (i.e. *Phase2.txt*) containing the data of component 2 of second combined set:



Select Combined Phase Data 2 (X-Y ASCII)

Cerca in: combined

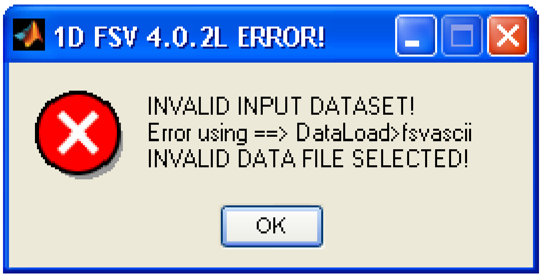
Nome file: phase2.txt

Tipo file: *.txt

Fig. 4.11 - Window for phase files' selection 2

4.6 Invalid input data loading

- When input data files selected contain invalid data or structure an error dialog is displayed:

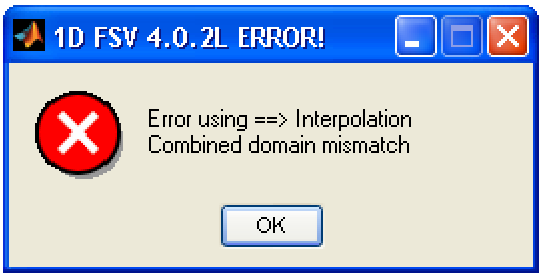


1D FSV 4.0.2L ERROR!

```
INVALID INPUT DATASET!
Error using ==> DataLoad>fsvascii
INVALID DATA FILE SELECTED!
```

Fig. 4.12 - Error window for invalid input data loading

- When in the combined analysis, **the domain of each Magnitude and Phase parts of a given combined set is not identical in every sample** this error dialog is displayed:



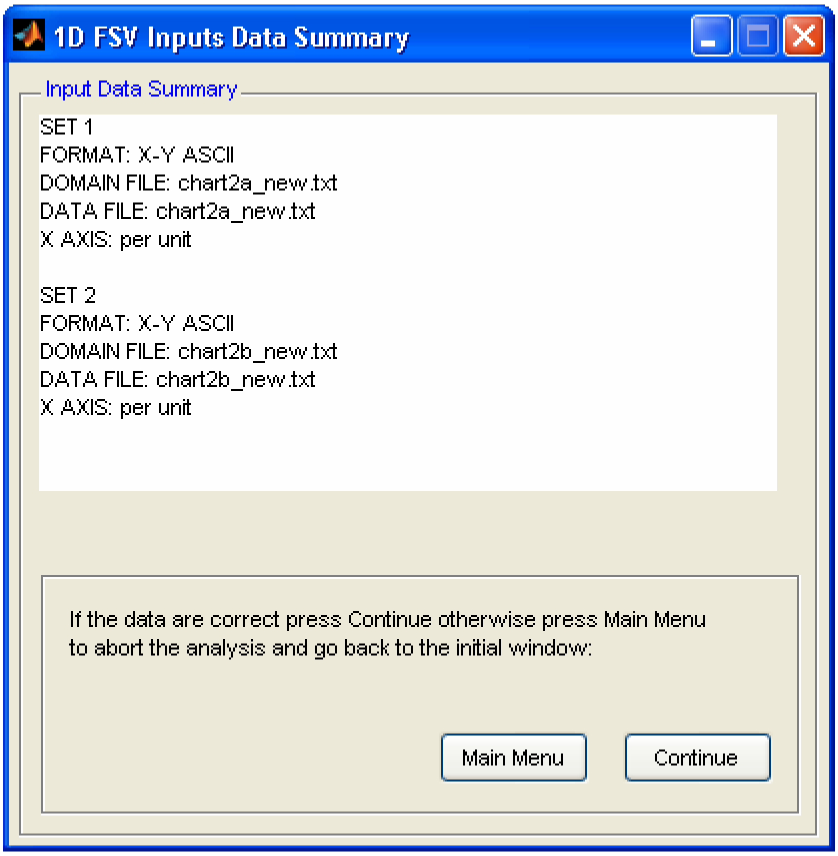
Error using ==> Interpolation
Combined domain mismatch

Fig. 4.13 - Error window for Combined domain mismatch

After an error data loading occurs FSV stop the current task and returns back to the Main menu (3.1).

4.7 Summary GUI

At the end of the data loading procedure, it is displayed a summary of the loaded data and domain's settings:



SET 1
FORMAT: X-Y ASCII
DOMAIN FILE: chart2a_new.txt
DATA FILE: chart2a_new.txt
X AXIS: per unit

SET 2
FORMAT: X-Y ASCII
DOMAIN FILE: chart2b_new.txt
DATA FILE: chart2b_new.txt
X AXIS: per unit

If the data are correct press Continue otherwise press Main Menu to abort the analysis and go back to the initial window:

Fig. 4.14 – Summary GUI

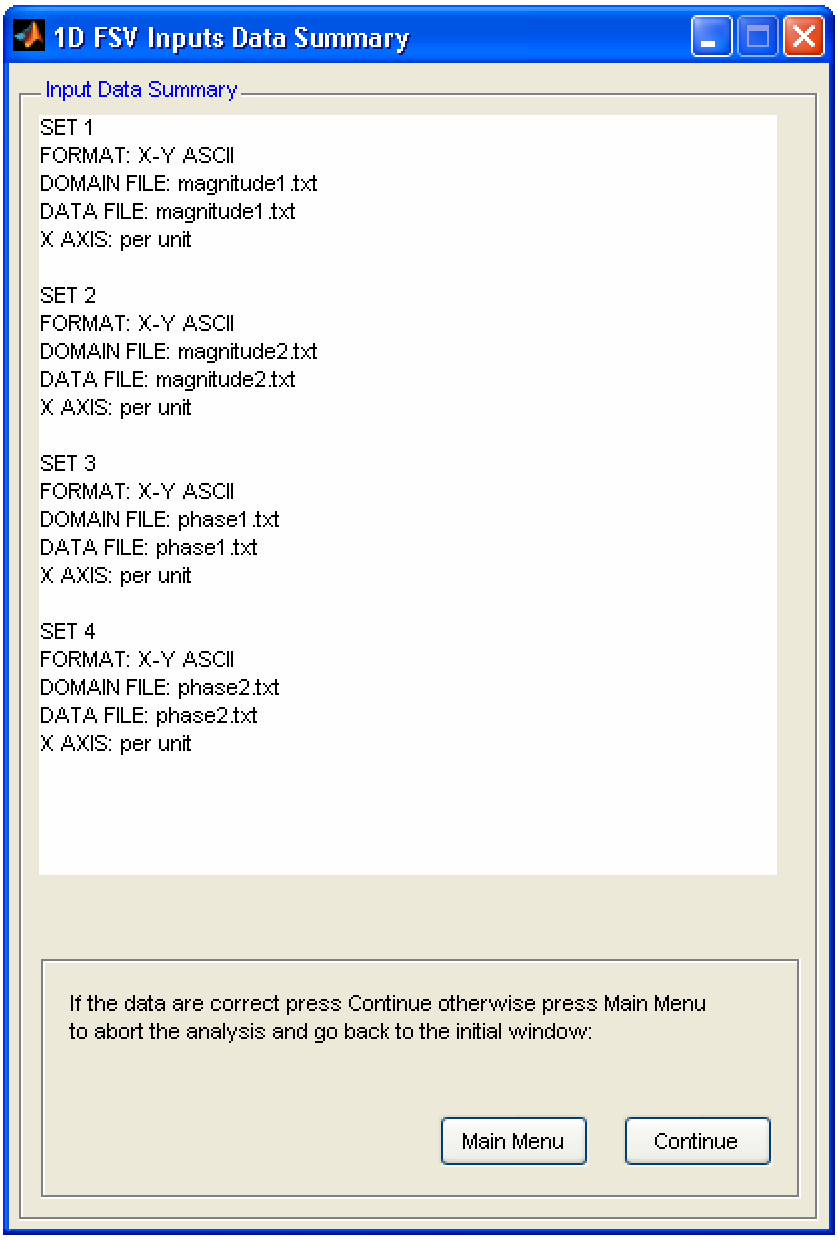
For each data set it is specified:

- **FORMAT**: the format of input data;
- **DOMAIN FILE:** name of the file that containing the domain;
- **DATA FILE:** name of the file that containing the data;
- **X AXIS:** dimensional unit set for the X axis

At this point the user can start the analysis pressing **Continue** or to go back to the initial window pressing **Main Menu**.

Combined analysis summary

For the combined data analysis is displayed an expanded version of summary GUI:



SET 1
FORMAT: X-Y ASCII
DOMAIN FILE: magnitude1.txt
DATA FILE: magnitude1.txt
X AXIS: per unit

SET 2
FORMAT: X-Y ASCII
DOMAIN FILE: magnitude2.txt
DATA FILE: magnitude2.txt
X AXIS: per unit

SET 3
FORMAT: X-Y ASCII
DOMAIN FILE: phase1.txt
DATA FILE: phase1.txt
X AXIS: per unit

SET 4
FORMAT: X-Y ASCII
DOMAIN FILE: phase2.txt
DATA FILE: phase2.txt
X AXIS: per unit

If the data are correct press Continue otherwise press Main Menu to abort the analysis and go back to the initial window:

Fig. 4.15 - Summary GUI in combined analysis

and an expanded version of **Scaling of domain's dataset** GUI:

5 The Data Display Tool

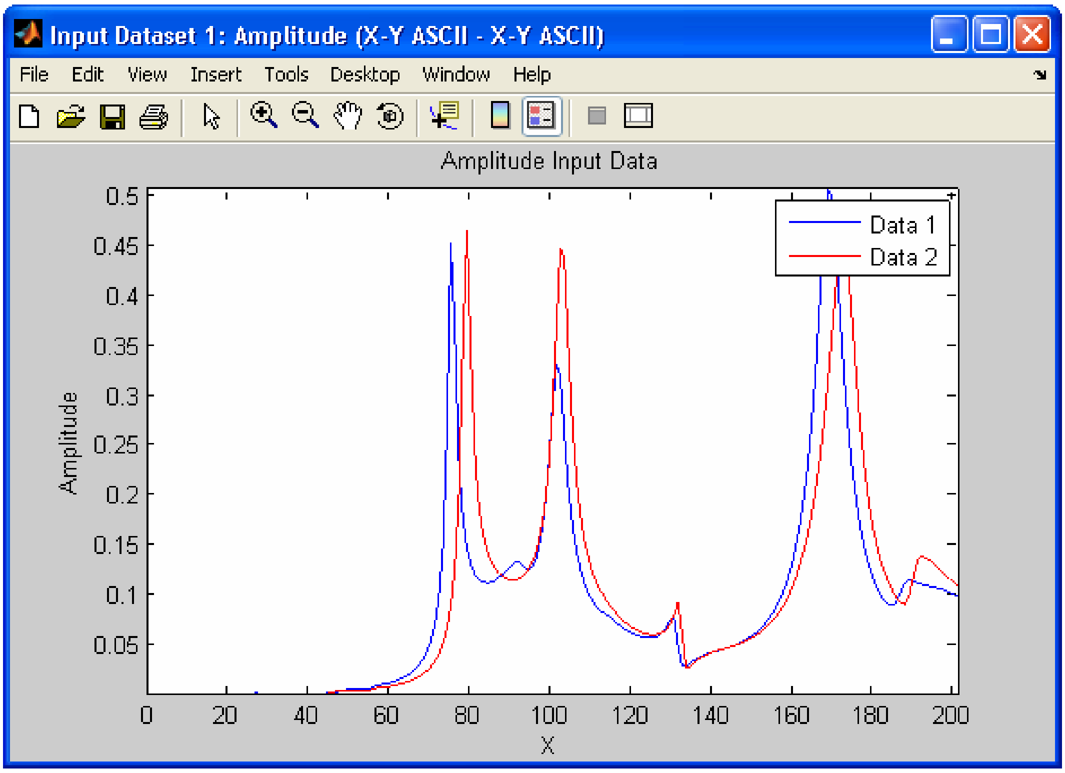
5.1 The Results GUI

The **Data Display Tool** is an application embedded in the **FSV Tool** that allows the user to visualize the relevant FSV variables associated with the comparison of two datasets. The **Data Display Tool** plots the data contained in the *.mat* files generated by the FSV procedure.
The **Data Display Tool** allows the visualization of the two original data sets and of the FSV variables associated at the FSV analysis performed.

The three buttons on top of the GUI are:

- **Main menu**: back to the FSV main window analysis (Fig. 3.1)
- **Data Display**: display the main results GUI panel
- **Grade/Spread chart**: display the Grade/Spread chart panel.

5.1.1 The Data Display panel



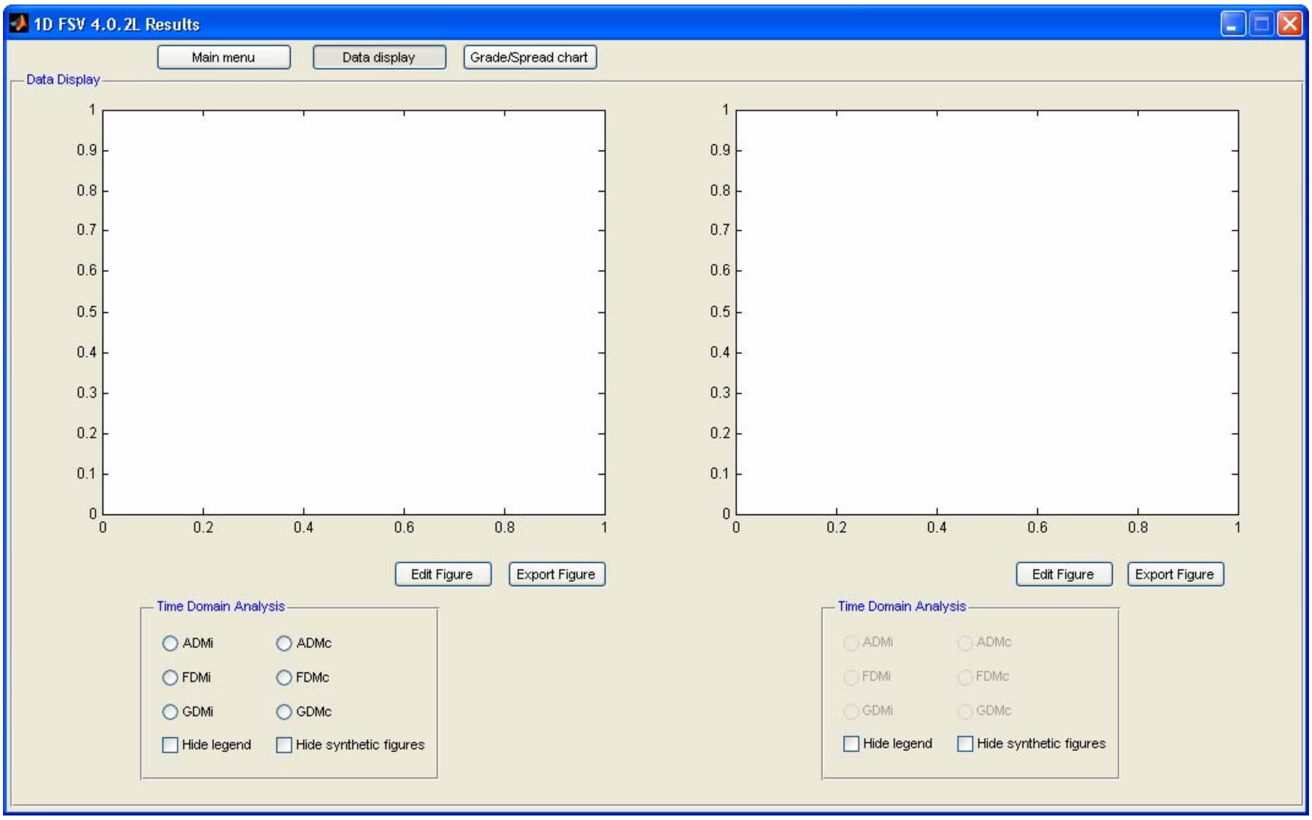


Fig. 5.1 - The original data window and main Data Display Tool window

In the main window of the Results GUI there are two drawing areas:

- **Drawing box**: area in which the graph are displayed.
- **Export Figure** button: take a screenshot of the currently graph displayed. The displayed graph is exported in PNG format. The figure is saved in a file, located in the subdirectory inside the selected directory for output data, with the name of the displayed FSV variable.
- **Edit Figure** button: open the current graph, displayed in drawing box, in a new window (Fig. 5.2) with the full figure toolbar to inspect and analyze the figure.
- **Selection box**: select the graph to display in corresponding drawing box from ADMi, FDMi, GDMi, ADMc, FDMc and GDMc radio buttons.
  Hide legend checkbox: hide the legend textbox in the ADMi, FDMi and GDMi graphs.
  Hide synthetic figures checkbox: hide the annotation textboxes in the ADMc, FDMc and GDMc graphs.

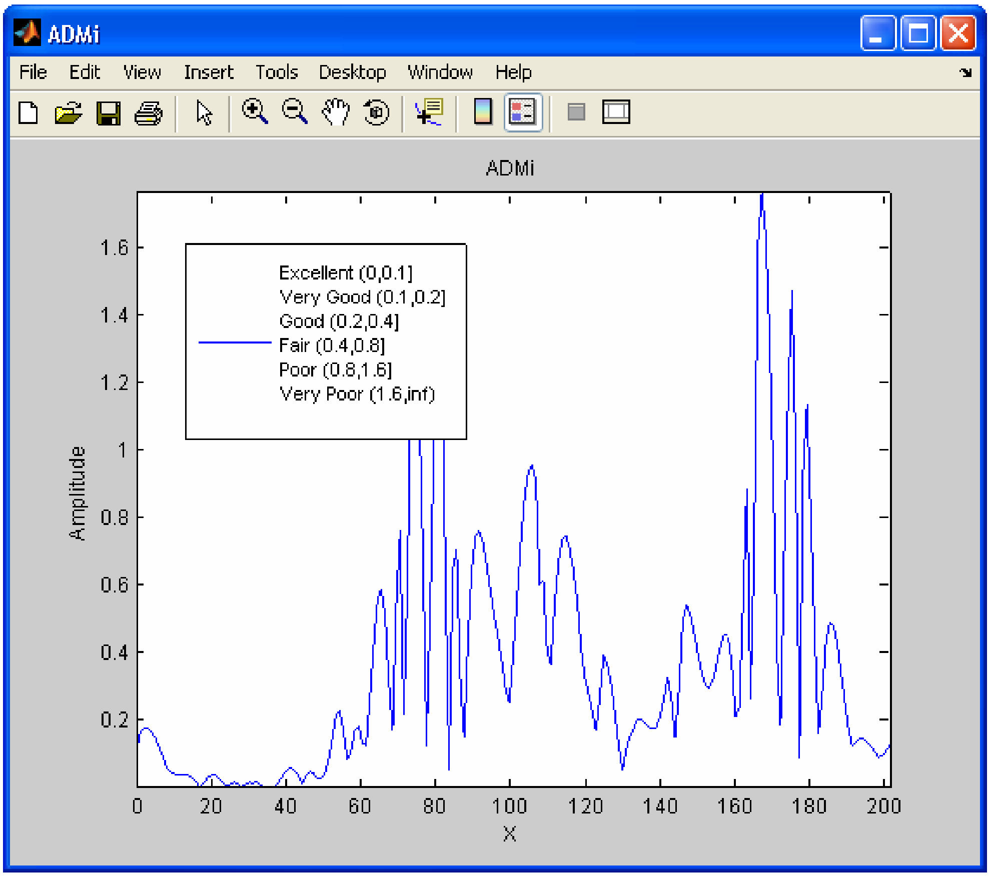


Fig. 5.2 – ADM$_i$ in the **Edit Figure** GUI

Select the radio-buttons on the bottom-left frame to display one variable (ADMi, ADMc, etc.). After this selection the radio-buttons on the opposite bottom-right frame are enabled for selection of another variable to be displayed:

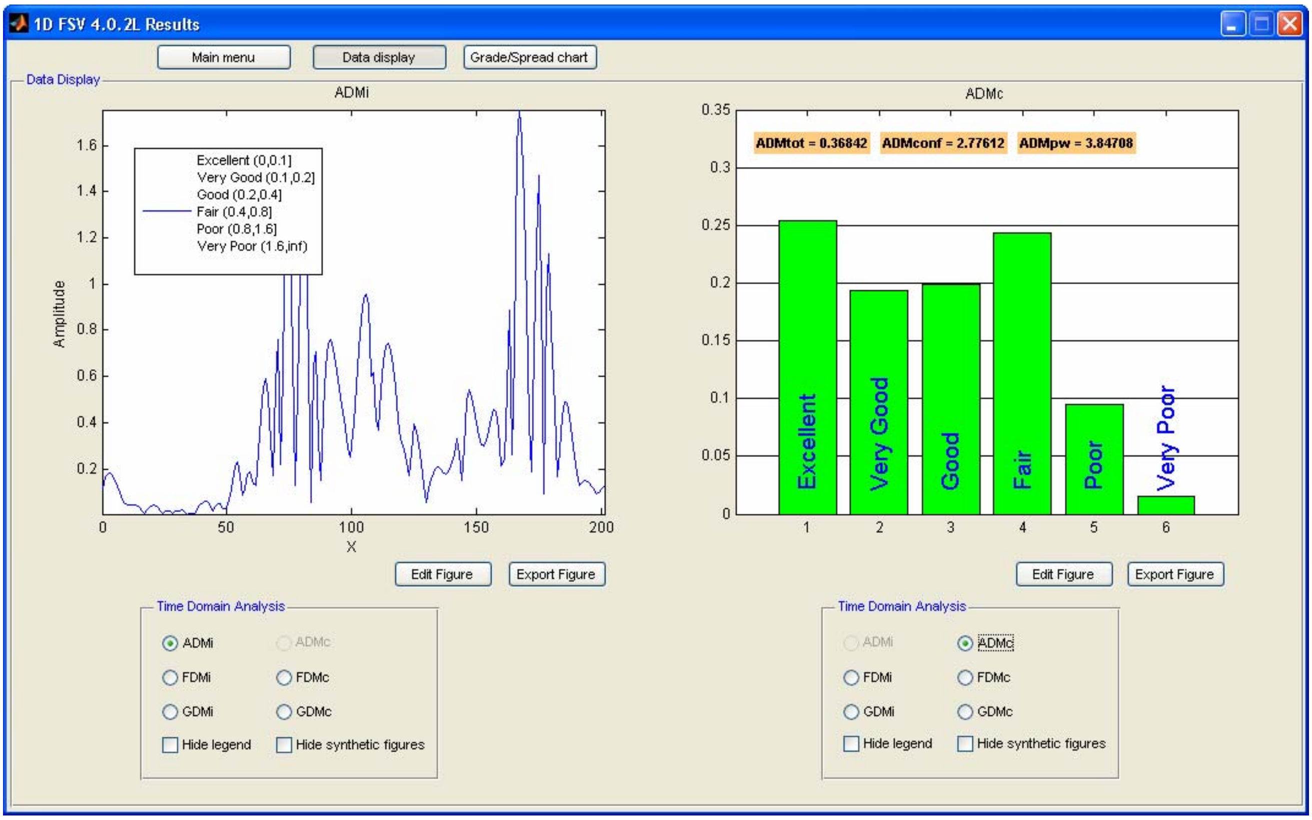


Fig. 5.3 - Data Display Tool with graphs displayed

ADMi, FDMi, GDMi

At the left of each 3D graph, ADMi, FDMi, GDMi, a colorbar is displayed. The bottom of the color scale is associated with 0 (Excellent values) and the top with 1.6 (Extremely poor values). Then the labels of the colorbar are 0-Excellent, 0.1-Very Good, 0.2 Good, 0.4 Fair, 0.8-Poor and 1.6 Extremely Poor.
Moreover inside the graph a legend is displayed that associates one of the six natural language descriptor categories to each range of values.

ADMc, FDMc, GDMc

This is a graph with six vertical bars, one for each six natural language descriptor categories.
In the top of graph is displayed *xDMtot*, *xDMconf*, *xDMpw* values (x = A,F,G) in a yellow textboxes (see Section 1.1).

5.1.2 Grade/Spread chart

By selecting the **Grade/Spread chart** button, the FSV Grade/Spread chart appears (see Section 1.1). All variables are displayed on the chart for the default threshold of 85%.

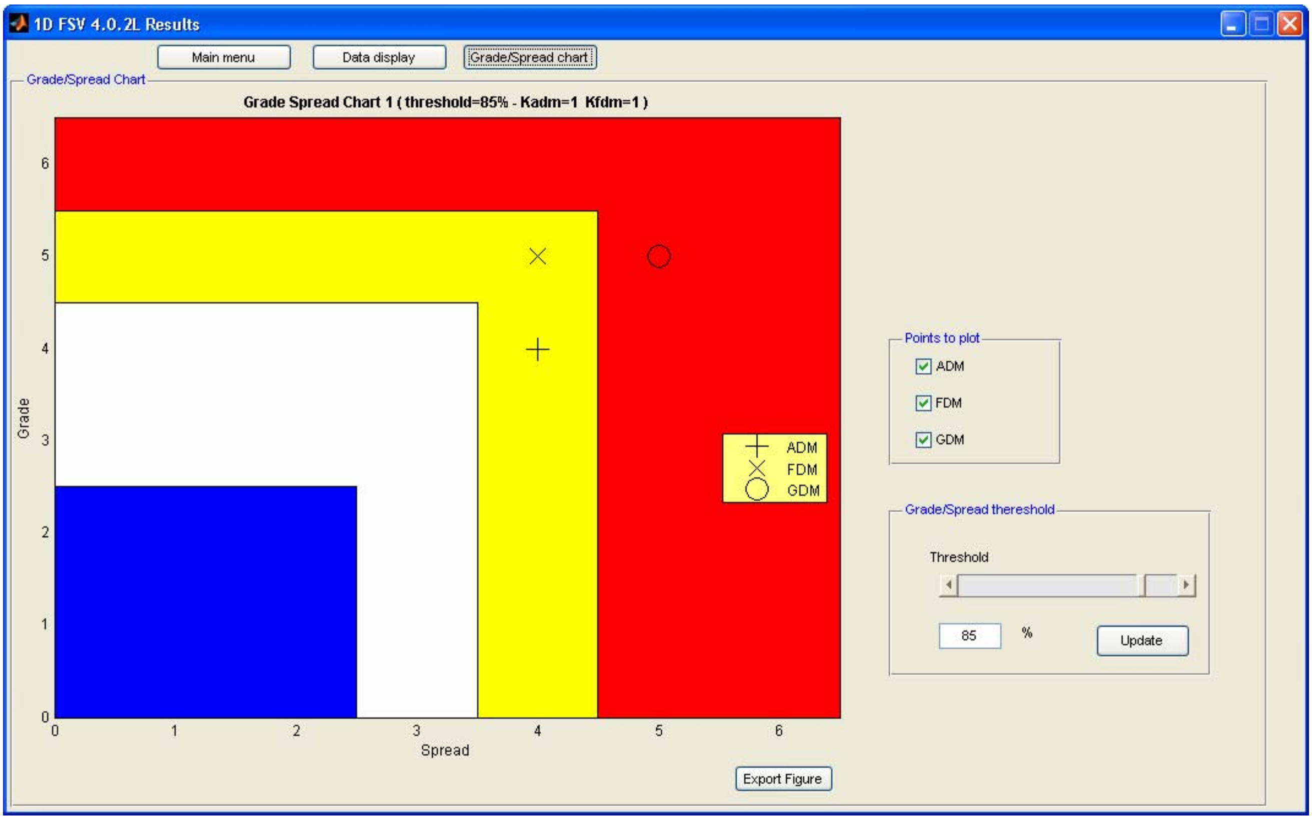
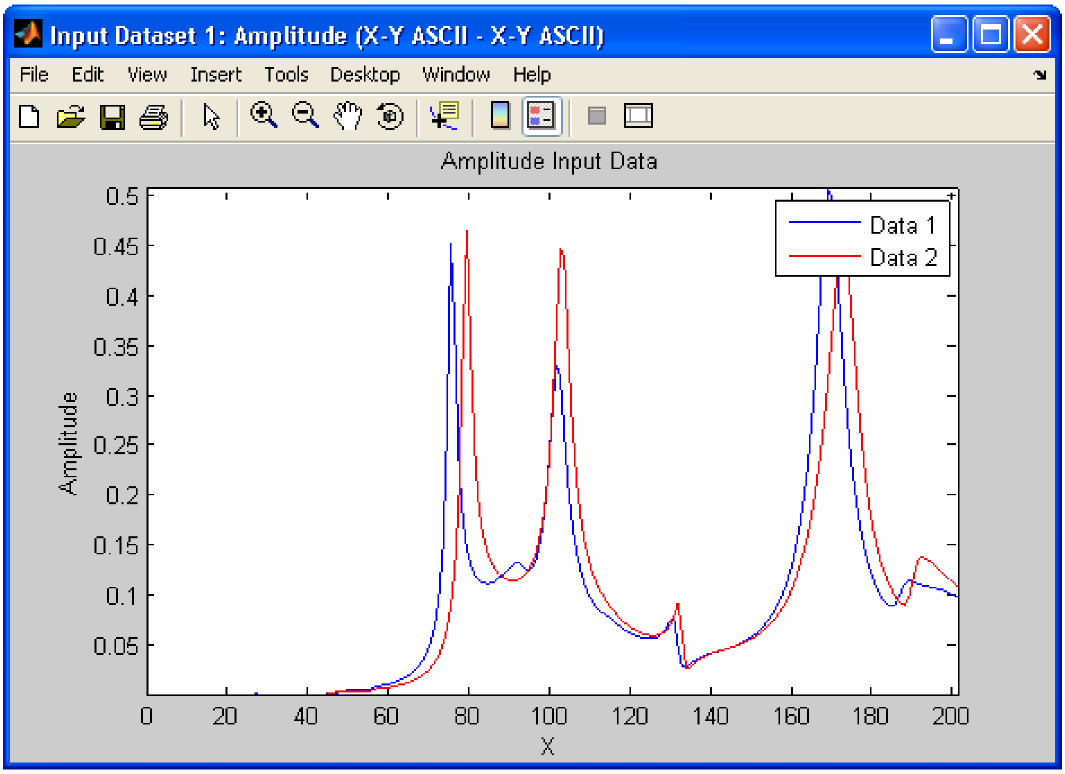


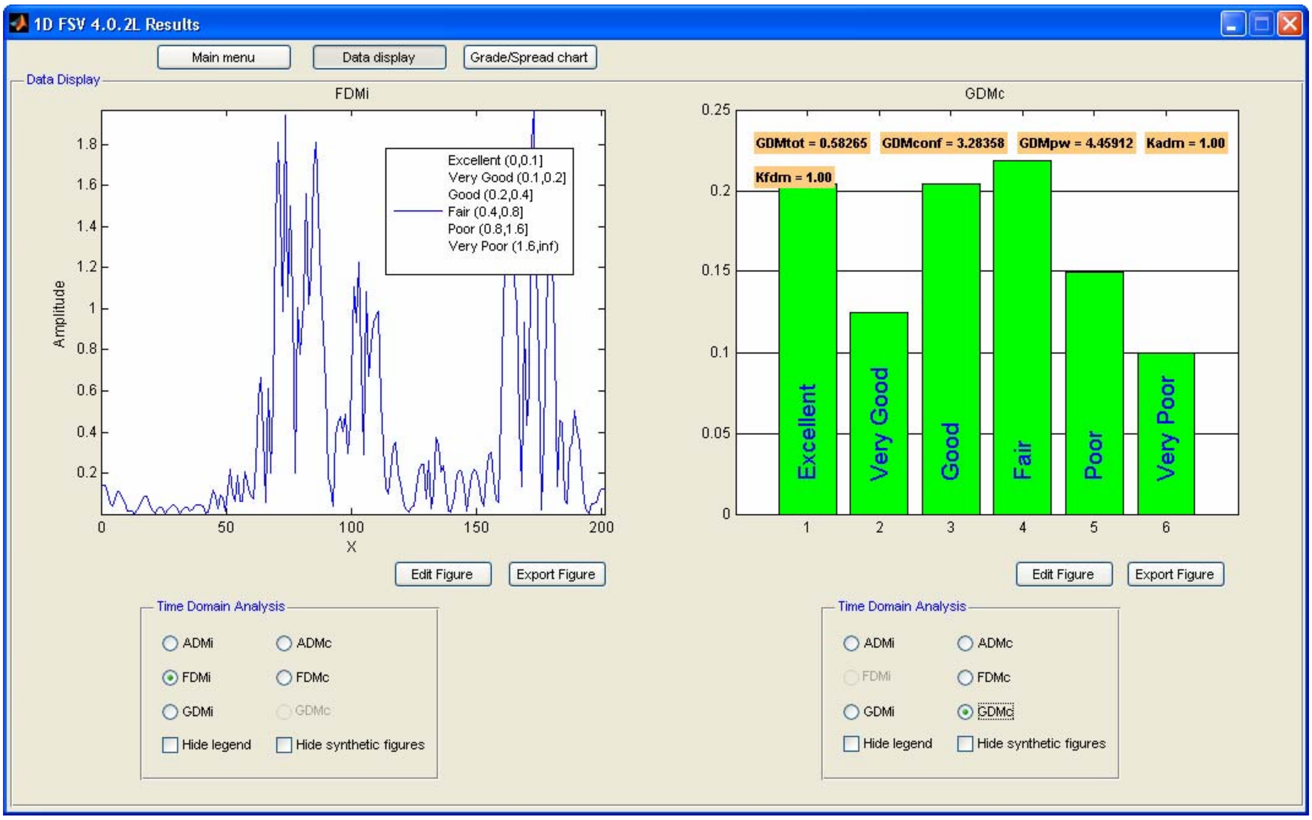
Fig. 5.4 - The GRADE-SPREAD coloured chart

- The value of threshold currently used and the k_{ADM} *and* k_{FDM} used in forming GDM (eq. 1.11) are shown above the GRADE/SPREAD chart.
- **Export Figure** button: take a screenshot of the currently graph displayed. The displayed graph is exported in PNG format. The figure is saved in a file, located in the subdirectory inside the selected directory for output data named with the value of the threshold.
- **Points to plot** checkboxes: select the GRADE/SPREAD points to plot from ADM, FDM and GDM.
- **Grade/Spread threshold** box**:** from this section, the threshold can be modified entering the new value in the appropriate text field or moving the slider, and pushing the “Update” button. The new values of GRADE and SPREAD are computed, and the variables can be displayed on the chart.

5.2 Displaing the results at the end of an FSV analysis

At the end of an FSV analysis it is possible to visualize the results of the last FSV analysis performed by selecting “view results” in the end analysis GUI (Fig. 3.8). The **Data Display Tool** starts and automatically loads the data of last FSV analysis performed. For combined analysis it loads the results relating the last K weighting factor used.





GDMtot = 0.58265 GDMconf = 3.28358 GDMpw = 4.45912 Kadm = 1.00 Kfdm = 1.00

Time Domain Analysis

○ ADMi ○ ADMc
● FDMi ○ FDMc
○ GDMi ○ GDMc
☐ Hide legend ☐ Hide synthetic figures

Time Domain Analysis

○ ADMi ○ ADMc
○ FDMi ○ FDMc
○ GDMi ● GDMc
☐ Hide legend ☐ Hide synthetic figures

Fig. 5.5 - The original data window and main Data Display Tool of last analysis performed

5.3 Displaing the results from the initial window

.
The **Data Display Tool** is an application embedded in the **FSV Tool** that allows the user to visualize the relevant FSV variables associated to the comparison of two datasets. The **Data Display Tool** plots the data contained in the *.mat* files generated by the FSV procedure. It can be started from the initial window by selecting the **Plot Results** (Fig. 3.1) option without running an FSV analysis.

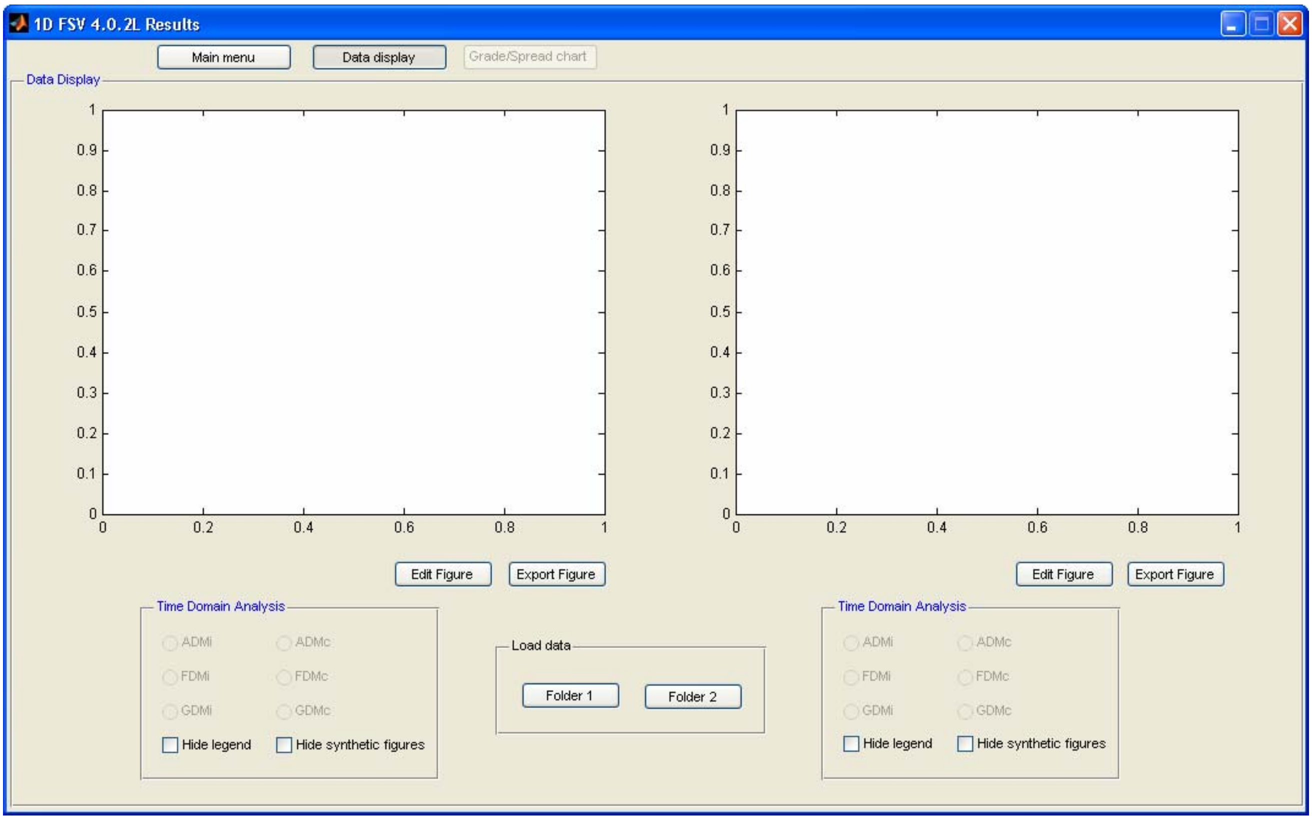
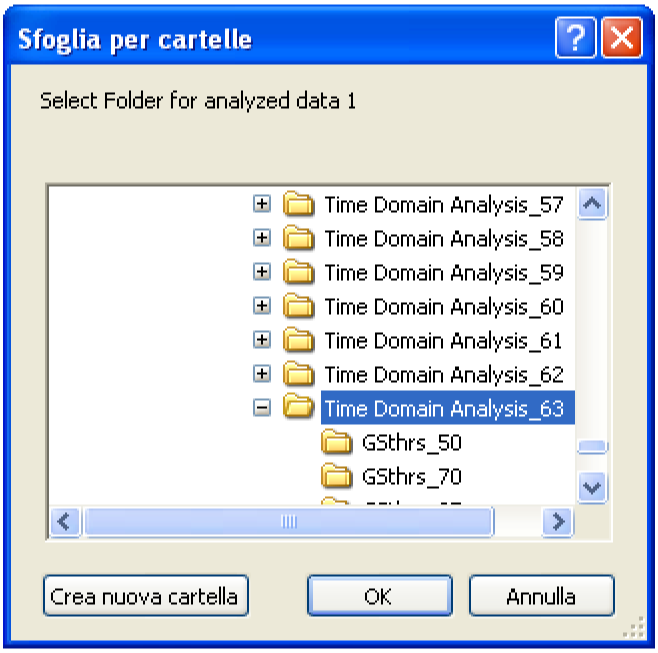


Fig. 5.6 - The Data Display Tool window before selecting the directory in which the .mat files are contained

After the initial window of the **Data Display Tool** appears on the screen, select the folders (directories) containing the **FSV Tool** output data to be displayed. They are contained in *.mat* files.

The User can select a directory for **Folder 1** and a different directory for **Folder 2** by pressing the corresponding button. The selected plots will appear in the corresponding windows (left side for Folder 1, right side for Folder 2). In this way it is possible to load and visualize two different FSV.

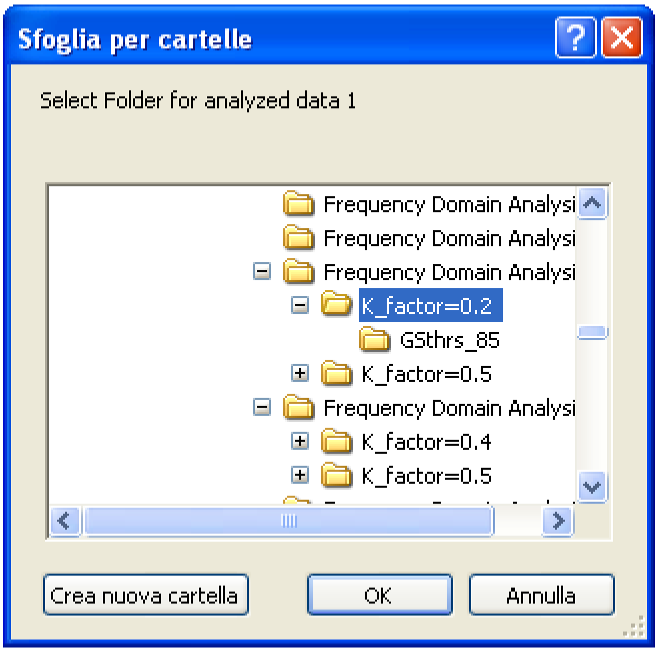
- **non-combined analysis**: select the automatically generated subdirectory inside the selected directory for output file (see Section 3.2). The names of these subdirectories are “Frequency Domain Analysis_x” (or “Time Domain Analysis_x”), in which x is an incremental number to distinguish the subdirectories.



Select Folder for analyzed data 1

Fig. 5.7 - Selecting a "Time Domain analysis" output folder

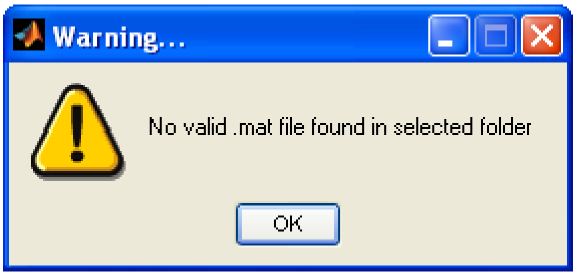
- **combined analysis**: select the automatically generated subdirectory “Frequency Domain Analysis_x” inside the selected directory for output file (see Section 3.2) and then select the subdirectory “K_factor=x” named with the value of the $K_{magnitude}$ parameter used.



Select Folder for analyzed data 1

Fig. 5.8 - Selecting a combined "Frequency Domain analysis" output folder

If the *.mat* file is not found in the selected directory or an invalid .mat file is found a warning is issued:

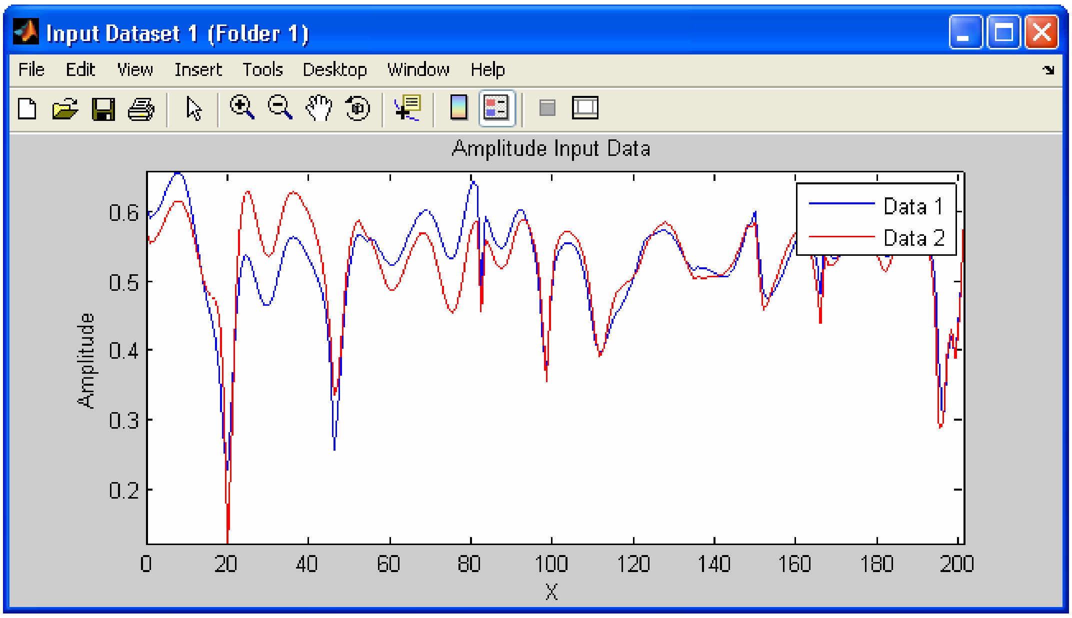


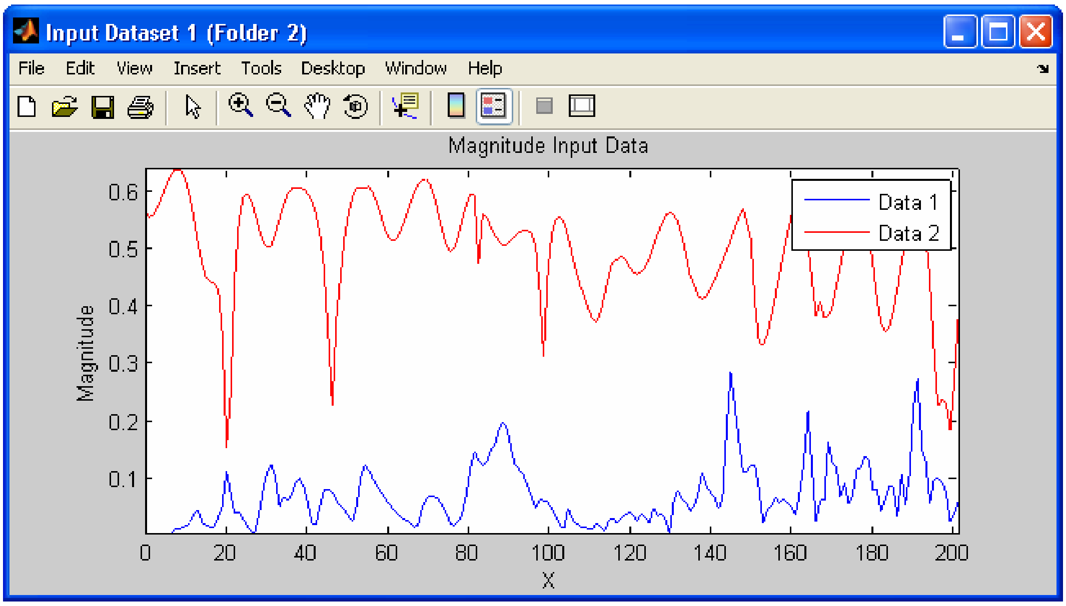
No valid .mat file found in selected folder

Fig. 5.9 - Data Display Tool warning.

5.3.1 Data Display

In the following example a Time Domain analysis in **Folder 1** and a Magnitude Frequency Domain analysis in **Folder 2** are shown (Fig. 5.10):





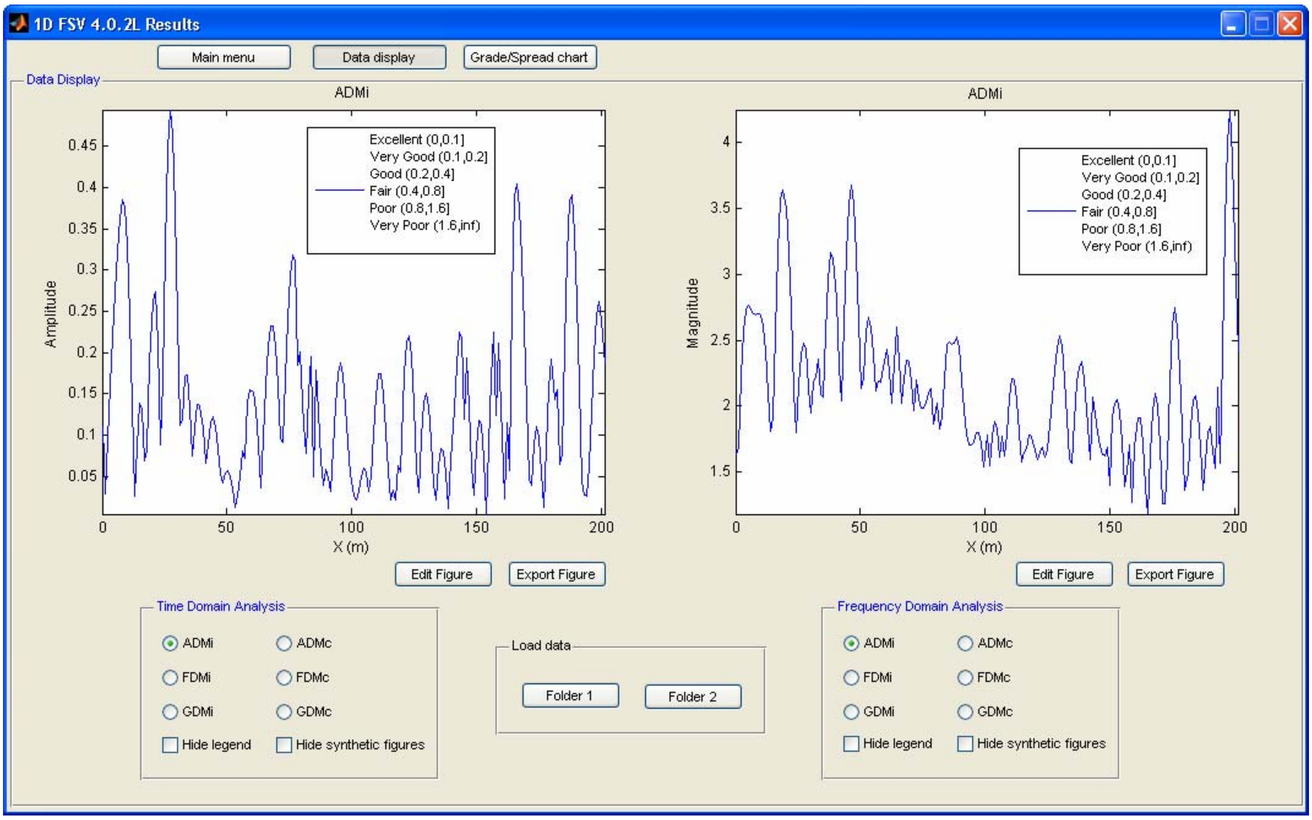
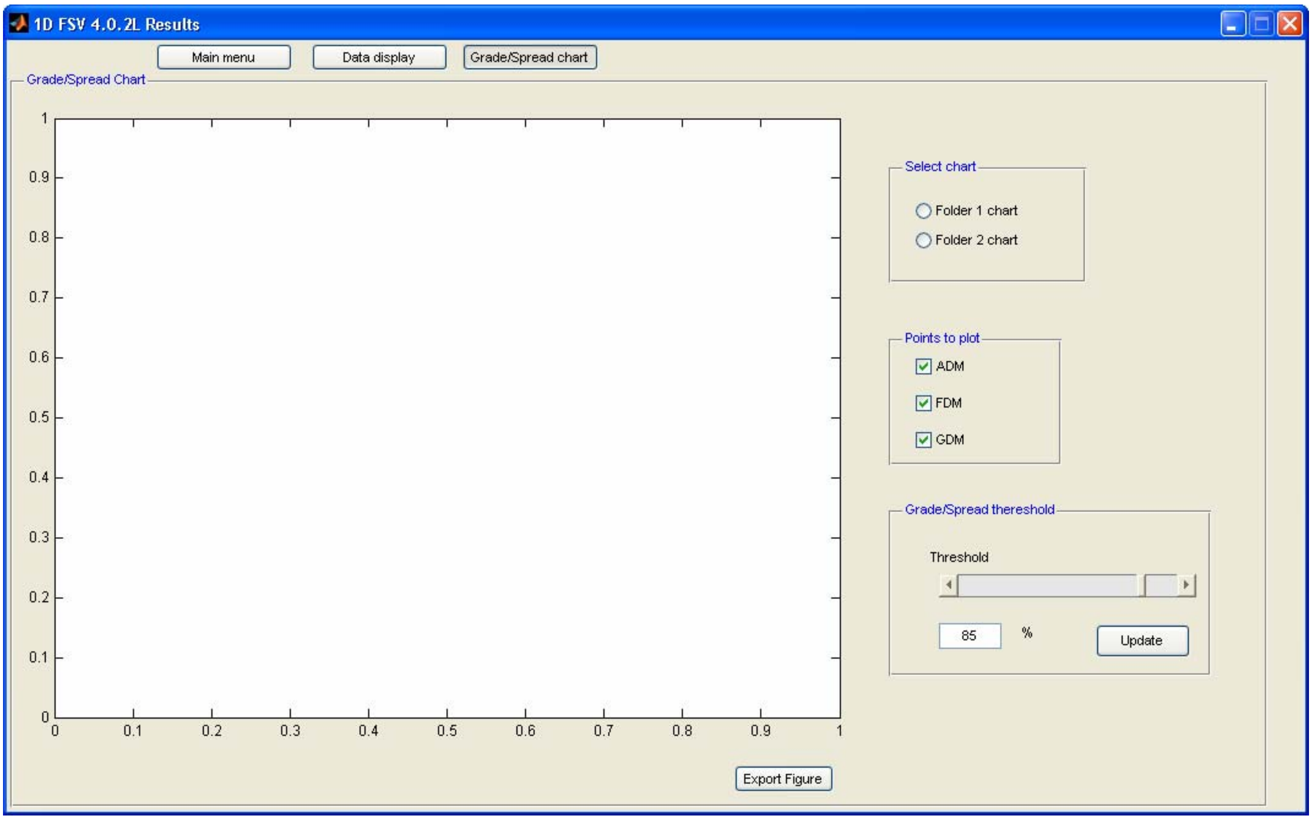


Fig. 5.10 - Data Display Tool after selecting two folder

5.3.2 Grade/Spread chart

Selecting the **Grade/Spread chart** button, the user has the option to select which output data should be considered for the GRADE-SPREAD chart: from the radio buttons of the **Select chart** selection box (Fig. 5.11).

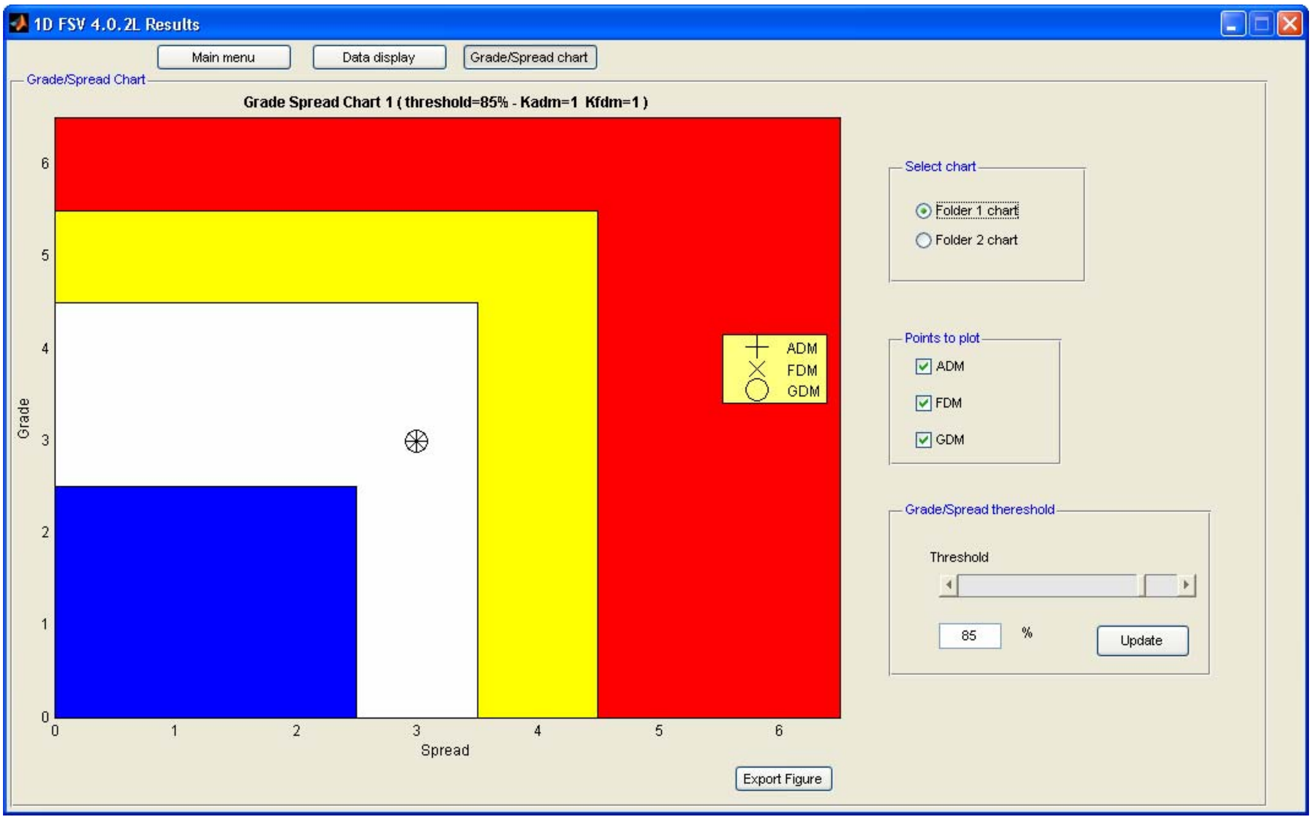


Select chart
○ Folder 1 chart
○ Folder 2 chart

Points to plot
☑ ADM
☑ FDM
☑ GDM

Grade/Spread thereshold
Threshold
85 %

Fig. 5.11 - Window of the Grade/Spread charts



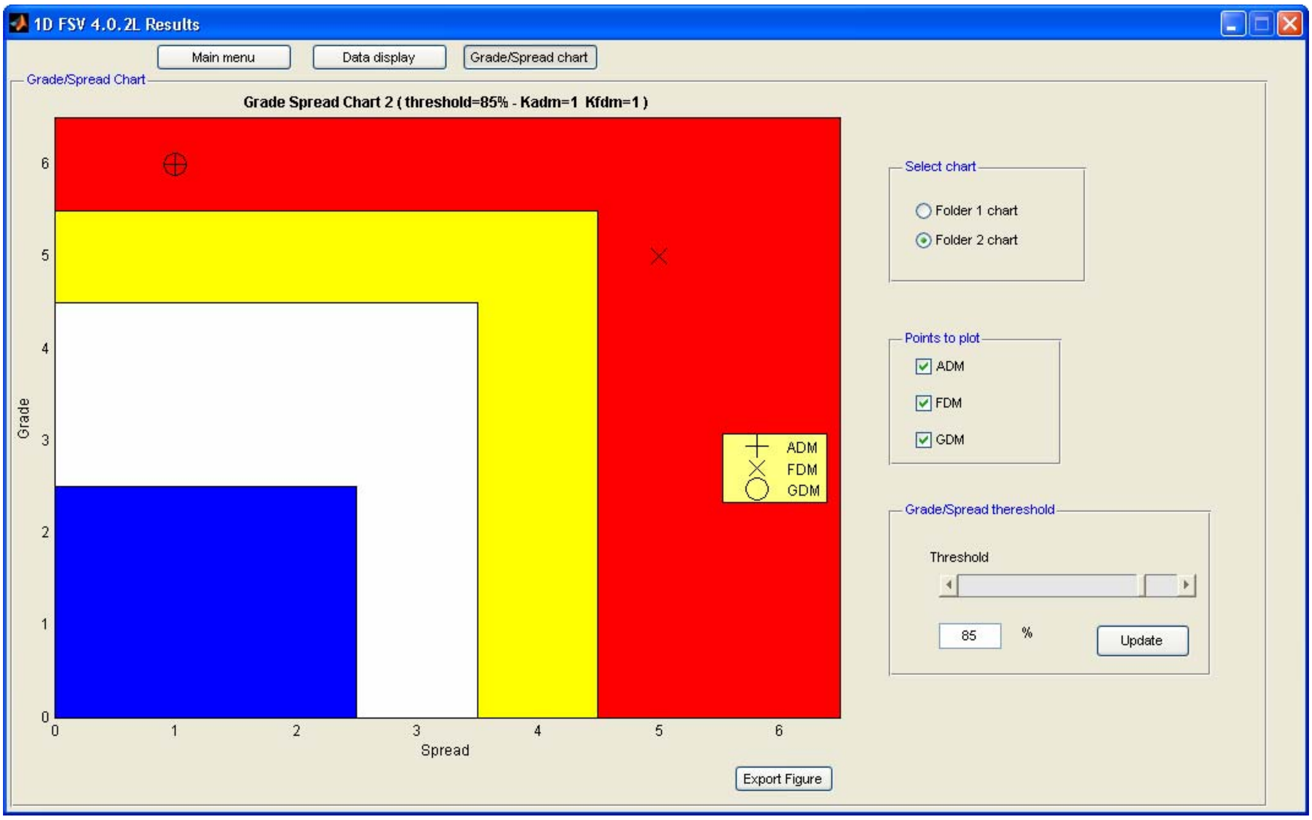
Select chart
● Folder 1 chart
○ Folder 2 chart

Points to plot
☑ ADM
☑ FDM
☑ GDM

Grade/Spread thereshold
Threshold
85 %

Fig. 5.12 - Selecting Grade/Spread chart of Folder 1 data

Selecting one chart is possible to independently update the threshold or the points to be displayed:



○ Folder 1 chart
● Folder 2 chart

☑ ADM
☑ FDM
☑ GDM

Threshold 85 %

Fig. 5.13 - Selecting Grade/Spread chart of Folder 2 data

6 Input Data Structure

6.1 X-Y ASCII format

1D FSV can import data stored in two column ASCII file as in Fig. 6.1:

X Domain	Y Data
X_1 X_2 ⋮ X_N	Y_1 Y_2 ⋮ Y_N

Fig. 6.1 - Structure of the of the Data file

The supported delimiter between two columns are *tabular character*, *space* and *comma*. Also the exponential format is supported.
If the data isn't available in this format then is needed a conversion how is described in the section 6.1.1.

6.1.1 Conversion to X-Y ASCII format

The aim of this section is to describe the X-Y ASCII format of the input data for the use of FSV 1D from ver. 4.0.0 on, and to show how to generate this format by using MATLAB.
The

Two cases are considered:

- **Case 1**: the function $y = f(x)$ is computed directly in MATLAB;
- **Case 2**: function $y = f(x)$ is generated (computed, measured, etc.) outside MATLAB.

In both cases MATLAB is used to recast the data in a proper format for input to FSV 1D , as described in Section 6.1.1.3.

6.1.1.1 Case 1: Set of data computed directly in MATLAB

Using MATLAB, generate a curve *y*:

$$y = f(x) \tag{6.1}$$

The first task is to define the range of the domain along the *x* directions, and then to compute *f(x)* at these points. Three steps are required:

1. Set the limit values for the *x* axis $x_{\min}$, $x_{\max}$. Then define the incremental steps for *x* as Δx.

2. Generate the x vector that represent the domain of the $y = f(x)$ function:

   x axis:

   Matlab Code:

   $$\mathrm{x} = x_{\min} : \Delta x : x_{\max} \tag{6.2}$$

The command lines (6.2) generate a row vector x from $x_{\min}$ to $x_{\max}$, step Δx.

3. The values of $y = f(x)$ can be now computed. An example of computation of $\mathrm{y} = x^2$ is:

   Matlab Code:

```
Y = X.^2
```

(6.3)

At this point one can plot or store the data given by the vectors (X,Y).

Matlab Code:

```
plot(X,Y);
```

(6.4)

The vectors X and Y are now ready to be cast in the proper format for FSV 1D. This is described in Section 6.1.1.3.

6.1.1.2 Case 2: Set of data generated outside MATLAB

Given the function

$$y = f(x) \tag{6.5}$$

Which has been evaluated (computed, measured, etc.) by the user outside MATLAB.

The user has to build the correct association between the values of *x* and y in MATLAB format in order to plot the data.

1. First set the domain values by defining the limits for the *x* axis, $x_{\min}$, $x_{\max}$. The samples along *x* can be uniformly spaced or non-uniformly spaced.

- **samples uniformly spaced**: the step is Δx for the *x* values. The x vector that represents the domain are generated as:

  x axis:

  Matlab Code:

  $$x = x_{\min} : \Delta x : x_{\max} \tag{6.6}$$

- **samples nonuniformly spaced**: the user has to manually enter the values for *x* axis.

  x axis:

  Matlab Code:

  $$x = [x_1, x_2, \ldots, x_n] \tag{6.7}$$

In this case FSV 1D, during import procedure, sets automatically the Δx for the *x* values to the minimum step between the *x* samples. Then recalculate the *x* domain values and interpolates the y values.

2. The values of $y = f(x)$ can be now computed. An example of computation of $y = x^2$ is: (6.15)

$$Y = \left[f(x_1) \quad f(x_2) \quad \cdots \quad f(x_n) \right] \tag{6.8}$$

- At this point one can plot or store the data given by the vectors (X,Y) by using the command

  Matlab Code:

  ```
  plot(X,Y);
  ```

  (6.9)

The vectors X and Y are now ready to be cast in the proper format for FSV 1D. This is described in Section 6.1.1.3.

6.1.1.3 Building the proper data format for FSV 1D

Assume that the vectors X and Y have been defined as in the previous sections. Now they should be cast for proper FSV 1D input.

FSV 1D requires, for each one of the two set that should be compared**, one input file.**
This file contains the domain *x* and the *y* values. The structure of this file is described in the following figure:

X Domain	Y Domain
X_1	Y_1
X_2	Y_2
$\vdots$	$\vdots$
X_N	Y_N

Fig. 6.2 - Structure of the of the Data file

The X and Y domain values are placed side by side and then stored in ASCII format. This file is created by the following MATLAB command that writes data into an ASCII file:

Matlab Code:

```
dlmwrite('inputdata1.txt',[x' y'],'delimiter',...
    '\t','precision', '%1.8e');
```

(6.10)

The first argument of `dlmwrite()` is the output filename, the second argument is the data to be stored in the ASCII file, then is specified the delimiter character (in this case the tabular character) and the resolution and format of the data.

This ASCII file *inputdata1.txt* define completely one set in 2D space.
Repeating entire procedure for the second set to be compared you obtain the other file *inputdata2.txt.*
At this point you can run FSV 1D and make a comparison of the two set using as input files: *inputdata1.txt* and *inputdata2.txt.*

6.2 Y only ASCII Format

1D FSV can import data stored in one column ASCII file as in **Errore. L'origine riferimento non è stata trovata.**:

Y Data
Y_1
Y_2
$\vdots$
Y_N

Fig. 6.3 - Structure of the of the Data file

The supported delimiter between two columns are *tabular character*, *space* and *comma.* Also the exponential format is supported.
If the data isn't available in this format then is needed a conversion how is described in the section 6.2.1.

6.2.1 Conversion to Y only ASCII Format

The aim of this section is to describe the Y only ASCII format of the input data for the use of FSV 1D from ver. 4.0.0 on, and to show how to generate this format by using MATLAB.
Two cases are considered:

- **Case 1**: the data y is computed directly in MATLAB;
- **Case 2**: the data y is generated (computed, measured, etc.) outside MATLAB.

In the case 1 the data are ready to be stored in Y only ASCII format .
In the case 2 it’s possible to recast the data in this way:

$$Y = \begin{bmatrix} y_1 & y_2 & \cdots & y_N \end{bmatrix} \tag{6.11}$$

6.2.1.1 Building the proper data format for FSV 1D

Assume that the vector Y has been defined as in the previous sections. Now they should be cast for proper FSV 1D input.

FSV 1D requires, for each one of the two set that should be compared**, one input file.**
This file contains the *y* values. The structure of this file is described in the following figure:

Y Data
Y_1
Y_2
$\vdots$
Y_N

Fig. 6.4 - Structure of the of the Data file

TheY values are stored in ASCII format. This file is created by the following MATLAB command that writes data into an ASCII file:

Matlab Code:

```
dlmwrite('inputdata1.txt',y','delimiter',...
    '\t','precision', '%1.8e');
```

(6.12)

The first argument of `dlmwrite()` is the output filename, the second argument is the data to be stored in the ASCII file, then is specified the delimiter character (in this case the tabular character) and the resolution and format of the data.

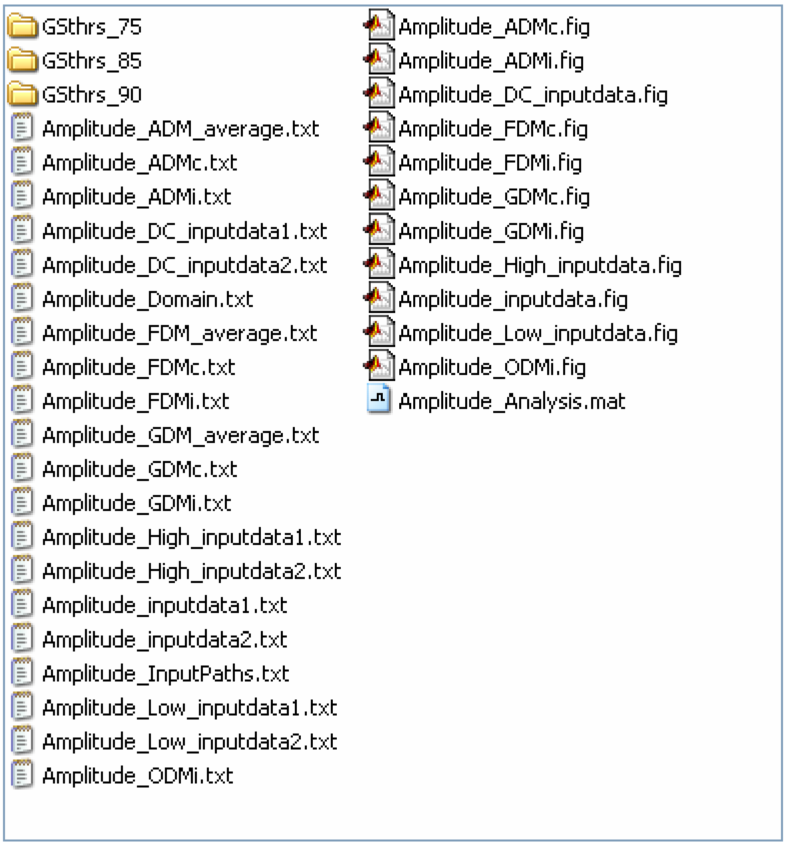
This ASCII file *inputdata1.txt* define completely one set in 2D space without a defined *x* domain. Repeating entire procedure for the second set to be compared you obtain the other file *inputdata2.txt*. At this point you can run FSV 1D and make a comparison of the two set using as input files: *inputdata1.txt* and *inputdata2.txt.*

7 Output Data Structure & Location

The output data files (*.txt, .fig* and *.mat*) and the screenshots generated by the user are stored in an automatically generated subdirectory inside the selected directory for output file (see Section 4.4). The names of these subdirectories are “Frequency Domain Analysis_x” (or “Time Domain Analysis_x”) in which ‘x’ is an incremental number to distinguish the subdirectories.

7.1 Data Structure

The main level of an output data folder appears like in Fig. 7.1:



GSthrs_75
GSthrs_85
GSthrs_90
Amplitude_ADM_average.txt
Amplitude_ADMc.txt
Amplitude_ADMi.txt
Amplitude_DC_inputdata1.txt
Amplitude_DC_inputdata2.txt
Amplitude_Domain.txt
Amplitude_FDM_average.txt
Amplitude_FDMc.txt
Amplitude_FDMi.txt
Amplitude_GDM_average.txt
Amplitude_GDMc.txt
Amplitude_GDMi.txt
Amplitude_High_inputdata1.txt
Amplitude_High_inputdata2.txt
Amplitude_inputdata1.txt
Amplitude_inputdata2.txt
Amplitude_InputPaths.txt
Amplitude_Low_inputdata1.txt
Amplitude_Low_inputdata2.txt
Amplitude_ODMi.txt
Amplitude_ADMc.fig
Amplitude_ADMi.fig
Amplitude_DC_inputdata.fig
Amplitude_FDMc.fig
Amplitude_FDMi.fig
Amplitude_GDMc.fig
Amplitude_GDMi.fig
Amplitude_High_inputdata.fig
Amplitude_inputdata.fig
Amplitude_Low_inputdata.fig
Amplitude_ODMi.fig
Amplitude_Analysis.mat

Fig. 7.1 - Output data folder for Time Domain – Amplitude analysis

All data files are saved in the main level of the output folder except in the combined analysis mode. Grade/Spread data files are saved in appropriate subdirectories; their name is given by "GSthrs_x", x suffix is the threshold value used.

The *.txt* files are ASCII files[1]:

- *{Analysis mode}_inputdata*$_i$: contains the input data after synchronization;
- *{Analysis mode}_DC_inputdata*$_i$: contains the DC Data used in the calculation of ADM, FDM and GDM;
- *{Analysis mode}_Low_inputdata*$_i$: contains the Low Data used in the calculation of ADM, FDM and GDM;
- *{Analysis mode}_High_inputdata*$_i$: contains the High Data used in the calculation of ADM, FDM and GDM;
- *{Analysis mode}_{x}DMi* : contains the point-by-point values of FSV output*;*
- *{Analysis mode}_ODMi* : contains the point-by-point values of FSV output of offset components*;*
- *{Analysis mode}_{x}DMc* : contains the confidence levels of the FSV output;

---

[1] *{Analysis mode}* expands in {Amplitude, Magnitude, Phase, Combined} , *{x}* expands in {A, F, G}

- *{Analysis mode}_{x}DM_average*: contains the *A/F/G-DM*tot, *A/F/G-Dm*conf, *A/F/G-DM*pw_conv values and when available the GDM weighting factors: Kadm, Kfdm.
- *{Analysis mode}_inputpaths*: contains the complete path of the input files used in the FSV run

  The ***.fig*** files are MATLAB figure files:
- *{Analysis mode}_inputdata* : figure of the input data after synchronization;
- *{Analysis mode}_DC_inputdata* : figure of the DC Data used in the calculation of ADM, FDM and GDM;
- *{Analysis mode}_Low_inputdata* : figure of the Low Data used in the calculation of ADM, FDM and GDM;
- *{Analysis mode}_High_inputdata* : figure of the High Data used in the calculation of ADM, FDM and GDM;
- *{Analysis mode}_{x}DMc* : confidence histogram,
- *{Analysis mode}_{x}DMi :* figure of the point by point amplitude differences,
- *{Analysis mode}_ODMi :* figure of the point by point offset amplitude differences.

The ***.mat*** file, is MATLAB data file containing all the relevant FSV variables. It is the input file for the **Data Display Tool**:

- *{Analysis mode}_Analysis:* contains the analysis data in MAT format

The *GSthrs_{x}* subdirectories have this structure (*{x}* is the threshold value):

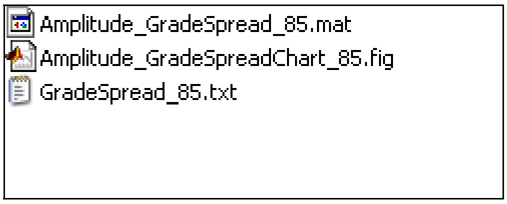

Amplitude_GradeSpread_85.mat
Amplitude_GradeSpreadChart_85.fig
GradeSpread_85.txt

Fig. 7.2 - Grade/Spread folder for Time Domain – *Amplitude* analysis (*{x}*= threshold = 85%)

- *Greadspread_{x}.txt*: contains the values and the ranges of Grade and Spread for each FSV variable: ADM, FDM and GDM .
- *{Analysis mode}_GradeSpreadChart_{x}.fig:* figure of the Grade/Spread chart.
- *{Analysis mode}_GradeSpread_{x}.mat:* contains the Grade/Spread data in MAT format.

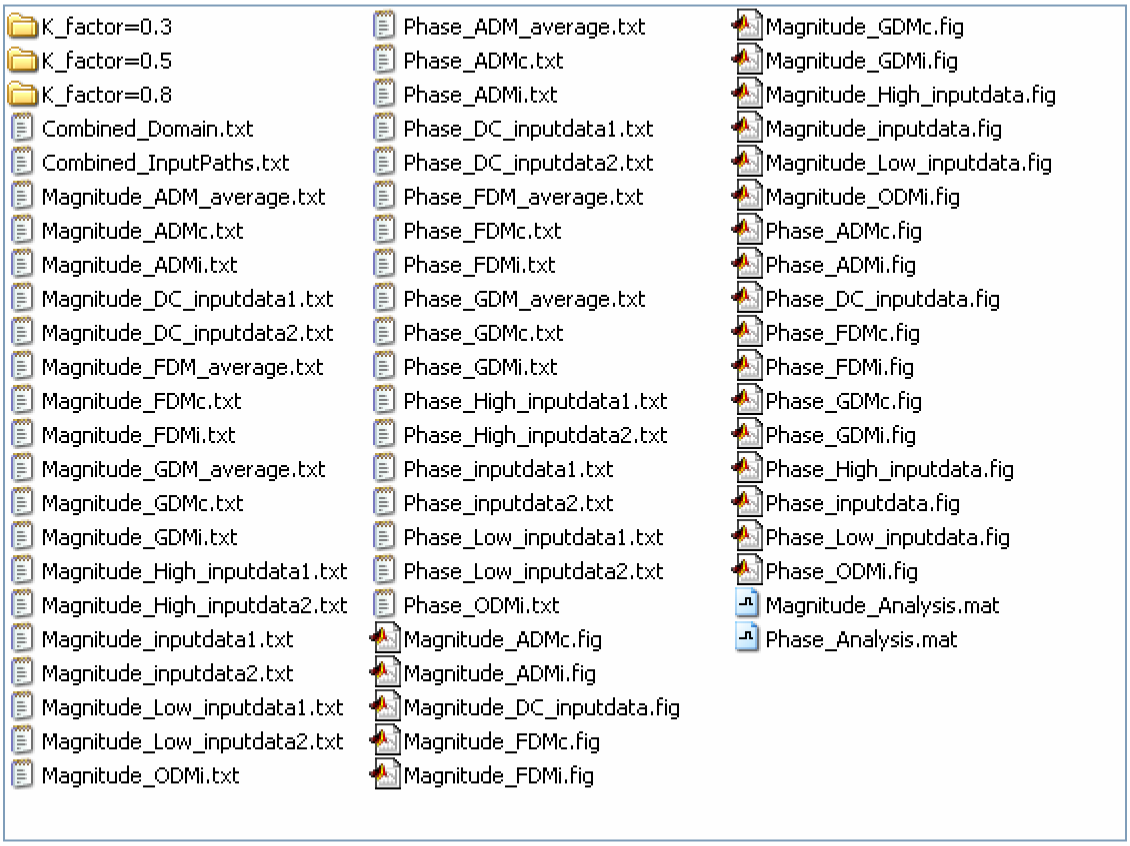
7.2 Non combined data

In this case the output folder appears like in Fig. 7.1 and the Grade/Spread subdirectories like in Fig. 7.2.

7.3 Combined data

For the **Combined** analysis the output data are saved in subdirectories of the "Frequency Domain Analysis" directory named with the value of the $K_{magnitude}$ parameter used.

At the top level of the output folder are saved the data files of the two components forming the combined set as described in Section 7.1, except the Grade/Spread subdirectories that are saved in relative “K” subdirectories.

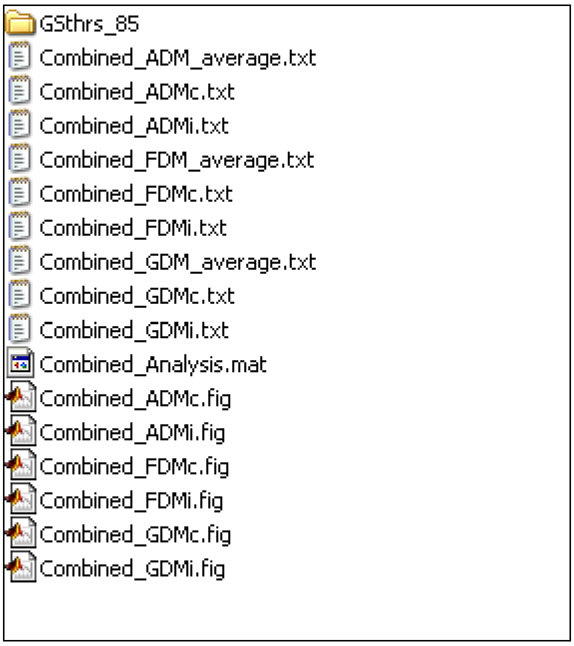


K_factor=0.3
K_factor=0.5
K_factor=0.8
Combined_Domain.txt
Combined_InputPaths.txt
Magnitude_ADM_average.txt
Magnitude_ADMc.txt
Magnitude_ADMi.txt
Magnitude_DC_inputdata1.txt
Magnitude_DC_inputdata2.txt
Magnitude_FDM_average.txt
Magnitude_FDMc.txt
Magnitude_FDMi.txt
Magnitude_GDM_average.txt
Magnitude_GDMc.txt
Magnitude_GDMi.txt
Magnitude_High_inputdata1.txt
Magnitude_High_inputdata2.txt
Magnitude_inputdata1.txt
Magnitude_inputdata2.txt
Magnitude_Low_inputdata1.txt
Magnitude_Low_inputdata2.txt
Magnitude_ODMi.txt
Phase_ADM_average.txt
Phase_ADMc.txt
Phase_ADMi.txt
Phase_DC_inputdata1.txt
Phase_DC_inputdata2.txt
Phase_FDM_average.txt
Phase_FDMc.txt
Phase_FDMi.txt
Phase_GDM_average.txt
Phase_GDMc.txt
Phase_GDMi.txt
Phase_High_inputdata1.txt
Phase_High_inputdata2.txt
Phase_inputdata1.txt
Phase_inputdata2.txt
Phase_Low_inputdata1.txt
Phase_Low_inputdata2.txt
Phase_ODMi.txt
Magnitude_ADMc.fig
Magnitude_ADMi.fig
Magnitude_DC_inputdata.fig
Magnitude_FDMc.fig
Magnitude_FDMi.fig
Magnitude_GDMc.fig
Magnitude_GDMi.fig
Magnitude_High_inputdata.fig
Magnitude_inputdata.fig
Magnitude_Low_inputdata.fig
Magnitude_ODMi.fig
Phase_ADMc.fig
Phase_ADMi.fig
Phase_DC_inputdata.fig
Phase_FDMc.fig
Phase_FDMi.fig
Phase_GDMc.fig
Phase_GDMi.fig
Phase_High_inputdata.fig
Phase_inputdata.fig
Phase_Low_inputdata.fig
Phase_ODMi.fig
Magnitude_Analysis.mat
Phase_Analysis.mat

Fig. 7.3 - Output data folder for Frequency Domain – Combined analysis

Combined_domain : contains the input domain after synchronization between all the four sets.

The *K_factor={x}* subdirectories have this structure (*{x}* is the $K_{magnitude}$ value):



GSthrs_85
Combined_ADM_average.txt
Combined_ADMc.txt
Combined_ADMi.txt
Combined_FDM_average.txt
Combined_FDMc.txt
Combined_FDMi.txt
Combined_GDM_average.txt
Combined_GDMc.txt
Combined_GDMi.txt
Combined_Analysis.mat
Combined_ADMc.fig
Combined_ADMi.fig
Combined_FDMc.fig
Combined_FDMi.fig
Combined_GDMc.fig
Combined_GDMi.fig

Fig. 7.4 - K_factor={x} folder for Frequency Domain – Combined analysis

The data file structure and content is as described in Section 7.1. Note that all the data files relating the input data are absent because they are saved in the top level of output folder (Fig. 7.3); moreover the data files related to offset calculations (ODM) are absent because the offset computation is only performed on input components.

8 Output Results

Consider two "Peaks" distributions as input data, in which Peaks 2 is the mirror image of Input data 1 with respect the y axis:

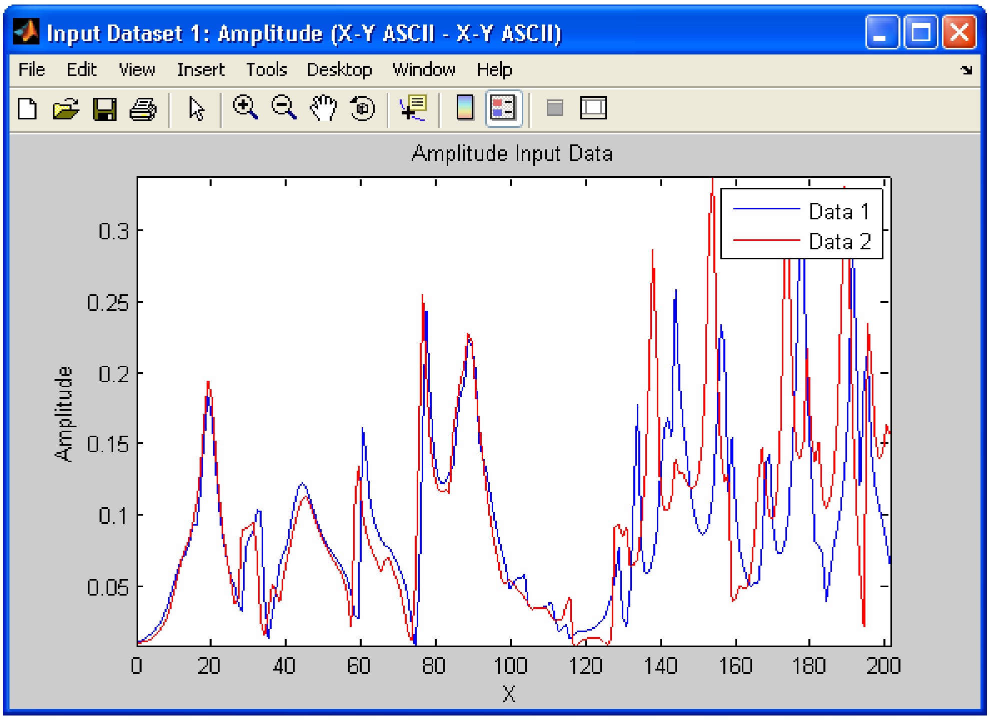


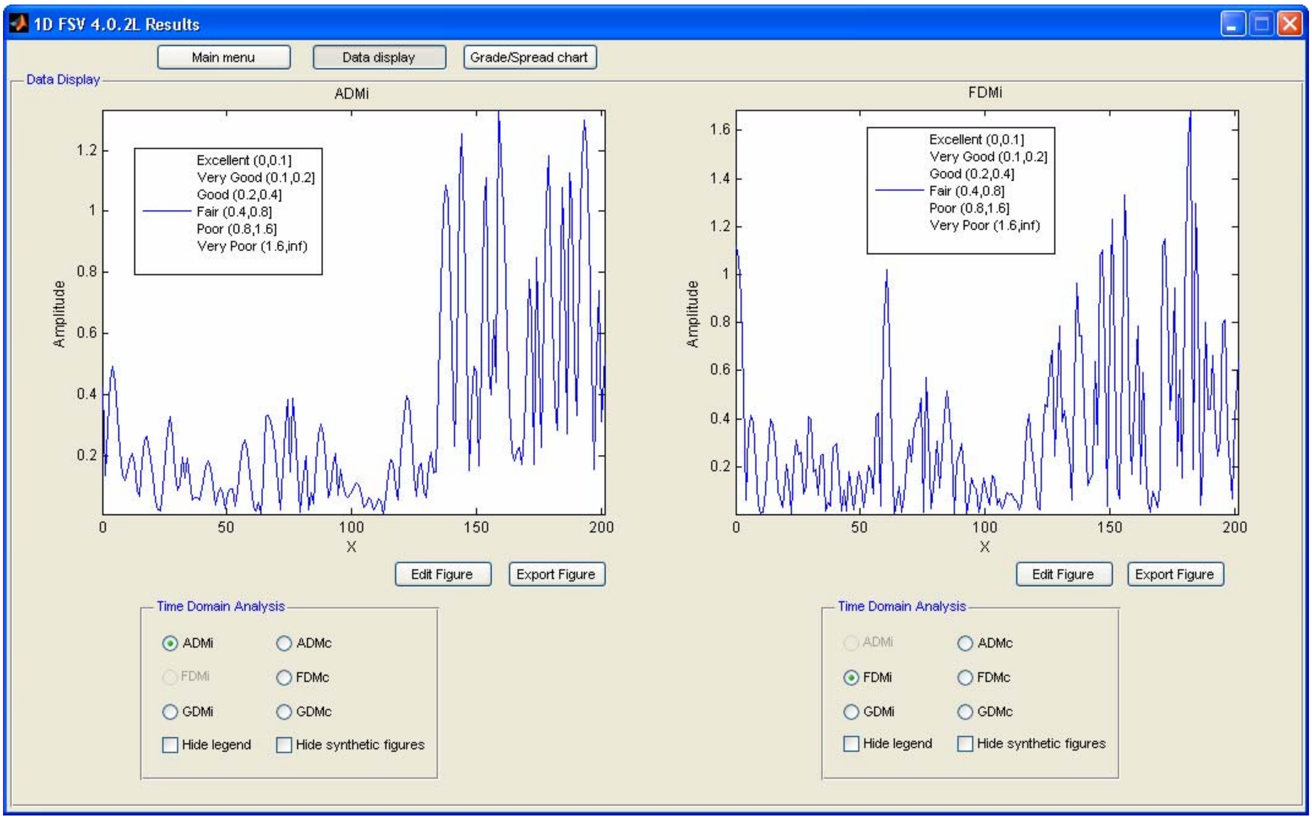
Fig. 8.1 – Input data example,

The significant FSV outputs are:

- *ADM*: is a figure of merit of the comparison of amplitudes and trends of the two data sets to compare (the lower the ADM, the better the comparison);
- *FDM*: is a figure of merit of the comparison of details (derivatives) of the two datasets to be compared (the lower the FDM, the better the comparison);
- *GDM*: is a figure of merit of the combination of ADM and GDM.

These output can be at the end of the algorithm:

- *xDMi*: values of (x = A,F,G)DM for each pair of samples of the two datasets to be compared. An example of ADMi and FDMi is shown in Fig. 8.2:

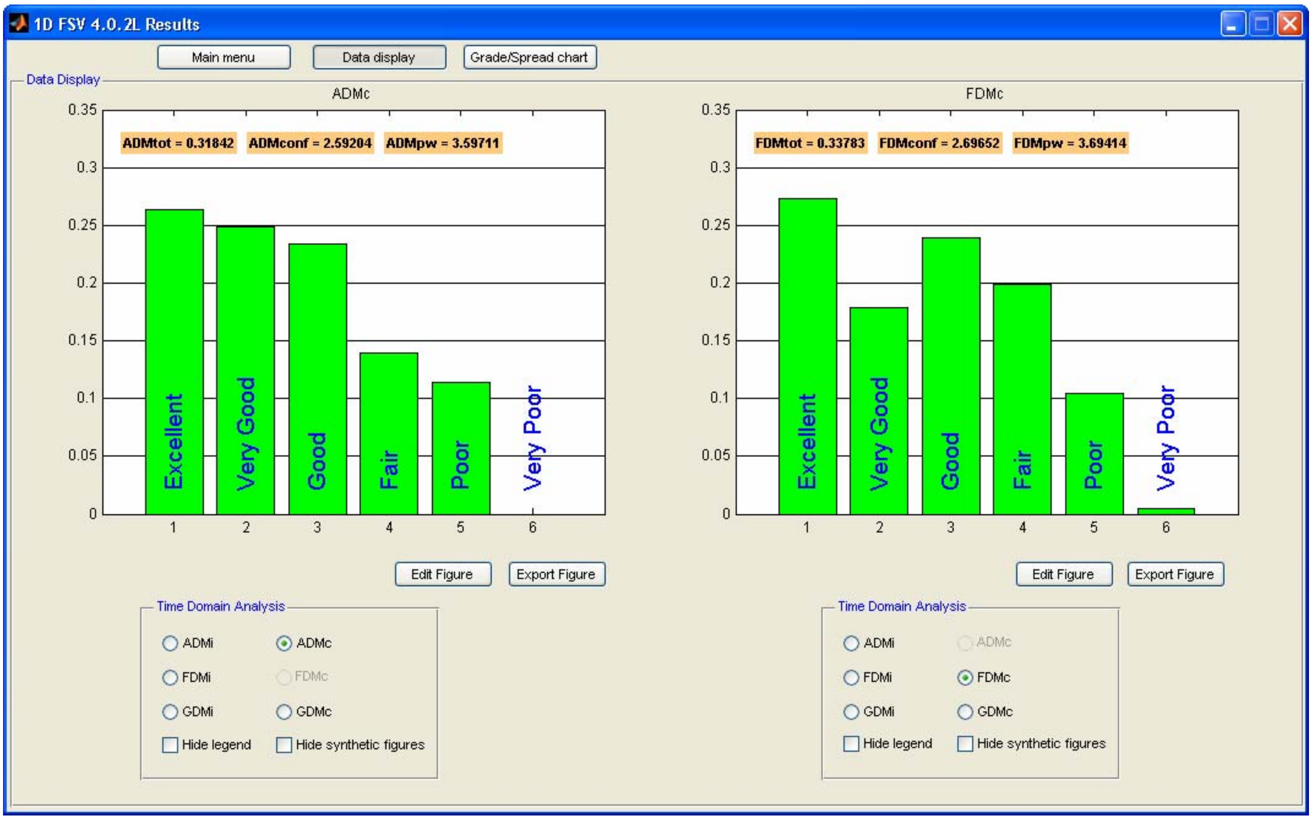


Left panel: ● ADMi ○ ADMc ○ FDMi ○ FDMc ○ GDMi ○ GDMc ☐ Hide legend ☐ Hide synthetic figures

Right panel: ○ ADMi ○ ADMc ● FDMi ○ FDMc ○ GDMi ○ GDMc ☐ Hide legend ☐ Hide synthetic figures

Fig. 8.2- An example of ADMi and FDMi

- *xDMc*: percentage of points in (x = A,F,G)DMi that fall in each of the six classes of Table 1.1 described in Chapter 1 (see Fig. 8.3)



ADMtot = 0.31842 ADMconf = 2.59204 ADMpw = 3.59711

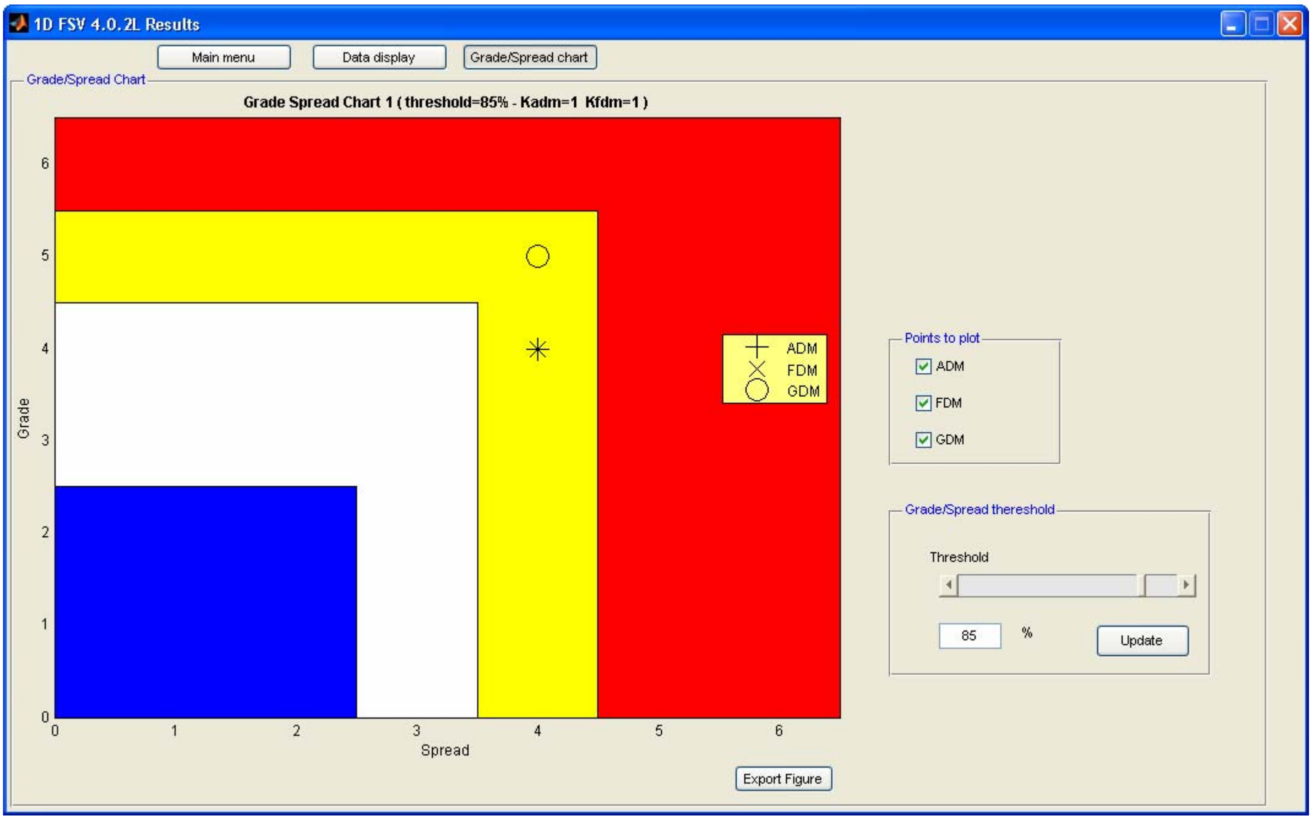
FDMtot = 0.33783 FDMconf = 2.69652 FDMpw = 3.69414

Left panel: ○ ADMi ● ADMc ○ FDMi ○ FDMc ○ GDMi ○ GDMc ☐ Hide legend ☐ Hide synthetic figures

Right panel: ○ ADMi ○ ADMc ○ FDMi ● FDMc ○ GDMi ○ GDMc ☐ Hide legend ☐ Hide synthetic figures

Fig. 8.3 - An example of ADMc and FDMc

The values of *xDMc* are used to compute the GRADE and SPREAD values and displayed in form of the GRADE-SPREAD chart:



☑ ADM

☑ FDM

☑ GDM

Threshold

85 %

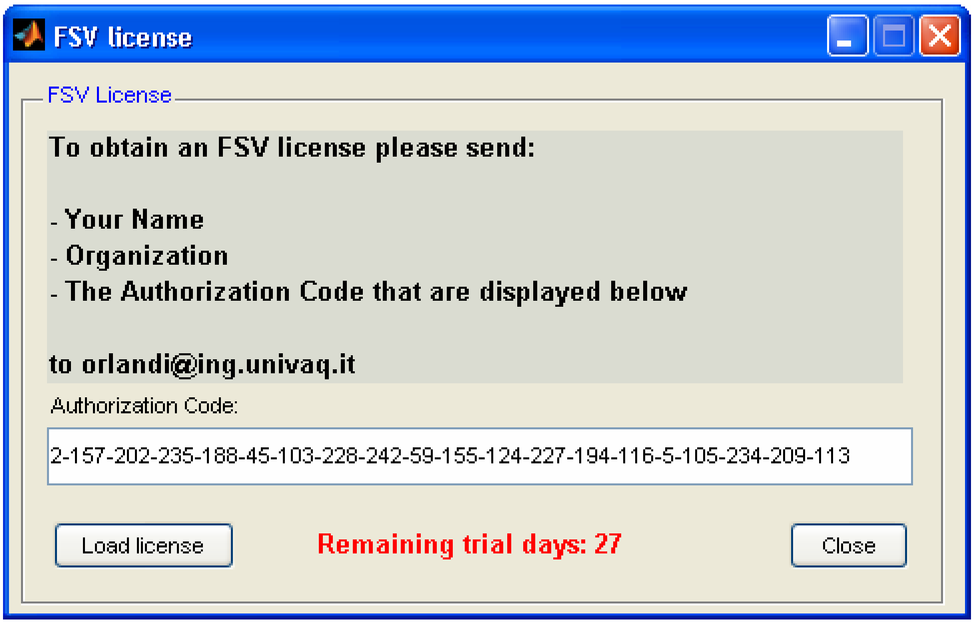
Fig. 8.4 - Grade/Spread chart

9 Examples

In the directory “data_examples” there are sets of data (two files for each set) that can be used for the FSV algorithm by means of the **FSV Tool.**

10 License

This software is distributed with a trial period of 30 days, at the end of this the user can request a license with a time limited or unlimited validity to continue the use of the software.
By clicking on **License** button in **Main menu** or when the trial\license period is expired, is displayed the GUI of Fig. 10.1:



To obtain an FSV license please send:

- Your Name
- Organization
- The Authorization Code that are displayed below

to orlandi@ing.univaq.it

Authorization Code:

2-157-202-235-188-45-103-228-242-59-155-124-227-194-116-5-105-234-209-113

Remaining trial days: 27

Fig. 10.1 – License GUI dialog

In this GUI is shown a remaining trial days and the instructions to obtain an valid license.

When the trial time is expired is displayed this error message at FSV start:

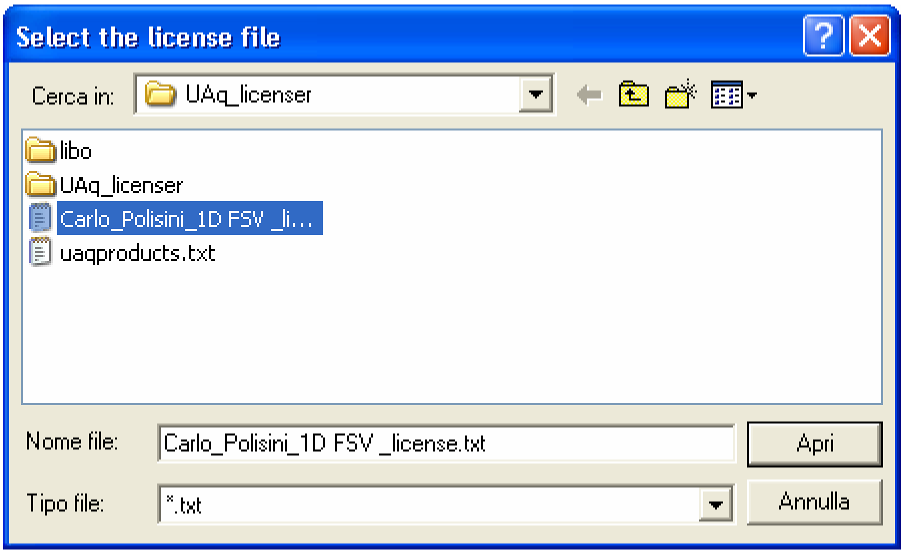
TRIAL PERIOD EXPIRED!

Fig. 10.2 – Trial expired GUI

Pressing **OK** is displayed the **License GUI dialog** and from here is possible to load the license file. To obtain a license contact us at orlandi@ing.univaq.it and send the following informations:

- Your Name
- Organization name
- The authorization code that is displayed in the specific text box. (Use the key combination Ctrl+C to copy it in the clipboard.)

When you receive the license file you have to load it from the **License GUI dialog.** Pressing **Load license** button is displayed the following GUI:



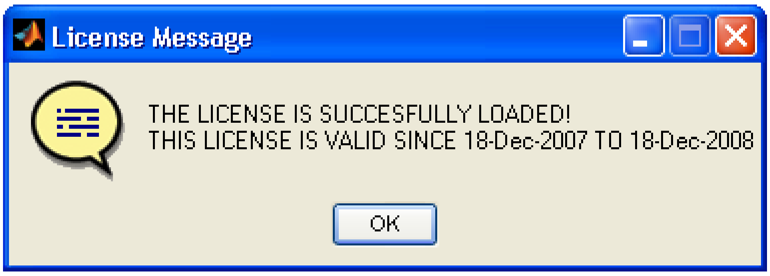
Cerca in: UAq_licenser

Nome file: Carlo_Polisini_1D FSV _license.txt

Tipo file: *.txt

Fig. 10.3 – License loading confirmation dialog

From here browse to the license file and select it. If the license is valid you get a confirmation message like this:



THE LICENSE IS SUCCESFULLY LOADED!
THIS LICENSE IS VALID SINCE 18-Dec-2007 TO 18-Dec-2008

Fig. 10.4 – License loading confirmation dialog

11 Contacts

For any problem or comment, please contact:

Dr. A. Duffy, DMU Applied Electromagnetics Group, apd@dmu.ac.uk
Prof. A.Orlandi, UAq EMC Laboratory, orlandi@ing.univaq.it

If you wish to be included in the FSV User List please e-mail a short request to
Prof. A.Orlandi, UAq EMC Laboratory orlandi@ing.univaq.it

For downloading the most recent version, please frequently check the UAq EMC Laboratory FTP site at http://ing.univaq.it/uaqemc/

More information on the FSV project can be found at http://www.eng.cse.dmu.ac.uk/FSVweb

12 Acknowledgement

A special thanks to Ing. Carlo Polisini, Ing. Carmine Ritota, Ing. Franco Campitelli and of the *UAq EMC Laboratory* for their substantial contribution to this project.

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