

Dynamic validation of model per correlation calculation-tests

Summary

This documentation is intended to describe the principal tools of assistance to the validation of models in dynamics of the structures by correlation calculation-tests. One describes in particular:

- how to import data resulting from measurements,
- validation by criterion of MAC,
- validation by comparison of calculated/simulated FRF

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1 Introduction

In order to evaluate the predictive capacity of a digital model in dynamics of the structures, it can be useful, even essential to validate this one compared to measured data *in situ*. The most classical manner is the comparison of the clean modes (frequencies and deformations) calculated and identified in experiments two to two. The clean modes reflect the total behavior of the structure, and are often used like single tool for validation. The main difficulty in this case is to be able to pair the digital and experimental modes two to two.

This documentation aims to describe the methods and tools usable in Code_Aster to compare the data of calculation and measurement. One treats in section 2 importation of the data resulting from software of measurement in Code_Aster. In section 3, one details the use of one of the principal criteria for the validation of model: the matrix of MAC. In section 4, one approaches other means suggested in the environment of Code_Aster for the validation (comparison of FRF and deformations).

2 To import data measured in Code_Aster

2.1 Which data to import?

The measured data result from a software of acquisition and treatment of the signal. One can quote among them:

- LMS TestLab,
- Me' Scope,
- B&K Pulsates,
- Labview,
- ...

Most this software allow to export data with the universal format, put does not have by software IDEAS (extension *.unv), given which can be read again in Code_Aster by LIRE_RESU (FORMAT='IDEAS').

These files in general contain the relative information with the grid of the structure and the experimental data. The files unv are ASCII files. Each whole of data is called "dataset", and is framed in the file by two "-1". The number which follows the first occurrence "-1" corresponds to the type of dataset. Each dataset is composed of several lines (record), and each line contains data lines in columns (field)

In the example below, one presents some lines of a dataset 55, which describes a base of clean modes.

```
-1
55 %VALEURS WITH THE NODES
ASTER 7.03.29 CONCEPT MODINTS1 CALC - FIELD WITH THE NODES OF REFERENCE SYMBOL
FIELD WITH THE NODES OF REFERENCE SYMBOL DEPL - DX DY DZ DRX DRY MARTINI DRZ
ASTER 7.03.29 CONCEPT MODINTS1 CALCULATES THE 11/22/2004 AT 19:24: 57 OF TYPE
FIELD WITH THE NODES OF REFERENCE SYMBOL DEPL
SEQUENCE NUMBER: 1 NUME_MODE: 1 FREQ: 2.66902E-01
      1      2      3      8      2      6
      2      4      1      1
2.18331e+01 1.00000e+00 3.74657e-03
      1011 % NODE NO1011
-1.37933E-001 7.39432E-007 3.38287E-001 0.00000E+000 0.00000E+000 0.00000E+000
      1001 % NODE NO1001
-1.37933E-001-2.80459E-009 1.72767E-001 0.00000E+000 0.00000E+000 0.00000E+000
-1
```

2.1.1 Grid

Several dated sets are used by the software of measurement to describe a grid. That presented here is the format used by LMS to export simple grids, only made up of nodes and lines connecting them. The nodes are described by dated set 2411, and connectivities by dated set 82 (example below).

```

-1
2411
      1      0      0      8
0.0000000000000000e+000 0.0000000000000000e+000 0.0000000000000000e+000
      2      0      0      8
0.0000000000000000e+000 1.199999973177910e-001 0.0000000000000000e+000
      3      0      0      8
0.0000000000000000e+000 3.300000131130219e-001 0.0000000000000000e+000

-1
-1
82
      1      30      8
LDN
      1      2      3      0      0      0      0
-1
    
```

The importation of the grid is done in Code_Aster with `PRE_IDEAS`. The description of dated sets 2411 and 82 is detailed in appendix 5.1.

2.1.2 Rough temporal data, and FRF

It is possible to import the rough temporal data, or of the FRF in Code_Aster, in order to compare them with simulated data. These data are stored in the files `unv` under dated set 58. One gives below an example of this kind of dated set:

```

-1
58
FRF (H1-estimator)
answer/load
95-Oct.-12 11:52: 48
Alternate/identified FRF"
NUN
      0      4      0      139      NUN      1011      3      NUN      12      -3
      5      3124      1 4.00390e+000 1.95312e-002 0.00000e+000
      18      0      0      0 Frequency      Hz
      12      1      0      0 Chanel 3(3)      m/s2
      13      0      1      0 Chanel 1(1)      NR
      0      0      0      0 Unknown      NUN
-1.33781e-001-5.07456e-003-1.31790e-001-5.19607e-003-1.29762e-001-5.32069e-003
-1.27699e-001-5.44850e-003-1.25597e-001-5.57962e-003-1.23458e-001-5.71414e-003
-1.21279e-001-5.85217e-003-1.19060e-001-5.99383e-003-1.16800e-001-6.13924e-003
-1.14497e-001-6.28851e-003-1.12151e-001-6.44177e-003-1.09760e-001-6.59917e-003
-1.07324e-001-6.76083e-003-1.04841e-001-6.92691e-003-1.02310e-001-7.09754e-003
    
```

The headers describe the type of data. Here, it is about a FRF “acceleration/force”, on the degree of freedom 1011: +Z compared to the reference 12: -Z.

For more details, to see the reference material of dated set 58 in appendix 5.2.

The use of `LIRE_RESU` in this case does not pose particular problems, and is described in the CAS-test `sdl112a`. To note:

- the structures of data created (temporal or frequential) are filled only for the DDL corresponding to the data read. That can generate structures of incomplete data, contrary to *data set 55* in which all the degrees of freedom have a defined value,
- the definite structure of data uses a local frame of reference, with the components `D1`, `D2`, and `D3`, of which the orientations are given in the components `D1X`, `D1Y`, `D1Z`, `D2X`, `D2Y` ... It is not possible to display the result in Salomé.
- For more details, to see the documentation of `LIRE_RESU`.

2.1.3 Bases of identified modes

The identified modes are stored in *dataset 55*, which is dedicated to the fields with the nodes. In *dataset 58*, each block corresponds to a function on a node (equivalent with a function in Aster), while in *dataset 55*, each block corresponds to a field with the nodes (one *cham_no* in Aster).

```

-1
55 %VALEURS WITH THE NODES
ASTER 7.03.29 CONCEPT MODINTS1 CALC - FIELD WITH THE NODES OF REFERENCE SYMBOL
FIELD WITH THE NODES OF REFERENCE SYMBOL DEPL - DX DY DZ DRX DRY MARTINI DRZ
ASTER 7.03.29 CONCEPT MODINTS1 CALCULATES THE 11/22/2004 AT 19:24: 57 OF TYPE
FIELD WITH THE NODES OF REFERENCE SYMBOL DEPL
SEQUENCE NUMBER: 1 NUME_MODE: 1 FREQ: 2.18331E+01
      1      2      2      8      2      3
      2      4      1      1
2.18331e+01 1.00000e+00 3.74657e-03
      1011 % NODE NO1011
-1.37933E-001 7.39432E-007 3.38287E-001
      1001 % NODE NO1001
-1.37933E-001-2.80459E-009 1.72767E-001
-1
    
```

The detailed documentation of dated set is given in appendix 5.3 .

It is important to understand certain characteristics of this storage, because the data must be recalled to the call of `LIRE_RESU` . In particular:

- Record 6 (1,2,2,8,2,3) :
 - 1: field of the mechanics of the structures,
 - 2: a clean mode is described ("normal mode")
 - 2: 3 degrees of freedom per node,
 - 8: field of displacement,
 - 2: real field (5 for complex),
 - 6: many columns of values
- Record 7 (2,4,1,1) :
 - 2.4: specific to the clean modes,
 - 1: loading case (1 by default),
 - 1, number of the mode
- Record 8: 2.18331e+01 1.00000e+00 3.74657e-03 0.00000e+00
 - 2.18331e+01 : Eigen frequency,
 - 1.00000e+00 : modal mass,
 - 3.74657e-03 : modal damping

The value of these lines is given in `LIRE_RESU`, as the example shows it below. That makes it possible in particular Aster to differentiate in a file `unv` the classical clean modes from the static residues which are often calculated by the software used.

```

MODMES=LIRE_RESU (TYPE_RESU=' MODE_MECA',
                  FORMAT=' IDEAS',
                  MODELE=MODEXP,
                  UNITE=21,
                  NOM_CHAM=' DEPL',
                  MATR_RIGI =KASSEXP,
                  MATR_MASS =MASSEXP,
                  FORMAT_IDEAS=_F (NOM_CHAM=' DEPL',
                                   NUME_DATASET=55,
                                   RECORD_6= (1,2,2,8,2,3),
                                   POSI_ORDR= (7.4),
                                   POSI_NUME_MODE= (7.4),
                                   POSI_FREQ= (8.1),
                                   POSI_MASS_GENE= (8.2),
                                   POSI_AMOR_GENE= (8.3),
                                   NOM_CMP= ('DX', 'DY', 'DZ')),
                  TOUT_ORDRE=' OUI',);
    
```

2.2 Creation of an experimental model in Code_Aster

The handling of experimental data in Code_Aster requires to create the structures of adequate data, with the formalism of the code. One must thus reproduce all the stages of creation of the model, until the assembly of the matrices which are used in LIRE_RESU (keywords MATR_RIGI and MATR_MASS in the example above).

2.2.1 Case general

In the case general, the nodes all are connected the ones to the others by linear elements SEG2. The orders to be connected are the following ones:

- importation and reading of the grid with PRE_IDEAS and LIRE_MAILLAGE ,
- assignment of a mechanical modeling of type DIS_T ; one could use a modeling DIS_TR if the field with reading would have 6 degrees of freedom by nodes (for example, if one is able to measure the degrees of freedom of rotation),
- assignment of geometrical characteristics in arbitrary mass and stiffness on the nodes and segments with AFFE_CARA_ELEM ,
- assembly of the matrices with ASSEMBLY ,
- reading of the data with LIRE_RESU .

Example: CAS-test slds112a, slightly modified in order not to take into account the orphan nodes.

```
PRE_IDEAS (UNITE_IDEAS=32, UNITE_MAILLAGE=22);

MAYAEXP=LIRE_MAILLAGE (UNITE=22);

MAYAEXP=DEFI_GROUP (reuse =MAYAEXP,
                    MAILLAGE=MAYAEXP,
                    CREA_GROUP_MA=_F (NOM=' ALL EXP', TOUT=' OUI',),
                    CREA_GROUP_NO=_F (GROUP_MA=' ALL EXP',),);

MODEXP=AFFE_MODELE (MAILLAGE=MAYAEXP,
                    AFFE=_F (GROUP_MA=' ALL EXP',
                              PHENOMENE=' MECANIQUE',
                              MODELISATION=' DIS_T',),);

CHCAREXP=AFFE_CARA_ELEM (MODELE=MODEXP,
                        DISCRET= (_F (GROUP_MA=' ALL EXP',
                                       CARA=' K_T_D_L',
                                       VALE= (1.0, 1.0, 1.0),),
                                   _F (GROUP_MA=' ALL EXP',
                                       REPERE=' GLOBAL',
                                       CARA=' M_T_D_L',
                                       VALE= (1.0),),),);

ASSEMBLY ( MODELE=MODEXP,
           CARA_ELEM=CHCAREXP,
           NUME_DDL=CO ('NUMEXP'),
           MATR_ASSE= (_F (MATRICE=CO ('KASSEXP'),
                           OPTION=' RIGI_MECA',),
                       _F (MATRICE=CO ('MASSEXP'),
                           OPTION=' MASS_MECA',),),);

MODMES=LIRE_RESU (TYPE_RESU=' MODE_MECA',
                  FORMAT=' IDEAS',
                  MODELE=MODEXP,
                  UNITE=32,
                  NOM_CHAM=' DEPL',
                  MATR_RIGI =KASSEXP,
                  MATR_MASS =MASSEXP,
                  FORMAT_IDEAS=_F (NOM_CHAM=' DEPL',
                                    NUME_DATASET=55,
                                    RECORD_6= (1,2,2,8,2,3),
                                    POSI_ORDRE= (7.4),
                                    POSI_NUME_MODE= (7.4),
                                    POSI_FREQ= (8.1),
                                    POSI_MASS_GENE= (8.2),
                                    POSI_AMOR_GENE= (8.3),
                                    NOM_CMP= ('DX', 'DY', 'DZ'),),
                  TOUT_ORDRE=' OUI',);
```

Some advices and traps to be avoided:

- The order of the components (keyword `NOM_CMP`) in `LIRE_RESU` is not obligatory; it is possible to make a simple change of reference mark (similar for all the nodes) by choosing the order of the components judiciously.
- Attention with the keyword `RECORD_6`, this one can vary; it is in particular the case when the file `unv` was created by `Code_Aster` itself. Indeed, it can happen that the data are printed on 6 columns, if the user printed his data on a modeling `DIS_TR`. The 3 last columns contain the degrees of freedom of rotation. It is the case in the CAS-test `sdl112a`. One can read again only the three first if the experimental model have only 3 degrees of freedom per node.
- It is possible to read data resulting from gauges of deformation. In this case,
 - `NOM_CHAM=' EPSI_NOEU'`,
 - `NOM_CMP= ('EPXX', 'EPYY'...)` to choose according to the reference mark used.
 - To compare these data with numerical data, one will be able to use the macro-order `OBSERVATION`.

2.2.2 Case of the orphan nodes

It is not advised to use orphan nodes in the grid, because the associated fields are difficult to visualize in Salomé. One can nevertheless read experimental data on these nodes, on condition that their applying a specific modeling of specific type (`POI1`).

The case is treated in the CAS-test `sdl112a`.

```
MAYAEXP=CRÉA_MALLAGE (MALLAGE=MAYAtmp,  
                      CREA_POI1=_F (TOUT=' OUI', NOM_GROUP_MA=' NOEU'),)  
  
MODEXP=AFFE_MODELE (MALLAGE=MAYAEXP,  
                   AFPE=_F (GROUP_MA=' NOEU',  
                           PHENOMENE=' MECANIQUE',  
                           MODELISATION=' DIS_T',),),  
  
CHCAREXP=AFFE_CARA_ELEM (MODELE=MODEXP,  
                        DISCRET= (_F (GROUP_MA=' NOEU',  
                                     REPERE=' GLOBAL',  
                                     CARA=' K_T_D_N',  
                                     VALE= (1.0, 1.0, 1.0),),  
                                _F (GROUP_MA=' NOEU',  
                                     REPERE=' GLOBAL',  
                                     CARA=' M_T_D_N',  
                                     VALE= (1.0),),),),)
```

3 Validation of model per criterion of MAC

3.1 What MAC?

MAC, Modal Criterion Insurance, is a criterion ranging between 0 and 1 giving the colinearity between two modes compared to a given standard.

$$MAC_{ij} = \frac{(\Phi_i^H W \Phi_j)^2}{(\Phi_i^H W \Phi_i)(\Phi_j^H W \Phi_j)}$$

The use of the matrices of weighting (W in the formula) is optional. When they are known, one can use the matrices of mass or stiffness of the model. It is the case when numerical data are handled, because the matrices were assembled on the model. It makes it possible to check the orthogonality of the clean modes compared to the matrices of mass and stiffness:

- $MAC_{ij} = 1$ si $i = j$
- $MAC_{ij} = 0$ sinon

But when experimental data are handled, one does not know the matrices condensed on this model. One can manufacture them by condensation of Guyan starting from the digital model, but this one not being readjusted, one is likely to make a mistake.

One can, more simply, to calculate MAC without matrix of weighting, and to look at the colinearity of the modes on the standard L_2 .

- If the objective is to check the orthogonality of the base, one can consider, at first approximation, that MAC without matrix of weighting is rather similar to MAC balanced by the matrix of mass,
- If the objective is to compare two bases of modes between them, then, the choice of this standard is equivalent to the different one: MAC will be worth 1 if the modes are colinéaires (thus if they “resemble each other”) and 0 if not.

NB: the use of MAC on experimental modes in particular makes it possible to check the capacity of the sensors to separate the modes. Indeed, more there are sensors, more the modes “will look various” seen those. MAC of two correctly identified different modes will be thus close to 0. If there is only one sensor, then MAC between two modes will always be worth 1: the modes are not separable.

3.2 Projection of fields

3.2.1 Projection of the numerical data on the experimental model with PROJ_CHAMP

The modes are comparable only if they are defined on the same model. One thus projects the digital base of modes, calculated with *Code_Aster*, on the experimental model, with the order PROJ_CHAMP.

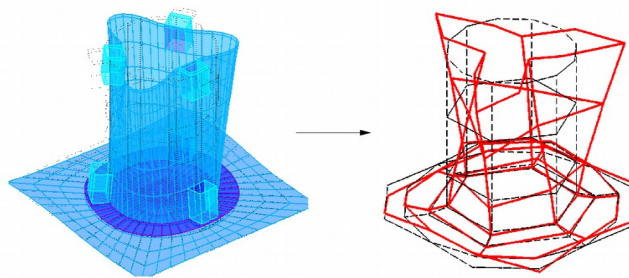


Image 3.2-1: projection of data.

Note:

- Important note: it is necessary to specify, in PROJ_CHAMP, the name of NUME_DDL experimental model, so that classifications of the experimental modes and projected digital modes are the same ones.
 - If it NUME_DDL is not the same one, one will not be able to calculate criterion of MAC.
- In PROJ_CHAMP, it is necessary to specify the dimension on which one projects: by default, one will associate the nodes of the experimental model with elements 3D of the digital model.
 - If the digital model consists of elements of plate, it should be specified with CAS=' 2.5D'
 - If the digital model is composed of elements 3D and 2D, then it is not possible to specify several types of projections. A suggested solution is to affect a modeling of plate (DKT for example) with the elements of skin which recover the elements 3D and to place itself in the case '2.5D'.
- The operator OBSERVATION allows to carry out the same operation, with additional options:
 - use of local reference marks sensors by sensors,
 - suppression of data measured of structure of data result (for the cases where the mesure had been made with uniaxial sensors),
 - creation of a structure of mixed data including of the accelerometer and extensiometric data, to reproduce an accelerometers measurement + gauges,
 - simulation of a “virtual gauge”.
- The description of this operator is proposed in the following paragraph.

3.2.2 Use of the macro-order OBSERVATION for the projection of the data

One proposes to give a practical example of the use of the macro-order on the following case:

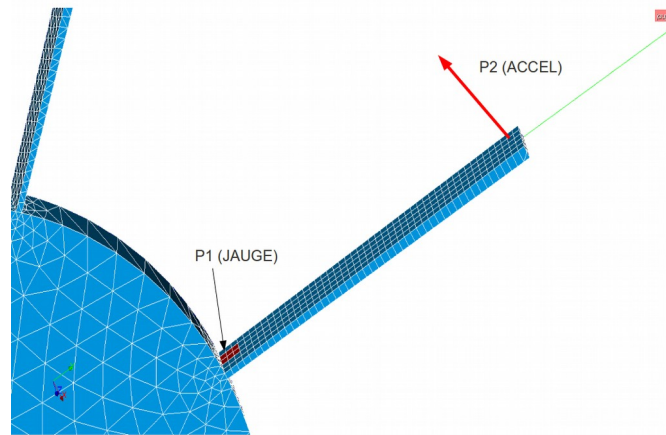


Image 3.2-2: measurement of the vibrations of one wing using a gauge and an accelerometer.

One supposes to have measured the vibrations of the aubagée wheel represented on the grid below by posing a gauge at the base of each wing and an accelerometer at the top. The identified clean modes are exported with the format unv **without passing to the total reference mark**. The vibrations at the top having been measured only in one direction, there will be a line of the form:

| | | | |
|-------------|-------------|-------------|---|
| 2 | 4 | 1 | 1 |
| 2.18331e+01 | 1.00000e+00 | 3.74657e-03 | |
| 1 | % NODE NO1 | | |
| 0.00000e+00 | 0.00000e+00 | 7.39432e-01 | |
| -1 | | | |

On the node *NO1*, only the local component *DZ* was measured. The not measured directions are put at 0. It is not possible, in one dated set 55, to make the difference between not measured data and worthless measurements.

To compare the experimental data and the reduced digital clean modes, two operations are necessary:

- on the experimental data, one filters the modes so as to eliminate the not measured data, by keeping only one direction for the gauge and the accelerometer
- one uses `OBSERVATION` without projection (`PROJECTION='NON'`), because one does nothing but filter the data,

```
OBSMXT = OBSERVATION ( RESULT = MEASUREMENT,
MODELE_1 = MODMESUR,
MODELE_2 = MODMESUR,
PROJECTION = 'NOT',
TOUT_ORDRE = 'YES',
NOM_CHAM = ('DEPL', 'EPSI_NOEU',),),
FILTER = ( _F (GROUP_NO = 'P1',
NOM_CHAM = 'EPSI_NOEU',
DDL_ACTIF = ('EPXX',),),),
_F (GROUP_NO = 'P2',
NOM_CHAM = 'DEPL',
DDL_ACTIF = ('DZ',),),),),);
```

- on the numerical data, one projects the clean modes on the experimental model:
 - one uses `PROJECTION='OUI'` ,

- one calculates the average deformation for the group of nodes in red on the figure before carrying out projection: this surface corresponds to the surface actually measured by the gauge,
- one makes the changes of reference mark, by using the option 'NORMAL' : one calculates the normal with the digital grid to define the axis Z local reference mark (the second axis is defined with the keyword VECT_Y); here, one could also have used the option 'CYNLINDRIQUE' .
- one filters the components corresponding to the measured data.

```
OBSJAU = OBSERVATION (RESULT = CALCULATION,  
MODELE_1 = MODNUME,  
MODELE_2 = MODMESUR,  
PROJECTION = 'YES',  
TOUT_ORDRE = 'YES',  
NOM_CHAM = 'EPSI_NOEU',  
EPSI_MOYENNE = _F (GROUP_MA=' SURF1', SEUIL_VARI= (0.1,),  
MASQUE= ('EPYY', 'EPZZ', 'EPXY',  
          'EPXZ', 'EPYZ')),  
MODI_REPERE = _F (GROUP_NO = ('P1', P2'),  
REFERENCE MARK = 'NORMAL',  
VECT_Y = (0. , 1. , 0.)),),  
FILTER = (_F (GROUP_NO = 'P1',  
NOM_CHAM = 'EPSI_NOEU',  
DDL_ACTIF = ('EPXX')),  
_F (GROUP_NO = 'P2',  
NOM_CHAM = 'DEPL',  
DDL_ACTIF = ('DZ',),),),);
```

3.3 Calculation of MAC between two bases of modes

The calculation of MAC can be carried out with the operator MAC_MODES, which calculates the matrix of MAC between all the modes of two bases. The structure of data produced is a table, which one prints with INFO=2 in MAC_MODES.

The keyword MATR_ASSE allows to use a matrix of weighting.

The printed table has the following form:

```
ASTER 11.01.03 CONCEPT MAC_ET CALCULATES THE 2/15/2012 AT 14:18: 54 OF TYPE  
TABLE_SDASTER  
MAC  
! NUME_MODE_1  
! 1 2 3 4 5  
-----  
NUME_MODE_2 1! 1.00000E+00 2.17692E-14 7.49505E-16 5.23742E-22 1.66188E-21  
2! 2.17692E-14 1.00000E+00 4.21440E-13 9.40269E-19 1.12652E-19  
3! 7.49505E-16 4.21440E-13 1.00000E+00 7.24387E-18 1.28403E-17  
4! 5.23742E-22 9.40269E-19 7.24387E-18 1.00000E+00 2.11012E-13  
5! 1.66188E-21 1.12652E-19 1.28403E-17 2.11012E-13 1.00000E+00
```

One can visualize MAC produced in Excel, or use the macro-order CALC_ESSAI, which proposes a visualization in 2D. For that, throw the macro-order without keyword at the end of calculation, and to position on the mitre "expansion of models".



Image 3.3-1: Image 3.3-1: CALC_ESSAI: expansion of models.

Within the framework it low, to choose the two bases of modes to be compared (if only one of the two bases is selected, one will make MAC of the base by itself), and to click on MAC. If the selected bases are not defined on the same model, the MAC button is grayed.
The matrix of MAC which appears is the following one:

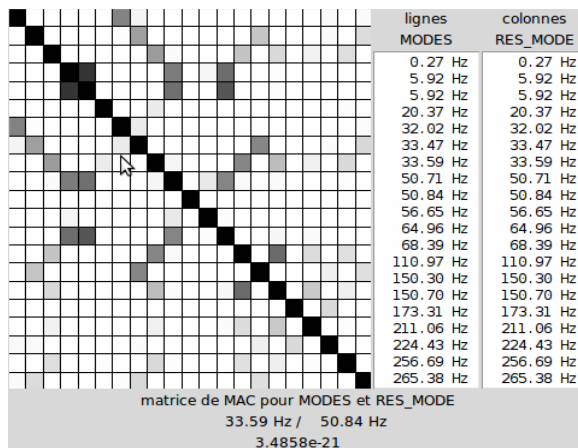


Image 3.3-2: MAC between two bases of modes visualized under CALC_ESSAI.

While passing the mouse on the boxes, one sees in bottom the frequencies of the modes concerned and the value of MAC for the latter.

NB: in appendix 5.4, one proposes a script using the library python matplotlib allowing to create diagrams of MAC in 3D more easily interpretable than that implemented by default in CALC_ESSAI. Later on, one studies feasibility to integrate MAC 3D by default into the operator.

4 Other methods of validation

4.1 Validation by visual comparison of modal deformations

This mode of validation is most direct. It can be done by printing in a classical way the modal deformations in Salomé.

NB: in CALC_ESSAI, in the mitre "Expansion of models", it is possible to select one or two bases (opposite "Result 1" and "Result 2") and to visualize them in GMSH while clicking on "Deformations". It is not possible to currently visualize the deformations in Salomé, this development must be carried out in 2012 (by adding the possibility of superimposing the deformations).

4.2 Validation by comparison of FRF

One proposes a procedure in CALC_ESSAI allowing to compare a FRF resulting from measurement with a FRF simulated by blow of hammer. This method of validation is different, because the comparison is done on a point of measurement at the same time, but on a wide waveband. She makes it possible to check the validity even modal model. For that, to click on "FRF" in the mitre "Expansion of models". The following window appears:

Image 4.2-1: simulations of FRF in CALC_ESSAI.

One can select on a side a concept of the modes type and simulate a FRF, and visualize other side a measured experimental FRF. By displaying the curves, one can obtain the following graph, product in XMGrace:

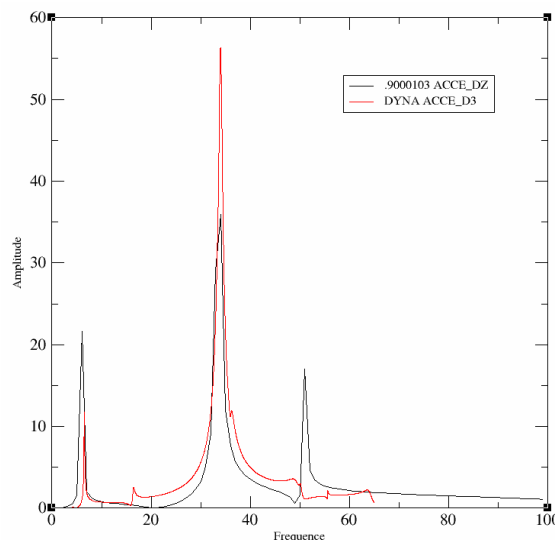


Image 4.2-2: posting of FRF in XMGrace.

5 Appendix

5.1 Documentation unv on went back set to grid

Set 2411 dated: description of the nodes:

```
Name: Nodes - Double precision
Status: Current
Owner: Simulation
Revision Dates: 23-OCT-1992
-----
Record 1: FORMAT (4I10)
          Field 1 -- node label
          Field 2 -- export coordinate system number
          Field 3 -- displacement coordinate system number
          Field 4 -- color
Record 2: FORMAT (1P3D25.16)
          Fields 1-3 -- node coordinates in the share coordinate
                    system

Records 1 and 2 are repeated for each node in the model.

Example:

-1
2411
    121      1      1      11
5.0000000000000000D+00  1.0000000000000000D+00  0.0000000000000000D+00
    122      1      1      11
6.0000000000
```

Set 82 dated: description of connectivities : this set dated is used more only in the very particular cases of experimental grids. The elements are more generally described by dated set 2412.

```
Name: Tracelines
Status: Obsolete
Owner: Simulation
Revision Dates: 27-Aug-1987
Additional Comments: This dataset is written by I-DEAS Test.
-----

Record 1: FORMAT (3I10)
          Field 1 - trace line number
          Field 2 - number of nodes defining trace line
                    (maximum of 250)
          Field 3 - color

Record 2: FORMAT (80A1)
          Field 1 - Identification line

Record 3: FORMAT (8I10)
          Field 1 - nodes defining trace line
                    = > 0 Draw line to node
                    = 0 move to node (has move to the first
                    node is implied)

Notes: 1) MODAL-PLUS node numbers must not exceed 8000.
       2) Identification line may not Be blank.
       3) Systan only use the first 60 characters of the
          identification text.
       4) MODAL-PLUS does not support traces lines to skirt than
          125 nodes.
       5) Supertab only use the first 40 characters of the
          identification line for has name.
       6) Repeat Datasets for each Trace_Line
```

Set 2412 dated: description of the elements (classical model EF):

```
Name: Elements
Status: Current
```

Warning : The translation process used on this website is a "Machine Translation". It may be imprecise and inaccurate in whole or in part and is provided as a convenience.

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```

Owner: Simulation
Revision Dates: 14-AUG-1992
-----

Record 1:      FORMAT (6I10)
                Field 1      -- element label
                Field 2      -- Fe descriptor id
                Field 3      -- physical property table number
                Field 4      -- material property table number
                Field 5      -- color
                Field 6      -- number of nodes one element

Record 2:      *** FOR NON-BEAM ELEMENTS ***
                FORMAT (8I10)
                Fields 1-n   -- node labels defining element

Record 2:      *** FOR BEAM ELEMENTS ONLY ***
                FORMAT (3I10)
                Field 1      -- beam orientation node number
                Field 2      -- beam drills-end cross-country race section number
                Field 3      -- beam aft-end cross-country race section number

Record 3:      *** FOR BEAM ELEMENTS ONLY ***
                FORMAT (8I10)
                Fields 1-n   -- node labels defining element

Records 1 and 2 are repeated for each non-beam element in the model.
Records 1 - 3 are repeated for each beam element in the model.

Example:

  -1
 2412
    1      11      1      5380      7      2
    0      1      1
    1      2
    2      21      2      5380      7      2
    0      1      1
    3      4
    3      22      3      5380      7      2
    0      1      2
    5      6
    6      91      6      5380      7      3
   11      18      12
    9      95      6      5380      7      8
   22      25      29      30      31      26      24      23
   14      136     8      0      7      2
   53      54
   36      116     16      5380      7      20
  152      159     168     167     166     158     150     151
  154      170     169     153     157     161     173     172
  171      160     155     156

  -1

```

5.2 Reference material on dated set 58

```

Number: 58
Name: Function Nodal At DOF
Status: Current
Owner: Test
Revision Dates: 23-Apr-1993
-----

Record 1:      Format (80A1)
                Field 1      - ID Line 1

                                NOTE

                                ID Line 1 is generally used for the function
                                description.

Record 2:      Format (80A1)
                Field 1      - ID Line 2

```

Record 3: Format (80A1)
Field 1 - ID Line 3

NOTE

ID Line 3 is generally used to identify when the function was created. The dates is in the forms DD-MMM-YY, and the time is in the forms HH: MM: SS, with has general Format (9A1,1X, 8A1).

Record 4: Format (80A1)
Field 1 - ID Line 4

Record 5: Format (80A1)
Field 1 - ID Line 5

Record 6: Format (2 (I5, I10), 2 (1X, 10A1, I10, I4))
 DOF Identification
Field 1 - Standard Function
 0 - General gold Unknown
 1 - Time Answer
 2 - Spectrum car
 3 - Spectrum cross-country race
 4 - Frequency Function Answer
 5 - Transmissibility
 6 - Coherence
 7 - Car Correlation
 8 - Cross-country race Correlation
 9 - Spectral Power Density (PSD)
 10 - Spectral Energy Density (ESD)
 11 - Probability Density Function
 12 - Spectrum
 13 - Cumulative Frequency Distribution
 14 - Peaks Valley
 15 - Stress/Cycles
 16 - Strain/Cycles
 17 - Orbit
 18 - Mode Indicator Function
 19 - Pattern force
 20 - Partial Power
 21 - Partial Coherence
 22 - Eigenvalue
 23 - Eigenvector
 24 - Shock Spectrum Answer
 25 - Finite Impels Filter Answer
 26 - Multiple Coherence
 27 - Order Function
Field 2 - Function Number Identification
Field 3 - Number version, gold sequence number
Field 4 - Load Puts Number Identification
 0 - Individual Point Excitation
Field 5 - Answer Entity Name ("NUN" yew unused)
Field 6 - Node answer
Field 7 - Answer Direction
 0 - Scalar
 1 - +X Translation 4 - +X Rotation
 -1 - - X Translation -4 - - X Rotation
 2 - +Y Translation 5 - +Y Rotation
 -2 - There Translation -5 - There Rotation
 3 - +Z Translation 6 - +Z Rotation
 -3 - - Z Translation -6 - - Z Rotation
Field 8 - Reference Entity Name ("NUN" yew unused)
Field 9 - Node reference
Field 10 - Reference Direction (same ace field 7)

NOTE

Fields 8.9, and 10 are only depending yew field 4 is zero.

Record 7: Format (3I10,3E13.5)
 Dated Forms
Field 1 - Ordinate Dated Standard

| | | |
|------------|-------------------------------|---|
| | | 2 - real, individual precision |
| | | 4 - real, double precision |
| | | 5 - complex, individual precision |
| | | 6 - complex, double precision |
| Field 2 | - | Number of dated even for uneven abscissa spacing, but number of dated been worth for even |
| | | abscissa spacing |
| Field 3 | - | Abscissa Spacing |
| | | 0 - uneven |
| | | 1 - even (been worth No abscissa stored) |
| Field 4 | - | Minimum Abscissa (0.0 yew spacing uneven) |
| Field 5 | - | Abscissa increment (0.0 yew spacing uneven) |
| Field 6 | - | Z-axis been worth (0.0 yew unused) |
| Record 8: | Format (I10,3I5,2 (1X, 20A1)) | Abscissa Dated Characteristics |
| Field 1 | - | Specific Dated Standard |
| | | 0 - unknown |
| | | 1 - general |
| | | 2 - stress |
| | | 3 - strain |
| | | 5 - temperature |
| | | 6 - heat flow |
| | | 8 - displacement |
| | | 9 - reaction forces |
| | | 11 - velocity |
| | | 12 - acceleration |
| | | 13 - excitation forces |
| | | 15 - press |
| | | 16 - farmhouse |
| | | 17 - time |
| | | 18 - frequency |
| | | 19 - rpm |
| | | 20 - order |
| Field 2 | - | Length units exponent |
| Field 3 | - | Force units exponent |
| Field 4 | - | Temperature units exponent |
| | | NOTE |
| | | Fields 2.3 and 4 are raising only yew the Specific Dated Standard is General, gold in the box of ordinates, the answer/reference direction has scalar, but the functions are being used for nonlinear connectors in System Dynamics Analysis. See Addendum 'with' for the units exponent table. |
| Field 5 | - | Axis label ("NUN" yew not used) |
| Field 6 | - | Axis units label ("NUN" yew not used) |
| | | NOTE |
| | | Yew fields 5 and 6 are supplied, they take precedence over program generated labels and units. |
| Record 9: | Format (I10,3I5,2 (1X, 20A1)) | Ordinate (gold ordinate numerator) Dated Characteristics |
| Record 10: | Format (I10,3I5,2 (1X, 20A1)) | Ordinate Denominator Dated Characteristics |
| Record 11: | Format (I10,3I5,2 (1X, 20A1)) | Z-axis Dated Characteristics |
| | | NOTE |
| | | Records 9.10, and 11 are always included and cut fields the same ace record 8. Yew records 10 and 11 are not used, set field 1 to zero. |
| Record 12: | | Dated Been worth |
| | Ordinate | Abscissa |

| Box | Type | Precision | Spacing | Format |
|-----|---------|------------|---------|-------------------|
| 1 | real | individual | even | 6E13.5 |
| 2 | real | individual | uneven | 6E13.5 |
| 3 | complex | individual | even | 6E13.5 |
| 4 | complex | individual | uneven | 6E13.5 |
| 5 | real | double | even | 4E20.12 |
| 6 | real | double | uneven | 2 (E13.5, E20.12) |
| 7 | complex | double | even | 4E20.12 |
| 8 | complex | double | uneven | E13.5, 2E20.12 |

NOTE

See Addendum 'B' for typical FORTRAN READ/WRITE statements for each box.

General Notes:

1. ID lines may not be blank. Yew No information is required, the word "NUN" must appear in columns 1 through 4.
2. ID line 1 appears one studs in Finite Element Modeling and is used ace the function description in System Dynamics Analysis.
3. Dataloaders uses the following ID line conventions
ID Line 1 - Model Identification
ID Line 2 - Run Identification
ID Line 3 - Run Dates and Time
ID Line 4 - Load Puts Name
4. Coordinates codes from MODAL-PLUS and MODALX are decoded into node and direction.
5. Entity names used in System Dynamics Analysis prior to I-DEAS Level 5 cuts has 4 character maximum. Beginning with Level 5, entity names will be ignored yew this dataset is preceded by dataset 259. Yew No dataset 259 precede this dataset, then the entity name will be assumed to exist in model bin number 1.
6. Record 10 is ignored by System Dynamics Analysis unless load box = 0. Record 11 is always ignored by System Dynamics Analysis.
7. In record 6, yew the answer gold reference names are "NUN" and are not overridden by has dataset 259, goal the corresponds ing node is non-zero, System Dynamics Analysis adds the node and direction to the function description yew space is sufficie
8. ID line 1 appears one XY studs in Test Dated Analysis along with ID line 5 yew it is defined. Yew defined, the axis units labels also appear one the XY normal stud instead of the labeling based one the dated standard of the function.
9. For functions used with nonlinear connectors in System Dynamics Analysis, the following requirements must be adhered to:
 - a) Record 6: For has displacement-depend function, the standard function must be 0; for has frequency-depend function, it must be 4. In either box, the load box identification number must be 0.
 - b) Record 8: For has displacement-depend function, the specific dated standard must be 8 and the length units exponent must be 0 gold 1; for has frequency-depend function, the specific dated standard must be 18 and the length units exponent must be 0. In either box, the other units exponents must be 0.
 - c) Record 9: The specific dated standard must be 13. The temperature units exponent must be 0. For year ordinate numerator of force, the length and force units exponents must be 0 and 1, respectively. For year ordinate numerator of moment, the length and force

units exponents must Be 1 and 1, respectively.

- d) Record 10: The specific dated standard must Be 8 for stiffness and hysteretic damping; it must Be 11 for viscous damping. For year ordinate denominator of translational displacement, the length units exponent must Be 1; for has rotational displacement, it must Be 0. The other units exponents must Be 0.
- e) Dataset 217 must precedes each function in order to define the function' S use (i.e stiffness, viscous damping, hysteretic damping).

5.3 Reference material on dated set 55

Name: At Nodes dated
Status: Obsolete
Owner: Simulation
Revision Dates: 07-Mar-1997
Additional Comments: This dataset is written and read by I-DEAS Test.

RECORD 1: Format (40A2)
FIELD 1: ID Line 1

RECORD 2: Format (40A2)
FIELD 1: ID Line 2

RECORD 3: Format (40A2)
FIELD 1: ID Line 3

RECORD 4: Format (40A2)
FIELD 1: ID Line 4

RECORD 5: Format (40A2)
FIELD 1: ID Line 5

RECORD 6: Format (6I10)

Dated Parameters Definition

FIELD 1: Standard Model
0: Unknown
1: Structural
2: Heat Transfer
3: Fluid Flow

FIELD 2: Standard Analysis
0: Unknown
1: Static
2: Normal Mode
3: Complex eigenvalue first order
4: Transient
5: Frequency Answer
6: Buckling
7: Complex eigenvalue second order

FIELD 3: Characteristic dated
0: Unknown
1: Scalar
2: 3 Total DOF Translation
Vector
3: 6 Total DOF Translation
& Vector Rotation
4: Total Symmetric Tensor
5: General Total Tensor

FIELD 4: Specific Dated Standard
0: Unknown
1: General
2: Stress

```
3: Strain (Engineering)
4: Element Forces
5: Temperature
6: Heat Flow
7: Strain Energy
8: Displacement
9: Reaction Forces
10: Kinetic Energy
11: Velocity
12: Acceleration
13: Strain Energy Density
14: Kinetic Energy Density
15: Hydro-Static Presses
16: Heat Gradient
17: Checking code Been worth
18: Coefficient Of Pressure

FIELD 5: Dated Standard
2: Real
5: Complex

FIELD 6: Number Of Data Been worth Per Node (NDV)

Records 7 And 8 Are Standard Analysis Specific

General Forms

RECORD 7:      Format (8I10)

FIELD 1:      Number Of Integer Dated Been worth
1 < Gold = Nint < Gold = 10
FIELD 2:      Number Of Real Data Values
1 < Gold = Nrval < Gold = 12
FIELDS 3-N:   Type Specific Integer Parameters

RECORD 8:      Format (6E13.5)
FIELDS 1-N:   Type Specific Real Parameters

Standard For Analysis = 0, Unknown

RECORD 7:

FIELD 1: 1
FIELD 2: 1
FIELD 3: ID Number

RECORD 8:

FIELD 1: 0.0

Standard For Analysis = 1, Static

RECORD 7:

FIELD 1: 1
FIELD 2: 1
FIELD 3: Load Puts Number

RECORD 8:

FIELD 11: 0.0

Standard For Analysis = 2, Normal Mode

RECORD 7:

FIELD 1: 2
FIELD 2: 4
FIELD 3: Load Puts Number
FIELD 4: Number mode

RECORD 8:

FIELD 1: Frequency (Hertz)
FIELD 2: Modal Farmhouse
```

```
FIELD 3:    Modal Viscous Damping Ratio
FIELD 4:    Modal Hysteretic Damping Ratio

For Analysis Standard = 3, Complex Eigenvalue

RECORD 7:
FIELD 1:    2
FIELD 2:    6
FIELD 3:    Load Puts Number
FIELD 4:    Number mode

RECORD 8:
FIELD 1:    Real Part Eigenvalue
FIELD 2:    Imaginary Leaves Eigenvalue
FIELD 3:    Real Part Of Modal A
FIELD 4:    Imaginary Leaves Of Modal A
FIELD 5:    Real Part Of Modal B
FIELD 6:    Imaginary Leaves Of Modal B

Standard For Analysis = 4, Transient

RECORD 7:
FIELD 1:    2
FIELD 2:    1
FIELD 3:    Load Puts Number
FIELD 4:    Time Step Number

RECORD 8:
FIELD 1:    Time (Seconds)

For Analysis Standard = 5, Frequency Answer

RECORD 7:
FIELD 1:    2
FIELD 2:    1
FIELD 3:    Load Puts Number
FIELD 4:    Frequency Step Number

RECORD 8:
FIELD 1:    Frequency (Hertz)

Standard For Analysis = 6, Buckling

RECORD 7:
FIELD 1:    1
FIELD 2:    1
FIELD 3:    Load Puts Number

RECORD 8:
FIELD 1:    Eigenvalue

RECORD 9:    Format (I10)
FIELD 1:    Node Number

RECORD 10:   Format (6E13.5)
FIELDS 1-N:  At This Node (NDV Real Or dated
              Been worth Complex)

Records 9 And 10 Are Repeated For Each Node.
```

5.4 Script for the representation 3D of a diagram of MAC

This script can be recopied in bottom of a command file, by replacing the names *B1* and *B2* on the last line by the names of the two bases which one wishes to compare by MAC.

Caution: this script is pressed on the library `matplotlib` who must be installed.

```
def mac_plot_lib (BASE1, BASE2):
    """ calculates mac between two bases, the extract and represents it in a graph 3D
        matplotlib """
    __MAC=MAC_MODES (BASE_1=BASE1,
                     BASE_2=BASE2);

    mactmp=__MAC.EXTR_TABLE ()
    mac = mactmp ['NUMÉRIQUE_MODE_1', 'NUMÉRIQUE_MODE_2', 'MAC']. Cross ()
    mac_py = mac.values ()

    importation numpy ace Np
    from mpl_toolkits.mplot3d importation axes3d
    importation matplotlib.pyplot ace plt

    freq_1 = BASE1.LISTE_PARA () ['FREQ']
    freq_2 = BASE2.LISTE_PARA () ['FREQ']
    nume_ordre_1 = BASE1.LISTE_PARA () ['NUMÉRIQUE_ORDRE']
    nume_ordre_2 = BASE2.LISTE_PARA () ['NUMÉRIQUE_ORDRE']
    nb_freq_1 = len (freq_1)
    nb_freq_2 = len (freq_2)
    matrice_mac = np.transpose (np.array ([mac_py [kk] for kk in nume_ordre_1]))

    fig = plt.figure ()
    ax = axes3d. Axes3D (fig)

    # Create regular mesh from coordinates
    xpos, ypos = np.meshgrid (np.arange (nb_freq_1), arranges (nb_freq_2))
    xpos = xpos + 0.5* (np.ones (matrice_mac.shape) - matrice_mac)
    ypos = ypos + 0.5* (np.ones (matrice_mac.shape) - matrice_mac)
    xpos = xpos.flatten ()
    ypos = ypos.flatten ()
    dx = matrice_mac.flatten ()
    Dy = dx.copy ()
    dz = dx.copy ()
    zpos=np.zeros (nb_freq_1*nb_freq_2)

    for kk in arranges (len (xpos)):
        yew dx [kk] <1.0E-6:
            # to avoid plantings in the event of too small mac
            dx [kk] =dy [kk] =dz [kk] =1.0E-6
            ax.bar3d (xpos [kk], ypos [kk], zpos [kk],
                     dx [kk], Dy [kk], dz [kk],
                     color=mac2col (dz [kk]))

    ax.set_xlabel (u' FREQ_I')
    ax.set_ylabel (u' FREQ_J')
    ax.set_zlabel (u' MAC')
    plt.show ()

def mac2col (been worth):
    # gives the value of the color corresponding has a value of MAC
    # ranging between 0 and 1
    importation matplotlib.colors ace colors
    importation matplotlib.cm ace cm
    been worth = 1-been worth
    desc=cm.RdYlBu. _segmentdata
    segments= [desc ['blue'] [kk] [0] for kk in arranges (len (desc ['blue']))]
    num_seg=0
    for kk in segments:
        yew been worth > kk:
            num_seg = num_seg+1
    tri= (desc ['red'] [num_seg] [1],
          desc ['green'] [num_seg] [1],
          desc ['blue'] [num_seg] [1])
    return colors.rgb2hex (tri)

mac_plot_lib (B1, B2)
```

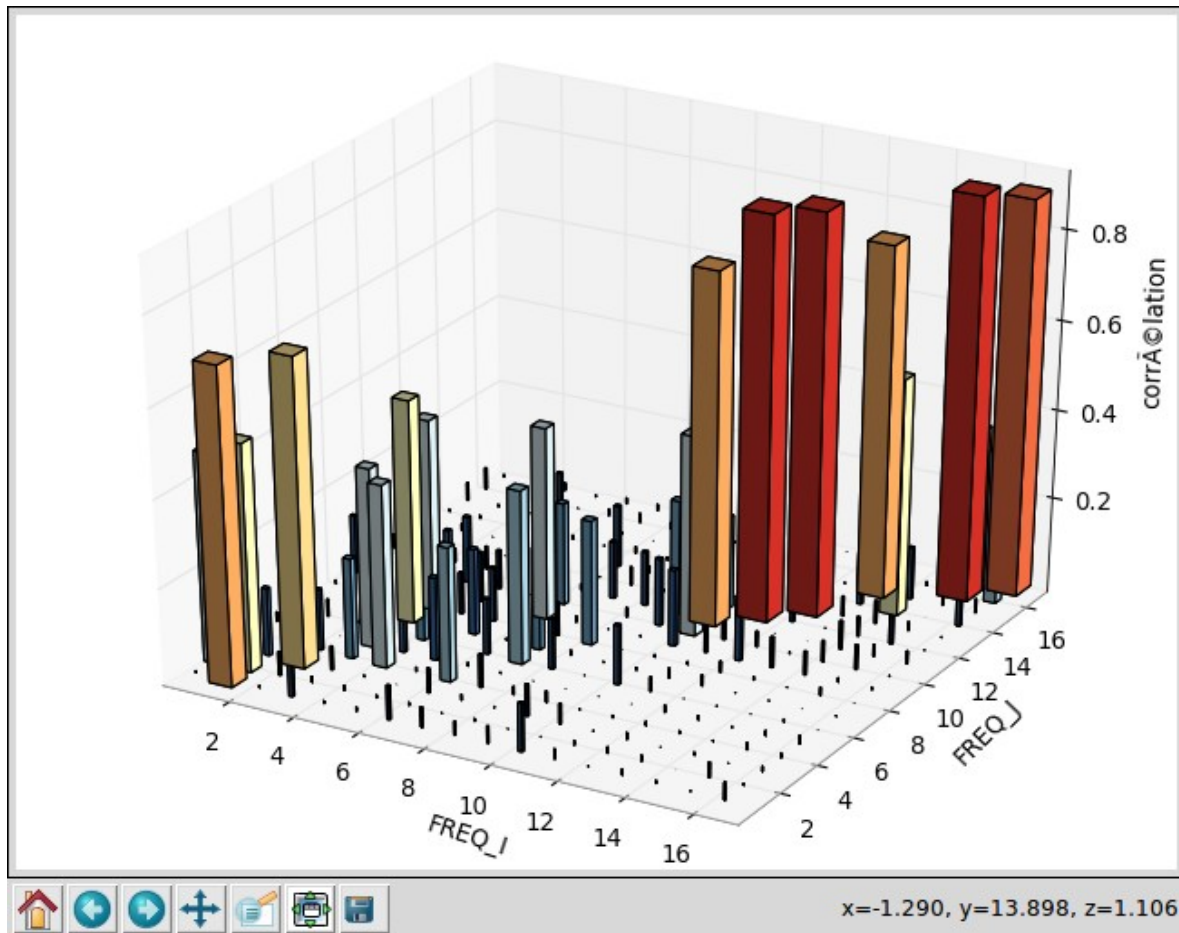


Image 5.4-1: MAC 3D.