E*xplorer*3D
User's Manual
Release 1.2

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Contents

1 A Foreword on the english documentation

E*xplorer***3D** has been first written in French. So was its documentation. The software has been for long internationalized. The documentation has been more recently. Most of the snapshots come from the French version. They might thus slightly differ from the actual english-version interface. If you feel like updating the snapshots or improve the english level of this documentation, do not hesitate to contact us!

2 What is E*xplorer*3D ?

E*xplorer***3D** is an interactive visualization software. It allows object spatial positionning in a 2D or 3D space, based on various projection techniques:

- When attribute-value files are given, **E***xplorer***3D** relies on dimensionality reduction, either supervised (e.g. linear discriminant analysis) or unsupervised (e.g. principal component analysis).
- When a distance file is given (distance -or dissimilarity- between pairs of objects), **E***xplorer***3D** relies on multidimensional scaling.

Various unsupervised classification tool are available, in ordre to help the user's graphical interpretation.
E*xplorer***3D** is globally oriented towards an interactive use, in order to allow for subset extractions, positionning constraints, ...

3 E*xplorer*3D in a nutshell...

- **Loading a file**: in menu "Files", choose "load a file". If data cannot be directly interpreted by **E***xplorer***3D** an import tool will open automatically (see section 5.9).
- **Viewing pictures associated to objects**: In order to use this feature, your source file must contain a column that indicates the name of the file containing the picture associated with the corresponding object (see section 5). Once your data file has been loaded (and visualized), go to "Additional features" sub-window, and associate "Associated data" with the relevant column (i.e. the one containing the picture file names).
- **Viewing pictures permanently in the 3D frame**: righ-click on the object and select "Show / hide picture". Depending on option settings ("Draw pictures out-of 3D window"), pictures will be displayed either in a separate window or in the 3D view.
- **Viewing pictures dynamically**: Pictures can get displayed dynamically when the mouse pointer passes over the corresponding object, and hidden when the mouse leaves the object. This function is enable when the "Show pictures when mouse is over"option gets selected.
- **Managing options**: Get in the "Tools / options" menu.

- **Picture-driven exploring**: You can alternatively choose to hide all ojects in the 3d view and view only the ones that correspond to specific pictures. This feature gets activated when you choose "Tools / Explorer from Images".
- **Moving points closer or away in the 3D frame**: Exploring from images allox for projection modifications (i.e. to modify the spatial positionning of objects). There exists a second mean to achieve projection modification, moe complete and also more complex, relying on another interface. This can be reach trough the "Tools/interaction" menu.

4 Install

4.1 Prerequisites

Before using **E**xplorer**3D** you should have installed a recent version of Java Standard Edition (> 1.6u12), along with the Java3D library. JavaSE and Java3D can respectively be dowloaded at:

- `http://www.oracle.com/technetwork/java/javase/downloads/index.html`
- `http://www.oracle.com/technetwork/java/javase/tech/index-jsp-138252.html`

In case java3D is misinstalled or missing, a message should warn you at launch time or at your first try to display a 3D view. Meanwhile, if no control window get displayed at launch time, or misdisplayed window might be the result or the absence, wrong use or wrong version of Java or Java3D.

4.2 Install and start

Explorer**3D** is shipped as a java archive file(explorer3d.jar). Launching is thus done typing " `java -jar explorer3d.jar` ".
Depending on your O.S. (e.g. MacOS), you might be able to launch **E**xplorer**3D** by clicking on the "explorer3d.jar" file. Nevertheless, this might result in a faulty luanching, with no message displayed. Double-click launch is discouraged with Windows systems. An alternative consists in creating a "explorer.bat" file, in the directory where explorer3D.jar is stored, and fill this file with: " `java -jar explorer3d.jar` ". Double-clicking on explorer.bat should cause **E**xplorer**3D** to start.
This alternative start mode is also encouraged in the case of a personnalized install of Java3D, where an explicit classpath is needed. As the -jar option prohibits the use of -cp, the solution consists in first adding explorer3D.jar to the classpath and then directly select explorer.Explorer3D as the java class to be started. The following script illustrates how to proceed (example with bash et 64 bits java3D library) :

```
export LD_LIBRARY_PATH = $LD_LIBRARY_PATH:j3d_install_path/lib/amd64
export CLASSPATH = $CLASSPATH:j3d_install_path/lib/ext/j3dcore.jar:\
 j3d_install_path/lib/ext/j3dutils.jar:\
 j3d_install_path/lib/ext/vecmath.jar:\
 explorer_install_path/explorer3D.jar
java explorer.Explorer3D
```

5 Data input format

5.1 A Foreword on Additional Attributes

Besides projection data (e.g. features or distance matrices), input files might contain *additional attributes*, handling for instance the name of an associated picture file, the class of the object (if this stands), and so on. An input file might contain 0, 1 or several such attributes.

5.2 Multisource mode

In case the user possesses several data source file that concern a single set of objects (each of these files containing different features), several of these files can be loaded in a single project and projected simultaneously.
This mode is allowed depending on **E***xplorer***3D** options (see section 7.7). If this option is not activated, then each loading of a data source file will result in the reintialization of **E***xplorer***3D** and thus to discarding the current projection. Otherwise, the user will be asked if a new file is to be considered to contain a new set of features for the currently observed objects, or consists of a new set of objects, if which case **E***xplorer***3D** will be reinitialized.
In multisource mode, each data source file can contain whatever data input format is allowed (features, distance matrices, etc.). **Objects must appear in the same order in each of the files, unless the file is a subset one**.

5.3 Subset files

To be translated. Several kinds of input file can contain data for only a subset of the objects. This does mainly make sens in multisource mode, were some input can be available for a subset only of the objects, but were the user wishes to compare the resulating projection with a former one, based on another input data file.
A subset file is denoted by the presence of the SUBSET keyword (see the various file formats). The global rank of each object must then be given. In the current release, the user i supposed to load at least one complete set before loading a subset.
Subset files can contain additional data columns. The value of these columns will be set to “UNDEFINED” for the missing objects.

5.4 Features input file

Input file do commonly consist of a set of features, i.e. a table where each object is described according to a set of features. A 3D view is then computed by projecting the objects in a low dimension space that reflects the original large dimension space formed by the original features.

5.4.1 General format

E*xplorer***3D** accepts text files, structured as follows:

```
[SUBSET [START WITH x]]
number of objects
number of original features (excluding additional features)
names of original features followed by names of additional features
Description of objects (list of original and additional features, one object per line
```

Feature names and values are separated by a delimiter, which is by default the space character. This delimiter might be explicitly defined and changed in case the space character can not be used (see section5.4.2).
Here is a sample file (first lines of the very standard "iris" data set) :

```
150
4
A B C D class
5.1 3.5 1.4 0.2 Iris-setosa
4.9 3.0 1.4 0.2 Iris-setosa
4.7 3.2 1.3 0.2 Iris-setosa
...
```

In this sample, 4 original attributes are given, named "A","B", "C" and "D". they are followed by an additional attribute, "class". In this sample, the original attributes consist of numerical values (reals).
Remark: the user should be careful, not to leave empty spaces at the end of lines, especially in the two first lines. Such empty spaces might be misinterpreted by E*xplorer*3D .

5.4.2 User-defined delimiter

If the space character might not be used as a delimiter, an additional line can be added at the beginning of the file (on its 3rd line, thus after the number of attributes and before the names of attributes), to declare the delimiter used. for instance, if "|" is the delimiter, the file starts like:

```
150
4
|
A|B|C|D|class
5.1|3.5|1.4|0.2|Iris-setosa
4.9|3.0|1.4|0.2|Iris-setosa
4.7|3.2|1.3|0.2|Iris-setosa
...
```

5.4.3 Subset data file

If "SUBSET" is set on the first line, then the file is supposed to contain only a subset of the global set of objects. An additional numeric value must then be added at the begining of each object-description line, that corresponds to the current object rank in the whole set, starting at value 0. If the ranks given do not start at 0, then the user must use the

optional parameter "START WITH", followed by the offset. For instance, if his personnal object numbering starts at 1, then he will write "START WITH 1".
For instance:

```
SUBSET START WITH 1
3
4
A B C D classe
5 5.1 3.5 1.4 0.2 Iris-setosa
20 4.9 3.0 1.4 0.2 Iris-setosa
110 4.7 3.2 1.3 0.2 Iris-setosa
```

The user only gives 3 objects, with she has numbered 5, 20 and 110 in her own numbering system that starts at 1. These objects are thus numbered 4, 19 and 109 in **E***xplorer***3D** .

5.4.4 How symbolic attributes are managed

Original attributes are by default supposed to be numerical (real). Symbolic values can also be handeld. Symbolic means that the values do not belong a continuous domain. Thus, both integers and strings might be considered as symbolic attributes (integer will be by default considered as numerical values unless they are be explicitly considered as symbols).
Symbolic attributes will be denoted by a ".S" suffix in their attribute name. Let us observe the following example:

```
151
5
R1.S R2.S R3.S R4.S R5 Clas
A Green YES + 19 TRUE
B Red NO - 17 TRUE
C Blue NO - 49 FALSE
...
```

The first four attributes are symbolic.
Concerning numerical attributes, their name can be suffixed by ".N", but this does remain optional.
In the current implementation of **E***xplorer***3D** a pre-processing is done on symbolic attributes in order to binarize them: A first scan of the column is done, in orderto list the existing values of the attribute. The unique attribute is then replaced by a list of attributes (taking value 0 or 1), each one corresponding to a value of the symbolic one. For a given object, all of these attributes are set to 0, except the one corresponding to the original symbolic value. Such forged attributes are named as the original attribute, except they are suffixed by "$*rank*", where *rank* is the rank of the symbolic value in the list of existing ones.
for instance, in our example data set, R1 get replaced with two attributes, "R1$1" and "R1$2", the values of which are respectively, for the first object, 1 et 0, and for the second object 0 and 1.
This decomposition is fully transparent to the user.

5.5 Distance files

Distance files contain distance matrices, i.e. matrices the elements of which correspond to the distance between pairs of objects. The 3D view is then computed so that the distance in the 3D space correspond as much as possible to the distances in the matrix. The file inner format is as follows:

```
number of objects [COMPLETE]
distances between objects (one object per line)
[Number ou list of names of additional attributes
Values of additional attributes]
```

Where the squares braces denote optional parts.
By default, only the upper triangular part of the distance matrix is given: if we have 3 objects a, b and c, the first line will contain $distance_{ab}$ and $distance_{ac}$, and the second line $distance_{bc}$
On the first line might occur the optional keyword "COMPLETE", which means that the full square matrix is given. According to our example, the first line will contain $distance_{a,a}$, $distance_{a,b}$ and $distance_{a,c}$, the second one $distance_{b,a}$, $distance_{b,b}$ et $distance_{b,c}$, etc.).
If additional attributes are given, and only their cardinality is given, their names are automatically coined as follows: "Att1", "Att2", etc.
Here is a sample file (very first lines of a inter-illumination distance matrix) :

```
166
...
1.0694574 1.1302139 1.0019832 1.0004523 ...
1.0656028 0.96607274 1.1858556 ...
...
image class
ms0001_1.jpg ms0001-Mazarine-Fr-SW-Début-12eme
ms0001_2.jpg ms0001-Mazarine-Fr-SW-Début-12eme
...
```

This data set consists of 166 objects. For each of them we have two additional attributes: the name of an associated image file, and the name of the document the illumination comes from.
the first object belongs to document "ms0001 - Mazarine - Fr - SW - Début 12eme", and the user might find a picture of the illumination in the file "ms0001_1.jpg". The second illumination comes from the same document and can be viewed in file "ms0001_2.jpg". The distance between the first and the second object is 1.0694574; the distance between the first and the third object is "1.1302139"; etc.

5.6 Raw 3D coordinates file

This kind of file does start by the number of objects it contains (it is computed automatically). *This might be reconsider in some future released of* **E***xplorer***3D** .
Optionnaly, the file might start by a line that contains the names of the 3 attributes.
Each remaining line contains the 3 coordinates (real values) of an object. These values might be followed by additional attributes.
Here is a example file with three objects:

```
0.5 0.5 0.5
-0.5 -0.5 -0.5
0 0 -2
```

5.6.1 Subset data file

Optionnaly, the keyword “SUBSET” should be added, alone on the first line of the file. Each remaining line will thus consist of four values, the first one beeing the global rank of each object. As with feature input files, SUBSET might be followed by “START WITH” to specify an offset. for instance :

```
SUBSET START WITH 1
4 0.5 0.5 0.5
2 -0.5 -0.5 -0.5
1 0 0 -2
```

This file contains the coordinates of objects number 4, 2 and 1, with an offset of 1, that is to say that the global rank of these objects are 3, 1 and 0.

5.7 Pure additional attributes files

the user can load files that consist of additional attributes with no projection data. Such files are structured as feature input file, where the number of projection features is set to 0. Such files do only make sense in multisource mode.

5.8 Reserved attribute names (additional attributes)

Some reserved attribute names might be used, that are linked to a pre-defined visual behaviour of **E***xplorer***3D** (i.e. automatic object coloring, direct link to picture files), that should normally be set by hand (see section 7.2.1). two names are currently reserved:

- **ImgFileName** : the column contains picture file names. The path to files is relative to the data file directory (e.g. concerning the data file in section 5.5, picture files are supposed to be in the same directory as this data file). An absolute path can be set, starting from the root directory (e.g. “/data/images/enluminures/img0001.png”). Pictures will be displayed either statically, on demand, on dynamically, when the pointer passes over the corresponding object.

- **Class** : a predefined class for each object. In **E***xplorer***3D** , object class is displayed by colouring objects. A class attribute can be either numerical or symbolic. The class-to-colour mapping is automatically set (**E***xplorer***3D** does nevertheless allow the user to modify this mapping by hand).

5.9 Data import

If the data file inner format does not match **E***xplorer***3D** format, a data import tool can be executed. This latter will be automatically loaded in case the user tries to load a misformatted file. It can also be manually launched choosing the “Files / Data import

tool" menu. This wizard tool does allow to re-organize rows and columns and guides the user step by step. One must notice that only text (no binary files) feature input files (neither distance matrices nor rax 3D coorindates) are currently supported. This does nevertheless cover most of needs. Do not hesitate to contact the authors in case additional import features would be necessary.
To import spreadsheet data, please do first save your file using the CVS (i.e. text) format, and then open this file in the **E**_xplorer_**3D** import tool.

6 Visualisation interface: an Overview

6.1 Handover

This section consists in a small tutorial on how to use **E**_xplorer_**3D** in the context of a PCA.
When starting **E**_xplorer_**3D** , the main control window opens (cf. fig. 1).

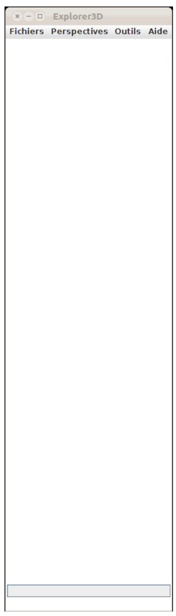


Figure 1: **E**_xplorer_**3D** main control window (at launch time)

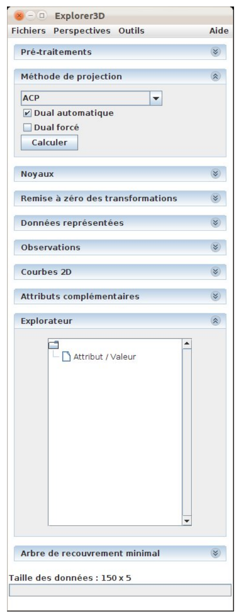


Figure 2: PCA commands

Let us first load the data file. In the menu bar, let use choose "Files / Load local file (new project)", and pick the _iris.csv_ file. The main window aspect changes, so that it now offers the functionnalities that are relevant to a feature file (also called the "ND[imensions] → 3D[imensions]" perspective (see fig. 2).
In order to compute a classical PCA, we first check, in the "Pre-treatments" sub-window, that "Center variables" is checked, and that "Reduced variables" is selected in the "Reduction method" list. Let us then click on "Compute" in the "Projection Method" sub-window. The 3D view then opens and displays objects using their default shape and colour, that is blue spheres on a dark background (fig. 3).
Let us now display an additional visual information, by the mean of object colouring according to their class (each sphere correspond to a given kind of iris, and each kind of

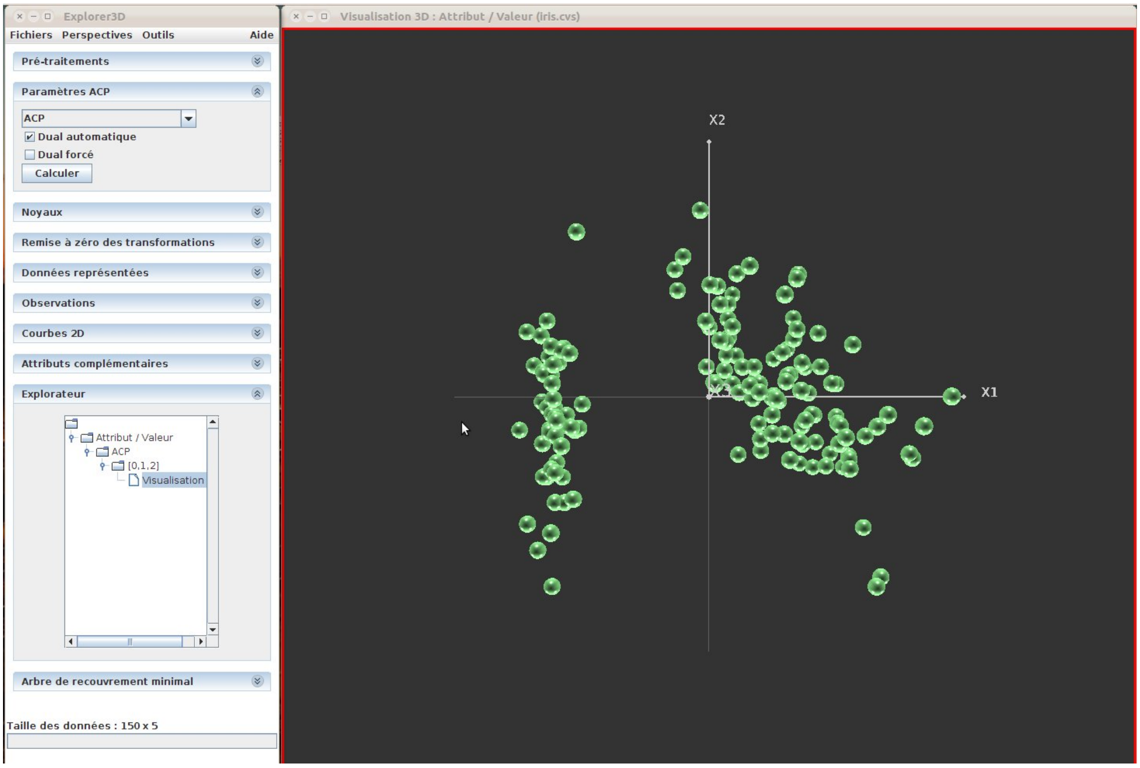


Figure 3: Default 3D view

iris belongs to one of three varieties). The class of a given iris (i.e. its variety) is stored in an additional attribute, load together with the features, and named “classe”. Let us display the sub-window “Additional attributes” by clicking on the upper-rigth arrows of this sub-window, and let us choose “classe” in the “Groups” list (which is the only attribute available, let-us ignore “multigroups” for the moment). spheres are then coloured and a legend window pops up (fig. 4).

We can notice the presence of check boxes in the legend window. The “class” check boxes allow to display or hide the objects that belong to a given class. The “Ellipsoid” checkboxes allow to display an ellipsoid around the corresponding group of objects (i.e. the objects of a given class), that reflects their spreading in space (fig. 5) (Basically, this ellipsoid is centered on the center of gravity of the group, and its diameters correspond to the variance of the group along its three mains axes, based on the hypothesis of a multinormal distribution). Figure 5 illustrate a visualisation of objects and the classes ellipsoids.

One must notice that the top-line check boxes (blue background) are shortcuts to check or uncheck the whole column.

It is also possible to view the convex envelop of a group. This is done by checking boxes in the “Convex Envelop” column. Figure 6 illustrates a 3D view where objects have been hiden and only convex envelops are displayed.

Last, we can interact with the 3D view by using the three mouse buttons (left: rotation; center: zoom; right: translation).

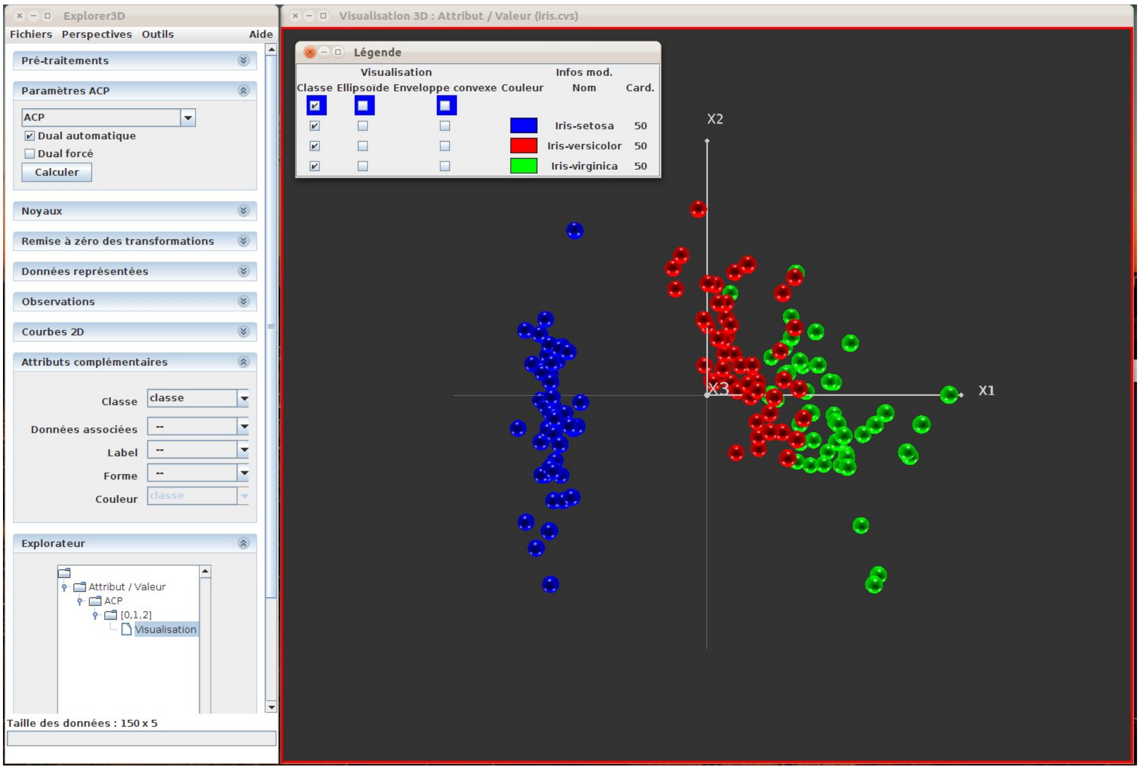


Figure 4: 3D View with colour and legend

6.2 Control window menus

- **Files**: data loading tools
  - **Load local file**: allow to load the various supported kind of data files. The file content is automatically discovered by *Explorer*3D . If no standard format is detected, an error message is displayed, and the data import tool is automatically opened. Let us remind the three kind of data files managed by *Explorer*3D :
    - ∗ Feature files: the file is structured like a table where objects are described by a set of numerical or symbolic features. 3D projection will be computed by the mean of a dimensionnality reduction method (e.g. PCA).
    - ∗ Distance matrix files: used when the only available data concern the distance or (di)similarity between objects. Projection will be computed by the mean of a MDS.
    - ∗ Raw 3D coordinates: when we directly get such data, for instance using the output of another software.
  - **Load online file**: this does permit to load a file stored on a distant machine, on a HTTP server. The secondary that opens then allow to set the site URL and then to explorer the web site directories. Supported file formats are the same as for local files.
  - **Data import tool**: This tool allow to the content of a file text and to port it to a *Explorer*3D -supported file format.

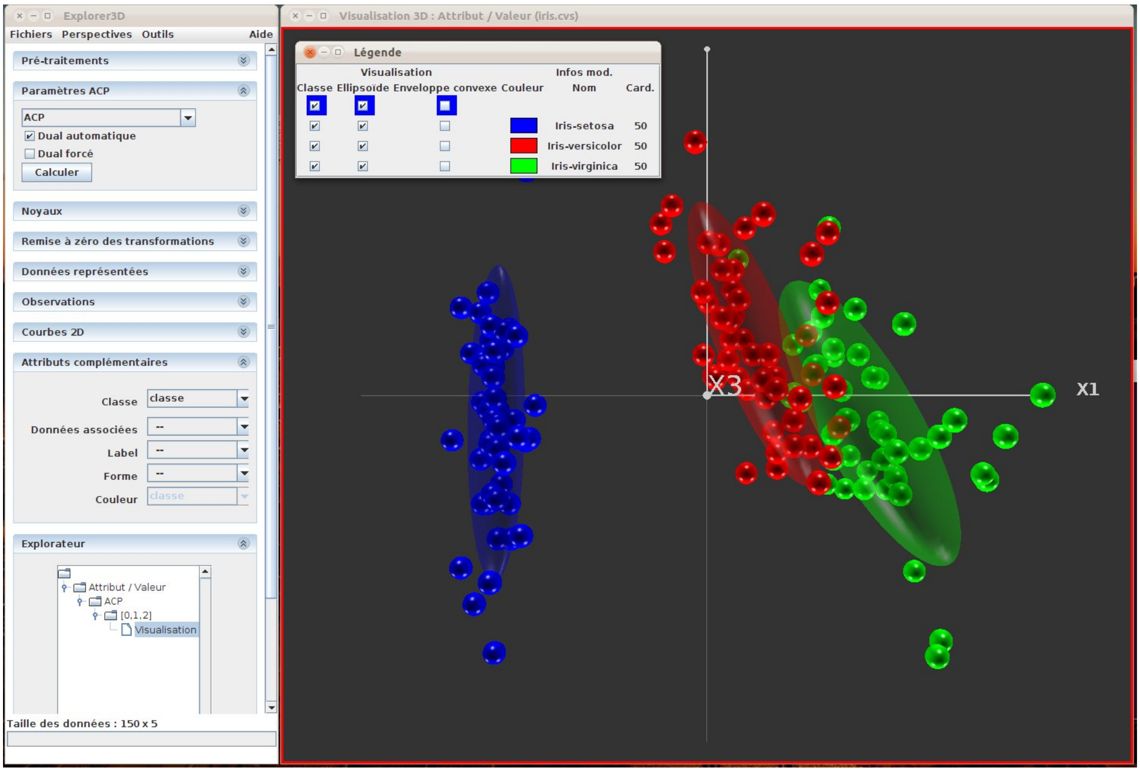


Figure 5: Groups Ellipsoids

  - *list of previously loaded files*: once a file has been (succesfully) loaded, it gets memorized by **E***xplorer***3D** and proposed to the user and the bottom of the **Files** menu.
  - **Exit**: To shut down **E***xplorer***3D** cleanly.

- **Perspectives**: This menu leads to some relevant sets of sub-windows with respect to a given kind data file, or to a specific kind of task.
  - **ND -> 3D**: Perspective that corresponds to features data files (projection from "N" to 3 dimensions).
  - **Distance -> 3D**: Perspective that corresponds to distance matrix files.
  - **Aspect**: Tuning of visual parameters (e.g. background colour, size of objects, etc.).
  - **Classification**: Offers a set of clustering algorithms (e.g. kmeans, gaussian mixtures,...).
  - **SVM**: Offers various SVM visualisation tools, that is to says means to visualize a separating hyperplan between two groups of objects (see section 8.6).

- **Tools** :
  - **Crop**: Data cropping based on a 3D box. This consisst in a way to select a subset of objects and compute a new projection that limits to this set of objects

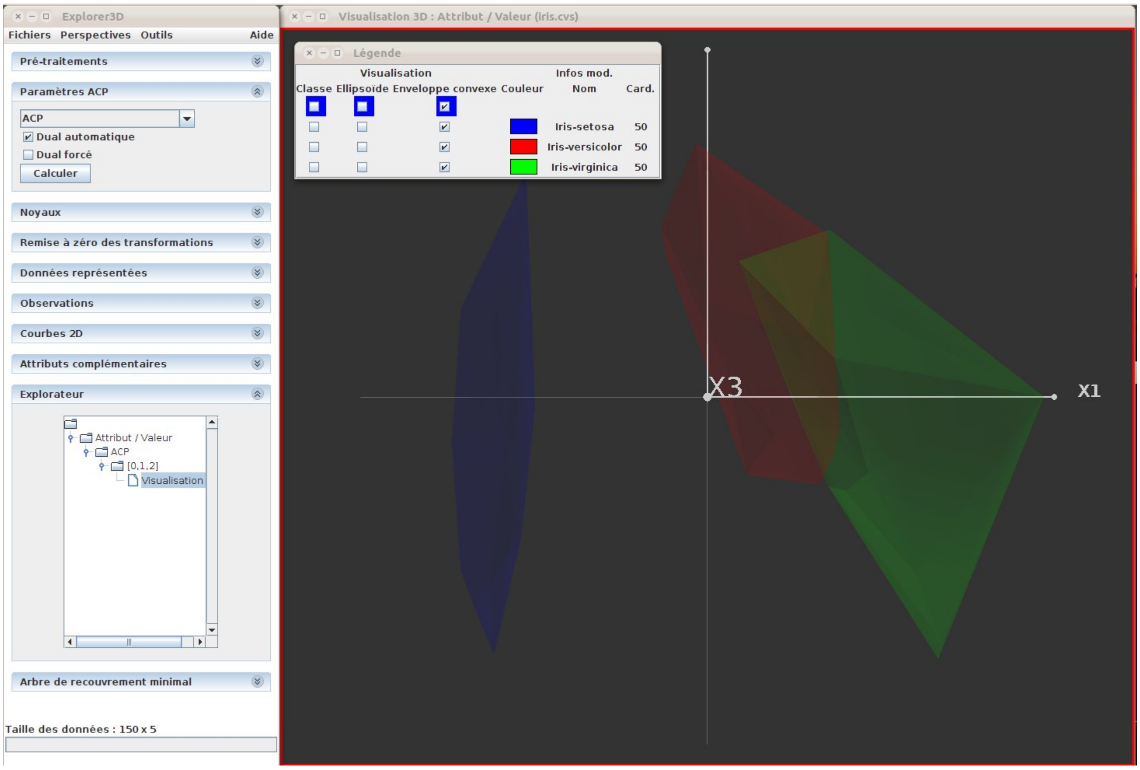


Figure 6: Convex envelops

and is optimal for that subset (according to the projection criteria). The crop dialog is described in section 7.6.

- **Interaction**: A tool to modify the projection axes. In this tool one set a list of spatial anomalies and ask for a modified projection that corrects these anomalies. See section 8.4
- **Travel thrgough dimensions**: A tool to manually set the projection axes by chossing or mixing the axes available. See section 9.1.
- **Explore from images**: A tool to choose which objects to view in the projection space, together with the associated pictures and nearest neighbors. See section 8.5.
- **Options**: To set various options, most of them corresponding to visual elements. See section 7.7.

- **Help**

  - **On-line manual**: Opens a browser the browse the on-line version of this manual.
  - **About Explorer3D** : Version facts, mains authors, etc.

7 Main functions

7.1 Projection methods

7.1.1 Based on a set of features

Projection method Several techniques are currently proposed in the "Projection Method" sub-window (reached through the "Perspectives / ND -> 3D" menu). The actual method is chosen from a list. Currently available methods are:

- **PCA** is the default method; it projects objects so that the distance between them in the projection space corresponds as muh as possible to their distance in the original space (input features are seen as coordinates in a high dimension space). Two options are proposed with PCA: *dual auto* and *dual forced*. Roughly speaking, the PCA dual method leads to the same projection as PCA, but can be much faster when the number of input features is larger thet the number of objects. The user must notice that dual projection forbids the future use of some complementary tools, such as interactive projection. **dual auto** compares the number of features and the number of objects, and uses the dual method if needed. **dual forced** uses the dual method whatever.

- **LDA** This method and all of the following ones rely on the availability of a class attribute defined for each object. In other words, this supposes that an additional attribute is available, that indicates the class of each object, and has been explicitely set as the "Groups" attribute in the "Additional attributes" sub-window (see section 7.2.1). Projection is computed so that objects that belong to the same class tend to be grouped, while objects that belong to different classes tend to be moved away one from the other. This projection is computed in order to respect to some end the original spatial distribution.

- **R-discriminant Analysis** similar to LDA, but only the interclass variance is maximized (it only focuses on moving away objects of different classes).

- **Rw-discriminant analysis** similar to r-discriminant analysis, but the original distance is also taken into account: the moving away of objects belonging to different classes will be proportional to the inverse of the distance in the original space (i.e. objects that are already far ont from the other in the original feature space will be less affected than ones that were near one from the other). The sigma parameter allows to tune the original distance impact. The greater sigma, the smaller the impact on originally distant objects (sigma=1 leads to a r-discriminant analysis).

- **KNN PCA** experimental - not documented

- **LLE** experimental - not documented

Pre-treatments The "Projection Method" sub-window is tightly associated with the "Pre-treatment" sub-window. This latter is used to apply to data a so-called conditioning. This window offers various treatments to be done on data before applying the projection method.

A check-box allows to choose wether data has to be centered or not. Centering means that the values of each feature are translated so that their is zero. This pre-treatment has to be done for ACP, and might be suitable for other method.
The data variance can be modified depending on the value chosen on the "Reduction method" list: with **Raw data** variance is not modified; with **Reduced variables** values are rescaled so that the variance gets equal to 1 –this option is suitable for PCA–; with **Normalized distances** the values are rescaled so that the amplitude gets equal to 2, and thus, together with data centering, values are between -1 and +1.

7.1.2 Based on a distance matrix

We currently propose a single projection method, which consists in a linear multidimensional scaling (MDS), that is a linear projection that computes 3D coordinates so that the distances between pairs of projected objects do correspond as much to their distances in the matrix. Theoretically speaking, this projection stands if the input matrix does really contain distances (with triangular inequality), in which case we can consider that these distances were computed in a high-dimension space, and we thus make some kind of dimensionality reducation. No pre-treatment is available.
We did recently had kernel methods. Those are presented in a specific section (8.7). Kernel methods can be found in the "kernel" sub-window. They allow for the computation of non euclidean distances. For instance, using the "isomap" kernal, we will obtain a new projection, were the only original distances that are kept in the projection space are the ones between nearby objects (this kind of kernel is usually suited when the user knows or guesses that objects are placed on the surface of some non plane surface (i.e. a mathematical variety).

7.1.3 Based on 3D coordinates

In the case of 3D coordinates, projection is identical to input data. Centering and dimension dilatation are available (see section 7.4).

7.2 Using/displaying additional attributes

7.2.1 General Overview

Additional attributes are given as input but not directly used in the object spatial projection. They can for instance consist of the class of the object, an associated image file name, etc. Five kinds of display modes are currently available:

- *classes:* The selected attribute consists of the class of the objects. By default this attribute is also used to colour objects (but colouring is not the only goal of the class attribute). Fuzzy classes can also be visualized. In this case, each object is supposed to belong to each group to a given level, the sum of these levels being equal to 1. Fuzzy classes visualization is described in section 7.2.2.

- *associated data:* In the current release, this function corresponds to the associated images visualization;

- *Label:* the textual value of the attribute is display in the projection space, near the object;

- *Shape:* A specific shape is associated with each value of the attribute. Only a limited set of shapes are currently avaible, and this should no be used with an attribute taking more than 4 different values.
- *Colour:* One different colour is associated with each value of the attribute. There is no limit to the number of colours. Colouring can not be set directly, but can be through the setting of the class attribute.

7.2.2 Multi Class Objects

When identifying groups of objects, the user can either associate a single group to each object, or choose a fuzzy classification, where each object belongs to each group to a certain level. While standard classification relies on a single attribute, multiclassification relies on several *numerical* attributes, each one corresponding to the level of belonging to a given class. In **E***xplorer***3D** for a given object, *the sum of these levels must be equals to 1.*

Multiclassification can be visualized as follows: In the "classes" dropbox, the user chooses the special value "–Multiclasses–". A secondary list is then displayed in which the user has to select the list of class attributes. The resulting display mode is similar to the one describe in the fuzzy kmean-method (see section 8.3.3).

7.2.3 Image display

If an "associated data" attribute has been defined, then the image corresponding to each object can be displayed on the basis of the file name stored in this attribute. Image display can be either static or dynamic. Dynamic display occurs when the mouse pointer passes over a given object. The corresponding image is then displayed, and hidden back when the mouse pointer leaves the object. Dynamic display of images is optionanl and occurs only if "Show pictures when mouse is over" is checked. Static image display is controled through the popup menu that opens when the user makes a right-clic –on a given object– with her mouse (see section 7.3.3).

Depending on user's options (see section 7.7), image static display will occur either in the 3D view or in a specific window. If option "Draw pictures out-of 3D" is checked, then a specific window is use (see fig. 7); otherwise they are directly displayed in the 3D view (see fig. 8).

We can notice, in figure 7, that the objected linked to the pictures have been lected (red background in the picture window, and highlighted color in the 3D view). We can also notice that one image is currently dynamically displayed in the 3D view.

The default option consists in displaying images out-of the 3D view, in a spcific window.

7.2.4 Multiple picture sources

If several images are available for a single object, the user can decide to display them simultaneously using a set of 3D scenes. To be more precise, the user can define a specific image attribute for each of her 3D scenes.

The default configuration consists in using a single image attribute for all of the 3D scenes. If several additional attributes are available, that correspond to the name of picture files, and if the user wishes to view a least two of them simultaneously, the way this can be

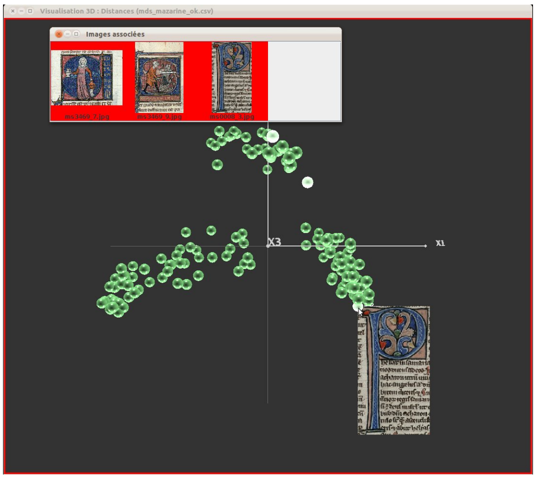


Figure 7: Out-of 3D scene (static) image display + a dynamically displayed image (mouse over the object).

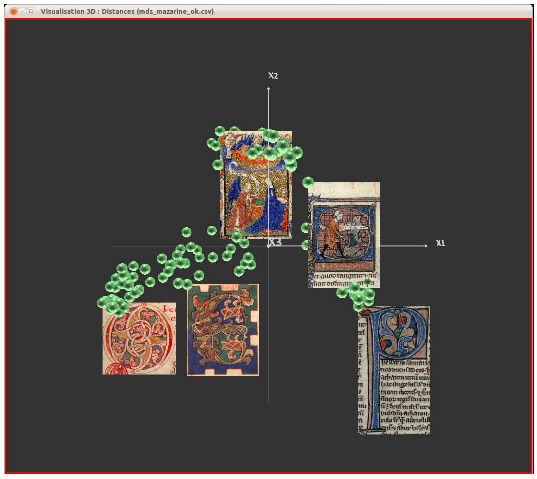


Figure 8: In 3D scene (static) image display. The corresponding object is at the upper left corner of the picture.

achieved with **E***xplorer***3D** consists in creating several 3D scenes, possibly using the same projection, and then associating a specific image attribute to each of these scenes. For this purpose, the user must first activate the view a specific image attribute will be associated with, then check the "Specific A.D." box in the "Additional attributes" sub-window, and last choose the specific picture attribute. Any scene for which the "Specific A.D." box has not been checked will use the global image attribute, if any has been defined. Conversely, several scenes can use a specific image attribute.
Multiple picture sources can exist, for instance in the case multisource data, each of this source bringing its own set of images, or more generally in the case images are just a side information of the object studied and not the sources of features.

7.2.5 Management of colors

By default, colors are associated with classes, which means that setting a class attribute implies that the same attribute is automatically set as the color one.
Nevertheless, it is possible to choose a color attribute directly, and thus to dissociate it from the role of class attribute. This also allows gradient colouring (see fig. 9). Gradient colouring is automatically used if the color attribute is of numerical type. **Note : E***xplorer***3D** does by default consider that additional atributes are of symbolic type. For an additional attribute to be considered numerical, it must be explicitely declared as, in the source file, its name being suffixed with ".N".
Colours can be replaced with black and white textures. The use of textures is activated by checking the "Texture" box in the "Additional attributes" subwindow. There are currently ab. ten textures available. The user can change the texture associated with a set of objects by clicking on it in the legend window. Textures are also displayed on ellipsoids and convex envelopes if these laters are displayed.

Colours remain displayed, in the current release, to highlight selected objects (a selected object will be coloured, even if textures are active; it be become textured again if deselected).

Figure 10 illustrates the use of textures. We can see that the user is currently changing the texture associated with the third group (iris-virginica).

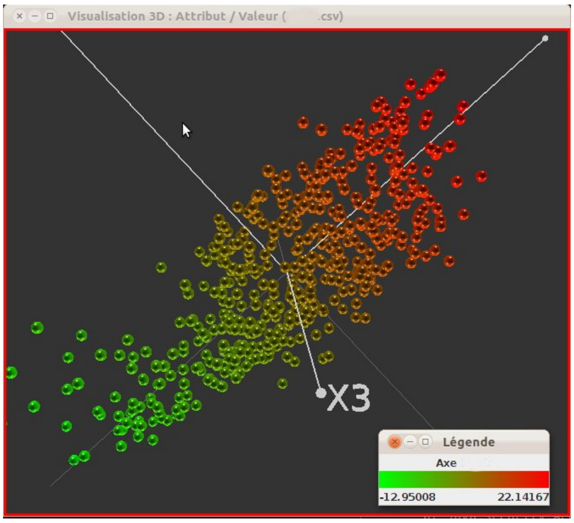


Figure 9: Gradient coulouring

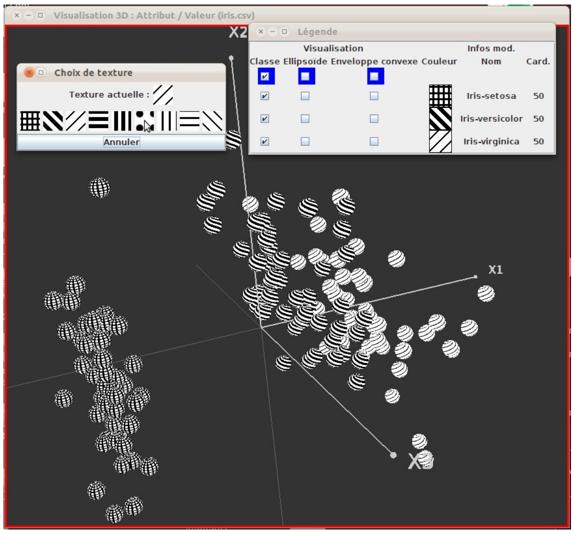


Figure 10: Textures

7.3 Mouse control

Using a 3-button mouse is recommended. Many tasks can be achieved throught he mouse: selecting objects, displaying information, etc.

7.3.1 Manipulating the 3D scene

Pressing the mouse buttons on the background (i.e. with no object under the mouse pointer), the user obtains the following behaviours:

- *Left press + move:* rotation
- *Center press +move:* zoom
- *Right button +move:* translation

7.3.2 Acting on objects

- *Shift + left click:* select / deselect the object under the mouse pointer (a selected object is highlighted in the scene). Object selection is used in several tasks.
- *Right click:* Opens the popup menu

7.3.3 Popup Menu

Right clicking in the 3D scene opens a popup menu, form which various actions can be achieved. When opening the menu while the mouse points on a projected objects, the following ations are proposed:

- Show / hide the picture associated with the object (if a picture attribute has been defined);
- Show / hide all pictures (same remark);
- Show / hide the label associated with the object. If no label attribute has been defined, the object number is displayed;
- Show / hide all labels;
- Show / hide labels for the selected objects;
- Make a spherical crop, centered on the currently pointed object. See section 7.6;
- Make a planar selection. See section 7.4.1;
- Center the scene on the currently pointed object;
- Activate the magnifyer (see section 7.5).

If the menu is poped up while no object is pointed, only global actions are proposed (global show / hide actions and planar selection).

7.4 Object selection

a uniform selection mecanism has been implemented. There exist several ways to get a object selected: from the 3D scene, from the separated image windows, etc.
When an object gets selected in one of these views, in is also displayed as selected in the other ones. For instance, when an object gets selected in the 3D scene, it gets highlighted in this scene, but the corresponding picture (if displayed) does also get displayed on a red background.

7.4.1 Multiple selection

Several objects can be selected at once. Choosing the planar selection in the popup menu allow the user to draw a rectangle in the 3D view (clicking on the background a first time to set the upper left angle, and a second time to set the lower right angle of the rectangle, see fig. 11). All the objects within the rectangle get selected (see fig. 12).

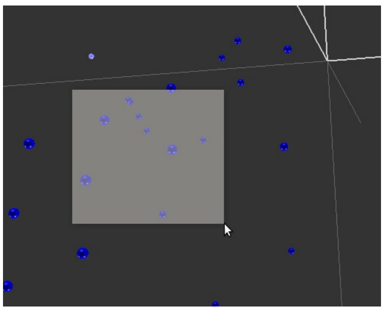


Figure 11: Multi selection (ongoing)

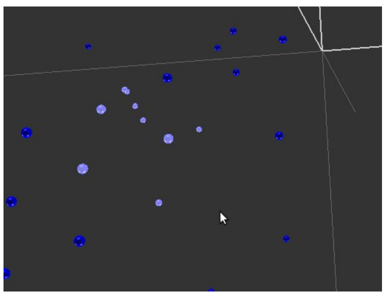


Figure 12: Multi slection (finished)

7.5 Magnifier

This tool, which can be activated through the popup menu, displays a leans in the 3D scene, that magnifies the objects under it. A very interesting side effect comes from the fact that the magnified objects do also get selected. The user can thus see how objects of a given view spread in other viws, if several are displayed. Magnifying parameters (diameter, coefficient) can be adpted in the "Magnifier" sub-window, which is displayed when the "Aspect" perspective is chosen. Figure 13 illustrates the use of the magnifier.

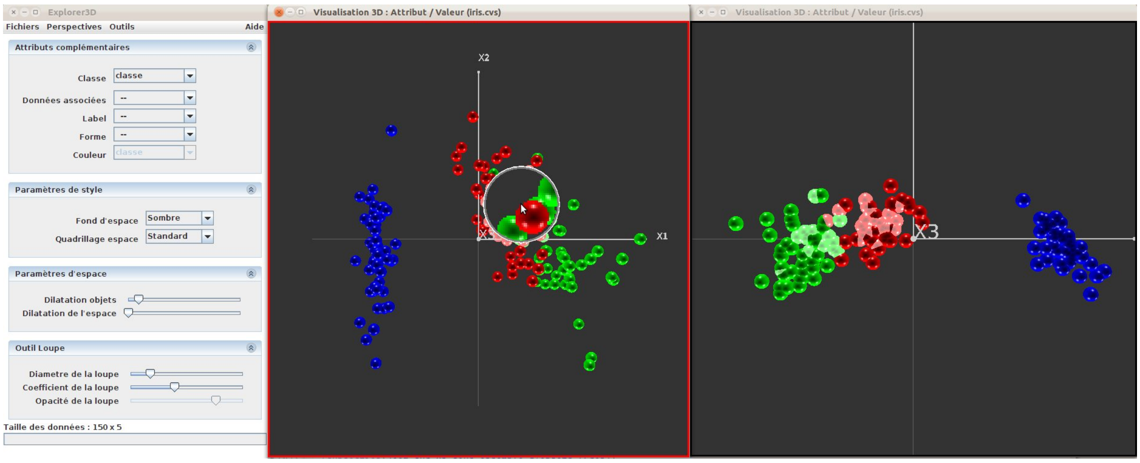


Figure 13: Magnifier. In the left-most scene, selected objects are one that are magnified (to be more precise, the ones that are under the magnifier) in the right-most scene. One can notice the magnifier parameters sub-window, in the control window.

7.6 Crop

Crop consists in choosing a subset of the objects displayed and then to compute a new projection and scene that fits this subset. The resulting projection can be quite different from the original one.
There are two ways to crop:

- **Box crop** the selection zone is a box. Such a crop is initiated from the "Tools/crop" menu, which displays a crop dialog. Clicking on "New Crop" is this dialog, a cubic box gets displayed, that is centered at the origin of the scene. This box can be moved and /or resized using the sliders in the "crop" dialog (fig. 14). S If objects were selected when "New crop" is clicked, then the box is automatically sized and moved to contain these objects.

  When the bow has resized and moved as suited, clicking on "Crop!" causes a new dataset to be produced, that contains the croped object, and a new projection and 3D scene to be computed. Croped view can be croped in turn, and so on.

- **Spherical crop** This crop zone is centered on a given object (fig. 15). Such a crop is accessed through the 3D scene popup menu;

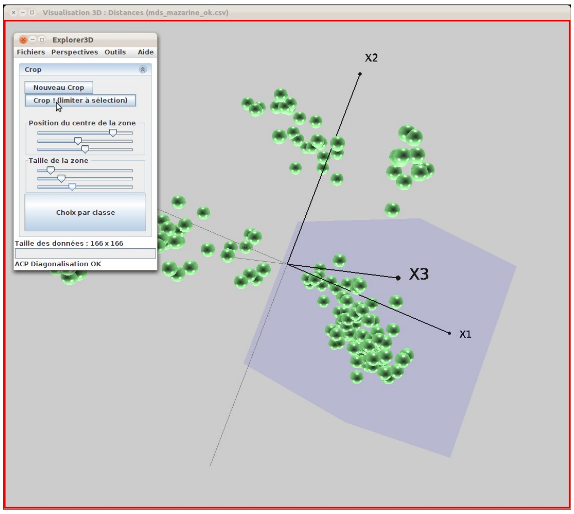


Figure 14: Box crop

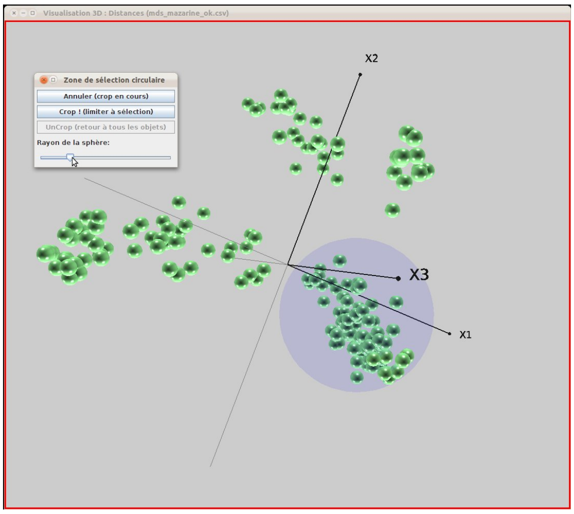


Figure 15: Sperical crop

7.7 Options

The option window is accessed through the "Tools/options" menu. The current options are:

- **Default color** of the objects: The cvoloured rectangle can be clicked, in order to modify this default colour;
- **Enhancement of 3rd dimension at display time**: When the 3D scene gets displayed, a slight rotation is applied, so that the 3 projections axes get visible;
- **Display original axes**: Original axes (i.e. input features) get displayed in the projection sub-space. This option affectes only feature-based projections. This action should moved away from the option list in a further release.
- **Draw pictures out-of 3D window**: to choose whether statically displayed pictures get displayed in the 3D scene or in a separate window (default value);
- **Autocompute 3D projection**: If not checked, the user has to choose and launch a projection technique once data has been loaded. Otherwise, the projection and 3D scene are automatically computed. In case of a feature data source, the default projection technique is PCA.
- **Activate distant execution**: this option should be checked in case the user wants to display the 3D scene on an image wall. This old option has not been maintained in the recent releases and should not be used.
- **Show source data (array)**: to display in a table the values of additional attributes (see section 8.2).
- **Show picture when mouse is over**: controls the dynamic display of pictures in the 3D scene (see section 7.2.1).
- **Activate stereo if available**: If the graphical card (and screen) of the computer support stereoscopic viewing, then stereo gets activated.

- **Size of labels**: a slider to set the size of labels in 3D scenes;
- **Dynamic object size**: If checked, object size is computed depending on the number of number to display (the larger the number of objects, the smaller their individual size). If checked, then "Size of objects" is not available.
- **Size of objects**: A slider to manually set the default object size.
- **Multisource mode**: Allow the user to manipulate multi source data sets (see 5.2).
- **Network command available**: If checked, then **E***xplorer***3D** listens on a port (by default, port 50000) for some commands. The protocol and available commands are presented in section 8.9.
- **Port number**: to manually set the network command port. Currently unavailable.
- **Legend available**: If unchecked, the legend window is not displayed. Legend windows and their functionalities are presented in section 7.8.

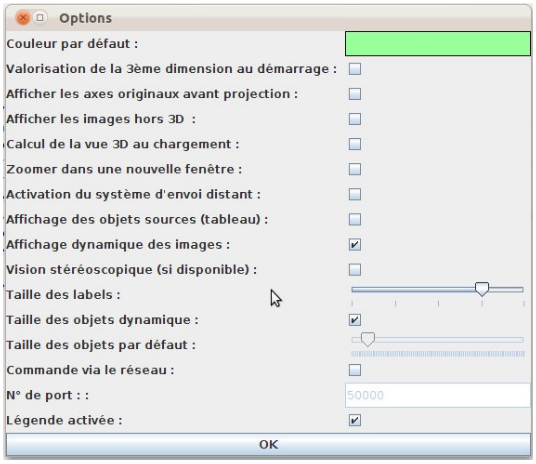


Figure 16: Options

7.8 Legend

Depending on the object colouring policy, the legend window displayed will vary. The standard legend window (one colour per object, a finite set of colours) as already been presented in section 6.1. Two others kinds of legend windows are available: the multiclass legend window and the continuous colour attribute legend window.

7.8.1 Multiclass legend window

This legend window is displayed when multiclassification is active. This occurs when the user does manually set a multi-class system (see section 7.2.2) or when a fuzzy classification tool is used (see section 8.3.3). Objects ar coloured according to the class they belong "at most". Due to **E***xplorer***3D** current evolutions, additional actions proposed by this legend window are not currently fully functional; nevertheless, the user can visualize the centroïd of each group (appears as a small cross, coloured as the group). Class diffusion through objects can also be observed using convex envelops: by checking "activate convex envelops" and moving the bottom slider, envelop either dilate or shrink to the objects that belong to the class at a higher level than the one indicated by the slider. The "ellipsoïd" column is not currently used.

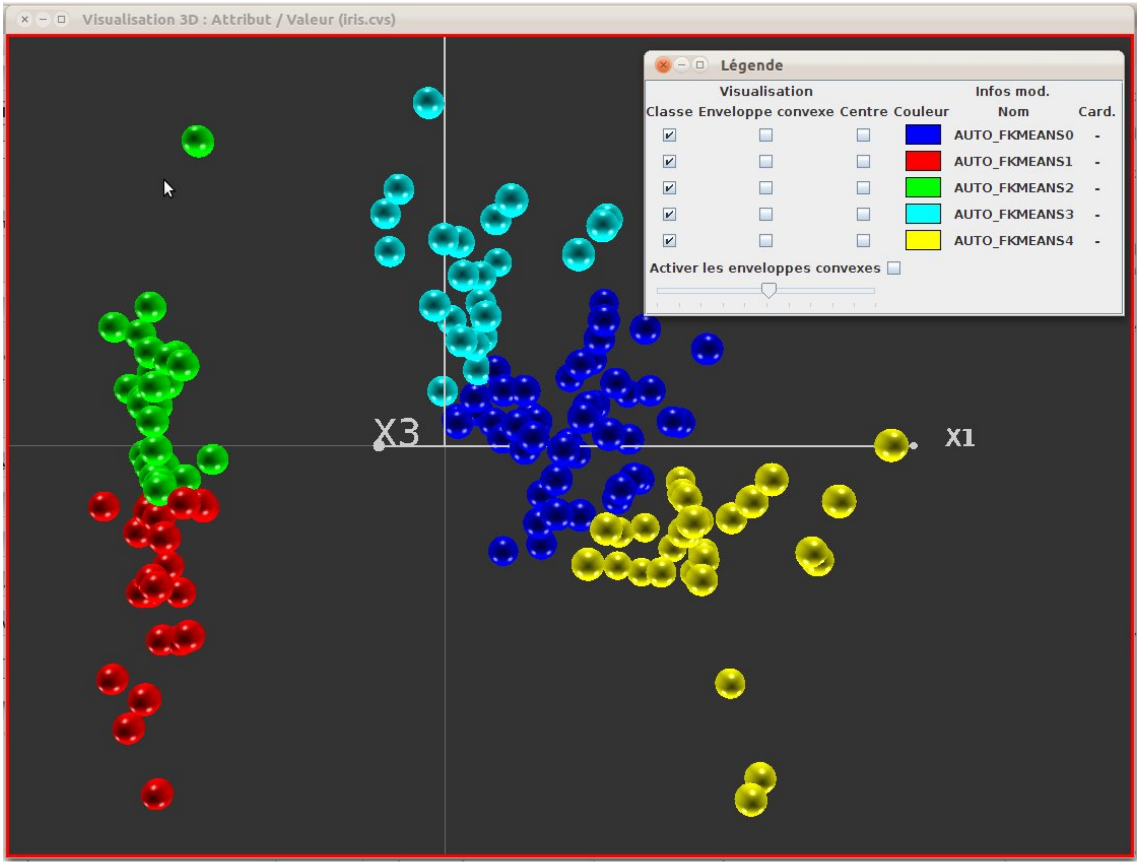


Figure 17: Multiclass legend window. Here we observe a fuzzy kmeans. Each objetct is coloured according to its main class.

7.8.2 Continuous attribute legend window

The user can define a colouring that does not rely on a given (set of) class(es), but rather on a single, numerical (floating point) attribute. A colour gradation is then computed to handle any value of the chosen attrifute, from the smallest one to the largest one (see figure 18). Each object gets coloured depending on the attribute value it is associated with. Such a colouring technique is not chosen through the "additional attributes" sub-window. This colouring technique can be activate by three kinds of actions: selection of an explicitely numerical additional attribute as colouring attribute; SVM visualization using colour to materialize the distance of the object to the separating hyperplan (see section 8.6); and materialization of a fourth projection axis by the mean of colouring (see section 7.9). This legend window does only contain the gradation together the min and max values of the attribute.

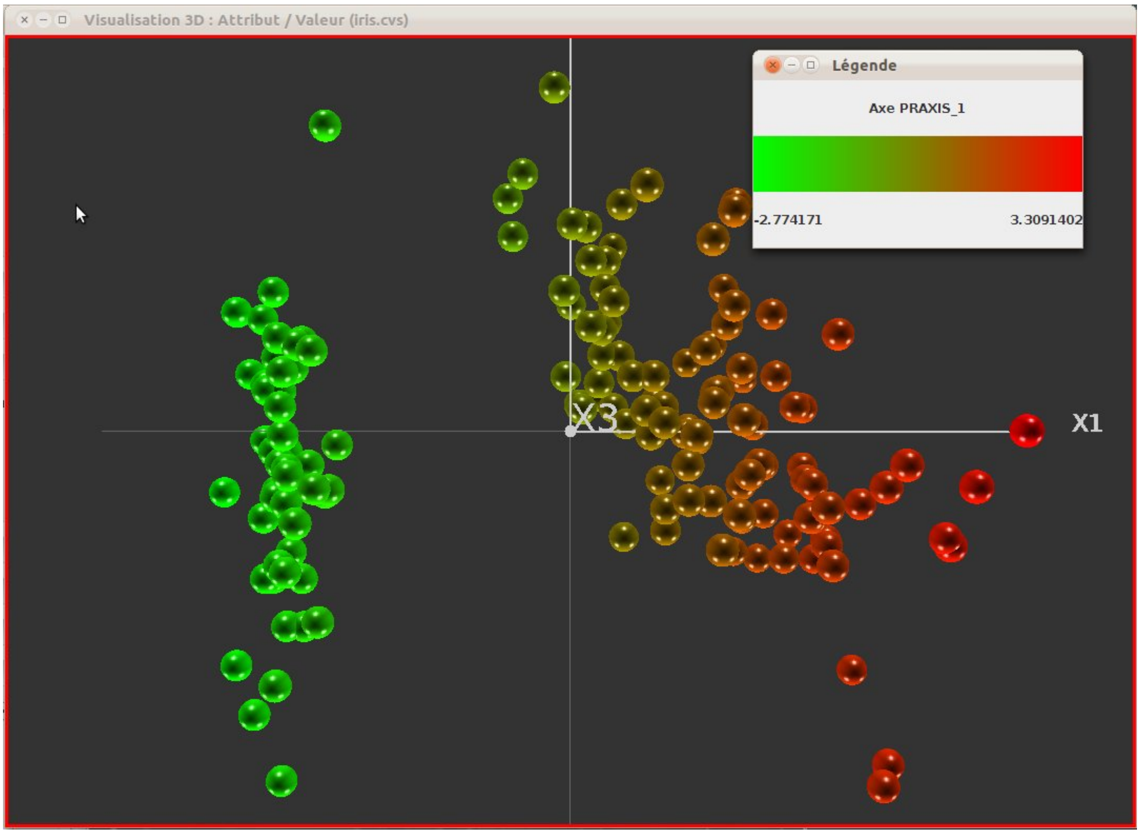


Figure 18: Continuous attribute legend. On can notice that the colouring corresponds to a fourth axis materialization, that in fact is the same as x1.

7.8.3 Texture-based legend

As introduced in section 7.2.5, colours can be replaced by textures. The legend will allow the user to identify and possibly modify the texture associated with a given group.

7.9 Projection axes

The "Projection axes" sub-window allow several actions on the 3D scene. The two first proposed actions are:

- **Zoom on less discriminative dimensions** : depending on the projection technique, it might frequently occur that objects get well spread along x1, but more concentrated along x2 and even more on x3. To get a better dispersion in the scene the user might check this optionin order to dilate object coordinate on the less exploited axes (see figure 19).

- **Center cloud** : this option translates the objects so that the origin does not correspond to the baryceeter any more but to the median value along each axis.

This two options do apply to the current scene and to the ones that are computed afterwards.

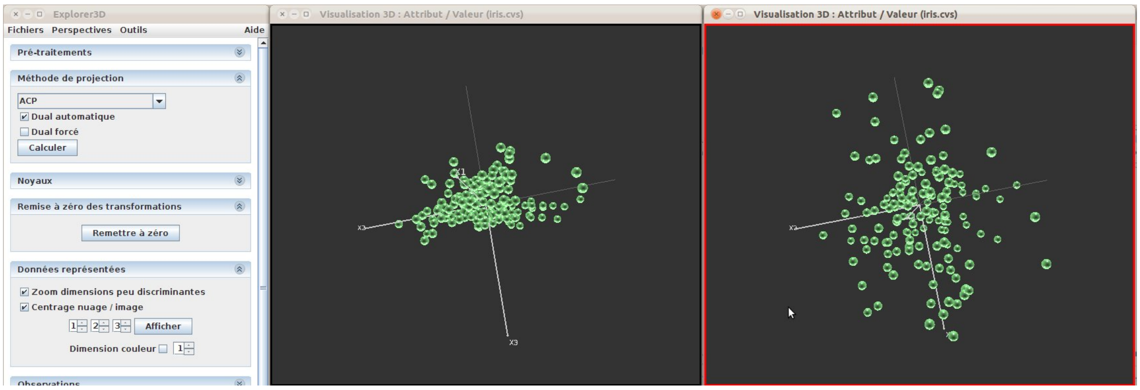


Figure 19: Zoom on less discriminative dimensions et cloud centering. The left-most scene corresponds to a basic PCA projection, the right-most one to the PCA where the two options have been used. The scenes have been rotated so that axes x2 and x3 can be well observed. We can see that objects get more spreaded along x3 in the right-most scene than in the left-most one (this can be also observe, while less important, along x2) and that the object cloud has been translated to the left (centering) compared to the one in the left-most scene.

A third action is available, that alow to choose the projection axes. This functionnality does only make sense when at least three axes are available, that is to say with a "nD->3D" projection, based on feature input data. Nevertheless, the user can always choose at least to invert the dimension-to-axes mapping, or to use the same dimension along several axes. The user can specify the projection dimension used on each axes, in the following order: x1 (breadth), x2 (heigth) and x3 (depth). The scene is only modified once the user clicks on "Draw". This manually-set projection does not generate a new scene, but rather move objects in the current scene.
The dimensions available are numbered from 1 to n (these are the dimensions computed by the projectin method, not the raw input features). An additional value is given, denoted "X", which indicates that the corresponding axis is not used. For instance setting x3 to "X" means that objects with all be placed in the x1-x2 plan.
Last, we can choose a projection dimension to colour object (continuous attribute colouring). The coulouring dimensions can be chosen among the projection dimensions computed by the projection method (not among the raw features; this might proposed in a further release). Checking the "Colouring dimension" box, the user activates the continuous attribute colouring, based on the dimension value of each object. Figure 18 illustrates the dimension-based colouring. We can see in this figure that we used the same dimension for colouring as the one used to project objects along x1. Nevertheless, any other available projection dimension might have been used.

7.10 Observations

This sub-window indicates the amount of original variance that is displayed using the 3 current projection dimensions (figure 20). a histogramm gives the amount of variance each available projection dimension brings; currently used projection dimensions are drawn red, unused ones are drawn blue. A pie-chart chart gives the amount of original variance that

the current scene offers.
If a class attribute has been selected, then a class purity index is displayed at the bottom of the sub-window (Dunn index).

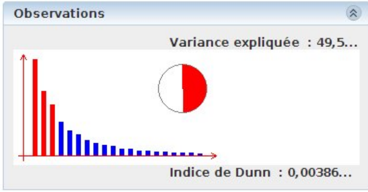


Figure 20: "Observations" sub-window. We can notice that many projection dimensions are available. The three most significant have been chosen for the 3D display (red bars of the histogram), and that they support 49.5 % of the original variance (pie-chart). A class attribute has been selected (the quality of which is displayed, according to the Dunn index).

7.11 Project save and load

The user can save the current project, in order to reload it later. The current saving strategy manages data sources, 3D scenes, and the active additional attributes (class, colours, etc.).
To save the current project, choose "Save project" in the "Files" menu. To load a project, choose "Load project".
Projects are by default saved with the ".e3d" file extension. Technically speaking, they consist of text files using the JSON format.

8 Main tools

8.1 Multi-view visualization

E*xplorer***3D** is oriented towards a multi-scene interactive use. This can be used to follow several goals: first to open several visualization windows simultaneously, and second to observe the behaviour of a set of selected objects in these various windows.

8.1.1 Multi-view principle

The term view does mainly correspond to the 3d scene window. It also corresponds to less used windows, such as tables or 2D graphs. The user can compute and manipulate several 3D scenes for a unique dataset, mainly to:

- observe the same projection under several points of view;
- observe different projections on a unique dataset (PCA, LDA, etc.);
- observe both a global view and one or several crops.

8.1.2 How controls affect 3D scenes

Some control have a global effect on 3D scenes; colouring is currently one of them (mainly to identify the of classes in several scenes). Conversely, many control are not supposed to have a global effect, and rather a local one on a single 3D scene; this stands for clustering, crops, etc.
For this purpose we introduce the notion of *active* view: the *active* view is the one that is affected by the execution of a non global control action. How can we set and highlight the *active* view?
A view can be set active by giving the focus to its window Once the view has been set active, the window border gets red (see figure 21). A view remains active until another one is set active, either explicitely or implicitly. For instance, computing a new 3D scene makes it active. Only one view at most is active at any time.

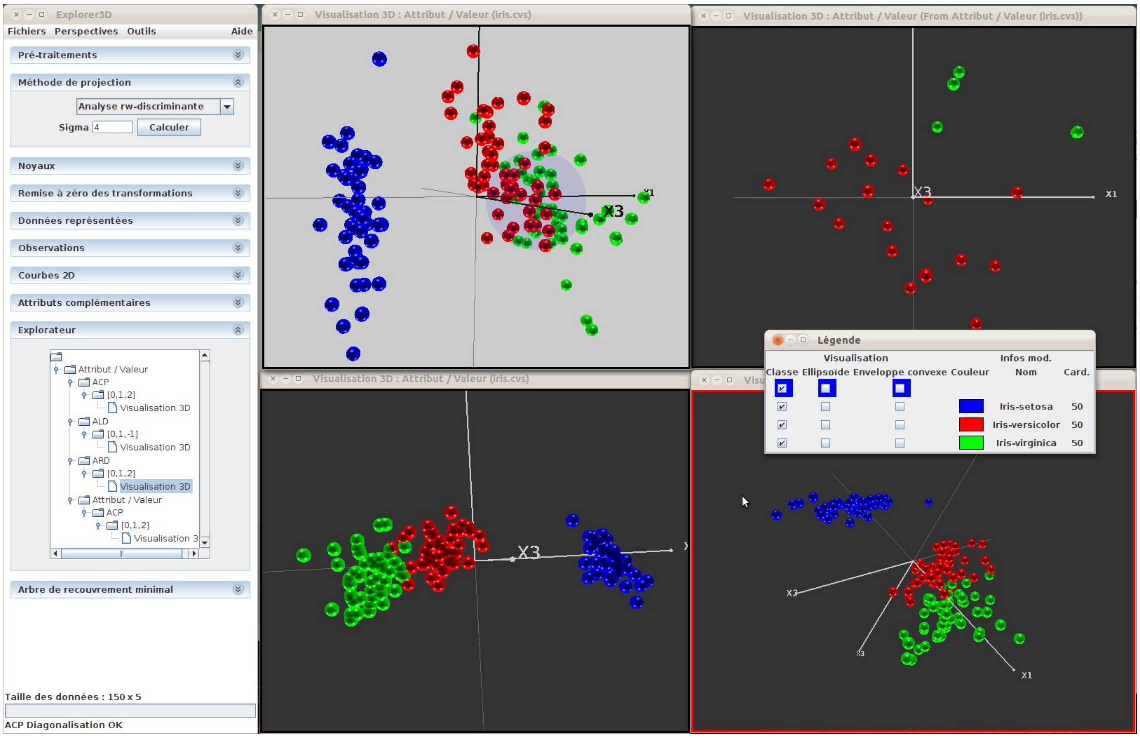


Figure 21: Several simultaneous views. The active view (bottom-right) can be identified by its red border. We can notice that global controls have been used on the views (colouring according to classes), as well as local controls (the lightgrey background of the upper-left scene)

8.1.3 View browser

The set of available views can be browsed in the "View Exlorer" sub-window. This sub-window contains a tree-view of the current state of explorer3D, with data input files (data sources) as roots, followed by the projection method, the projection (axes) and finally the view (usually: the 3D scene). The currently active view is highlighted in this browser. Clicking on a given view in the browser gives makes it active.

Figure 22 presents the view browser. We can notice that we currently use an “attribute-value” (feature set) data source, on which we computed a PCA and used the 3 main axes of this latter to compute the 3D scene. We can also observe that we used another projection method, were the 3rd projection axis is set to “-1”, which means that the “x3” (z) axis is not used.

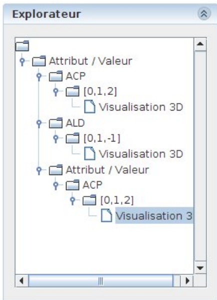


Figure 22: View browser. An “Attribut / Value” (feature set) data source has been used, on which both a PCA and a LDA have been computed. A crop has been computed on one of these views (there is a secondary data source, that is a child of the first one). The crop-based scene is currently active (grey background).

8.1.4 Selected objects in views

Selected objects are highlighted in the 3D scenes. The set of selected objects is global to all views. This means that selecting an object in one view highlights it in all the views. This can be usefull to look for a given (set of) object(s) throughout several views.

8.2 Tabular view of objects

Options allow the user to view a table that contains the additional attributes for the current object set As defined previously, additional attributes consist of data that are not used to compute the object projection, but rather to bring additional knowledge on the objects.
This table contains all of the objects sorted according to their index number. By default, all additional attributes are available. Whether each attribute is displayed can be chosen by the mean of the **Column visibility/ additional attributes** menu. Projection coordinates can also be displayed using the **column visibility / projection coordinates** menu. By default, projection coordinates are not displayed.
Object selection is availale in this table, and the set of objects displayed can be limited to the selected ones (see fig. 23). for this purpose, check “Filter (selection)” in the “Lines visibility menu”.
For more details on the selection mechanism, please see section 7.4 .

8.3 Clustering

Several clustering methods are available. They can be reached by choosing the “Classification” perspective (see fig.24) in the main window menu. Several of the proposed method

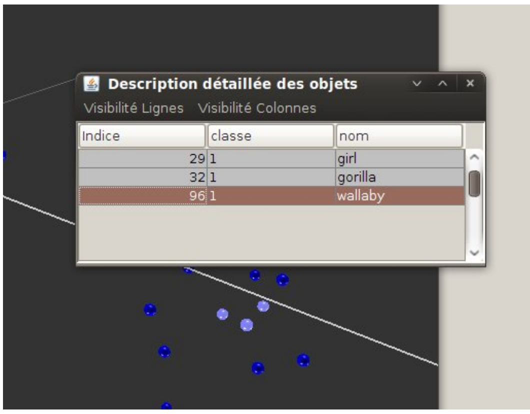
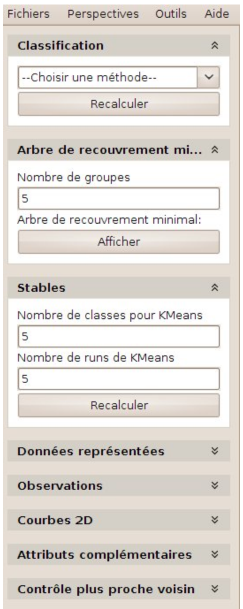


Figure 23: Tabular view of additional attributes (with filter)

shared a common weakness: they are fully stable (they do not always produce exactly the same set of groups). For this reason we encourage the user to compute them several times (using the "recompute" button) to ensure a good understanding of the methods stability w.r.t. the current dataset (let us also underline that the "Recompute" button should also be pressed if the classification parameters, if any, such as the number of groups to produce, have been modified).



when opening

once a method has been chosen

Figure 24: "classification" perspective

8.3.1 Gaussian mixture

Gaussian mixture classification is built on the idea that objects are distributed according to a ste of multivariate gaussian laws. A technique is thus use to compute the most likely set of underlying laws. Each computed law is displayed by the mean of an ellipsoid that is centered oriented and sized as the law (see fig. 25). The current method (which relies on the klustakwik algorithm) does automatically compute the number of laws.

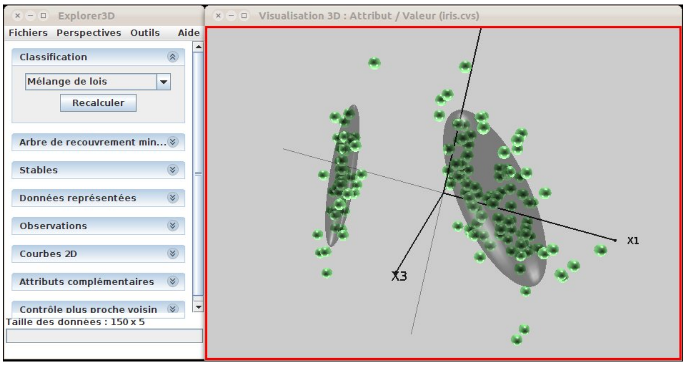


Figure 25: Gaussian mixture

8.3.2 Kmeans

The principle under that very standard hard clustering method, consists in producing clusters of similar diameters. To be more precise, this algorithm minimizes the sum of the distance of each object to the nearest cluster center. The user first sets the expected number of groups. Group Centers are then randomly initialized and each object is put in to the group of the nearest center. Each center is then updated to the barycenter of the group objects. This process is iterated until stabilization (or a maximum number of iterations is reached). In our current implementation, the default number of centers is set to 5. The user can modify this number and recompute the corresponding clustering result.

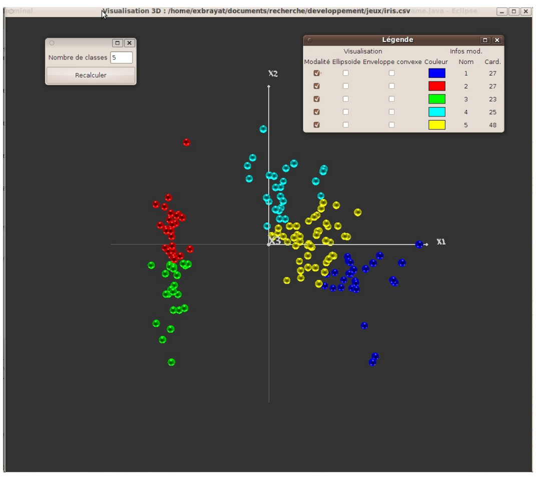


Figure 26: Kmeans

Kmeans being not stable, an additional tool is proposed, that computes the stable components. This tool is accessible through the “stables” subwindow. a stable is a set of object that are “always” put in the same cluster by a given clustering method (i.e. kmeans in our software). By "always" we mean in any of a given number of runs of the clustering method. In this tool we can choose the number of classes and also the number of runs to be conducted. Once the runs have all been done, the resulting set of stables is displayed. Stables are currently computed for kmeans only.

8.3.3 Fuzzy kmeans

This method is derived from the former one, where each object now belongs to all of the groups at a certain level (degree). The degree is related to the distanceto the center. The sum of degrees is equal to 1. Here again the user can choose the number of centers (default: 5). On one hand, the interest behind this method is to leave more freedom of interpretation to the user. On the other hand, visualization is bit more tricky. We thus developed a specific technic, based on convex envelops, that we did already partly present in section 7.8. Two kinds of information has to be displayed : first, the main group of an object, and second the set of objects that belong to a group "to a given degree". The main class is displayed using a classical legend. Concerning the "degree", we use convex envelops (see fig. 27): for each group (or a set of groups) we display the set of objects that belong to it "to a certain degree", i.e. for which the degree of belonging is "higher that x percent" (remind that we assume that the sum of degrees is 1). The current value of the x threshold can be set using a slider, and the evolution of envelops can thus be observed dynamically. One can notice that this tool can also be used when a fuzzy classification is given as an input and thus coming from a third-tier tool.

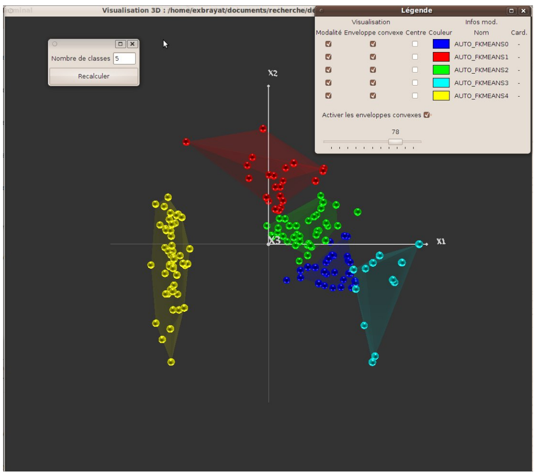


Figure 27: Fuzzy kmeans visualization with convex envelops and threshold.

8.3.4 Density-based classification (DBSCAN)

Differing from the former methods, that rely on the distance to a given group center, and thus lead to spherically-structured groups, density-based methods build groups starting from the dense parts of the objects space. Objects are then aggregated in groups depending on their neighboorhood (diffusion). Such methods are relevant when objects are structured in dense, arbitrary shaped groups.

Two parameters can be manually set: first the neighborhood radius (the maximum distance within which two objects are considered as neighbors), and the minimum group cardinality (how many neighbors are needed at least to form a group). In order to help the user to set the radius, a sphere is displayed at the enter of the 3D scene.

Figure 28 presents the result of a DBSCAN clustering. We can notice that the first group consists of the isolated objects (i.e. the ones that do not belong to a cluster). This group might be empty.

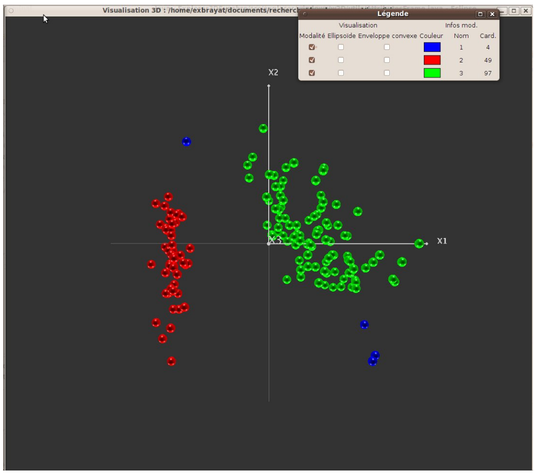


Figure 28: Density-based classification (dbscan)

8.3.5 Minimal spanning tree and hierarchical classification

The minimum spanning tree is a tree that links the objects displayed. Briefly speaking, this tree links each object to its nearest neighbor, starting from the nearest pair of objects). Visualising this tree shows how objects are linked from near to near. A long link will highlight the existence of two distant groups, etc.

A hierarchical classification consists in grouping objects starting from the nearest ones, always adding the nearest remaining one, which might be either a object or an already formed group. There exists several ways to compute the distance between two groups. The one we use is called “minimal jump”: The distance between an object and a group is the distance between the object and the object opf the group that is the nearest to him. Between two groups, it is the minimum distance between two objects that belong to each of the group respectively. We produce a classification tree, called dendrogram. Dendrograms are very common, for instance to classify species. While they are usually display in a flat manner, we propose to view them directly in the 3D scene (see fig. 29).

The reader might notice the strong link between the minimum spanning tree and the hierarchical classification based on minimal jump. The number of clusters to be formed is set by the user. Forming the groups does simply correspond to cut the tree at a certain level, starting from the root, where the number of branches equals the expected number of groups.

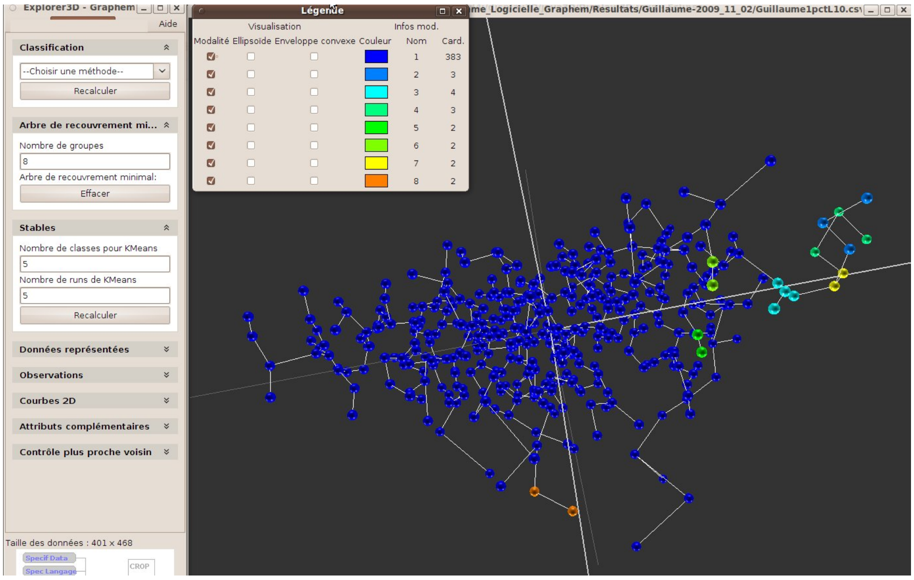


Figure 29: Minimal spanning tree et hierarchical classification

8.4 Spatial reconfiguration

This tool is an experimental one the user is encouraged to test. This tool can be reached through the "Tools/Interaction" menu. It allows to set a list of relative distance constraints, in order to ask for objects to be moved closer or far away, and to modify the projection dimensions in order to respect these constraints as much as possible while introducing as few global distorsion as possible. We firts invite the user to try the "Comparison" tool.

8.4.1 Comparison

- First check the "Object A" box, and then click on any object within the 3D scene. A red target is then displayed around this object (fig. 30). A green target is also displayed that surround the second object (the one the distance to object A should be modified). By default, this second object is the object with global rank 0.
- Check the "Object B" box and click on the second object, i.e. the one you really want to move away or nearer to object A. T green target is moved in order to surround this object (fig. 30).
- Using the horizontal slider, set the expected distance: to the left, objects have to be moved closer; to the right they have to be moved away (fig. 30).
- Click on "OK" to validate your constraint.
- Click on "Run !" in order to compute the new projection dimensions.
- When computing is over, targets get hidden, and the projection space gets modified (fig. 31).

Several constraints should be entered and taken into account for a space modification.

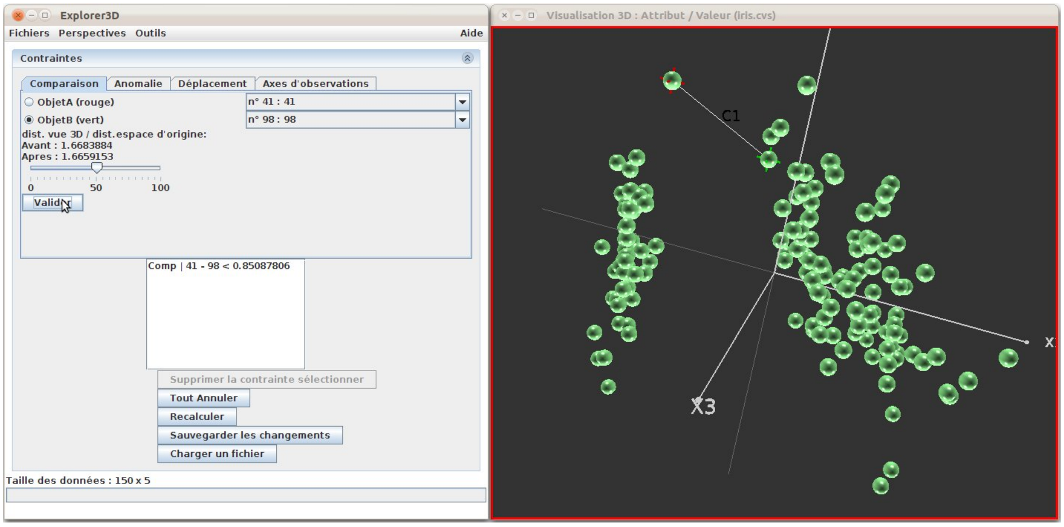


Figure 30: Distance constraints: The two objects concerned can be identified in the 3D scene (object A-41 :red target; object B-98 : green target). The constraint asks for the two objects to be moved closer (slider in the left-most window, and the constraint is textually displayed in the bottom-left list (Comp | 41-98 < 0.85...)

Figure 31: Distance constraints: the constraint has been integrated in the projection framework. We can see that projection has been modified and that the two objects are now closer.

8.4.2 Anomaly

The Anomaly tool allow the user to modify the relative positionning of three objects. We thus manipulate three objects A, B and C. The underlying idea consists in modifying distance A-C with regards to distance A-B. In other words, the user expect C to be moved close to or away from A so that in becomes closer or more far away from A than B.
We proceed as before, using the checkboxes and the scene to set A, B and C and then modifying the distance rate using the slider.

8.4.3 Move

The underlying idea consists in changing the neighborhood of an object. This is a rather complex method the user might use with care. The user must first set the target neighborhood by selecting the objects that belong to it, and then by clicking on "Add". She must then click on "object to move", and click on the corresponding object. Just like before, the user than has to click on "OK" and then on "Run !".

8.4.4 Observation axis

In order to observe a subset of objects along a given axis, the user can set observations axes. For this purpose, the user chooses the "Observation Axis" tab (fig. 32), and then chooses to objects to from the ends of the axis (by clicking on them in the 3D scene). The number of objects to be displayed is then set (default: 10), and the user clicks on "OK". The 10 objects that are the nearest ones to the segment are then selected, and a table containing informatin about these objects (global rank and additional attributes) is then displayed ("Objects description" window). Several axes can be available simultaneously. The user selects the ones to be displayed / hidden using the "Axis:" window.

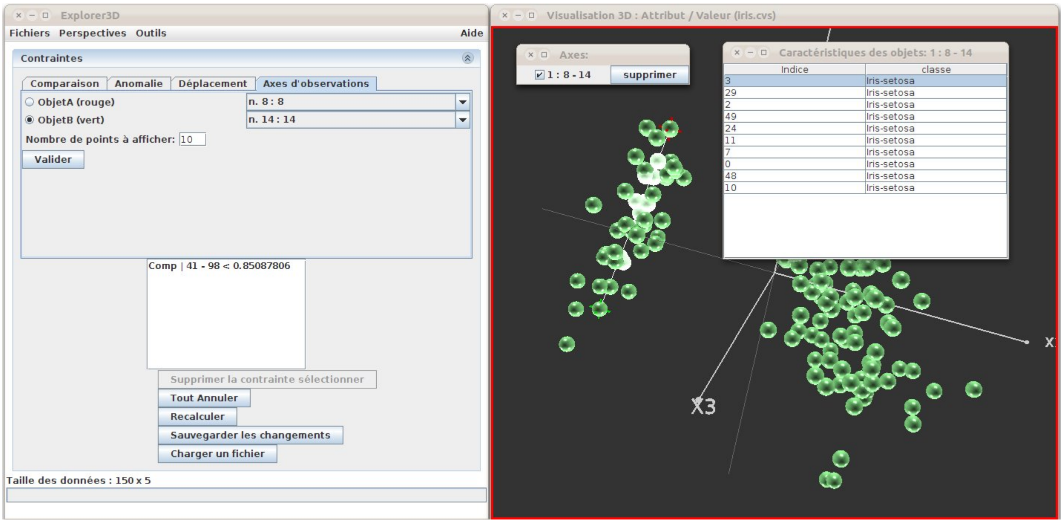


Figure 32: Displaying an observation axis: we observe the ten nearest objects to "axis" 8-14.

8.5 Explore from Images

In order to make the projection space more readable, we add the possibility to only display a subset of the objects, based on the associated pictures. For this tool to work properly, the "associated data" additional attribute must have been set. The user then activates the tool by checking "Explore from Images" in the "Tools" menu. All objects are then removed (hidden) from the 3D scene and a new window, "Associated pictures" opens, where the user can choose the objects he wants to display (fig. 33). The user then chooses the pictures he wants to observe, either in the drop-down list available at the top of the window ("List" tab + validate) or by typing the picture file name ("Name" tab + validate).

Each time a new picture is choosen, this picture gets displayed in the window, and the corresponding objects is set visible back in the 3D scene. When a picture gets clicked, the object is swaped to the “selected” state, and the corresponding shape in the 3D scene becomes haighlighted. Clicking again on a picture causes the object to be deselected.
The object “n” neighbors can be displayed, together with their picture. the value of “n” is set by the user in the “Neighbors” tab, and is by default set to 0. When an object gets hidden back, so are its neighbors.
This explroation can be superimposed with the standard dynamic display of pictures in the 3D scene.

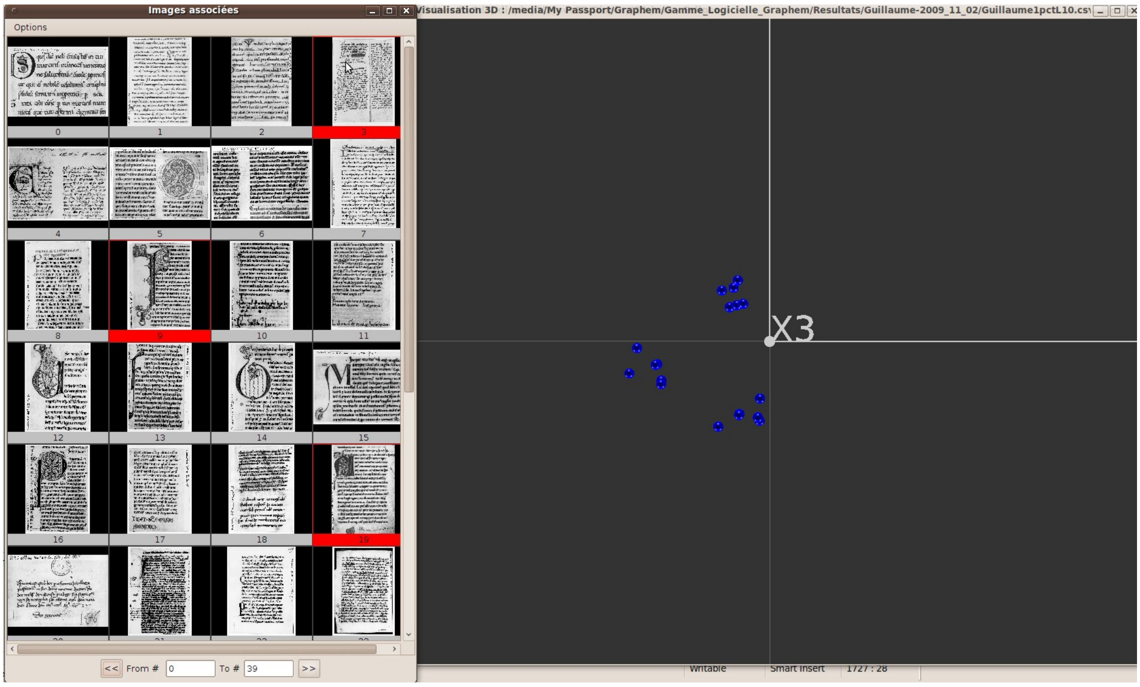


Figure 33: Explore from images (with 5 nearest neighbors)

8.6 SVM

SVM stands for support vector machine, which are a classification tool that try to separate two groups of objects using a (hyper)plane. They are thus usable when the user knows the class of at least a subset of the objects.
In the easiest configuration, the separation is a plane in the original or projection space, that perfectly separates the groups. Moreover, this plane must be as far as possible of the two groups (i.e. as central as possible). Such a clear separation is not always available. Either the groups might be somehow mixed, or separated by a surface that does not look like a plane. For this reason, SVM are usually used together with kernels (see section 8.7).
If more that two groups exist, it is possible either to define a SVM between two of the groups or between one group and all the remaining ones.
In **E***xplorer***3D** the SVM control are accessed through the SVM perspective. The class attribute must have been set before using SVMs.

Figure 34 illustrates a SVM simple case, based on the very standard "iris" dataset. We can see that a plane has been drawn in the 3D scence that materializes a SVM computed between the "iris-setosa" group on one side, and the remaining groups on the other side.

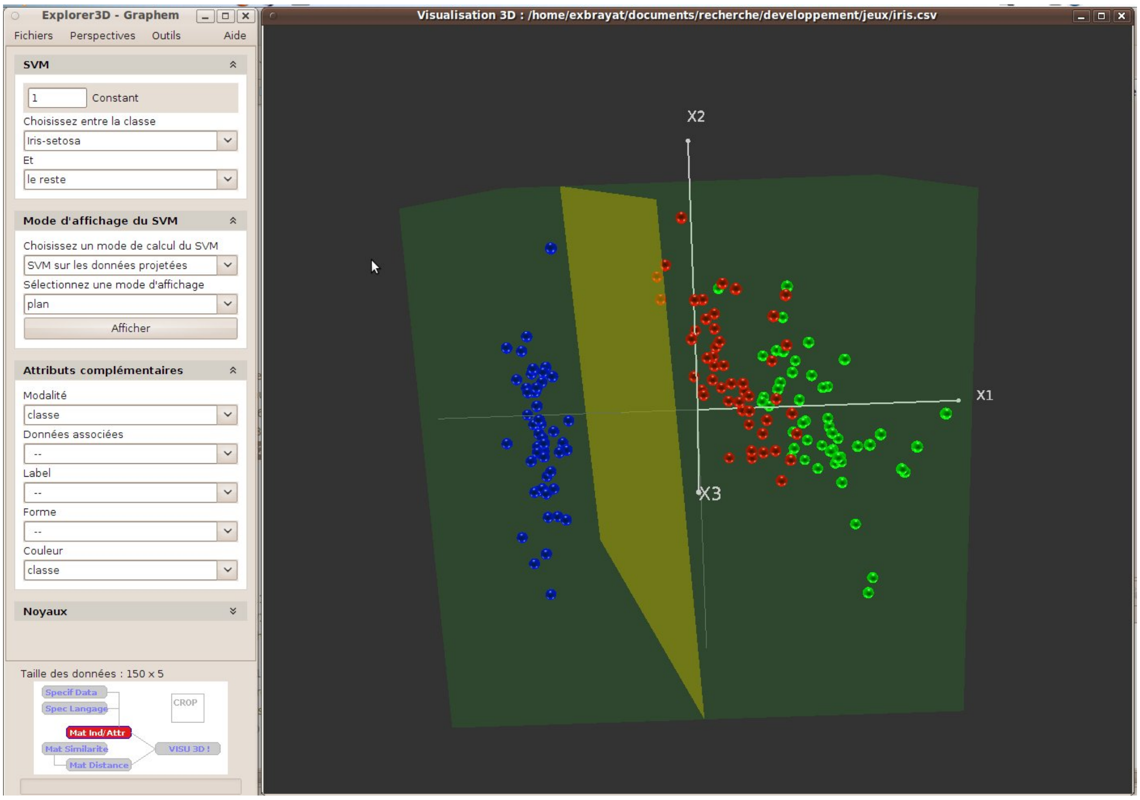


Figure 34: SVM with separating plane (iris dataset)

Availables commands are as follows:

- "SVM" subwindow: to defined the groups to be separated.
  - "constant": do not modify this value, which is currently unused (1);
  - first group: one class among the available ones
  - second group: either one of the remaining class, or all of them;
- "SVM Display Mode" subwindow:
  - computation mode: the SVM can be computed either based on the orginal dimensions (input features) or on the projection space. An original dimension-based SVM will be more accurate, but it will not be possible to draw it as a plane in the 3D scene.
  - display mode: the simplest and easiest to interpret display mode consists of a plane.Nevertheless, two additional modes are available, that allow some kind of materialization when plane display is not possible "coloring" et "replace 3rd axis".

The colouring mode uses a colour grade to recolor the objects relatively to their side and distance to the hyperplane (red on one side, green on the other one). Figure 35 illustrates this mode.

the “replace 3rd axis” used the x3 projection axis to materialize the side and distance to the hyperplane for each object. Projection based on input features is then limited to the “x1” and “x2” axes. Figure 36 illustrates this mode.

Theses two modes can be used with both SVM computed in the original or projected space.

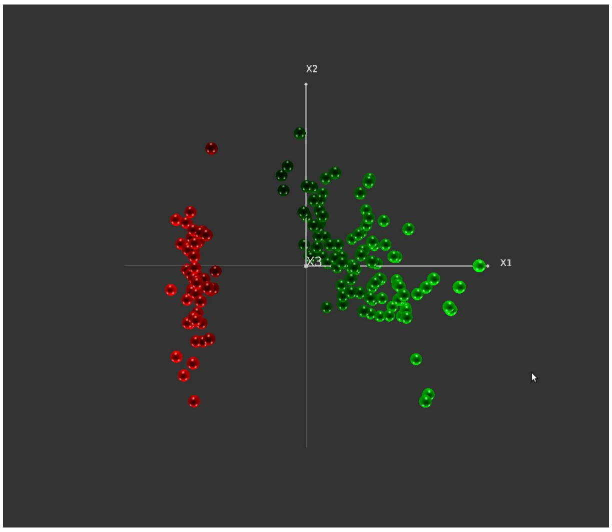


Figure 35: SVM coloring display mode

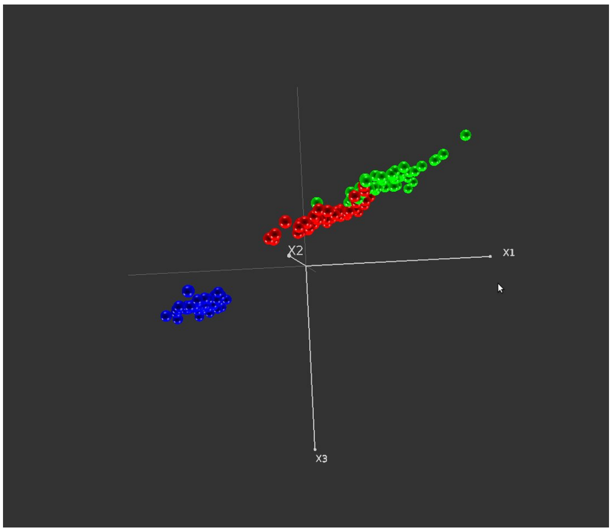


Figure 36: SVM with 3rd axis display mode

8.7 Kernels

Kernels are powerful tools that have been widely used in machin learning due originally to SVM. As we said before, identified an separating hyperplane is not always easy nor feasible both in the original and projected space. Kernels "compute" new attributes based on some combinations of the original ones. Most of these combinations are not linear, but must anyway respect some criterias. The "trick" with kernels is that in fact they all allow to compute a distance between object without really computing the new attributes, and thus propose various and potentially complex spaces at a low cost. We invite the reader to consult the abundant bibliography of the field for more details.
In **E**xplorer**3D** kernels are available in the "SVM" and "ND->3D" perspectives. The "Kernels" subwindow allow the user to select a given kernel in a drop-down list and to set the potential parameters of that kernel. Once a kernel has been choosen , it is applied on any new peojection (click on the "Compute" button of the "Projection Methode" subwindow to apply the kernel to the current scene).

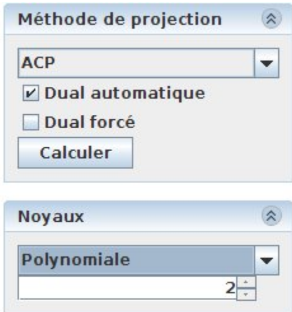


Figure 37: kernel control subwindow. We can see that a polynomial kernel has been choosen, with a degree 2 polynom.

We just list the kernels available in **E**xplorer**3D** and encourage the reader to refer to kernels litterature to get more details:

- linear kernel: this is dummy kernel that allows the user to keep using the original dimension space while kernels are active.
- polynomial kernel
- RBF kernel
- Sigmoid
- Isomap
- LLE

Even not kowing much on their specificities, the newby user might test them, looking for an interesting projection space.

8.8 2D Graphs

The “2D Curves” subwindow allow the user to use various additional curves:

- **Shepard diagram** this diagram highlights the link between distances in the original and projection spaces.
- **2D (symboles)** and **2D (labels)** produce the same projection as a 3D scene, using only the two first axes. The *Symboles* mode displays each object using the shape of its class. The *labels* mode display the objects labels (by default, their rank).
- **Contributions**
- **Square cos**
- **Voronoi cells** These tools are supposed to help interpreting the 3D scene. they rely on a snapshot of the scene, in which the Voronoi cell around each object is computed. We remind to the user that Voronoi celle in the portion of space that is nearer to a given object (point in the space) than to any other object. The cells coloring depends on the kind of visualisation: **Proximity** tells how far objects are in the original space from a given object. The user must select a single object in the 3D scene before opening this kind of graph; **Distorsion** tells how much the distance between two neighbors has been affected by the 3D projection. Distorsions do not rely on Voronoi cells, but on Delaunay triangle, which are complementary to Voronoi cells. Neighbors in the 2D graph are linked by a quadrilateral the colour of which runs from white (no distorsion) to black (strong distorsion).
  Proximity and distorsion graphs can be used to compare 2D and 3D projections, 2D projections and ND (original space), 3D projections and ND.
  These tools might not be fully functional currently.

8.9 Network-driven control

This tool allow the user to connect a third-tier software to **E***xplorer***3D** , in order to visualize objects and additional data coming from this third-tier software. This function gets activated through the option window (see section 7.7). **E***xplorer***3D** then listens on a given port (currently port 50 000), and waits for text commands sent using the json format.
The list of commands available is quite simple for the moment, and focus on receiving a set of objects features et on setting or updating their class (and, by the way, their colouring)

- **loading objects** : objects are described by a set of features. Their are two parts in the message: the command name (`‘‘msg’’:’’set-data’’`), then the objects description (`"val" : [ [object1], [object2], ...]`). Here is an example with 4 objects described by four features:

```
{
  "val": [
    [
```

```
        0.09995818,
        0.8450656,
        0.31611204,
        0.9885413
      ],
      [
        0.20870173,
        0.6817836,
        0.30197513,
        0.20966005
      ],
      [
        0.95933825,
        0.7643002,
        0.23336774,
        0.7409621
      ],
      [
        0.075930595,
        0.12991834,
        0.6995411,
        0.092056274
      ]
    ],
    "msg": "set-data"
}
```

- **objects class definition (full set)** : The class of all objects is given. the message consists of three parts: the command name (`‘‘msg’’:’’set-classes’’`), then the number of classes (`‘‘nbclasses’’: value`) and last the class value for each object, sorted in the same order as objects in the "set-data" message (`"val" : [ [classe_object1], [cl`
  Here is an example with our set of 4 objects: there are 2 classes; the 3 first objects belong to class 1, the fourth one belongs to class 0 :

```
{
  "val": [
    1,
    1,
    1,
    0
  ],
  "msg": "set-classes",
  "nbclasses": 2
}
```

- **objects class definition (subset)** : this command allows to change the class of some given objects and *can only be invoked after the global class setting command has* *been invoked at least once.* The message consists of two parts: the command name (`‘‘msg’’:’’set-classes-fast’’`) and the list of changes. This latter consists of a table (`"val" : [ [classe_object1], [classe_object2], [jump_objects], ...]`), the encoding of which is as follows: values ar sorted as the objects appeared in the “set-data” command. A positive value stands for a new class value of the corresponding object; a negative value indicates a jump in the set (objects the class of which is not modified). Here is an example with our 4 objects; The class of the two first objects is not modified (jump 2). The class of the third one is set to 0. The class of the fourth one is not modified (jump 1).

```
{
  "val": [
    -2,
    0,
    -1
  ],
  "msg": "set-classes-fast"
}
```

8.10 Data import

The data import tool is open when the user tries to laod a file with an unknown format. It might also be directly open to format an input file, through the “Files / Data import tool” menu. This rather intuitive tool does first load the source file (fig. 38). The user then indicates the delimiters used in the file: field separator, dot symbol and text separator (fig. 39). A view of the input file is available during this step. In the proposed example we use the “Parkinson” dataset (UC Irvine machine learning repository).

During the next step, the source file is cut according to the delimiters and presented

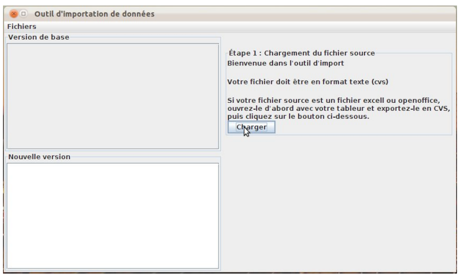


Figure 38: Import: initial window

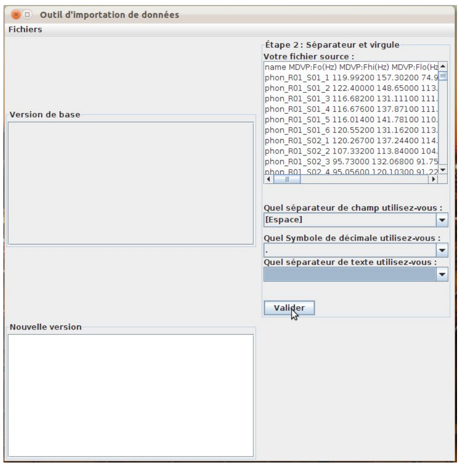


Figure 39: Import: setting delimiters

as a table (fig. 40); the user indicates the kind of data that is stored in this file. In the current implementation, only feature sets files are managed by the import tool.
The user then indicates whether the features of an object are organized as a row or as a column (fig. 41). In our example file, a row correspond to the description of an object,

and the projection-relevant features are stored in rows 2 to 196 and in columns 2 to 24. The first column contains the object names (this is an additional attribute). The first row contains the names of attributes.
In the current release, description features and additional attributes might not be interlaced (i.e. there is exactly one block of features and at most one block of additional attributes). The import then proposes a summary of the imported data (fig. 42), then

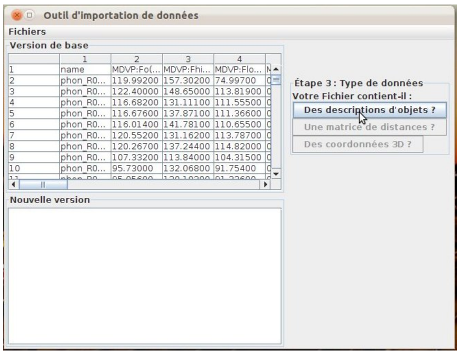


Figure 40: Import: data type

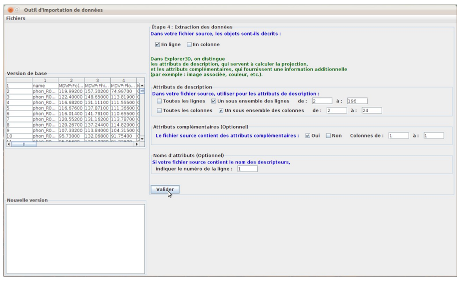


Figure 41: Import: description of file content

a view of the final imported file using the **E**_xplorer_**3D** format (fig. 43). The user can then either save the file or save it and compute a projection. Figure 44 presents the PCA computed after importing the Parkinson dataset.

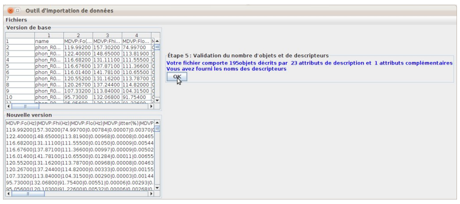


Figure 42: Import: summary

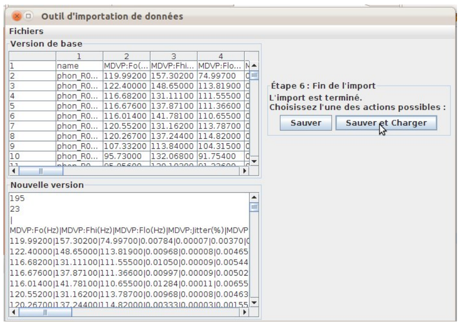


Figure 43: Import: end of import

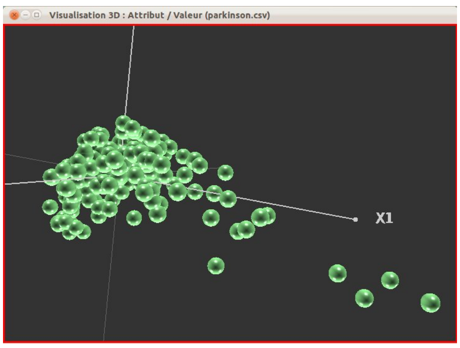


Figure 44: Projection after import ("Parkinson" dataset)

9 Secondary tools

9.1 Travel throughout dimensions

This tool can be reached through the "Tools / Travel throughout dimensions" menu. It allows the user to manually set the three projection dimensions by mixing the projection dimensions computed by the system (ND -> 3D mode). The content of each axis is set by the mean of sliders, each slider corresponding to an available projection dimensions. Clicking the "Draw" button causes the objects to move smoothly to their new coordinates (see figures 45 to 47). The most simple use of this tool is quite similar to the one offered by the "Projection axes" subwindow of the "3D->ND" perspective (see section 7.9). Nevertheless, using this secondary tool, the user can compute any mix of dimensions, for instance summing the values of several dimensions on the x3 axis.

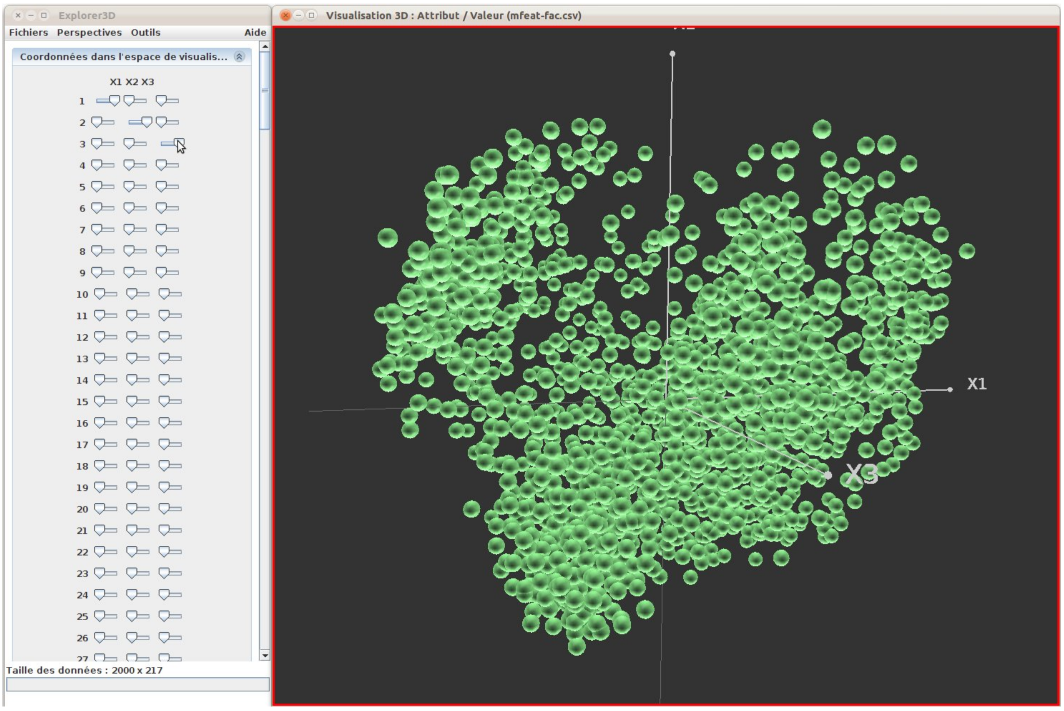


Figure 45: Travel throughout dimensions:objects are projected on the three main projection dimensions.

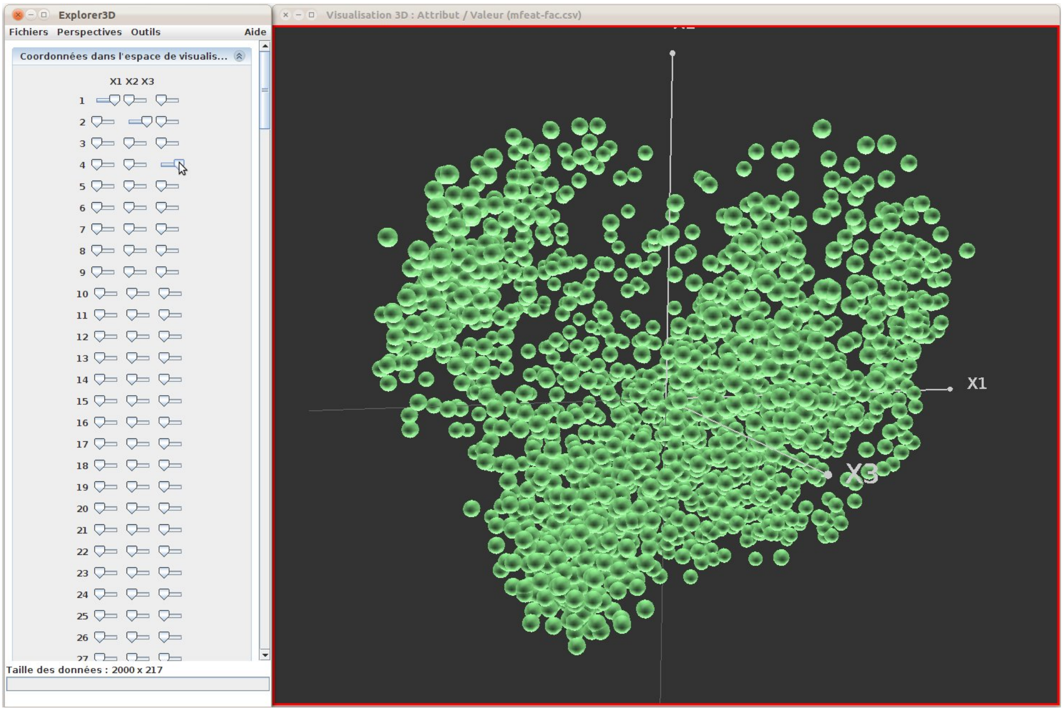


Figure 46: Travel throughout dimensions: we choose to replace the third dimension with the fourth on axis x3.

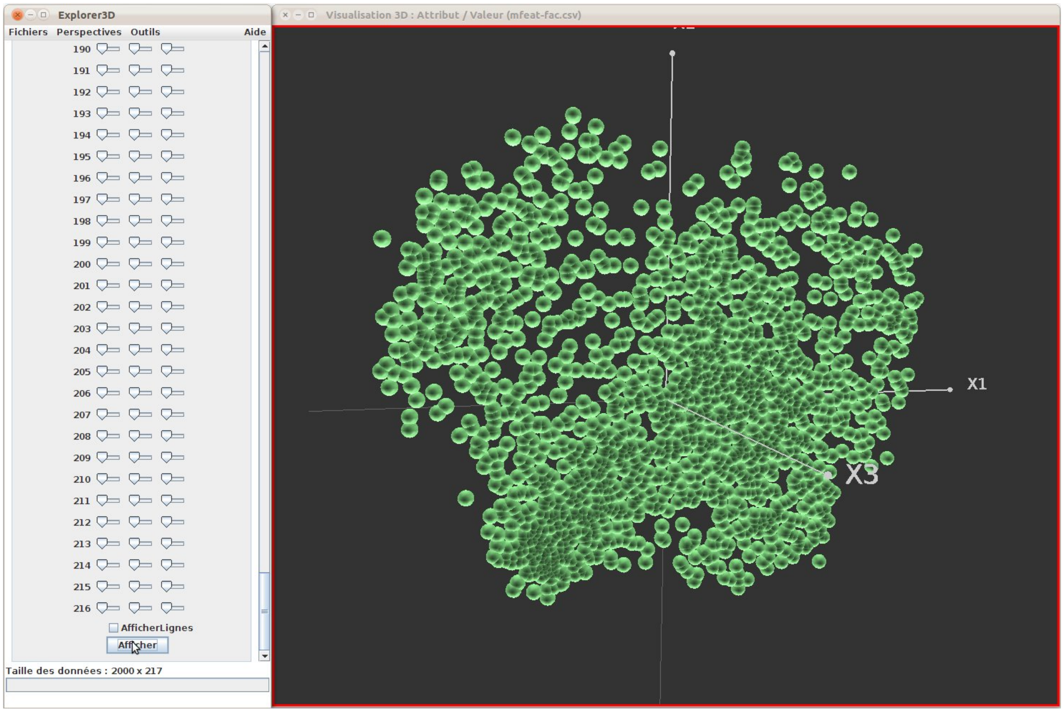


Figure 47: Travel throughout dimensions: after the axis modification.

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