EAnalysis: developing a sound-based music analytical tool

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1. Introduction

Analysing electroacoustic music is always difficult. Mostly works do not have visual support or score and when the music has a score, e.g. mixed music, the electronic part is usually written as a form of code and understanding relations between the signs and sound is complex. This is why most musicians use graphic representation to analyse electroacoustic music, to create spatialisation scores, or to transmit knowledge to their students. Also composers use sketches to elaborate forms, structures or memorise their works during the creative process.

Acousmatic music is not representative of current electroacoustic music. A lot of musicians use live electronics, improvisation, other arts — such as video, sound sculpture, poetry, etc. — where technical means are an important part of the work and recording these performances is very difficult. A stereophonic sound file alone cannot define the work. Many current electroacoustic works are allographics (Genette, 1997), they are defined by different recordings of different performances, multitrack recordings of different instruments/devices, video recordings, scores, data from different devices, and so on. Electroacoustic means and electronic instruments are hybrid and modular. Analysing an electroacoustic performance is a real challenge because you may need to use a range of software to segment sound material, compare various data in different formats, analyse interactions between musicians through movie recordings, and create representations of structures and relations between parts or elements of the performance. Moreover, most software is not compatible, there is no standard exchange format.

Enhancing analytical software is very important but enhancing representation is also essential. To analyse various types of data, we need to create suitable representations: sound representation, line and form/structure charts, graphic representation of units or moments. These representations need also to integrate images or other representations of performance, and even from the creative process itself. Representation in electroacoustic music analysis is not only a graphic representation with beautiful shapes in various colours, each of them representing a sound. Representation can also include sonograms, curve charts of audio descriptors, representation of interaction message lists between musician and computer, tables with time cues, structure representations, space motions, or relations between image and sound in video music.

EAnalysis[1] was created to fill the gaps that exist between various analysis software applications. EAnalysis cannot do everything musicologists, teachers, or musicians want, it is a workspace where the user can create representations, import data from other software or recorded during performance, and analyse them. I did not reinvent the wheel; this piece of software offers the possibility to import data and to export analyses in different formats. It is based on another programme, iAnalyse, which was created for written music analysis. But

[1] EAnalysis is available from http://eanalysis.pierrecouprie.fr.

EAnalysis is very different because the main support of iAnalyse is the score and the main support of EAnalysis is the sound.

This chapter presents the development of EAnalysis from three angles. The first is representation and its role in music analysis. The second is new concepts introduced by the software. The final angle presents the most important features of EAnalysis through presenting different examples.

2. Analysis with graphic representation

2.1. Role of graphic representation in musical analysis

Musical analysis generates representations (Chouvel, 2011), representations of form, structures, relations between various elements, representations with or without time, etc. Musicologists need representations to analyse or to present their analyses. Several theories of analysis are also based on representations such as Schenkerian reduction, paradigmatic segmentation, or various representations of harmony. Representation is important for musical analysis because this is a study of a time art. Humans need to write time down to capture the ephemeral moment and study it. For example a representation of structural segmentation in a formal diagram can reveal new points of view on musical structures. Analytical representation is always a reduction of the musical process. They focus on one or several musical parameters to reveal internal or external relationships between them. In a pedagogical field, analytical representation can also reveal implicit relations or structural processes.

One of the particularities of electroacoustic music is to have no (or to have incomplete) visual support. Mixed music uses a score with various symbols or graphic shapes to represent the electronic part. These symbols can represent a number of preset, simple text indications of sound transformation, or graphic shapes representing a reduction of the electroacoustic part. All of these have great importance for the musician and/or technical assistant. Musicologists and musicians can also use them to analyse the work, to understand the musical ideas of the composer, or to reconstruct the creative process. Teachers can use them to understand the work and to prepare presentations for their students. But these texts, symbols, or graphic reductions are limited to what the composer wants to give you, to what he thinks important to perform his work. These indications are important to analyse the work but they are not in themselves an analysis.

Analysing a work means understanding complex relations between parts/moments/units and revealing something difficult to perceive through simple listening. The most important goal of analysis is to give you keys to understand music. Students need these keys to understand how the composer works or to create their own music. Teachers need these keys to present work to their students and to move their ears to what they need to hear. Musicologists need these keys to develop their own theory of music, to create links between different works, or simply to understand aspects of a work. These keys cannot exist only in thought, you have to record them through text, simple graphics, or more elaborated graphic representations. Moreover, these records are also very important for memory. With them, you can memorise, anticipate, link moments of a work even if they are not close, and navigate inside one or several works.

Graphic or text representations are important to study and understand electroacoustic music (Couprie, 2009). But there is also another aspect, the transmission of knowledge: how a teacher can transmit to his students an analysis of electroacoustic music; how a researcher can transmit his analysis or his music theory; how a student can share experiences of listening to a work. For many different reasons, graphic/text representations are a good solution to sharing and publishing analysis. Interactive examples of electroacoustic music created with sonogram/waveforms and graphic/text representations are more efficient at communication than a simple reference to an extract of an audio track.

2.2. How to create a graphical representation?

How to create a graphic/text representation depends to what you want to do with (Couprie, 2006). If you need to guide your students inside a work, maybe it is better to use iconic graphics. Links between music properties and iconic graphics are easier to understand. Listeners will not need any explanation or key to associate particular aspects of music and graphic shapes. Figure 1 represents two types of representation: an iconic shape that represents the dynamic part of the sound, a symbolic shape that represents the sound type. I used the second in a representation of a work by Alain Savouret (Couprie, 2001). The colour of the shape represented the level of sound transformation and the form of the shape represented the sound type. I decided to use symbolic rather than iconic representations because the structure of the work is very formal, a theme and variations. Demonstrating how the composer used sound transformations to structure his work seemed to be easier using symbolic representation.

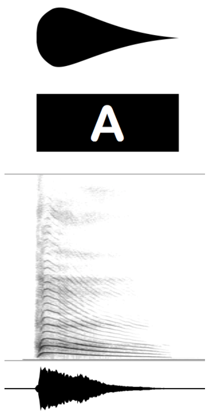

Figure 1. Iconic versus symbolic graphic representation.

If you need to communicate complex analysis with a number of different parameters, you need to associate iconic and symbolic representations. The iconic part allows the representation of significant moments or saliences of musical flow. With the symbolic part (text or graphics), you can represent numerous sonic properties, structural layers, musical functions, or very detailed analysis of moments. This takes more time but a key to understand it is a good complement to the iconic part.

The symbolic part also allows the analyst to represent several points of view. Placing side-by-side different interpretations of structure or different segmentations of musical flow is a good way to transmit complex relationships or indeterminate aspects of analysis (Roy, 2003).

One last point I want to make concerns the aesthetic aspect of graphic representation. Do we need to be neutral or do we authorise an aesthetic look to the graphics without links with the music? Once again, this aspect depends on what you want to do with your graphic representation. If representation is only to analyse or is only a part of your research process, you do not need to consider this question. But if you have to communicate your analysis to a range of different people, maybe you have to consider further the communicational aspect of your work. For a paper on Luc Ferrari, I realised graphic representations (Teruggi and Couprie, 2001) that are very close to artistic or pedagogical realisations. These representations were an experiment to extend the borders of analysis by representation.

3. EAnalysis : New concepts for analysis and graphic representation

3.1. Applications and limitations of current software

As I have developed in several papers, creating a graphic representation of electroacoustic music is complex. Complex because analysis is complex: you have to determine a point of view, you have to learn the work in depth, you have to extract significant aspects and link them to others in the work or in other works. The process of analysis of electroacoustic music is like discovering a new landscape without knowing the right way forward… and there is no right way. Very often, you have to change direction or to start again in a different direction. Knowing the final direction when you start the analysis is very rare.

Using software to analyse electroacoustic music is important because you need to learn about properties of sounds, to validate your listening or to help your listening when the musical flow is too complex. Maybe it will be useful to mask some sounds or to change the gain of other sounds to understand the different layers of the music. Several software programmes are very useful for this. There are 4 categories:

1. Software to manipulate audio by filtering, changing gain, or changing pitch: Audiosculpt[2] and SPEAR[3] are perfect examples for that. Both of them are analysis/synthesis software. Audiosculpt was developed for composers to sculpt the sound. With SPEAR, you can extract formants and manipulate them individually. These programmes are complex to use but very important for musicologists who want to work on sound. They can extract parts of a complex spectrum and thus focus their analysis on specific sound properties.
2. Software to extract data from sound: Audiosculpt and Sonic Visualiser[4] (with Vamp plug-ins) are good examples. Sonic Visualiser uses the Vamp plug-ins to extract audio descriptors such as spectral centroid, inharmonicity, energy, etc. These descriptors help researchers to isolate individual sound characteristics as clues for musical analysis.
3. Software to annotate or to create graphic representations: Sonic Visualiser, ASAnnotation[5], MetaScore[6], Acousmographe[7], or Flash/Multimedia sketches. Creating flash or HTML5 animation is a good option for multimedia publications but this needs coding and complex development. Then, other software such as Acousmographe or MetaScore are good compromises. Unfortunately MetaScore is not publicly available, this software was developed for the library of Cité de la Musique (Paris) and is only used for internal publications. If you only need to annotate, e.g. to add small texts (markers) to a sound, then you also can use Sonic Visualiser or ASAnnotation.

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[2] Audiosculpt is developed by Ircam and is available through the Forum: http://forumnet.ircam.fr.
[3] SPEAR is free software developed by Michael Klingbeil: http://www.klingbeil.com/spear/.
[4] Sonic Visualiser is developed by the Centre for Digital Music at Queen Mary University of London: http://www.sonicvisualiser.org. Sonic Visualiser uses Vamp Plug-ins: http://www.vamp-plugins.org.
[5] ASAnnotation is a free software based on Audiosculpt and developed by Ircam: http://recherche.ircam.fr/anasyn/ASAnnotation/.
[6] MetaScore is developed by Olivier Koechlin (Koechlin, 2011).
[7] Acousmographe is developed by INA-GRM: http://www.inagrm.com/accueil/outils/acousmographe.

4. Software oriented musical analysis: Acousmographe with the Aural Sonology Plug-In[8], Acousmoscribe[9], and TIAALS[10]. The first two packages contain tools to describe and represent sounds with an augmented version of Pierre Schaeffer's sound object theory (Thoresen, 2007 and Di Santo, 2009). TIAALS focuses on sound material analysis and realisation of typological, paradigmatical or other analytical charts.

These categories are of course not limited to these specific software packages. I only presented here the most advanced or useful software to analyse electroacoustic music.

Unfortunately, these software packages have limitations:

- They cannot analyse audio-visual files, they only use sound files, and most of them only stereophonic files. Video music and multitrack works are very common in electroacoustic music. Moreover, video is a good support to analyse performance.
- Several of them cannot export their data to readable files or import data from other software. There is no format to exchange analysis data between them but nevertheless, analysing electroacoustic music requires the use of several software applications from the extraction of data to creating representations.
- The interface is often limited and not adapted for musical studies. E.g.: there is no possibility to navigate inside a file and to compare different moments of a work or of different works.
- While they have interesting features (such as the Timbre Scope of Acousmographe or drawing of audio descriptor values on the sonogram with Sonic Visualiser), most of them are difficult to use in some contexts (e.g. with a long work, without the possibility to filter data, or to synchronise with a graphic representation, etc.).

To this list of software, I have to add programmes for interactive analysis. Several musicologists have published realisations that are closed software, proposing interactive experiences or musical material for reader. Michael Clarke has published several analyses as standalone software applications (Clarke, 2012). Even if these realisations are not exactly software because the user cannot use them to analyse other pieces, the interactive parts are very complex and seem to consist of small applications to explore the composer's musical researches. In the field of creative process analysis, Ircam has published several CD-ROMs such as those on Philippe Manoury (Battier, Cheret, Lemouton, Manoury, 2003) and Roger Reynolds (McAdams, Battier, 2005). These CD-ROMs contain analysis and musical material from the specific work. Readers can use them to create their own analysis.

This short presentation of the most common software used in analytical research demonstrates that current packages offer a huge array of possibilities to the researcher. Each software application is focused on very specific and powerful features. Unfortunately, most of them were not developed by or with musicologists. They are not the result of the study of musical analysis workflow. Analysing music requires some useful features that these software packages do not integrate.

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[8] Aural Sonology Plug-in is developed by INA-GRM from Lasse Thoresen's research: http://www.inagrm.com/aural-sonology-plugin-0.

[9] Acousmoscribe is developed by SCRIME from ideas by Jean-Louis Di Santo: http://scrime.labri.fr.

[10] TIAALS is developed by the university of Huddersfield and the Durham university: http://www.hud.ac.uk/research/researchcentres/tacem/.

3.2. EAnalysis: Towards a new tool for electroacoustic music analysis

If these limitations were not so important 15 or 20 years ago, they are more problematic to study more recent electroacoustic music. This is why I decided to reverse the method and to develop EAnalysis in a different way:

- To develop software suitable for musicologists and musicians - while not only for them they are the primary targets.
- Not to reinvent the wheel: e.g. there already exists good software to realise data extraction from sound, so use their results but do not redevelop them.
- To develop a useful player for electroacoustic music: to navigate and compare different moments of a work or of different works, to play different tracks of a multitrack work, use audio-visual or image files.
- To create analytic/text/graphic tools for the study of music. Simply to create software with beautiful graphic tools to draw anything you want may not be useful to realise a graphic representation. Musicologist, students, teachers, even children need very specific tools to create a music representation during the time of listening or very quickly after.
- To develop specific analytic tools using analytic tags or an interface to compare analyses. Moreover, analytic tools have to be linked to graphic tools.
- To analyse, we need to present and manipulate various values. This is not always possible with a simple two-dimensional view; we need to use them in different kinds of view to create augmented representations.
- Finally, I wanted to create a laboratory to experiment with new types of representation, and new tools without any limits[11].

Various limitations of other software had to be resolved with EAnalysis:

- Projects in EAnalysis would be able to use one or several audio-visual files.
- EAnalysis would interact with other software through import/export features.
- The interface would be developed to study sound and music, not only to play a sound file like a very simple player.
- Each feature would be well configured not to be limited to a specific context.

This list of goals is the result of several years of research. I have used various software packages in my papers and experimented with them for musical analysis. Unfortunately, musicology rarely integrates digital developments but nevertheless to study recent electroacoustic composition and to go beyond common representation/analysis are very important goals for research.

4. Inside the development of EAnalysis

4.1. From iAnalyse Studio to EAnalysis

The development of EAnalysis was a long process. The project ‘New multimedia Tools for Electroacoustic Music Analysis’ started in October 2010 but EAnalysis is in part the result of my previous research. Over several years around 2006, I developed a first piece of software, iAnalyse[12], which was a presentation application for musicians. It contained slides and graphic shapes much like Powerpoint but each of them could be synchronised to an audio-visual file. iAnalyse was perfectly adapted to the presentation of written music. The user

[11] This is why several of them are not finalised and need further research to be accomplished.
[12] iAnalyse Studio is available as a free software: http://ianalyse.pierrecouprie.fr.

could annotate a score, create a playhead to help the following of the score, and create simple animations for musicologists or teachers. Around 2008, I imagined a development of this idea to extend it with analytical tools. In 2008, I presented to the EMS Conference new features that included possibilities to analyse electroacoustic music. Annotations were based on Lasse Thoresen's system (Thoresen, 2007) and were used with a sonogram. This first presentation was very incomplete and worked only as a simulated part of iAnalyse. Then, I started research to create a system of annotation that was more open and that included other analytical theories. Indeed, soundscape analysis (Schafer, 1994), spectromophology (Smalley, 1997), Temporal Semiotic Units (Hautbois, 2013), functions (Roy, 2003), or language grid (Emmerson, 1986) are good examples of what an analytical software package must include. Finally the 'New Multimedia Tools for Electroacoustic Music Analysis' project started and we decided to create a separate piece of software instead to include the electroacoustic analytic tools already inside iAnalyse.

During these years of research, I realised that to create tools for electroacoustic music analysis needs very specific thought and solutions for analysis. Then, I needed to re-think the current tools. I followed 3 main ideas:

- Analysis of electroacoustic music involves starting with analysis, not with drawing. Drawing is the final step and it should be possible to automate the mapping between analytic and graphical parameters
- Analysis is a great tool to understand music and concerns not only musicologists. One of the aims of the 'New Multimedia Tools for Electroacoustic Music Analysis' project was to create a toolbox for different types of users. The software must offer a range of strategies adapted to very different types of music, users and habits.
- Analysis means to use and to link various different research and results, the software must be able to import and export data from and to other software. Moreover, users must be able to exchange part of a work, develop libraries or a whole analysis.

Some of these ideas have been realised in EAnalysis as it exists at the time of writing, others have yet to be developed to be more efficient. But research has been started and if EAnalysis is only a laboratory for these ideas, it is a substantial laboratory for future developments.

4.2. Associating various points of view

One of the most important goals of EAnalysis is to represent several parameters or values at the same time. In previous research, I demonstrated the difficulty of representing more than 4 analytic parameters in the same representation (Couprie, 2009). Common graphic representation uses X/Y-axes and shapes to represent sound parameters:

- X-axis usually represents time position and time duration.
- Y-axis usually represents pitch or a frequency range.
- Morphology of shape is used to represent amplitude of the sound.
- The analyst can also use colour and texture to represent frequency range, grain, or structural level.

Figure 2 represents the beginning of a piece by Alain Savouret. I worked on a graphical representation of this piece for the CD-ROM *La musique électroacoustique* by INA-GRM (Couprie, 2000) and this new representation is based on it. The space of figure 2 allows the representation of several parameters of sound:

- X-axis: time position and time duration.
- Y-axis: panoramic position indicated by letters R, C, L for right, centre and left.

- The morphology of shape is used to represent type of sound and/or amplitude morphology.
- Colour represents sound transformation: black is original sound, grey is original sound with filter processing, and the light grey ellipse is reverberation.

This graphic representation is very simple but we can observe an important point. Graphic representation is a good tool to represent listening characteristics of sound (type, space position, transformation) and implicit musical aspects (rhythm and duration, structural construction). Moreover, associated graphics, waveform and sonogram allow us to represent more parameters (pitches, range of spectrum, intensity variations).

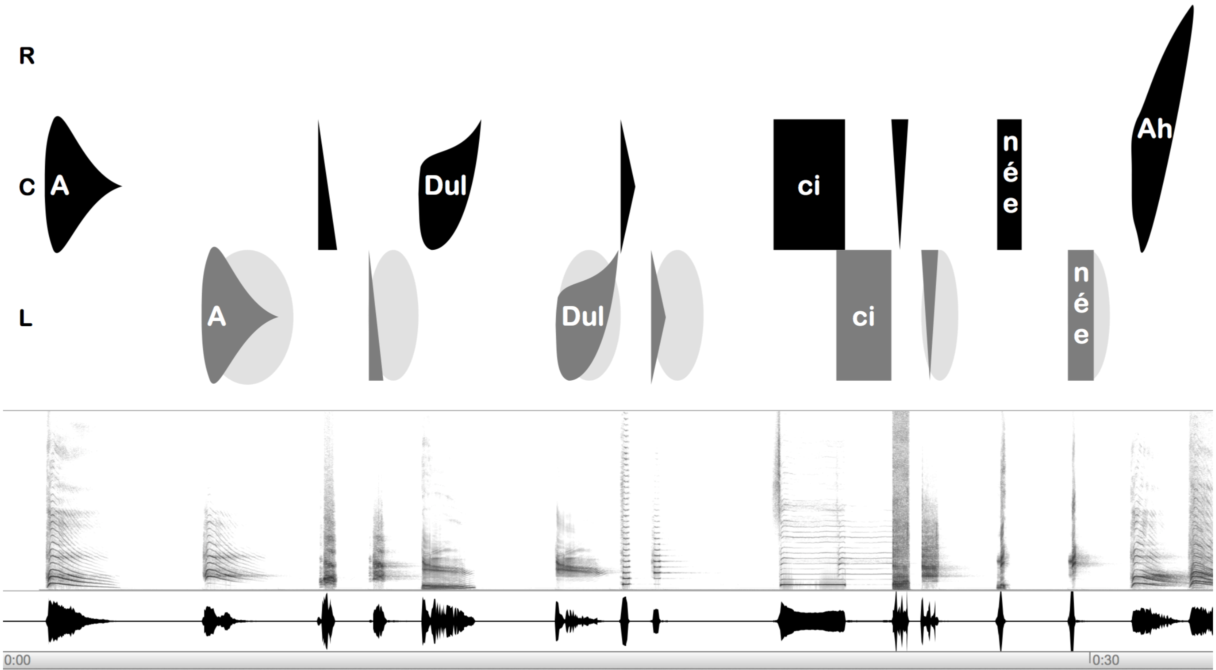

Figure 2. Graphic representation of the beginning of *Dulcinea*, extract of *Don Quichotte Corporation* by Alain Savouret.

Is it possible to create a complex graphic representation that will associate the information of these three representations?

Adding more parameters demands more dimensions to extend the graphic representation. Use of 3D causes two important problems:

- The listener misses precision. Distinguishing exact positions between different shapes becomes complex.
- 3D adds only 1 further dimension for 1 parameter: How can we add more parameters?

Another issue is to create different kinds of representations within only one analysis. Musicologists needs to change their point of view without recreating their graphic representation. Current software is limited because analysis is created through drawing: you segment sound material and analyse structure by drawing shapes. Changing point of view or creating another representation with time and frequency positions of shape you have already created demands a redraw, a new representation. This limitation can be removed by disconnecting analysis from drawing. EAnalysis offers the possibility to create analytic events with time and frequency positions. The analytic part of the event consists of several analytic properties that you have created for your analysis. After you analyse, you decide how shapes are drawn. A system of rules, like in style sheets, allows associating analytic properties to graphic properties. Events contain 3 types of properties: bound, that is the global frame properties; graphic, that contain all properties for drawing, and analytic, that are optional properties to list any kind of analytic description of sound. These events are drawn in a time view from bound and graphic properties. But the user has the possibility to change any bound and graphic properties from graphic, or analytic properties.

This system is powerful and allows working with several strategies:

- Creating a common graphic representation without analytic properties and without rules.
- Creating a common graphic representation with analytic properties and drawing different types of representation, different types of analysis.
- Focussing on analysis by working with analytic properties: drawing simple shapes (e.g. a rectangle), adding analytic properties and deciding after how they will be drawn.

4.3. Tools for different types of users

Working with different types of users at different levels is one of aims of the project 'New Multimedia Tools for Electroacoustic Music Analysis'. EAnalysis integrates this possibility in 3 parts: modes, types of view, and types of event.

4.3.1. Modes

EAnalysis integrates 3 modes: normal, add text and drawing. These modes allow the user to create events with different tools. Normal mode is the default mode. The user adds an event by 'drag and drop' from a preformatted list or from his own library to the view. With add text mode, the user enters text during playback and can annotate audio-visual files with words or sentences. Each part of the text is an event and the user can switch to normal mode to change its graphic properties. This mode is realised for analysts who prefer to work with text or for simple annotations of ideas during the first listening. Drawing mode is for users who prefer to draw with mouse, graphic tablet, or interactive whiteboard. This mode is very useful to create very simple annotations on a white page, to highlight a sonogram, to work on a whiteboard while listening with children. Moreover, if the user uses a graphic tablet, pressure is detected and might be used to create artistic drawing like calligraphy.

These three modes were the first features that were developed to respond to various users and were not created as individual elements but as part of a global architecture.

4.3.2. Views

The user can create several types of view. These are used to edit and/or show events, images or other data:

- *Time view* is the most important view. The background contains waveform, linear or logarithmic sonogram, layers of sonograms, differential sonogram (Chouvel, Bresson, Agon, 2007), image, or colour. The middleground shows imported data from other software such as audio descriptors with curve charts. The foreground shows markers and graphic events. The user creates graphic representations with this view.
- *Image view* displays slideshows of images. E.g. pictures taken during a performance or a soundwalk can be synchronised with the sound recording.
- *Map view* is used to create a chart from extracts of audio files. These extracts are represented by sonogram, waveform, events or colour and can be linked with lines like a mind map.

- *Structure view* shows linear structures with different representations: linear, formal diagram, arc diagram to display patterns, similarity matrix.
- *Video view* displays the image of movie files.

Views are stacked in a vertical axis. Time position can be synchronised or not. Unsynchronised time allows the comparing of different time positions or different track positions in the same piece, or in different pieces.

With EAnalysis, the user can associate different types of view. Figure 3 displays 2 types of view (from bottom to top):

1. 5 time views: waveform of the whole piece, sonogram, graphic representation, chart with data (audio descriptors), similarity matrix from audio descriptors.
2. A video view with animated film by Robert Lapoujade (Bayle, 2013).

Associating different views creates a complex representation to study or present results of an analysis.

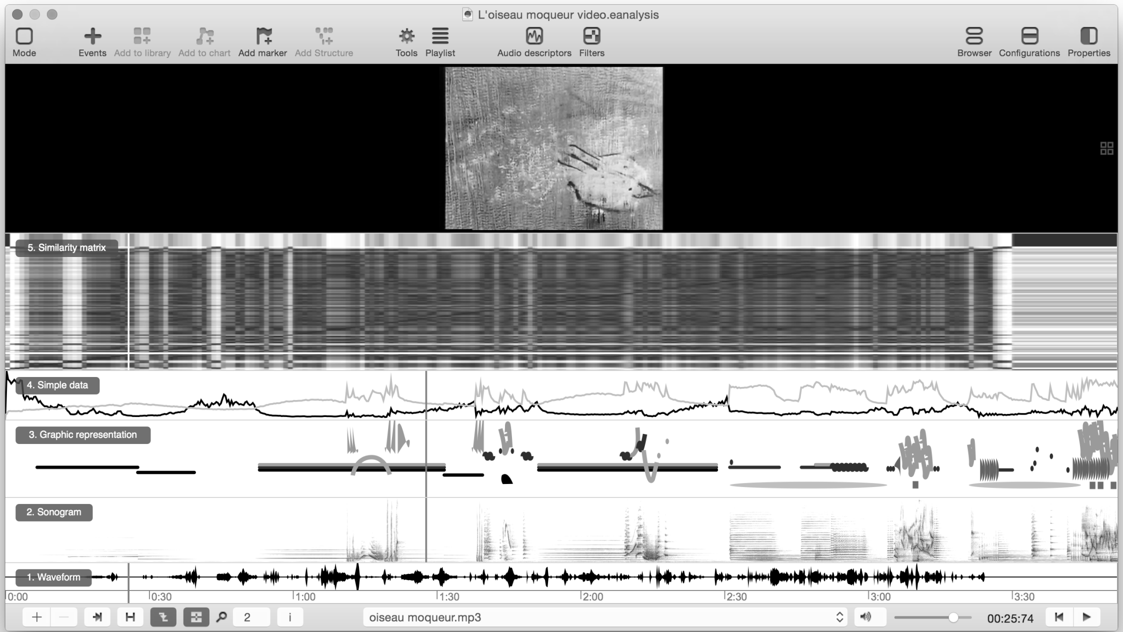

Figure 3. *L'oiseau moqueur* by François Bayle (animated film by Robert Lapoujade). EAnalysis displays different types of view: 5 time views, and video view.

Figure 4 displays another example of complex representation. The piece *NoaNoa* by Kaija Saariaho for flute and electronics is structured around a root cell of two notes. All other segmented micro-structures can be analysed with a paradigmatic chart. This figure represents 3 views (from bottom to top):

1. The sonogram.
2. The paradigmatic chart of the opening with 3 units (y-axis) displayed in time (x-axis).
3. The score of this opening extract.

The chart view allows the creation of any kind of chart from extracts of audio files. Blocks of colour, waveform, sonogram, or graphic events represent these extracts. Blocks can be linked and positioned on a white view. In this example, positions represent units and time, but blocks are movable in any direction. The user can select a block and play the corresponding extract or visualise what block is under the playhead when playing the whole piece.

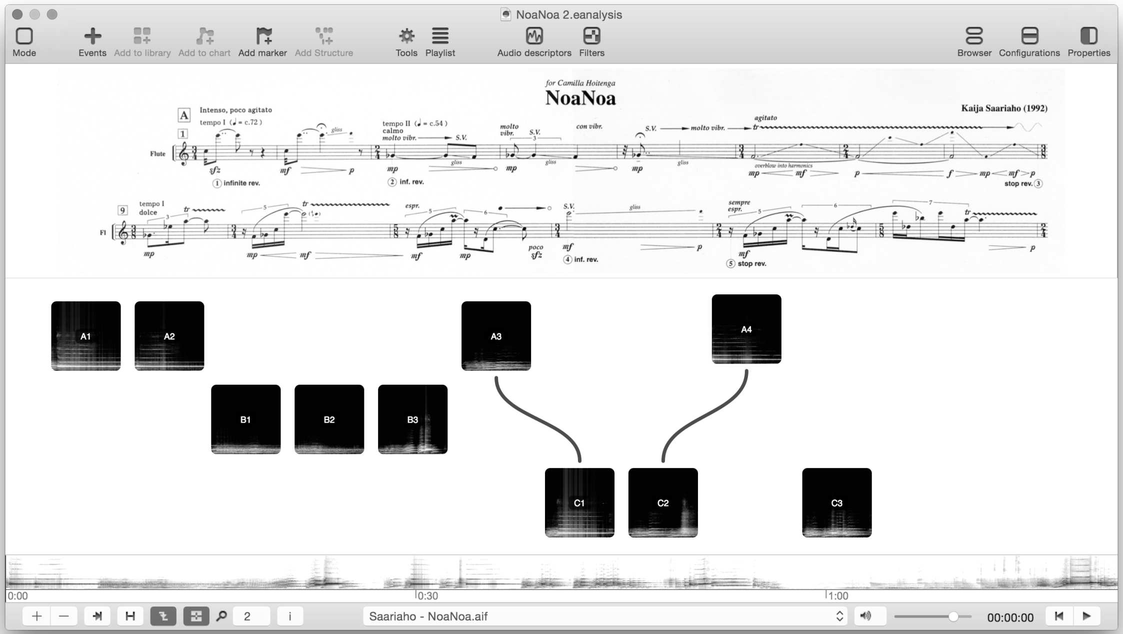

Figure 4. Sonogram, paradigmatic chart, and score of beginning of *NoaNoa* by Kaija Saariaho.

Figure 5 shows different types of structure representations (from bottom to top):

1. *Linear structure* shows segmentation in a classical manner but colours can be mapped to time duration or title of units.
2. *Formal diagram* highlight novelty and repetitions of units.
3. *Arc diagram* represent patterns by linking similar sets of units.
4. *Similarity matrix* is computed from titles of units and reveals similarity between different parts of the structure.

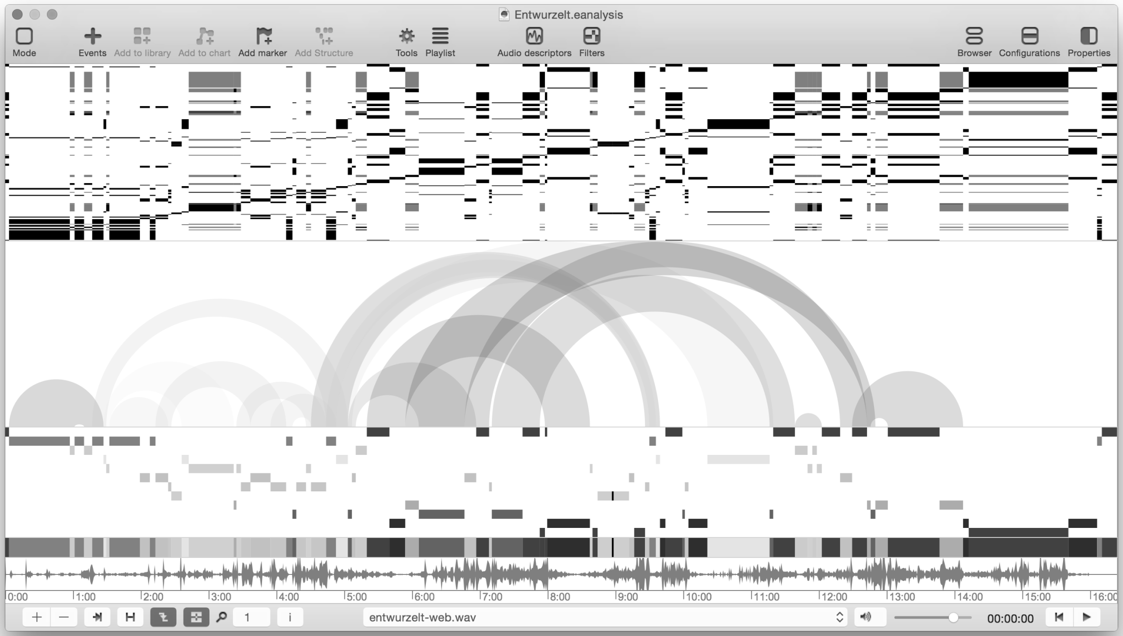

Figure 5. Different types of structure representations (from bottom to top): linear, formal diagram, arc diagram, similarity matrix.

Figure 3 uses a chart and similarity matrix to represent data imported from Sonic Visualiser. Because visualisation of data is important to extract similarity and singularities for musical analysis, EAnalysis also offers other possibilities to create representations from data. Figure 6 presents five type of graphs (from bottom to top):

1. A *similarity matrix* does not show values but similarities between values (black represents similarities and white non-similarities).
2. Simple chart to represent data in a very simple way.
3. A BStD chart (Malt, Jourdan, 2015) represents evolution of timbre from three audio descriptors in only one line: spectral centroid (Y), spectral variance (height), and intensity (gradient of colours).
4. A cloud of points can represent five data (X, Y, size, colour, opacity). EAnalysis uses one or more charts in cloud point to represent data from different tracks to help in comparative analysis.
5. A *hierarchical correlation plot* (Collective, 2009) represents correlation between two sets of data from different levels of structure.

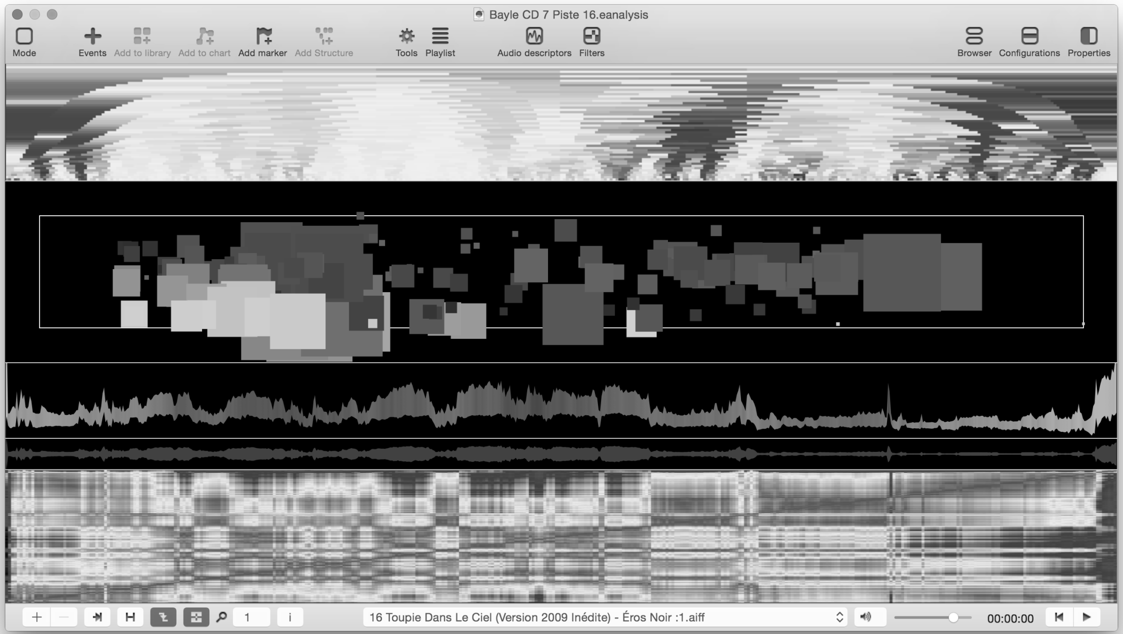

Figure 6. Different type of representation of data (from bottom to top): similarity matrix, simple chart (mirrored line), BStD chart, point cloud chart, hierarchical correlation plot.

These four examples demonstrate possibilities in term of analysing, teaching, or communicating with EAnalysis. Different configurations of view can also be saved in the same project.

4.3.3. Events

Because events contain three types of property, they can be used for different strategies and with different levels of complexity:

1. Graphic events are very simple shapes such as are available in every drawing software application: rectangle, ellipse, text, polygon, image, etc. This level is adapted to first annotations of the piece before analysis, working at listening with children, or creating beautiful graphic representations.
2. Analytic events are preformatted shapes for analysis. Each event contains a graphic shape and one or more analytic parameters. Working with preformatted analytic events is a good starting point for students to learn musical analysis or specialists to apply existing theories.
3. Users can also create their own analytic events with personalised analytic parameters. This level is highly flexible allowing the user to adapt representation and analytic segmentation to the analysed work or to a personalised analytical theory.

Figure 7 is 3 extracts of an EAnalysis interface: an example of a selected event and its graphical and analytical properties. Graphical properties contain 3 groups of parameters (graphic, text and advanced) and are very close to graphic software. Analytical properties are key-value pairs of parameters.

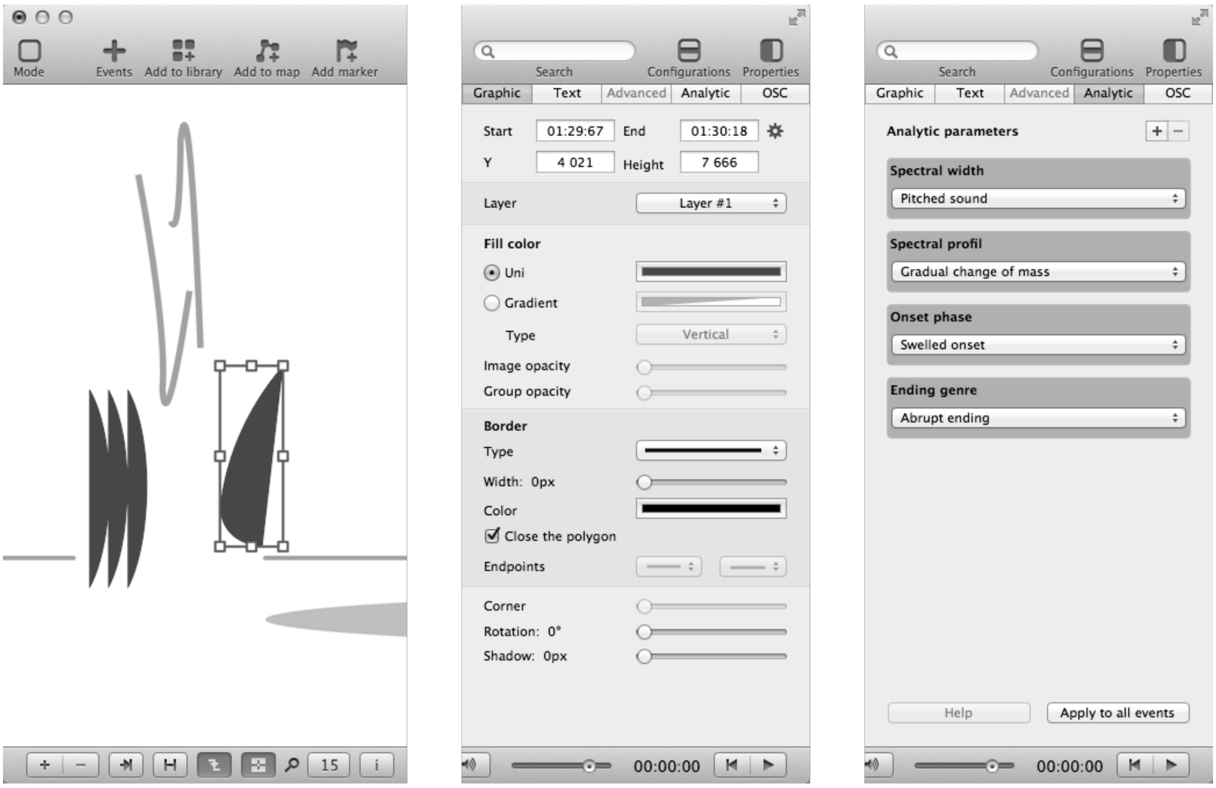

Figure 7. A selected event (left) and its graphical (centre) and analytical (right) properties.

EAnalysis contains fifteen preformatted analytic parameters (sound objects, spectromorphologies, language grid, space, etc.) and users can add their own parameters and group them into a list and library to share with other users. The interface to edit events and manage their properties is simple and flexible.

Events are also completed with markers. Markers are only time positions with simple graphic properties. They can be used to annotate ideas on first listening, or to mark breaks or structure parts. Events and markers are editable in time view. This is why time view is the default view to visualise, listen, and edit analyses. Other views are to display other data.

4.4. Import, export, share works with communities, and communicate

4.4.1 Import and export data

As explained above, modern software must be able to communicate with other software. Musicologists do not work with only one application, they use different software to prepare audio files, to create representations, or to analyse data with several different procedures. EAnalysis can import and export data from other software through four categories of files:

1. **Audio-visual file** is the root file from which the project is created and a common export format. EAnalysis creates a project from a monophonic or stereophonic audio or video file. The user can also import other audio-visual files to work with multitrack pieces or compare different pieces.
2. **Image file** is used to create an image event or slideshow inside image view. As an export file format, image is useful to create a key (with export selected event as image feature) or to export an analysis to images.
3. **Text file** is a common format to exchange various types of data. EAnalysis uses this to import a list of time cues (to create markers), time value pairs (to create curves in data view), or graphic representations (from ProTools information sessions or

Acousmographe XML export). It can also export lists of events and markers to analyse or use in other software such as Open Music, Max, Excel, etc.

4. EAnalysis has also 2 types of format: **eanalysis** project and **ealibrary**. Both of them allow the user to share analyses with or without media files (if copyright does not allow that) as well as event library including personalised analytic parameters.

The fourth point is very important for the 'New Multimedia Tools for Electroacoustic Music Analysis' project. To share their work or research with other communities is the main activity of the musicologist or musician. With the OREMA web site[13], Michael Gatt aims to enhance sharing works, tools, and to develop theory discussion around musical analysis of electroacoustic music. EAnalysis offers two formats to share projects (with or without media) and theoretical research (analytical event library).

In parallel with file exchange data, current version of EAnalysis can also use the LibXtract plug-in and SuperVP[14] to compute audio descriptors and modification of gain. The workflow (export from one application to import in EAnalysis) is reduced to some actions inside EAnalysis that use command line tools to communicate with both technologies. The LibXtract plug-in offers the computation of about forty audio descriptors and SuperVP allows us to transform the gain within spectrum areas drawn with graphical events.

4.5. Perspectives

With import/export data, EAnalysis can be defined as a workspace. Because it is difficult to create a real synergy between different software applications, allowing the user to exchange data is essential. It increases research in musicology and the power of each piece of software. The first step of development was to offer a large range of possibilities; the second step will be demonstrating them through the realisation of different examples and increasing them by adding new features.

One part of the perspective of EAnalysis development is to show how to use it with other software such as in figure 6 that uses data from Sonic Visualiser. Visualisation of data is a powerful feature of EAnalysis - any kind of lists that contain time-value pairs of data may be visualised.

The second part of the perspective will be adding new software compatibilities. The list presented in section 3.1 contains common software used in musical analysis but musicologists use also other software such as statistical applications or software used in musical production. EAnalysis needs to integrate these other applications and maybe new types of view to represent their data. These perspectives are very exciting but also very complex, indeed not possible in several cases, because some software uses a specific format with particular representations. As I mentioned, there does not exist a compatible format to exchange data: only software that use text formats (text, XML, JSON) can currently be used in EAnalysis. EAnalysis was developed to facilitate adding new types of view. But as discussed in section 4.2, new types of representation have to emerge from needs.

EAnalysis answers to the need for a multipurpose tool for electroacoustic music analysis. Of course, this workspace gives new possibilities by working with many types of data and creating representations with them, but EAnalysis is also a classical piece of software because it works with historical theories of analysis. Musicology needs also to go beyond these simple perspectives. During the development of EAnalysis, some decisions were difficult because I

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[13] Online Repository for Electroacoustic Music Analysis: http://www.orema.dmu.ac.uk.

[14] SuperVP is a technology developed at Ircam to compute spectrum and time transformation. Audiosculpt is based on SuperVP.

realised that several steps were important but appeared also an outdated method and there was a need to restart and go beyond the original aim. The best example is events. In EAnalysis, events are objects with a border (e.g. time and frequency) but are adapted to specific analytical strategies. A lot of recent electroacoustic music works are very complex in term of media or musical realisation and cannot be analysed with bordered or statical objects. Another example of an EAnalysis limitation is the representation of sound. The software proposes different representations from waveform or sonogram. One of them, the similarity matrix, allows us to research singularities inside spectromorphologies but realisation of the matrix from data of different tracks or different pieces needs to be improved with the dynamic time warping (DTW) algorithm (Zattra, Orio, 2009). Finally, some researchers are exploring new forms of analytical representation: the MaMux seminar at Ircam presented some of them[15]. The emergence of researches in this field is evidence that musicologists need new kinds of representation for complex musical relationships.

5. Conclusion

This paper presents an account of the development of the EAnalysis software. EAnalysis, as a sound-based music (Landy, 2007) analytical software, is created for the study of music based on sound, not only electroacoustic music but also other non-written music. Choices I made to create two or more possibilities to achieve the same result, or different interface parts for the same feature are going in the same direction: to respond to different types of user and to allow analyse of different genres and categories of music. This chapter has presented theoretical origins and technical choices to propose a software package that is more adapted to musical analysis than other software. As I mentioned, above all other goals, EAnalysis is an experimental laboratory[16]. Realisations by Michael Clarke in the field of aural analysis, research on archive preservations (Barkati, Bonardi, Vincent, Rousseaux, 2012), or new representations of sound (differential sonogram or similarity matrix of sonograms) demonstrate the importance of software development in the analysis of electroacoustic music.

Most of the current graphical representations used for the analysis of electroacoustic music are based on the same paradigm: a 2D representation of time and frequency with some annotations. EAnalysis offers other possibilities but this is probably only a first step in a different direction. In the field of electroacoustic music, analytical researches are in their teenage years. Computer science and multimedia possibilities have been developed significantly in recent years. Musicologists have now more keys to explore new paradigms of representation.

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[15] MaMux: Mathematics and Music research seminar (Ircam). Several sessions presented mathematical representations of musical and one session explored analytical representation: http://repmus.ircam.fr/mamux/saisons/saison12-2012-2013/2013-02-01.

[16] It appears also to be an important step for my research. In this software, I have realised and experimented with some of the research ideas I havedeveloped in several papers since 2005.

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