Proceedings of the Electroacoustic Music Studies Conference
Electroacoustic Music in the Context of Interactive Approaches and Networks, Lisbon, June 2013
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T*IAA*LS: A New Generic Set of Tools
for the Interactive Aural Analysis of Electroacoustic Music

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Abstract

This paper introduces and demonstrates T*IAA*LS, a new set of generic software tools designed to facilitate an interactive aural approach to the analysis of electroacoustic music. T*IAA*LS is being developed as one element of a 30-month AHRC-funded project investigating the relationship between Technology and Creativity in Electroacoustic Music (TaCEM)[1]. TaCEM will examine a series of case studies, specific works exemplifying different technical and compositional approaches, from contextual, technical and analytical perspectives. It builds on the previous experience of the project team in terms of historical/contextual study[2], organology of computer music[3] and electroacoustic analysis[4].

In recent years there have been an increasing number of important texts on the analysis of electroacoustic music. All have faced a common challenge, how to present analyses that exist primarily in sound, not on the page, in the form of written text and graphics. Interactive Aural Analysis (IAA) provides one approach to resolving these issues. It was first developed by Clarke for analyses of specific electroacoustic works, beginning with Jonathan Harvey's *Mortuos Plango, Vivos Voco* in 2006[5], and later Denis Smalley's *Wind Chimes*[6] and Pierre

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[1] "TaCEM: Technology and Creativity in Electroacoustic Music", project presentation webpage, http://www.hud.ac.uk/research/researchcentres/tacem/ (last visited August 31st, 2013).
[2] Peter Manning, *Electronic and Computer Music*, 4th Edition, New York, Oxford University Press, 2013.
[3] Frédéric Dufeu, "L'instrument numérique comme objet d'analyse des musiques mixtes", in *Proceedings of Journées d'Informatique Musicale (JIM10)*, Rennes (France), 2010, pp. 221-227.
[4] Michael Clarke, "Analysing Electroacoustic Music: An Interactive Aural Approach", *Music Analysis*, 31(3), 2012, pp. 347-380.
[5] Michael Clarke, "Jonathan Harvey's *Mortuos Plango, Vivos Voco*", in Mary Simoni (éd.), *Analytical Methods of Electroacoustic Music*, New York, Routledge, 2006, pp. 111-143.

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Boulez's *Anthèmes 2*[7]. The underlying principle is that analysis of such works, in which the musical development involves aspects that cannot be notated traditionally, complex textural transformations and subtle spectromorphological variations, is best undertaken and presented not solely by means of verbal and visual representations on the printed page but through the use of software permitting the analyst and the reader to engage with the musical materials interactively as sound. Technical exercises also form an important part of the IAA software, enabling readers to engage with the techniques used by the composer and discover their potential. Previously only limited attention has been paid to the possibility of modelling the techniques employed as part of analytical study, and using modern software emulation facilitates a better understanding of the technical and creative processes that have underpinned the composition process. In each analysis therefore a substantial written text accompanies software that enables the exploration of the sound world and of the techniques used to produce the music[8].

Within TaCEM, one important part of the project will be the making of an IAA of each of the case studies. In preparation for this a set of generic software tools is being developed, both for use in the project and more widely by others. The tools are in many cases developed from those specifically produced for the earlier analyses but take advantage of significant new technical developments and are designed to be adaptable. Whereas with the previous IAAs the software was developed specifically for each work in question, the aim here is to create generic tools that can be of use with any piece of music as appropriate (T*IAA*LS does not, however, include the technical exercises which, by their very nature, are specific to the individual works and the techniques used to produce them).

A beta version of the software has been released in August 2013, this will then be refined and extended as it is trailed by members of the TaCEM team and by others. T*IAA*LS is being made freely available. All the tools are built in Max 6. This is so that they can be fully integrated into the software we devise to accompany the presentations of our case studies for the TaCEM project. Being built in Max also means that the tools are easily adaptable to different contexts and extensible.

Sonograms are often employed in analyses of electroacoustic music. However, presented as fixed graphical representations on the printed page they are often severely limited in what they can show[9]. T*IAA*LS however makes use of a sonogram that is interactive and aural. It is a highly developed version of the similar tool used in the analysis of *Wind Chimes*. The user can draw regions on the graphic display and hear the sound of just this region. It is also possible to scrub, moving a cursor of variable frequency range at variable speed through the display and hearing the results. Regions that have been drawn onto the sonogram display can be grouped and these groups soloed or muted. These and other features of the interactive sonogram enable users to interact with the sonogram and explore the musical significance of

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[6] Michael Clarke, "*Wind Chimes*: An Interactive Aural Analysis", in Évelyne Gayou (éd.), *Denis Smalley: Polychrome Portraits*, Paris, Ina-GRM, 2010, pp. 35-57.
[7] Michael Clarke, "Pierre Boulez's *Anthèmes 2*", online text and software, Paris, Ircam, forthcoming.
[8] For more information on Interactive Aural Analysis and the earlier analyses see "Interactive Aural Analysis", presentation webpage, http://www.hud.ac.uk/research/researchcentres/iaa/ (last visited August 31st, 2013) and for a fuller account of the ideas behind Interactive Aural Analysis see Michael Clarke, "Analysing Electroacoustic Music: An Interactive Aural Approach", *op. cit.*
[9] See Michael Clarke, "Analysing Electroacoustic Music: An Interactive Aural Approach", *op. cit.*

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the visual display. It provides a means of investigating the different components of complex textures or timbres by identifying elements in the overall texture and hearing them in isolation, and possibly in slow motion.

Analysis is more than simply a matter of description: it is about making connections between musical ideas and showing the evolution of musical material, sometimes across long time spans. Traditionally in analysis of acoustic music such relationships are presented using charts, often employing musical notation. Since musical notation and other forms of graphical representation are often of limited use in electroacoustic music[10], T*IAA*LS offers a means of creating aural charts in software. This builds on the interactive sonogram. Regions that have been created using the interactive sonogram (by drawing time and frequency selections on the visual display) can be exported into a palette. The palette can then be used as the basis for making aural charts to demonstrate features of the music. Regions in the palette can be imported into a chart as a (labelled) button. Clicking on a button plays the region it represents (and regions in charts can be related back to their context in the work as a whole). Charts might for example be used to show the evolution of a particular type of sound or musical motif through the course of a work. Or they might be used to present a taxonomy of the sounds used in a work or a genealogical chart of the relationships between different sounds[11]. Paradigmatic charts or other structural charts can be used to show the shape of the work. Which charts are most appropriate and how they are best presented is up to the analyst, T*IAA*LS simply facilitates the creation of such charts, and the prioritization of aural experience and interaction with sound as the preferred means of communicating ideas about the music.

Despite the obviously greatly increased importance of timbral, textural and spatial components in much electroacoustic music, pitch continues to be a significant factor in the shaping of many works. A pitch/frequency finder tool provides an aid to identifying significant pitch and frequency elements. Sections of a work can be analysed and data about the most prominent frequencies presented using both musical notation and numerical data. It is also possible to set up a pitch filter to help demonstrate the recurrence of key pitch components (e.g. harmonic fields) in the course of a passage. Spatial positioning of sound is a complex phenomenon and disaggregating a spatial mix is not an insignificant task. This task becomes even more complex in multichannel works. The spatial display tool in T*IAA*LS does not claim to resolve all these complexities and needs to be used with intelligent reflection but it can provide some useful insights. The spatial display tool (developed from an idea by Sam Freeman for the *Wind Chimes* analysis) colour-codes each frequency bin in the sonogram analysis according to the amplitude balance between left and right channels. This can give some indication of the spatial distribution of sounds across the frequency range at each moment in the work.

T*IAA*LS is a development from earlier Interactive Aural Analyses. As well as playing an important role in the TaCEM project, T*IAA*LS provides a set of generic tools that can be used by any analyst seeking a means of working interactively with the sound of a piece in creating and presenting their analyses. IAA is not a method of automated analysis by computer (although we may build some automated options into later versions); it is primarily a set of

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[10] See *ibid.*

[11] See Michael Clarke, "*Wind Chimes*: An Interactive Aural Analysis", *op. cit.* for examples.

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tools for an analyst to use to help in their own interactive aural investigation of works and in the presentation of their findings. It is envisaged that T*IAA*LS will be further refined and extended in response to our own needs in relation to the TaCEM project over the next two years and in response to feedback from other users.

Introduction

T*IAA*LS (Tools for Interactive Aural Analysis) is a software currently developed within the TaCEM project (Technology and Creativity in Electroacoustic Music), a collaboration between the University of Huddersfield and Durham University, funded by the United Kingdom's AHRC (Arts and Humanities Research Council) for a duration of 30 months (2012-2015), and led by the three authors of this paper[12]. The primary aim of the TaCEM project is the examination of a series of eight case studies from the electroacoustic repertoire, specific works exemplifying different technical and compositional approaches, from contextual, technical and analytical perspectives. Building on the previous experience of the project team in terms of historical and contextual study[13], organology of digital instruments[14] and electroacoustic music analysis[15], this research will lead to outcomes in the form of both writings and pieces of software. For each case study, the results of the contextual research, musical analysis and technical investigation are to be presented as a substantial written chapter from which the reader is also guided through a software application that allows for further engagement with the considered music and technologies. Such a framework inherits from Michael Clarke's earlier developments of Interactive Aural Analysis, an approach that addresses the issue of presenting musical works that exist primarily in sound, not on the page, in the form of written text and graphics, by directly elaborating and disseminating software[16]. The underlying principle is that the analysis of most electroacoustic works, in which the musical development involves aspects that cannot be notated traditionally, complex textural transformations and subtle spectromorphological variations, is best undertaken and presented not solely by means of verbal and visual representations on the printed page but through the use of software permitting the analyst and the reader to engage with the musical materials interactively as sound. Technical exercises also form an important part of the Interactive Aural Analysis software, enabling readers to engage with the techniques used by the composer and discover their potential. Previously only limited attention has been paid to the possibility of modelling the techniques employed as part of analytical study, and using modern software emulation facilitates a better understanding of the technical and creative operations that have underpinned the composition process. Actual analyses of electroacoustic works following this approach have been undertaken prior to the TaCEM project: Jonathan

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[12] "TaCEM: Technology and Creativity in Electroacoustic Music", project presentation webpage, http://www.hud.ac.uk/research/researchcentres/tacem/ (last visited August 31st, 2013).
[13] Peter Manning, *Electronic and Computer Music*, 4th Edition, New York, Oxford University Press, 2013.
[14] Frédéric Dufeu, "L'instrument numérique comme objet d'analyse des musiques mixtes", in *Proceedings of Journées d'Informatique Musicale (JIM10)*, Rennes (France), 2010, pp. 221-227.
[15] Michael Clarke, "Analysing Electroacoustic Music: An Interactive Aural Approach", *Music Analysis*, 31(3), 2012, pp. 347-380.
[16] See "Interactive Aural Analysis", presentation webpage, http://www.hud.ac.uk/research/researchcentres/iaa/ (last visited August 31st, 2013).

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Harvey's *Mortuos Plango, Vivos Voco*[17], Denis Smalley's *Wind Chimes*[18] and Pierre Boulez's *Anthèmes 2*[19].

In addition to the individual pieces of software dedicated to each of the eight cases studies of the TaCEM project, T*IAA*LS is being developed as a generic environment that can be used for any work available as a digital audio file. Conceived as a large development and generalisation of the aforementioned Interactive Aural Analyses, its purpose is to facilitate the investigations of the works studied within TaCEM but also to enable broader musicologists to make their own explorations and analyses, and to present them to their audience directly from the software itself. Like other software dedicated to music analysis such as Ina-GRM's Acousmographe[20], Sonic Visualiser, developed at Queen Mary, University of London[21], or Pierre Couprie's EAnalysis for De Montfort University[22], T*IAA*LS provides a sonogram visualisation of the imported sound file. The reason for us developing yet another sonogram based tool was that none of the existing tools fulfilled our essential requirements. Most importantly, none of them were based on Cycling'74's Max and extensible in order to allow the incorporation of sonogram based analyses into our larger software-based analytical presentations of works. Furthermore, we wanted to introduce into our software the ability to extract regions in time and frequency and export these to interactive aural charts in which the regions identified could be placed in analytical charts and played as sound from them. Programs such as Sonic Visualiser and Acousmographe do not incorporate such a chart feature and EAnalysis, being based on a graphical representation of the sonogram and not directly accessing FFT data for sound reproduction, cannot play back specific frequency regions.

Developed as a standalone from Max, T*IAA*LS has components that can be integrated to other specific projects built in this environment, which has both a good flexibility and powerful features to process and arrange audio and visual data. Objects drawn on the sonogram window are fully interactive and can be listened to according to their time and frequency bounds. T*IAA*LS's most significant singularity is the possibility to transfer the objects from the sonogram towards an open-ended chart maker that relies on an FFT playback engine, enabling the musicologist to arrange objects as tables or diagrams, with further graphical features in a fully integrated and aural environment. In this paper, we describe the detailed

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[17] Michael Clarke, "Jonathan Harvey's *Mortuos Plango, Vivos Voco*", in Mary Simoni (éd.), *Analytical Methods of Electroacoustic Music*, New York, Routledge, 2006, pp. 111-143.

[18] Michael Clarke, "*Wind Chimes*: An Interactive Aural Analysis", in Évelyne Gayou (éd.), *Denis Smalley: Polychrome Portraits*, Paris, Ina-GRM, 2010, pp. 35-57.

[19] Michael Clarke, "Pierre Boulez's *Anthèmes 2*", online text and software, Paris, Ircam, forthcoming.

[20] See Emmanuel Favreau, Yann Geslin and Adrien Lefèvre , "L'Acousmographe 3", in *Proceedings of Journées d'Informatique Musicale (JIM10)*, Rennes (France), 2010, pp. 105-111.

[21] See Chris Cannam, Christian Landone and Mark Sandler, "Sonic Visualiser: An Open Source Application for Viewing, Analysing, and Annotating Music Audio Files", in *Proceedings of the ACM Multimedia Conference (MM'10)*, Firenze (Italy) 2010, pp. 1467-1468.

[22] See Pierre Couprie, "EAnalysis : Aide à l'analyse de la musique électroacoustique", in *Proceedings of Journées d'Informatique Musicale (JIM2012)*, Mons (Belgium), 2012, pp. 183-189.

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features of both the sonogram and the chart maker, and discuss the future perspectives for the development of T*IAA*LS, beyond the currently available beta version[23].

1. An Interactive Sonogram for Aural Exploration and Segmentation

Under its current version, T*IAA*LS is organised in four principal windows: the main window, the interactive sonogram, the palette and the chart maker. The main window, located at top, includes all the controls needed to create, handle and restore a project, create, edit and play interactive objects and navigate through the three other windows. When creating a new project, the user is asked to select a sound file from the OS explorer[24], and to make an FFT[25] analysis to create the sonogram data[26]. The FFT analysis is powered by Jitter objects and is, on a standard computer, about ten times faster than real time. All the information related to a project, including the FFT data, is stored and organised within a folder that is created within the application path, so that a session can at any point be quit and later restored under its most recent state.

The sonogram window and the transport section of the main window can be used to play the imported sound in a standard way, but also with a playback speed scaling that takes advantage of the FFT resynthesis to implement time stretching or freezing, which enables the user to better focus his attention on a particular time fragment of the piece. The sonogram can be fully zoomed in and out, maintaining a high resolution display in all cases. A dynamic matrix fragmentation and loading processer has been implemented in Jitter and JavaScript so that very long pieces (one hour or more) can be imported and visualised as a whole without overloading the system memory. The association of an MSP[27] playback engine and a Jitter-based sonogram visualisation has been inspired by Jean-François Charles's research on sound processing as FFT frames in Jitter matrices, published in a *Computer Music Journal* article in 2008[28]. The integration of matrices in JavaScript and the MGraphics library have led to a flexible and powerful development for dynamic allocation and object drawing and visualisation within T*IAA*LS. A menu gives access to the channel to be displayed, and the grayscale for the magnitudes of frequency bins and frames can be adjusted so that both quiet and very loud regions can be visualised with as much detail as possible. To enhance the aural exploration of the sonogram, a scrub mode can be activated to click and drag over any location of the sonogram and hear what is under the mouse cursor, which can be set to reduced frequency ranges so that any time-frequency region can accurately be heard (figure 1).

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[23] The first beta version of T*IAA*LS, released in August 2013 shortly after the Lisbon EMS conference, can be downloaded from "TaCEM: Technology and Creativity in Electroacoustic Music", project presentation webpage, *op. cit.* Future releases and the final version of T*IAA*LS will also be downloadable from that page.

[24] The currently supported formats are aiff, wave, mp3. Files can be mono or stereo.

[25] Fast Fourier Transform.

[26] Default settings for the FFT analysis are set so that the user can proceed immediately, but advanced FFT settings are available for choosing FFT size, FFT overlap size, and standard analysis windows (triangle, Hanning, Hamming, Blackman).

[27] Max Signal Processing.

[28] Jean-François Charles, "A Tutorial on Spectral Sound Processing Using Max/MSP and Jitter", *Computer Music Journal*, 32(3), 2008, pp. 87-102.

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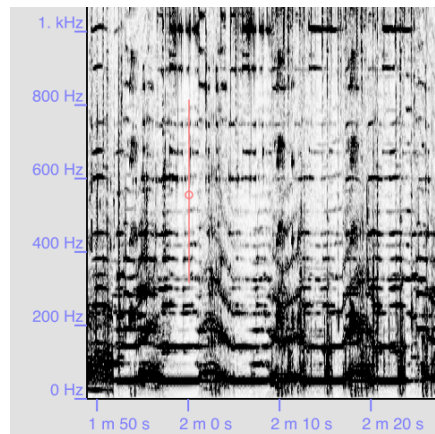
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Figure 1. Detail of the sonogram window in scrub mode.
In red, the scrub cursor with a 500 Hz range enables to hear the contents of the 300 to 800 Hz band
at position 2 minutes in the imported sound file.

In the analysis process, the step following aural exploration is the segmentation of the piece into relevant music or sound objects. In drawing mode, different types of graphical shapes can be painted onto the sonogram (rectangles, lines, free-hand shapes). Figure 2 shows the sonogram window of T*IAA*LS after different objects have been drawn in the beginning section of "Pleins et déliés", the eleventh movement of Bernard Parmegiani's *De Natura Sonorum* (1975).
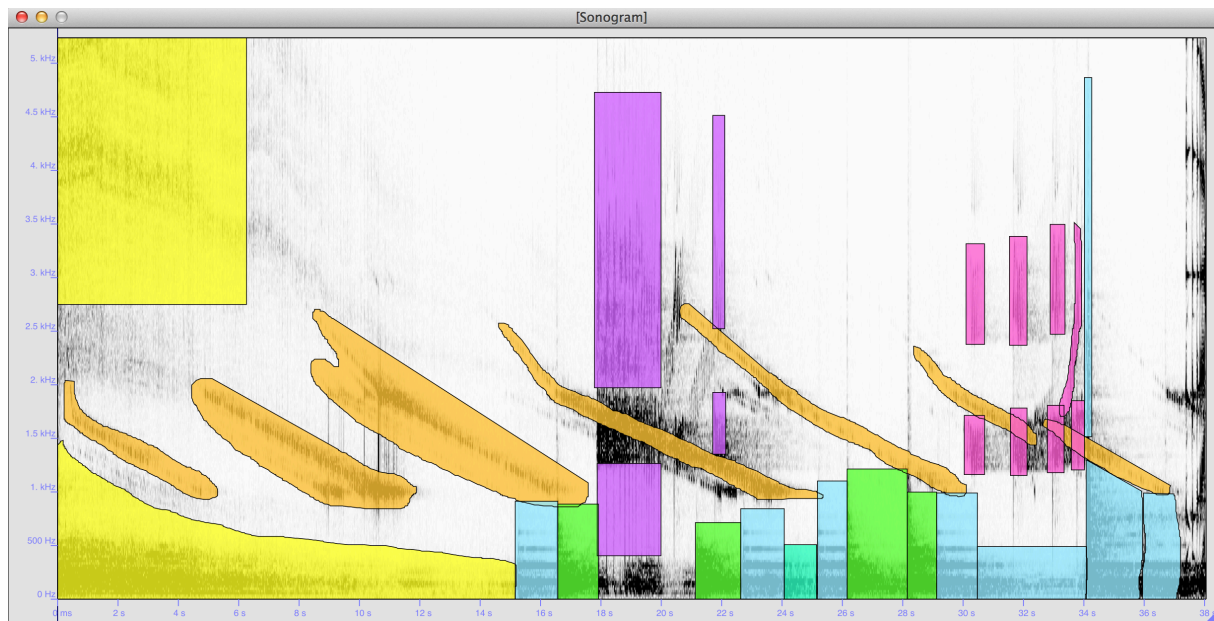

Figure 2. Sonogram window of T*IAA*LS, with sound objects drawn on Bernard Parmegiani's
"Pleins et déliés" from *De Natura Sonorum*

Shapes can be selected, moved, copied, deleted and edited. An inspector enables to attribute names to shapes before further categorisation, and to change their colours. When the analyst wants to consider several disjoint shapes as one unique significant object, he can select these shapes and associate them as a group. In figure 2 above, the four purple rectangles and the

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eight pink objects, respectively, have been set as two groups – they will later on appear and be handled as two items on the palette and the chart maker.

In addition to the standard and time-stretched playback modes of the overall sonogram and to the scrub mode, the interactive aural exploration can be applied to objects themselves. When selecting one or several objects, playback is made within the corresponding time region. Figure 3 shows the different options available from the transport section of the main window.
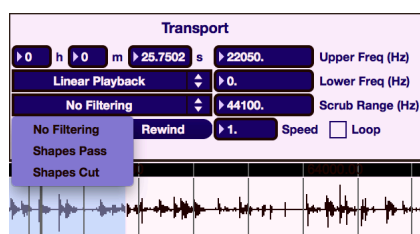

Figure 3. Transport section of the main window of T*IAA*LS, showing options for sonogram objects playback

The filter menu activates different statuses for graphical objects: the full spectrum range (0 to Nyquist) can be heard when playing an object, but an object can also be heard on its own, according to its time and frequency contour ("Shapes pass"). Conversely, the "Shapes cut" option leads to hear everything but the selected objects. Above the filter menu, a playback mode menu enables to play the selected objects following the temporality of the piece ("Linear playback"), or one after the other ("Sequential playback").

All the information related to the shapes and groups drawn on the sonogram is stored as text in a database. Every user action related to these objects (drawing, moving, copying, editing, deleting) implicitly stores an incremented state of the database, which implements multiple undo/redo actions. The user can also explicitly store the current state of the database in numbered presets, which can be recalled in later sessions. This database architecture and state management is also applied to the relevant characteristics of the palette and the chart maker, which help the musicologist elaborate his analysis from the objects resulting from the sonogram exploration and segmentation.

2. A Chart Maker for Analysis Elaboration and Dissemination

The T*IAA*LS interface between the interactive sonogram and the chart maker is a palette, upon which some or all of the shapes and groups can be placed. The user can create named categories for the palette objects to be arranged and sorted. The palette objects are themselves interactive and aural: it is possible to select them and directly play them from the palette window. Figure 4 shows an arrangement of the sonogram objects drawn for the "Pleins et déliés" example under five categories: glissandi, noise glissandi, harmonic attacks, noise attacks and repeated objects. When the palette is populated with objects, the user can create a new default chart in the chart maker and dump some of or all the palette objects to it (figure 5).
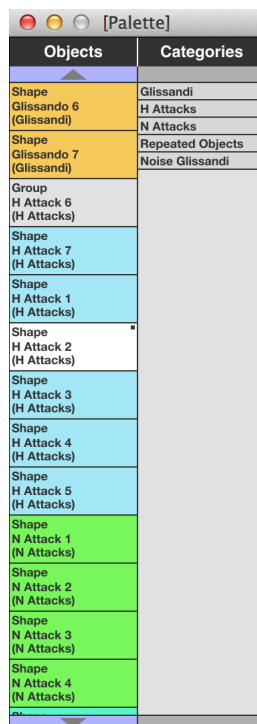
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Figure 4. T*IAA*LS palette with categorised objects from "Pleins et déliés"
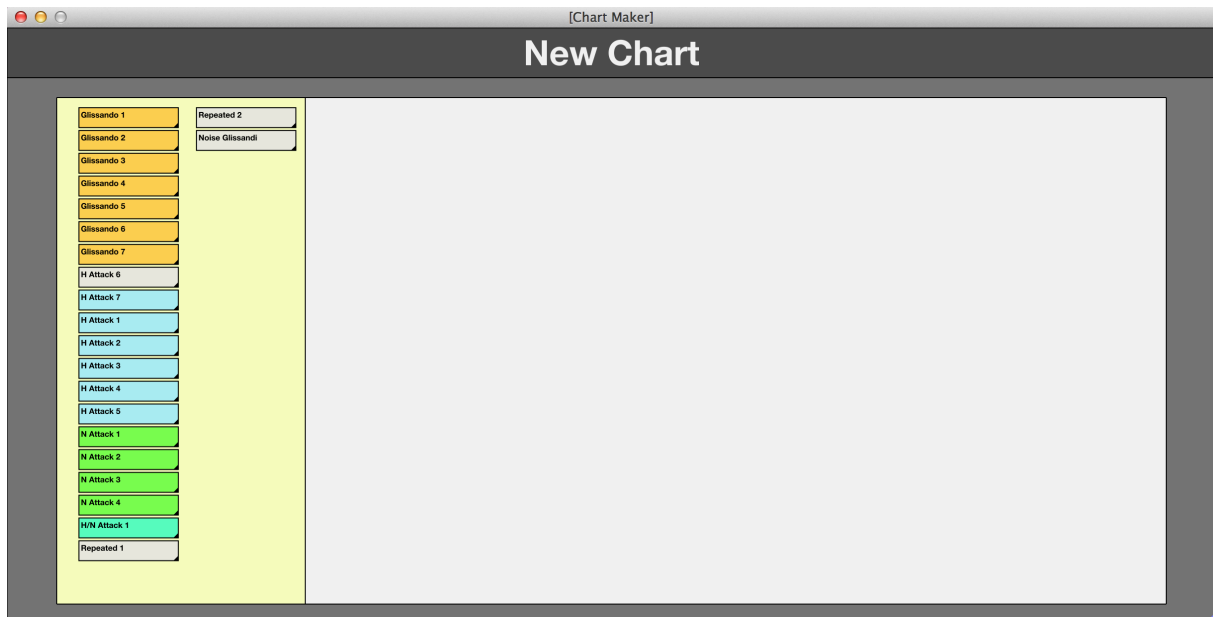

Figure 5. T*IAA*LS chart maker window with default chart and objects dumped from the palette

The development of the chart maker of T*IAA*LS has been inspired by Michael Clarke's earlier Interactive Aural Analysis of *Wind Chimes*[29], in which several aural charts (genealogies, taxonomies, paradigmatic representation) can be found. The creation of these charts required specific programming in Max, not only to arrange objects according to the relevant

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[29] Michael Clarke, "*Wind Chimes*: An Interactive Aural Analysis", *op. cit.*

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representations, but also to connect them to the different playback DSP modules and user interface buttons. The idea behind T*IAA*LS is to generalise this approach and to make the elaboration of advanced charts accessible to non-programmers. The chart maker is open-ended in terms of graphical layout, and objects are directly associated to their sonogram equivalents, and can thus be listened to as soon as they are placed on a chart.

The following general attributes of a chart can be edited: name, header and margin sizes and colours, background colour. In the background, a grid can be created with an initial number of rows and columns to facilitate the organisation of objects. With a simple user access, the chart objects can be relocated and resized (by dragging their bottom-right corner handle). Lines can be drawn to show logical connections between objects, and attached to objects themselves to follow them as they are relocated. Textual annotations with different sizes can be also be created and placed on the chart. Cells of the initial grid can be merged or split in further columns or rows to fine-tune the chart organisation. Like the interactive sonogram, the chart maker includes zoom and navigation functions, but also implements a chart size scaler, so that when the chart starts being populated with many objects, the user can stretch its dimensions without resizing the existing objects themselves, thus creating more available space to continue the arrangement operations.

The user can create any number of charts, which can then be made visible from a menu. Figures 6 and 7 show two different charts made from the same set of objects: a taxonomy and a paradigmatic chart.
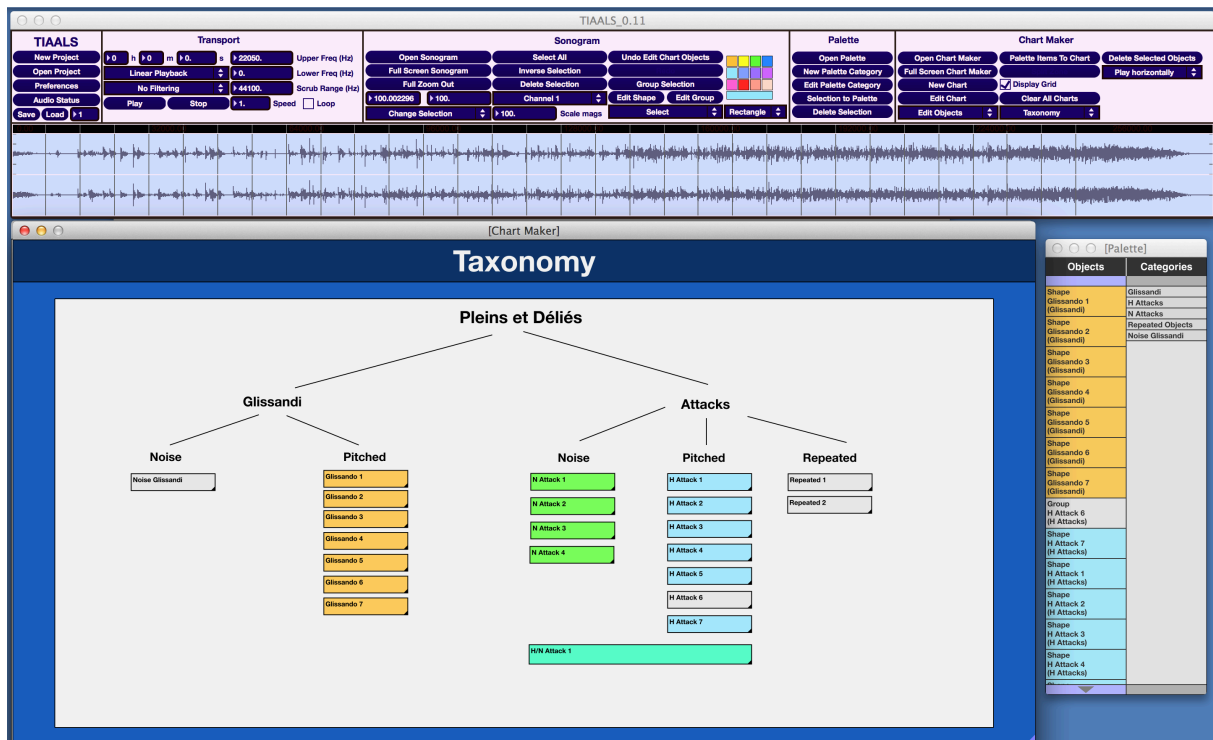

Figure 6. Overall view of T*IAA*LS with a taxonomy chart from the "Pleins et déliés" example

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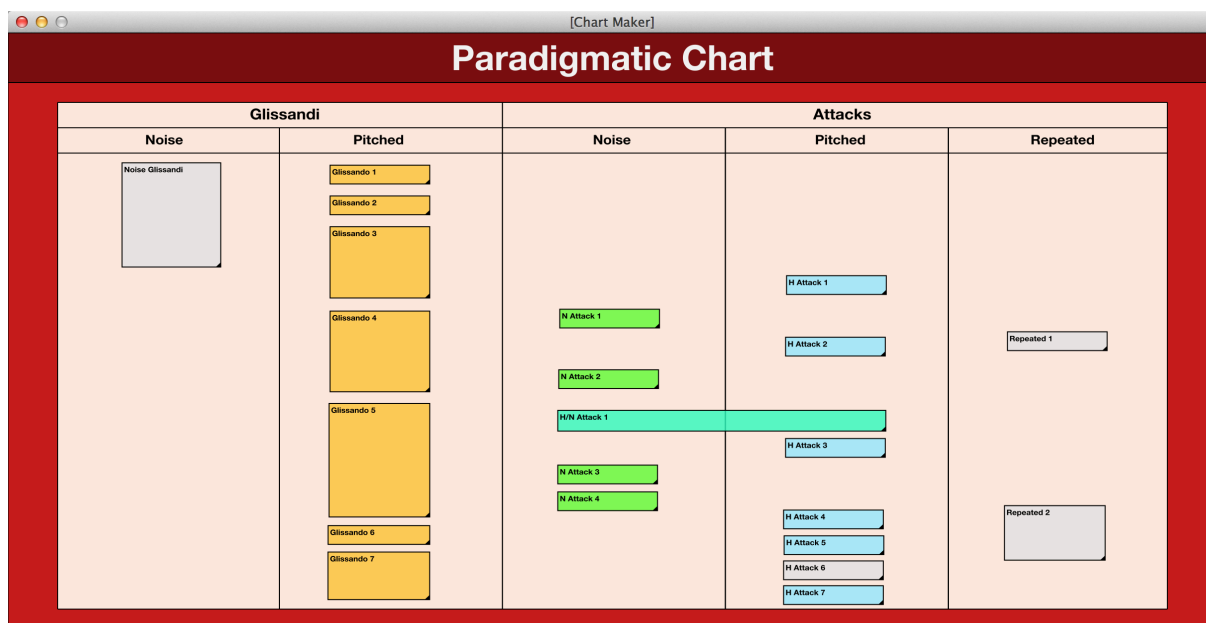
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Figure 7. Paradigmatic chart with the same set of objects as in figure 6

Individual objects can be played, according to the same settings as those of the sonogram (standard, time stretched, filtered), and a selection of objects can be played in sequence according to their order along the horizontal or the vertical axis. Future developments will include advanced playback features, such as a sequential playback following tree-shaped relationships, as visible above in the taxonomy chart.

Conclusion

In its current version, a preliminary beta that has been made publically available, T*IAA*LS is operational under its main framework: an interactive sonogram enabling flexible navigation and segmentation into sound objects, and a chart maker that facilitates the elaboration of open-ended analytical representations that are directly accessible in sound. Future releases will integrate features that have been suggested by user feedback, from the Lisbon EMS conference and elsewhere, and ongoing developments are being made to pursue the implementation of the initially wished specifications. Amongst these, a better handling of multichannel files will lead to a spatial display tool, after an idea by Sam Freeman at the University of Huddersfield for the earlier *Wind Chimes* analysis, which colour-codes each frequency bin in the sonogram analysis according to the amplitude balance between left and right channels. This can give some indication of the spatial distribution of sounds across the frequency range at each moment in the work. Furthermore, despite the greatly increased importance of timbral, textural and spatial components in much electroacoustic music, pitch continues to be a significant factor in the shaping of many works. A pitch/frequency tracker tool will provide an aid to identifying significant pitch and frequency elements. Sections of a work will thus be possibly analysed and data about the most prominent frequencies presented using both musical notation and numerical data. It will also possible to set up a pitch filter to help demonstrate the recurrence of key pitch components (for instance, harmonic fields) in the

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course of a passage. The integration of Music Information Retrieval descriptors will also enhance the set of methods for the creation of objects on the interactive sonogram.

Whilst T*IAA*LS is able to provide generalised tools for certain aspects of the analytical process, there is another important part of the earlier Interactive Aural Analyses that cannot easily be generalised – the emulation of the synthesis and processing techniques used in the works. These processes are inevitably very different for each work and hard to generalise (except in so far as a program such Max already does at a low level). Nevertheless, it is interesting to reflect on the invariants found amongst technological tools for sound synthesis and processing in composition and performance, and to consider the potential for creating demonstrations modelling general processes. In this matter, the development of specialised software for the eight case studies of the TaCEM project will hopefully raise perspectives for bringing Interactive Aural Analysis towards an even broader degree of accessibility to musicologists investigating the creative processes involved in the electroacoustic repertoire.

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