Augmented Interactive Scores for Music Creation

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This article addresses music representation issues in the context of the contemporary music creation and performance. It exposes the main challenges in terms of music notation and representation, in regard of the new forms of music and with an emphasis on interactive music issues. It presents INScore, an environment for the design of augmented, interactive music scores that has been developed in response to current artistic evolutions. It gives an overview of the system with a presentation of its main features and highlights on the main technologies involved. Concrete examples of use with recent music creations, composers' viewpoint and an electro-acoustic piece modelling will also be given.

Up to a few years, the support provided by computer music to digital music scores has remained quite conventional. Regarding the symbolic notation of music, the approach was mimicking the traditional engraving process. Sophisticated software like MuseScore [1], or Lilypond[2] (Nienhuys H.-W., Nieuwenhuizen J. 2003) – to cite just a few among free software - provide very efficient ways to generate music scores but for traditional usages i.e. similar to paper scores.

Acousmatic and electro-acoustic music genres have lead to new forms of graphic representation of the music, for analytic and musicological purposes, with music scores made *a posteriori*. This kind of notation has found little support from computer music, apart the approach proposed for years by the Acousmograph (Geslin and Lefevre, 2004) or more recently with EAnalysis (Couprie 2012).

Premises of interactive music are present for a long time. Stockhausen (Stockhausen 1959) or Cage with the Variation series (Cage 1960-1966), have explored indeterminacy and performers interaction, with specifically designed music scores. But with the use of computers, interactive music has become a common musical form.

More generally, the music score has to face the new musical forms resulting from the digital tools used at all levels of the music process, from composition to performance, including live coding (Magnusson T. 2011). It has also to face the migration of musical instruments to gestural and mobile platforms, hybridizations with dance, design, and multimedia.

Music notation generated in interaction with live performance exists for more than a decade. As mentioned by Freeman (Freeman 2011), numerous approaches exist: selection of pre-determined score excerpts (Kim-Boyle 2005), mixture of symbolic and graphic elements (Winkler 2004), use of unconventional graphical notation (Gutknecht & al. 2005), complex staff based notation (Didkovsky 2004).

These works are based on custom tools that are generally specifically suited to a composer approach. Didkovsky used JMSL (Didkovsky, Burk 2001), a programming language for Java applications, to design interactive scores. Baird is using Lilypond for audience interaction (Baird 2005). Lilypond can't be considered as a real-time environment for generating music scores, but it works in Baird's context due to relaxed time constraints.

With the recent Bach (Agostini, Ghisi 2012) or MaxScore (Didkovsky, Hajdu 2008) environments, the symbolic dimension of the music notation starts to be accessible to interaction using common tools.

Representation of the interaction process may also help for the design and the performance of interactive music pieces. When a computer is involved in a performance, almost no feedback is provided to the performer regarding the interaction system state. When there is, the system displays information like cues, time, or pedals state on a separate monitor that is presented is parallel to a paper score. Most of the time, the performer has to concentrate on the score, which makes the separate display hard to follow.

(François & al.2007) has designed a system for visual feedback in performer-machine interaction that is focusing on musical improvisation. In the improvisation domain, OMax is also proposing a visualization (Lévy & al. 2012) under the form of a graphic representation of the Factor Oracle graph.

Mostly, audio feedback remains the main channel to convey the interactions system state, which is far from being sufficient in many cases.

Performance representation may also be valuable for the performer in rehearsal situation or for pedagogic purpose. For the latter and based on a mirror metaphor, experiments have been made to extend the music score in order to provide feedback to students learning and practicing traditional music instruments (Fober &al. 2007). This approach was based on an extended music score, supporting various annotations, including performance representations based on the audio signal, but the system was limited by a monophonic score centred approach and a static design of the performance representation.

In regard of the issues above and of the contemporary music creation needs, a unified environment, covering symbolic and graphic notation, opened to real-time interaction is missing from the current landscape of solutions for digital scores and music notation. This has been the main motivation for the development of INScore, an environment for the design of augmented interactive music scores (Fober & al. 2012a).

The next sections give an overview of the INScore environment and of the main technologies involved. Next, this article explains how these technologies are involved in the creation of innovative music scores. Examples of use in concrete artistic situations are given with pieces from Richard Hoadley, Sandeep Baghwati, Jean-Baptiste Barrière and a modelling of *Turenas* from John Chowning.

INScore Overview

INScore is an environment for the design of interactive augmented digital music scores. It extends the traditional music score to arbitrary heterogeneous graphic objects:

- symbolic music notation using the Guido Music Notation format (Hoos & al. 1998) or the MusicXML format (Good 2001),
- text (utf8 encoded or html format),
- images (jpeg, tiff, gif, png, bmp),
- vectorial graphics (basic shapes like rectangles, ellipses, bezier curves or SVG),
- video,
- an original performance representation system (Fober & al. 2010).

Each component of a score has a graphic and a temporal dimension and can be addressed in both the graphic and temporal space.

The graphic properties include common attributes like position, scale, colour, basic transformations like 3-axis rotations, shear, and effects like blur, colorize or shadow.

The time properties include a date and duration.

Time synchronization in the graphic space

A simple formalism is used to describe relations between the graphic and time space and to represent the time relations of any score components in the graphic space on a *master/slave* basis.

The formalism relies on segments and mathematical relations between segments. Time segmentation constitutes the spine of the system. Each object includes at least one *mapping* that is a relation between the object graphic and time segmentations. Composition of different objects relations through their time segmentation results in a *graphic-to-graphic relation* that expresses the objects time relationships in the graphic space.

The scope of this formalism extends beyond the music score context and could be used as well to described relations between gestures and audio in a performance setting. A detailed description is available from (Fober & al. 2012b).

Figure 1 shows graphic rectangles used as time cursors and synchronized to a symbolic score.

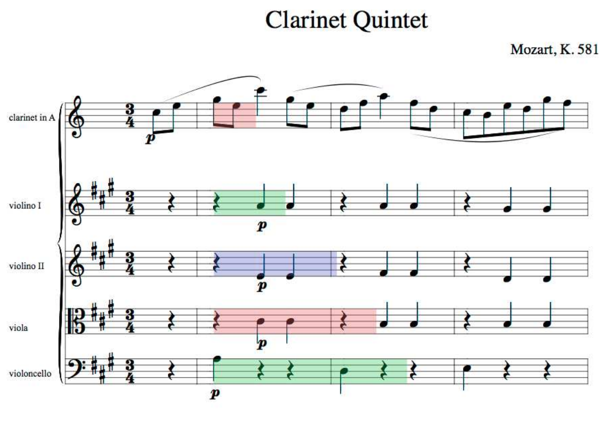

Figure 1. A multi-voices score with synchronized cursors. The cursors date is '1/4' and their duration varies from 1 to 5 quarter note. The cursors' width is graphically extended to the corresponding score duration.

Performance representation

Performance representation proved to be valuable in particular in a pedagogic context (Fober &al. 2007).

INScore includes a performance representation system based on signals (audio or gestural signals). The system approaches the graphic of a signal as a *graphic signal*, i.e. as a composite signal made of several signals in parallel:

- a y coordinate signal
- a thickness signal
- a color signal

Figure 2 illustrates the components of a graphic signal at a time *t*.

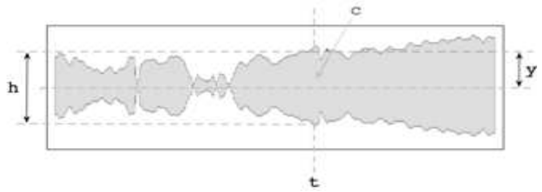

Figure 2. A composite signal at a time *t*. Any vertical graphic slice is defined at a time *t* by its *y* coordinate, a thickness *h* and a color *c*.

A composite graphic signal includes all the information required for drawing without additional computation. It constitutes a very flexible system to elaborate dynamic representations of a performance. Figure 3 gives the example of a combination used to represent both pitch and articulations.

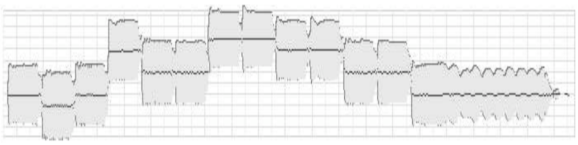

Figure 3. Pitch and articulation combined in a single representation using f_0 and *rms* values in parallel.

The graphic signal *g* is expressed using 3 signals in parallel as follows:

$$g = S_{f0} / S_{rms} / k_c$$

where S_{f0} is the fundamental frequency, S_{rms} is the RMS values and k_c is a constant colour signal.

A message based system

INScore is a message driven system that is based on the Open Sound Control [OSC] protocol (Wright 2002).

An OSC message is composed of an address, specified like a Unix path, followed by arbitrary parameters. The parameters type is among *integer*, *floating point* and *string* values. Example:

```
/mysynth/channel1/vol  0.7
```

INScore specializes the basic OSC format with a string as first parameter that describes an action or an attribute of the target object of the OSC address (Figure 4).

Figure 4. General format of an INScore message.

For example, the following message:

```
/ITL/scene/score x 0.8
```

addresses an object named *score* to set its *x* position attribute to 0.8.

Messages are provided to control the graphic and time attributes of the score components, to design graphic signals, to synchronize objects and to describe interactive behaviours.

The set of supported messages constitutes the application programming interface [API] and the main way to design music scores.

This message-oriented design opens the door to remote control and to interaction using any OSC capable application or device (typically Max/MSP, Pure Data, but also Python, CSound, Super Collider, etc.)

Musical process representation

Representation of musical process may be critical for the performer in case of interactive music. Existing representation systems are coupled to specific environments and disconnected from the music representation itself.

INScore approach to process representation is inspired by (Berthaut & al. 2013), where the objective was to improve audience experience notably in the case of electronic music. Computer musical processes are characterized in (Fober & al. 2014). From INScore viewpoint, a process state and activity is denoted by signals. INScore allows connecting a signal to any graphic attribute of a score component (position, rotation, scale, colour…). This way, any object of a score may convey information about interaction processes.

Events based interaction system

INScore provides interaction features provided at score component level by the way of *watchable* events. These events are typical UI events (like mouse clicks, mouse move, mouse enter, etc.) extended in the time domain (time enter, time leave, etc.). The principle consists in associating a list of messages to an event (Figure 5). When an event occurs, the associated messages are triggered.

Figure 5. Basic mechanism to describe interactions: a set of messages is associated to an event by sending the *watch* message to an object.

The messages could be any valid INScore message but arbitrary messages as well, which can be send to any external application using an extended address scheme.

Plugins

INScore can be dynamically extended via external plugins, which are loaded when the corresponding objects are created. It supports currently 2 extensions, one in the domain of gesture following with the IRCAM gesture follower (Bevilacqua & al. 2010), another one in the domain of signal processing with the FAUST compiler (Orlarey & al. 2009).

With the gesture follower, specific events are available to design gestural interactions.

The FAUST compiler has been included to provide pre-processing of signals for representation purposes (performance of interaction process representation).

Scripting language

A textual version of the OSC messages that describe a score constitutes the INScore storage format. This textual version has been extended as a scripting language with the inclusion of variables, extended OSC addresses to control external applications, and support for embedded JavaScript sections.

INScore script files can be dropped to score windows to *send* the enclosed messages. It constitutes an original way of programming since these files may represent a score, but interaction features as well. In a given way, one may think of script files as an extensible commands system.

An open source software

INScore is an open source software that is available from SourceForge[3]. It runs on the main operating systems (GNU Linux, Windows and MacOS).

INScore in Music Creation

Since its first public release, INScore has been used in several musical creations, notably to design interactive music scores.

Calder's Violin

Calder's violin has been composed by Richard Hoadley and was premiered in Cambridge on October 2011. The piece is defined as "*automatic music for violin and computer*". It involves the live presentation of common practice symbolic music notation created through algorithmically generated material (Figure 6). The notation is then performed by a human musician alongside computer-generated diffused sound or other 'real' musicians. Technologies used include the SuperCollider audio programming environment and INScore with the OSC protocol used to communicate between them. More details can be found in (Hoadley 2012).

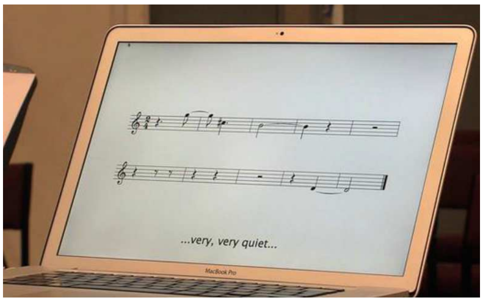

Figure 6. Calder's Violin - a typical output as displayed to the performer.

Alien Lands

"*Alien Lands*" is the title of a concert given in Montreal in February 2011, entirely dedicated to Sandeep Bhagwati. Three compositions were presented: *Alien Lands*, *Monochrom*, and *Nil Nisi Nive*. All the pieces were using INScore for presenting the music score to the performers, with uses that fall in 4 different categories:

- *automatic traditional music score*: the system is used as a traditional music score but with automatic page turning.
- *music score with computed choice*: in *Divide* (a movement of *Alien Lands*), the performer was instructed to change the order of the measures, lines etc. With the INScore version, the choice was made by the computer and the pages simply presented to the musician.

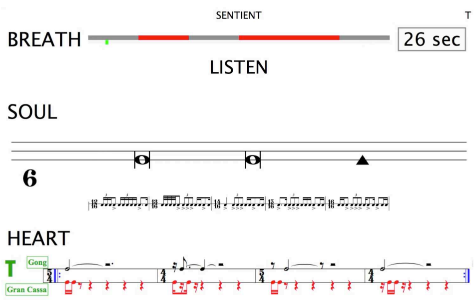

Figure 7. A *complex computed music score* as presented to the performer.

- *complex computed music score*: in *Sentient* (last movement of *Alien Lands*) and *Monochrom* 1 & 2, the computer was automatically distributing the score pages. Some elements of the score were generated algorithmically in real-time (like instructions, notes, some elements remained unchanged. A counter was displaying the remaining time. Red and grey coloured boxes at the top of the score were indicating when to play (Figure 7).
- *complex interactive score*: in *Nil Nisi Nive*, the performer was controlling the musical elements. The score was generated algorithmically but on performer request, who could ask for a new page at any time.

Miroirs distants

Miroirs distants has been composed by Jean-Baptiste Barrière and was premiered in Lyon and New York, in March 2014, during the Musiques en Scène biennale.

It proposes a special musical situation: two flautists are face to face, look and play straight in the eyes while they are in two remote locations (Lyon and New York for the creation), through what appears to be a large electronic mirror, reflecting both their image and that of the distant performer. The resulting enigmatic image must be deciphered and interpreted: it is in fact a music score (Figure 8).

Figure 8. Aesthetic and musical functions of the score in *Miroirs distants*.

The composition of the image has two functions: one plastic, the other musical. Part of the aesthetic challenge of this project was to mix the two without compromising the quality of both functions.

The image is generated in real-time using a combination of Max/MSP-Jitter and INScore for the symbolic music notation.

Turenas

Turenas has been composed by John Chowning in 1972. It was one of the first electronic compositions to have the illusion of sounds moving in a 360-degree space. A graphic transcription of the piece has been designed by Laurent Pottier (Pottier 2004), which has been turned into an interactive score with INScore (Figure 9).

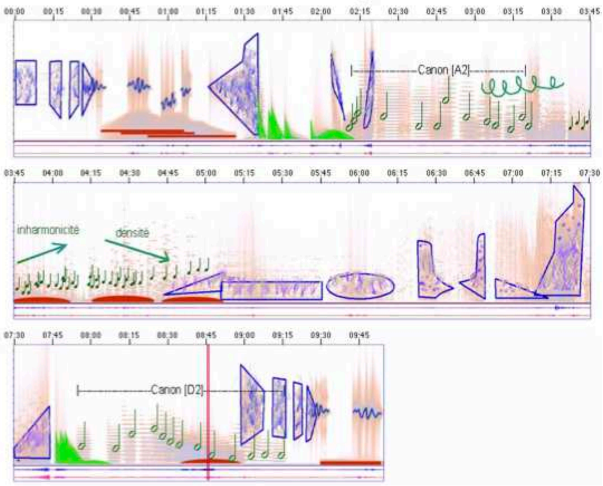

Figure 9. *Turenas* score, as transcribed by Laurent Pottier and as it appears in INScore. A red cursor indicates the current position in the audio recording of the piece.

The whole piece modelling makes use of Max/MSP or Pure Data to play the audio file and to send clock messages to INScore, in order to move a cursor to the corresponding time location.

The score implementation supports multiple views, which can be switched by simple drag & drop of INScore scripts, even in real-time. Figure 10 displays a structural representation of the piece, presented on a single line. In this case, the master/slave synchronisation scheme is inverted: master object is the cursor and the graphic representation is slave of the cursor, which has the effect to scroll the score when the cursor moves in time.

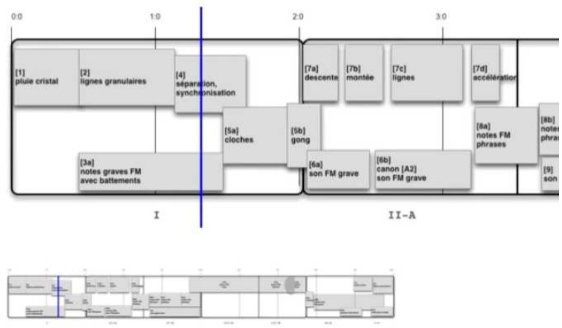

Figure 10. A structural view of *Turenas*. The score is presented as a single line. The bottom view gives the whole score overview and can be used to move the current reading position. The blue cursors indicate the same time position in both views.

The score makes use of interactive features: mouse clicks trigger time position messages that are sent to the audio player and internally to the cursor as well. Time events are used to temporary display analytic information over the score, as if living only for a given time span.

Conclusion

Computer technologies for music notation start to be mature enough to support new forms of representations and new artistic forms based on digital scores. Today, many interesting approaches exist, but music notation is mostly used as auxiliary to the composition and writing tools.

Although the way we represent the music is central to the composition process and thus to the musical thought, it is also critical for the performer. Indeed, with the preservation role, the transmission function has been one of the primary orientations of the music notation, which influences the composition process as well.

Today, tools for the performance start to emerge, proposing new approaches to music notation. Although it supports many applications, INScore can be focused to performance issues and proposes a graphic space opened to arbitrary representations (from symbolic notation to pure graphics) and features especially designed to take account of the dynamic aspects of the notation explored by interactive music.

As shown by the presented artistic works, INScore is mature, stable and ready to be involved into music creation. However, it remains an on-going project that takes place in a global research on music notation and representation. Future extensions should enforce the scripting approach in order to develop the system programmability. Migration to mobile platforms (e.g. tablets) and to the Web is also planned, and issues like collaborative approaches to music score design, web performance using shared scores, should be part of future research.

Technological note. INScore makes use of the following technologies:

- The GUIDOEngine[4]
- The IRCAM Gesture Follower[5]
- The FAUST Compiler[6]
- The Qt5 cross-platform application and UI framework[7]
- The V8 JavaScript Engine[8]

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[1] http://musescore.org/

[2] http://www.lilypond.org/

[3] http://inscore.sourceforge.net/

[4] http://guidolib.sourceforge.net

[5] http://imtr.ircam.fr/imtr/Gesture_Follower

[6] http://faust.grame.fr/

[7] http://qt-project.org/qt5

[8] https://code.google.com/p/v8/