On the Realization of NuoNao and Prêâ, 
Two Pieces for Solo Instruments and Ircam Signal Processing Workstation

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Abstract
NuoNao and Prêâ are two solo pieces, one for flute, the other for cello, realized during 1992 by Kaija Saario and the Ircam Signal Processing Workstation (ISPW, based on the Next computer), and with Xavier Chabot from the Ircam Pedagogy department, in the pedagogical perspective to explore the potentialities of Max on the ISPW, and specially its connexion with Patchwork used to prepare data and patches. In the two pieces, the electronic parts amplify and develop the sonic structure of the solo instrument, exemplify the close relationship between sound material and musical structure, and explore real-time strategies for control over various synthesis and signal processing algorithms.

1 Introduction: timbre and harmony, from analysis to performance
Kaija Saario is interested in timbre as an extension of acoustical instruments and as a globalisation of sonic phenomenon. Consequently, she is interested in the idea of a timbral space, in which one can define variations and interpolations, and finally by the relations between timbre and harmony, which allows her to unify instrumental and syntactical writing. These ideas are present in nearly all her pieces with sound synthesis. K. Saario generally uses two types of models for the control of synthesis: referential models, based on unprocessed analysis data of an instrumental sound; and abstract models, created after compositional and psychoacoustical selection criteria on analysis data of the same instrumental sounds. Referential models, for example models of resonance, are used for sound synthesis and sound processing. For each work a specific set of such models is created in order to define a timbral space which permits timbral interpolations controlled by compositional processes. Synthesis or referential models allow stepping out of the normal behavior of instrumental sounds: for instance gong models with glissandi of partials, or with timbral and harmonic transformations, processes which again, are under compositional control.

Abstract models can be interpolated with referential models and are used mainly to embody the timbre/harmony relationship. They can be seen as chords which, depending on their content will fuse in one timbre, or separate as a more or less inharmonic chord. The composition aid environment Patchwork [Laurson 1989][Malt 1993] is used at all stages of the development process: producing analysis commands, getting, displaying, and processing analysis data, producing synthesis data and control structures; see [Barrière 1993] for examples.

Both NuoNao and Prêâ tend to create a continuum out of very contrasting musical material. Several layers of processes (for instance pitch, rhythm, playing mode transformations) add up and evolve independently or in correlation, resulting in a very rich and complex texture although coming from a solo instrument such as the cello or the flute. Each of these interpolation processes implies a movement; one has to invent directionality that can really be perceived and make sense in the composition, by playing on polarities and contrasts between models. In this way, synthesis becomes an integrated resource to music composition. In NuoNao and Prêâ, these analysis and interpolation processes are used not only in the instrumental writing or for the production of synthetic models of prepared sounds, but also in real-time with various strategies of realization depending on the musical and technical contexts. For both works the instrumental score was completely written out before starting developing the live electronics part. Sound synthesis and transformation are not meant to stage new equipment; in fact they are independent of a particular machine (several versions already exist for various setups). The electronic part is meant to develop, amplify, underline musical processes, instrumental gestures, and
sonic material; it is thought as resulting from the music composition and the performance rather than the opposite. The two pieces also have to be related to other works by Kaja Saariho for the same instruments: Lacaunisme de l'aile (1982) for solo flute, Pétails (1986) for cello and electronics, A la fumée (1991) for solo cello, alto flute and orchestra, Amera for solo cello, ensemble, and live electronics (1992).

2 NoaNoa

NoaNoa is a piece for flute and the Ircam Signal Processing Workstation (ISPW, based on the Next computer) [Lindemann, 1991]. The basic material includes various classes of playing modes and patterns controlled by several layers of interpolation processes. For example the 'trill' class includes: mordant, trill, microtonal trill, vibrato, flutter tongue, multiphonics; the 'noisy' class includes: breathy notes, overflowing into harmonics, speaking in the flute, tonguing with spoken phonemes, multiphonics, flutter tongue; the 'pattern' class includes: scale, microtonal scale, glissando, repetitive pattern, etc.

The real-time electronics part implements the following modules: a prepared 'sampled flute' able to interpolate continuously between normal flute sound, breathy flute sound, and flute with phome tonguing; time stretching modules used to playback recorded speech at various speeds and to control playback loops; infinite reverberation units with glissando, tremolo, and vibrato features, a convolution module able to sample spectra on the fly and to convolve them with the instrument sound (see below); models of resonance modules (bank of filters whose parameters are derived from a specific analysis technique developed at Ircam) [Barrère, 1985] [Postard, 1986] [Bainsée, 1986]; finally, commonly used modules such as harmonizers, delays, reverberation unit.

The control structure is built around the pitch tracker and the score follower [Puckette, 1992] which triggers enabling and disabling modules and processes, establishes module interconnections, and triggers data uploading. The piece in its last version is highly interactive and almost every module is controlled in real-time from the flute using pitch inflection, amplitude, trill speed, spectral content, note duration, and articulation. Control data pre-computed by Patchwork consists of pitch and rhythm sequences, timbral interpolation trajectories, reading trajectories in a sampled spoken phrase, and models of resonance data, and is prepared and packaged for Max with the aid to composition environment Patchwork.

2.1 Example of real-time convolution with Max-ISPW

Let us detail here the convolution module. The multiplied spectrum is the performing instrument, while the multiplying spectrum is static and stored in a table, but can be updated in real-time.

The Max-ISPW 'ftr-' module takes a sample stream, or 'signal', at its input and outputs two 'signals': the real and complex parts of the transform, plus one output sending a trigger message with each new FFT window. Convolution here is performed by multiplying each sample of both the real and complex parts of the FFT by the sample corresponding to the same frequency read in the multiplying spectrum table. Thus the multiplying spectrum table must be read synchronously with the output of the FFT samples. This is done through a Max extern object realized by Z. Settel, which takes the message from the 'ftr-' module and outputs samples one by one. The multiplying spectrum table is updated as often as needed, either entirely or reset and written at selected frequencies. Convolution was used in the following cases. First, simple filtering, where the spectrum table is set with frequency/amplitude pair lists obtained from the lana program [Assayag, 1985] (implementation of Terhardt's algorithms) [Terhardt, 1982] analysis and processed by Patchwork. Such a filtering is static but a sequence of frames can also be played back as in additive synthesis. The result sounds like an efficient implementation of a bandpass filter bank with fixed bandwidth. Second, cross-synthesis between two spectra, where the multiplying spectrum is written on the fly during performance by another fft module connected to the live instrument input. Several spectrum tables can be sampled and mixed before being written in the multiplying spectrum table.
This has been used to cross-synthesize an instrumental sound with such a characteristic spectral shape as a vowel. For example, in *NoaNoa*, spectra of vowels sung by the flutist while playing, or of a breathed low C, are memorized and convolved later with the flute sound.

The title of the piece refers to a woodcut by Paul Gauguin called *NoaNoa*. It also refers to a travelling diary of the same name, written by Gauguin during his visit to Tahiti 1891-95. The fragments of phrases selected for the voice part in the piece come from this book. 

*NoaNoa* is also a team work. Many details in the flute part were worked out with the flutist Camilla Eifizenga to whom the piece is dedicated.

Another version for Macintosh was realized by Alexandre Mihalic; here the performer sends triggers to Max, thus controlling a direct-to-disk, on which all transformations have been recorded, and a digital reverberation whose parameters are controlled by the amplitude of the flute.

**1 Prés**

Prés for cello, ISPW, and direct-to-disk, was developed at the same time than *Amers* for solo cello, ensemble, and electronics. The original idea and the basic material of the solo cello part is similar for the two works, but form, structure, sound space, and overall atmosphere are very different. The cello is mounted with a special microphone originally developed for *Amers*; this microphone is made of four pickups which allows isolating the audio signal of the four strings from each other. Thus a single bow stroke becomes a spatial gesture. The first of *Prés* three sections centers around analysis at successive time intervals, of an evolving cello

trill which is at the beginning of *Amers* and *Prés*. The analyzed trill alternates between normal sound and natural harmonic sound, and evolves from normal playing 'slustasto' to playing with more bow pressure 'sul ponticello'. Two spectra are deduced from each analysis: a complete spectrum with all components and a reduced spectrum holding only components which are perceptually relevant, after frequency masking. An analysis set taken at the beginning of the trill is quasi harmonic while another set, taken towards the end of trill when the sound is noisy and, richer in inharmonic partials. For each set, synthesis of the complete spectrum gives a unique timbre while synthesis of the reduced spectrum generates a set of pitches, that are perceived as an harmony. Many more sounds were analyzed to give material for *Amers* and *Prés* but the analysis of this first trill is central for the piece in defining the movement between harmonic relaxation and tensions as well as the coherence between instrumental and synthetic sounds.

More transformation processes run concurrently with the duality timbre-harmony. First, playing modes transformations (which induce timbre transformation) for example normal sound-sul ponticello-sul tasto, or trill-remolo-glibissando-microtones-harmonics, or again normal sound-natural harmonic-under pressured-over pressured bow (the last one producing a noisy 'scratched' sound) and more generally the transformation of sound into noise, represented by the 'scratchy' cello sound and its counterpart: ocean waves samples. Second, rhythmic processes. Third, the opposition between static and dynamic elements. Each of these processes in the cello part has its equivalent in the electronic part. The second section deals with spatialisation of the four strings. The cello part is made of pseudo regular and repetitive patterns which spreads out on the four strings and thus in space, and overlaps with playing noise transformations as in the first section. The electronic part is based on a 'sampled cello' which is able to interpolate between sounds with more or less harmonics; the sampled cello is controlled by independent processes for rhythm and timbre variation, and creates with the live cello a dense polyrhythmic
texture. The contrast pure/noisy is introduced again in the cello part, this time being sudden instead of progressive, and is amplified in the electronics by the playback of a 'cluster' sound and the activation of a real-time time stretching module.

The third section summarises ideas from the two first sections. The research for both Amor and Près was conducted by Kaija Saariaho with the cellist Ants Karttunen who also created the pieces, and with Ramon Gonzales-Arroyo and Xavier Chabot for the electronic part.

The real-time computer processing allows creating various textures starting from cello sounds, and evolving between noisy and crystalline character, echoing the violence and the quietness of the sea.

The title Près, or rather Près de la mer (close to the ocean) is referring first to the twin piece. It also refers to the poetry of Saint-John Perse, and specially his work Amor, "(...) 'Sea of trance and infliction', it initiates to all the experiences which allow man to cross the usual borders" [Sacotte, 1991]. In Amor, the cello is a navigator who directs himself toward different aims between the waves created by the others instruments and the synthesised sounds. Près is more concentrated on the navigator himself, on his thoughts and reactions when looking at the sea, 'diversity in the principle and parity of the being'.

4 Conclusion: composing timbre
Près and NoaNoa are fighting against the limits of a solo piece. To find ways of extension, Kaija Saariaho is using an electronic set up, which allows her to amplify, to multiply, and to extend the sonic structures of her writing for cello or flute. They were made in the spirit of experimentation with instrument timbre and its relationship to synthesis. Interaction between instrument and computer is not only based on digital signal processing and intelligent feature detection modules, but relies also on the coherence of the underlying compositional concepts.

References