Interaction Strategies in Composition for Karlax and Acoustic Instruments

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Abstract. The Karlax is a gestural controller which arose substantial interest among composers since its inception in 2010 and continues to be commonly used in solo and group performances. One of the reasons for its longevity is the device's remarkable adaptability, especially in musical contexts involving acoustic instruments. This article analyses six chamber music pieces for Karlax and acoustic instruments by comparing performance videos, sounds generated, and the writing process (scores, sound synthesis, and mapping strategies in each piece). We further discuss the various composition strategies using interaction metaphor concepts from the computer music literature. These metaphors prove to be powerful analysis tools that allow describing the use of a digital musical instrument in a chamber music context. In the last part of this article, we discuss five such interaction strategies and their use in sketches of an original composition for Karlax and ensemble.

Keywords: Digital Music Instruments (DMI) · Mixed pieces · Computer Music · Electronic Music · Input Devices · Mapping · Interaction Strategies

1 Introduction

Though several hundred interfaces for musical expression have been developed and described in a variety of venues, most notably in the last two decades at the International Conference on New interfaces for Musical Expression (NIME)[1], relatively few articles discuss how these interfaces ares used in actual musical contexts, for instance [4,13,14] and [7]. Indeed, the use of DMIs is not often discussed from the perspective of artistic and musical composition. In other words, *the "M" in NIME*: why don't we talk more about music performance with musical interfaces, beyond sound control? In part, this is the consequence that most of the interfaces described in the literature have short life spans and/or are mainly used by their designers [5]. In this sense, the Karlax offers a vibrant subject of study with an existence of more than ten years, a community of regular users from different musical cultures, and several significant creations, notably with acoustic instruments, incorporating some form of music notation.

The Karlax is an input device in the shape of a clarinet or soprano saxophone that combines various sensors: ten continuous keys, eight velocity pistons, an inertial

[1] www.nime.org.

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https://doi.org/10.1007/978-3-031-35382-6_13

measurement unit, and several switches (Fig. 1)[2]. It also includes a rotary axis with bends at each end, allowing the performer to rotate controller's axis, a degree-of-freedom also explored in Cook's Hirn Controller [2]. Musicians have praised its "ability to detect subtle as well as larger gestures, continuous as well as event-based control, its low latency and high bandwidth, its reliability and portability" [10]. Like many musical interfaces that output sensor data but do not have a pre-defined sound, the Karlax is defined solely by its control characteristics, i.e., its gestural affordances, instead of a given sonic palette. This opens up unlimited musical possibilities but requires the composer to describe the sounds controlled and the mapping between sensor data and sound generation to be used in each context. A digital musical instrument (DMI) comprises the control interface + mapping + sound generation [12].

In a general way, we can define the "identity" of Karlax in three ways. First, *what remains unchanged for each project*: that is to say, the physical object, its control qualities, the types of data sent by the interface (MIDI mainly), and the basic gestures it allows. Secondly, *what concerns the writing of the Karlax instrument and which is specific to each project*: the choices of sound synthesis and mapping, gesture writing, notation, etc. Finally, *what has to do with the interactions with other instruments and devices*. Given that the Karlax is a controller, it allows us to consider many types of interaction, particularly in real-time, which are typically determined during the composition.

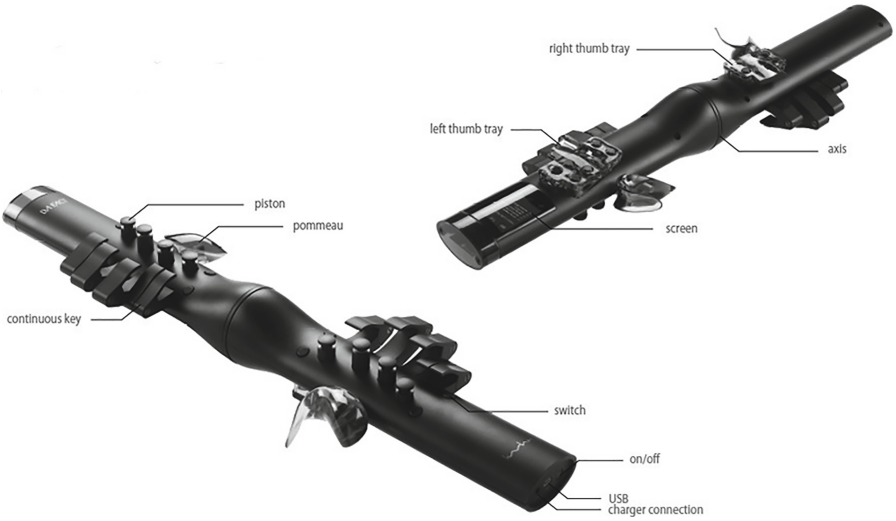


Fig. 1. Front and rear views of the Karlax (Source: www.dafact.com)

This study analyzes a corpus of six pieces for Karlax and acoustic instruments from audio and video recordings, scores, Max/MSP patches, presets, and information from published articles. We first identify three compositional models defining the main areas

[2] www.dafact.com.

of inspiration. In a second step, we discuss excerpts in the corpus by detailing the action of the Karlax and its interaction with the acoustic instruments, thanks to interaction metaphors from computer music. Finally, we comment on the use of interaction strategies in an original composition for Karlax and an ensemble of 14 acoustic instruments.

2 Analysis of the Pieces

We have selected six pieces written between 2013 and 2018 that combine the Karlax with one or two acoustic instruments, including a flute, a violin, and a cello.

1. *Fogg* by Lorenzo Bianchi for violin, cello and Karlax, 2013 (performed by *Fabrique Nomade* ensemble)
2. *Frottement, Bourdon, Craquement* by Francis Faber for cello, Karlax and electronic, 2013 (performed by *Fabrique Nomade* ensemble)
3. *Le Patch Bien Tempéré III* by Tom Mays, for flute, Karlax and real time electonic, 2013 (performed by *Fabrique Nomade* ensemble)(abbreviated *R.N.C.B.*)
4. *Ripples Never Come Back* by Michele Tadini for violin, cello and Karlax, 2013 (performed by *Fabrique Nomade* ensemble)(abbreviated *P.B.T.III*)
5. *Discontinuous Devices "In-between"* by Michele Tadini for cello and Karlax, 2015 (performed by *Fabrique Nomade* ensemble)(abbreviated *D.D.*)
6. *Le Violon, l'Oeillet et le Bambou* by Raphaël-Tristan Jouaville, for violin and Karlax, 2018 (abbreviated *V.O.B.*)

Five of the six pieces have been commissioned and performed by the *Fabrique Nomade* ensemble. This ensemble is an "electronic chamber music ensemble that wishes to rediscover the gestures and listening of classical chamber music"[3]. In this regard, "each musician is independent and has total control over their acoustic or electronic instrument" (each instrumentalist has their laptop and sound broadcasting system). It means acoustic instrument performers trigger their own electronic part, mostly real-time sound processing, thanks to a midi pedal. Furthermore, the Karlax does not process the acoustic sound of an instrumentalist in real time. This is not the case for the sixth piece, where the Karlax transforms the violin's sound in real-time in addition to having its own sound synthesis.

2.1 Sound Synthesis and Mapping Strategies

Table 1 indicates the main types of sound synthesis used in the pieces of the corpus. Tables 2, 3 and 4 indicate the mapping strategies for each Karlax sensor for the six pieces[4].

We can observe different trends in the use of the Karlax sensors. For example, the activation of the keys follows two main models. The first consists of associating to the keys the amplitude of different voices of the same type of sound synthesis as frequency

[3] www.fabriquenomade.com.

[4] P1 for piston 1, K1 for key 1 of the Karlax.

Table 1. Sound Synthesis types in the corpus pieces

Pieces	Sound synthesis type
Fogg	Additive synthesis and Sampling
R.N.C.B.	Subtractive synthesis and Sampling
P.B.T. III	Phase Aligned Formant Synthesis (PAF synthesis)
F.B.C.	Synthesized sounds from *Reaktor, Kontakt and Absynth* softwares
D.D.	Sampling
V.O.B.	Physical modeling from *String Studio* module

Table 2. Mapping strategies for keys and pistons

Pieces	Pistons	Keys
Fogg	– Trig sounds (velocity controls playback rate)	– Control volume parameter of 'voices' of the additive synthesis)
R.N.C.B.	– P1: Volume accent – P2–4: Trig sounds – P5–8: Change chords	– Control parameters of a stream of pitches (K1: Volume, K2: Note repetition, K3: Arpeggiation, K5: Random volume change, K6: Envelope, K7: Speed up, slow down, K8: Distortion, K9: Pitch Bend, K10: Filter)
P.B.T. III	– Trig sounds	– Control volume parameter of the voices of the "PAF" synthesis)
F.B.C.	– Synthesized sounds from *Reaktor, Kontakt and Absynth* softwares	– Control parameters of the synthesised sounds (K1: Oscillations, K2: Glide effect, K3: LFO, K4: Envelope, K5: Feedback, K9: Echo effect, K10 Acceleration)
D.D.	– Trig sounds	– K1: Reverb (Part I) – K1–10: Volume of looped samples (Part III)
V.O.B.	– Play and hold violin-like sounds (*String Studio*)	– K6: Activate Trill mode in *String Studio* – K7–8: Activate Damp mode in *String Studio*)

bands (*Fogg*, *P.B.T. III*, *D.D.*). In the second model, each key controls additional processing of the main sound stream (*R.N.C.B.*, *F.B.C.*, *V.O.B.*). Piston's use seems to follow a central model of activation and holding of sounds. We note a convergent mapping (described in [15]) type in *Fogg* where the indication of the velocity of the piston will be associated with the playback rate (the higher the velocity indication, the faster the sound is played). The axis is mainly used to modify the timbre of a sound flow (*P.B.T. III*, *Fogg*, *R.N.C.B.*, *D.D.*), more rarely associated with the amplitude (*V.O.B.*, *D.D.*). The bends are not used much and describe mostly accent-type sound morphology (*Fogg*). Motion sensors have different functions. They can control changes in timbre, pitch, or volume. We observe that the roll axis is privileged for pitch and volume control: upward gestures are associated with volume increasing or pitch shifting from the low to the high register.

Impulse/jab gestures are not used much. Finally, switches are rarely used because, for most of the pieces, the activation/deactivation changes are written in the program score (often in MAX/MSP environment). However, the use of switches will allow modifying specific characteristics in real-time, such as the activation of plug-ins (*V.O.B*). In rare cases, they are used to trigger sounds (*R.N.C.B.*).

Table 3. Mapping strategies for axis and bends and inertial units. Note that the mapping data for *F.B.C* concerning the axis bends and inertial unit are missing

Pieces	Axis and bends	Inertial Units
Fogg	– Comb-Filter (frequency), bend (accent)	– Inclin-roll axis: Comb-filter (volume)
R.N.C.B.	– Pitch center of the chord of the stream	– Pitch-axis: envelop and filter
P.B.T. III	– Variable speed tremolo	– Roll-axis (Acc-z): Volume and brightness – Pitch-axis (Acc-x): pitch glissandi
D.D.	– Volume (Part I) – Oscillation speed and resonance (Part II)	– K1: Reverb (Part I) – K1–10: Volume of looped samples (Part III)
V.O.B.	– Volume	– Mass parameter in Damp mode of *String Studio* plug-in – Parameter nodes in *GRM Tools* Plug-ins

In the corpus pieces, the data sent from Karlax are mapped without specific conditioning. The conditioning step transforms the raw data emitted by the Karlax into "cooked" data using algorithms. For example, Karlax contains two types of conditioning: signals from the inclinometer and impulses, both calculated from the accelerometer and gyroscope data. The piece *Ritual* (2015) by Andrew Stewart, for Karlax solo, has a significant conditioning phase of the raw Karlax signals, which provides essential insights into the composition of the Karlax, particularly in terms of gestural vocabulary. Even if this piece does not fit in with our study, its gestural approach elicits original interaction strategies.

The choices of synthesis and mapping have important consequences in the interaction strategies used, depending on whether the sound and gestural identity of the Karlax is close or not to the instrument with which it interacts.

Table 4. Mapping strategies for switches and impulses

Pieces	Switches	Impulses
Fogg	– Not used	– Not used
R.N.C.B.	– Trig sounds	– Not used
P.B.T. III	– Not used	– Not used
D.D.	– Volume (Part I) – Oscillation speed and resonance (Part II)	– K1: Reverb (Part I) – K1–10: Volume of looped samples (Part III)
V.O.B.	– Activation of Plug-Ins (*GRM Pitch Accum* and *GRM Delays*	– Mass parameter in Damp mode of *String Studio* plug-ins – Parameter nodes in *GRM Tools* Plug-ins

3 Composition Models

Among the corpus pieces, we have identified three compositional models representing three main sources of inspiration for the composers: model based on acoustic sounds, model based on electronic sounds, and Karlax as model. These allow describing the "role" of this controller in relation to the other instruments.

Model Based on Acoustic Instruments Sounds
For several pieces in the corpus, the acoustic sound of the instrument(s) with which the Karlax plays is used as the basic composition material. For example, in the piece *Fogg*, the sound synthesis of the Karlax is realized through an additive synthesis from the spectral analysis of several violin pizzicati with different "preparations" (addition of objects like pegs attached to the string). The Karlax triggers and controls processes related to the spectral content of pizzicato sounds by pressing continuous keys (control of the spectral envelope) (Fig. 2).

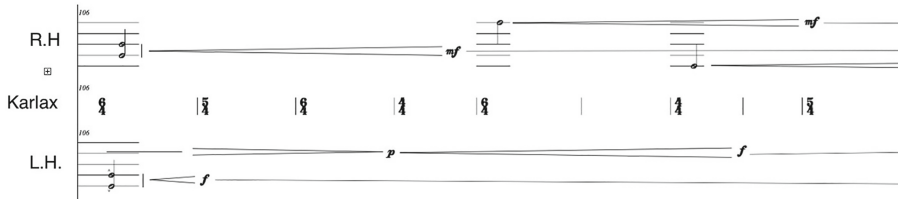


Fig. 2. "Shaping" of the spectral envelope with Karlax continuous keys in *Fogg* by Lorenzo Bianchi (mes. 68–69, karlax part) (with the permission of the composer). Each staff line represents the activation of a continuous key that will control the volume of a group of oscillators.

Other examples are pieces where the Karlax plays sounds very close to the sounds played by the instrument(s) it interacts with. In this way, the acoustic instrument is "augmented" by the action of the Karlax. For example, in the third part of *Discontinuous Devices*, the Karlax activates flautando and harmonics cello samples by pressing the continuous keys. The pistons also trigger shorter samples of the same type. It forms a harmonic environment for the cello, which performs more percussive figures like jettatti and glissandi, letting the open strings' natural harmonics resonate. With the same idea, in Jouaville's piece, the Karlax plays a physical model of a string by activating the pistons in a consecutive way whose pitches are previously set up (*String Studio* module). In most of the piece, the Karlax highlights and develops the melodic contour of the violin and creates a harmonic accompaniment (Fig. 3).

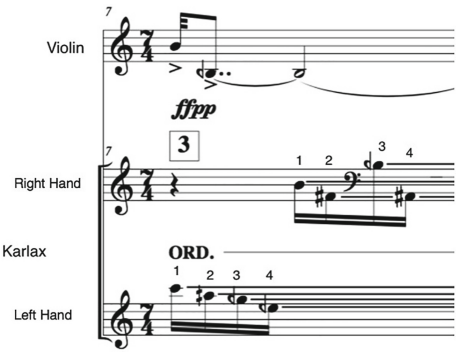


Fig. 3. Results of pitches played by the Karlax pistons with the corresponding fingerings in *Le Violon, l'Oeillet et le Bambou*, by Raphaël-Tristan Jouaville (mes. 7) (with the permission of the composer). See video from 00:30 to 00:32 www.youtube.com/watch?v=IrCmiwwFSUs

Model Based on Electronic Sounds

This type of composition model is the most common in the selected pieces. This category represents sound synthesis techniques and the treatments of the audio signal associated with electronic music, such as filtering, delay, granular synthesis, additive synthesis, etc. By assigning sound synthesis and digital sound processing parameters to different sensors, the Karlax can "drive" processes in real-time and bring an expressive dimension to the transformations. In this model, the sound of the Karlax is perceived as independent from the acoustic sound of the instruments.

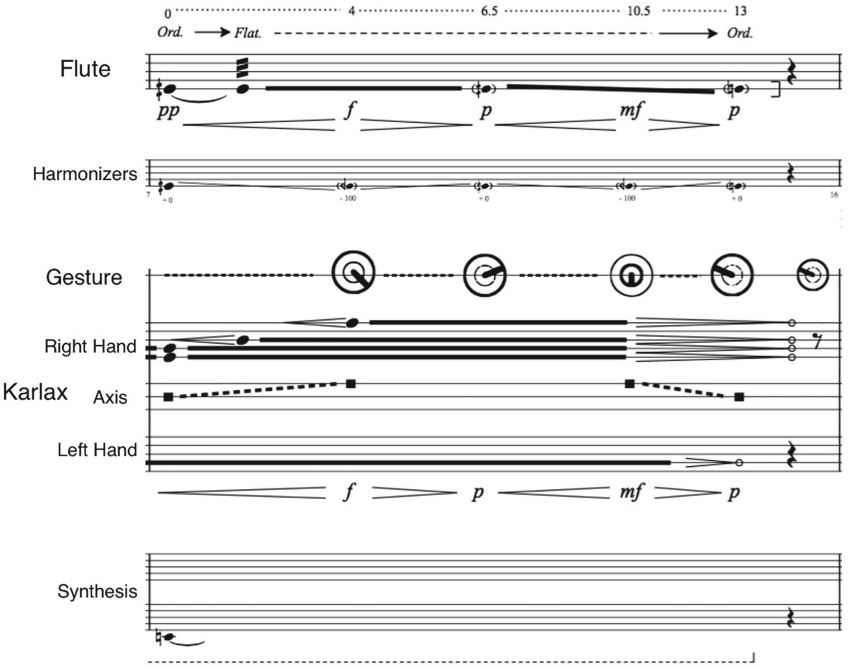


Fig. 4. General score of *Le Patch bien tempéré III* by Tom Mays (mes.6) (with the permission of the composer). The Karlax part combines -movements ("Gesture" staff with circle symbols) which control intensity, brightness, and pitch-bend of the sound synthesis, -rotation of the axis (dotted lines) which controls a speed tremolo and -continuous keys depression ("Right Hand" and "Left Hand" staves with thick lines) which activates "PAF" synthesis voices. The numbers at the top of the score represent the time in seconds. See video from 01:44 to 02:00 https://vimeo.com/80464641

For example, in *P.B.T. III*, the composer focuses on complementary electronic techniques such as harmonizers, delays, and "PAF" synthesis based on voice formants[5]. The input device activates different synthetic voices and modifies parameters in this piece. Generally, the accelerometer data corresponding to the forward-backward movements are associated with dynamics (brightness and intensity), and the left-right movements are associated with pitch (glissandi) (Table 3). At the same time, the central axis applies a speed tremolo [11]. In the score are noted the part of the flute, the Karlax movements laid out on four staves, and the acoustic results (Harmonizers and Synthesis staves) (Fig. 4).

Karlax as model

The design of the Karlax can also inspire the composition and constitutes a model in itself. Indeed, the conception of this controller is inspired by the keys system of wind and keyboard instruments (pistons and continuous keys) enriched with an axis (with bends) and movement sensors (accelerometer and gyroscope). For example, at the

[5] *Phase Aligned Formant* developed by Miller Puckette in 1995.

beginning of Faber's piece (*F.B.C.)*, the instrumentalist executes a "call" thanks to the pistons, which remind one of trumpet playing. Indeed, the instrumentalist performs a "call" thanks to the pistons produced by short harmonic synthetic sounds (Fig. 5). Also, the possibilities of the Karlax can inspire the "trajectory" of the piece. For instance, *D.D.* starts with an extensive use of the pistons and then in the second section the Karlax triggers and controls long sequences through the accelerometer and gyroscope data, making the Karlax gestures more and more expressive.

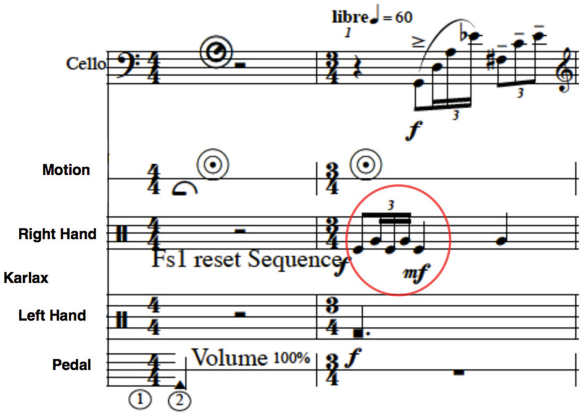


Fig. 5. "Call" played by the Karlax pistons in *Frottement, Bourdon, Craquement* (mes. 1-2) (with the composer permission). See video from 00:00 to 00:04 https://vimeo.com/118148219

4 Interaction Metaphors from Computer Music

In this part, we analyze excerpts of the corpus pieces thanks to metaphors from Computer Music. We have selected five metaphors from three articles: [1,18,20], for their relevance to describe the action of a gestural controller such as the Karlax (particularly in interaction with acoustic instruments) and for their capacity to give an overview of compositional strategies.

"Shaping" [Caramiaux et al., 2014]
Shaping "refers to scenarios where performers control sound morphologies by "tracing" in the air those salient sound features they desire to control" [1]. This metaphor is described as the "transfer of variations into a gestural morphology" and as synchronization of sound with movement. It is widely used in the analyzed pieces using Karlax's motion sensors but also with continuous keys. For example, in *P.B.T.III*, the Karlax imitates the distortions of the flute sound (created by harmonizers, flatterzunge, etc.) by "shaping" the "PAF" synthesis. At the same time, the ancillary gestures [19] of the flutist seem to imitate the gestures of the Karlax player (Fig. 4). With a more reduced gestural expression, the continuous key activation allows the Karlax performer in *Fogg* to "shape" the spectral envelope in a differentiated way to provide a harmonic accompaniment to the violin and the cello (Fig. 2).

"Catch and Throw" [Wessel & Wright, 2002]
This interaction strategy "involves the notion of selectively trapping musical phrases from an ongoing performance, transforming them in some way, and then sending these transformed materials back into the performance" [20]. This way of interaction, which could be defined as delayed real-time processing, was exploited in improvisational situations by Tom Mays in the early 2010s, where the direct sound of the acoustic instrument is captured, transformed by the Karlax and broadcast in real-time[6] Jouaville uses this type of interaction in the last part of *V.O.B.* where the acoustic sound of the violin is processed by resonator, delay, and pitch shift modules (*GRM Tools)* whose parameter nodes are controlled by the Karlax movements. This brings a sonic halo to the violin sound.[7]

"Fishing" [Caramiaux et al., 2014]
This metaphor is related to the learning stage in gesture recognition. When a dedicated program recognizes some gesture, a sound will be "fished" out to be played. One can compare this scenario of interactions with certain compositional strategies. For example, at the beginning of *Fogg*, several violin and cello actions with obvious gestural characteristics such as jettati, glissandi, strokes on the body of the instrument seem to be "recognized" by the Karlax, which reacts by imitating gestures, triggering and transforming nearby sounds.[8]

Musical tasks [Wanderley & Orio, 2002]
Related to the idea in the composition model *Karlax as model*, [18] proposes two levels of metaphors: *Musical Instrument Manipulation Metaphor* and *Control Metaphor*. In the first category are listed the interactions metaphors that refer to traditional instrumental playing (isolated notes, basic musical gestures like glissandi, vibrato, musical phrases, rhythmic playing, etc.) that appear for example in Faber's piece with the "call" (Fig. 5). In the second category, the authors evoke the actions of triggering of sequences but also their organization in time: synchronization, envelope control, continuous modulation features, etc.

"Space" [Wessel & Wright, 2002]
The purpose of using a control interface like Karlax in this type of strategy is to "suggest musically interesting trajectories for gesture", keeping in mind the "importance of proximity and timbre in the perception of these trajectories" [20].

Composers of the corpus employ various strategies to suggest movements and trajectories. For example, in *R.N.C.B.*, the composer evokes a distancing through repeated sequences where the violin and cello instruments begin a quasi homorhythmic figure "taken up" by the Karlax part in the form of arpeggios towards the high register. The input device controls a flow of notes produced by a subtractive synthesis: the axis controls the pitch of the arpeggio, the continuous keys control parameters like volume, filtering, or speed, while the inclination combined with a key activation control the amplitude envelope (Fig. 6 and Table 2).

[6] In this video, the Karlax controls the transformations of the acoustic sound of a Sheng, a mouth-blown free reed instrument: https://www.youtube.com/watch?v=fg9TgbI4gTM.
[7] See video from 05:43 to 06:42 https://www.youtube.com/watch?v=IrCmiwwFSUs.
[8] See video from 00:00 to 01:10 https://vimeo.com/67049071.

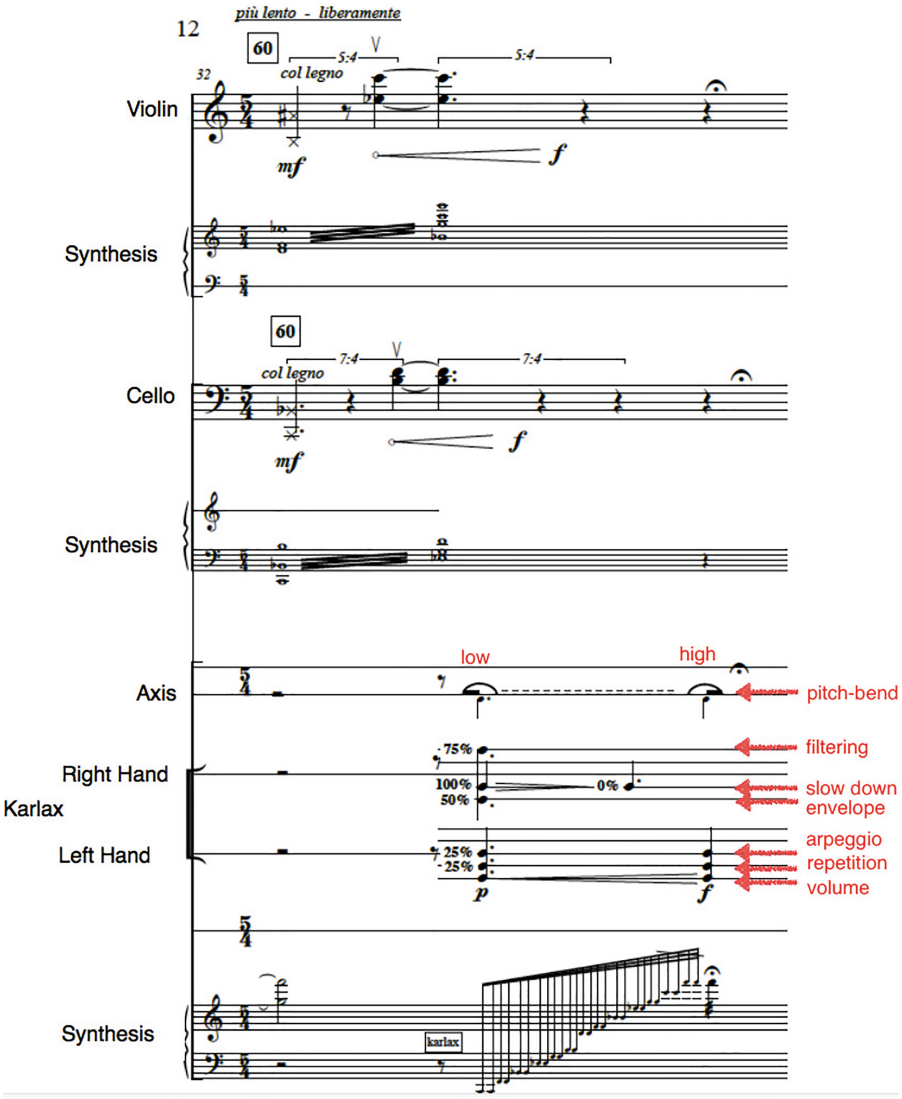


Fig. 6. Sequence that evokes a distancing in *Ripples Never Come Back* by Michele Tadini (mes. 32) (with the composer permission). See video from 00:48 to 01:00 https://vimeo.com/72995021

5 Composing with Interaction Strategies

The first author explored the use of interactions strategies in a new piece for Karlax and ensemble (*Instrumental Interaction*, 2022, ongoing work). Five interaction strategies were chosen through a perceptual-based approach.

The piece *Instrumental Interaction*, as its name suggests, explores the interaction strategies between the Karlax controller and the ensemble's instruments[9]. These strategies, noted in the score, tell the Karlax player the role they should play in relation to the ensemble (control of sound synthesis and gestures to be made). Some situations require the performer to be perceived prominently (using strategies "Imitating", "Borrowing", and "Transforming/Activation") or in the background (with strategies "Space" and "Shadowing").

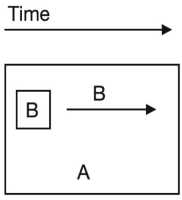
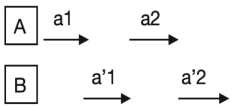
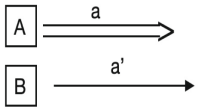
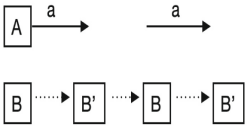
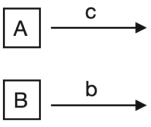
Let us consider *A* and *B* as acoustic units, where *A* is associated with the sound synthesis controlled by the Karlax and *B* is associated with the acoustic sound of the instrument or instrumental group with which the controller interacts. Also, *a* and *b* are the respective musical proposals of the acoustic units *A* and *B*. Table 5 describes the five interactions strategies.

The composition process also allowed us to refine the definition of the predefined interactions. For example, we had previously elaborated a distinction between the interaction strategies "Transformation" which would describe a real-time transformation of the acoustic sound, and "Activation" which would describe a sensor activation type of interaction (Table 5). Given the angle of perception adopted and the conditions of creation of the piece where no real-time interaction was used, these two interaction strategies appeared to be challenging to differentiate.

Also, by focusing on perceptual and rhetorical elements, we establish situations not specific to playing with gestural controllers or DMIs. These, however, are more likely to adopt different roles due to their flexible sound identity. In this regard, we have experimented with interaction strategies presented in Table 5 between the ensemble's acoustic instruments or instrumental groups. Therefore, the perceptual units *A* and *B* are associated with the acoustic instruments' timbre of the ensemble.

[9] The ensemble is composed of 14 acoustic instruments (1111-1110-perc-pn-11111) + Karlax solo).

Table 5. Interaction strategies used in *Instrumental Interaction*

Interactions	Schema	Description
1. ”Space”		The sound synthesis controlled by the Karlax constitutes a kind of sonic environment. *A* is perceived in the background, while *B* is perceived in the foreground. This strategy is related to the ”Space” metaphor, though not directly more concerned with the trajectory of a sound source.
2. ”Imitating”		*A* reacts to *B*’s proposal (or vice versa) by imitating it. This type of interaction is close to the ”Fishing” metaphor.
3. ”Shadowing”		This interaction strategy consists of a quasi-synchronous imitation but *a* is perceived in the foreground while *b* (perceived as *a*’) is perceived in the background. Also *a*’ is slightly delayed compare to *a* (cf. Fig. 7).
4. ”Transforming /Activation”		A’s proposal modifies B’s characteristics. This interaction strategy can be compared to a real-time transformation strategy (close to the ”Catch and Throw” metaphor) or, in a broader sense, to the activation of a sensor. This must be repeated to perceive *a*’s action on *B* more clearly.
5. ”Borrowing”		*A* interacts with *B* through sound and gesture behavior borrowed from a typical instrumental playing mode (*c* represents the borrowed proposition). This strategy contains, for example, the metaphor ”Shaking” described in [11], where the performer imitates a kind of maracas playing.

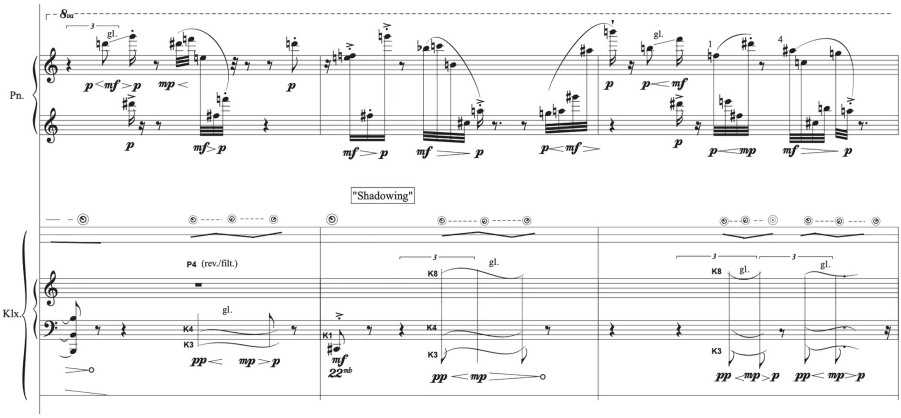


Fig. 7. "Shadowing" interaction between the Karlax and the piano part of *Instrumental Interaction* piece (mes.91–93). In this excerpt, the Karlax plays FM synthesis type of sounds that underline the high-pitched sound of the piano. The axis and the inclination of the Karlax control the modulation coefficients of the synthesis.

6 Discussion

The use of compositional models and Computer Music metaphors provide a framework and constitute powerful analytical tools to apprehend pieces that are, at first sight, complex. Generally speaking, they allow categorizing of specific roles of the Karlax and discussing typical situations of interaction.

For example, the piece *Fogg* by Lorenzo Bianchi seemed to us to belong to both the first and the second composition models, depending on whether one considers the process of composition or the sound result. Indeed, the process of additive synthesis and the fact that the "target" sounds are prepared (with the addition of pegs) make the sound synthesis played by the Karlax particularly distant from the acoustic sound of the violin. From a perceptual perspective, we would then need to determine whether or not the timbre of the sounds played by the Karlax "blends" with the sound of the instrument and determine what allows us to assert this. For the other examples given for the first model: *D.D.* (Part III) and *V.O.B.*, we can use the terminology of "timbral augmentation" as presented in [17].

The selected metaphors are thought in real-time interactions context. Though the composition process necessarily evolves in delayed time, we have seen that these metaphors are still appropriate to comment on typical situations of the pieces of the corpus. On the one hand, because they offer situations of real-time transformations and secondly because the composition strategies in terms of dramaturgy can be compared to situations of improvisations. Moreover, the setup chosen by the *Fabrique Nomade* ensemble influences these strategies. As the instrumentalists are independent and trigger more or less random processes (for example, delays), the composer tends to opt for "encompassing" strategies, highly describable by the metaphors [3]. On the other hand, these metaphors are limited to describe temporal and rhythmic aspects as specified in

[18]. In addition, metaphors that qualify the action of a controller such as "Shaping", or "Musical Tasks", facilitate the interaction with the instrumentalist(s) and the "reading" of the piece by the spectator/listener as they help to identify acoustically and gesturally the part played by the Karlax.

Furthermore, the description of the conditions of creation and the type of writing of the mixed pieces with Karlax seem fundamental to characterize the interaction strategies. Indeed, the venue's acoustics, the characteristics of the diffusion system (number of loudspeakers, spatialization), the existence or not of real-time processing of the acoustic instruments, and the freedom left to the performers will considerably influence the use and the perception of the interaction strategies. In *Instrumental Interaction*, we have opted for the ensemble's sound not to be used for typical real-time processing. Also, the venue for the premiere, a large rectangular box with 64 loudspeakers (the Music Multimedia Room at McGill University, Montreal), influences how we conceive the electronics and its spatialization and the poetic seeds of the piece. On the other hand, the idea that we wanted these interaction strategies to be perceptible also conditioned the writing.

Another critical aspect to qualify the action of the Karlax is its notation. Depending on the project of each piece, composers adopt a prescriptive (oriented on the action of the Karlax player) or descriptive method of notation (which reports the acoustic result) [8]. As a reference point, the composers of the corpus use the basics of Karlax notation presented in [10]. We can mention, however, the more pragmatic approach described in *V.O.B.*, which consists in assigning events in order of appearance to a simple range of fingerings and allows to visualize the pitches played by the Karlax and movements on a single staff (Fig. 3). Also, it is particularly interesting to relate to the approach of the composer D. Andrew Stewart in his piece *Ritual* for Karlax solo, based, among others, on gesture categorization and a spatial representation of space in the form of a grid [16]. In general, composers rarely add information related to mapping and sound synthesis, which would allow performers to appropriate the Karlax instrument further. Simultaneously, the notation must be practical and represent the composer's intention accurately and concisely. As such, an indication in the score of the metaphorical context, as presented above, would provide valuable information about how the Karlax is played and how it interacts with other instruments. In *Instrumental Interaction*, we opted for a hybrid approach by prescriptive (use of keys, pistons, axis, and inclination indications) and descriptive notation (main pitches, graphic description of the electronics). As for the mixed pieces with electronics, the composers can add audio files of the electronic part of the Karlax to communicate their musical ideas in the best possible way.

7 Conclusion and Future Work

In this article, we analyzed in detail six pieces for Karlax and acoustic instruments. We discussed how the Karlax was used by presenting the choices of synthesis and mapping in each piece. Three models of compositions have been identified, and five metaphors from the computer music literature have been proposed to characterize typical musical situations. Finally, we discussed the use of interaction strategies as main inspirations for a new piece for Karlax and ensemble of 14 acoustic musical instruments.

Several directions for future work arise from this research. Exploring interaction strategies in mixed compositions with a DMI contains many challenges from a creative, pedagogical, and perception point of view.

In the creative part of this project, we will further explore the interaction strategies with Karlax by diversifying the conditions for creating new pieces (types of instruments, types of diffusion, types of writing, etc.). Also, we want to focus on DMI-DMI type interactions, as with the T-Stick [9]. With these new inputs, we would like to propose new types of interactions and better qualify their use in the composition process.

Another follow-up to this research-creation project is to offer a workshop on writing mixed works with DMI to student composers. Pedagogical and demonstration activities are essential to understand the needs of DMI users, as shown with the Music Creation Project with the T-Stick [6]. The main objective of this workshop is to accompany the students in writing a mixed piece with DMI by experimenting with different interaction strategies. At the end of the workshop, students will be able to comment on the sound and gesture characteristics of the DMI and the interaction strategies they have chosen.

Finally, the study of perception between electroacoustic and acoustic components is generally not well explored, even less when the electroacoustic part is embodied with a gestural controller. As such, interaction strategies seem interesting tools to qualify these components.

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