The Obstacle Course of DMI Performance: Two Case Studies with T-Stick and Karlax

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ABSTRACT

This article presents two case studies featuring DMIs, the T-Stick and the Karlax, aiming to showcase various technical and performance obstacles encountered in existing and new compositions for novel instruments. The analysis covers different stages of a performance, including preparatory processes, practice sessions, and the actual performance, highlighting challenges faced and solutions implemented. The support obtained through communicating with composers is emphasized. Additionally, the discussion delves into technical considerations, score interpretations, and playing techniques specific to the two DMIs, contributing to a deeper understanding of performance practice. These case studies can inspire DMI designers when creating their instruments so that barriers to performance can be eliminated. Furthermore, the findings underscore the necessity for composers to create documentation with comprehensive information, facilitating a thorough understanding for performers of both the instrument's manipulations and their artistic vision.

Author Keywords

Human-Computer Interaction, Digital Musical Instruments, T-Stick, Karlax, Performance Practice

CCS Concepts

•**Applied computing** → **Performing arts;** *Sound and music computing;*

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1. INTRODUCTION

Since the mid-80s, a large number of DMIs have emerged [18]. Although musicians like Laetitia Sonami (The Lady Glove), Michel Waisvisz (The Hands), Andy Schloss (The Radio Drum), and Mark Goldstein (The Buchla Lightning II and The Marimba Lumina), among others, have mastered these instruments through extensive use, many new DMIs are often abandoned after a few performances. Identified reasons include a lack of dedicated instrumental technique, the need for a new adapted notation, and the absence of an established repertoire [13].

To address this longevity issue, various approaches have been taken. Some offer recommendations for designing DMIs [19], while other efforts focus on developing performance techniques and notation systems [21, 15] or propose pedagogical frameworks for learning and long-term practice with DMIs [8, 4, 2, 14]. Additionally, community-building initiatives have been proposed [5, 16]. In this paper, we examine this issue from the perspective of performers.

For acoustic instrument pieces, it is generally considered that a performer only requires access to the instrument and a score to practice and render the music in concert. However, the scenario for DMIs is often far more intricate. Developing a repertoire entails more than just a score detailing what and how to play. Even with instruments and scores at hand, numerous hurdles must be navigated before presenting a DMI piece. In other words, what information and resources are needed for a performer to be able to play a DMI piece?

This paper focuses on two case studies on the performance of DMIs, highlighting technical issues and performance challenges. The first describes the steps needed to perform an existing piece for solo T-Stick. The second study describes the techniques used by a performer learning to perform a new piece composed for solo Karlax.

The T-Stick and Karlax were selected not only for their availability but also for their extended repertoire and active community of users [17, 9, 21, 15].

We hypothesize that executing established DMI repertoire might in many cases necessitate the involvement of not only the performer but also the composer and the instrument designer. Their roles are crucial in offering insights into the functionality of the hardware and software, including interface firmware, mapping, and sound synthesis choices. The documentation supplementing a score should provide the performer with information on the DMI, its setup and its interaction with the various software needed to perform the piece [1, 7].

2. T-STICK CASE STUDY

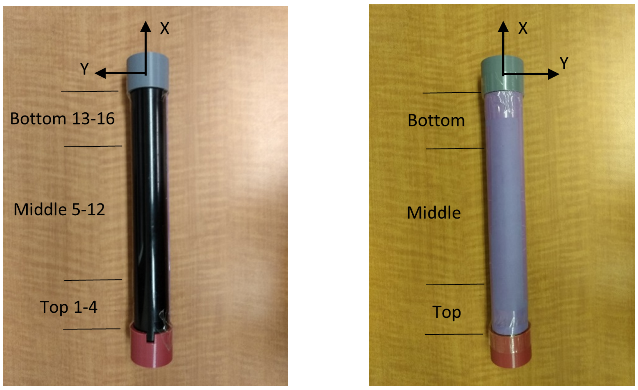
In this section, we describe the steps needed to perform Antoine Goudreau's *Les multiples usages du mot "geste"*, a piece for solo T-Stick composed and premiered in 2021. Although the piece was not actually performed at the end of the study, a performance would have been possible.

2.1 Background

2.1.1 Interface Description

The T-Stick is a family of hand-held cylindrical gestural controllers developed at the Input Devices and Music Interaction Laboratory (IDMIL) [12]. The most prevalent version available nowadays at IDMIL is the Sopranino T-Stick. It contains various sensors that allow for touching, shaking, and squeezing: one inertial measurement unit inside the tube, with 16 capacitive strips on one side, and one force sensing resistor (FSR) on the other side (see Figure 1). The interface sports a firmware that not only exposes the raw sensor data but also computes gestural descriptors such as "jab" or "shake" [17].

Since its creation, efforts have been made to establish a community of performers and composers as well as develop the repertoire for the instrument [6], leading to a catalog of 20+ compositions for solo T-Stick or various instrumentation [17].



(a) Capacitive Strips Side (b) FSR side

Figure 1: Front and back views of a Sopranino T-Stick illustrating the three touch-sensitive areas and corresponding capacitive strip numbers.

2.1.2 Context of the Composition

Antoine Goudreau's *Les multiples usages du mot "geste"* is a solo Sopranino T-Stick piece with a duration of approximately 5 minutes. It marked Goudreau 's debut composition for the T-Stick. The piece explores various ways in which the T-Stick can interact with the parameters of a granular synthesizer. The original performer was not the composer but a classically trained jazz pianist with limited technological knowledge. The performer contributed sound material through a piano improvisation, and an excerpt from the recording was used as the granulation sound file.

A video recording of the unique performance is available online[1] and served as a reference for rehearsal, both for better understanding instrument manipulations and checking that the sound produced matched the timbre originally defined by the composer.

Figure 2: Performer Jean-Christophe Melançon holding the T-Stick during the première of *Les multiples usages du mot "geste"*. Credits: Le Vivier Interuniversitaire.

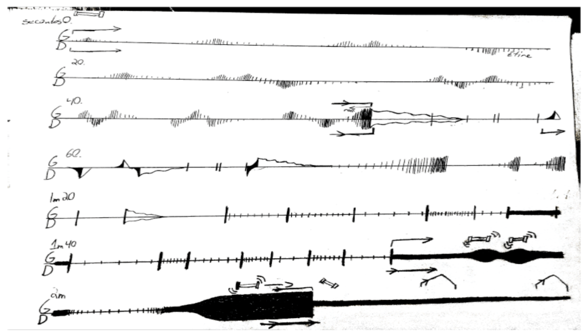


Figure 3: The first page of the two-page time-based score. © Antoine Goudreau, 2021.

This case study focuses on assessing the capability of a musician already familiar with the T-Stick and computer music software (the first author) to act as the second performer of a piece for solo T-Stick.

2.2 Preparatory Stage

2.2.1 Technical Setup

As DMIs aren't self-contained instruments, several technical setup stages are necessary to make them functional. For this piece, the required hardware includes a T-Stick, a computer, and an audio interface for stereo output to a pair of loudspeakers. Furthermore, a WiFi network must be set up to allow communication between the interface and the computer.

For his composition, the composer based his approach of the T-Stick on incorporating multiple mapping layers (see Figure 4). Initially, OSC data transmitted from the T-Stick is routed to a Max patch, where the composer devised the first layer of mapping, selecting T-Stick data that suited his requirements to capture the performer's gestures. For example, the tilt value of the interface was determined based on the impact of gravity on the data from the accelerometers.

[1] `https://vimeo.com/592196722`

Table 1: List of software and related libraries required for performing the piece.

Software	**Library**
Max/MSP	Libmapper
	Digital Orchestra Toolbox
	IRCAM's Max Sound Box
Libmapper	N/A
Webmapper	N/A

Subsequently, the data is transmitted to Libmapper, a software engineered for rapid and dynamic experimentation during the mapping phase of instrument design[2] [11]. This mapping layer is processed in Webmapper [22], a browser-based graphical user interface (GUI) designed for Libmapper. This tool facilitates the visualization and manipulation of mappings within the context of DMI design. The resulting signal controls from the Libmapper layer are then directed to a second Max patch, where they are mapped to the IRCAM's Max Sound Box granulation engine[3]. Several objects from the Digital Orchestra Toolbox[4] [10] are used to process control signals.

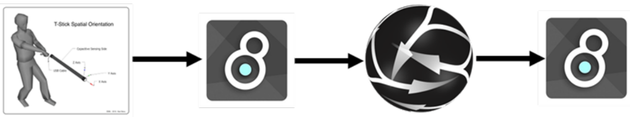


Figure 4: Mapping Layers: T-Stick data is initially sent to a Max patch for initial mapping, with the bulk of mapping done in Webmapper before being sent to a second Max patch for sound production.

Due to this mapping architecture, the computer requires installing numerous software packages and libraries. The complete list can be found in Table 1.

2.2.2 *Challenges during Technical Setup*

The first obstacle encountered in the preparatory phase revolved around the obsolete Libmapper library for Max. The Max objects included in the initial 2021 patches proved incompatible with the 2023 release of the library, requiring an upgrade to their most recent versions to guarantee the proper functioning of both the patch transmitting data to Libmapper and the one receiving Libmapper's output.

Furthermore, the issue of Libmapper obsolescence also impacted the mapping layer conducted in Webmapper. Although mapping equations in Webmapper can be saved in a JSON file, the format of the provided JSON file was incompatible with the current software version. With Libmapper's mapping layer consisting of only 12 parameter associations and the associated equations being relatively simple—generally involving linear scaling—the most straightforward solution was to manually recreate the mapping layer in Webmapper (see Figure 5).

The specific version of the T-Stick used by Goudreau in 2021 is unidentified. An examination of the Max patches revealed several disparities in hardware and firmware compared to T-Sticks available in 2023. Notably, the original Max patches relied on data from a piezoelectric sensor, which was removed from the latest version of the interface

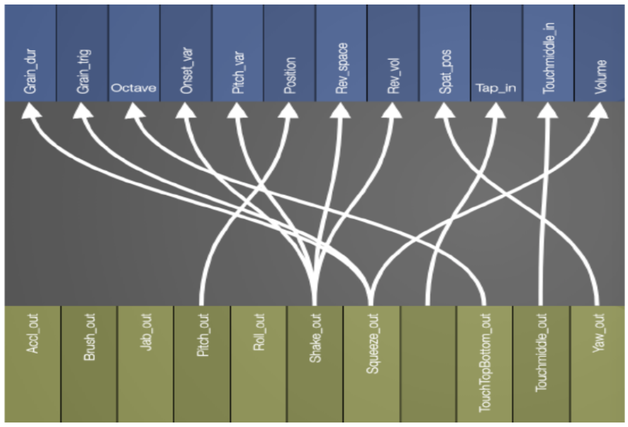


Figure 5: Picture of Webmapper's mapping layer, as provided in Goudreau's documentation.

[20]. In Goudreau's piece, the piezoelectric sensor was employed to trigger significant sonic events (see 2.3.1). A "jab" gesture extracted from the interface's firmware was selected as an alternative to replicate this functionality, as the piezo sensor was unavailable in the current interface.

2.2.3 *Score Reading*

The accompanying documentation for the graphical score provides an explanation of its visual elements. The score serves a dual function: certain graphical elements visually represent the intended sound, while others prescribe specific actions or manipulations for the performer. It features a single-line staff, acting as a reference line for musical events within the stereophonic space. The labels G and D denote the left and right audio channels, respectively.

Figure 6: The score notation consists of graphical elements arranged on a single-line staff with temporal references. G and D indicate panning to the left and right audio channels, respectively.

Elements of the score were crafted specifically for the composition, covering aspects such as grain notation, T-Stick orientation, hand placement on the T-Stick, hand opening and closing, tapping, and shaking. The grain notation indicates not only the grains' left or right position and volume but also their density from individually perceivable grains to a continuous texture and the expected sound volume.

2.3 Challenges during Practice

2.3.1 *Playing Techniques*

While the score specifies whether the hands should be open or closed on the instrument, it provides no instruction on how to hold it. Insights from the original performance video and discussions with the composer were essential in understanding hand positioning. The performer should maintain an approximately horizontal hold, resting the instrument on their right thumb and left palm, as depicted in Figure 2.

[2] https://libmapper.github.io/
[3] https://forum.ircam.fr/projects/detail/max-sound-box/
[4] https://github.com/malloch/digital-orchestra-toolbox

(a) Grain density notation (b) Shaking instruction

Figure 7: Examples of graphical score elements: figure 7a represents the desired sound texture (discernible grains or continuous), and Figure 7b depicts a shaking manipulation.

The T-Stick is typically positioned horizontally as instructed on the score. However, it does not specify whether the FSR side or the side of the capacitive strips should face upward. Unfortunately, the accompanying video does not provide any clarification on this matter. However, after consulting with the composer, it was clarified that the T-Stick should be held with the FSR side facing upward.

The most significant insight gleaned from discussions with the composer clarified the temporal progression of the piece. While Goudreau's documentation states that grains are generated by squeezing the T-Stick's body, the graphical score does not aim for timing precision. Instead, the composer insisted that the timing of the piece could be interpreted loosely. The lines depicted on the score, as shown in Figure 7a, do not represent each grain to be produced; instead, they provide a general indication of whether the temporal gap between the grains should be tight or loose.

Similarly, considering the instrument's lack of independent volume control, the performer will deduce that while the score indicates when the produced sound should be louder (as indicated by the height of the lines on the staff), achieving a louder sound requires triggering a larger quantity of grains.

Single louder grain or short cluster of louder grains is achieved by slightly tapping the middle section of the instrument on the side of the capacitive strips (see Figure 8). There is no specific recommendation about the manipulation required to achieve this result. The composer indicated that the gesture is typically performed using the little finger on the left hand. This provides a better understanding of the video. Besides, once the handling of the T-Stick is understood, this gesture can be mastered with little practice.

Figure 8: Middle tapping. Longer and thicker vertical lines signify generating a short cluster of louder grains by tapping the middle section of the interface.

As outlined in section 2.2.2, the absence of a piezoelectric sensor in the T-Stick used for the case study led to the adoption of a jab gesture. This adjustment necessitated a change in playing technique whereby the performer thrusts the T-Stick forward instead of striking it forcefully with one hand. The intended outcome is to trigger a significant reverberation, thereby amplifying and sustaining the sound of the grains being played. In the score, this climactic moment occurs twice, and the duration of the reverberation effect is extended by continuously shaking the instrument (see Figure 9).

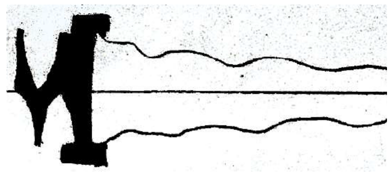


Figure 9: Strike gesture. In the original performance, striking one end of the T-Stick triggered a reverberation effect. The resonance is prolonged by shaking.

Once proficiency in the "jab" technique was attained, it was easy to follow with a shaking since both gestures could be executed without releasing one hand.

2.3.2 Instrument Adjustments

The composer stressed the crucial role of reverberation in his piece, as it enables the resonance of short events to be prolonged or even "frozen" in time. During practice, it was observed that the shaking gesture resulted in excessive reverberation beyond the intended effect. This discrepancy is likely due to inconsistencies in the shake calculation within the T-Stick firmware, which has been updated since the 2021 version of the instrument. Consequently, the mapping equation associated with this function was adjusted to restore the reverberation to the intended level.

Similarly, as hand pressure influences the generation of grains, the mapping between FSR values and grain density needed to be re-scaled to achieve the density specified in the score. Notably, the composer stressed the importance of maintaining the pressure applied on the FSR within a comfortable range for the performer throughout the piece.

The current version of the T-Stick also includes a modified calculation of the interface's orientation angles in space (yaw, pitch, roll). This calculation is unreliable in the 2023 version of the firmware, so it is impossible to say if the results are similar to what Goudreau experienced two years prior. These angles are linked to the position in the sound file where the grains will be extracted. Nevertheless, after listening to the sounds produced by our instrument reconstruction, the composer judged that they were similar enough to the original intended sounds. The similarity of the sound material (piano sounds) and the short length of the grains made that the position in the sound file had little influence.

2.4 Readiness for a performance

The activities described in the previous sections lasted about six weeks. Although the piece was not performed in concert, the efforts undertaken during this case study enable an evaluation of the level of preparedness achieved for future performance.

Throughout the case study, there were several discussions with Goudreau, debating the qualities of the produced sounds and allowing for a deeper understanding of the composer's aesthetic intentions.

The composer's approval of patch modifications, including introducing the "jab" gesture, and a thorough understanding of his artistic intentions were pivotal in interpreting the score effectively. Moreover, ensuring the instrument was comfortable to hold and play was essential for the performer's ease and performance quality. The "reconstructed" DMI was deemed sufficiently reliable for performance.

Ultimately, the composer agreed that the piece could be played. The only remaining task would have been to complete a recommended one-month practice period. A concert performance would then be an achievable goal.

3. KARLAX CASE STUDY

This case study discusses the steps taken by a musician (the second author, a pianist and composer) to perform a new piece for solo Karlax.

3.1 Background

3.1.1 Interface Description

The Karlax[5] is a gestural controller shaped like a clarinet or soprano saxophone that aroused substantial interest among composers since its inception in 2010 and continues to be commonly used in solo and group performances. Various sensors are integrated into the device: ten continuous keys, eight velocity pistons, a rotary axis with bends, an inertial measurement unit, and multiple switches (see Figure 10). It also features a rotary axis with bends at each end, enabling the musician to twist the controller's axis. Like many musical interfaces that output sensor data without having a pre-defined sound, the Karlax is defined solely by its control characteristics, i.e., its gestural affordances, instead of by a given sonic palette [9].

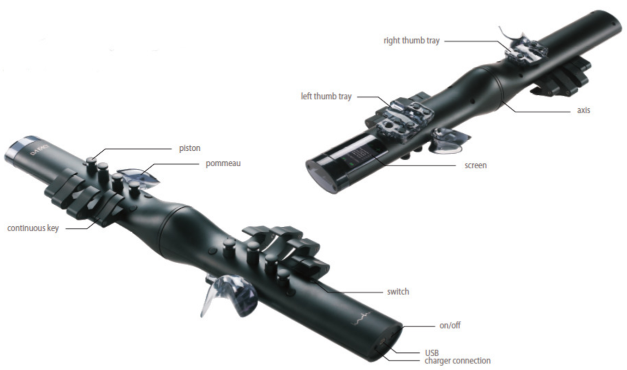


Figure 10: Front and rear views of a Karlax illustrating its main sensors, including ten continuous keys, eight velocity pistons, a rotary axis, and an embedded inertial measurement unit. Credits: DA FACT.

3.1.2 Context of the Composition

Instrumental Interaction IV, subtitled *4 studies for Karlax solo*, was composed by Benjamin Lavastre in 2023. It is part of a series of compositions called *Instrumental Interaction*, which, as its name suggests, is dedicated to exploring the interaction strategies between the Karlax and acoustic instruments. This solo Karlax piece, the fourth of the series, encompasses four distinct movements with a total duration of approximately 7 minutes, specifically exploring the dual identity of the Karlax as both a gestural controller and an instrument.

The major research question in this case study is how to approach a newly composed piece for Karlax as a novice DMI performer, composer, and pianist with intermediate knowledge of music technology.

Although *Instrumental Interaction IV* was premiered by the second author, an improvisational excerpt by the composer using the same sound synthesis was available online and was a reference for the practice progression. The rehearsal phase available to the performer was less than a month, and the final recording session was scheduled for November 30, 2023, at the Performance Research Laboratory (PeRL), Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT).

3.2 Prepatory Stage

3.2.1 Technical Preparation

Before starting to practice a new DMI piece, having an accurate technical setup is essential. In this case study, the composer was available to meet in person and assist with clarifying the necessary steps for preparing both hardware and software. To perform *Instrumental Interaction IV*, a Karlax with a MIDI receiver, an audio interface, and a computer running Max/MSP (version 8 or later) were required. Additionally, a configuration of loudspeakers with adjustable spatialization was necessary. The Max patch necessitates specific libraries and VSTs, including the Digital Orchestra Toolbox, CNMAT-Externals, GRMPitchAccum, and GRMReson.

3.2.2 Score Reading

In this piece, the composer chooses a hybrid approach combining prescriptive (use of keys, pistons, axis, and inclination indications) and descriptive (main pitches in sound synthesis) notation. A four-part score is utilized to notate gestures and the music: movements, axis and bends, pistons and keys, and electronic content, as shown in Figure 11. The top part of the score includes various symbols to represent specific movements. Axis rotation is depicted on a three-line staff with a thick line to indicate the axis's orientation: proximity to the top line suggests an open axis (wrists turned outwards), whereas closeness to the bottom line suggests a closed axis (wrists turned inwards). For the staves labelled *Karlax* and *Electronics*, pistons and keys are denoted using abbreviations and numbers, and a descriptive part for the electronic content (main pitches) is also included. For instance, in the first measure of Figure 11, *P3* represents pressing piston 3 with a resulting sound of boobam in E flat.

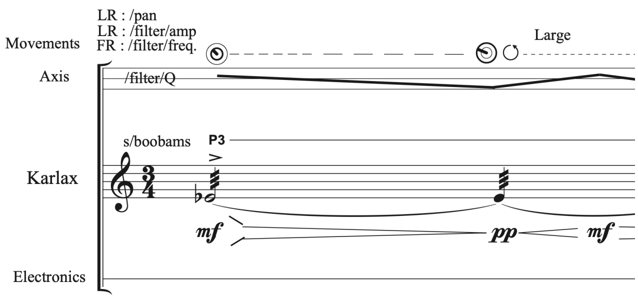


Figure 11: Score excerpt of *Instrumental Interaction IV*, showing the full notation consisting of four parts: movement representation in symbols, axis rotation, Karlax keys and pistons with their corresponding electronic content, and a complementary staff for electronics.

In terms of instructions for movements, the composer uses five types of symbols to indicate the main movements in the piece: transitional positions, circular movements, wavy movements, and gestures of lifting and thrusting, as seen in Figure 12. To indicate Karlax's inclination during transitions, the composer adopts the symbol of concentric cir-

[5] `http://www.dafact.com/`

cles developed in a notation system by Mays and Faber[15], where the speed of the transitions is represented by dotted lines (the shorter the dotted lines, the faster the transition).

Movements and Gestures	Symbols
Transitional positions	
Circular movement	
Wavy movement	
Lift	
Thrust	

Figure 12: Five types of gestures used in *Instrumental Interaction IV* and their corresponding symbols.

For interpreting a precisely notated score like *Instrumental Interaction IV*, it is advisable to establish a systematic reading and practicing process beforehand. The performer in this case study recommends the following approach to the score: begin with the Karlax stave to familiarize yourself with the pistons and keys. Then, proceed to the axis and movement staves to understand the gestures required. Finally, the electronic description must be examined to confirm and adjust the produced sounds.

3.3 Challenges During Practice

The four movements have distinctive durations and characteristics:

- Study I, the longest movement in the piece, spans approximately 3 minutes and 35 seconds with a tempo of 60-66 bpm. It features a combination of pistons and keys (both discrete and continuous). The samples in the electronics include several kinds of percussive sounds, such as boobams, roto-toms, and bongos, while white noise is assigned to continuous keys.
- Study II lasts about 1 minute and 5 seconds with a tempo of 50 bpm. This movement exclusively utilizes pistons, characterized by continuous gestures and calm musical imagery. The electronic content comprises bowed crotales, rain sticks, and crackling sounds.
- In Study III, the duration is approximately 2 minutes and 10 seconds with a tempo of 72 bpm. This movement is unique in its exclusive use of continuous keys combined with FM synthesis. The composer specifies that the gestures in this movement should be performed steadily and mechanically.
- The last movement, Study IV, is the shortest of all, lasting approximately 52 seconds. It mainly focuses on discrete keys, and the electronic components include nearly every sample used in the first three movements, including FM synthesis, boobams, roto-toms, rain sticks, and bowed crotales.

In the following sections, three excerpts extracted from movements I, III, and IV will be discussed. These excerpts highlight performance techniques such as playing pistons with thrusts in complex rhythms, applying staccato on continuous keys for short timbre control, and adjusting fingerings and hand-holding positions.

3.3.1 Excerpt 1

The first excerpt presents a challenge regarding its complex rhythms on pistons with thrusts, as seen in measure 37 of the first movement (see Figure 13). While these rhythms might be more easily reproduced on an acoustic instrument like a piano, they pose challenges when performed on a Karlax. The indications *P3TC* and *P3TL* mean thrusting towards the center and the left bottom while holding piston 3 down. However, the corresponding sounds can only be triggered when the inclination values are within the valid range.

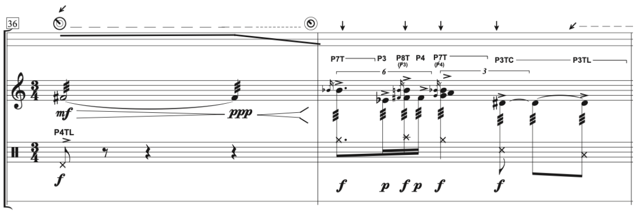


Figure 13: Score of measures 36-37 in the first movement, illustrating an example of complex rhythms on pistons with thrusts.

When playing the Karlax, a short time is needed to return to the initial sensing state after a certain amount of activity. This results in latency that is difficult to avoid, mainly due to the need for rapid switches between standard piston pressing and thrusting movements. Most thrusts in this excerpt are directed toward the top center (*P7T*, *P8T*, *P3TC*), which are easier to control than thrusts toward the two sides (*TL* and *TR*), and this somewhat mitigates the problem. One potential solution is to maintain steadiness before each thrust, though this approach primarily applies to slower phrases. Another potential solution is to slow down the tempo during practice, similar to practicing with an acoustic instrument, and attempt to establish muscle memory for the precise inclination of each thrust.

3.3.2 Excerpt 2

The most challenging aspect of the second excerpt, drawn from the third movement, is maintaining steady, regular rhythms while simultaneously controlling the timbre on continuous keys. In this movement, executing regular FM synthesis staccatos becomes unstable when playing continuous keys. With short staccatos, latency can easily disrupt the performer's rhythm consistency due to delayed auditory feedback. Additionally, as indicated in measure 7, Figure 14, achieving the exact 0.2 value for axis rotation poses a significant challenge.

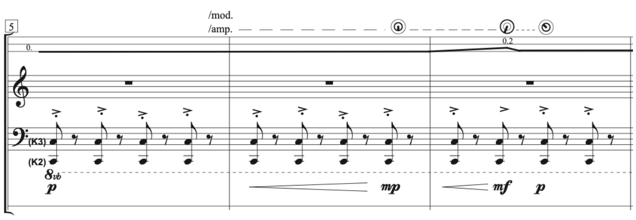


Figure 14: Score of measures 5-7 in the third movement, illustrating how continuous keys produce subtle timbral changes while maintaining a strictly steady rhythm.

After consultation with the composer, he clarified the expected sounds and proposed an alternative approach: rather than aiming for a specific degree of rotation, the performer should adjust the axis towards more modulated sounds based on their auditory perception. This solution grants the performer greater flexibility to modify the gesture in response to auditory feedback. For parts like excerpt 2, understanding the signal processing strategies used in the patch would help achieve the desired sound outcome.

3.3.3 Excerpt 3

A challenging aspect of the fourth movement, as depicted in Figure 15, involves executing fast phrases with discrete keys. To accurately reproduce the rhythms and dynamics as indicated in the score, a performer, especially those with relatively small hands, might need to consider making adjustments to how they hold the Karlax. In this case study, the performer's right hand was adjusted to be positioned more towards the front than the originally indicated position. Additionally, reordering the fingering for complex passages would help achieve precise rhythms. These adjustments allow for the production of clean sounds from the keys without inadvertently simultaneously activating the pistons.

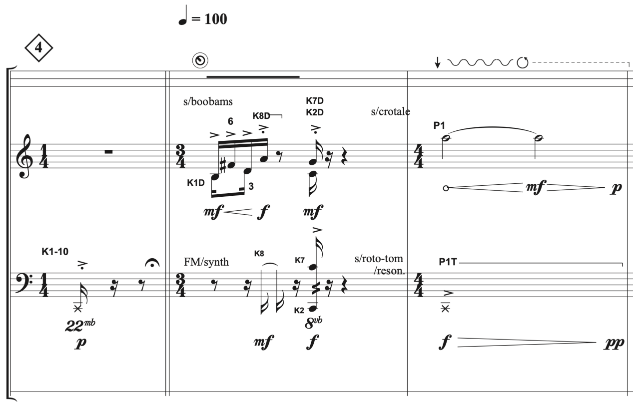


Figure 15: Score of measures 1-3 in the fourth movement, illustrating the challenge of performing fast phrases on discrete keys. When the letter "D" follows a key number (e.g. *K1D* in the second measure), it indicates that the composer has changed this key from continuous to discrete.

3.4 Issues Encountered in Performance

One significant challenge in DMI performance is that the final result often depends on the specific conditions of the performance venue, requiring time for troubleshooting and sensor value adjustments. During the recording session of *Instrumental Interaction IV*, the time allocated for technical setup was minimal, leading to difficulties in making the 36-channel surround system function properly. This issue significantly impacted the spatialization effect on performance. Recording equipment was also an issue; the unavailability of an ideal multichannel microphone led to an alternative setup to capture sound trajectories. The final recording is a studio mix combining two sources: *clean sounds* recorded binaurally within the patch using the Spat object in Max [3], and a stereo recording from a Sony PCM-D100 placed at the sweet spot inside the room (see Figure 16).

Another challenge the performer encountered during the performance was managing unexpected sounds, which mainly occurred during passages involving a lot of thrusts with pistons. Despite the potential instability and insensitivity of the inclinometer, controlling a thrust associated with a live-synthesized sound, for example, via GRMReson, proved particularly difficult. Achieving the ideal volume balance required meticulous gesture control and simultaneously rescaling the parameters in the Max patch. These issues could potentially be alleviated with additional time for in-hall setup and rehearsals, as well as revisions to the patch.

Figure 16: Screenshot of the video of the second author performing *Instrumental Interaction IV* in Performance Research Laboratory (PeRL) at CIRMMT. Credits: Yue Wang.

4. DISCUSSION

The two studies presented offer valuable insights into the complexities of DMI performance, emphasizing the importance of composers' involvement in technical and artistic preparation. The final results of the two case studies, performance readiness for the T-Stick and a full-fledged performance of the Karlax piece[6], indicate that the presence of the composer (and sometimes the interface designer) during the initial technical preparation stage is beneficial. This is particularly true for older pieces where issues of interface changes and software obsolescence may arise. Newer compositions involving more stable interfaces like the Karlax, still benefit from the composer's guidance. Given the technical complexity involved in both cases, having a performer with a technical background would facilitate the setup process.

Score and notation systems differed considerably between the two studies, reflecting the diverse nature of DMIs and composers' intentions. The T-Stick piece, for which the notation was specifically developed, embraced a flexible approach, granting performers a degree of interpretative freedom. In contrast, the Karlax study employed a highly detailed notation system that left little room for interpretation. This contrast underscores how the choice of notation system is influenced by the specific DMI and compositional objectives, leading to different situations: a Karlax notation system has been primarily established [15], while notation for T-Stick may vary depending on each piece.

The examination of performing techniques across the two case studies further illustrates the adaptive nature of DMI performance. For both DMIs, especially the T-Stick, the development of playing techniques forms an integral part of the composition process, differing from traditional acoustic instruments. This requires adaptations due to obsolescence and evolving interfaces as well. However, the Karlax partially allows for applying traditional acoustic instrument techniques, such as those involving keys and pistons found in saxophones or pianos, to its performance. The required

[6] `https://youtu.be/k6fNKeH19KY?si=ti-4w66OF04AQ2Vh`

practice time varies depending on the unique features of each piece and the specific DMI involved. Nevertheless, in both case studies, the input of composers regarding score interpretation and artistic expression proved beneficial.

5. CONCLUSIONS

This paper presented some of the multifaceted challenges performers face when learning and performing compositions for DMIs. These challenges extend beyond acquiring the interface and the score, encompassing technological, technical, and artistic aspects inherent to these instruments. Both case studies underscored the importance of the composers in helping performers understand the piece. However, as the availability of composers cannot be guaranteed, it becomes essential for them to devise means to provide comprehensive documentation to performers covering both the instrument's manipulations and their artistic vision.

The T-Stick study also shed light on how changes in the instrument can potentially impact the piece's playability. Such observations should inspire DMI designers to achieve stability in their instruments' hardware and software components. This emphasis on stability will contribute to the instruments' longevity and facilitate wider adoption.

Despite the obstacles encountered during the preparatory phase, the rehearsals, and the final performance, the two studies ultimately ended up with positive outcomes. These experiences enabled performers to practice DMI playing techniques. Given the range of DMIs available, conducting multiple similar case studies could provide further insights into the implications of DMI performance practice, contribute to its development, and ultimately enhance the longevity of these instruments.

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7. ETHICAL STANDARDS

The authors do not recognize any potential conflicts of interest in this research project. They recognize that all DMIs require the utilization of electronic materials and resources and acknowledge the lasting environmental and social impacts associated with their production.

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