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# Expressive potentials of motion capture in the *Vis Insita* musical performance

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## ABSTRACT

The paper presents the electronic music performance project *Vis Insita* implementing the design of experimental instrumental interfaces based on optical motion capture technology with passive infrared markers (MoCap), and the analysis of their use in a real scenic presentation context. Because of MoCap's predisposition to capture the movements of the body, a lot of research and musical applications in the performing arts concern dance or the sonification of gesture. For our research, we wanted to move away from the capture of the human body to analyse the possibilities of a kinetic object handled by a performer, both in terms of musical expression, but also in the broader context of a multimodal scenic interpretation.

## Author Keywords

Motion capture, control interface, musical performance

## CCS Concepts

• **Human centered computing** → **Sound based input/output**; **Gestural input**; • **Applied computing** → **Sound and music computing**;

## 1. INTRODUCTION

Since the early 2000s and the industrial development of optical motion capture systems, several studies [4, 5, 9, 10] have been carried out on the use of such systems in musical applications, particularly within the NIME community. However, partly due to the significant financial investment that a professional motion capture (MoCap) system represents, few musical performances based on this technology have yet been created [5, 13].

Moreover, because of MoCap's predisposition to capture the movements of the human body, we can see that a large majority of the work that has been done concerns the field of dance or the sonification of gesture.

This research-creation project was therefore mainly interested in the problems of performing electronic music live,

and the potential of MoCap's technologies to stage this music and make it heard through plastic elements.

In order to approach our subject as exhaustively as possible, we included it in a bibliographical research on how art historians, artists and researchers question the way in which live electronic music is perceived by the audience and interpreted by the performer-musicians [2, 3, 8].

However, the study described in this article focused on practical and experimental research through the creation of a musical performance that attempts to implement expressive and poetic forms of musical interpretation. The objective was multiple: to analyse the possibilities and limits of this instrumental interface under real conditions of presentation, to make a video recording of the performance<sup>1</sup> in order to keep an analyzable trace, and to collect the feedback of spectators.

We relied on the NIME community, in particular on the research of the University of Oslo about the results of the experiment with the *SoundSaber* [15], an instrument designed on a similar principle of motion capture. Unlike the *Soundsaber*, which requires continuous manipulation to be kinetically active (except in the case where it is launched by the performer), the tangible interfaces we imagined had to be able to behave autonomously after being manipulated because of their own energy (kinetic energy) and bring a contingent dimension to the performance.

From an artistic point of view, we wanted the aesthetics of these kinetic objects to visually arouse the viewer's curiosity and attention. We had thus imagined very early giving them a very strong plastic dimension, as much in their shape, their colour, their material, their lines, as in their own lighting, with as reference and inspiration, the kinetic art of the 50s and 60s [1, 6, 7].

The term "motion capture instrument" (MCI) used in this article will refer to the instrumental interface as a whole, including both hardware and software. Proposed by K. Ny-moen *et al.* [15], it well reflects both the idea of a musical instrument and the technology from which it is designed.

This article will propose a reflection on these two aspects: the hardware - the motion capture system and the objects captured - as well as the software that had to be developed for digital audio use, MoCap systems being generally designed for applications in the field of video games, cinema or biomechanical research.

Finally, we will attempt to report on the points that seemed important and original to us at the end of a complete creative process that goes as far as the public presentation of the performance.

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<sup>1</sup><https://vimeo.com/328923793>

## 2. METHODOLOGY

The project was carried out in two stages at the University of Rennes: (1) a research, experimentation and development phase of approximately six months in *Immersia*, a virtual reality platform equipped with motion capture systems; (2) a two-week artistic residency in the *Pôle Numérique Rennes-Villejean* (PNRV), a university building equipped with digital tools and dedicated to the creation of shows and interactive installations.

The performance was shown four times to the public during the *JACES*<sup>2</sup> in the University of Rennes2, a one-week group exhibition dedicated to digital art productions, as well as once for the *Journée Science et Musique*<sup>3</sup>, a general public event organized by the IRISA computer science research laboratory. These performances gave rise to valuable exchanges with the audience, contributing to the analysis presented here.

### 2.1 In the virtual reality platform

The preliminary research and experiments in the *Immersia* platform were carried out in a space of approximately 20m<sup>2</sup> equipped with an ARTTrack2<sup>4</sup> motion capture system. A first phase focused on the detailed operation of the MoCap system made it possible to consider the applications that would have to be developed in the light of the project's objectives. These applications (*ARTtoOSC* and *μZYX*) will be presented in detail later in this paper.

The second phase concerned the design of kinetic objects in order to prepare their subsequent manufacture in the fablab of the University of Rennes2 equipped with the necessary tools (laser cutting machine, power tools, 3D printer, etc.). During this phase, work was made on both the functional and technical aspects of these objects (grip, strength, etc.), while keeping good aesthetics.

### 2.2 Intermediate period

An intermediate period of a few weeks before the artistic residency made it possible to finalize the prototyping of six infrared targets, one kinetic object (a light pendulum), and to create an Ableton *Live* session in preparation for the mapping of the traditional instruments used on stage. This included the import of different virtual synthesizers and audio processing plugins that we wanted to be able to control during the performance. Finally, we established a lightplot with the projectors that we intended to control with the MCI.

### 2.3 Artistic residency

Following this preliminary research and validation of the technical viability of the system, a two-week residency period was held at the PNRV, during which the performer worked independently to compose the music, develop the staging and dramatic construction of the performance and create the lighting.

## 3. THE KINETIC OBJECTS

This section will describe the design of the pendulum used for the *Vis Insita* performance, as well as the infrared targets necessary for a kinetic object to be detected.

### 3.1 The luminous pendulum

In order to make it easy to read for the audience and implement it into our study, we imagined from the outset an

object that could be handed in several ways and capable of occupying the entire stage space.

A simple solution was to suspend an infrared target from the ceiling. However, the target was not heavy enough to swing for a long enough time, so we had to weigh it down. From there came the idea of making a kinetic object inspired by a pendulum.

As the object was intended to be observed by the public, it was important to also think about its aesthetic aspect. Poetically inspired by the inner force of matter (*Vis Insita*) defined by Isaac Newton [14], we started with the aesthetic idea of an "energy ball" (Figure 1).



**Figure 1: The light pendulum equipped with its passive infrared target.**

The pendulum consists of thin white PVC plates assembled in the shape of a sphere using threaded rods, inside which we have placed a 24V-50W incandescent lamp that can be dimmed using a lighting application installed on a laptop computer, and a dimmer controlled via a USB/DMX interface.

The target for tracking the pendulum was attached to the cable at the top with a metal clamp, where the MoCap system has less occlusions during the performance.

### 3.2 Passive infrared targets

Unlike an isolated marker, a passive infrared target (IrT) composed of several markers is a robust way to track the objects in space: the multi-marker geometry allows, after a recognition phase by the MoCap system, an indexing and thus a re-detection in case of partial or total momentary occlusion. It also allows a capture of rotation, which is impossible with a single spherical marker.

However, in order for the system to discriminate different targets present on stage, it was necessary to give them differentiating enough geometries to avoid any ambiguity.

During the first tests with the targets supplied with the MoCap system, we quickly realized that we would have to manufacture our own ones.

First, from a functional point of view, the manufacturer's targets were only designed to be attached to the human body, including wrist and ankle joints, with an adjustable elastic band. This system prevented us from attaching them to the moving objects we imagined. On the other hand, they did not correspond to the general aesthetics we wanted to give to our kinetic objects, and it was not technically possible to modify them.

Considering these targets are the basic element of our MCI, we approached their design by taking inspiration from the atom, the latter being made up of a nucleus around which elementary particles gravitate.

<sup>2</sup><https://journées-arts-culture-sup.fr/>

<sup>3</sup><https://jms.irisa.fr/>

<sup>4</sup>from the German manufacturer A.R. Tracking

However, these handmade IrT had to be able to withstand potential shocks and be firmly attached to kinetic objects. The IrT nucleus was carved from a piece of raw wood (beech) dense enough to add wooden inserts in order to securely screw threaded rods, to the opposite end of which the infrared markers were attached.

In order to standardize and stiffen the entire IrT, we covered it with a thermosetting polymer paste and then covered it with a white acrylic paint.

The markers were made from commercially available beech logs to which we applied retro-reflective tape. This tape was laser cut to optimize the quantity and cleanliness of the contours.

## 4. SOFTWARE IMPLEMENTATION

The software implementation is based on two main components, as shown in Figure 2: (1) the *ARTtoOSC* component is dedicated to converting raw MoCap system data into OSC data via a VRPN interface; (2) the  $\mu$ ZYX component is dedicated to managing these OSC data for use in music and lighting applications.

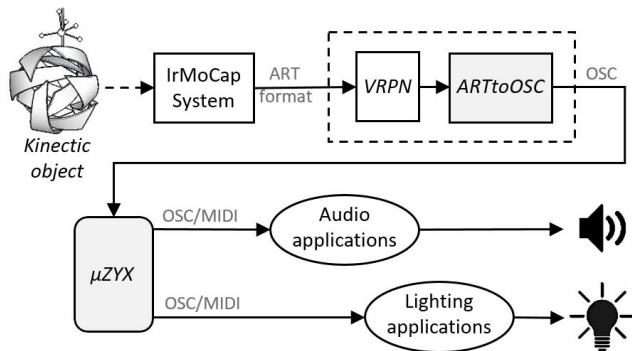


Figure 2: Software implementation diagram.

### 4.1 The *ARTtoOSC* application

Natively, the ARTTrack2 system sends angular and spatial data from the optical capture to its embedded *DTrack2* application in a proprietary format. It was therefore necessary, as a first step, to convert these data into usable data for our project. The choice was quickly made on the Open Sound Control (OSC) [11] protocol, which is fast, open and versatile. For this purpose, we coded in C# an application called *ARTtoOSC*.

In order to allow portability to MoCap systems from different manufacturers, we chose to code this application using the set of VRPN<sup>5</sup> (Virtual Reality Peripheral Network) classes and servers. This open-source system, designed to implement a transparent interface between software applications and the many physical devices used in a virtual reality system, was perfectly suited to the devices of the ART system.

The *ARTtoOSC* application returns two types of OSC messages:

- The target identifier (integer) and its position in the three-dimensional reference frame (Cartesian coordinates  $x$ ,  $y$  and  $z$  expressed in metres with respect to the reference point determined during the calibration of the MoCap system), in format `body/identifiant/pos [x] [y] [z]`.

- The target identifier (integer) and its three rotation angles (Euler angles  $rx$ ,  $ry$  and  $rz$  expressed in degrees on a scale from  $-180^\circ$  to  $180^\circ$ ) in format `body/identifiant/rot`

<sup>5</sup><https://github.com/vrpn/vrpn/wiki>

`[rx] [ry] [rz]`. The OSC data from *ARTtoOSC* is then sent to  $\mu$ ZYX via UDP in order to speed up the communication (to the detriment of lost packets).

## 4.2 The $\mu$ ZYX interface

The main functions of the  $\mu$ ZYX interface are to format the spatial and rotational data from IrTs into MIDI data compatible with digital audio space, as well as to calibrate and route them.

As our MCI must potentially be able to control other heterogeneous parameters such as light parameters for example, we have opted for a second possibility of conversion to OSC, a communication protocol that is also very widespread among applications encountered in the performing arts.

The  $\mu$ ZYX application was developed in *Max 8*<sup>6</sup>, on the one hand because this programming environment is completely prescribed for the realization of patches requiring OSC and MIDI data management, and on the other hand because it allowed to quickly realize a graphical interface essential to an efficient data management in scenic conditions, both in repetition and presentation.

This graphical interface consists of a main module and as many target modules as necessary (Figure 3).

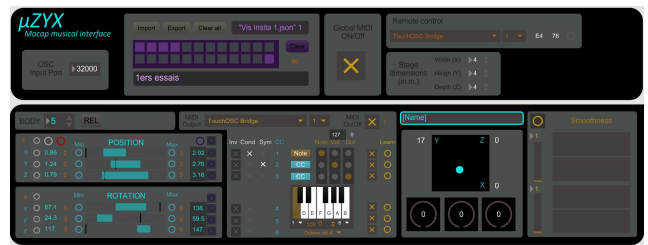


Figure 3: Graphical interface of  $\mu$ ZYX: main module (top) and one target module (bottom).

The main module allows selecting the OSC data input port, saving the configuration of all target modules as presets, disabling the general MIDI output, choosing the MIDI input port for remote patch control and pre-configuring the dimensions of the playing area.

The target module allows (according to a reading from left to right) the calibration to the digital audio space of the physical data of the IrT specified in the upper left corner, the calibration, routing, visualization and smoothing of this data to a MIDI or OSC output port.

Additional options enhance these features, such as the ability to specify an offset for each of the six input parameters and initialize them in a position in the physical space different from the zero point of the MoCap system.

The central window of the target module also offers various options for setting MIDI signals, such as disabling them or inverting the range. It also has an arpeggiator that discretizes incoming continuous signals into MIDI notes. The range, mode and tone of this arpeggiator are adjustable. The velocity and duration of the notes can be associated with a gestural parameter within this window.

## 5. THE *VIS INSITA* PERFORMANCE

### 5.1 Creation

The creation of the performance followed our preliminary research and took place over a period of two weeks in a PNRV plateau of about 60m<sup>2</sup> in which we installed the device. This stage could accommodate approximately thirty

<sup>6</sup><https://cycling74.com/>



people per performance, for one hundred and twenty people out of the four performances given.

The device consisted of several standard instruments (electric bass guitar, MIDI keyboard, electronic percussion kit) connected to a laptop computer via a sound card. The solo performer sampled live these instruments in the Ableton *Live* software using a MIDI pedalboard to trigger both recording and playback of the samples. This management of live sampling was supported in *Live* by MIDI remote scripts.

The pendulum was suspended in the centre of the playing area, as presented in Figure 4. It was equipped with an IrT whose movements were captured by the eight cameras of the MoCap system, four hung on the technical grid, and four placed on the ground.



**Figure 4: Overview of the *Vis Insita* performance.**

The displacements and rotations of this IrT acted during the first quarter of the performance on the tone, height and distortion of a synth pad. In the final part, it modulated dozens of sound processing parameters (glitch, delay, reverb, phasing, pan, etc.) on the main audio output bus, and controlled the horizontal and vertical movements of the automated LED projector located above.

This switch of the parameters controlled by the same target was made possible thanks to the preset system of the  $\mu ZYX$  interface. These presets, accessible in the main window of the interface (Figure 3, at the top) and remotely selectable in MIDI, instantly recalled a set of different configurations for the target concerned, but also for all the targets used on stage.

For a greater variety of movements and instrumental controls, we decided to implement two other IrTs. The first was fixed on the head of the electric bass guitar (Figure 5, left), modulating in real time the sound of the latter according to its movement on stage, as well as the luminous intensity of the pendulum. The guitar became therefore an augmented instrument. The second IrT appeared in the last third of the performance, when the performer played the electronic percussion kit (Figure 5, right). It was fixed on his left wrist and then modulated different sound treatments that altered the sounds of these percussions according to the three-dimensional movements of the wrist. These percussions were themselves connected directly in MIDI to the lighting software in order to turn on some projectors in a synchronized way with the drum strikes.

## 5.2 Presentation

The public presentation for the *Journée Science et Musique* event was performed in front of an audience of about one hundred and fifty people, and lasted about twenty minutes.



**Figure 5: Left: target on bass guitar; Right: target on performer's wrist.**

For this event, the Company ART provided us with the latest generation equipment (ARTTrack5) equipped with POE (Power Over Ethernet) technology, reducing the system's assembly time, and providing a higher refresh rate (150Hz instead of 60Hz with the ARTTRACK2 system), improving the quality of tracking and reducing overall latency by about 10ms.

## 6. DISCUSSIONS

### 6.1 MCIs in scenic context

One of the main technical unknowns before the field tests was to know to what extent an MoCap system designed for the fields of virtual reality, animation cinema or biomechanical research, would be adaptable to an environment for which it was not planned at all: the stage.

First, since the system was *de facto* sensitive to infrared radiation, the first question was whether it would be affected by incandescent light sources installed on stage, which, in addition to the visible spectrum, also emit in infrared wavelengths (850nm). After tests and adjustments, it turned out that this did not affect the quality of the tracking, the system being robust enough to recognize the geometry of the targets despite the presence of many parasitic detection points.

If MCIs in live conditions offer a number of expressive and artistic perspectives that we will see later, they raise spatial questions for the performer that do not exist for a standard instrument.

In the case of an MCI, it is necessary to clearly define the two universes to which we have to deal: the real universe - the room, the stage, the physical place of the presentation - and the computer universe, which has its own size ranges according to the transfer protocol considered (from 0 to 127 in MIDI and from 0 to 1 in OSC in the case of  $\mu ZYX$ ). These two universes are not isomorphic since different calibrations for each dimension as well as non-linear transfer curves (exponential, logarithmic, inverted, etc.) can occur.

One of the main tasks in designing the  $\mu ZYX$  software interface was therefore to allow an easy transposition from the physical to the digital universe. We used six horizontal sliders (Figure 3, bottom), three for positions and three for rotations, allowing both to visualize the modulations of the input signal with the black cursor and to set an output range (in cyan blue).

These essential spatial data calibration operations can be tedious and daunting because they require the performer to be present on stage to position and move the IrTs while

having to work on the  $\mu ZYX$  interface. In order to make the MCIs viable in stage conditions, a lot of work had to be done on the creation of a clear, light and intuitive graphical interface, as well as on the possibilities of controlling this interface wirelessly and remotely via a Bluetooth alphanumeric keyboard.

Beyond this problem, MCIs seem to offer interesting potential in terms of space. Indeed, the evolution zone of musicians is often constrained by the fixed nature of the electronic instruments and control interfaces they use, especially in electronic music [8]. Most of the time, they remain standing behind them, and have very little places to move. Although the MCIs are spatially limited by the detection zone of infrared cameras, we can see that the evolution - and therefore expression - zone can become much larger and act on macroscopic levels [13] order of several meters.

## 6.2 Autonomous movements

As we saw in the introduction, the most widespread examples of musical applications of MoCap are particularly relevant to dance, with technological and aesthetic issues in this field becoming well known and analysed.

Of the three targets used during the performance, the target of the wrist is certainly the one that most closely resembles a case of body capture (in this case, a part of the body) as found in dance. On the other hand, the pendulum represents a different scenario since the capture takes place on an object that is both manipulated by the performer (and therefore dependent on his movements) and also has autonomous movements.

In both cases, the activation energy source remains the performer. But in the case of the pendulum, the movements are also related to physical forces during the autonomous phases (for example when the pendulum makes large circular trajectories throughout the stage space) such as gravity, rebound, elasticity, etc., giving it very specific movement qualities that the performer (and even a dancer) would most certainly have great difficulty reproducing.

What seems important to us here is therefore the propensity of the pendulum - and kinetic objects in general - to generate natures of movement (and therefore parameter control) that are difficult to obtain in any other way, whether in their regularity, scale, complexity, velocity, or regular damping, for example.

This opens up interesting interpretation perspectives for a performer: the influence on sound parameters is no longer directly linked to his/her gestures; it is mediated by an interface with its own physical and kinetic characteristics that he/she can creatively exploit. This type of relationship involves a sonification of movement and an intentionality on the part of the performer in the trajectories he/she imprints on the object. In return, the object's behaviour influences the performer's actions.

The work of learning beforehand becomes essential: like a juggler with clubs or a puppeteer with articulated characters, by working at length with the object and taking over its kinematics, the performer ends up knowing the slightest reactions and can play with them in a very subtle way. There is then interaction between him/her, the object and the music. If it is a dance, then it is neither a solo nor a duo, but a dynamic and creative trio, using both improvisation and an important kinesthetic mastery.

In addition, the dissociation of the sound generator (virtual synthesizers and sound engine) from the action device (e.g. the pendulum) offers the possibility of adapting the latter to both the morphology and the proprioception of the musician. The interface is configurable and customizable regardless of the nature of the sound to be generated.

## 6.3 A relational interface

We have seen that the choice of manufacture of the pendulum, with its fins entangled in each other, was to allow easy gripping in different ways.

If this was the case during the performance, it turned out that the affordance of the object was not satisfactory, the number of plates and the rotation of the pendulum on its vertical axis sometimes making it difficult to grasp and anticipate. This difficulty was felt by some spectators: even without having had the opportunity to manipulate the pendulum, they talked, for example, about their feeling of "fear" that the object would fall out of the performer's hands, or that he/she would not be able to catch it.

This phenomenon, called "motor resonance" by perception neurophysiologists [16], describes the empathic relationship that occurs in an individual's mind through his/her mirror neurons, when he/she watches another person performs a movement and mentally simulates the same movement within his/her own body.

Thus, in the case of the pendulum, the unstable and dynamic relationship between the object and the performer created a palpable tension on stage. The emotion transmitted was not only through musical expression but also through anticipation and physical appropriation of the artist's gestures.

On the other hand, one of the problems frequently encountered during a concert in the field of live electronic music is the doubt that the spectator may sometimes have between what he/she sees of the performer's actions and the real consequences on the sound [8]. Feedback regarding our performance has shown that if the movements are partly autonomous, even random, and the sounds heard are perceived as being related to their movements, then the viewer has offered confidence in this relationship, since he/she considers that it cannot be pre-programmed, or planned in advance. Just like the string of a guitar that can break at any moment, creating the random aspect of the interface on stage would therefore be a way to restore a relationship of trust between the performer's actions and what is shown and heard by the spectator.

## 6.4 Plasticity of interfaces

Among the various existing motion capture technologies, optical MoCap is distinguished by the non-invasive aspect of electronics. The captured part of the MCI then becomes constitutable of any material and can take on almost any shape or appearance, the only constraint being that it must be equipped with an IrT to be detected.

This has the effect of promoting a design based not only on a technical, functional or technological approach, but also on plastic and aesthetic considerations.

To think of an instrumental interface with regard to its own movements is above all to think of an object in the space it occupies, in its materiality, in its relationship to the one who manipulates it, but also to the one who looks at it. It means considering this object in its spatial qualities, its geometry, its lines, its balance, its dynamics, and in the astonishment and questioning it arouses in the viewer. The history of visual arts sheds light on a trend that has insatiably sought an aesthetic of movement in the object: kinetic sculpture.

Particularly active in Europe and the United States in the 1950s and 1960s, this movement, led by artists such as Jean Tinguely, Nicolas Schöffer and Alexander Calder, has constantly challenged the spectator's perceptive faculties. Could the instrumental interface not thus tend towards this fully-fledged art object, capable of combining movement, sound and visual?

In the case of the *Vis Insita* performance, we have seen earlier that the pendulum has been designed to be easily gripped, to be readable by the public, and to have certain luminous aspects. However, it has also been based on artistic intent: creating a poetry of movement and musical interpretation on stage and shaking up the spectator's usual perception in order to encourage multi-sensory listening to live music.

Through technologies and new interfaces, the role of musicians is shifting: not only are they becoming luthiers of their own instruments, but also their field of relational potentialities with the spectator is expanding. The instrumental interface is no longer only used to generate or control a sound; it becomes an artistic element in itself, an integral part of an overall creative process.

## 7. CONCLUSION AND FUTURE WORK

Our initial intention was mainly to evaluate the expressive and instrumental potential of a MCI designed from a kinetic object that can be manipulated by a performer, beyond the capture of his/her own body itself.

There are many tracks and they will deserve to be further developed technologically, especially with regard to the  $\mu$ ZYX interface (improvement of the graphic user interface, preset management, implementation of remote control via smartphone, etc.).

We would like to conclude this article by focusing on how the creation of performance has evolved the conceptual approach of our MCI throughout our research.

Faced with the constraints imposed by the challenge of a real presentation in public, we have indeed gradually become aware of the possibilities of MCIs in terms of multimodal interaction and simultaneous management of heterogeneous parameters, with synthesis and sound processing parameters, but also light parameters.

The prospects for applications of this type of research can therefore extend well beyond the *Vis Insita* project and are addressed not only to digital musicians, but also to any artist (visual artists, dancers, choreographers, etc.) working on interactive installations requiring tangible, plastic and original means of human-machine interaction, and even human-human interaction.

The consideration of the place of presentation and the proximity to the public led us to have a global reflection on the design of the interface with an ecological approach [12].

We believe that this type of practical approach by confronting concrete situations of meeting the public in less and less conventional places will deserve to be developed in the future in order to cross-fertilize experiences and to bring new theoretical elements to the design of NIMEs.

## 8. ACKNOWLEDGMENTS

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