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Introduction

Acoustic Pendulum¹ is an immersive and modular project in which gravity and acoustics are brought into a generative equation. This kinetic installation is an extension of Steve Reich's "Pendulum Music", in which hanging microphones oscillated above speakers on the ground. Here the device is reversed: the microphone remains stationary while the speakers arranged inside the pendulum move within the room space. Initially motionless, the pendulum oscillates very slightly at human height and progresses at the speed of its resonance frequency, until it sways widely throughout the exhibition space. From lines to ellipses, the pendulum redraws the architectural contours of the space that the visitor discovers, listening to a soundscape finally modulated by the movement. With its audio engine based on acoustic feedback, Acoustic Pendulum operates a translation from movement to the sound, through the acoustic imprint of the exhibition room. This sound evolves slowly over time like a musical flow arising from the combination of the resonance frequencies of the pendulum and the ones of that location. Through a complex network of harmonic interpolations, this project offers the viewer a synesthetic perception resulting from a subtle balance between the movement of the pendulum and the sound generated through the acoustic response of the space, making this installation a resolutely in situ work. Echoing Foucault's pendulum, this contemplative installation proposes to the audience an aesthetic experience of immateriality, capable of connecting us to our cosmic condition. Through the vibratory nature of all matter that forms it, each atomic unit shapes the work, between the balanced behavior of the movement and the chaotic one of the sound performance.

For a 3 years Art & Science residency, Acoustic Pendulum is supported since 2017 by the MAS (Music-Audio-Sound) platform of the LMA (Laboratory of Mechanics and Acoustics) of the CNRS (French-National Center for Scientific Research) in Marseille, known worldwide for pioneering researches by Jean-Claude Risset in sound synthesis and computer music, and ECM (National high school of engineering) at Aix-Marseille University. Acoustic Pendulum is the 2020 winner of the "Brouillon d'un rêve - Pierre Schaeffer" grant from SCAM (the civil society of multimedia authors), and has received the support of "La Copie Privée".

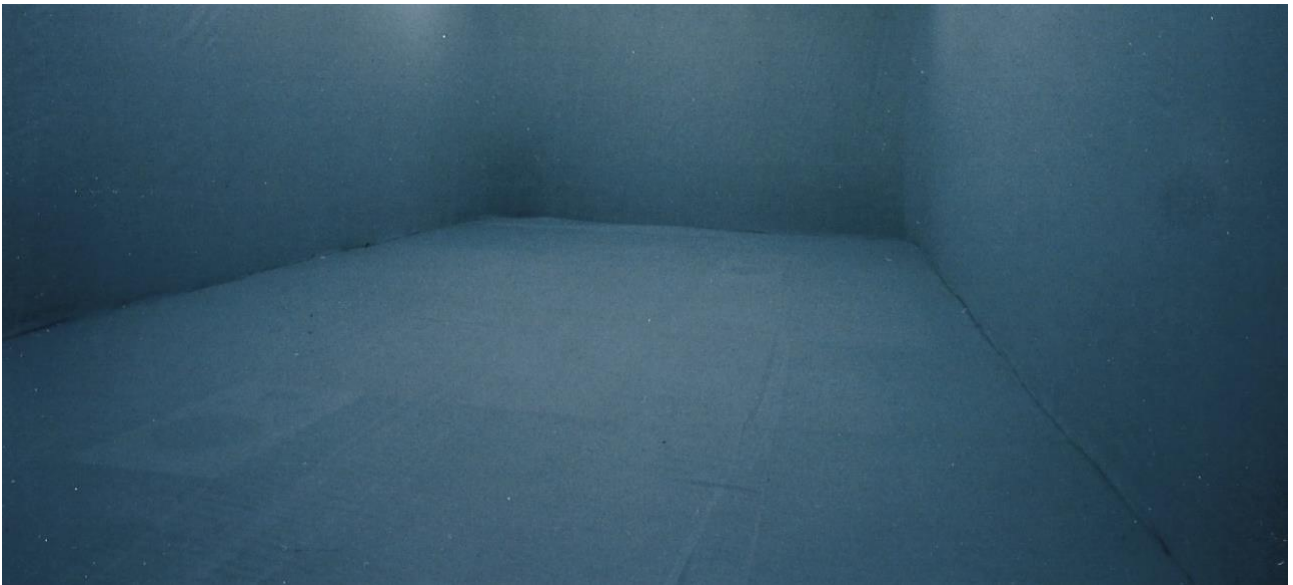


Acoustic Pendulum_ Chateau Ephémère, 2019

Genesis

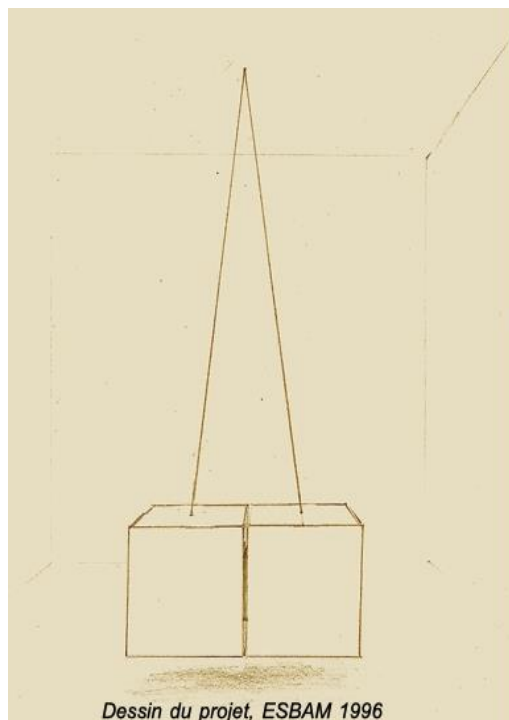
It was at the beginning of my studies at the Marseille School of Fine Arts that I discovered a real interest in immateriality. As a musician, and more precisely as a drummer, I was fascinated by the plasticity of the sound of skins and cymbals, which, when excited by mallets, release a multitimbrality very rich in harmonics. My sound art teacher was the composer Lucien Bertolina, with whom I discovered studio creation, an experimentation that I completed in the electroacoustic class of the Conservatoire National de Marseille, with Pascal Gobain. From recording to sound editing and plastic reflection linked to space, I laid the foundations for research into the question of time and vibration in the fields of music, live performance, sound art and digital art, which I am still pursuing.

I obtained a Dnsep (national diploma of plastic expression) in 1997 with an installation called *Nowhere*, a formula borrowed from the Swiss artist Markus Raetz, meaning here and now, or nowhere, depending on whether one considers the caesura at the "w" or the "h". This poetic anagram echoes the distortion of time and space sought in the experience of dissociation of sight and hearing offered to the spectator: a room in a 210 m³ room whose walls, floor and ceiling were covered with stretched white cotton, and was gradually saturated with white light. The dazzled visitors moved through an empty space behind which 8 hidden loudspeakers spatialized a sound composition based on recordings of heavy objects falling, smashing into the floor or against the walls under the effect of an imaginary gravity revealed by the sound. It is a question of abstracting sight in favour of a plasticity of sound in movement, whose experiential physicality of space represents, for the visitor, the immaterial substance of a project that conceptually, structurally and artistically implies 3 states of time: *time-state* [landscape], *time-duration* [composition], *time-deferred* [memory].

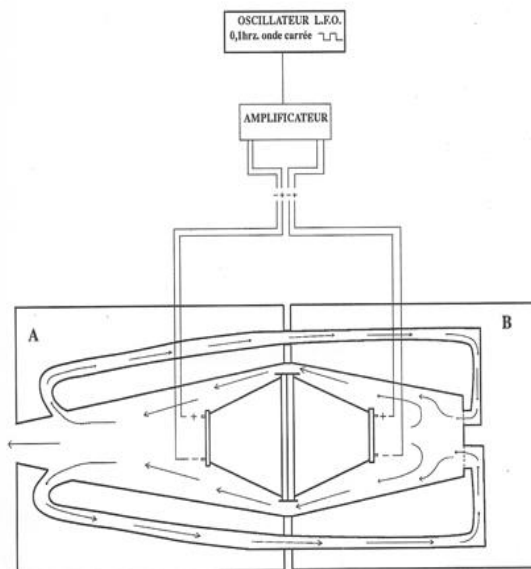


Nowhere, installation 1997

It was with these concerns in mind that, among other things, I designed Acoustic Pendulum for the first time in 1996.



Dessin du projet, ESBAM 1996



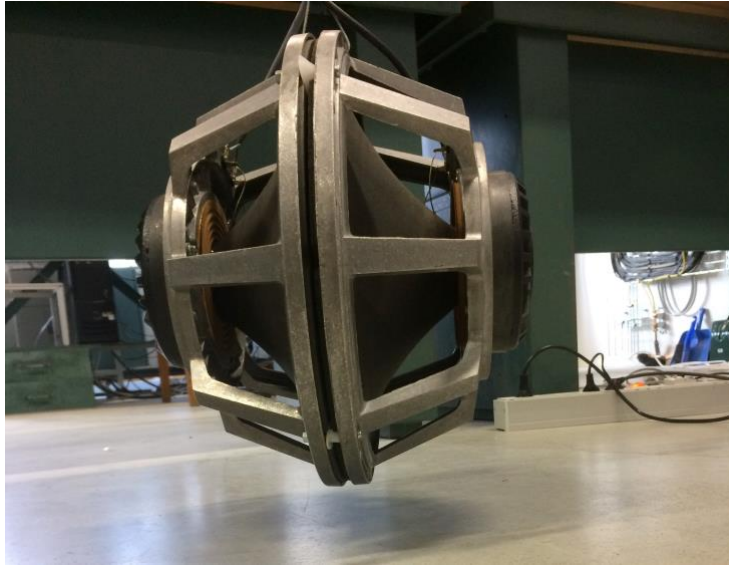
Dessin de la maquette LMA 1996

Acoustic Pendulum, first drawings, 1996

Lucien Bertolina introduced me to Jean-Claude Risset (1938-2016), a composer and a researcher internationally recognized for his work in sound synthesis and computer music, whom I met immediately at the LMA (Mechanics and Acoustics Laboratory). He suggested that I made a prototype in the form of a model with the help of the laboratory. Far too inexperienced and without financial means, I did not follow up. I spent the next twenty years mainly composing and improvising music. From sound art to radio editing, from free improvisation to contemporary jazz, I gradually stretched time and sound matter in instrumental projects such as *hoaxhoax*² or *Inner Island*³, with the aim of freezing the *time-duration* of the music in a *time-state* feeling for the listener. Then I left the studio to develop my own real-time tools on max/msp with Julien Bayle, a sound artist and an internationally reputed expert known for his works on this software⁴.

It was in 2017 that this pendulum came back to swing in my head. The technologies had evolved enough to consider its realisation. I wrote the project and sent it to Guillaume Quiquerez, the assistant director of the ECM (National School of Engineering), who relayed it to the CNRS (National Center for Scientific Research) network. Ten days later, Patrick Sanchez, head of the MAS (Music Audio Sound) Platform⁵ at the LMA, contacted me to offer me an Art / Science residency.

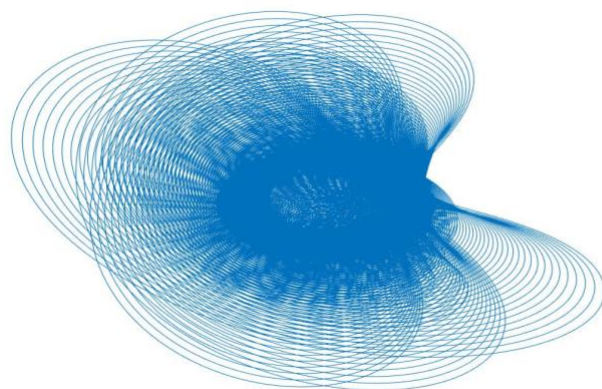
I started again from my 1996 drawing, looking for a pendular movement initiated by sound: a single pulsed sound tuned to the resonance frequency of the ensemble sat in motion two membranes stuck face to face, like a kiss. One of the two loudspeakers is wired in phase opposition so as to synchronize their lateral translations between their stop and their coil, causing a cyclic displacement of the center of gravity with each sound impulse. I planned to increase this imbalance by pushing air out of the speaker vent provided for this purpose in order to increase the balance of the pendulum. This was a failure because the weight of the coils exceeded the force delivered in the air by the device.



Loudspeakers kiss pendulum
Tests at the Mechanics and Acoustics Laboratory, 2017

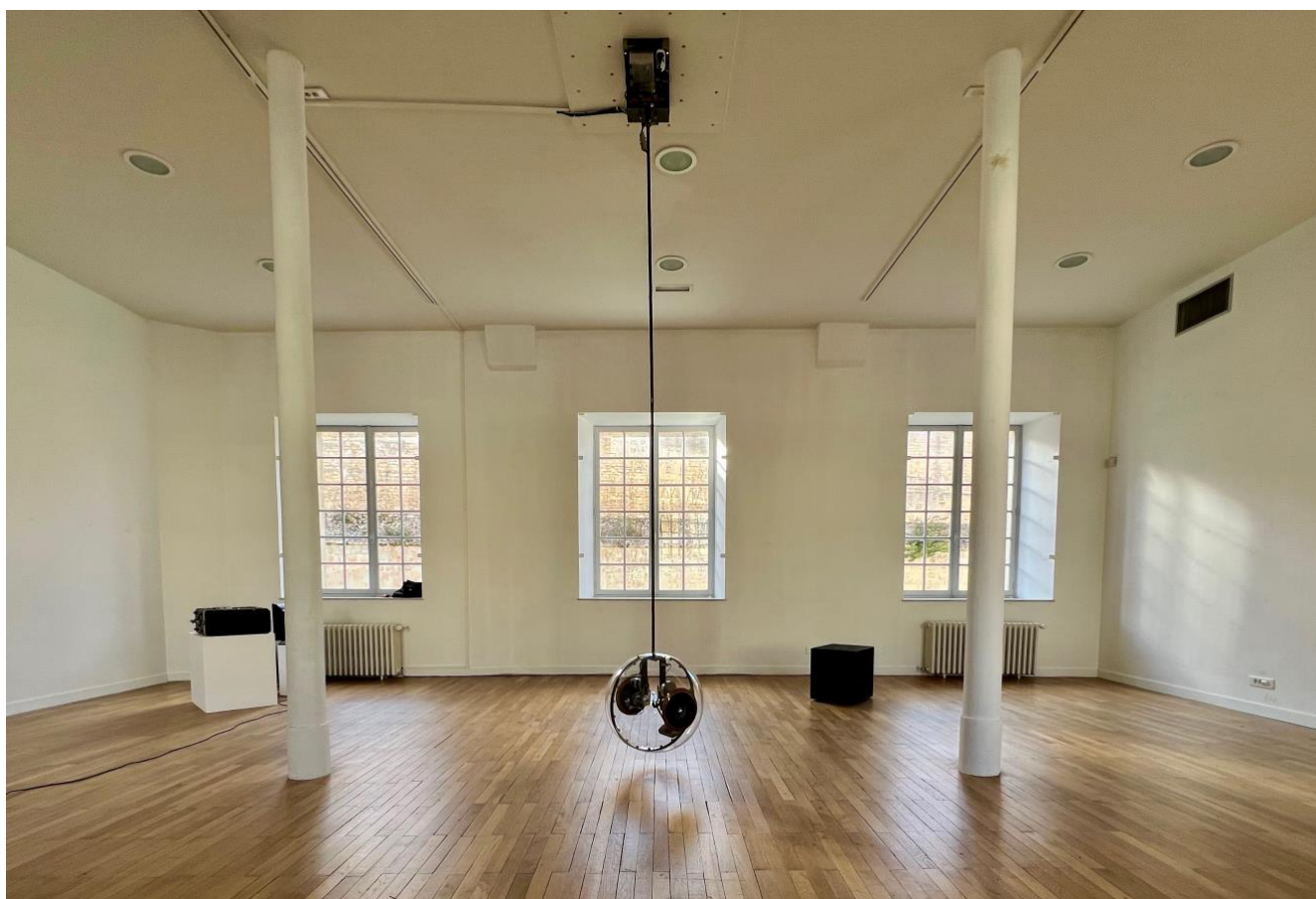
Patrick Sanchez noted that this idea was technically a double pendulum⁶ - consisting of two pendulums, one of which is attached to the end of the other and whose added forces cause non-linear and therefore unpredictable movements, characteristic of a chaotic system. However, for this project we were looking for a predictable, fluid and progressive behaviour, in accordance with the initial idea. Moreover, in order to keep the interaction between movement and sound, we had to reverse the roles. From now on, the movement would act on the sound to create the organicity of the project. The sound material was not yet defined and the starting framework of my work, twenty years earlier, had evolved. I was no longer trying to resolve the dichotomy between the *time-state* of the landscape and the *time-duration* of the music by the *time-deferred* of the sound object as in *Nowhere*, but rather to create the conditions of an [eco]system capable of generating its own sound and dynamic material in real time, from the in situ acoustic and gravitational initial conditions. This made the project all the more accurate, since the constants of gravity and inertia are permanently balanced by a force deployed according to the resonance frequency of the pendulum, like a flow. The sound should therefore also be the result of a continuous interrelation with the movement, which was itself the clock of the project. This is why the programming does not have a time line: here, the Movement is Time. I then developed an audio feedback patch that generates temporal granular synthesis, which under the effect of variations in the feedback duration provokes folding effects acting on the granularity of the feedback timbre. This system has the characteristic of revealing itself in the acoustic imprint of the place in which the microphone is opened. I then planned to assign to the numerous sound modulation inputs of the patch the accelerometric and gyroscopic data of an inertial unit intended to trace in real time the activity of the pendulum in order to increase the influence of the movement on the sound, generated in space. All the elements were in place to start a research phase that lasted two years.

Patrick Sanchez involved Etienne Gourc⁷, a researcher in vibration, to model the project on Matlab using Lagrange's equations, in order to define the constraints within which he would then build the pendulum. At the same time, the ECM (National School of Engineering) set up a design office, involving three young engineers, Martin Barbaud, Eliot Drees and Julien Garot, working under the direction of Christian Jalain.



Motion Modeling, Matlab code, Etienne Gourc 2017

The first version of the prototype was finally completed in June 2019 and released its first oscillations. It was to reach technical maturity in July 2020. After three public presentations during creation residencies (Chateau Ephémère in Carrières-sous-Poissy, at the Gamerz-15 Festival in Aix-en-Provence and at the Art Center le Milieu in Sault) and a year and a half break due to Covid, Acoustic Pendulum has been presented for the first time at the Festival Interstice - Rencontre des Inclassables in Caen (Fr) in October 2021.



Acoustic Pendulum Installation, Interstice Festival, 2021, Caen. Photo credit Etienne Rey / Video click on picture

The basics of a research

Stillness, as a starting point of any movement, dominates the origin of this research: how to give birth to a fluid pendulum movement and keep it going without any time limitation and without any outside help?

Physics tells us that $\text{Frequency} = 1 / \text{Time}$. Therefore the frequency principle of resonance is applied as the central element of the technical approach serving this plastic research.

In the ambivalent enigma of immateriality, what is the quantum part of matter, flow and energy involved in it? And how can we apprehend these concepts aesthetically, dynamically and sonically within the ecosystem of the installation form?



Out of a residency at Gamerz-15 festival_ESAAix, Aix-en-Provence, 2019. Photo credit Luce Moreau

Aesthetic

The pendulum imposes itself by its presence in space like a totem pole, with the difference that its anchor point is not a fixed point on the ground that connects it to the center of the earth, but an elevated point in height that radiates in multiple directions. Its dimensions remain within our human conception of volume: comforting in its form, yet destabilising in its movements.

Raw yet orderly, the materials, are mainly metal for the structure and plexiglass for the sphere. The object seeks a certain elegance in the simplicity of its lines and stripped down to its functionality. The transparent sphere renders the animality of the mechanism visible as it arouses our innate curiosity.

When the functioning of the mechanism is assimilated, the viewers forget it and abandon themselves to the sonified movements of the unfolding landscape. The object is reminiscent of a certain science-fiction aesthetic and lends itself to an anthropomorphic imagination of robotics with its cyclops eye, moving parts, membrane ears, fluid movement and luminescent sensors.



Acoustic Pendulum Solution F residency, 2020

Dynamic

From the design phase, the project was significantly associated with the lexical field of dance, primarily the search for the “right gesture” in a time that takes the time to be here. A temporality which has no task other than to disappear, leaving a mark, much like the memory of a drawing, or the body during the choreographic act.

Lateral, elliptical or circular, the movement technically results from implementation of a double-pendulum⁶ in which gravity cyclically rectifies the imbalance caused by the periodic shift of its balanced weight towards the center of the device.

The weight transfer that displaces the equilibrium point has long been explored in contemporary dance, as evidenced by the recent creations in 2019 of Yoan Bourgeois with “Scala” or Angelin Preljocaj with “Gravity”.

Just as dancers work with their gravitational consciousness combined with an increased knowledge of their bodies, the pendulum invariably requires a resonance frequency at all times to precisely modulate its amplitudes. To do this, its frequency is recorded, then updated in real time by a sensor which tracks all angles of the x, y and z planes of sound oscillation. When going in the opposite direction, the pendulum crosses a brief moment of immobility which the sensor registers with 0, which is then transformed into a Bang (trigger). Thus, between two Bangs (triggers), the patch calculates a Time (= Frequency).

This time is applied to the swing of the balanced weight in 3 angular speeds (acceleration, constant and deceleration) in order to give the movement of the balance a sinusoidal envelope. Each angular velocity is thus calculated in order to cover the correct distance between the ends of its amplitude: the apex.

The fluidity of its progression is obtained by allowing the natural inertia of the pendulum to complete each of its oscillations. To do this, the engine executes 60% of its course, leaving it to inertia to bring the pendulum to the moment of immobility to be analyzed, so that the patch will translate into a Bang to relaunch a new command in the opposite direction, and so forth.

The pendulum begins to oscillate, increasing its angle and speed by one degree every five oscillations. In this way, the pendulum can come to life on its own up to an amplitude of 2, 3, 4 meters above the ground, depending on the height of its range. So, it is through the conjunction of electromechanical, gravitational and inertial forces that the pendulum finds its natural fluidity, a kind of animality sought through the diversity of its behaviors.

Finally, the pendulum has at its hook a rotation motor, used alone, or combined with the oscillation motor. These rotations allow ellipses or circles in space, and favor a mobile projection of the sound in 3 dimensions.



Acoustic Pendulum, out of residency GAMERZ-15 Photo credit Luce Moreau

Sound

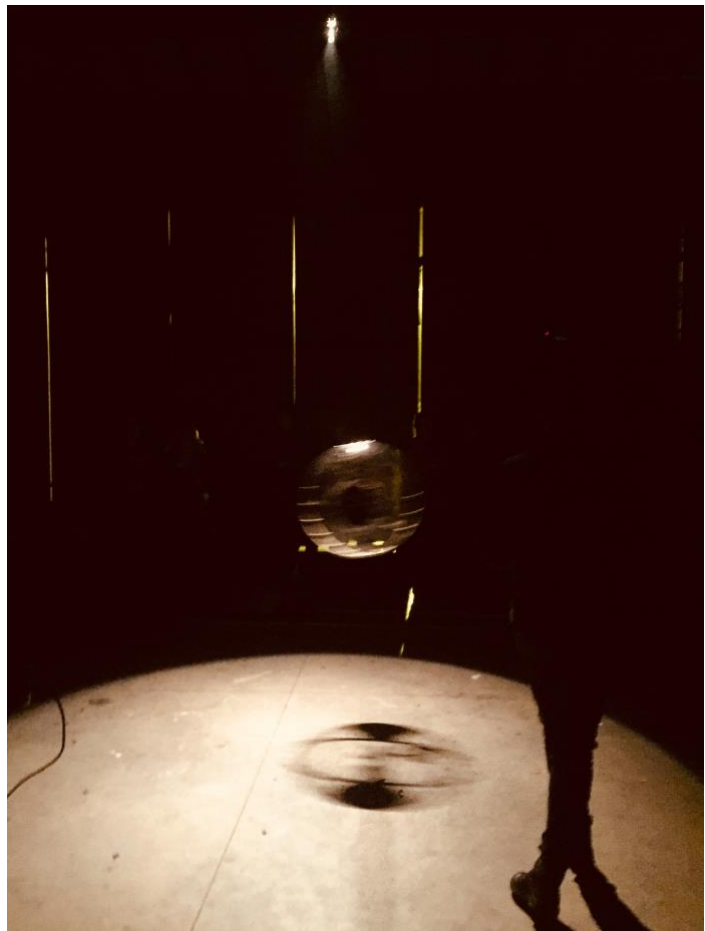
Acoustic Pendulum creates a favorable environment for the sequential generation of sound landscapes which are sensitive to the situation, capturing and restoring the acoustics of the location. The sound emitted is the result of the continuous acoustic field between the speakers and the microphone, so there are no sample banks or memory in play, other than its own ability to sample itself to play accidents by granular synthesis. The audio engine multiplies the incoming signal in 4 matrix programmable units. Within each unit, the signal is fed back on itself with a variable delay from 10 seconds to several minutes, creating a continuum. The data from the inertial unit (gyroscopic & accelerometric sensor) is routed to the audio engine and, depending on the sequences, stimulates various sound modulations, especially time feedback resulting from relatively granular effects. So the pendulum becomes the interpreter of the sound installation.

At times, it manages to achieve a perfect synchronization between movement and sound, causing all sorts of natural phenomena, such as phasing and doppler effects, as if the spectator had been immersed inside a Leslie cabinet. So we sometimes hear melodies, made by major second or third intervals, fifths and octaves... These are purely aleatoric electroacoustic variations of the natural harmonics of the fundamental feedback, which the movements of the pendulum modulate within the acoustic character of the space.

Most of the sound work is focused on a spectral approach to timbres and on the projection of sound. The sounds can sometimes bear resemblance to acoustic wind instruments, electric bass or chimes, or else modular synthesis.

Performance

Acoustic Pendulum is also offered to the public in the form of a sound performance, where I invite myself into the interaction between movement and sound by musically interpreting the sound flow generated in real time, based on the sound modulation parameters developed in the patch. In this way, the installation is transformed into an instrumental device for the duration of a concert lasting about thirty minutes. For the improviser, the challenge is to be in phase with what is manifested in the installation by diverting its generative principle to confront it with the arbitrary dimension of the musical act, with the awareness of inoculating, like a virus, his own emotion into the feedback loop.



Performance GAMERZ-15_Photo credit Valerie Texier

Light

The purpose of this project being to reveal to the public its own vibrational manifestation, its relationship to light is inscribed in two possible ways. If the exhibition space has beautiful natural light, it will be favoured so that its slow revolution accompanies it in its way of inhabiting the space. In the same way that all exogenous sound is likely to interfere in the feedback loop, daylight invites itself as an essential actor in the project, offering our eyes its own manifestation of iridescence, diffraction and reflection.



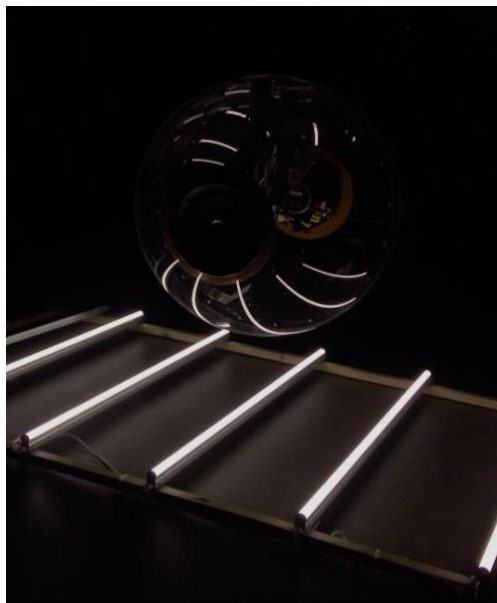
Acoustic Pendulum natural light, Interstice Festival 2021

However, if there is not enough natural light available or if the project is presented at night, then artificial light is necessary. For the GAMERZ-15 festival in Aix-en-Provence in November 2019, we installed a projector from above, drawing a large circle on the ground in which the shadow of the Pendulum came to life like a star, recalling the interrelation that coexists between the Earth and the moon turning around each other through the kinetic energy of their respective gravitational attractions.



Acoustic Pendulum artificial light, GAMERZ-15_photo credit Luce Moreau

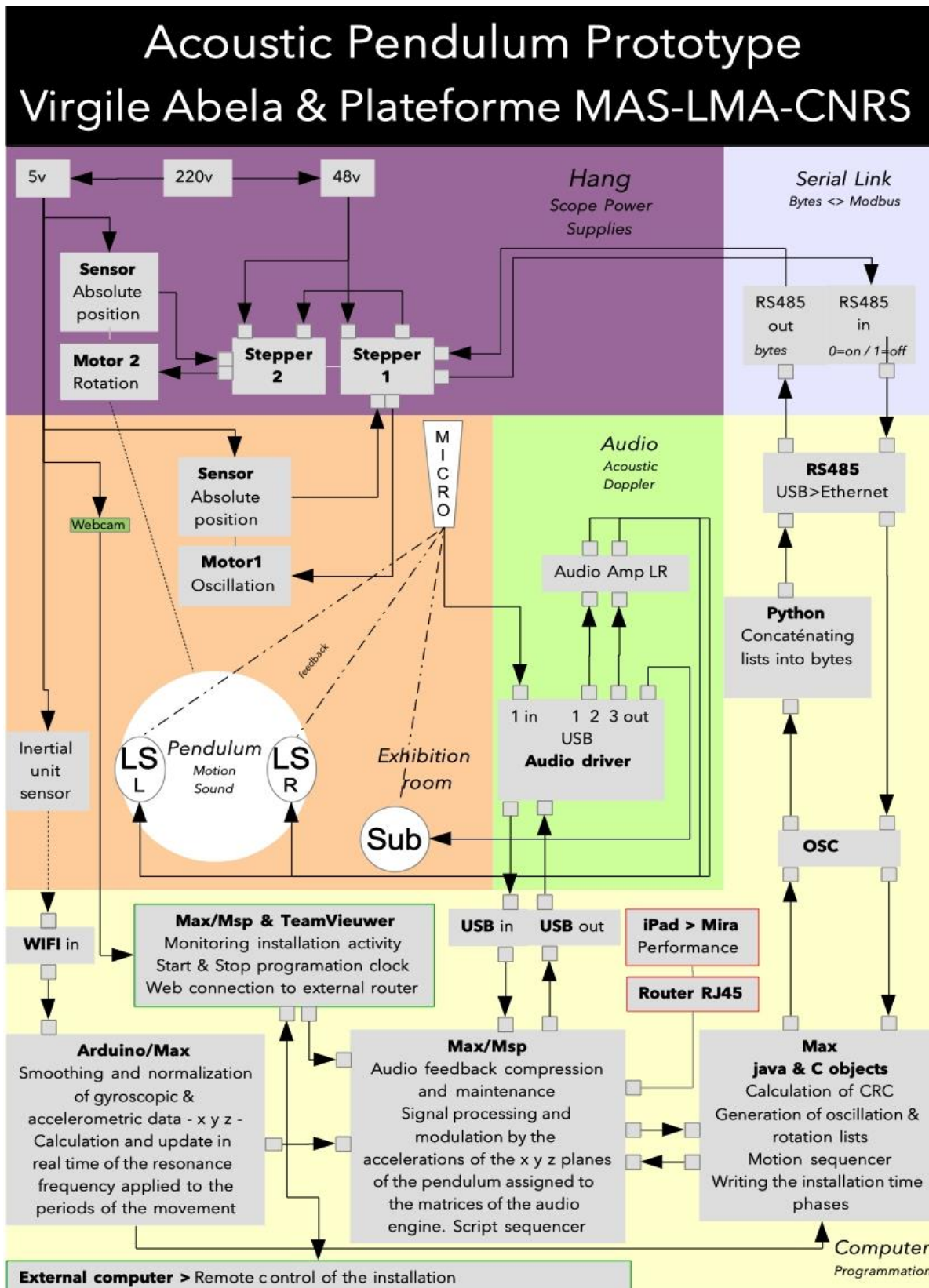
Finally, for the performance of the exhibition at the gallery Un Singe en Hiver in Dijon in January and February 2022, we experimented with an illumination from below with several neon lights. The light emitted by the device directly projects its own luminescent lines onto the Plexiglas sphere, creating a triple visual illusion depending on how you place yourself in the space. The first is that the lines are drawn in motion, accentuating the sensation of the object floating in space. The second gives the impression that the pendulum is filled with a fatty liquid, reminiscent of visualisations of organic cells, through the deformation caused by the roundness of the object on which the light is reflected. The third makes the object partially disappear in favour of the visual vibratory manifestation of its own movement.



Acoustic Pendulum neon light, Un Singe en Hiver

Ecosystem

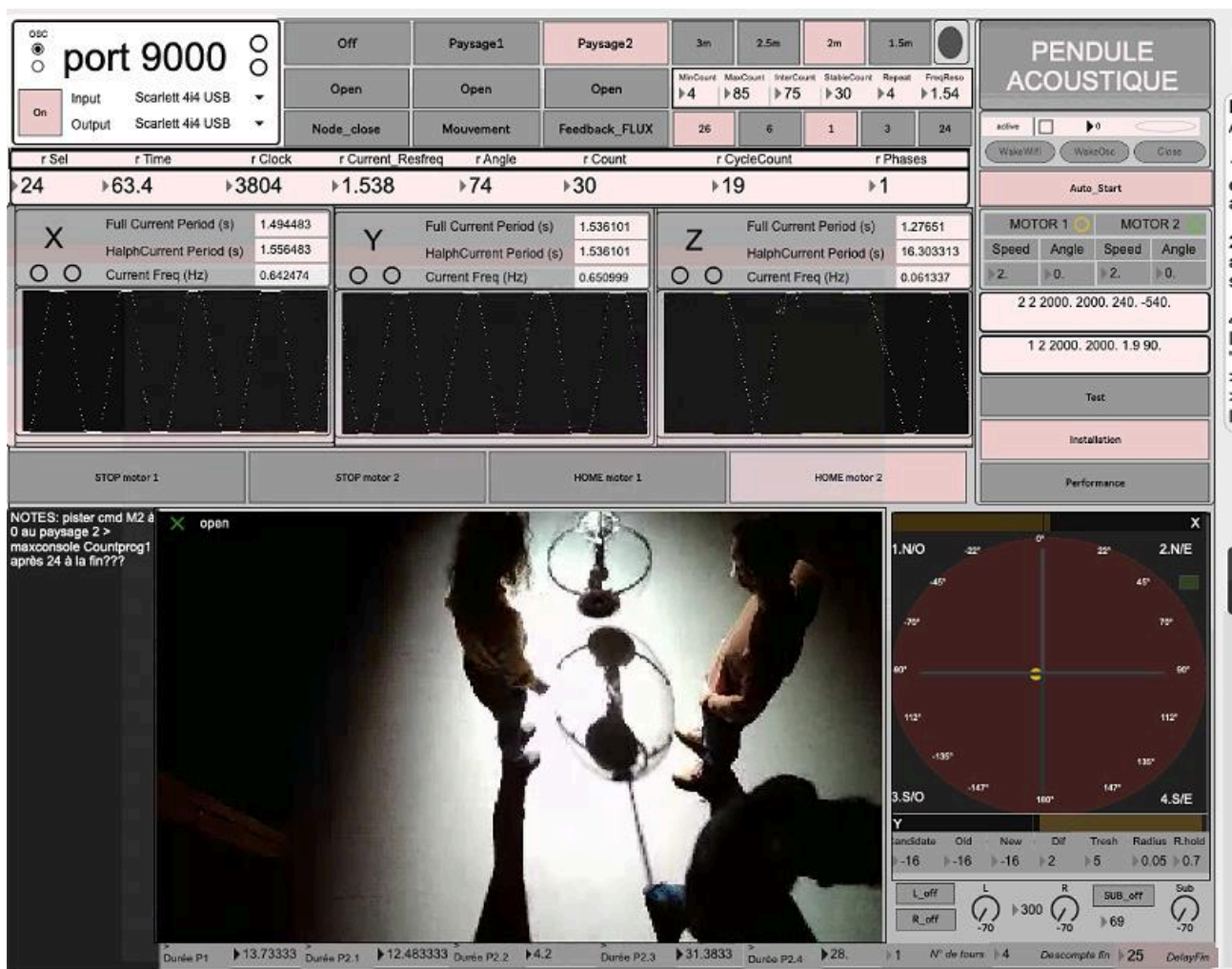
Acoustic Pendulum induces a conception of global circularity between the machine and the living, the computational part is designed in max/msp, which constitutes the brain of the loop. Other softwares are also involved, such as Python for the concatenation of messages sent by RS-485 serial link to the steppers using modbus coding, as well as C++ for Arduino for programming the sensors.



Acoustic Pendulum Device plan

The patch is equipped with a form of artificial intelligence capable of translating into polar degrees the progressive changes in the axis of the pendulum due to its own internal imbalances. Thus a rotation matrix is implemented in such a way as to position the pendulum in its oscillation axis, whatever the unpredictable angle in which it will gradually drift sooner or later. This quality gives it a real sense of self-determination.

The general principle of the programming comes alive like a body composed of different organs, each of which plays a precise role in coordination with others. The part that calculates the resonance frequency thus imposes itself as the organic heart of the global system. The part which mainly deals with the movement and the sound is sequenced in the form of phases called "Landscapes". They each succeed one another, as in a score, offering a time frame for the installation. This last one finds its permanence in balancing the predictable functioning of the movement and the chaotic behaviour of the sound, all synchronized through the rhythm of the oscillations that gravity imposes on the pendulum.

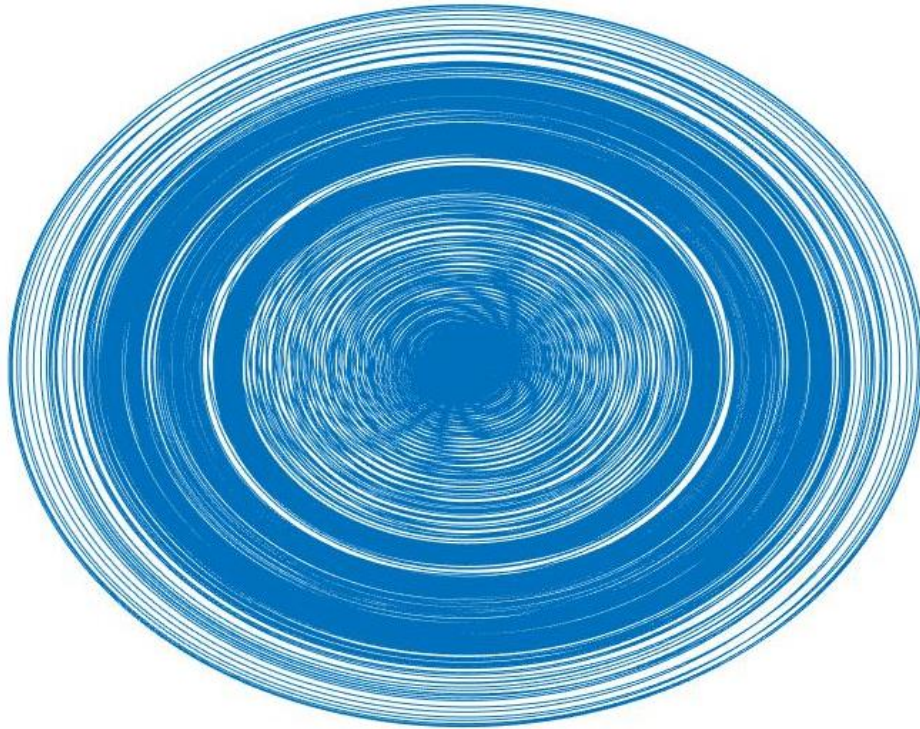


View of max patch at Un Singe en Hiver, Dijon, 2022

In addition to this article, you can discover Acoustic Pendulum at:

- [Un Singe en Hiver gallery](#) in Dijon (Fr) from January 21 to February 5, 2022.
 - Live performance for the closing of the exhibition on February 5th at 6.30 pm

- [The Sonica Biennial](#) in Glasgow (Gb) from 9 to 20 March 2022.
 - [Live Performance](#) on 13 March at 3pm



¹ <https://www.virgileabela.com/pendule-acoustique-1>

² Instrumental postrock_mathrock trio 2011-2017 with David Merlo and Damien Ravnich
<https://www.virgileabela.com/hoaxhoax>

³ Experimental duo with Jean-François Laporte since 2009, Marseille-Montréal
<https://totemcontemporain.com/fr/totem-hors-serie/innerisland>

⁴ <http://julienbayle.net/>

⁵ <https://mas-lma.cnrs.fr/>

⁶ https://en.wikipedia.org/wiki/Double_pendulum

⁷ [Author of the thesis](#) “Study of passive control by energy pumping under harmonic loading: Theoretical and experimental analyses », INSA Toulouse, 2013.

