The Méta-instrument. How the project started

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In order to better comprehend the Méta-instrument, let's start with some historical facts. From 1983 to 1988, the Espace Musical has been working on the simulation of moving sound in a three dimensional space. This research has led to the design and implementation of the Octophonic Spatial Processor, which computes the distribution of sound over eight or sixteen loudspeakers from the coordinates of the sound (in Cartesian or polar form). The distribution of the loudspeakers in space is variable: line, cube, circle, etc.

Since 1988, after several experiments, we have mostly been using a configuration where the eight loudspeakers are situated at the corners of a cube. This cube is placed on one of its edges which, in a concert situation, corresponds to the limit between stage and hall.
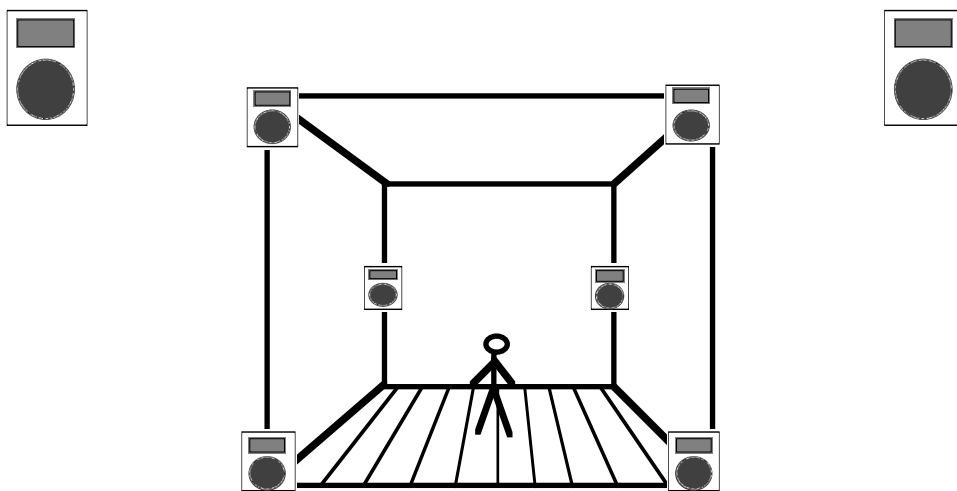

Fig. 1. Usual distribution of the loudspeakers.

The different types of music composed using this system led straight away to one observation: there is no point in moving sound in space if its movement isn't linked to its spectral movement. The nature of this link between internal movement and architectural movement is a complex one since it combines several fields of knowledge: acoustics, music and psychology of perception. We will try further on to make some observations.

The possible paths of exploration for music which were emerging from this very stimulating research did however come up against a real problem of accessibility. Space in music may well be omnipresent Métaphorically, but traditional instruments are not designed for moving sound in space. The aim was then to imagine a system capable of simultaneously moving sounds in space and making them evolve spectrally.

The second reason for implementing the Méta-instrument was linked to the musicians of the Espace Musical who had asked to play "musique concrète", not for recording this time, but for a concert, therefore live. Associating the upheaval of recording which enabled the musician to work with sounds, but who most often produced recorded music, fixed onto a recording medium (music of fixed sounds), while recreating the short-lived dimension of instrument playing and concerts.

Fig. 2. The orchestra of Sonocannes.

This request was made after the implementation of several devices like the Sound Transducer Modelling Filter, which is a floppy Métallic ruler which is two meters long with at one end a contact microphone, at the other a contact loudspeaker, and in between some signal processors; the musician controls the feedback in the ruler by modifying its shape and the way it is held) or the Sonocanne, a long carbon fibre stick onto which is fixed a tweeter; the Sonocanne is a very light tool which enables the musician to move sound in space with virtuosity.

Rather than develop a specific electroacoustic device for each composition, the request was made to implement a general-purpose device which could model specific devices inspired by musique concrète.

How the Méta-instrument works

These two points led to the design of a general-purpose system made up of three parts: sensing gestures, processing gestures, and perceiving the processing that has been done.

The function of the Méta-instrument is to sense gestures. It is therefore a gestural transducer designed to measure and digitize the gestures of the musician. The first Méta-instrument was built in 1989 and still works to this day. A second generation of Méta-instruments, compatible with the first, has been in existence since October 1995. A third, also compatible, is now being designed.

The Méta-instrument is plugged into an analogue MIDI interface.

All the variables are calibrated in the analogue domain for gain and offset, then they are digitized. The rate of MIDI information and the transmission channel may also be changed.

This interface is then connected to a Macintosh computer on which the programmes which process the gestural information are developed with MAX. Nowadays, 80 "instrument programmes" exist for different compositions. Each "instrument programme" is part of a standardized architecture called a bank, which manages the switching or mixing between "instrument programmes".
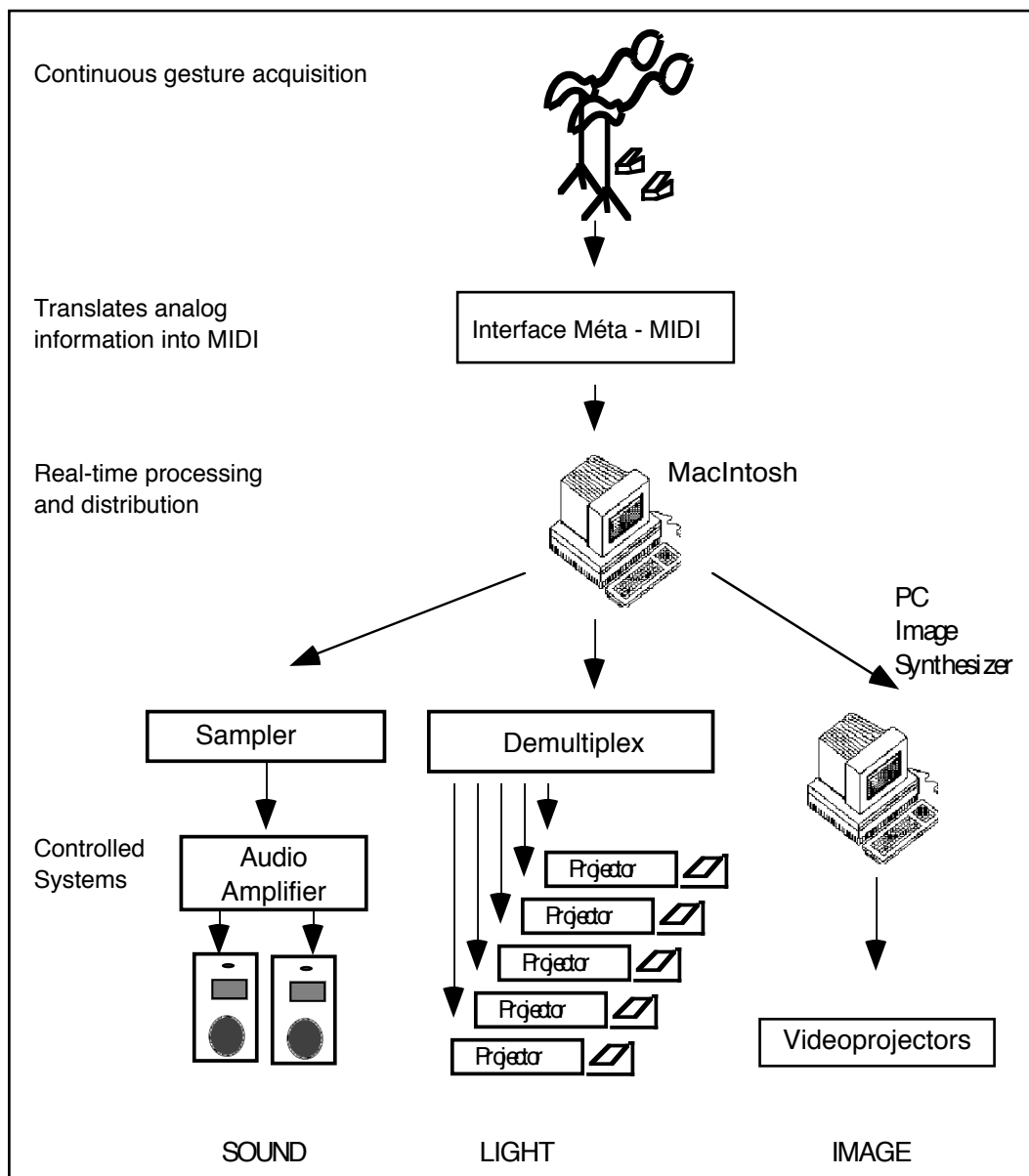
Fig. 3. Synoptic of the general system

Finally, these "instrument programmes" can control sound, graphical or lighting systems.

• For sound, these are mainly samplers (EMU IV, mixing desks (Yamaha O2R), DSPs (Mars station) and MSP.

• For video, this is mainly a program developed at the Espace Musical which runs under Windows NT: "The Graphical Synthesizer".

For lighting, these are mainly automated projectors with which it is possible to control the movement of a beam of light, its shape and its color (using the DMX 512 protocol).

Here is a summary of the specifications:

• The Méta-instrument must control **a** *maximum number of variables simultaneously and independently.* (It is now capable of controlling 32 continuous variables simultaneously and independently).

• Its mechanical structure must be close to the way the body works so that *comparisons* can be made *between gestural movement and the movement of sound.*

• It must be easy to move and the digitized data must be transmitted using the MIDI standard in order to *make experimenting easier.*

• It must be *pleasant to perform and look at.* This is an instrument, not a machine.

Description of the access

The Méta-instrument is the most original part of the system, so here is a more detailed description of it. The left and right halves of the Méta-instrument are *symmetrical*. The variables are laid out in the following way:

> • Ten keys for the forefinger, middle finger, ring finger and little finger. These keys can be depressed over 3 mm for pressure levels varying between 1 and 300 grams. The minimum pressure value can be set electronically. When the key is fully depressed, it hits against a stop piece.

The keys are laid out in two rows of five keys. This layout was chosen because one finger can then play four keys simultaneously by playing with pressure, and longitudinal and lateral movements. This can be done with a good independence when only one finger plays; independence goes down as the number of fingers used goes up. Ten keys is therefore an average.

It is worthwhile noting that the keys are activated as soon as they are brushed against which gives them a *sensitivity very close to that of the skin*.

For each key, two types of measurements are made: as the key is depressed, a *measurement* is made *of the attack speed*, and then a *measurement* is made *of the position of the key*. The sensors used are Hall effect sensors, which eliminate the possibility of the key and the sensor rubbing together, which in turn minimizes the problem of errors in the measurements and of mechanical wear from rubbing.

> • *two keys for the thumb*. These keys function in the same way as the ones described above. The number of keys for the thumb is limited to two because the thumb is sometimes used for support of the handle. Since the first keyboard, on the other side of the handle, functions with attack speeds, therefore with fast and powerful strokes, the thumb needs to be used to stabilise the handle.

> • *The handle is itself articulated around an axis* which is like an extension of the forearm. It is possible to modify the position of the handle using the palm of the hand, without using the fingers. A return spring is used to bring the handle back to its central position. The axis of rotation of the handle is slightly tilted so that the rest position of the hand is that of "shaking someone's hand". A correct positioning of the axis is essential so that the musician doesn't modify any other data when he changes the position of the handle.

> • This handle is connected to an elbow on a ball and socket joint. It is possible to move the handle without using the hands, and *by using the forearm only*, which generates *two extra variables x, y*. A system with counterweights behind the elbow is used to maintain the system in equilibrium. Horizontal and vertical movements of the forearm are measured over an angle of 90°; stops are used at each end.

For all rotations, the sensors used are of the Hall effect type. Unlike potentiometers, they eliminate the rubbing problems and suppress any mechanical hysteresis. Moreover, the measurement quality is incomparable with that of a potentiometer; one may compare the measurement with a potentiometer to movement over gravel, and the measurement with these sensors to movement over marble! It is therefore possible to work out with good precision the speed of movement of the arm and the handle.

> • Finally, *a simple pedal* of the Yamaha FC7 type is used *by the foot*. It will soon be modified by replacing the original potentiometer by Hall effect sensors.

The first consequences

From Métaphor to illusion

When we were thinking about a spatialization system for the electroacoustic concert in 1983 (year of the start of the research on the Octophonic Spatial Processor), we didn't realize what the consequences would be on the way we would think about music. We had only been thinking about creating an illusion of moving sound. I do however think that these few words already contained a unsuspected potential.

The change from Métaphor to illusion. Movement is omnipresent in music. This movement which may be that of the musician playing his instrument, is also that of the music and of the Métaphor of its "song". Do we not talk of the <u>space of pitches</u>, or of <u>"high" and "low" pitches</u>? Annotations on scores are also evocative:

-"in a softly sounding mist", "...the engulfed cathedral" in a prelude by Debussy

-"Very shiny", "Question", "From the end of thought", etc. in *Gnossienne* N°1 by Eric Satie

Titles and subtitles often illustrate this Métaphorical dimension of music in the numerous nocturnes, but also in *Images* (pictures) or *La Mer* (the sea) by Debussy, or *Farewell*, *The Tempest*, *The Heroic* by Beethoven.

The characteristics of the movements themselves also have a double role: describing movements of the musician but also the musical ideas. The tempo which describes the movement is, for example, a Métaphor of the heartbeat.

It appears to me however that the change from Métaphor to illusion is not a trivial one, but extends part of the heritage of musique concrète which starts composing with the actual recordings of the sounds themselves. Change is made from *Pacific 231* by Honegger to *L'Etude aux chemins de fer* (railway study) by Pierre Schaeffer.

Moving from Métaphor to the illusion of sound moving in space does lead to several problems:

• Which technique do we use? (if we are talking about the magical dimension, we could say which special effects?)

• How do we control the direction of the sounds? (if we refer to the musical dimension, we would say, how do we play them?) Traditional instrument making does not appear to have been designed for this purpose!

• How do you solve the problem of a conflict between acoustical spaces? A simulated acoustical space and a real acoustical space can be incompatible.

• How do you solve the problem of differences between auditory perception and visual perception? If the acoustical illusion is of good quality, one may make an audience hear sound travelling around it, although nothing is actually moving visually.

The aim of this article is not to answer these questions, but rather to ask them, and to try and understand the consequences of using the Méta-instrument and the abundance of problems it creates.

Internal space / Architectural space

Auditory space could be defined as an ensemble of properties associated with some variables (or dimensions). The number of theoretical variables is unlimited. These variables are then turned into sound so they can be heard.

For example $Y = a \sin b$ defines two variables a and b which can control a sound parameter. a and b can be directly coupled to one or two gestures of the musician or they may go through intermediary functions. Y can be coupled to any sound variation which remains to be defined by a coupling law. For example, if Y defines the frequency of an oscillator, will b vary in semitone intervals? What will its limits be?

This very simple equation becomes very complicated very quickly. The result of a variable may be the result of several variables. For example $a = a_1 \sin b_1$ so $Y = (a_1 \sin b_1) \sin b$. This small process is infinite and shows how far the exploration field can extend.

Work on listening does however try to find these variables and their progression in time. The ear is constantly listening for organizational clues in the flood of sounds which it receives. The more variables converge, the easier or even the more boring the perception will be. In the same way, the previous equation is an example which can, with several extra variables, generate unforeseen evolutions which may therefore also be perceived as boring.

The coupling of internal variables of sound and simulated spatial movement is still perceived as an improvement in the legibility of sound, like a real effect. A good coupling between internal space and architectural space gives the impression when it stops, of dying sound, of gesticulating on the spot.

Composing or inventing multidimensional perceptible spaces

In composing with the Méta-instrument, the design of a virtual instrument becomes closely linked to the musical idea itself. The description of the algorithm becomes the main part of this work with gestures on one side, and sound on the other. Composition therefore creates a new problem: What should the musician play, or what should he play on? We may have forgotten this expression: "Make the record player play". Instrumental action can circulate from a microscopic to a macroscopic level. The score can be entirely entered onto a computer and the musician can influence its course, or on the contrary intervene on the phrasing or even the grain of each sound.

Composing then equates to inventing multidimensional spaces where each dimension is a gestural variable, the biggest spaces having 32 dimensions! Composing then involves exploring these spaces. The variables left for the musician to play with form a group of sound palettes which the musician uses to tell the story of exploring these spaces, forming a route by following the trail given by the composer.

Notation then becomes a problem. Here, it takes on a lot of different forms: traditional score, dynamic envelope waveforms, graphics, comments or mini-scenarios, graphs on a spreadsheet, Jazz chords, recordings, tablatures. This list is not exhaustive, and different types of notation are generally combined.

But here, composing means giving to play. There is no absolute ideal way of playing, since if it did exist, it would be more interesting to play this ideal version rather than an open way of playing. It appears to me that the meeting between musician and audience and the context within which the music exists is too unpredictable and complex for a model of fixed interpretation to be imagined.

Putting an instrument on

The gesture itself also sounds. You can hear its mechanical properties. A parameter controlled by a heavy therefore slow but precise forearm, or by a rapid but much more unstable finger will radically change the resulting sound and the sound of the algorithm. The variables may also combine: for example, the position of the foot for an overall control, added to the values of the fingers for particular fine tunings.

The gesture itself may be where the instrument came from. A gesture, even silent, caries a potential sound morphology. It is these associations between gesture and sound which make instrumental playing more legible. For example, turning the forearm in one direction to unroll a score and in the other to roll it back up again such as in the limonaire.

The gesture itself can have a theatrical dimension. One instrument which is often used to understand the Méta-instrument is one which is used to move footsteps in space. These footsteps are generated with pedals and steered with the arms. Their timbre changes as the exploration progresses: floor, stairs, gravel, dull or reverberant spaces. Here the situation is nearly that of radio: the musician plays with gestures very similar to real ones, a situation for sound which is very explicit.

A gesture on a Méta-instrument is often of a very different nature to that of an acoustic instrument, because its main function is to "manage" the energy more than to provide it. Energy from the amplifier, but also energy from the calculator engines. The gesture most often resembles that of the driver of some very sophisticated machine, rather than that of a musician playing an acoustic instrument and who must supply extra energy to produce the sound himself from his instrument.

The appropriateness of a gesture and of an idea of a sound influences the success of an instrument. When the gesture is right, you feel that the instrument "fits" without any pain, that you touch space, that you play well. If the instrument is an extension of the body, then the body becomes space.

Orchestration or turning space into sound

In order to "show" multidimensional space, it needs to be made perceptible. The first use of the Méta-instrument is for music. Algorithms and gestures must then be amplified, turned into sound, and orchestrated. There is no order in the implementation of an instrument, the driving force may be the algorithm, the gesture or the sound. You cannot however use any sound and any sound parameter on an instrument. Varying the sound on a same algorithm is however instructive. In the same way, coupling a variable to different sound parameters sometimes has surprising effects. A family resemblance often appears even though the instrument seems to be a new one.

Some sound parameters are perceived more quickly than others. For example, the pitch of a periodic sound is more precise than its vertical position in space. This pitch is itself better defined if its fundamental frequency is in the mid-high range. The precision determines the value of the digital quantization or the smallest needed interval. But precision also determines the measurement rate or the refresh rate of the sound parameter.

Orchestration in this case is an economy between plus and minus. Plus which would like to augment the number of sounds, the number of sound variables, to make the algorithm more legible, and minus which tries to get rid of useless sounds so that sounds do not mask each other. Minus tries to work on the smallest interval possible to maximize the range of notes and the expressive amplitude. Minus tries to shorten certain phenomena so that others can be heard.

Foreseeing, seeing or post-seeing the instrument

Multidimensional space may also be perceived by the eye. Movement can be shown on a computer screen or by lighting variations. The study of a sinusoidal function is more often shown with a picture than with sound. Visual variations also have perceptual properties, but the concept of precision is still valid.

Fig. 4. Méta-instruments in performance.

Using visual information for the implementation of an instrument also relies on the following statement. An instrument made up of the Méta-instrument, an algorithm and associated sounds is easily perceived as being invisible. The gestural interface only is visible, but when the instrument changes (algorithms and sounds), the interface itself does not change. This gestural interface must also be as neutral as possible mechanically (no rubbing, looseness or inertia). It is therefore lighter and lighter, virtually "rubbed out". When the musician is playing, the Méta-instrument is barely visible.

Visual information can therefore have several functions which revolve round foreseeing, seeing and post-seeing.

Foreseeing is similar to monitoring. Just as a pianist can see his keyboard, it is possible to represent fragments of an algorithm in order to foresee how an instrument will sound. For example, several instruments on the Méta-instrument separate the vertical and horizontal axes into squares a bit like the fingerboard of a guitar with its frets. It is much more pleasant to be able to see these frets on the screen so as to be sure to be in the right position, especially as certain instruments can vary their number of frets dynamically.

Seeing is nearer to redundancy. Here it is possible to trigger visual phenomena which are exactly synchronous with sound. It is then possible to augment the expressive palette, to underline imperceptible sounds, reinforce fortissimos, etc.

Post-seeing is without a doubt the newest dimension which has emerged from the association of picture and sound. It is possible here to trace the gestures of the musician, and therefore to "look at what has just been played" while listening to what is being played. Moreover, the graphical representation mode of gestures also influences the way music is memorized. Music played with gestural visual feedback will be memorized with great ease, and the comments made after listening will be much more precise.
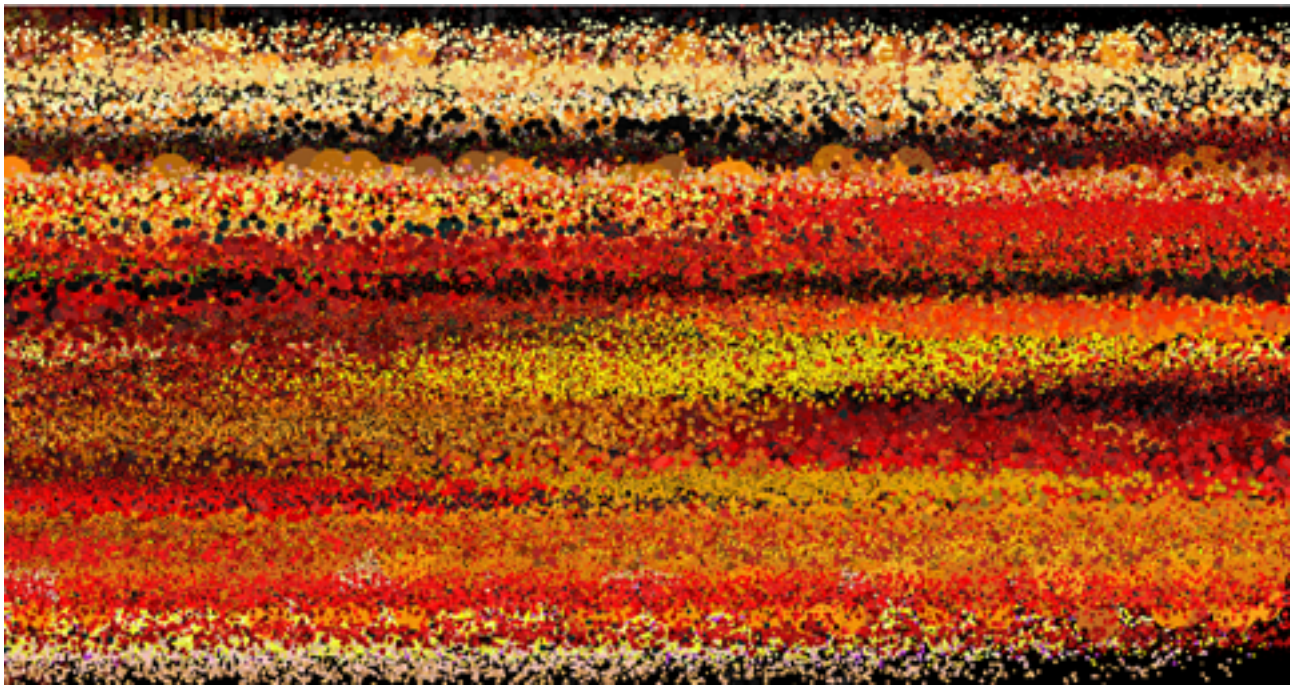
Fig. 5. A trace of gestures using the Méta-instrument.

It would appear however that the absence of visual feedback is quite acceptable, radio and (acousmatic?) music are good illustrations of this, whereas the absence of sound for a moving picture is disturbing. There are no more silent movies.

Elements for a conclusion

The Méta-instrument does not replace the digital synthesizer; the former works with continuous signals, and the latter with discrete signals, the former is skilled in sliding, evolving, manipulating, the latter cuts off with precision, the former generates roundness, the second angles. If the Méta-instrument had a sound, it would be *mamoula*, in contrast with the *takete* of the keyboard.

The representation of shapes in three dimensions can be complicated, but the manipulation of algorithms in 10 dimensions is relatively easy! It appears that the virtuosity of the Méta-instrument resides in the possibility of chaining two different instruments (multidimensional musical spaces) together instantaneously.

Each composer uses the Méta-instrument in very different ways, but each one would also like to develop his own instruments. The act of instrument making has become linked to that of composition, just as orchestration did at the end of the 19th century.

One could say that creating instruments is a four input problem: gesture, sound, sight and text. A successful instrument is probably one where the relationships between these four entities are correct. This work may seem to be unlimited, but many concepts from one territory may be transposed to another. For example the notion of picture-chord which consists in creating audio and visual states which are stable and ordered, to play with their transformations or the change from one state to the other. In the same way, the text which can be written or heard can also play with changing from one sense to the other.

It appears that the notion of instrument comes from daily practice. This regular practice enables the progression from the sate of a machine to that of an instrument. It also imposes certain ergonomic requirements on the instrument which suppress technical problems and parasite gestures so as to tend towards music.

Developing the Méta-instrument meant developing three poles that cannot be dissociated: creation, teaching, heritage.

Creation means increasing the number of compositions which can be played and therefore commissioning composers who are interested.