A Computer Tool for Simultaneous Musical and Animation Creation Real Time and Gestual Control

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A COMPUTER TOOL FOR SIMULTANEOUS MUSICAL AND ANIMATION CREATION REAL TIME AND GESTUAL CONTROL

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This is a presentation of research work aiming at the conception and creation of an computer tool that can be used simultaneously for musical and animated image creation.

These two arts are closely alike, and their resemblance goes far beyond appearances. These similitudes, that will first be formalised, are the basis for our creation tool.
We are not concerned here with constructing a relation, be it arbitrary, functional, or operatory, from and between these visual and sound effects, as, for instance, synchronism relations or metaphoric associations.
But to point out and to use the common axioms of these 2 arts, independent of any particularised esthetics or state-of-the-art technology.

These principles, of which there are two, seem on the one hand to be sufficiently fundamental to be discriminative from the other arts, and, on the other, sufficiently general to be valid for each of these two arts, without restricting either.
On the one hand, they operate with time, and produce temporal perception objects.
On the other, they require a medium of production, e.g., an instrument that is exterior to the individual.

If these two points bring about a close resemblance, and if, in other respects informatics is considered as a generalised representation tool, then it is possible today to define for both concepts and means that will be highly homogeneous.
Our purpose is therefore mostly fundamental, and is located beyond present-day or intrinsic specificities of each of the two arts.

However, and before thinking in terms of a new art associating sound and vision organically, an art that we will leave until later, the generalisation of the production process that is attempted here should enable an itemisation of the fundamental constituent parts of each of the two arts.
Finally, in technological or artistic productions, even if new links between these two arts can be objectivised, it nevertheless remains that they can both develop individually according to their own objectives, without the one owing anything to the other.

The following paragraphs I and II analyse the two basic principles that we have just stated:
*for an art in time, the representation and creation of dynamic phenomena,
*for an instrumental art, the use of a medium aparatus, an instrument,
Paragraph III presents the resulting technological problems and the solutions adopted in the CORDIS-ANIMA system (Luciani 84).

I. REPRESENTATION AND PRODUCTION OF DYNAMIC PHENOMENA

I.1.The mental representation of dynamic phenomena

Our analysis opens with two examples, one from animation, and the other from music related to timbre.

1. First of all, let us examine the animated images examples.
The image sequences in figure 1 are taken from an animation training manual and, though very simple, nevertheless illustrate the points we consider as fundamental (Engler 83).
It would seem that these images do not originate directly from visual observation.We have never "seen" such objects be deformed and interact in such a way.Even so, they are nevertheless not simply the fruit of our imagination, for they seem to be quite consistent with the laws of physics, at least qualitatively.Hence, the relation between displacement interaction and deformation between the two objects stems from a knowledge of these laws.

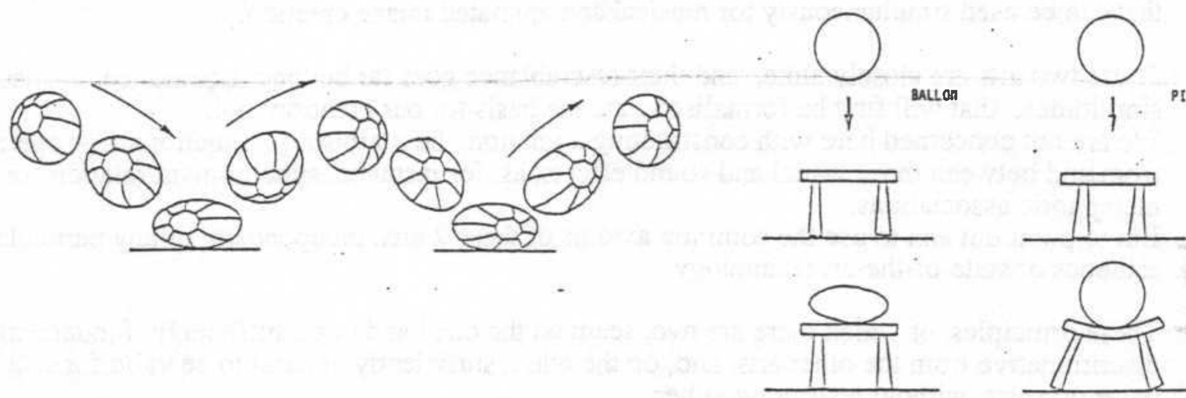


Figure 1 - The laws of Animation - (Engler 83)

It seems as if :
1.There is a mental representation of the physics of dynamic phenomena produced by real objects at our disposal,
2.We seem to have the faculty of applying this to other objects that are real or totally invented, borrowed objects, i.e. kinds of extrapolations from physical objects.

This is where an operatory reasoning comes into play that works upon a mental representation of dynamic physical phenomena.

Hence, the production and knowledge of dynamic phenomena is not simply a question of memorising sensorial data, but puts into play, on the one hand, a mental representation of the physical causality, and, on the other, a physical reasoning applied to this representation.

<u>The mental representation of causality</u>
This mental representation is an abstraction of perceived and /or acted physical phenomena, that extracted from the same phenomena the intrinsic properties of the objects, their constants, i.e. what can be more generally called their "underlying structure".This representation is the result of a complex procedure combining deduction, active experimentation and perception that is not directly available to the senses.
Such abstract rules, totally independent from the acting or perceiving subject, are invariant durind the movement : We refer here to properties such as inertia, viscosity, elasticity, the conservation of matter and certain form attributes, as well as the transmission of movements, interactions ...etc.

Reasoning concerning causality
Now that we have extracted these properties from real, perceived or manipulated objects, we can :
* apply them to other objects, real or imaginary,
* mentally submit these objects to "physical" actions, such as pushing, leaning or stretching, ...etc, i.e. mentally apply forces and displacements to them.

Everything that comes before is valid for all human subjects (Piaget 71).
The artist, though, explicitly uses this knowledge to produce or create something new from other objects of perception than from real objects.
It can be suggested that :
*the artist is equipped with an interiorised causality model,
*that voluntarily, he experiments with it and mentally applies actions to it that also proceed from physical knowledge, to discover the desired effects.
The essential property of this model is genericity.Thus, it is not merely a simple enumerative bank of particular movements or sounds, but, in fact, a representation of the experimentable generator-processes of sounds and movements.

2. Instrumental identification in music
As regards musical timbre, several authors have pointed out that timbre identification, which in many cases corresponds to instrument identification, does not occur according to fixed criteria in regard to an acoustic or psycho-perceptive analysis of the sound effect.
Thus in the case of the piano if a major part of the attack of its sound is removed, the instrument remains identifiable whilst for a vibraphone this is not the case.Clipping the start of attack on the latter instrument rebders it impossible to identify.
For wind instruments, it appears that the spectral envelope is determinant if its form is unique for all the notes played on the instrument whilst in other cases the temporal envelope is at least as important.
For vowels, formant structure overrides spectral distribution under these formants, whilst the sound quality of a piano may be linked to a spectrum form that is subtley inharmonic: the 15th partial has a frequency 16 times bigger than the fundamental.

The dispersion that appears with this type of analysis has already indicated that the perception mechanism does not merely process sensory data as a simple transmission chain.

It would appear that the ear fixes those sign characteristics that can either confirm a pre-established hypothesis from amongst all others , and, once this has been done, then rejects all the factors that have no pertinence for this verification.This confirms quite plausibly the existence of a pre-existing mental representation to perception, or more generally, as Lindsay and Norman hav e formalised it (Lindsay & Norman 1977), the simultaneous existence of two types of sensory information processing, "concept -driven - processing" which supposes the existence of this mental model, and "data-driven-processing".

What is the nature of these mental representations that we use to infer a timbre or an instrument?

If we admit that perception brings into play a cause identification mechanism (MacAdams 82, Cadoz 84), then quite a number of facts become clearer. To mention but a few :
* The invariant that enables the perception system to identify a consonant, whilst voicing conditions make the acoustic sign characteristics vary, seems to be the place of articulation in the buccal cavity.
* The pertinence of the temporal envelope for all percussive sounds correponds to a frequent natural situation : the existence of a vibrating object that is excited by a quasi-instantaneous action and then left free to evolve,
* The importance of formants in vowel recognition, irrespective of the under formant signal indicates that the perceptual system understands clearly the production system structure and in particular the relative independence of an exciter system (the vocal chords), and a resonating system (the buccal and nasal cavities),

A mental representation of this producer cause, its constituent parts, its states, and its behaviour will therefore make up the essential substance of this "concept" driving process, of this mental representation of acoustic phenomena .

I.2. The materialised causality model

Parallel to the mental function we have just talked about , there exists the necessary exteriorisation of all or part of the process.

In this way, in the series of image sequences that we took as an example, we may say that the drawings carried out sketch out possible output from the mental model.
In actual fact, nothing is done totally mentally, there is always the need for a trace.Moreover, there is a constant dialogue between the exterior, objective trace, and the mental, interior model.

However, a new notion appears with the computer, one that we have coined the "materialised model". We can not only objectivise the model outputs, the "effects", but also the model itself, or a part of it (Figure 2).

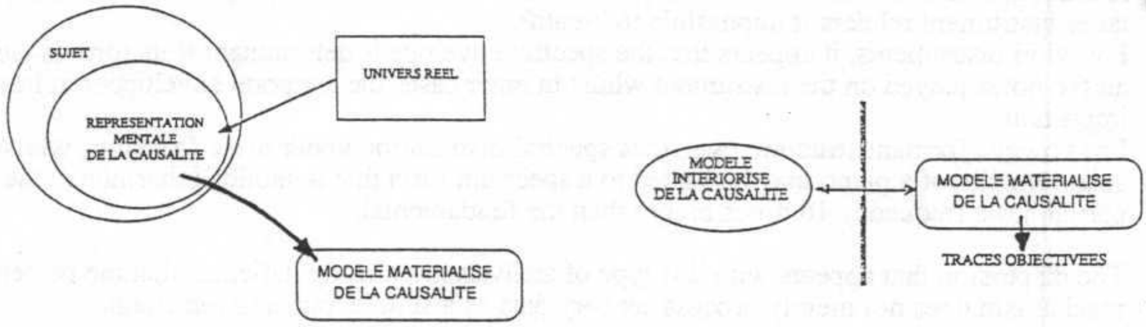


Figure 2 . Materialised model

Under all circumstances the artist remains the master of his mental reasonings and representations and aims. However, this "materialisation" operates like an opposite number, a kind of more or less faithful echo of the interior model, that the artist can dialogue with or confront.
Within this dialogue, the following develop:
* The artist's knowledge heuristics : He thus learns, within this objectivisation process to "know his own knowledge",
* A creation and discovery heuristics : his own representation potential is enhanced, by new ideas springing to life that are not contained within the interiorised model, by means of tjhe specific properties of the material that he has created and with which he communicates.

From the above stem a few of the prime characteristics of the creation tool and of musical and visual material production models, which we shall take into account in our informatic projects.
1.The creation tool must enable a more or less faithful representation of the physical universe.
2.It must apear as a generative model.
3.These models must possess a strong causal component.

II. THE INSTRUMENT AND THE INSTRUMENTAL RELATION

II.1. The instrument as an object

The instrument has a triple determination :
* it is a material device
* it is model or symbol,
* it is also a structuring element of creational thought.

First of all, it is what we have termed this "materialised model". It is a borrowed object, taken out of the real world, and endowed with the power of materialising our thought.It is a substitute object. Though taken out of the real world it nevertheless requires in most cases a construction activity to realise the thought materialisation function, and to assume this symbolic function.
It is thus the prime necessary act of creation.

As a simultaneous material device, i.e. a piece of the real universe, and model, i.e. a symbolic object of predefined knowledge, it simultaneously carries out a structuration, by categorisation, from thought, and a structuration of the perceptible phenomena to be produced by the artist.
It is a categoriser and a generator, that is, capable of providing a certain , but finite, variety of sensible phenomena. The same reasoning as for mental representation holds true here : the instrument is a class of effects,that are, in our case, visual or sound-producing.

This double operation, which is essential for the creation, the "forming as object" of our thought, and the "forming as symbol" of a piece of reality, operates the essential function of knowledge and creation, that of the simultaneous structuration of thought , actions and perception.

From the minimal act of taking home a piece of wood that has been found in the country and of keeping it without any other modification apart from that of having removed it from its original surroundings, and passing by the modification of this object so that it reveals the idea more explicitly, up to its total construction so that at the same time it is symbol and production tool, and then finally as far as the complete synthesis , by a computer programme... This is the same function in operation.

The instrument for creation is distinguished from the instrument in general by the fact that this symbolic function is a priori very strong. It cannot be considered merely as a production tool.
To build the instrument, to realise this "materialised model" is neither an obligation that should be avoided, nor, on the contrary, with computer, a commodity, that may be foregone.

The fundamental necessity of this function must be stressed, as well as, in an computer context, the importance and the difficulty of the choice of a language to construct this object, in order that, in conjunction with its production function, it can play the part of "thought/knowledge system materialiser".

We will now discuss another fun ction of the creation tool, that of a model producing system.

II.2. The instrument as effective experimentation medium

We saw previously that with the absence of an objective opposite number, we mentally applied "physical" actions to a mental causality model to mentally obtain the effects that we then translated into perceptible phenomena.

When we have the instrument as a materialised model effective experimentation is added to mental reasoning, i.e.the production of perceptible phenomena from action that have been really carried out.

The interest of this situation is obvious. Thought is highly volatile and agile and because of this nature, many situations can escape it : omission, ellipses, too much rapidity, and the like...etc.

This effective experimentation then plays the same role as a trace on paper of a pre-imagined effect : being materialised by real actions and effectively associated sensorial effects, causal reasoning becomes carnate and controllable.
The instrumental situation then appears as a materialised opposite number to mental reasoning in the research and production operation of dynamic phenomena.
This endows it with the properties already mentioned for the materialised model of causality :
* A real situation, enabling objectivisation,
* a symbolic mirror to a mental situation,
* varied but nevertheless more limited than my thought, it structures

This is the last function that we must instance in a computer tool for instrumental creation, which is to bring about the instrumental situation in a computer context, i.e. to enable the operator to actually act on the causal models and to obtain in response and simultaneously perceptible visual and/or sound effects.

II.3. The instrument as an aid to discovery

It is impossible for this model, a material image of a small part of our knowledge, to be the exact mirror of it or an exact objective reply to it.
Luckily so, for here is the germ of discovery, in knowing that the internal/external knowledge dialogue is not a closed system, and hence, in the long run, sterile.
The slight gap between the idea and the matter that represents it is fertile , because without having to voluntarily look for them, other ideas and other suggestions germinate from aspects of the object that were not chosen intentionally.
The same reasoning follows equally well for thought, which has its own drifts and off-centre suggestions which also enable creation. Thus, in an infinite representative interplay, from clearly decoded knowledge to the unforeseen, thought and materialisation mutually correspond in a symbolic and organisative movement.

In our opinion the above are the necessary principles that are the necessary basis for the arts that interest us, i.e. the instrumental arts of time.

We shall now look into some aspects of how these different fundamental considerations can be translated in more operatory and technological terms.

III. OVERVIEW OF THE CORDIS - ANIMA CREATION TOOL

III.1. Models

Our interest is centred on highly generative causal models that will stand up to effective experimentation (Luciani 84).
Some synthesis models aim at recreating the effect, the perceptive, directly.For example in frame by frame animation or in describing movement in terms of a timed trajectory, and in musical synthesis with additive synthesis or by frequency modulation.
These models are not causal because they process perceptible effects.They are not generators either, since they require knowledge of each effect individually, each sound, each movement, as well as the means to describe them case by case. Effective experimentation is also ruled out, since as they directly act on the level of the effect, they neither integrate the principle of action, which is the

cause of the effect, nor, in consequence the correspondence between action and resultant. We call the above "descriptive models".

The models that satisfy these tree properties set out above are precisely "physical models".
A physical model is a model object whose behaviour is governed by the laws of physics , and in particular those of dynamics.It is thus an object that is deformed and displaced when subjected to actions, forces, and displacements.

A drawing design, or an image is not a physical object, and is not a physical model of a physical object.No more than a sound is.
An animated puppet is a physical object and also a physical object model.
A program that calculates the displacements of a spring in function of the effort aplied to it and in functiion of the "stiffness" of the spring, which is a particular parameter of it, is a physical model of a physical object.
A model that associates the deformation of the armchair to the inertia of the seated person is a physical model of a non physical "object".
A program that simulates a vibrating string is a physical object physical model...etc.

III.1.1. The typology of the object to be modelised

A physical model can be broken down into several parts in function of the dynamic phenomena it is to produce. Thus, an initial breakdown sorts objects that are likely to vibrate on an acoustic bandwidth from objects that are deformed on a lower bandwidth.
For sound instrument simulation, the object will be made up of two parts : a vibrating part - the vibrating structure - and a deformable part - the exciter. The vibrating structure may be an object with a single degree of freedom.
The exciter and also animated image objects must be displacable and deformable on 2 or 3 degrees of freedom.These objects, for musical or visual use, are of the same nature.
Finally, in the case of the vibrating structure, we can limit ourselves to linear structures.In the case of the exciter and of the object for the image, the non-linearities are frequent and essential - e.g. shocks from non-permanent relations between objects ...

The CORDIS-ANIMA system can modelise all types of objects, vibrating or deformable, in physical relation with other objects by all types of interaction - elastic, viscous, non-permanent.

III.1.2. Characteristics of the physical model

1. Dual variables
What characterises the physical model compared to other synthesis models, in sound as in the animated image, is the fact that it processes two types of coupled dual variables, one intensive, the other extensive, for example forces and positions.Thus for example geometric image synthesis models work on a position type variable. Additive synthesis works on a representation of the sound time - amplitude signal.
From an alogrithmic point of view, such a model can only be described in the form of looped networks, whilst descriptive models may be represented by oriented graphs.

2.Interaction
Object interaction is a physical interaction.The objects exchange physical variables of the same type as the variables that define the status of the object at each moment.
This type of interaction should be distinguished from communications between objects by messages or events.The physical interaction is a process that is calculated at the same occurence as the objects. As many variables are produced as are transmitted. Because of this the simulation by physical models is fundamentaly different from actor languages or object oriented languages.

3. Implicite time

Another essential difference between physical and descriptive models is that time is not explicitly shown in the model.Time is "real", in the sense that it is not represented. In physical model simulation algorithms, it is not processed as a data.
In this way, the fall of a ponctual mass will be given by the equation linking force and acceleration F = M*G, where time does not intervene explicitly. However, in a descriptive model, it will be described, for example, by the relation (X, Y, Z) = F(t). This explains the "generator" aspect of the physical model.

From an algorithmic point of view, physical model calculation depends on parallel and vector calculation techniques. The fact that there are systematically 2 dual variables linked by an equational relation and hence not oriented, allies physical model calculation more to systolic calculation, with variable propagation at each calculation step, than to artificial intelligence methods with constraints propagation or to object oriented language with communication by messages.

III.1.3. The assets of physical models

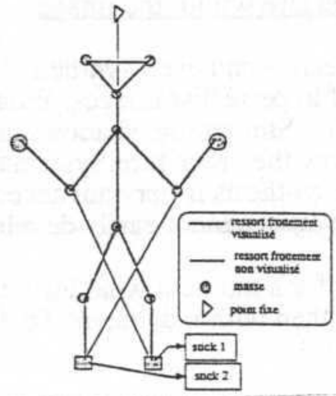
1. Representation economy
A physical model structuraly codes dynamic information.
On one hand, the data of the object's physical constitution - equations and parameters - enables deduction of all object movements.
On the other, knowledge of the temporal law aplied to model input points, which correspond to the actions exerted upon the object, are sufficient to deduce the movement of all the points of the object at each moment and therefore to totally define a sound or an animated image.
Such a model hence achieves an economical representation (Figures and photos 3).

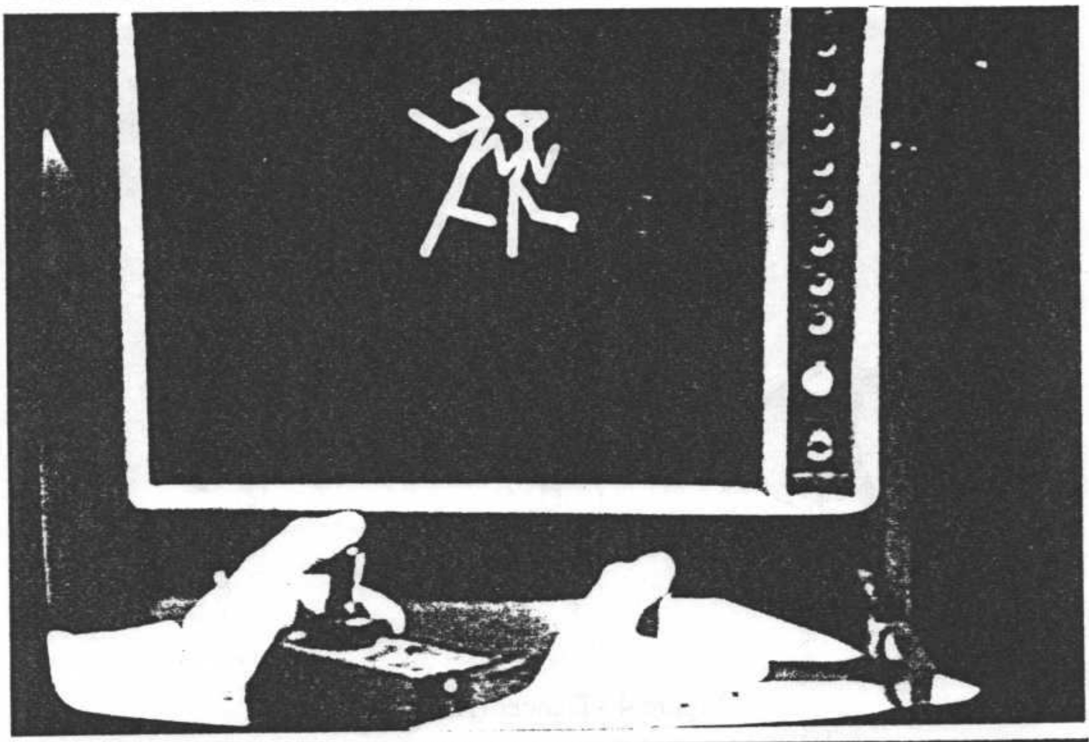
2. Control economy
The notion of control supposes that the quantity of information to provide is less than that produced. Control economy occurs here on two levels.
The first is the corollary of economical representation : We have observed that the existence of prestocked structural information means that the quantity of dynamic information to provide for the model is less than that produced by it : for example, it is enough to move a point on a surface for this deformation to affect the whole object.
The second is the possibility offered by the physical models to reduce the number of degrees of freedom to be controlled by the instrumentalist by interposing a physical system between the instrumentalist and the object to be controlled (Figures and photos 3).
Here is one example (Beaubaton 83): "It is highly unlikely that the 792 degrees of articular freedom in the human body are controlled by as many processes... The analogy of the puppeteer commanding his puppet's complex movements by the combination of a limited number of finger displacements shows a good example of a sub-system with several degrees of freedom controlled by a master system with less degrees of freedom."

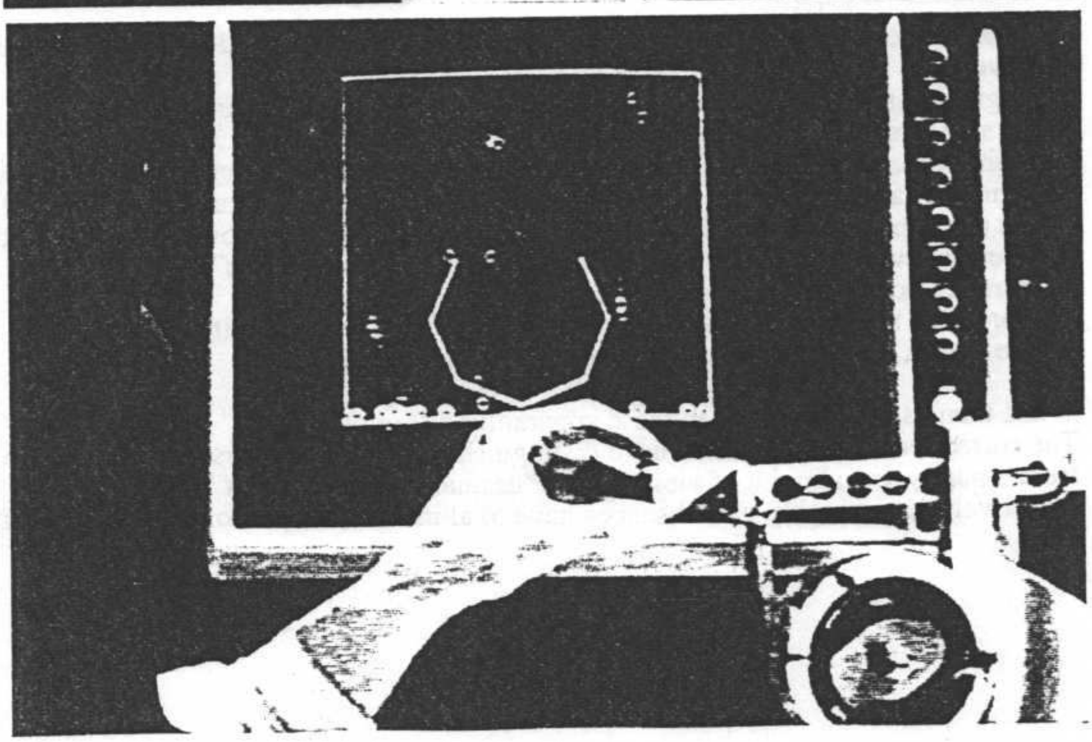
3.interaction with the animator or the instrumentalist
We have already observed that a physical model intrinsically expresses the interactions.
In an instrumental situation, the musician or animator produces actions - forces and displacements - that are physical variables. Hence, interaction between objects or between them and the human subject are of the same nature (Figures and photos 3).
The forces and positions produced by the instrumentalist become inputs to the model by means of adequate physical devices called "force feedback transducers". In return, the model produces forces and positions that are relayed back to the artist via these transducers, thus enabling him to gestually perceive the simulated objects.
With these types of devices, it seems as if, to the nearest morphological limit, the object were really under the fingers of the instrumentalist.

Figures and photos 3 - Representation, control and interaction with physical models - Examples

Animation d'une marionnette par le déplacement de ses 2 pieds balancement de la tête, des bras, des mains, du cou, du bassin







III.2. The instrumental gesture

III.2.1. The gesture within the image

In image synthesis - and even synthetic images animated by physical models, a strong point is the reproduction of hyperrealist images. What is needed to test the tools is hardly good enough for artistic creation. Smoothing, shadowing, and even the shapes, however free, non analytical, always give away the procedure.Systematisation always appears.
Although form synthesis is very advanced it still remains an enumerative group of individualised procedures.The artist cannot easily develop an esthetic or a system of thought from it.

Let us consider for a moment what form means to the plastician and the relation it establishes with his gesture and then with movement.To do this we are going to examine the following sequence of images (figure 4).

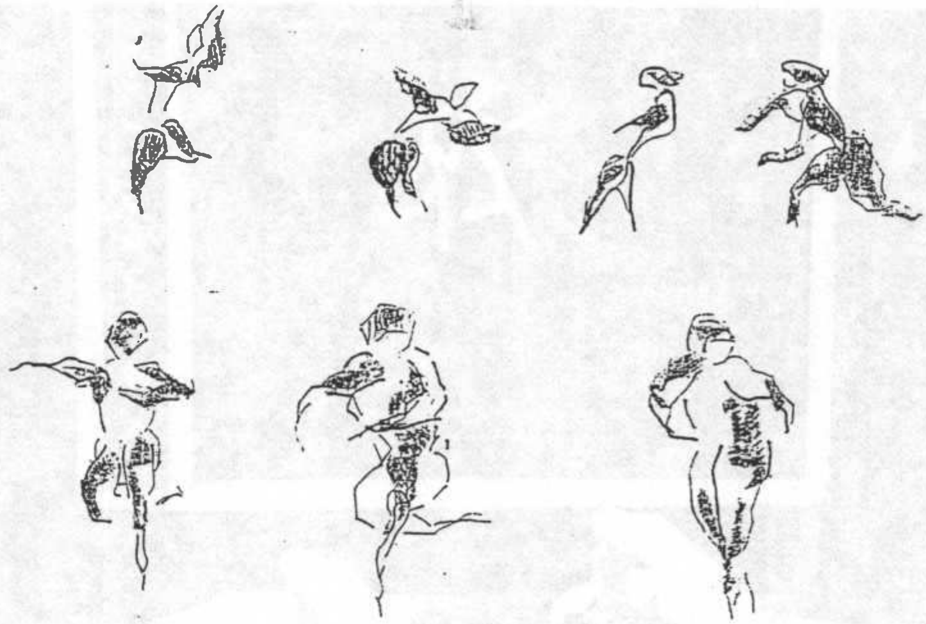


Figure 4 - Dancer (A. LUCIANI)

As soon as there is a static image, i.e. on each figure and independent of their sequencing, we can observe :
* the graphic shapes used -primitives - are very varied : points, lines, surfaces . . . .
* The same image integrates all the primitives simultaneously.
* At the same time there is a close link between the represented object - here a dancer - and a detachment , a separation between this object and the graphic forms that represent it.

These trivial considerations for the plastician, are totally absent from the synthesised image.
Besides, the way each figure has been produced is extremely "free" :
* There are no constraints on contour closing,
* Moreover, there is no apparent constraint on surface homogeneity,
* The traces, dynamics, show up accentuations and suppleness.

What, then, is the link between these apparently different traits?
The correct parameter to enable us to distinguish and to link up these shapes that are so different from a purely visual point of view, is of a "gestual" nature and not "visual".
Effectively, these highly varied shapes have to al intents and purposes, a stamp, a signature.

Graphism and pictural are at the crossroads of the visual and the gestual.
This explains that computer image production by "image synthesis", that excludes any gesture , is inadequate for artistic creation.

On an operatory level, producing such sequences requires :
* acquiring the gesture
* applying it to a material, that is an atemporal structural knowledge,
* to go further, by undertaking a gesture analysis to extract the shapes, patterns, or gestual structures, in fact, to carry out an identification of gestual shapes that are pertinent in the gestures that are actually effected.

Similar analysis can be carried out as regards figure sequencing :
* The successive pictures have little bearing on each other from a graphic point of view
- the elements are never processed in the same manner - the head, the arms . . . .
- the colored areas change places compared to the shape drawn. . . .

Nevertheless, the sequence appears to be very homogeneous.
The shape sequencing is not haphazard although this is difficult to demonstrate by image analysis methods.
What, then is the leitmotive, the binder agent ?
As in painting where the colored paste's fluidity is provided by a binding agent that is physico-chemically distinct from a pigment or a thinner, the binder is not of a visual nature.
It has a double, gestual and causal nature.
Causal : to draw, understanding is important not copying, i.e. understanding what we mean by the "underlying structure " of the object.Then, the shape and appearance applied to this structure can be abstract. In this example, we can detecte easely the underlying structure that enables us to understand this set of forms (figure 5)
Gestal : it is also easy to imagine that with a gesture - choregraphic or animation gesture - applied to this underlying structure, that this sequence may be generated, and thus made coherent , as it has been produced by an single process taht is the "manipulation of a unique structure".

Figure 5 - Extracting the underlying structure

Then, we would point out the relation which exists between this underlying structure and its apparent form : the graphic forms do not follow this model in a "mechanistic" way, but interpret it. For example, the spots are located at high tension points and therefore stress the place where the movement originates.
The shape, appearance, even when abstract, entertain an organic non arbitrary relationship with the gesture and the structure of represented objects.

In conclusion, gesture, form, and causal structure interpenetrate each other to form rich and structured animations.

2. Gesture in music

There is no common comparison between a musician's gesture and someone using an alphanumeric keyboard. In the second, case the gesture boils down to issuing a command, in the sense that its shape, its dynamic do not affect the resultant information.
In the first case, not only the sound dynamic, but also even the timbre are affected by the gesture. The sound thus produced is representative of the instrumentalist's gesture.This is evidenced by listening to the opening bars of Lutoslawski's cello concerto, where a brief note is repeated with highly varied sound variety. This, moreover, is one of the rules of the instrumental play.

The sound is thus not only produced by a gesture and the instrumental gesture is not merely a command. The sound phenomenon produced by an object or a natural instrument bears an indelible trace of the gesture, and in this respect the gesture cannot be disassociated from the meaningful function of sound.

In addition, the control of a sound phenomenon on the level of its symbolic functioning can be based on an understanding of causal logic, in which the instrumental gesture intervenes as one of its components.

3. Force feedback transducers

We have developed a hardware and software system , and one of its prime functions is to restitute the conditions of the experimental experience (Figure 6). To do this we first analysed this as a sensorimotor and multisensory relationship, whereby a gestual instrumental behaviour corresponds to a set of sensible sensations of three types: acoustical, visual, but also tactilo-proprio-kinesthetic.

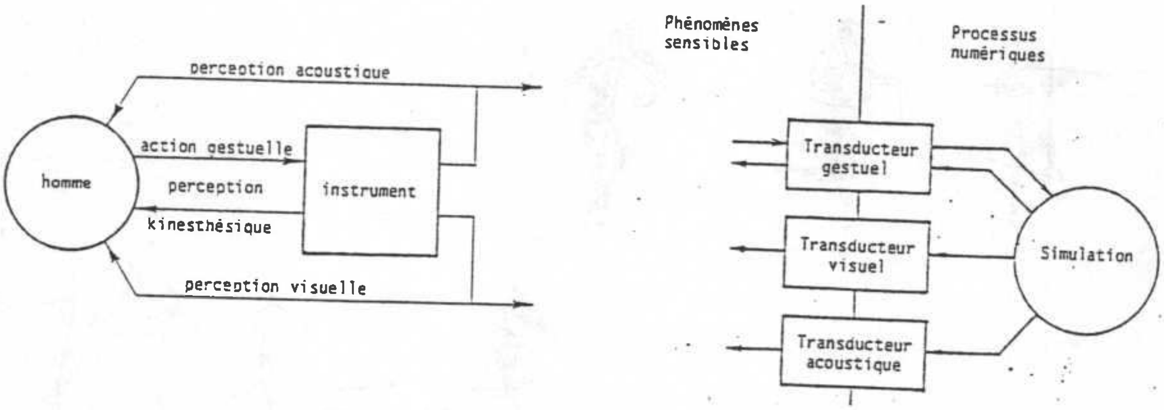


Figure 6 - Instrumental situation

The instrumental gesture is applied to material objects. For it to be applied, in a total synthesis situation of the instrumental situation, the vital device is the "gestual feedback transducer". This device fulfills a dual function :
* It must detects the instrumentalist's gestures finely and transforms them into command signals for the physical models.This is seen to by means of the sensors.
* It provides the instrumentalist with a gestual perception of the simulated object.To do this the intrinsic behaviour of this device must be cancellable, as the device must behave like the simulated instrument.This is handled by the simulation slave motors, and their behaviour is programmable. This device is doubly "transducer", from the instrumentalist towards the model, and vice-versa.

The typology of the gestual transducers

The universal gestual transducer does not exist.
For this reason a system of varied and complementary transducers must be defined and built.
To do this, the instrumental gesture itself must first be categorised to help us categorise the gestual transducers.The other categorisation constraints are technological.

First of all, we would point out that there is an initial operatory difference between the gesture that leads directly to displacements and deformations of the object and that which may , if necessary, modify the object's composition.Take, for example, the violin.The bowing gesture makes the string vibrate, whilst the fingering gesture modifies the string length.
The first gesture therefore communicates a given movement and energy to the object. The instrumentalist's action is met with a mechanical resistance from the object which is the source of proprio - kinesthetic perceptions.The instrumentalist / instrument liaison is two-way, and the Gestual Feedback Transducers should translate this.
In the second case, the energy produced by the instrumentalist takes no part in setting the object in motion, for example, vibrating the string.While he is playing the instrumentalist introduces or removes elements, and modifies certain mechanisms.This type of gesture, where energy exchange is low, is supported by pure sensors, non retroactive gestual transducers.

We are aware of the variety of sensors that today's technology can offer, so nothing more need be added on this point, except to recall that we refer to the different force, position, speed and pressure sensors and that the work is essentially one of conditioning these sensors to a mechanism adapted to the different modulation gestures' ergonomy.

The question of Force Feedback Gestual Transducers (TGR) is somewhat more complex.
In a TGR, sensors and motors are linked in a closed-loop system.This servo-control is effected by the simulated object itself.
There are two distinguishable types of feedback : tactile and tactilo -proprio -kinesthetic.

In the first case, energy communicated between instrumentalist and manipulated object is low.It should just be enough to excite the tactile sensors. This the category where we have filed the "feedback glove" (Foley 87) which includes, associated with the displacement sensors, the tactile exciters that enable the operator to perceive the simulated objects in a tactile manner. With this type of feedback, one can feel an object held in the hand, as well perceive its shape, but it is impossible to appreciate its behaviour when manipulated, since this is perceived more by the articular and muscular sensors.
In an instrumental relationship, more energy is required.Therefore quicker and more powerful motors are needed to sense the hardness of a surface, weight, elasticity, a displacement resistance, a collision or a break. The system designed by R. Feldman (Atkinson 78, Foley 87) is of this type.
As far as we are concerned, we have designed and built two feedback systems.The first was shaped like a stick. It was displaceable along a 50cm line (Florens 79).The second was shaped like a piano key (Cadoz 84)

Transducer Morphology - The modular feedback keyboard

Our latest TGR is a modular feedback keyboard.
We are going to introduce a criterion other than energy for the definition of a TGR group, which is a morphological one.Here again, choices are multiple : They stem from technological and ergonomic considerations but also cultural and social factors.Hence the piano keyboard, which has a specific morphology, still continues today to have a very strong influence, more perhaps from its distribution than from a genuine ergonomic adequation.

The keyboard is above all a particular case of a device whereby multiplicity prevails over multidimensionality.What we mean here is that it is made up of a large number of identical elements, that are small - for the piano key, one degree of freedom for displacement, and 1 degree of freedom in force.

This criterion is important in the domain of the TGR. On the contrary, a double "stick"device system could be set up, with one for each hand , each with 6 degrees of freedom for displacement and 6 degrees of freedom in force.
Now that the criterion of multiplicity has been submitted, it seems nevertheless important not to confine effective experimentation to predefined gestual registrations,as is presented at first sight in a piano keyboard. This keyboard's morphology may be configured,not only as regards the number of keys, but also their "packaging".
It might well be asked if the spatial arrangement of a piano keyboard system - " 2 for 3 " for the black keys and " 3 for 4 " for the white keys, the two systems overlapping - corresponds or not to the basic motor schemas. Even if this organisation seems particular a priori, there is nothing to prove that it is not founded intuitively,amongst other reasons,on a non - arbitrary motor organisation. The existence of so many keyboard players would seem to support this.
Such a device, i.e. whose behaviour is highly programmable and configurable, may enable us to answer such questions and to test other spatial organisations.

These analyses and realisations on gestual transducers are equally valid for the gesture of the animator and the graphic gesture. The specificities that appear concern morphology.
Thus,the sticks with 2 or 3 degrees of freedom tend to induce "rotary" gestures ; surfaces and gestures that are lineate. Feedback volumes are only possible if imperfect isotropy is accepted in the displacements. The "gloves" are difficult to make retroactive. Image gestual transducers will also be presented as a group of categorised devices.
A displacement dimension criterion also intervenes. The motor that we studied for the feedback keyboard is used to mount a retroactive 2D stick, on plan displacement over a large area 15*15 cm.

To suppose that there are pertinent gestual shapes has led us to carry out analysis of the instrumental gesture. This analysis and its objectives will be dealt with in the following paragraph.

4.coding, processing and representation of the instrumental gesture

Once the gesture has been detected there are 2 possible uses :
* as a constituent part of the instrumental situation, it is used directly to command the simulated models
* as a memorised object,it can be submitted to analysis, processing, and serve as a basis for a composition system equally well for music as for the animated image.

Coding the instrumental Gesture

The only widespread code is the MIDI coding communication standard for synthesisers with today's sound. Its major drawback is the fact that event coding is inappropriate for coding continuous, sampled gestures.
The latter carry much more information and must be sampled at approximately 100 Hz. This therefore supposes the definition of a specific instrumental gesture code.
We must first memorise all the information without any loss. It should be pointed out, however, that an initial loss of information occurs when the gesture is detected by the sensors. These signals are not an accurate image of the gestual signals transmitted.
Also,compaction must be effected by eliminating redundancies. To do this,coding by variation and duration have been chosen rather than coding by absolute value.
However,it is especially interesting to take gesture organisation possibilities into account Luciani 84, Cadoz 88). Let us take two examples :
* the 2 channels of a stick are closely correlated; this is a "single bidimensional gesture"; it is then not useful to decouple the processing effected on these 2 sets of information
* however, the different "instruments" played by a percussionist or keyboard player are not all acted upon simultaneously.
The quantity of gestual information produced by an instrumentalist is limited, and this can be taken into account to optimise coding techniques.

<u>Representation and Processing of the instrumental gesture</u>
The most immediate representation of gestual information is Amplitude/Time representation.This is too simplisitic,and cannot highlight the pertinent gesture forms.

We have developed 2 complementary procedures for the analysis of the instrumental gesture:
* representation and processing of the signals detected,
* modelisation by inference of the gestual signals motor production mechanisms.

The first method considers the signals from the sensors and, tries to extract the shapes and invariant structures from them without any hypothesis regarding their causality (Cadoz 88).
By analogy to the preceding analyses on causality, the gestual signals and then the detected signals may be considered as the effects of a possible cause. It is therefore close to psycho - acoustic analysis or image recognition. This means shape extraction from detected signals, supposing that we cannot access the cause. In this area,it is interesting to take the gestual signal structuration criteria into account that we discussed earlier as well as the criteria distinguishing local shapes and global organisation.

The second method consists in representing the detected signals by modelisation from a productive source.as for the instrumental models, 2 approaches are possible :
* one using the properties of a domain, considered as a frame of reference, here we are concerned with knowledge of human motricity,
* and the other which is a method by identification,which in our case concerns methods of automatics, which attempts to infer a causal model from the only accessible effects, i.e. the signals detected. J.L. Florens and S.Gibet (Gibet 87, Florens-Gibet 88) have essentially developed this second point. It was experimented on instrumental gestures applied to feedback devices, and the method enabled us, by appropriate analysis of the signals detected and the characteristic instrument reaction signals, to infer in simple cases, e.g. percussion or follow up gestures on a single feedback key, from the physical models that corresponded to the motor activity of the instrumentalist. It now remains to apply this method to organised structures.

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