"Chréode": the pathway to new music with the computer

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> "RESEARCH, which should form the basis of this new science — the science of art — has two goals and stems from two imperatives:
> 1. the desire to be aware, which comes spontaneously from the need to know, with no practical end in view: "pure" science, and
> 2. the need for an equilibrium of creative forces, classified schematically in two categories — intuition and calculation: "applied" science."
> Wassily Kandinsky, *Point-line-plan.*

In this short article I shall discuss the problems of computer composition on the basis of a work which I composed with reference to the human voice.

Two preliminary questions are worth asking: first of all, why compose with and for a computer, and secondly, why do it with reference to the human voice?

The replies to these two questions are closely related. It seems to me that what is new in the computer from the musical point of view, thanks to sound synthesis in general and to the methodology of rules for synthesis in particular, is the chance for the first time to extend the activity of composition to sound material in a really complete and radical way.

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What justifies recourse to vocal material in this context is the need to create afresh a mimetic process, if this step is to be constructive at all. The methodology of simulation offers us such a mimesis. Simulation is not simply the imitation of a model, it is rather the formalization of an implicit or explicit knowledge of the model. This formalization is not empty of meaning: when knowledge is "realized", it becomes available for compositional treatment and manipulation. Through this process of modelling, which makes explicit everything that was implicit or partially formalized, musical knowledge tumbles into the universe of "explicit control of processes", and enters arithmetical space (cf. J.C. Risset). Thanks to the computer, music acquires an additional level of abstraction, extending "literary artifice" ("*L'artifice d'écriture*", cf. H. Dufourt) to areas of musical activity which were previously beyond its reach. In fact, the explicit control of musical processes and their reconstitution in the computer results in an abstraction and a formalization comparable to the transition to *écriture* by the way of notation. We know that this abstraction gives rise to ideas and new concepts, and even to applications which would have been unimaginable had we not passed through this other dimension (*écriture*). It is now quite clear that the computer has made possible an important stage in this process, enabling us to circumscribe and control previously inaccessible musical phenomena, whether they be purely physical, as in synthesis, or organizational and structural, as in composition. At the same time it is indisputable that for computer science and more specifically for Artifical Intelligence (cf. C. Roads), music represents an extremely rich and complex object of study, if only as a prototype for a science of organization, and more particularly for processes of artificial organization. And here, there may arise a speculative and metaphorical interest in the comparison of musical organization with processes of biological and genetic organization.

At this point the choice of vocal material becomes an important one, because of a parallel resolve to move towards even more abstraction, by making play of a paradoxical perception, which hovers between a "disembodied" sound synthesis and an abstract presence which is never grasped, always assumed, endlessly sought, ever non-existent. There is a "voice", but no singer. There is only a corpus of material which is terribly abstract, but which retains an inevitable physical link with every listener.

The reference to vocal material has therefore real mimetic value: on the one hand it provides schemes for organization of material which we may draw upon, transform, anamorphize (in other words it offers the possibility of a grammar); on the other hand, it is a carrier of meaning, it speaks to us more intimately than any other reference, and it furnishes a real learning experience for the imagination and perceptions.

From this extremely rich point of departure, we may distinguish a scheme of three possible types of musical discourse:

— the complementary nature of the instrumental and vocal worlds: that is to say, the manipulation of musical parameters beyond traditional limits,

— the hybridization of models: that is to say, a completely new musical space which comprises a mixture of instrumental references, and/or their interpolation and progressive transformation,

— and the investigation of the specificity of materials: that is to say, a more radical approach, perhaps, which assumes specificity of material and its modes of description/representation, and produces organizational schemes which seem appropriate to them.

These three steps are not mutually exclusive, but pose different technical and compositional problems.

In my own work, I have been concerned essentially with the third aspect, sketching out a systematic investigation of material and its organization. *Chréode* starts from this possibly over-constructivist or over-programmatic point of departure.

The work was stimulated and made possible by some remarkable tools — the CHANT and FORMES programs designed at IRCAM. To clarify my method of work, I shall refer to a number of important considerations surrounding these programs, and then I shall descirbe their application in *Chréode I.*

CHANT is a synthesis program devised and created at IRCAM by X. Rodet and Y. Potard. Two basic characteristics of CHANT are worth emphasizing: it is a program for synthesis through rules, and is based on the model of vocal production. From the very start of CHANT, it was the intention to allow for accumulation of complexity on the one hand, and on the other, to offer the composer simple controls over this complexity. The model of synthesis through rules promotes, and proceeds through, an accumulation of knowledge. Physical models of sound production provide a realistic orientation for the formalization of this knowledge. Finally the voice provides generality and diversity, through the fantastic variety of its manner of production, from speech through to song, passing through a more or less infinite range of intonation and expression.

This is in perfect accord with the idea of simulation as a cognitive process whose function is perhaps to furnish models and paradigms for music.

These characteristics have contributed towards making CHANT an extremely powerful musical tool. Since its development at the end of 1979, CHANT has been used intensively in a wide variety of musical situations. We have developed an important library of "instruments", that is to say materials centred around the voice, but also departing from it: percussion, wind, strings, all families of instruments, and finally "instruments" more distant from instrumental reference, notably for the purposes of additive synthesis and inharmonic sounds.

The success of the methodology of synthesis through rules has led us to generalize this idea of accumulation of descriptions in terms of rules (i.e. alogrithms which are real models of sound production), and to develop new means dedicated to the control of structures, without reference to any particular synthesizer, or indeed to synthesis at all. The output of the program could just as well be some form of symbolic score, for example. This process led to the FORMES program developed by X. Rodet, Y. Potard and P. Cointe, which is essentially devoted to the development and manipulation of structures in time. The rules of CHANT, which are in fact algorithms of more or less complexity according to context, may become in FORMES objects/processes with broad qualities of modularity, generality and adaptability to the situation in which they are placed.

Chréode I was realized with the help of these two programs: CHANT for all the synthesis, and FORMES for composition and for the generation of scores for CHANT.

The term chreode is borrowed from genetics and morphogenesis (cf. C.H. Waddington and R. Thom). The word comes from the Greek "cre" — must — and "odos" — way — and presupposes for all, and *a fortiori*, new morphology the necessity of a way, of a road which must be followed.

"Another way of describing systems (in development), is to say that the path of change is channelled: for the route itself we may use the term chreode (. . .). Furthermore, in progressive biological systems, like embryos in course of development, or plants, we normally have to deal with systems which cannot be described in terms of a single chreode, or ensemble of parallel chreodes 'grosso modo'. . . . In the course of development of an egg, its two parts follow different paths and in the end form different parts of the animal; certain become the nerves, others muscles, and so on. We may give an intuitive picture of this in terms of an 'epigenetic landscape' where at the moment the process begins, there is just a single valley, but this subsequently separates into two or more valleys; in their turn, these bifurcations divide continuously until they form a number of separate valleys corresponding to separate parts of the adult animal (C. H. Waddington). "

Here I use the term chreode as a metaphor for our situation today, where we confront new musical morphologies made possible by the computer, at the intersection of organization and material. We are obliged to develop new strategies and new conceptual tools, better adapted and thought out to deal with this new situation.

For me "*Chréode I*" is a "window" or series of "windows" opening onto a work of larger scale. Its present state is therefore an incomplete puzzle whose overall form is less a result than a point of departure (even though it has been reworked subsequently to offer the sense of a whole, and a coherent point of view). The reason for this state of affairs relates as much to difficulties in advancing our research and the slow pace of putting it into practice, as to the questions of time and availability which are its corollary.

To begin with I set myself a very strict list of "tasks", which in a primitive way defined a system of constraints.

At the most general level, my concern was to approach the problem of a grammar of process and form by attempting to answer some elementary questions:

— what is a process?
— when/how may one recognize that a process has begun and ended, to be perceived as such?

In this version of the piece the types of process I examined were concerned with phenomena of change, of transition, or of trajectories defining lines between points. The points represent values for musical parameters, arranged for example in discrete scales. The lines represent modes of transition between these values, for example straight lines or continuous curves. The points and lines generate schemes, morphologies or structures, that is to say systems of transformation.

In the first part of the piece the points are defined and the lines are variable. In the second part, the terms are reversed. For me, these trajectories are strategies for exploration of a terrain, destined literally to invade sound space in all its dimensions. The organizational schemes of the piece have to do with oppositions such as continuity/discontinuity, parallelism/concurrence, etc.

But the whole of the first scheme concerns invasion of pitch space, through a pattern, a form which is repeated incessantly the whole length of the piece, through numerous figurations and metamorphoses. This form comprises a series of chords from which all the harmonic and melodic material of the piece is derived.

In order to avoid certain empirically established tendencies in the reception of computer music, a number of practical principles were defined:

— to encourage an accumulation of complexity: each repetition corresponds to an enrichment of material,

— to be watchful of significant dynamic variations, except in the case of specific effects,

— never to neglect any particular dimension: always to find an appropriate law/rule of variation for it.

I shall now talk about the sound materials.

I chose to concentrate on a single given type of sound material, to which I would apply certain transformations. This would be "from the inside": not as an interpolation from one "instrument to another", but rather as a variation of the internal structure of the material, and this process would be controlled by specific rules operating on a small number of specially chosen parameters:

— the compression and expansion of formants: a multiplier of the central frequencies of formants, providing a powerful control over spectral envelopes, and generating a wide variety of timbres from this single control,

— "octaviation", that is to say the differentiation of even and odd harmonics,

— aleatoric variation of the central frequencies of formants,
— aleatoric variation of bandwidth of formants,
— noise within each formant region,
— correlation between amplitude variation, spectral richness, and the various aleatoric variations of formants,
— various time envelopes, which are often also correlated, acting on most of the preceding parameters,
— modulation at low frequency on all parameters.

Beside the material based on the voice, I specially developed a series of new "instruments" which I used for specific disruptive effects in the middle and at the end of the piece. Their function is to break up temporarily the extreme homogeneity of the material as a whole.

Now I shall describe some of the processes.

I used libraries of values extensively for parameters such as frequency, amplitude, duration, phonemes (which are essentially used to describe spectral envelopes), and compression/expansion of formant frequencies.

The libraries are in fact simply lists of values for these parameters. These lists are "located", that is to say they contain values specially chosen for each parameter and each situation. Then there are event lists which correspond to these reference lists, and contain indices which "read" the values. The values in the reference lists are accessed dynamically by the indices or "pointers" of the event lists, or they are defined in a FORMES object (algorithm) which is then charged with reading these lists. The "pointers" go through the list and read it, extracting values which are either applied directly, or modify other values before being sent to the CHANT synthesizer (Figure 1a).

The beginning of the piece employs such a process (Figure 1b). The idea is of a trajectory defined by a FORMES object: it begins at a fast tempo from a simple repeated chord whose ambitus opens little by little before finally closing and fixing on another chord. This trajectory is repeated simultaneously along several lines with different lists or groups of values, allowing for both melodic and harmonic control at the same time. The form of this trajectory which is typical of most of the piece, is a sine curve multiplied by a decreasing exponential.

During this process the compression/expansion of formant frequencies is defined by a simple time function, evolving from a very weak value, around 0.1 of the normal vaue, towards a value of 1.0, which corresponds to the nominal values given by the spectral envelope of the phonemes. The phonemes themselves return in recurrent fashion, in a sequence looped onto itself. The result is a process of structural development which is extremely compressed at the outset, then unfolds little by little, revealing itself, and then affirms itself at the end. The same process is repeated several times with different targets, which differ at harmonic and melodic levels as well as at the level of compression/expansion of the spectral envelope.

Yet another process is used to generate an ostinato accelerando. A FORMES object is defined to generate a figure (a form) which will control most of the important parameters. This figure is a damped, inverted sine curve. This sine curve varies around an axis which represents the offset (the mean value) for a given parameter. The variations around this axis define the variations of the parameter. The phase and period of the curve are also specified. The resultant curve is also sampled, i.e. at certain precise intervals the curve is read to give a value for a parameter. The speed of reading, i.e. the quantum, or the intervals at which values are extracted, is determined recursively by the same curve, which therefore "reads" itself.

At a higher level in the hierarchy, another FORMES object is charged with jumping from one curve to another at each quantum of time. Each curve has a phase and a number of periods which are either slightly different or radically opposed. This gives a very subtle and complex interplay of phase displacement and delay, successively within individual lines, and simultaneously between them all.

The object/algorithm produces an alternating sequence of value samples, which may be used to construct metrical structures in continuous evolution, or very subtle variations of frequency, intonation and amplitude (Figures 2a, 2b, 2c).

The law of variation always yields results which are perceptually significant and interesting.

When the initial form has run its course and reached its apex, it is inverted and addressed with new values which produce a brutal *decellerando* in which different lines separate and "descend" to the only moment of repose in the piece (Figures 3a, 3b). At the same time the vocal material is replaced by instrumental-type material with percussion and wind timbres.

Another process is derived from entirely serial basic material for a four-part choir, where each voice "carries" the 12 transpositions of each form of the series. Each of the forms is constructed automatically by a FORMES process then anamorphized, transformed by a time function which describes three curve segments evolving in a progressive, sinusoidal manner from low to high (Figure 4). This process is further applied here to amplitude, frequency, duration, and compression/expansion of the spectral envelope (Figures 5a, 5b, 5c). Each of the three segments is applied to 4 transpositions of the series. The first segment varies between 0.1 and 0.9, the second between 0.9 and 1.1 (with sinusoidal variation), and the third between 1.1 and 3. Duration is in inverse proportion to the other parameters, and amplitude follows the same evolution but slightly compensated.

This process produces a slow, low-pitch ascent to begin with, which becomes increasing rapid and high, and finally ends in an extremely high and rich shearing of the spectrum. In the domain of pitch, the result is an intervallic and intonational structure in constant change, which generates intense and expressive emotion. In the timbral domain, the extreme values of frequency formants result in a total bursting of the spectrum, in parallel with numerous rules of correlation, and at the end of the process produce an extraordinarily rich and extended sound which evokes the image of a series of bowstrokes on living vocal chords!

This ascent is rounded off by material which begins with an extremely high gong stroke and quickly dissolves into a distant choir, which preserves from the timbral point of view part of the sound quality of the gong. This material is obtained by a special algorithm for the aleatoric variation of formant frequencies, general amplitude and pitch.

A reminder of the ostinato finally reappears in the distance before disappearing, taking the choir with it.

Chréode I is a first step, a mere sketch in the vast programme I have described. Never have the practical and theoretical resources of music been as extended as they are today. The horizons which are stretching ahead for composition are inspiring. I am convinced that the computer music movement, which has opened up in a global manner, is only at its beginning. Our only limitation, more than ever, is our imagination. To guide us in this universe, unthought of so little time ago, we need a pathway. But I believe this is a road of no return ...

"Many changes which take place in society have a more or less developed chreodic character; once a certain direction has been taken, it is very difficult to make them diverge from it (C. H. Waddington)."

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Translated by Nigel Osborne

liste de reference (liste passive)

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97	1396
110	1046
73	3322
69	3136
92	3520
77	2349
116	2217
123	2960
82	2489
87	3729
65	3951
207	2637
196	2793
220	2093
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185	
155	
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130	
415	
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4	1	2	68	70
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4	1	2	70	72
4	1	2	71	72
200	1	2	72	72

FIGURE 1A Illustration of the first process: in the active list a certain number of elements are specified as well as the upper and lower limits within which the probabilistic values in the reference list should be effected.

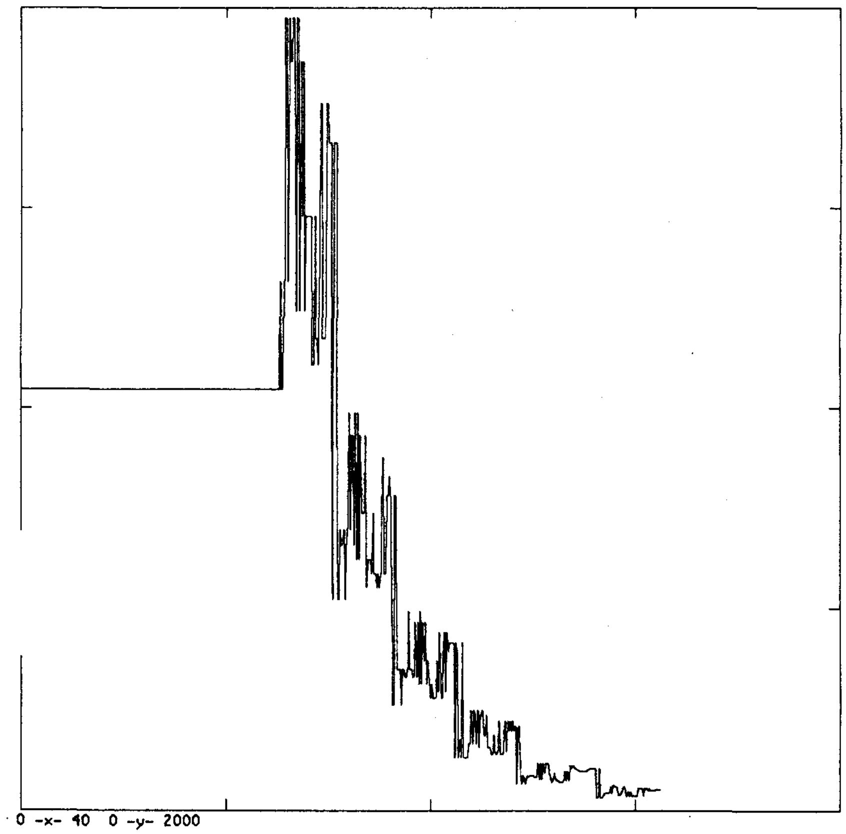

FIGURE 1B Frequency curve resulting from the first process for a voice. Exploration of the whole range.

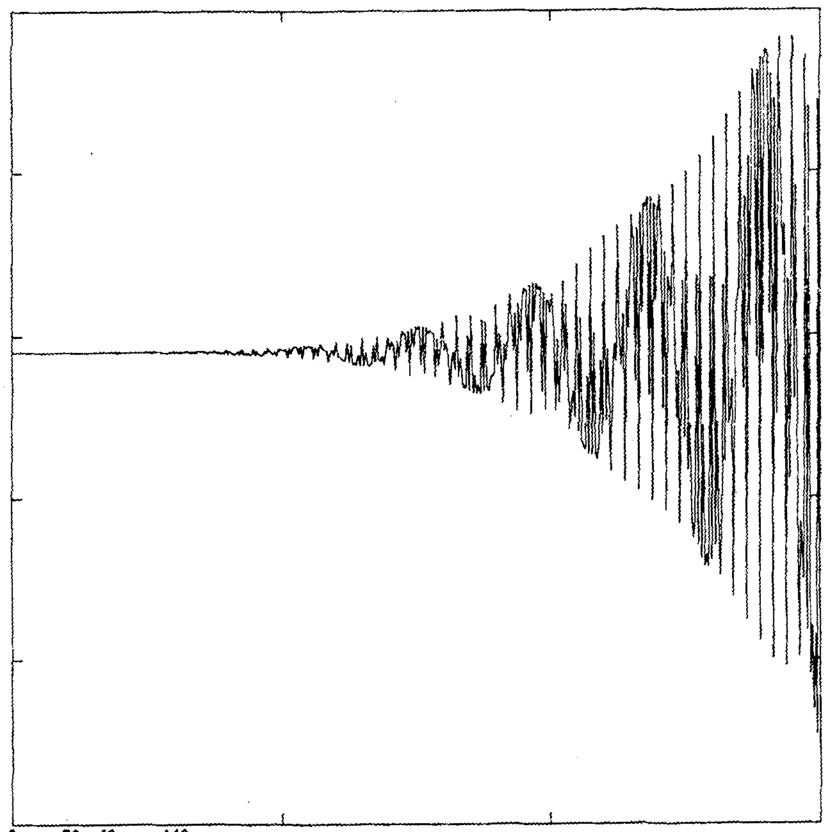

FIGURE 2A Frequency curve resulting from the second process. A jump backwards and forwards between damped and inverted sine waves with different phases produces an interplay of phase displacements and complex variations of pitch and intonation which leads to an enlargement of the ambitus.

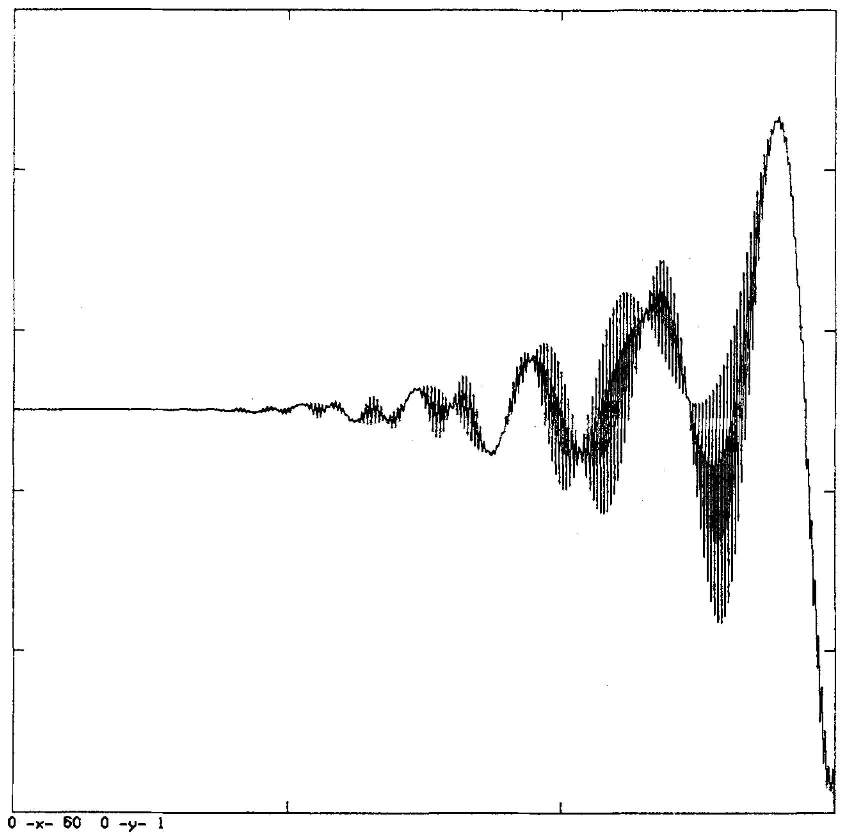

FIGURE 2B Amplitude curve resulting from the second process. The same jump backwards and forwards produces an ostinato accelerando as well as complex variations of rhythm and nuance.

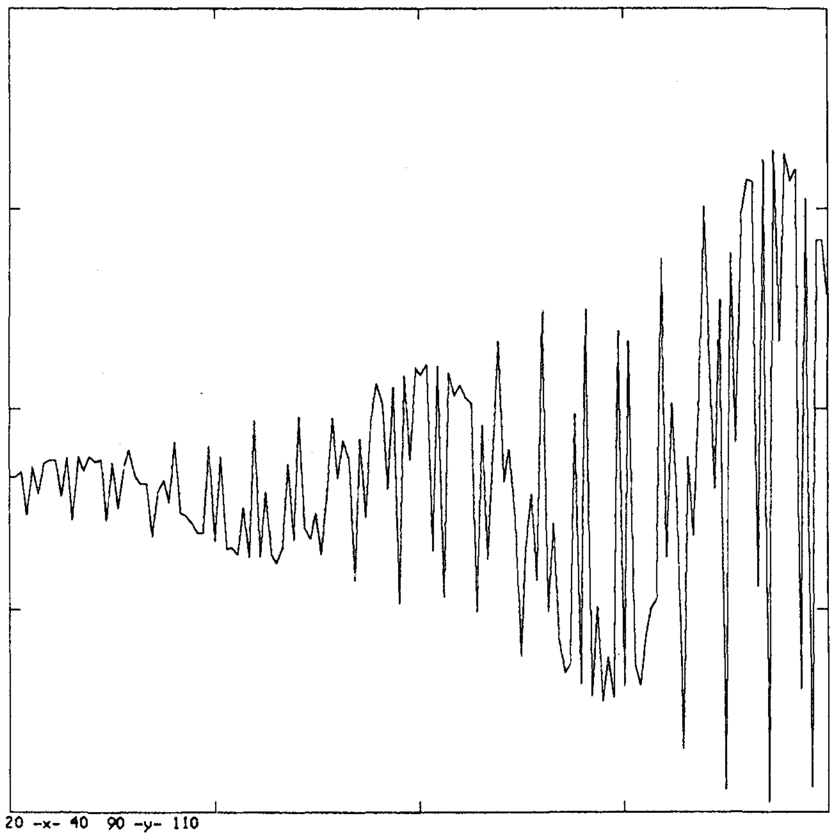

FIGURE 2C Detail of the frequency curve from the second process. We can see different alternating pitch hierarchies produced by the process of jumping from one curve to the next with different values of periodicity and phase.

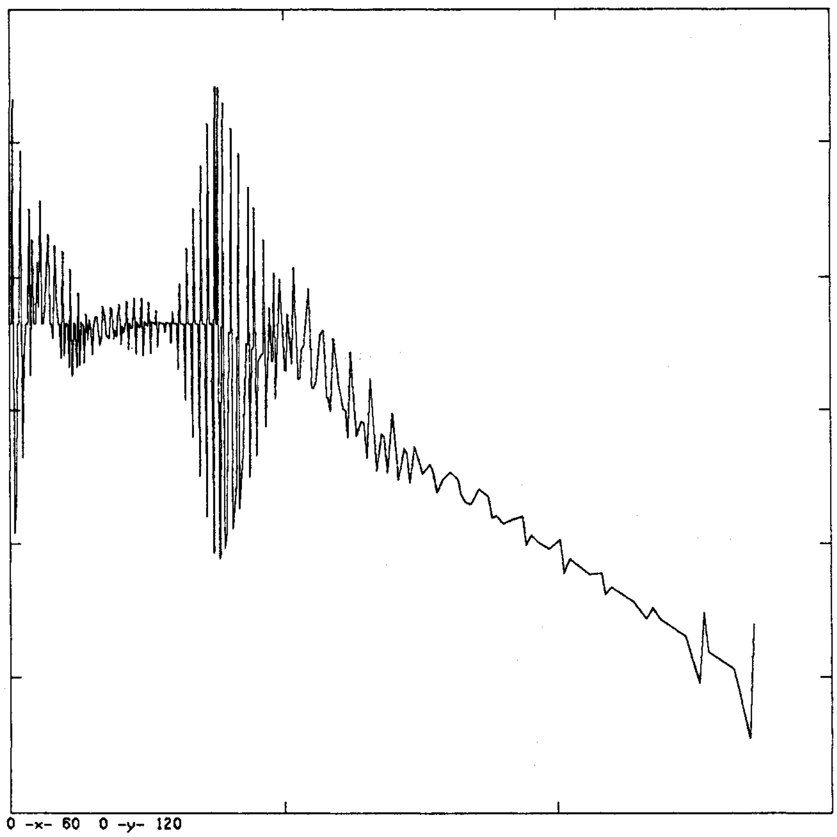

FIGURE 3A Frequency curve. The ostinato leads towards a decellerando realised by the same process as before, but this time inverted and descending to the bottom of the register.

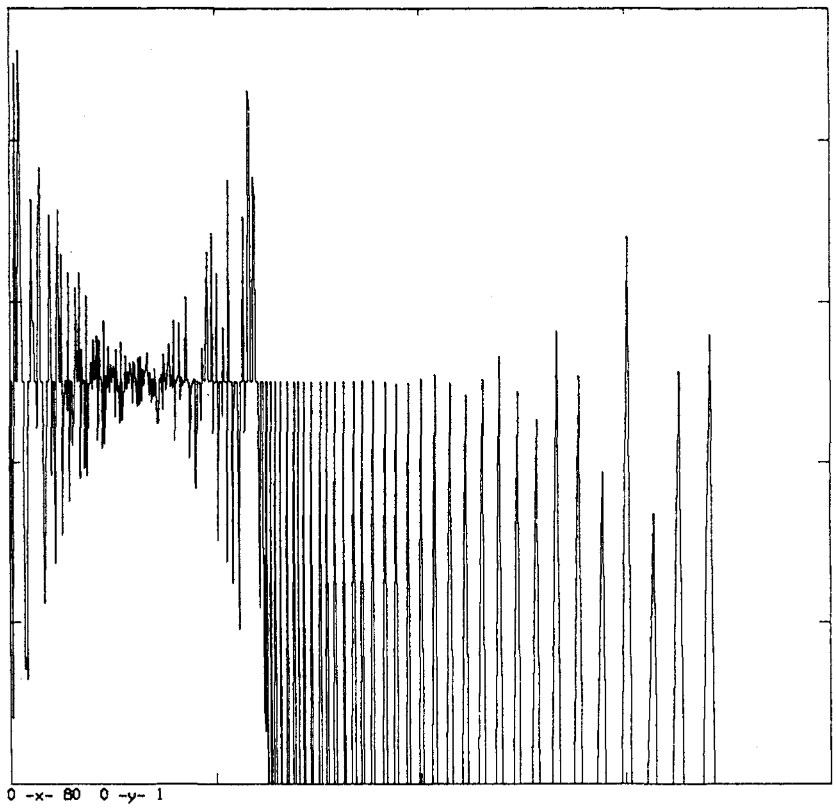

FIGURE 3B Amplitude curve from the same process as 3A.

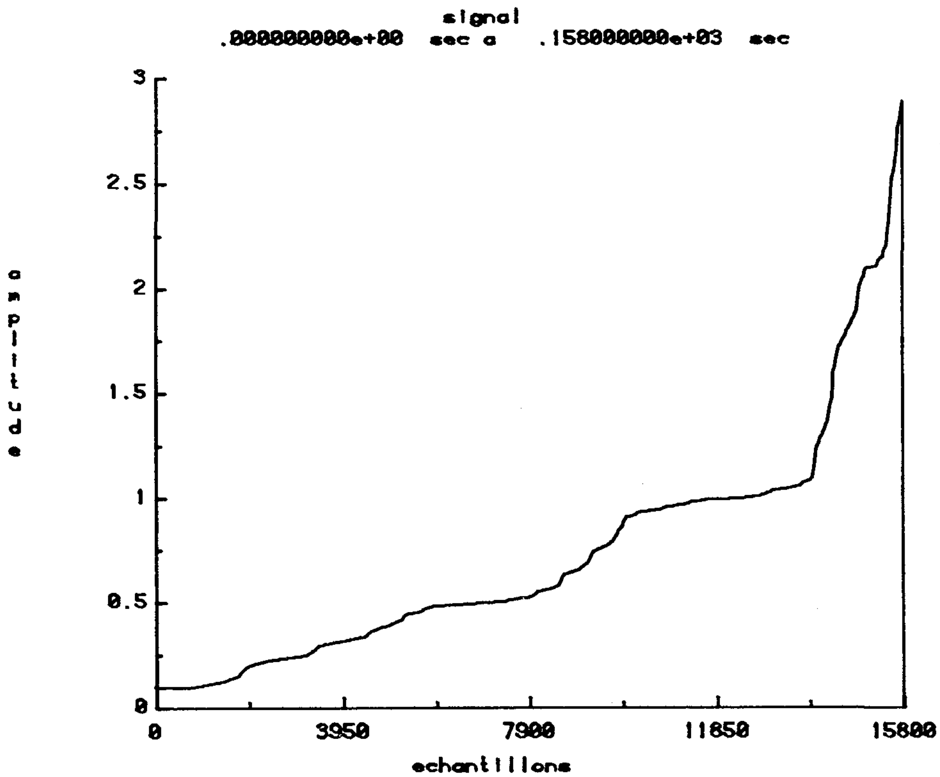

FIGURE 4 Curve of multiplying coefficient applied to amplitude, frequency, duration and the compression/expansion of the spectral envelope. This curve, which describes three sinusoidal segments between 0.1 and 0.9,0.9 and 1.1,1.1 and 1.3 gives a deviation based on reference values produced by the evolution of a serial process on each of the parameters.

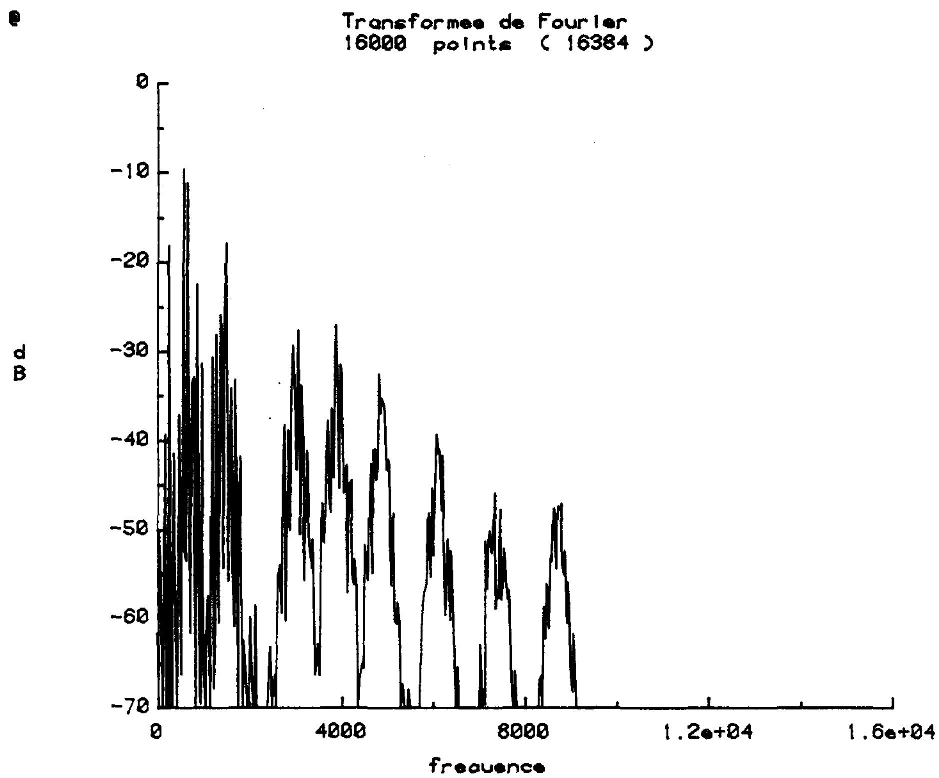

FIGURE 5A Spectrum of a phoneme with a multiplying coefficient of compression/expansion of 1: the values do not change.

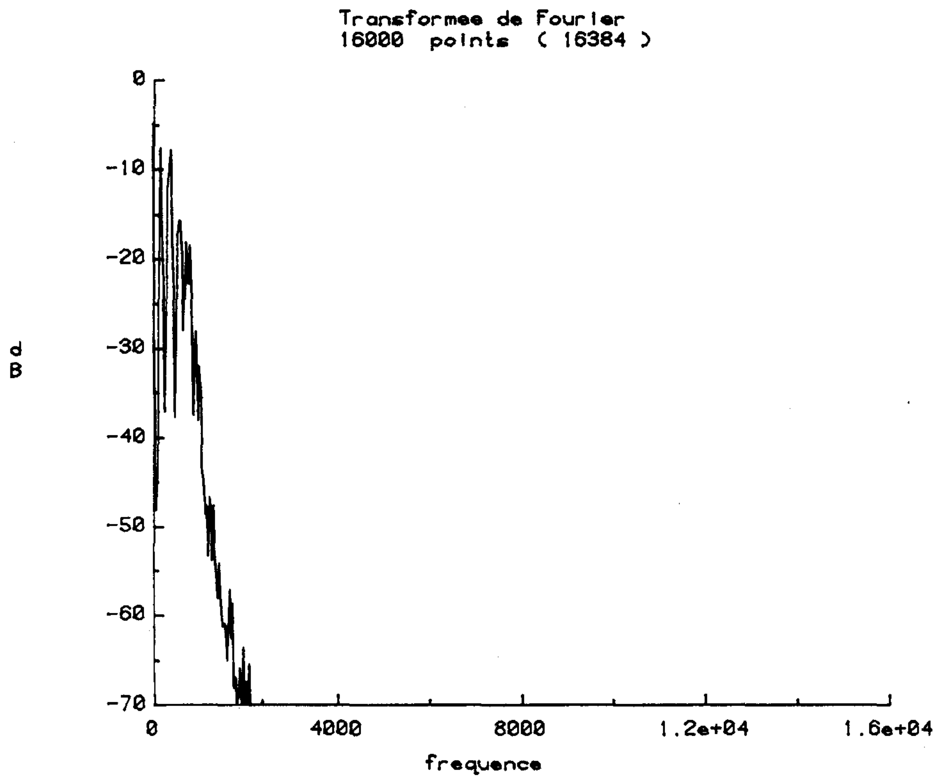

Figure 5B Spectrum of the same reference phoneme as before, at the beginning of the process, with a multiplying coefficient of compression/expansion and of frequency of 0.1. The frequency if 30 hz and the very muffled timbre approaches that of a cello or double bass.

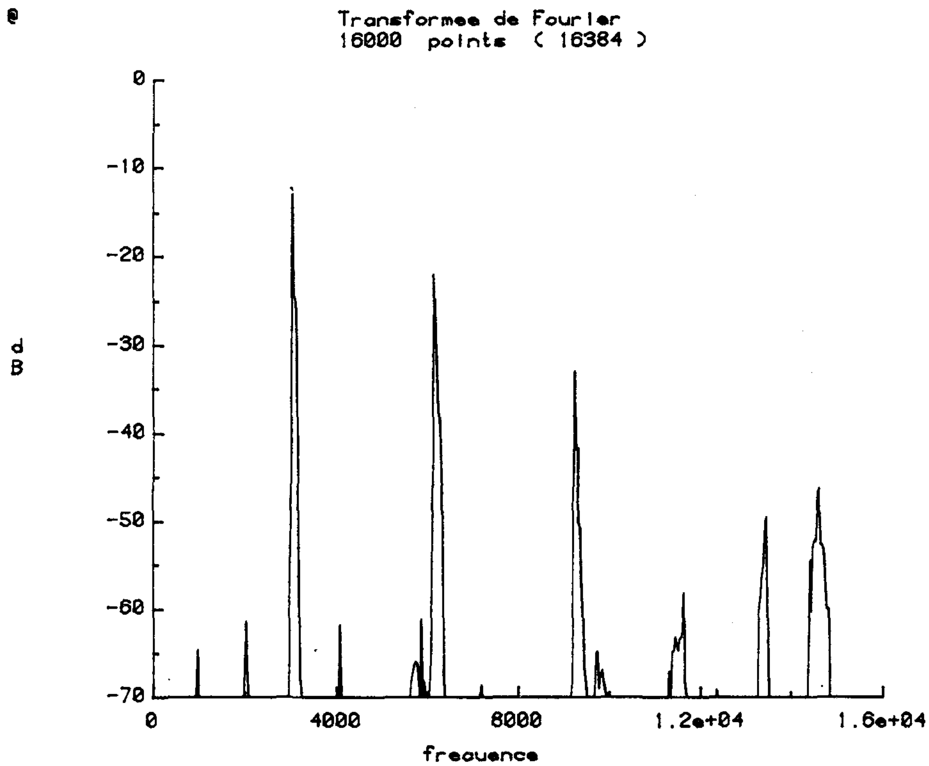

FIGURE 5C The same reference phoneme once again, this time at the end of the process, with a multiplying coefficient of 3. The frequency is 1000 hz and the extremely rich timbre is between that of a violin and a voice.