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Musical information organisms: An approach to composition

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This text is the beginning of a formalized reflection on some poetic aspects of my present compositional world. After a brief survey of our historical background, a general conceptual framework, inspired by research in knowledge representation and categorization, is established. Using two complementary representational systems, I develop a microworld paradigm, the paradigm which first sparks my imagination. Higher-level musical structures, considered as evolving societies in morphological spaces, are then examined, including the overall form of a piece. Excerpts from my own work are analyzed in terms of the writing techniques which are adopted. Finally, a few extensions to this compositional approach are succinctly discussed, together with some of the consequences that challenge traditional perception, analysis, performance, and interpretation.

KEY WORDS: Concept, *écriture*, knowledge representation, language, metaphor, morphology, poetics, similarity, society.

The context

We live in a musical age where common languages and common models no longer exist. One of the most immediate consequences is that an analysis of a piece of contemporary music requires the invention of a new model which describes some aspects of that specific piece. In spite of its intellectual interest, this attitude is often too passive from a composer's perspective. The model often has to be built on the visible surface of a piece, does not necessarily correspond to the composer's creative process, and can rarely be reused.

However, an analysis might point to some abstract compositional principles which could be adopted to generate a piece. It is not important then that these principles correspond to the ones that the composer followed. Indeed, this will not generally be the case. But they can be used – as a metaphor or as a technique – to generate new music. Such an analysis yields a way of exploring a compositional world.

This text is the beginning of a formalized reflection on some characteristics of my own musical world, in terms of the abstract writing techniques which have given rise to a particular compositional system. It is not my aim to provide at present an exhaustive picture of my current poetics: a more elaborate description of it will be discussed in future works. The main conceptual effort had to be an inductive one, since it was applied to a set of pieces which had already been completed. It was in the attempt to account for intuitive work of my imagination that I suddenly saw more sharply into some of the inner principles that spurred the growth of my musical thought.

The first clues of a different poetic direction can be traced in a short orchestral piece, *Metabolai*, written in 1982. Some of the writing techniques described in this article were already used there in an intuitive and somewhat simplistic way. In *Traiettoria* for piano and computer-generated sounds, a cycle of three works *(Traiettoria ...deviata, Dialoghi, Contrasti)* which followed *Metabolai*, the experiments became more accurate and their use more conscious: proof of an emerging compositional system[1]. *Contrasti* in fact, represents the first conscious use of such a system and therefore provides an ideal field from which to draw most of the examples analyzed here.

Defining a new compositional system entails establishing a general conceptual framework suited to the specific compositional process. Within this framework, one or more representational systems, together with some operative methodologies, can be specified. At this stage, the choice of appropriate representation(s) is critical, because of the consequences it will have on any further developments. I will employ two complementary representations to describe a compositional system used to analyze various musical examples. As a composer, I will mainly take a creative and poetic perspective and focus on the system's influence on musical composition.

A survey

The Historical Context

Let us imagine, for a moment, that we are listening to Beethoven's *Archduke Trio*, with its gentle, almost Schubertian initial melody, carefully arranged above a calm accompaniment and barely wrinkled by a final crescendo and two fleeting trills. If we wonder how to analyze what we are hearing and ask the same question of various people from different backgrounds, the range of answers we would get is enormous. If they tell us something about the way (rather, the ways) people perceive, represent, and think about music they will probably be either too vague or too analytical, that is, either not specific enough or too narrowly concentrated on isolated musical dimensions. A very important feature might still remain unaccounted for: if, for instance, the whole first theme is considered as a unique stimulus, how then can our perception relate to it? This stimulus must be seen from another perspective, as a complex element made of simpler parts whose interactions give it a certain, easily perceivable character or identity. Each part roughly corresponds to a classic dimension and does not have the same perceptual relevance with respect to the stimulus as a whole: some dimensions will be more important, other ones less so.

If we develop this perspective a little more formally, we suddenly realize that there are no tools in traditional music theory to help us cope with it: no ways to represent it adequately, no operators available to pursue it further. How to describe, for instance, the relationship between the whole first theme of a sonata-form and its development section? Is it possible to perceive which parts of it are developed? Does the theme's identity stay the same or is it transformed into something else? How are these transformations related to the global structure of the piece? If some kind of relationship is effectively grasped, this implies that

long-term memory has been involved, because of the temporal distance separating the two episodes. Since information is stored in long-term memory mainly on a semantic base, some structural, or, to use a personal term, some identity-based encoding of the material must have occurred. How can a composer represent and control it directly?

A Poetic Standpoint

If a better description of the approach that has just been put forward could be imagined, then a compositional technique might be derived and exploited. The first step is to find an adequate framework, a framework with a positive, generative quality, which can be directly related to the act of composing, that is, to symbolic writing, and not only to the auditory surface. Which is the best paradigm to tackle this kind of musical behavior?

Summarizing its most hard-to-represent characteristics, we have to take into account the issue of *definition*: the parts a complex musical element is made of are difficult to specify, quantify, and enumerate, and may be irrelevant under certain conditions. Their importance also varies according to the current context. A tempting strategy would be to consider them as "musical chunks", thus establishing a direct reference to short-term memory needs as far as complexity, size, number, and encoding strategies are concerned.

Another issue is *abstraction:* the behavior of a musical element has an identity which cannot be totally explained by the mere presence of its actual components, since it may not be affected by the change of some of them.[2] The real perception of this identity varies along a continuum and is a complex function of personal, cultural, historical and contextual factors. Their mutual influence, probably the most thorny issue to understand for someone who has never composed, is usually dealt with intuitively by musicians, and is virtually impossible to quantify satisfactorily.

A final issue is *similarity* how to describe the fact that many different elements may be an instance of the same identity, and are therefore similar? Tversky's *contrast model* has shown that the notion of similary is asymmetric, directional and can be biased by the differential availability of examples (Tversky & Gati, 1978). What is the role of attention and of such visual cues as the analysis of a score on the perception of an identity? Can one envisage something like linguistic "hedges" in the auditory world? Will an expression like "loosely hearing" ever make sense?

An Appropriate Framework

When I started looking at music in this way, I groped after some conceptual help in classic music theory, but unsuccessfully. Context-dependent behavior, for instance, was at best tacitly accounted for, but never dealt with explicitly. It was only some scientific ideas that provided me with the correct terms and a satisfactory framework to think about it. A close correspondence will then be found between the questions raised by my own complex musical stimuli and some issues tackled both by knowledge representation in artificial intelligence and by research on categorization in cognitive psychology. Explicit references to these areas will be given throughout this text.

Musical Information Organisms: The microworld paradigm

The *basic level* (as defined in Rosch, Mervis, Gray, Johnson & Boys-Braem, 1976) of composition, the level which first sparks my imagination, is not the development of pre-compositional material, like pitch relations, or any kind of work on single dimensions, but the birth of a *Musical Information Organism* (or OIM, from the Italian - *Organismo di Informazione Musicale*).

The term "organism" is used in a technical and formal way to refer to a complex and dynamic entity whose evolution cannot be described or predicted by synthetic rules (such as analytical functions, stochastic processes, deterministic or combinatorial procedures[3]). An organism is something active and consists of several *components* and *properties*[4] of varying complexity, maintaining certain *relationships* and giving rise to a particular *form* . Its *identity* is a cognitive representation of such a form. An OIM has a well-defined *life-span:* it comes into existence, develops, and fades away after some time. Its *evolution* is usually guided by a plan and is goal-oriented: it starts at some point and reaches a goal following various trajectories. The perception of the form of the trajectory is at least as important as the perception of the form of a single organism. Two apparently similar organisms can still be discriminated if they belong to two different trajectories. This mobile network of cross-references produces a complex *microscopic society* within a single OIM. However, this internal activity is perceived or dealt with non-analytically, as a whole. An OIM's identity is undoubtedly related to this holistic aspect as well as to various other factors, such as a particular behavior, a prominent attribute, an emerging relationship, a special musical figure, or an outstanding instrumental gesture.

An OIM's attributes or relationships are not of equal importance. They have different time-variant *weights* which are connected to perceptual or structural relevance. Perception and composition, on the other hand, are not automatically related: a component can be given more weight because of its structural relief, even if it is hard to perceive. Since the weight is also a measure of a component's contribution to the OIM's overall identity, it affects the choice and the use of a particular writing technique. A first, general rule is that the lower the weight, the more dramatically a component can be modified without influencing the identity, whereas the higher the weight, the more exposed and sensitive to small changes a component becomes, demanding a much more refined technique (see the notion of "family resemblance score" in Rosch & Mervis, 1975). During analysis or composition, it seems pointless to use an extremely sensitive technique for low-weight attributes, unless this is motivated by other structural reasons. Modifications applied to high-weight components or properties tend to have a structural significance: they might weaken an OIM's identity, change its place within the existing context, be a sign of a major formal change, and so on. Modifications applied to low-weight components or properties are more often due to local conditions and do not usually affect the global context.

A Complementary Representation: Energy Fields and Morphological Spaces

The representation of an OIM as an active element is best suited to describe the

micro-structural characteristics of single instances. This corresponds approximately to the level of musical material. However, when dealing with macroscopic, context-dependent properties – which play an important role at a higher formal level – as well as with the mutual interactions among several OIMs, this paradigm is insufficient. Another representation must then be used. Some means to pass from one to the other also need to be specified.

If the weight of a single property is seen as a measure of some *energy* radiating from it, and that we concentrate on this energetic aspect, then the overall strength of an OIM's identity will correspond to the total energy that results from the interactions of all its components' energies. From this perspective, the total energy generates a *field* around an OIM. Since each property's energy is varying and different from the others, the field will be stronger in the directions corresponding to heavy components, and weaker in the lighter ones. The field's main attributes are its *morphology* and its *identity*. The former is related to the concept of form defined earier, whereas the latter can be seen only from this viewpoint.

An energy-radiating OIM projects its action away from its core towards neighboring fields. The stage where all these fields interact, in other words, the musical context itself, is a *morphological space* with its own structure and constraints. As we will see, describing the evolution of such a space is one of the possible ways to deal with the issue of form in a piece.[5]

An Example: Static Identity

Let us now turn to a real OIM, the one starting the piano solo cadenza of *Contrasti*. It's final form is presented in Figure 8. A first, essential remark is that it is very pianistic and has a particularly strong sound identity attached to it. In fact, all the OIMs used in *Contrasti* are highly influenced by specific instrumental gestures.

If we emphasize only the most salient components (Fig. 1), the OIM can be divided into three parts:

a) *head*, made of a relatively long note (usually an accented chord), followed by two short repeated notes (usually less dense chords) in a different register of the instrument.
b) *middle part*, ascending pattern which uses a slightly extended version of the pianistic technique of alternate hands.
c) *joint*, composed of some flexible material that can be easily "bent" so as to fit whatever comes next. Because of its dependence on the context, it cannot be further specified at this stage.

By applying what has been worked out so far, it is fairly straightforward to analyze most properties of the present OIM and to recognize and learn the main aspects of its identity. However, it is only the *static identity* which is referred to here, that is, what can be inferred from just one instance of an OIM. Before being able to analyze its *dynamic identity* which derives from the behavioral properties of a class of OIMs, some writing techniques appropriate to this level need to be introduced.

Some Writing Techniques

The musical elements to which these techniques are applied are:

1) *Single items*. They span from traditional dimensions (such as a note, a duration,

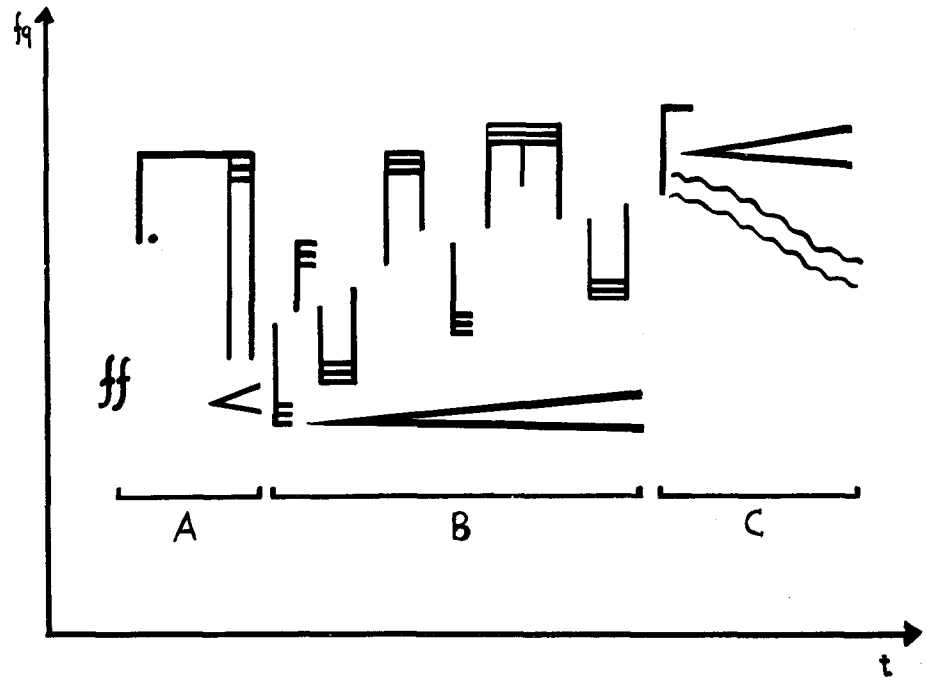


Figure 1 Synthetic view of *Contrasti*'s first OIM (A: head; B: middle part; C: joint).

an amplitude, an instrument's register, etc.), which have little or no identity, to single properties with their own micro-identity, and finally to single relations between dimensions and/or properties.

2) *Sets of items.* This is a collection of single items of any kind, size and order, which yields a unique pattern. Examples of sets are: a crescendo (a set of amplitudes), a musical figure, a chord, a special rhythm, and so on.
3) *Space.* This is the distance between two or more items or sets of items.
4) *Direction.* It refers to the evolution of a set of items and is represented as a vector with a certain magnitude.
5) *Energy.* This is a way to deal with the global force of a certain pattern, independently of how it is distributed and is computed by taking into account the weights of all the OIM's properties.

When one or several simultaneous techniques emphasize the same aspect of a given item, they are said to be *coherent* with respect to it. Otherwise, they are said to be *incoherent.* A coherent behavior has a particuarly strong perceptual relevance.

Defocusing

This technique consists in altering the sharpness of a given item, that is in putting it out of focus. One must distinguish the kind of item that is defocused from those that are used for defocusing. Figure 2 presents a few applications on an idealized note or chord. It is crucial to realize that the overall effect should be considered and played as a whole. It is still a single item which has gone out of focus,

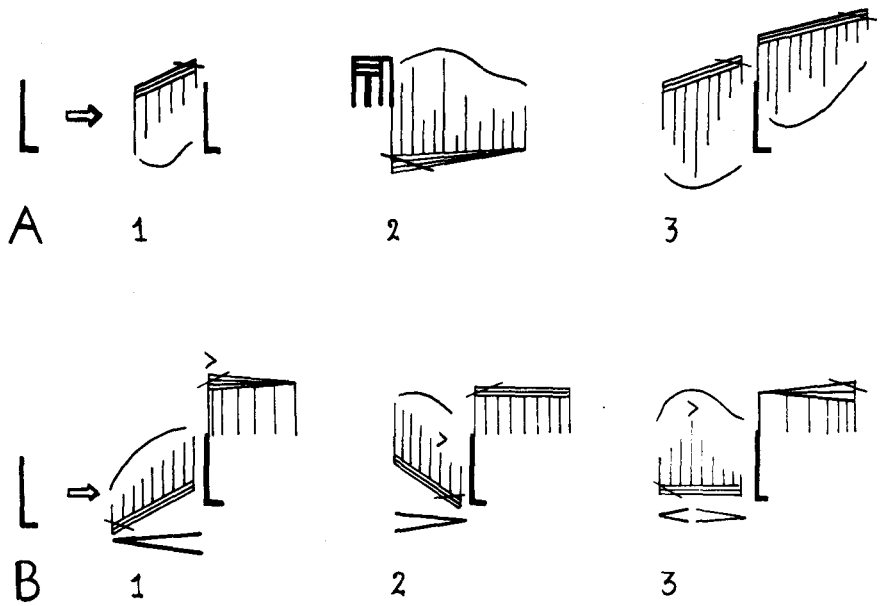


Figure 2 Defocusing Technique. A: simple cases. 1 = smooth up-beat arpeggio; 2 = smooth up-beat rhythmical anacrusis similar to remultiplication + rough down-beat melodic structure; 3 = smooth up- and down-beat melodic structure. The second structure repeats the pattern of the first one twice, with an upward melodic trajectory. B: example of coherent and incoherent use of a melodic structure (MS), a dynamic change (DC), an accent (ACC) and a rhythmical inflection (RI). 1 = all coherent; 2 = MS/DC coherent, ACC incoherent, RI neutral; 3 = MS/DC/ACC coherent, RI incoherent.

it is not a set of items!

To understand a simple use of coherence vs. incoherence, the case of Figure 2b should be studied in detail. A dynamic accent, a dynamic change, a fast melodic figure and a rhythmical inflection are used simultaneously. An accent is a source of energy coming from one point with a single value at any given time, while a dynamic change is a source of energy spread over a certain time and evolving within a certain range of intensities. The melodic figure has a smooth contour with a single highest point, where most of the energy is concentrated. Its evolution is always correlated with the dynamic change: higher pitches correspond to louder dynamics and so on. The energy of the final inflection is controlled by the speed of repetition of each element: accelerando (increase of energy), decelerando (decrease of energy) or no change (equally spread energy). Each component then, modulates energy by concentrating it in a certain temporal region, with different degrees of strength and sharpness. When acting on the amount of overlap of these regions, their energies can be made to converge or diverge at will.

A discretized variant of this technique is *remultiplication*, in which an item is blurred by modulated repetition. Among the various control parameters, the *duration*, *rate* and *regularity of the repetitions*, as well as the *arrangement* of the *anchor points* ought to be mentioned. A rough sketch of some cases of remultiplication of the second half of the head of our target OIM is shown in Figure 3.

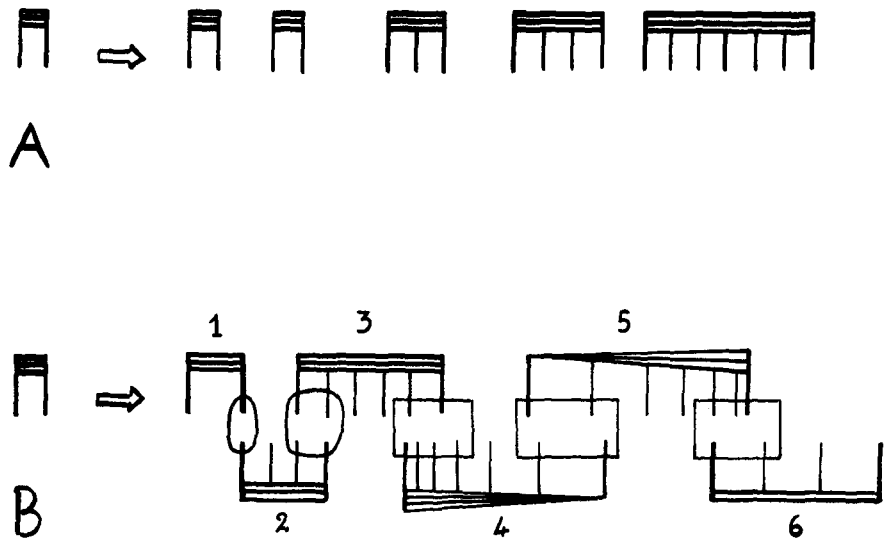


Figure 3 Remultiplication. A: separated remultiplication with five regular, fast repetitions. The distance between repetitions increases and decreases smoothly, the number of repeated notes increases smoothly at first and abruptly at the end. B: remultiplication with six overlapping repetitions and five variable anchor regions (circles = synchronous superpositions, rectangles = asynchronous superpositions). 1 to 3 are regular, fast repetitions with an increasing number of notes, 4 and 5 are smoothly accelerated and decelerated repetitions with the same number of notes, 6 is a short, regular and slow repetition.

Space filling and stretching

The space between items or sets of items can be filled in several different ways. As above, one has to distinguish between the nature of the items which delimit the space, the nature of the items which are employed to fill such space and the nature of the space itself. Some examples of a temporal space bounded by the two main components of the head of the OIM of Figure 2 and filled by various kinds of items are presented in Figure 8 (nos. 8, 11-14, 17). It is worth noting that the action of a certain technique can be considerably reinforced by profiting from the inherent limits of the instrument and/or the performer. For instance, a simple recombination of the order of presentation of the notes in a musical figure may transform it from a very natural one to play, to a nasty, awkward one. The smoothness of the final outcome will therefore be affected in ways which eventually depend on the performer.

The space can also be overfilled, so that no human being can play or perceive it without stretching the items which frame it. A *space filler* can be easily turned into a *space stretcher* by simply increasing the number of its components or the complexity of their behavior (see, for example, Fig. 8a, nos. 13-14).

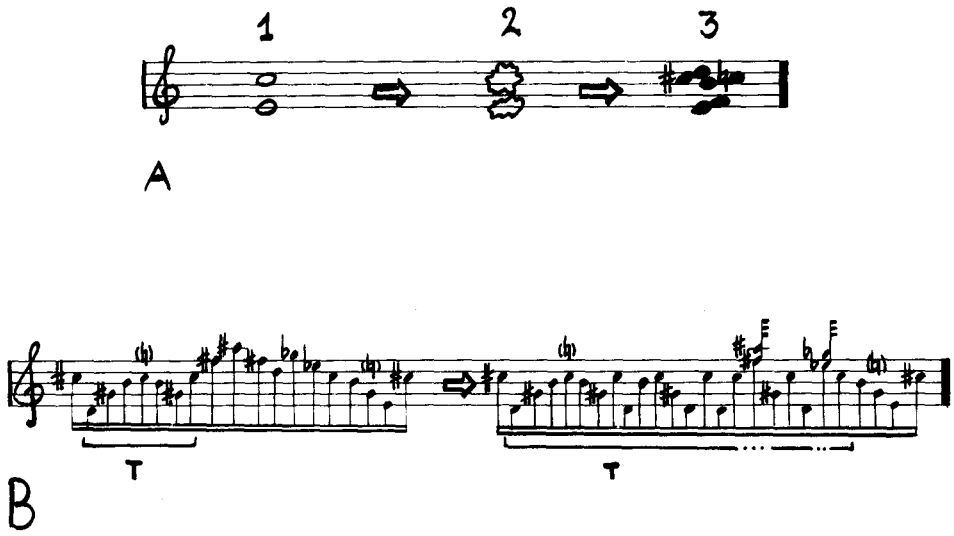


Figure 4 Tumoral Expansion. A: vertical tumor, which generates the first chord of Fig. 8, no. 1 (1 = reference pitches; 2 = ideal expansion; 3 = actual expansion). B: horizontal tumor (T), from *Contrasti*, part of the OIM labelled as XE2 in Fig. 13.

Vectors

A vector is characterized by a *direction* and a *magnitude* : musically speaking, the former is related to the direction of change within a certain domain, the latter refers to the width of such a change. For instance, in the frequency domain, an upward vector means higher frequencies; in the amplitude domain, it means louder sounds; in the complex domain of an energy field, it might mean increase of overall energy, or it might refer to the orientation of the field within the morphological space. In *Contrasti*, for instance, the head alone of the OIM of Figure 8 is developed by applying different vectors to it.

Energy modulation

This can only be applied to sets of items. In the frequency domain, for instance, the total energy of a given figure is approximately proportional to the quantity of notes of which it is made, provided they are played fast enough to be considered as a single unit. In the OIM under examination, the middle part ("b" in Fig. 8) maintains the same overall energy while gradually passing from an average density of two notes per hand (as in Fig. 8, no. 1) to an average density of one note per hand twice as fast (as in Fig. 8, no. 11).

Tumoral expansions

A tumoral expansion is a deviation from a "healthy" reference item, which proliferates abnormally via more or less modified repetitions. The exact order of such repetitions does not follow a precise rule, is not important, and may be completely chaotic. Usually "thicker" than the original item, a tumoral expansion can be

applied to every dimension and is an exclusively local phenomenon: its final details cannot be determined in advance and take shape only once the context has been defined. An example in the pitch domain is shown in Figure 4. When affecting a vertical structure (Fig. 4a) the tumor closely resembles a cluster. When affecting a horizontal structure (Fig. 4b), it looks more like an ostinato melodic elaboration.

Surface, density and contour

These techniques, together with those yet to come, are particularly varied and will only be outlined here. They deal with items' visible profiles, their phenotypes as opposed to their internal structure. When an item occupies some space along a given demension, this space can be schematically represented as a *surface*. The *density* corresponds then to the average number of components per unit of surface. An item is *smooth* if it is regularly distributed along that dimension: it does not change abruptly. Otherwise, it is *rough*. The transition between the two extreme cases is continuous.

For instance, the fast melodic segment used to defocus the item of Figure 2a is smooth along the pitch dimension in 1 and 3, whereas it is fairly rough in 2. The rhythmical dimension of the "B" part of the OIM of Figure 8 is perfectly smooth at the beginning, while during the evolution it gets at first progressively perturbed and then smooth again until it disappears in the last instance of the class. A final example (Fig. 5) shows a progressive increase in surface with an approximately constant density (nos. 1-10), followed by a decrease in density over a constant surface (nos. 11-16), along the domain of another of *Contrasti's* OIMs.

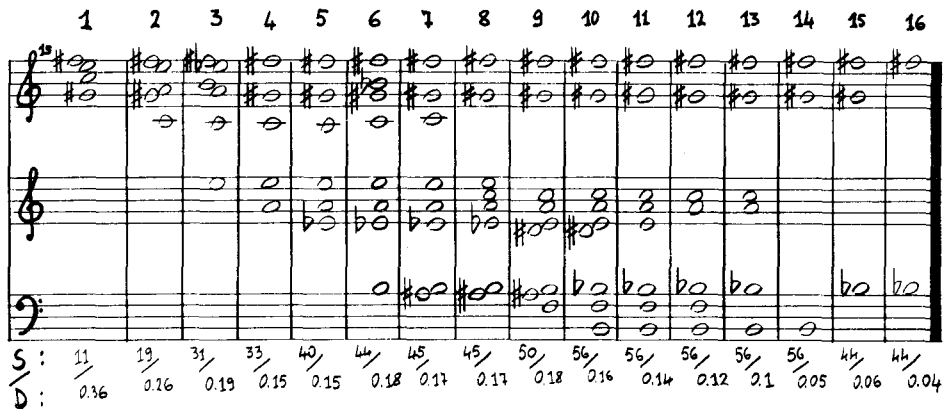


Figure 5 Modulation of Surface and Density along the pitch dimension of *Contrasti*'s "B" OIM of Fig. 13 (S = surface, in semitones; D = density).

Control of acoustic behavior

"Acoustic behavior" refers to a special attitude towards both the surface and the deep sound structure per se of OIMs, rather than towards the ways they are put together. The musical potential of work on sound structures is unlimited. A natural ally is found in the computer, the only instrument with which sound can

be radically explored and composed. Techniques to deal with the acoustic behavior may affect a single note, the most complex color "blob", a sophisticated sound texture, and so on. They are used to isolate parts of sounds, or to splice various pieces together, in both the frequency and time domains. Control of multiple acoustic behaviors is one of the main concerns of all my music.

Figure 6 presents three ways to modify the amplitude envelope of a sound with exclusively pianistic tools: a simple merging of two different touch qualities (staccato and tenuto, Fig. 6a), an attempt to artificially compose an amplitude envelope (dashed line of Fig. 6b), and various combinations of the defocusing technique creating a complex acoustic behavior (Fig. 6c). For the first two examples, both the actual pianistic implementation and the time domain representations are given.

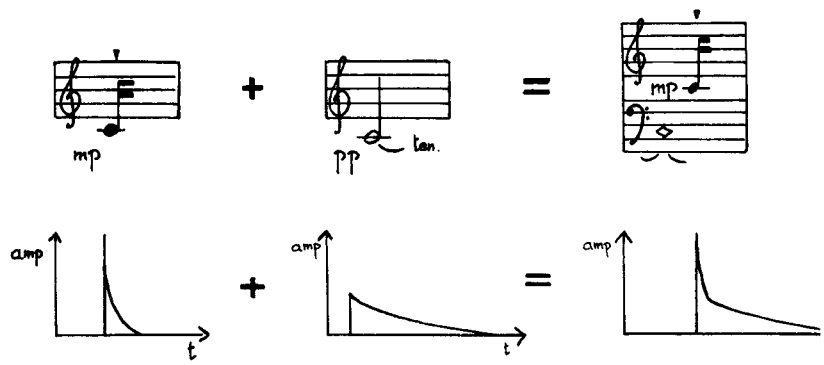
Magnets

Magnets are a source of pure energy which exert an influence on an OIM's property and bend its field. They can seldom be seen in a piece, but their action is easily felt. A straightforward application of a magnetic bias is the driving principle of the last section of *Metabolai* . A magnet sweeps across the amplitude and duration fields of three reference pitch structures (Fig. 7a), from low to high register, at different speeds, deforming the fields' original shape (Fig. 7b-c). In the actual piece, the magnetized structures are interleaved so as to produce three overlapping trajectories.

An example: Dynamic identity

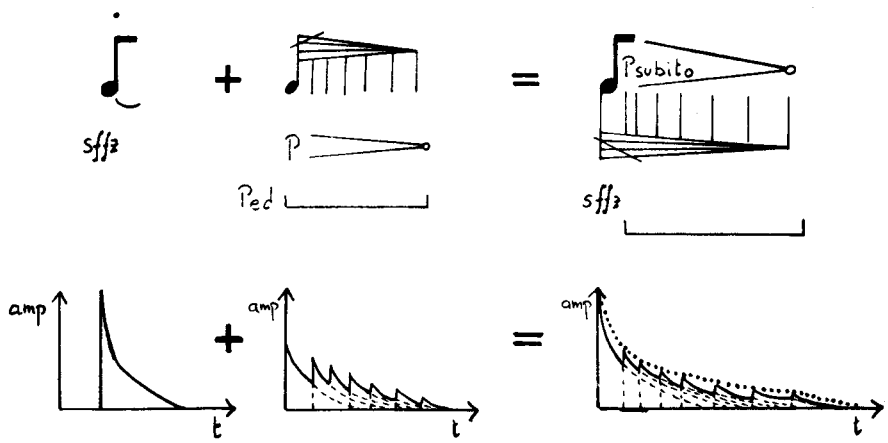
All the writing techniques described so far can freely interact with one another and be mixed with more traditional techniques. So, the items employed for space filling may resort to vectors to accomplish their task, remultiplication with variable anchors can be increasingly blurred by defocusing some of its components with rough patterns, which, in turn, may be derived from tumoral expansions, and so on. A prodigious variety can be achieved starting from relatively few basic tools. What is more important is that, even at this stage, the reality is deeply hierarchical and cannot be explained with a linear approach. The highest levels correspond to the most synthetic expressions of OIMs and are more explicitly related to their perceptual outline. The lowest levels constitute the structural substrate on which OIMs are built, but much harder to perceive.

Combining various techniques, one can modify an OIM's behavior and make it evolve according to certain trajectories. It is the abstraction and understanding of some principles of the way they evolve that yields the dynamic identity of a class of OIMs. Figure 8 shows the 19 instances which form the evolution of our target OIM. Its main principle consists of a progressive reduction of the differences between the identities of the OIM's three parts, until they turn into a kind of minimal inchoate matter. This is a good example of an "organic evolution" in that the sense of direction is clear, but its fine structure contains many local exceptions. The reference pitch contour is detailed in Figure 9.



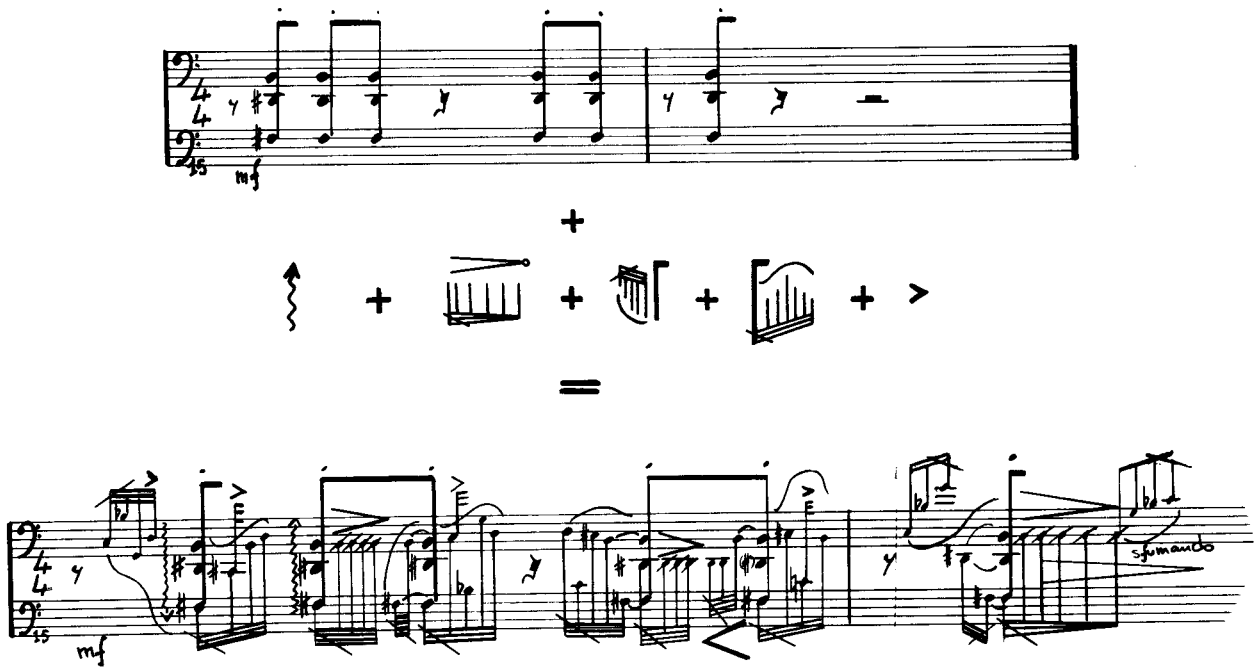
(a)

Figure 6 Control of the Acoustic Behavior: Modification of an Amplitude Envelope. (a) (From *Traiettoria . . . deviata*): the note has the character of a *mp*, dry staccato attack followed by a *pp* resonance (1 = time domain representation; 2 = actual pianistic implementation).



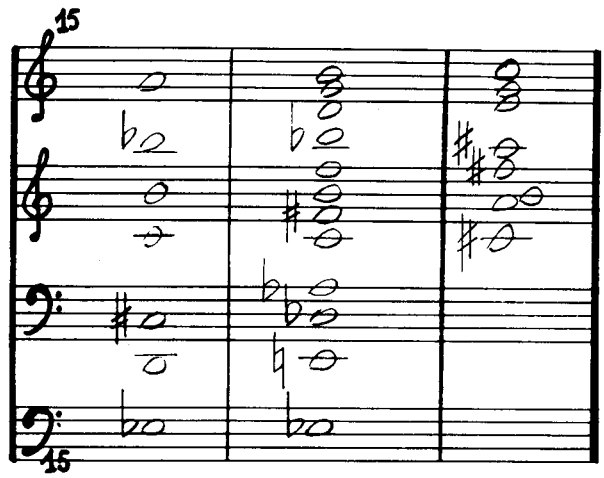
(b)

Figure 6 *Cont'd* (b) (From *Traiettoria . . . deviata*): artificial amplitude envelope (1 = time domain representation; 2 = actual pianistic implementation), built by combining a hard attack with a sequence of soft, rapid repetitions of the same note. The result is the effect of a single note, longer than the first one, with a perceivable amplitude tremolo added to it.



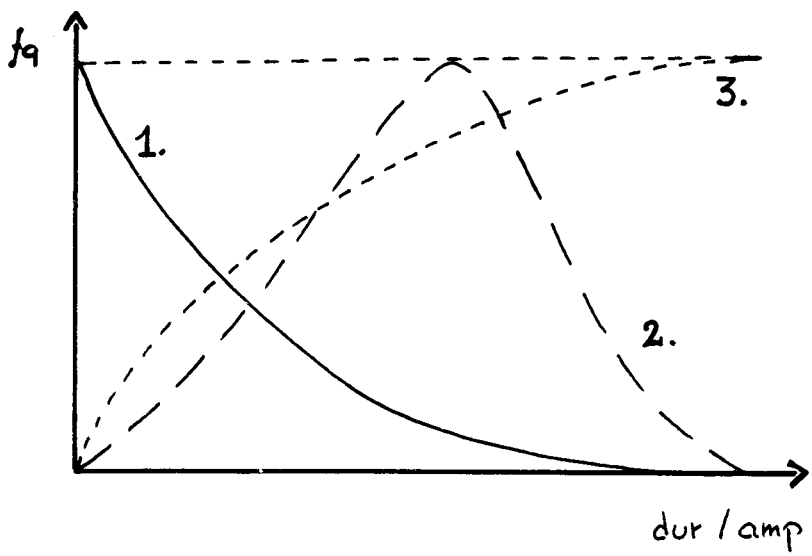
(c)

Figure 6 *Cont'd* (c) (From *Dialoghi*): complex acoustic behavior obtained with combinations of the defocusing technique.



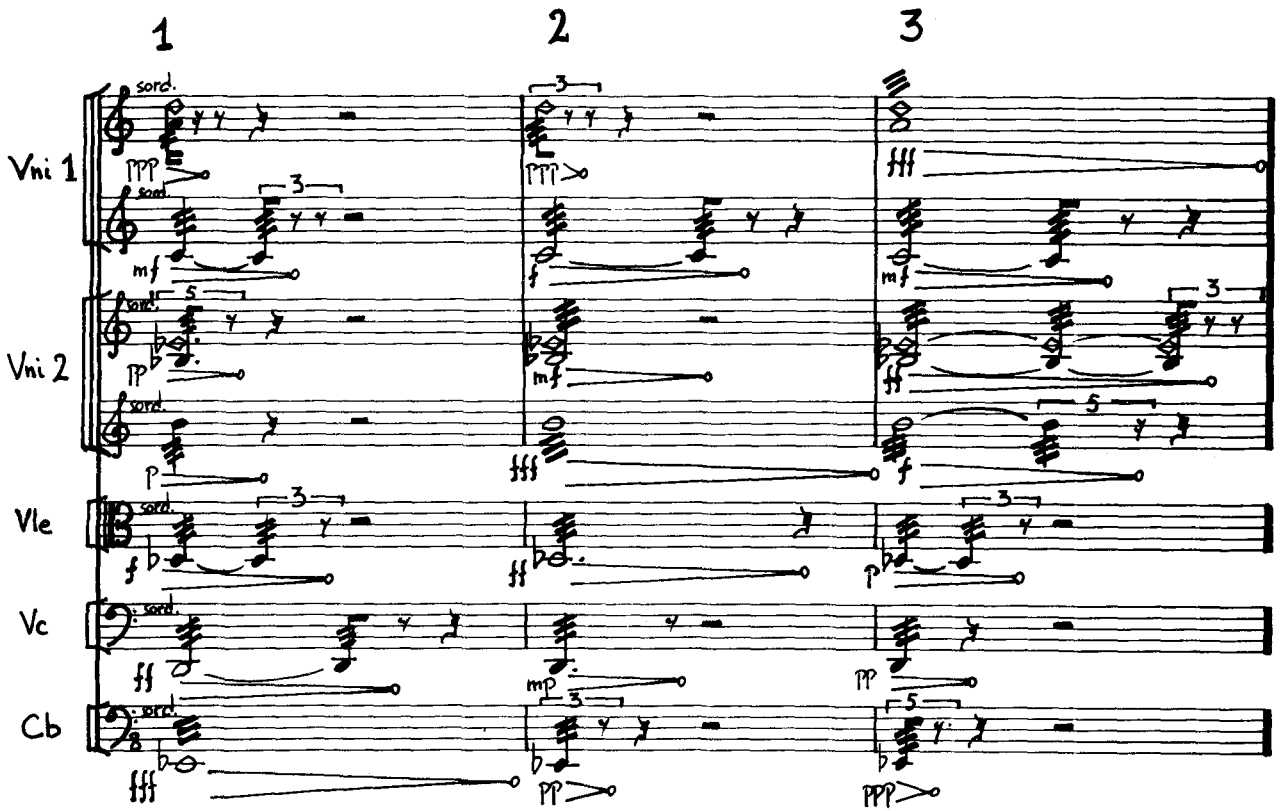
(a)

Figure 7 Magnet affecting the amplitude and duration fields of the last section of *Metabolai*. (a) Reference pitch structures.



(b)

Figure 7 *Cont'd* (b) Magnetic field (1 = initial position, 2 = mid-way position, 3 = final position).



(c)

Figure 7 *Cont'd* (c) Actual writing of the first structure corresponding to the three positions described above. The total durations are all normalized to four quarter-notes.

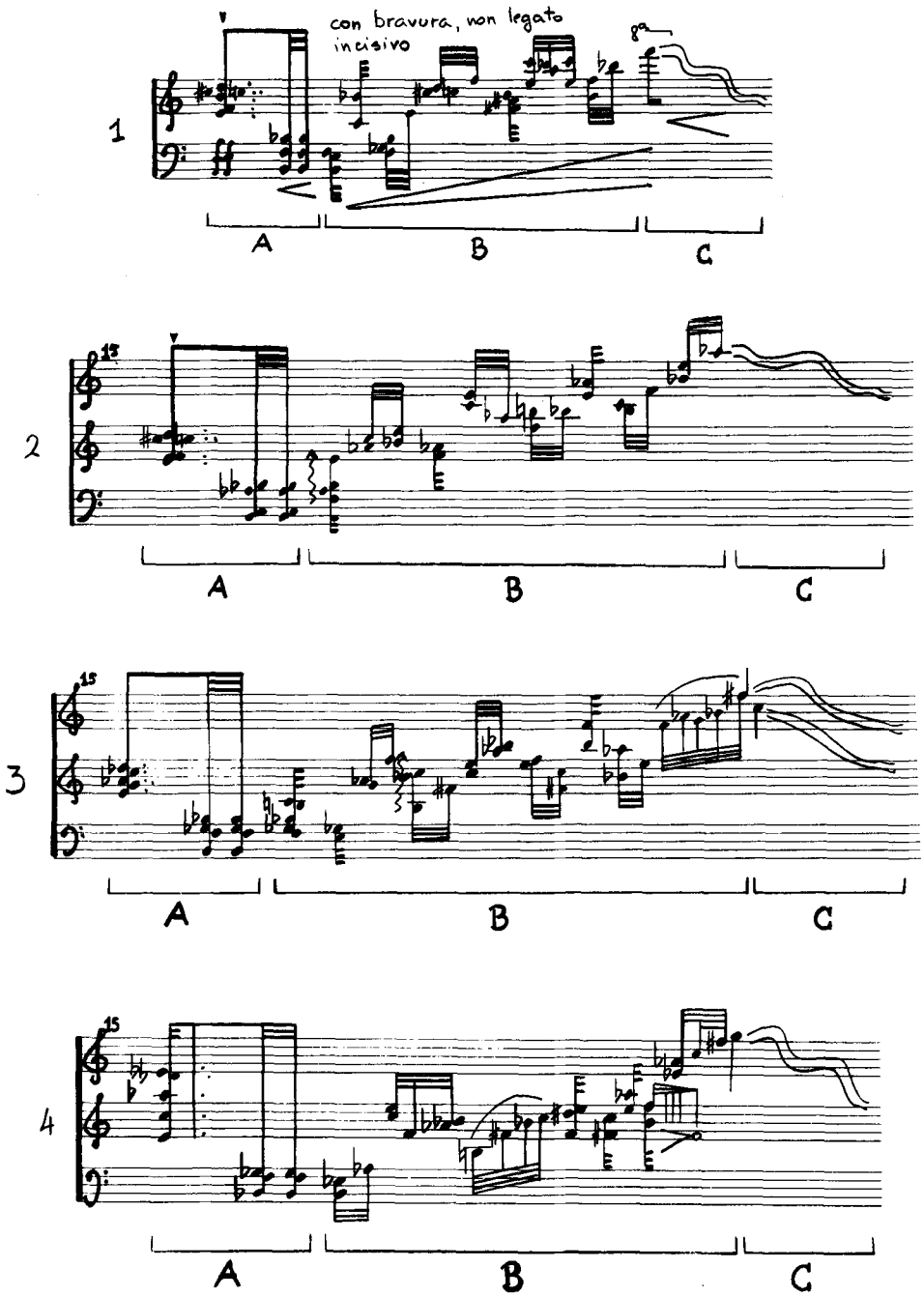


Figure 8 Complete evolution of an OIM from *Contrasti* (RM = remultiplication, DF = defocusing, SF = space filling, SS = space stretching, CAB =control of the acoustic behavior).

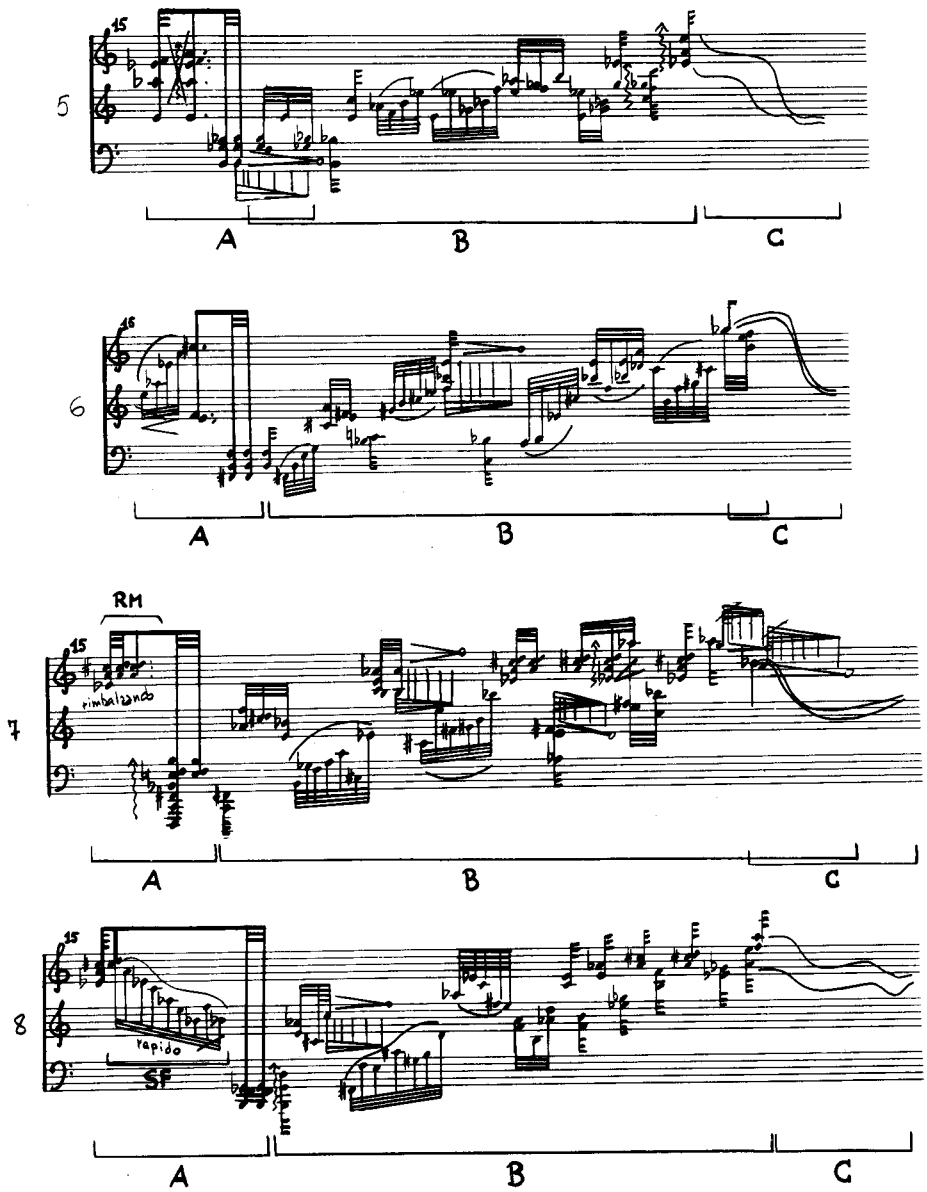
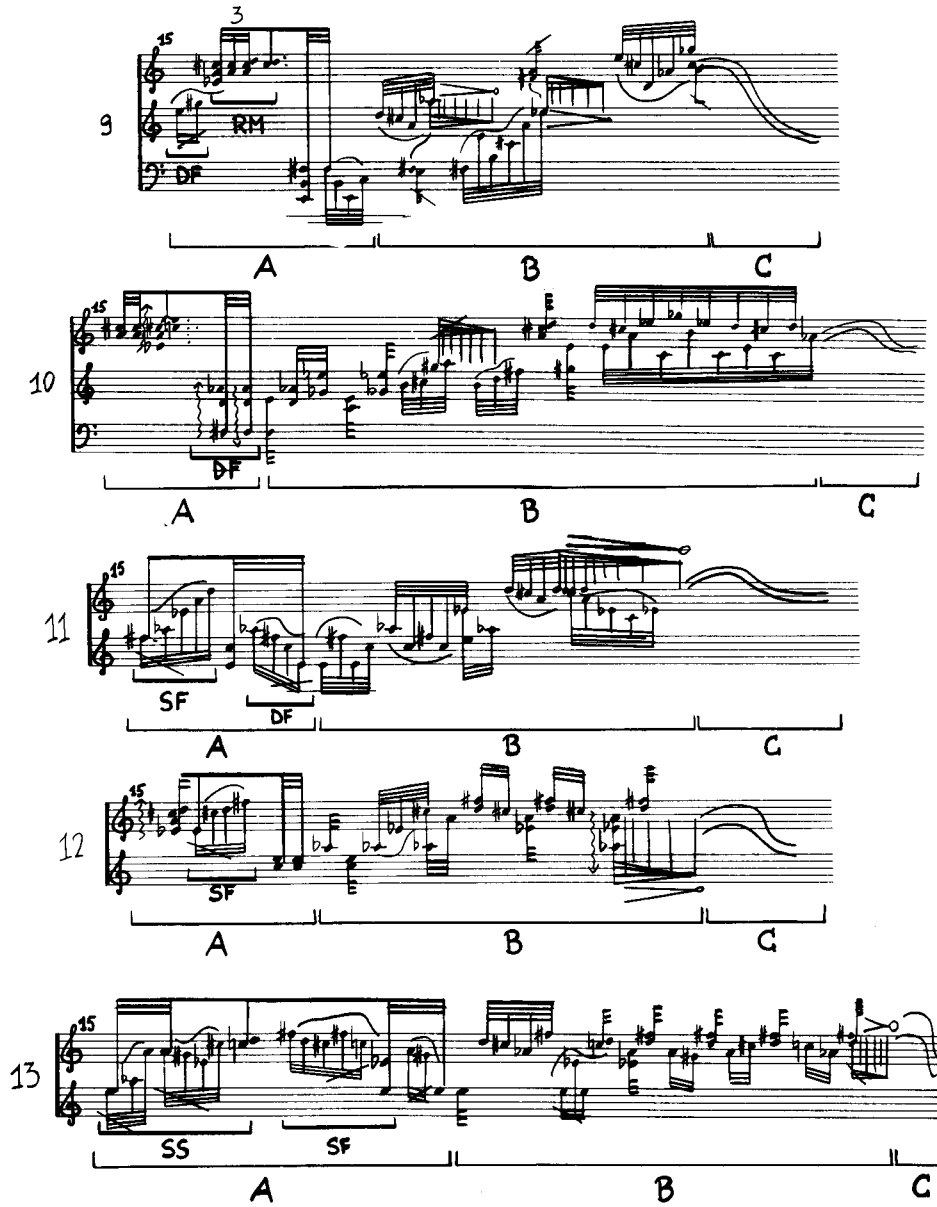


Figure 8 *Cont'd*



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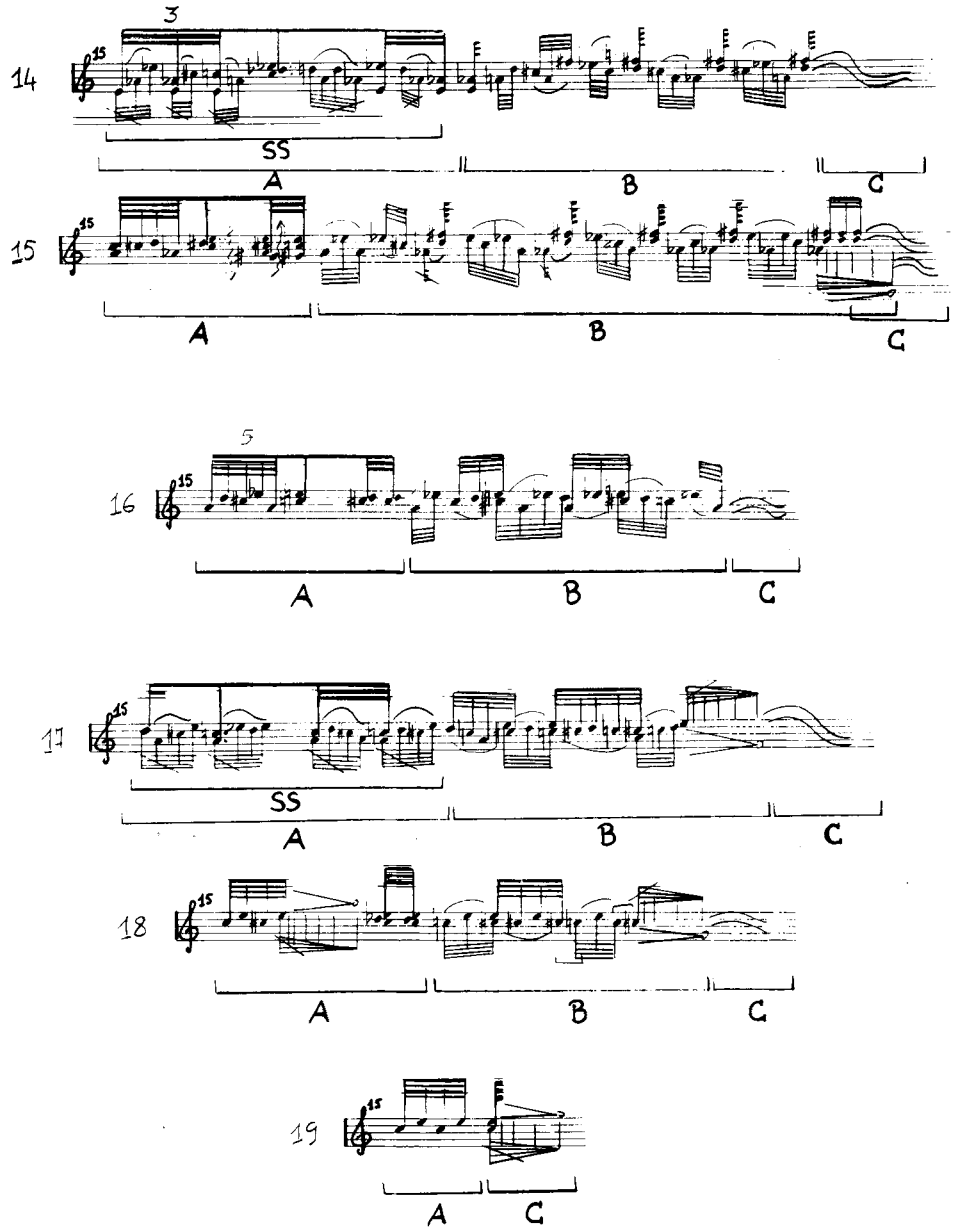

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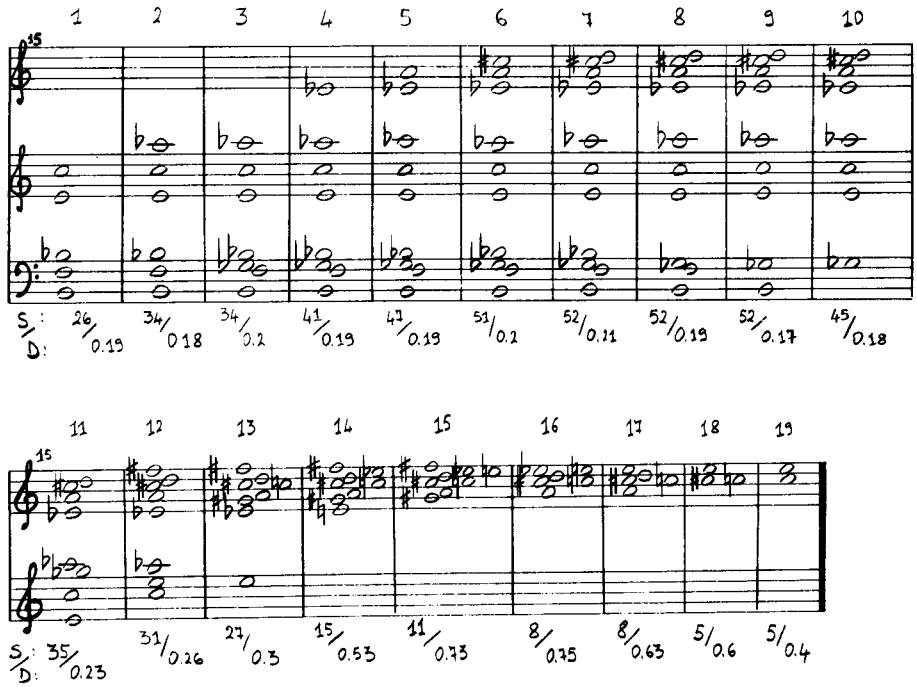


Figure 9 Structural pitch contour for the evolution of Fig. 8 (S = surface, in semitones; D = density).

The Society of OIMs

Social Constraints

A whole piece, or a large section, can be thought of as a *society*, where a group of OIMs interact and evolve according to certain *common laws* which affect their macroscopic characteristics and some microworld features. Although there are no limits on the definition, it is convenient to make a distinction between *arbitrary* laws, under the composer's complete poetic responsibility, and *compulsory* laws which are inevitable and used as a protection against those instrumentally impractical solutions which may arise when some OIMs are combined. It is only at this level that joints and other context-dependent elements, as well as an OIM's *life-span* (the interval between its first and last appearance in the structure), *speed*, and *regularity* of evolution will be defined. The form of a piece is therefore related to its *sociology*, i.e. to the study of the changes that affect a *community* of OIMs. The place where such a community evolves is the morphological space.

At this macroscopic level, an OIM's inner details are no longer important. It is only the interactions between different active OIMs sharing the same space which are to be taken into account. New problems arise; adequate writing techniques must be invented. I will distinguish between *local* and *global* techniques. The

former deal with a very limited number of OIMs; the latter are chiefly concerned with larger musical segments and are directly responsible for major structural changes.

Some Local Writing Techniques

Unbiased coexistence
This is the only neutral technique and the easiest and least disruptive way to link OIMs together. OIMs which are simultaneously active maintain their own independent life and place and simply ignore each other.

Adapted coexistence
This term succinctly summarizes various techniques which modify an OIM so as to fit it into the context. Adaptation may either be the result of an arbitrary compositional choice, or be forced by undesired or "illegal" results.

Among the procedures which are involved I will include:
- *spatial* or *temporal shifting*, like horizontal/vertical juxtaposition, fragmentation, stretching, shortening, etc.
- *local changes* of varying importance
- *register relocation* from a single pitch to a whole OIM.

During adapted coexistence, the OIMs usually maintain their own identity, in spite of a few modifications, even though their simultaneous presence tends to favor the establishment of local perceptual *bonds* between some of them. The balance of identities will be affected and new illusory ones will arise as a consequence. In addition, an OIM may be subject to transformations so drastic that it looses its identity completely, while others will tend to predominate and to attract weak OIMs within their own field. New hybrid structures emerge as a result.

In such cases, the following are among the most frequently employed techniques:
- *deletion:* a weak OIM is purely and simply scratched away. It is a quick, if not very elegant, solution to the problem.
- *parasitical reduction:* a weak OIM is turned into a *parasite* of a dominating one. Parasites are full-grown OIMs which cannot live on their own and are bound to stay attached to other OIMs in order to survive. Because of the necessity to adapt themselves to a preexisting context, they are often made of flexible materials similar to those used in joints. With respect, to their *target*, parasites can be *selective* (live only on certain OIMs and neglect the others) or *unselective* (able to plug themselves into whichever OIM is available at a given moment). Their *use* is exclusively under the composer's control who can literally *infest* a piece with a parasitical *epidemic!* With respect to their *effect*, they can be *benign* (do not substantially modify the OIM they live on) or *malignant* (modify it in an irreversible manner). *Viruses* are a good example of deadly parasites.[6] With respect to their *range of activity* parasitical reductions can be *local* or *global*. Figure 10 presents a benign, unselective, local reduction which could not have been avoided, since the dominating OIM calls for the pianist to use both hands. The head of the reduced OIM manages to keep its own identity, but the second half is completely splintered.
- *satellite reduction:* when a weak OIM becomes a satellite, it looses both its autonomy and its identity and is degraded to the role of a component of the

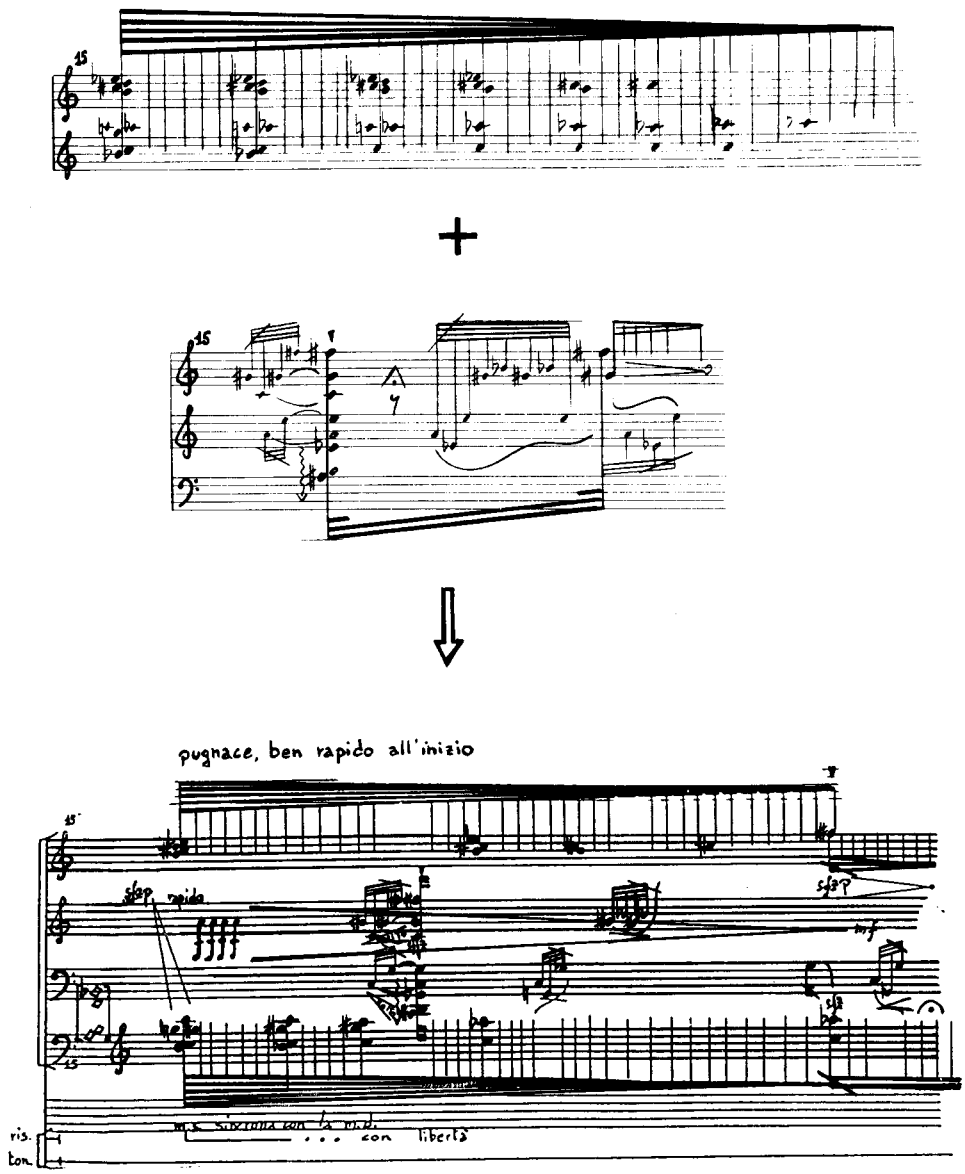


Figure 10 Adapted Coexistence (from *Contrasti*,© G. Ricordi and Co., Milan; reproduced with permission): parasitical reduction of OIMs C4 and B7 of Fig. 13.

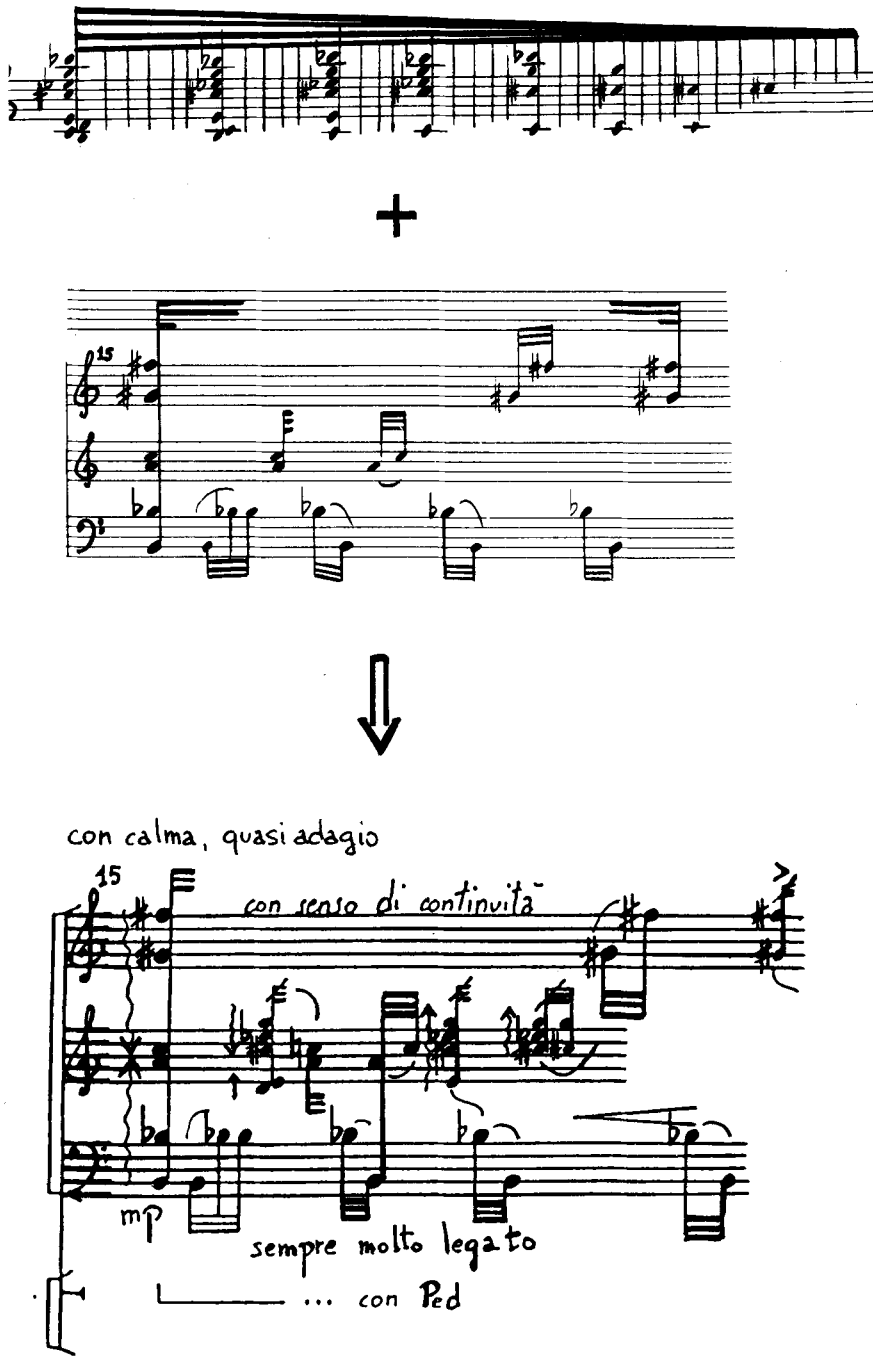


Figure 11 Adapted Coexistence (from *Contrasti*,© G. Ricordi and Co., Milan; reproduced with permission): satellite reduction of OIMs C13 and B14 of Fig. 13.

predominating OIM. This case is shown in Figure 11. Since satellite reductions entail the degeneration of an OIM, there is a qualitive leap from one level to another, whereas parasitical reductions maintain all the OIMs' identities, even if one is actually living on the other.

Some Global Writing Techniques

Magnets

Magnets are the only processes that can be found at any point within a musical structure. Depending on their intrinsic power, they operate on either simple musical dimensions, or on more elaborated structures, such as OIMs' properties or OIMs themselves. An example of their use is found during the first five minutes of *Dialoghi*. The magnet exerts a centripetal force in the pitch domain towards the absolute pitches C and E. At the beginning its energy is weak and therefore not very effective: the registers are variable and one of the notes is sometimes missing. It then becomes increasingly stronger, until the whole musical context has been obliged to comply with it and to take the form of a fast tremolo pianissimo.

Enzymes

A musical enzyme is a concrete entity with its own life-span – and not just a pure source of energy – which catalyzes some formal changes. Its structure is extremely varied: it can be derived from ongoing material or be completely new; it may change over time and even be endowed with a built-in regulatory mechanism which will automatically monitor its action and stop it when it is completed. Enzymes may remain *inert* for a long time and then suddenly wake up in response to some signal.

Figure 12 presents the pitch contents of the nine instances of the only enzyme of *Traiettoria*. It is a predominantly melodic structure which spirals around middle C at increasing speed and sweeps all the registers of the instrument. It catalyzes the transition between the two parts which form the starting section of *Dialoghi* by occupying the space used by the musical structures which had settled in from the beginning of the piece [7] (see also Fig. 14c-d).

Distribution functions

A distribution function is a two-dimensional graph whose x-coordinate is time and whose y-coordinate is the repetition rate of a class of OIMs: the higher the y-value, the shorter the interval between two adjacent instances of an OIM. This is the simplest technique which is actively concerned with the creation of large formal sections; when many functions are simultaneously active, the overall form emerges from their dialectical relationships. In spite of their straightforward definition, distribution functions can generate a virtually infinite amount of different forms, depending on their profile, envelope, life-span and maximum value.

The piano cadenza in *Contrasti* is entirely governed by eight distribution functions whose round shape mostly recalls the effect of a filter (Fig.13). When it exists, the peak region of each function lies at different places and corresponds to a moment of maximum density of a certain OIM, which will therefore tend to predominate over its neighbors. This specific choice produces a kind of overtly round form, with extremely bevelled angles.

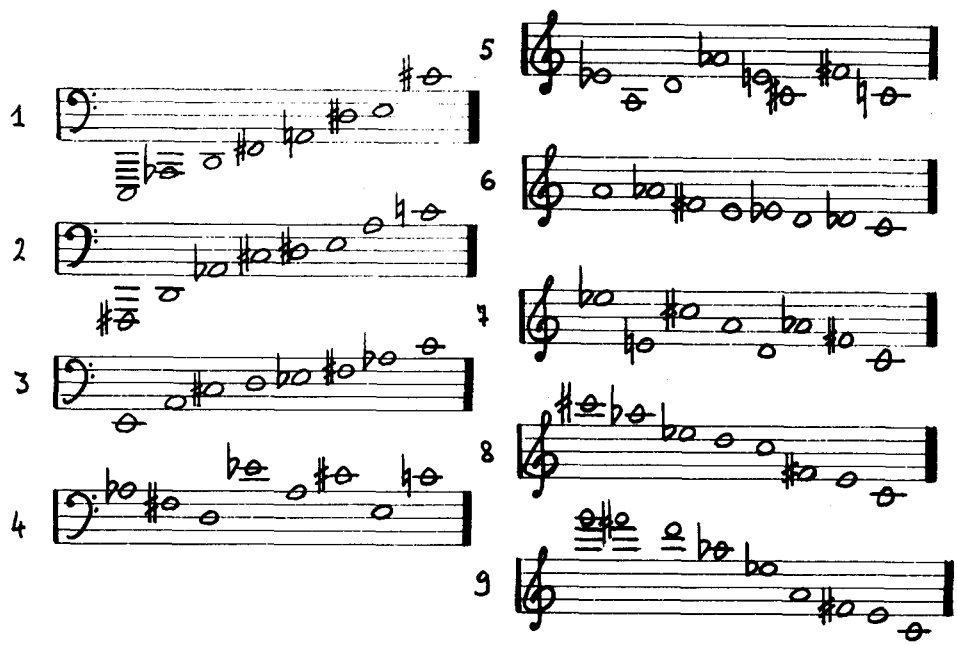


Figure 12 Musical Enzyme from *Dialoghi*: pitch structure.

Structural molds

Structural molds generate new forms in ways which are more refined than distribution functions, in that the structure of the materials making up a given piece is also taken into consideration. Quite often, it is the rhythmico-temporal structure which is processed and mapped onto the formal space: each component of the rhythm becomes an articulation point of the form. The mapping process may end up being completely incorporated into the existing context or artificially imposed on it. The formal articulation points may be used to control the inner temporal structure of an OIM, to trigger a new OIM, or even to give the starting signal to an entire sequence.

The whole form of *Dialoghi* is regulated by a single structural mold derived from some elementary cells which are found in the two rectangular frames at the end of *Traiettoria ... deviata* (Fig. 14a). The superposition of seven different rhythmic layers generates the reference mold of Figure 14b which is used from the time 1:40. Figure 14 c-d, on the other hand, is an example of the close interaction between the mold and the various musical structures which are present at that time. Later on in the piece the mold is slowed down by a factor of two or four and is used less strictly to trigger progressively longer compositional structures.

Advanced issues

The purpose of this final section is to skim over some plausible extensions and

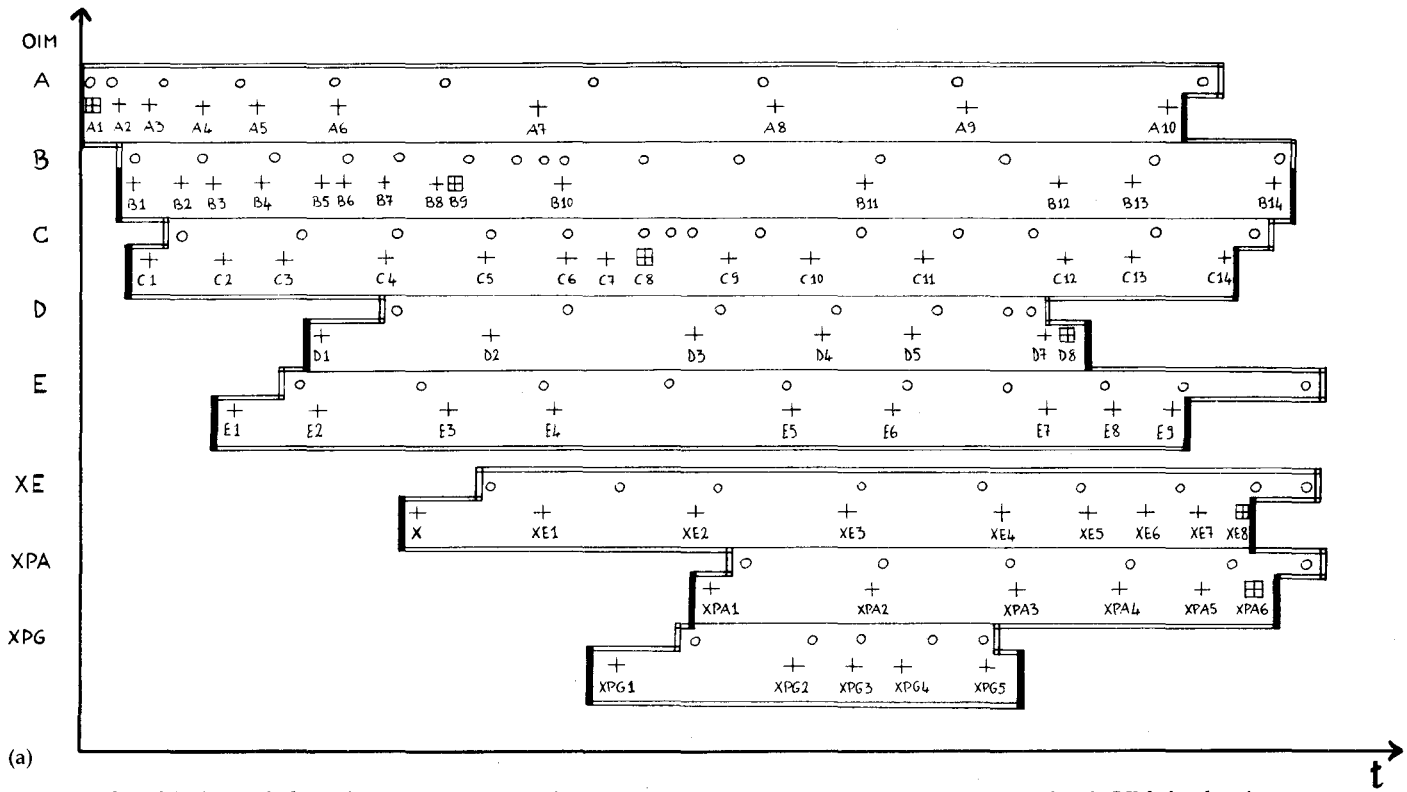
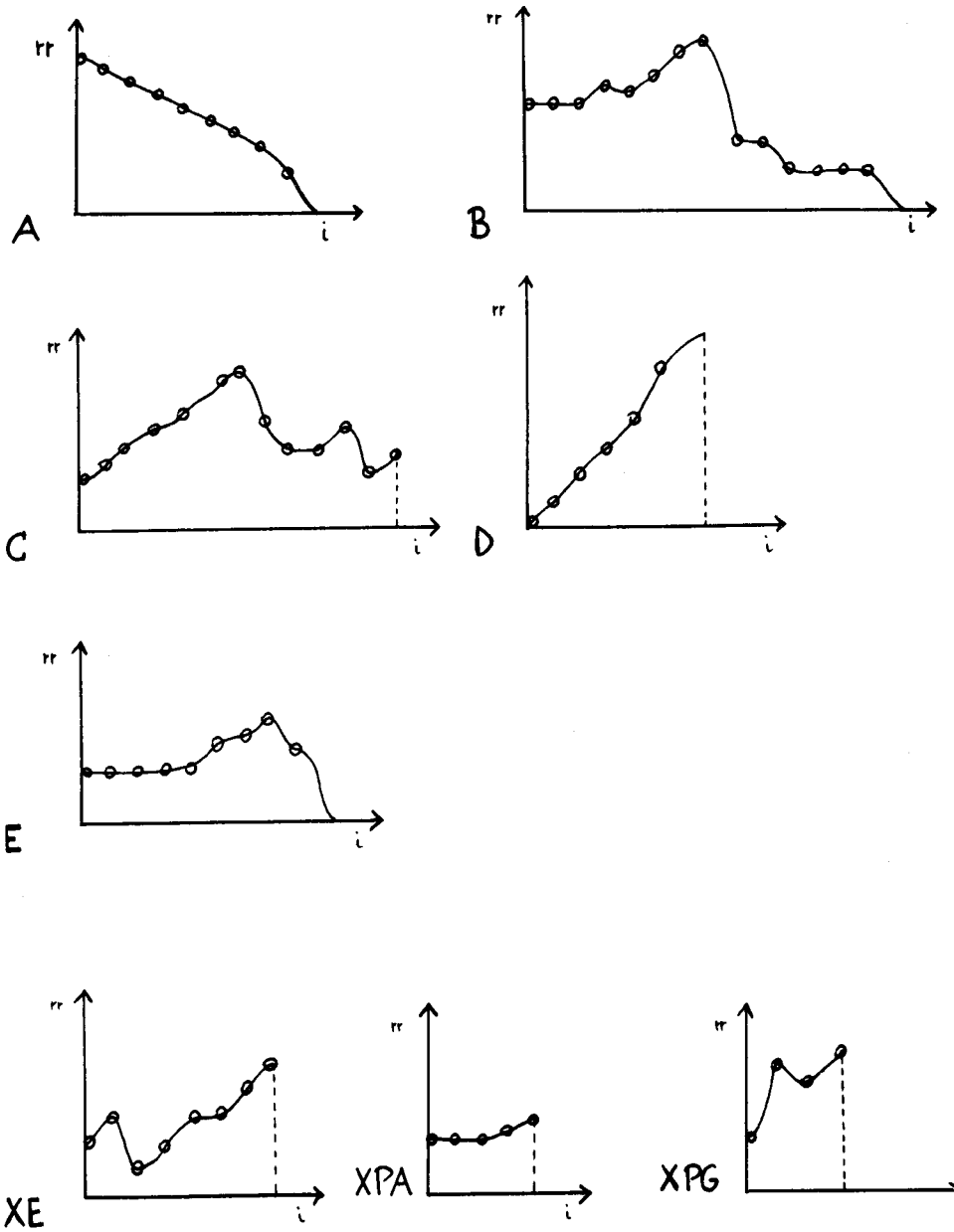
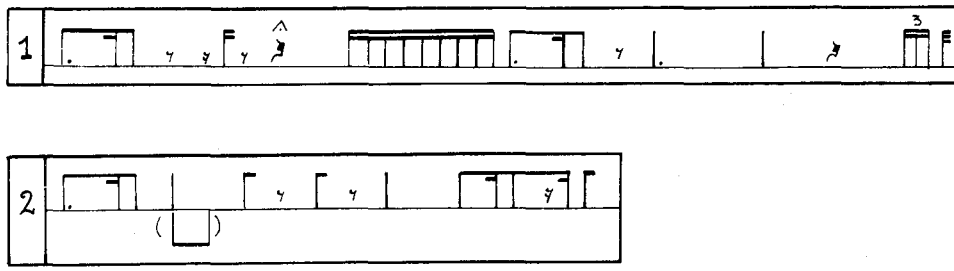


Figure 13 Simplified Morphological Time-Space, reduced to just one dimension representing the start time of each OIM, for the piano cadenza of *Contrasti*. (a) x-axis = time, y-axis = OIMs, o = ideal sequence issued from the distribution functions, + = actual sequence after the needed formal adaptations, + in squares = highest-density point, A-B-C-D-E-XE-XPA-XPG = classes of OIMs.



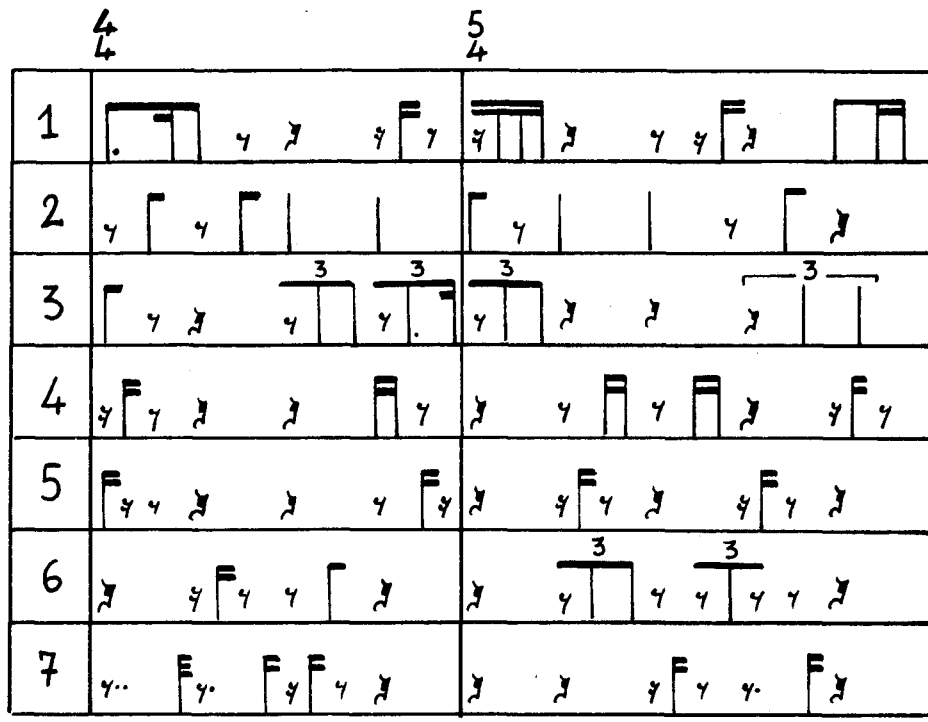
(b)

Figure 13 *Cont'd* (b) Distribution functions for each OIM, i = time interval between two consecutive instances, rr = repetition rate)



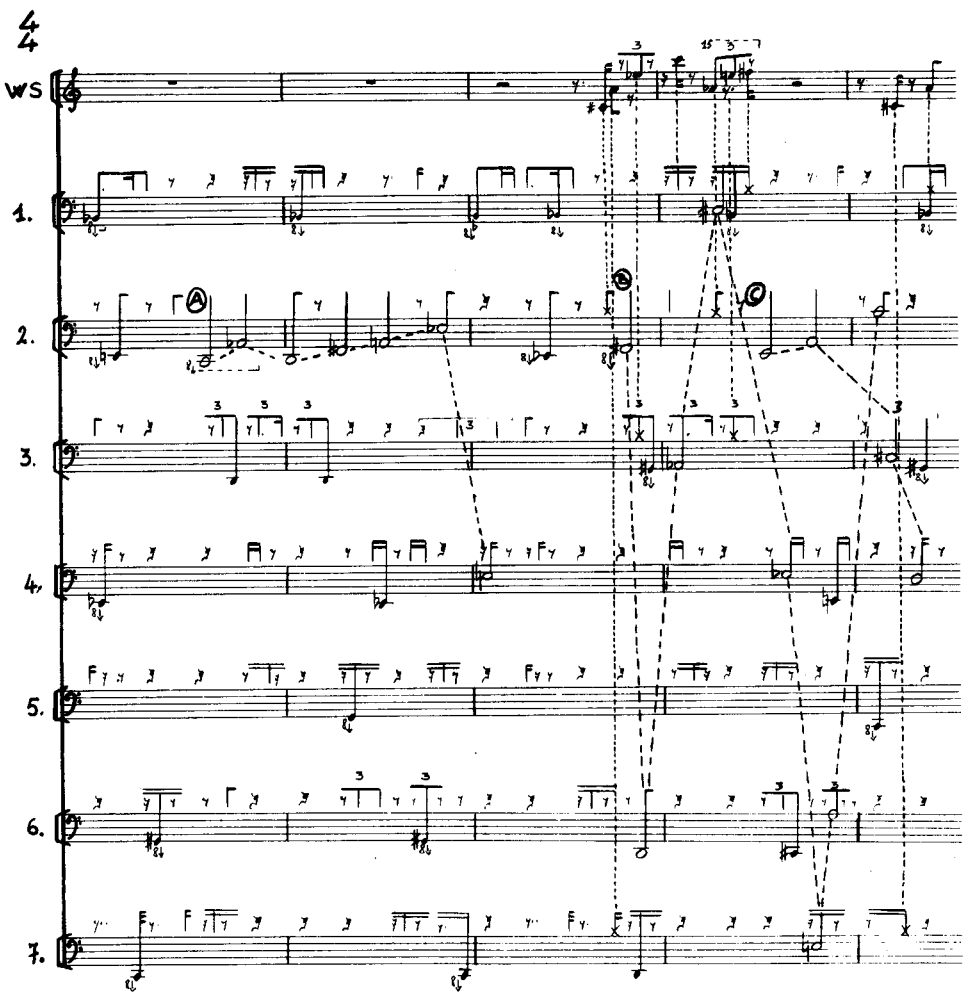
(a)

Figure 14 Structural Mold for *Dialoghi*. (a) Reference rhythmic patterns from *Traiettoria . . . deviata*.



(b)

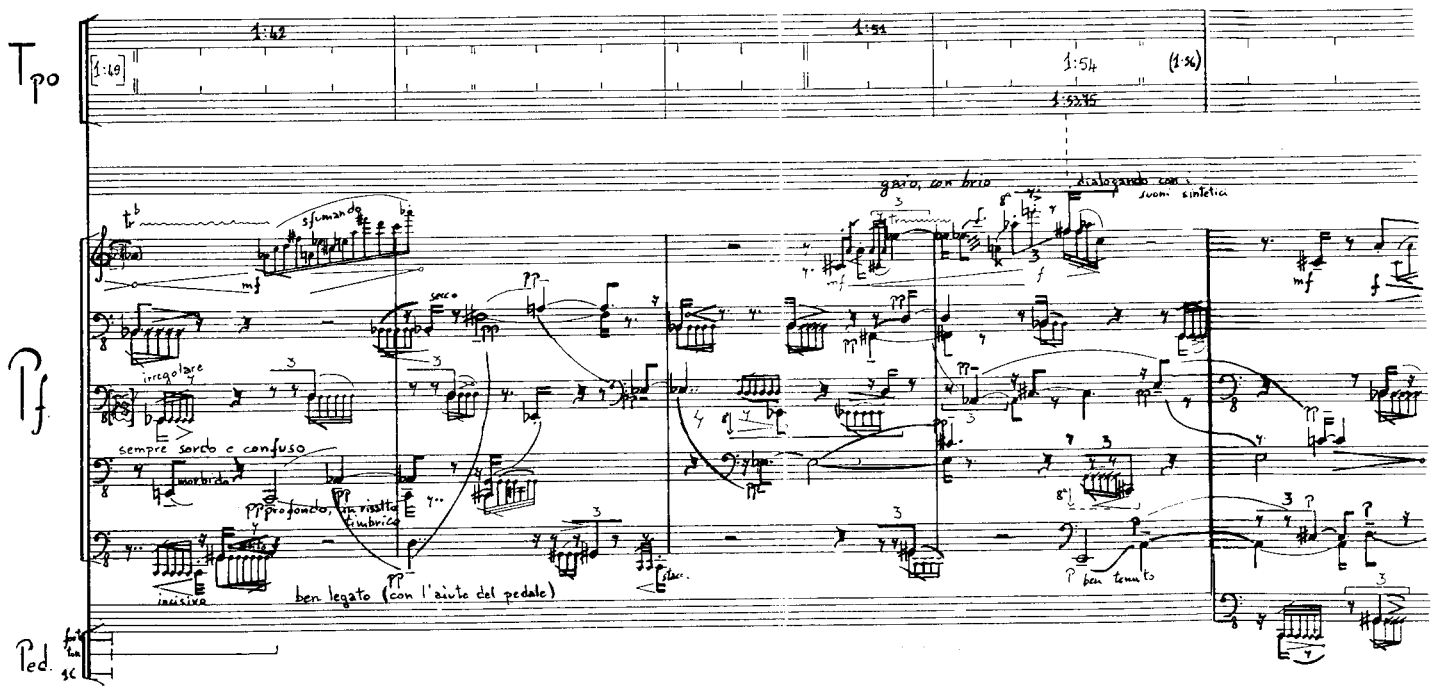
Figure 14 *Cont'd* (b) Structural mold from time 1:40 of *Dialoghi*.



(c)

Figure 14 *Cont'd* (c) Interaction between the mold and various simultaneous musical structures, before the control of acoustic behavior (1 - 7 = low-register rhythmic pedals, A - C = first three instances of the enzyme of Fig. 12, WS = waving structure.

some immediate consequences of an advanced use of the compositional approach I have just put forward. One such extension is to apply it to a hierarchy of OIMs, so as to create the state of *meta-OIM*, a higher-level structure made in turn of lower-level OIMs. Aside from its conceptual interest, such an extension opens up new ways of thinking about form, since a meta-OIM whether it evolves or not, already represents the form of a piece. Microworld writing techniques might then be applied to such a global shape with the same rights as social techniques. An entire piece will result from the behavior of a single meta-OIM. Another extension



(d)

Figure 14 *Cont'd* (d) Final score, © G. Ricordi and Co., Milan, reproduced with permission.

is to use this approach to control single musical dimensions, so as to think of them as rudimentary OIMs. A chord, a sequence of durations, even an absolute pitch do have identities, a timbre – not just traditional timbres, but mainly those fascinating computer-generated sounds which are hard to describe and use – is already a multidimensional OIM.

Perception, analysis and interpretation

Further research in cognitive psychology is needed before one can tell what is really perceivable by ear or by score analysis without clues given by the composer, even though some implicit knowledge about the OIM paradigm might already exist. I am convinced that the metaphor is audible – whether or not this is under the same conditions as those imagined by a composer is not important at this stage – and can therefore be used to parse a complex musical flow. In fact, from this perspective, it is a refinement of McAdams' (1984) auditory images.

The metaphor can also be used as a model to account for some features of other pieces, even if they use different compositional systems. I will demonstrate this in a later text.

Finally, even though it is not always essential that a performer be aware of the compositional structure of a piece in order to interpret it correctly, in the case of OIMs a certain familiarity can hardly be avoided. A different playing and listening attitude, including a performer's very physical movements, has to be found so as to respect an OIM's correct structure and interactions. A good performance can do wonders for perception, and although the remark is true for any real intepretation, it is especially valid in this case, because the performer is directly involved with all the levels of the system. From my personal experience, I was able to appreciate how important it was that the performers' attention be focused on the salient compositional principles before they were able to find the most appropriate instrumental gestures and play correctly.

I hope that a new species of "organic performers" will be educated and sensitized to the infinite facets of this compositional world!

Acknowledgments

I wish to express my deep gratitude to Deke Dusinberre, Andrew Gerzso, Stephen McAdams and Alvise Vidolin for their valuable remarks and suggestions. Before taking their final form, many of the ideas around OIMs were discussed within the IRCAM "Groupe d'Ecriture", composed of Pierre Boulez, Marc-André Dalbavie, Thierry Lancino and Philippe Manoury, whom I sincerely thank.

Notes

1. A *compositional system* may be considered as a collection of writing techniques operating on certain musical material.
   Musical material is what exists or is dealt with by a composer as such, independently of its use in a given piece. It is extremely varied: simple or complex, concrete or abstract, structured or unstructured, etc. Its definition may or may not need a preexisting compositional system and, with the

exception of the simplest material, is normally bound to the system and the historical context in which it originated and/or which used it. Within the tonal system for instance, the following are examples of possible material: an absolute pitch, an instrument, an interval, a chord, a melodic fragment, a long rhythmic pattern. Any kind of material requires an appropriate representation in order to be operated upon efficiently.

A *writing technique* is a set of useful directions, from vague principles to strict rules, that can be used to give a shape to *(mettre en forme)* the material available within the context of a piece. The generality and the power of extrapolation of a certain technique is inversely proportional to the complexity of both the material per se and the chosen representation. As an example, one might note that a technique as sophisticated as "tonal fugue writing" can only be applied to relatively neutral sound material and would not work if the very sounds were too complex.

The *function* of a compositional system is twofold: it can be used as a knowledge base to *analyze* a piece of music as well as an overall framework to *generate* new music, even though it can only describe standard cases and will never account for the "short circuits" which are probably the most interesting aspect of a composer's activity.

A compositional system is therefore concerned with the poetic side of musical creation, and should not be mistaken for a *compositional model*, a specific embodiment of a certain *theory of composition*, which can, in turn, be used to understand and test compositional systems. So, theories and models of composition are usually built on and account for already existing musical examples, while compositional systems are to be used in a conscious or tacit manner, independently of any theories.

2. There are at least three level of identity: the identity of the component itself (for instance, the identity of a figure such as a trill), the identity of the component as a part of the element (for instance, its place or function in it), and finally the identity of the element itself. One can imagine that any kind of modification would affect all these levels more or less dramatically.
3. It is very important to understand the purely formal meaning attached to the word "organism". It would be wrong and misleading to oppose organic matter to inorganic matter, or to hint at possible affective feelings towards living entities. I am simply trying to convey specific behavior with this word; possible alternatives to "organism" (such as objects, elements, processes, concepts, frames, crystals, etc.) all seemed too static, mechanic or artificial.

   OIMs have nothing to do with Stockhausen's use of "formulas", a mystical attempt to merge the characteristics of classic themes and of integral rows. Formulas contain all the musical parameters, control the development of a whole piece, if not a whole cycle of pieces, do not evolve and are mostly processed with traditional combinatorial techniques. As we will see, none of the ideas supporting formulas can be used when dealing with OIMs.
4. I will use Garner's (1978) distinction between components and properties and their further subdivisions. The main keywords of my compositional system are italicized the first time they appear.
5. This double perspective may seem puzzling at first: why not using a single, comprehensive representation? In fact, I purposefully forced a separation between the two levels of material and form so as to exploit their dialectical potentialities. This separation is also called for by my using multidimensional materials and complex forms.
6. A "malignant viral epidemic" is the principal cause of change between the first and the last section of *Metabolai*. Both sections are made of the same rhythmical and pitch structures, but the last one is "sick": it proceeds much more slowly and is continuously shaken by the parasite whose main symptoms are the tremolos, the use of mutes, the bow on the bridge and the presence of the magnet which was analyzed in the previous section (Fig. 7).

   An evident case of a "benign epidemic", on the other hand, can be observed in *Contrasti*. Here,the parasite is a trill, a continuous source of motion. At first, it infests the pianistic introduction unselectively; during the piano cadenza it becomes selective and attacks only one family of OIMs (those whose label starts with X in Fig. 13); finally it again infests all but one OIM and is eventually fought off by a new percussive OIM in the lower register of the computer sounds.
7. Since the most important structure is a rhythmic pedal in the low register, the enzyme starts from it so as to be more effective. In order of appearance, the other complex structures are: soft notes in the middle-high register using double-escapement, four prominent accents on C-sharp, A, C and A-flat, and the waving pattern shared by piano and computer in the medium and high registers. The fact that the enzyme always converges towards middle C is a sign of the magnet which has previously been described (see also Figs. 12 and 14).

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