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Morphological analysis

A mathematical model to describe the relation between morphological structure of the message, mnemonic–perceptive activities and psychic response.

1. Time and memory

The comprehension and interpretation processes involved during the listening, as well as during all the various perceptive activities, occur in the time through mechanisms linked to the mnemonic faculties.
The storage and retrieval of the information in and from the memory, both temporary and permanent, are variously stimulated during the perceptive act. In this process it is fundamental the sequential order, i.e. the morphological organization of the events succession in the time.
The morphological organization of the events chain has the function to give structure to the time, and it is the memory to enable the comprehension and interpretation processes of such a structure.
In the musical language this structure is particularly complex, as it is the result of the combination of different morphologic organization levels (melodic, rhythmic, timbric, harmonic level etc.), which are strictly interconnected.
This plurality of levels, along with their articulated connection, is the basis of the development of different listening competencies: from the most natural and spontaneous one (where a synthetic perception of the event prevails) to the most experienced one (where the distinction among the various organization levels allows to assign them weights and functions).

The main aim of this work is to simulate, through the algorithmic formalization, the behaviours of the mnemonic activity during the reception act of the single information units (which can be, depending on the adopted analysis level, simple or complex units) and to obtain indications about the psychic energy used in the reception and elaboration of the message. In brief, the purpose is to study the relation between morphologic organization, perception and psychic response.

The musical examples quoted in this article refer, to ensure a clear and linear exposition, to the morphologic organization of the pitches sequences (even if, as you will see, the implications are transversal to every music parameter). It is implicit that the deepening of the assumptions we propose implies the development of a methodology able to contextualize the analysis of the morphologic structures of the different parameters. Anyway, the stylistic and linguistic features of the pieces analysed will suggest a hierarchical relation among the music parameters, i.e. the prominence now of a certain parameter, then of another one.

2. Analysis of the contrasts

Analysis of the becoming of the form in the time

The *Analysis of the Contrasts*, formulated by Hervé Riviére and Frederic Voisin[1], and implemented in the *OpenMusic Morphologie Library*, is a model able to describe the becoming of the form in the time. It points out the hierarchic relation created by the temporal sequence of the events: in fact, for the mnemonic activity, each event is datum point for every following event and datum point for the previous ones. The numerical transcription carried out through the *Analysis of Contrasts* describes the entry order of the events in the time. The example 1 shows the analysis of a subject of a Bach's fugue, where the whole information is contained in the mere pitches structure. The absence of hierarchies regarding lengths, timbre and dynamics allows to test the validity of the assumptions working only on the level of the pitches.

(Example nr. 1: analysis of the contrasts. J. S. Bach, subject of the *Toccata and Fugue in D minor for organ*).

We could define the numerical transcription[2] created using the analysis of contrasts as *morphological structure of the entry order of the events*. From this starting point it is possible to identify the presence of internal patterns and analyse their potential capacity to describe and re-establish the form in its original status[3].

3. New/Old Analysis

Analysis of the relation between single event and context

The *analysis of contrasts,* which is the function at heart of the *Morphologie Library* developed by Jacopo Baboni Schilingi and Frederic Voisin, identifies the occurrences within any sequence of events[4]. Such analysis is of quantitative type, and has considerable development potentialities towards a qualitative description of the processes that put in relation morphologic structure of the message, mnemonic–perceptive activity and psychic response. The hierarchies

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[1] See the article *L'Analyse musicale contrastive* by Frederic Voisin in this volume.

[2] The result obtained through the analysis of contrasts is a pyramidal matrix (ex. nr. 1). In this kind of matrix, every line, from the first one until the last one, starts from the column, which follows immediately the previous line. This because each element of the list is taken as starting point to determine the entry order of the following elements. The application of the figures is simple: they indicate line by line the entry order of the events (the example nr. 1 shows notes); the correspondence is strictly complied with at every repetition of the same event, so that to each note is attributed the figure which has been applied at the very first entry of the note. For a more detailed description of the analysis of contrasts see *Composition par modèles interactifs, systèmes génératifs et applications informatiques*, DEA - *Diplôme d'Etudes Approfondies*, pp. 53 - 5, Jacopo Baboni Schilingi, IRCAM, 1998.

[3] In general see the *Morphologie Library 3.0* , "Analysis" and "Reconstitute" menus, Paolo Aralla, Jacopo Baboni Schilingi e Frederic Voisin, PRISMA, 2002.

[4] The Structure-I function allows to segment a list of element according to the elements and following the principle of the analysis of contrasts. To this matter see the documentation about the Structure-I function in *Morphologie, fonction d'analyse, de reconnaissance, de classification et de reconstitution de séquences symboliques et numériques*, pp. 22-26, troisième édition, novembre 1999, IRCAM, Paris.

that the analysis of contrasts describes become qualitatively pertinent to the mnemonic activity.
We have called *New/Old Analysis* the function that describes the newness level of an event in relation to the context in which it appears. The importance of such a function is crucial, because it describes from the point of view of the psychic response the different newness level of the single event in the time.
The steps to define *New/Old Analysis* are three:

1. Measurement of the distances: it allows to quantify the local distance between the different events in relation to their first appearance in the time.

(Example nr. 2: application of the derivative function implemented in *OpenMusic* with the name of x->dx – J. S. Bach, subject of the fugue from the *Toccata and Fugue in d minor for organ*).

2. Attribution of different weights to the datum points: this step is crucial, because it strengthens the global hierarchy among the various analysis level in relation to the time parameter.

(Example nr. 3: application of the summation function to all the points of each level of the resulting analysis, implemented in *OpenMusic* with the function *apply+* . J. S. Bach, subject of the Fugue from the *Toccata and Fugue in d minor for organ*).

3. Application of weights to the distances: this further step is just the application of different weights - obtained considering every time one of the events as datum point (global parameter, ex. nr. 3) - to the distances between the various contiguous events (local parameter, ex. nr. 2).

(Example nr. 4: application of the multiplication function, implemented in *OpenMusic* with the symbol *. J. S. Bach, subject of the fugue from the *Toccata and Fugue in d minor for organ*).

A theoretical problem we have faced is the relation between the object we have analysed and the previous and following events. Any events chain perceived as belonging to a whole and complete organism stays anyway in relation with the previous and following sequential chain. In case of performance of a music piece, the silence acts as a frame of the structure, and, being a frame, it becomes organic element of the structure analysed. It is worth to underline that even in case of extrapolation, like in the here quoted examples (a thematic fragment, a subject of a fugue, etc.), the object is perceived as an unit, and therefore the silence places it in a well defined mental space.

(Example nr. 5: frame function of the silence. J. S. Bach, subject of the fugue from the *Toccata and Fugue in d minor for organ*).

On this new structure the analysis of contrasts of the example nr.1 and the analysis of distances of the examples nrs. 2, 3 and 4 applies.
The last step is to put in relation the different analysis levels. So, we obtain a values profile that defines for each event, in relation to the general context, the degree of more or lesser newness.

(Example 6: *New/Old Analysis* function implemented in *Morphologie 3.0* of *OpenMusic*.. J. S. Bach, incipit of the subject of the fugue from the *Toccata and Fugue in d minor for organ*).

The following example shows the application of the *New/Old Analysis* function to the whole Bach's subject. From a musical point of view, the first consideration that we can make is the extremely dynamic description of the ageing degree of the "A" pedal. Anything but static, this note reaches the saturation climax immediately after the last important entry in terms of newness, the "h", then it recovers freshness in the final tract of the subject.

(Example nr. 7: application of the *New/Old Analysis* function to the subject of the Fugue from the *Toccata and Fugue in d minor for organ* by J. S. Bach).

4. Extreme cases to test the *New/Old Analysis* function

The example nr. 8 refers to an extreme case, used to test the algorithmic simulation. The 14 elements forming the sequence (a b c d e f g h i l m n o p) don't show repetitions (in any linguistic reality this is extremely unlikely, even if there is to reflect upon the assumption that the expressions of most abstract and structuralistic kind - where the ever variable combination possibilities of the different parameters produces complex objects that are steadily different – are just of this type). The function *New/Old Analysis* applied to this extreme typology reveals an important fact, i.e. the progressive reduction (from infinite to zero) of the local newness degree of the events during their appearance. Although the events are ever-new, their newness degree tends to flatten, and therefore the context makes the absence of repetitions predictable. At this point, it is possible to pass from a description of the newness level of the events to the simulation of the psychic response.

(Example nr. 8: *New/Old Analysis* function applied to a sequence without repetitions).

5. Energy profile

Analysis of the energy of the morphologic structure

The step that allows to transform the *New/Old Analysis* function into a model able to simulate the psychic response of the perceptive act to the morphologic structure occurs using three functions. In the example nr. 9 we can see the *New/Old Analysis* of a short melodic fragment (with the clarification of the

morphologic frame – (X) a b c b a (Y). Then, to this the three functions apply allowing to define the energy profile[5].
1. In the first passage, the transformation into absolute abs value contains all the relations with reference to the first element of the chain. At this point, the data don't represent the ageing degree of the events anymore, but they are mere distance (it doesn't matter if they are old or new, they are to be intended nearly as physical distance between the various data stored in space/memory) related to a virtual point zero (a kind of possible present);
2. In the second passage, the use of the local derivative, implemented in *OpenMusic* under the name of x-->dx, the contiguous relations are again pointed out, and the distance identified in the first passage is assimilated to the energy needed to cover the contiguous distances in the space/memory;
3 - Finally, the transformation into absolute abs value, because of the transformation of the distances into energy, brings all the data back to positive values.

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[5] We have decided to use the word "energy" instead of "information" to distinguish between the energy profile function and the one we have called bit "information analysis". The latter describes the quantity of binary information contained in a message (see the library of *Morphologie 3.0*, menus "Morphological analysys", Paolo Aralla, Jacopo Baboni Schilingi e Frederic Voisin, PRISMA, 2002.) The Energy-profile function doesn't describe the quantity of information, but the routes, i.e. the virtual distances that the interpretation activity have to carry out to compare the new entrying events to the ones previously stored.
The Bit-information-analysis describes the quantity of binary choices a certain datum imposes at the moment of decoding. It takes a method developed by Shannon and Weaver [*The Mathematical Theory of Communication*, University of Illinois Press, 1949].
The formula that the Bit-information-analysis function uses is: H = log2N/P.
H is the bit information number, N is the number of possible conclusions, P is the probability a certain conclusion happens. In the sequence '(a a a a b) 'a is more likely to occur than 'b, and right because of that, it has less information to transmit when it appears, on the contrary a very unlikely conclusion is high informative.

Example of sequence with same probability of conclusions '(a b c d e f g h):

- the sequence '(a) imposes a 0.0 number of binary choices;
- the sequence '(a b) imposes a 1.0 number of binary choice;
- the sequence '(a b c) imposes a number of 1585 binary choices and so on.

Sequence	a	B	c	d	e	f	g	h
Binary choices	0.0	1.0	1.58	2.0	2.32	2.58	2.80	3.0

Example of choice with different probabilities of conclusions '(a b b c d a f b):

- the sequence '(a) imposes a 0.0 number of binary choices;
- the sequence '(a b) imposes a 1.0 number of binary choice;
- the sequence '(a b b) imposes a 0.58 number of of binary choice and so on.

Sequence	a	B	b	c	d	a	f	b
Binary choices	0.0	1.0	0.58	1.32	1.80	1.58	2.0	1.93

(Example nr. 9: from the *New/Old-Analysis* function to the *Energy-profile* function).

Let's go back to the extreme case of sequence without repetitions, to see the specular relation between the progressive lowering of the newness degree of the events and the psychic energy fall, which corresponds to the progressive, high predictability degree of the structure[6].

(Example nr. 10 - The *New/Old-Analysis* and the *Energy-profile* functions applied to a sequence without repetitions).

A second extreme case is given by the constant repetition of the same event: the newness degree (New/Old-Analysis), starting from the second event, becomes zero, and the energy profile of the morphologic structure (*Energy-profile*), which is a relation datum, becomes also zero from the first repetition of relation on.

(Example nr. 12: the *New/Old-Analysis* and *Energy-profile* functions applied only to a sequence of repetitions).

If we finally complete the analysis of the Bach's subject using the *New/Old-Analysis* and *Energy-profile* functions, we can enlarge our observations of musical character. In a specular way to the dynamism of the newness level of the "A" pedal (*New/Old-Analysis*), it is interesting to note how the energy peak of the morphologic structure (*Energy-profile*) is situated on the climax note of the low register, and how the general energy curve progressively tends to find a kind of rest at the conclusion of the subject.
It is important to remind that the data processed by the algorythm don't have anything to do with relations of melodic nature, or concerning intervals, or with observations about harmony, but they refer only to the sequential positions of the "pitch" events.

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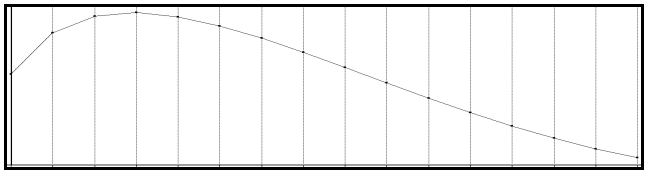
[6] In some tests on the sequence without repetitions we let interact the Energy-profile function with the Bit-information-analysis obtaining a very interesting curve from the point of view of the simulation of the psychic response:
Sequence '(a b c d e f g h i l m n o p q t)



As we can note after a first phase of increase of the curve, as soon as the sequence becomes predictable, the values decreases progressively. This kind of implementation, which is to find as sub-menu of the *Bit-information analysis* function, opens new development perspectives regarding the morphological analysis algorythms, because it allows to assess parallelly the quantitive aspects, which are linked to the statistic nature of the message analysed, and the qualitative aspects, linked to the fruition of the message in the time, as the message is object of the mnemonic activities.

(Example nr. 12: application of the *New/Old-Analysis* and *Energy-profile* functions to the subject of the fugue from the *Toccata and Fugue in d minor for organ* by J. S. Bach).

The following analysis, carried out on the Bach's subject deprived of the pedal note, points out the local function of the "A" pedal. It is interesting to note that there is coherence between the two analysis (the one with pedal note and the other one without). They represent two different focusings of the musical object analysed. Even in this case, the energy climax of the morphologic structure is on the "low A" (*Energy-profile*), but it is possible to note how it becomes the highest point of newness of the sequence (*New/Old-Analysis*). The comparison of the two analysis clearly shows that the A pedal function is to internally articulate the thematic subject characterizing the energy profile, see for instance the incipit.

(Example nr. 13: application of the *New/Old-Analysis* and *Energy-profile* functions to the subject of the fugue from the *Toccata and Fugue in d minor for organ* by J. S. Bach, without A-pedal.)

Again an example from J. S. Bach: the subject of the *Fugue in e minor* from the first book of the *Well-tempered Clavier*. Here, unlike the fugue in d minor, the analysis of the energy profile of the morphologic structure shows a clear increase toward the conclusion of the sequence (the final h) corresponding to the presentation of the dominant through the modulation process. It is particularly interesting to observe the relation between the ageing degree of the note "h" and its energy profile: the note "h" appears three times, the last time with a remarkable ageing degree compared to the context. It is just this ageing (note that from the moment where the modulation occurred, the "h", which has become the new tonica, won't be consumed until the end of the subject) that causes the sudden rise of the graph of the *Energy-profile* function.
The mere morphologic analysis gives also indications for another level: the harmony. To modulate, from a morphologic point of view, means to introduce newness elements (in fact, a scale is a selection from the field of possible. In the case of temperament, the field corresponds to 12 semitones, and the modulation produces a substitution of the selected elements). So, it is clear how the morphologic structure of the melodic sequence is at heart of the organization of the harmonic parameter.

(Example nr. 14: application of the *New/Old-Analysis* and *Energy-profile* functions to the subject of the *Fuge in e minor* from the first book of the *Well-tempered Clavier* by J. S. Bach)

Yet another example from the first book of the *Well-tempered Clavier*: Though the subject is also rythmically articulated, like in the previous cases, the analysis applies to the pitch parameter only. We immediately note that in the graph, in corrispondence to the note that marks the modulation (the natural

"f"), there is an upswing of morphologic structure energy, and to the climax reached in the passage "E - C-sharp", corresponds, at the level of the melodic curve, the enphatization created by the ascending interval of major sixth.

(Example nr. 15: application of the *Energy-profile* function to the subject and prolongation of the countersubject from the *Fugue in g minor* from the first book of the *Well-tempered Clavier* by J. S. Bach).

In the example nr. 16 we have carried out the analysis of the morphologic structure energy in two passages: in the first analysis (related only to the subject) the energy is fully directed to the melodic climax "a"; in the second analysis the subject has been contextualized into a wider structure including also the prolongation of coda and countersubject. Once again it is clear not only the relation between morphologic structure energy and modulation, but also the weight acquired by the dominant "g" after modulation: it expresses a much higher energy level than the three previous entries of this note in the body of the subject. To this correponds the enphasization of the duration of "g" itself after modulation, as if the morphologic structure of the pitches may have a direct impact on the choices regarding rythmic profile of the line. The last observation is about the very little weight that the graph of the *Energy-profile* function assignes to the sensible note "f sharp".

(Example nr. 16: application of the *Energy-profile* function to the subject and prolongation of countersubject of the *Fugue in C major* from the first book of the *Well-tempered Clavier* by J. S. Bach).

6. Morphologic structure and melodic transformation

An interesting aspect, connected with the artifices of the counterpoint, is the absolute correspondence between morphologic structure of a melodic sequence and morphologic structure of its inversion. In the quoted example, the subject of the *Art of the Fugue*, we can see how the *Energy-profile* function seems to let correspond the rythmical segmentation to the morphological one.

(Example nr. 17: application of the *Energy-profile* function to the subject of the *Art of the Fugue* by J. S. Bach).

The absolute naturalness with which the melodic inversion is recognizable has much to do with the mechanisms of the memory and their acting through the time. All this is much more evident, if we compair it to the difficulty of recognizing a thematic element presented in retrograde. In the retrograde, unlike the inversion, the morphologic structure changes, and also the energy profile of the morphologic structure changes with it.
In the example nr. 18 we see in blue the energy profile of the morphologic structure of the subject of the *Art of the Fugue* and its inversion (1 2 3 1 4 1 5 3 6 3 5 1), and in red the morphologic energy profile of its retrograde (1 5 3 6 3 5 1 4 1 3 2 1).

7 - Permutations of the morfologic structure of the entry order

Developement of thematism and motif elaboration

The Beethoven's thematic elaboration extensively uses the motif elaboration. From our analysis perspective this is very stimulating, because it indicates a possible way to pass from a microformal analysis level to a macroformal one.
To proceed in this direction we should deepen a fundamental aspect, i.e. the motif construction: a motif (from a morphologic point of view) is one of the possible sequential permutations of a set of pitches. To this regard, it is important to note that many of the permutations of a set of pitches are, from the point of view of the entry order structure, identical. In the example nr. 19 we can see how all the permutations of a three element set without repetitions bring to the same contrasts analysis (this is valid for all the sets without internal repetitions).

(Example nr. 19: permutations of 3 elements without repetitions and related analysis of contrasts).

We can note how the presence of even one repetition in a given set, applying the permutations, causes the repetition of some morphologic structures of the entry order.

a_1	a_2	b	→	0	0	1
a_1	b	a_2	→	0	1	0
a_2	a_1	b	→	0	0	1
a_2	b	a_1	→	0	1	0
b	a_1	a_2	→	0	1	1
b	a_2	a_1	→	0	1	1

The example nr. 20 shows permutations within sets of 2, 3, 4 elements, both with and without repetitions, which build different morphologic structures of the entry order.

In the example nr. 21 we can see which are the possible implications regarding the relation between motif elaboration and mnemonic/perceptive response. In this famous Beethoven's incipit, the motif vehemence and incisiveness, very clearly underlined at rythmical level, are absolutely consistent with the energy profile of the morphologic structure of the entry order. Among the possible permutations, the one choosen by the composer has the energy peak of the morphologic structure just on the fourth note.

In the *Sonata op. 2 nr. 1* by L. van Beethoven, the first theme is characterized by the repetition of a short motif unit situated at the climax of an ascending arpeggio. The analysis of the possible permutations of this unit shows clearly that, among various possibilities, the permutation choosen by the composer reaches the top of the energy of the morphologic structure exactly on the first note. Finally, to underline these climaxes, in the second phrase, the

composer wrote on the score, at the repetition of the two units, the indication *sforzato*. Once again a clue indicating the near relation between morphologic structure of the pitches and the other parameters, in this case the dynamics parameter.

(Example nr. 22: application on a motif level of the *Energy-profile* function to the first theme of the *Sonata op. 2 nr. 1* by L. van Beethoven).

The relation between morphologic structure of the pitches and dynamics becomes clearer reading the analysis of the whole first theme made by *Energy-profile*: To the energy climax of the morphologic structure corresponds the *fortissimo* (which is also the melodic climax of the theme). Moreover, it is possible to identify a function which divides into segments the energy of the morphologic structure, and to read from this analysis two waves of increasing energy.

(Example nr. 23: application of the *Energy-profile* function to the first theme of the *Sonata op. 2 nr. 1* in f minor by L. van Beethoven).

The example nr. 24 shows two levels of analysis of the morphologic structure energy: the first one is an analysis which is very similar to the ones we have seen so far, where every pitch is considered as a separate unit (at this level one can see in detail how the energy peak coincides exactly with the beginning of the *codetta* of the theme). The second analysis level applies to the motif segmentation of the theme. In this case the energy peak of the morphologic structure coincides perfectly with the resolute and assertive conclusion of the theme. From the point of view of the mnestic mechanisms, the segmentation into units of superior level is fundamental, and the assimilation to the same object of motifs - which are very similar from the point of view of the melodic profile and the rythmical structure - is not only acceptable, but it is also a tool needed to face a macroformal analysis level.

(Example nr. 24: application of the *Energy-profile* function to the first theme of the *Sonata op. 10 nr. 1* in c minor by L. van Beethoven).

8. Morphologic analysis of the iterative sequences

A particular aspect of music writing is the harmonic prolongation through the repetition of articulation formulas. The example nr. 25 shows an analysis of the practice called "Alberti bass": it is worth to note how the separation, in the analysis of the different harmonic components of the triad, brings about absolutely indipendent energy routes of the morphologic structure, as they were nearly in counterpoint among themselves. The analysis of the morphologic structure energy points out a constant and well-balanced evolution of the various harmonic layers.

The prelude in c major from the *Well-tempered Clavier* by J. S. Bach is a classic example of articulation of the time through the repetition of a formula, which remains always the same: a polyphony with five parts. The analysis of the morphologic structure energy of the harmonic loosening formula, strictly repeated nearly in every measure until the end of the piece, shows us how the high part expresses a low energy degree, while two of the middle voices are brought out right by the repetition. The general analysis of the first 11 measures, i.e. until the dominant is achieved, confirms the coherent correspondence between harmonic field and morphologic structure.

(Example nr. 26: application of the *Energy-profile* function to the first 11 measures of the *Prelude in C major* from the first book of *The Well-tempered Clavier* by J. S. Bach).

9. Harmonic polarization and morphologic structure in Anton Webern

One of the peculiar stylistic features to Webern's writing is the polarization, i.e. the technique that aims, through the fixation in the register of the pitches, to obtain a sort of clearness of the harmonic field, a crystallization of time and space. This particular stylistic trait becomes of crucial importance for the handling of the macroform: in the first movement of the *Symphony op. 21*, the classically tripartite structure is first defined right through the use of the harmonic polarization. In the exposition (example nr. 27) the harmonic field is single and simmetrically organized around the note "A". We won't go into details of the canonical structures and the extremely fine organization of timbres that we can listen to in this piece, but we would like to point out just an aspect strictly linked to the polarization technique, which is at the centre of this article: the repetition. The analysis of the morphologic structure energy in the exposition of the *Symphony op. 21* shows how the play of the repetitions created by the polarized harmonic tissue leads to a constant and gradual increase of the energy peaks.

(Example nr. 27: application of the *Energy-profile* function to the pitches sequence of the exposition of the first movement of the *Symphony op. 21* by A. Webern).

Revealer of the structurating function (from a perceptive point of view) of the polarization is the general analysis of the whole movement (example nr. 28). The polarizations of the second and third part of this piece, which sprang from superimposing different harmonic fields, have right the effect to segment the form. The analysis of the morphologic structure energy proves to be actually simmetric, in the central part of the piece, to the crab structure of the canons, while the final section has the function to set the energies free, which have been accumulated until that moment. In the third section of this movement, Webern dissolves the form disarticulating the musical tissue, as if the energies accumulated up to then could find a completion in the annihilation of the form itself.

(Example nr. 28: application of the *Energy-profile* function to the pitches sequence of the whole first movement of the *Symphony op. 21* by A. Webern).

10 - Perspectives

The possibility to extensively apply to all the music parameters the analysis algorythms we have presented makes the development perspectives particularly interesting. Each time, the stylistic features of the score analysed will suggest priorities regarding the parameters on applying the analysis algorythms.
At this time there are under test - always regarding melodic construction and using also the information analysis functions [*Bit-information analysis*, see notes 5 and 6] - the implications concerning the importance of the morphologic structure of:

- intervals;
- modul 12 (octave relation)
- melodic profile[7];
- use of the register (complying with the natural registers division of the music instrument used, therefore with implications related to the timbre);
- durations;
- durations registers (from the most slow articulations to the most quick ones);
- intensity;
- timbres.

To explain the researches carried out we will see some examples.

In the example 29 interact two energy analyses of the morphologic structure:
- The first one considers the input data (a chromatic scale with more than 4 octaves) like a sequence of ever-new events (1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53), as done in all the previous examples;
- The second one considers the input data as notes, then as series of repetitions of chromatic scale of 12 semitones (0 1 2 3 4 5 6 7 8 9 10 11 0 1 2 3 4 5 6 7 8 9 10 11 0 1 2 3 4 5 6 7 8 9 10 11 0 1 2 3 4);

It is evident that this implementation is fundamental to obtain a good simulation of the psychic response: a chromatic scale is not an undifferentiated succession of ever-new events, and the octave relation gives the sensation of a repetition, even if it is differentiated from the point of view of the timbre. The use of the repetition tends then to let progressively decrease the weight of the morphologic energy.

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[7] To this matter see the *Direct-analysis* function of the *Morphologie Library 3.0*, Paolo Aralla, J. Baboni Schilingi and F. Voisin, PRISMA, 2002.

In the example nr. 30b interact the morphologic structure energy analysis of the events sequence (0 1 2 3 4 5 6 7 8 9 10 11) and the intervals sequence analysis (0 0 0 0 0 0 0 0 1 2 1).
In the intervals sequence (where there are ascending semitones only, except two whole tones and a discending semitone at the end), the energy analysis of the morphologic structure reaches the peak when the interval of second major appears (example nr. 30a). In the example 30b one can note how the energy curve of the morphologic structure of the intervals is still recognizable, even if it is attenuated by the combination with the energy of the morphologic structure of the events sequence.
These last two examples refer to preliminar studies for the application of the morphologic analysis to the field of the dodecaphonic structures.

11. *Architektur der Ebene II*

An example of application of the morphologic analysis functions to the composition

In *Impromptu nr. 5* and even more in *Architektur der Ebene II*, a piece for concertante piano and ensemble I have composed in 2002, the morphologic analysis functions has found a first application in a creative sense. In particular, the long solo piano cadenza of *Architektur der Ebene II* is built using *New/Old-Analysis* as instrument to filter the music material of which it is made.
In the example nr. 31 we can see the last part of the cadenza, which is, from a compositional point of view, the material at the roots of the cadenza itself.

(Example nr. 31: basic material for morphologic fade-in, *Architektur der Ebene II*, final part of the piano cadenza, meas. 356-359).

The function used is of recursive kind and carries out for each passage the following operations:

- Application of the *New/Old-Analysis* function (in this case starting from the fragment quoted in the example nr. 31);
- Segmentation of the sequence in correspondence with the down peaks (i.e. the age peaks of the material) of the *New/Old-Analysis* function. The function used to identify the segmentation points is min-flex-max of the *Morphologie library*;
- Elimination of the down peaks and transposition of the remaining material on the removed pitches;
- Then, backwards readjustment of the material from the last recurrence to the original material.

The purpose is to build a long music passage, where the most redundant features of the starting fragment are progressively focused. This process can be defined "morphologic fade-in", and its function is to realize a progressive focusing of the opening music image. Similar methods have been developed

using the *Energy-profile* analysis, not only with the fade in function, but also with morphologic fade out function.

(Example nr. 32: morphologic fade-in, *Architektur der Ebene II*, piano cadenza, measures 286 - 359).

12. Conclusions

An important element, which has been brought to the light in the examples of application of the morphologic analysis functions, is the existence of a hierarchy strictly interconnected with the various music parameters. In particular, we have seen from the analysis examples of Bach and Beethoven quoted in this article, that the parameter of the absolut pitch has such a prominent function among the other parameters (harmonic parameter, melodic curve parameter, timbre, rhythm and so on ...), that it becomes crucial among the choices made with regard to the harmonic and rythmic construction. The *New/Old-Analysis* and *Energy-profile* functions applied to the absolute pitches sequence[8] give us useful information about the coincidence between morphologic structure energy of the melodic line and the harmonic parameter pointing out the deep link between the reasons of the harmonic/melodic development and the reasons of the form. This point is fundamental, for it underlines the common essence, which links melodic, harmonic and rythmic choices to the formal ones, in a complex and inseparable relation.

To naturally pass through the most disparate linguistic experiences is a hallmark of modernity and a symptom of the existence of a deeper level, which crosses and connects this plurality of experiences making it readable. Styles and languages seem to be an answer, each time unique and particular, to a basic need: to organize, to give form to the time through the cognitive processes linked to the memory. In this frame it should be interpreted the most radical expressions of the avant-garde of the second half of the twentieth-century. They have delivered us works able to give new form to the time (let us think to Ligeti, Scelsi, Grisey, but in a different way also Stockhausen, Boulez, Berio, Donatoni etc...), a wide field of experiences and experimentations, through which we can think new relations between form and memory.

Peculiar feature to the morphologic analysis is its applicability beyond the linguistic and stylistic traits of the work analysed. If we take as a reference model the cognitive processes, and simulate the psychic response to the perceptive act, the *New/Old-Analysis* and the *Energy-profile* functions prove to be versatile enough to give, once the hierarchic relation between the different parameters is identified, useful answers in completely different stylistic fields. Moreover, the application perspectives of the morphologic analysis can go

[8] It is again to point out that, in the analysis of the absolute pitches, the *New/Old-Analysis* functions and *Energy-profile* functions never consider the other parameters (harmonic, rythmic parameters and so on.) as entry data.

beyond the boundaries of the musical analysis strictly intended, to investigate the musical aspects of other artistic expressions: analysis of the phonetic sequences in the poetry, analysis of the movement sequences in dance etc...

(Translated by Claudio Cento)

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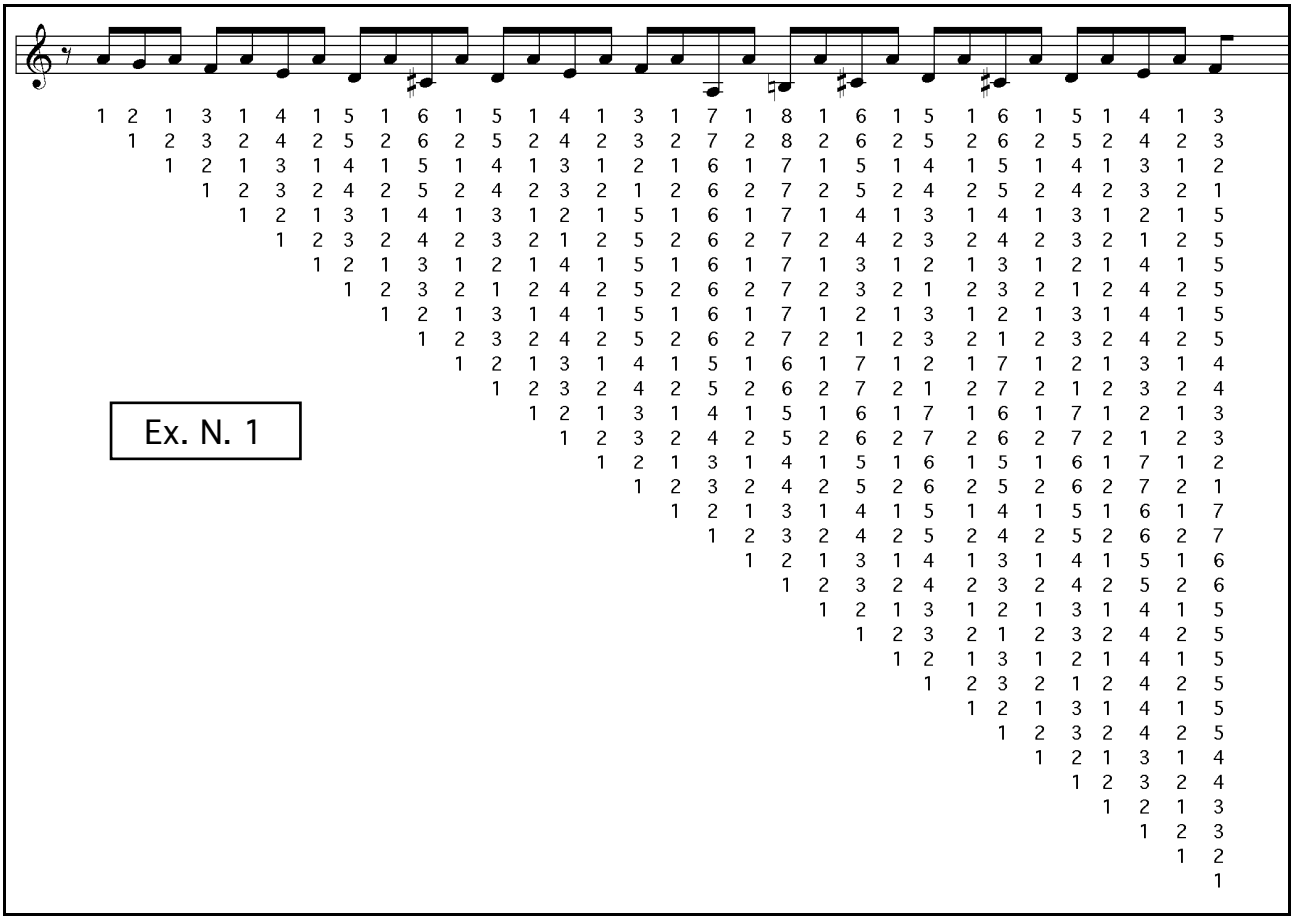
- Tadié J.Y. and Tadié M. 1999. *Le sens de la mémoire.* Paris: Edition Gallimard. Trad. it. *Il senso della memoria*, Dedalo, Bari, 2000.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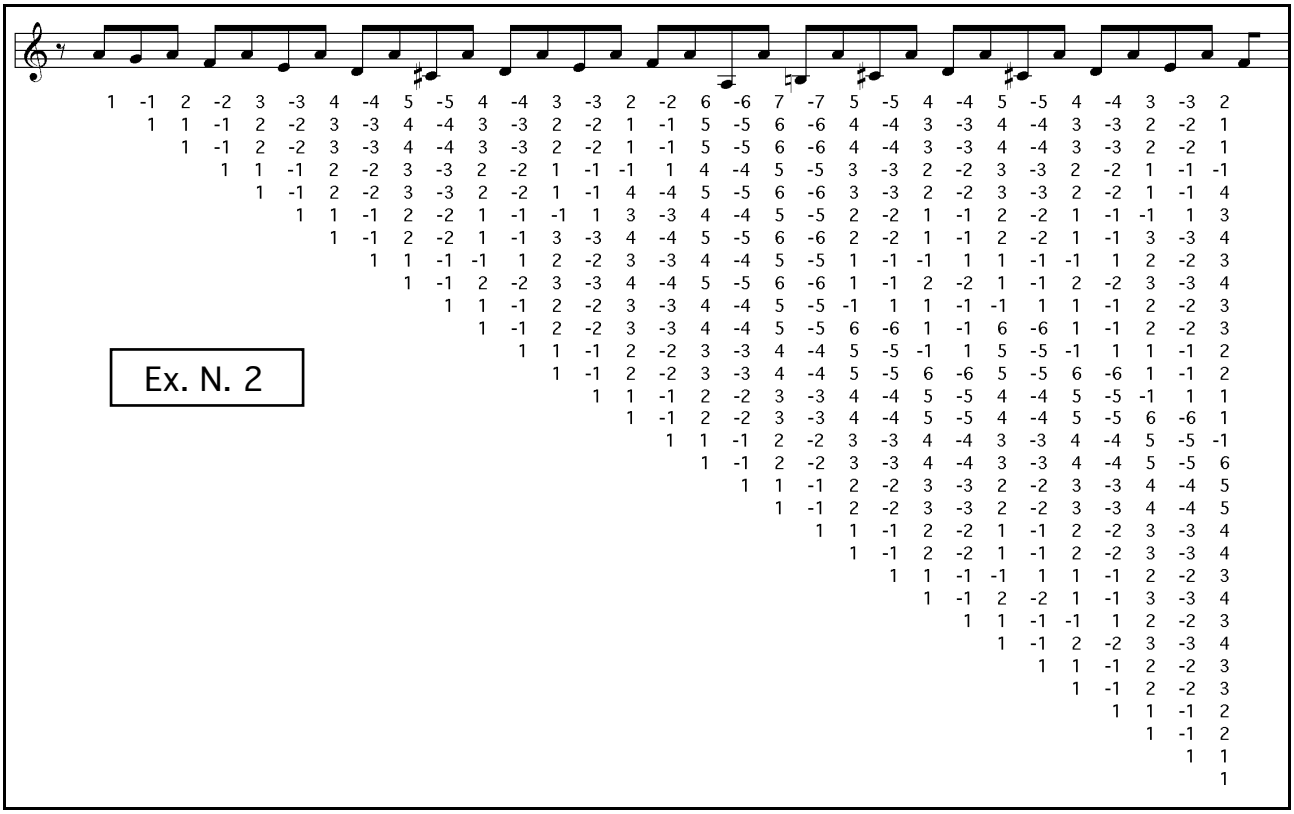
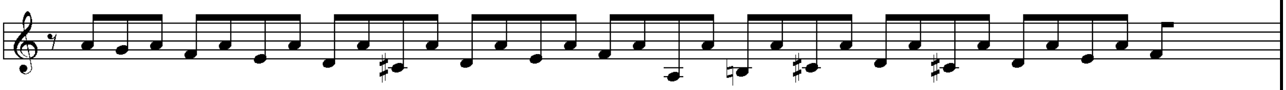

Ex. N. 2

Ex. N. 3



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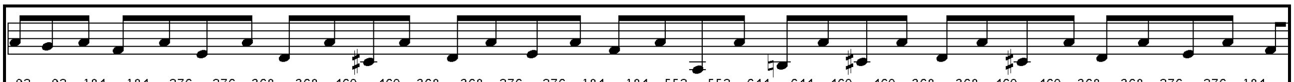
Ex. N. 4



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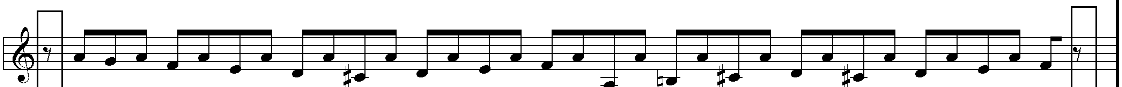
Ex. N. 5



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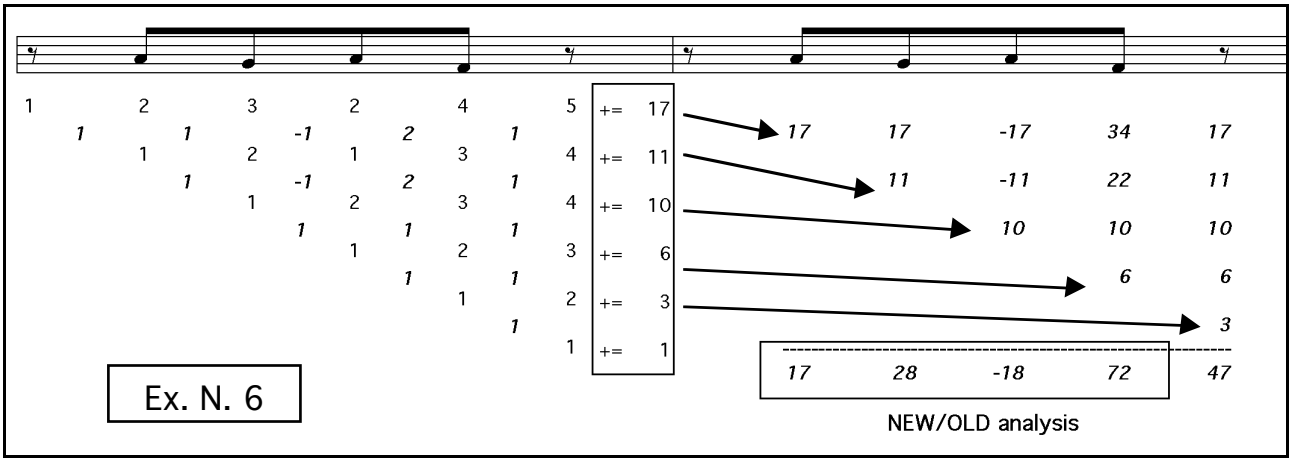
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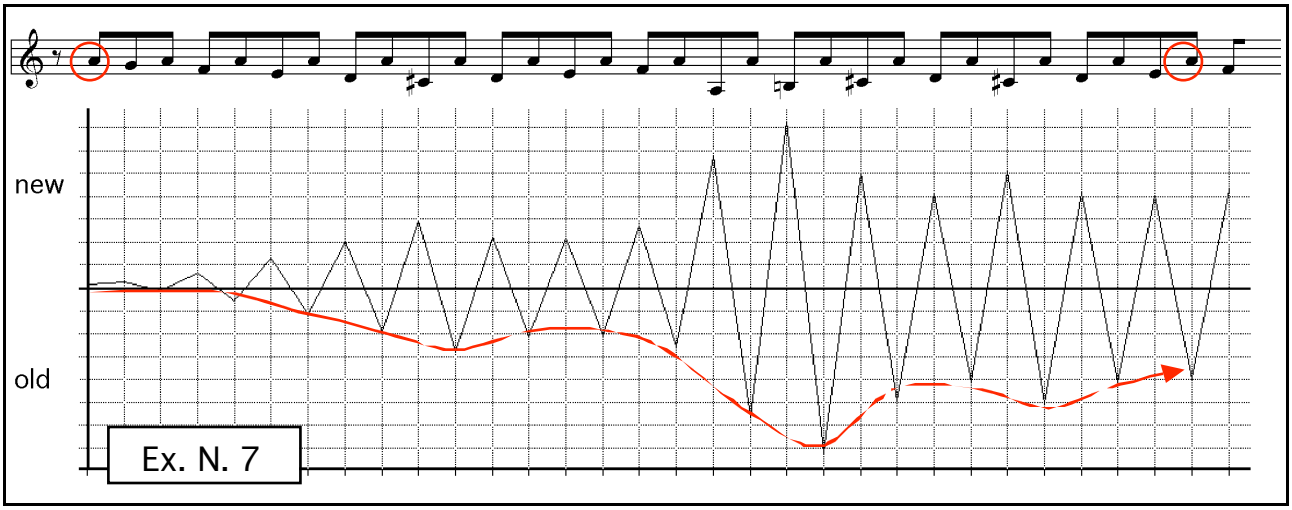
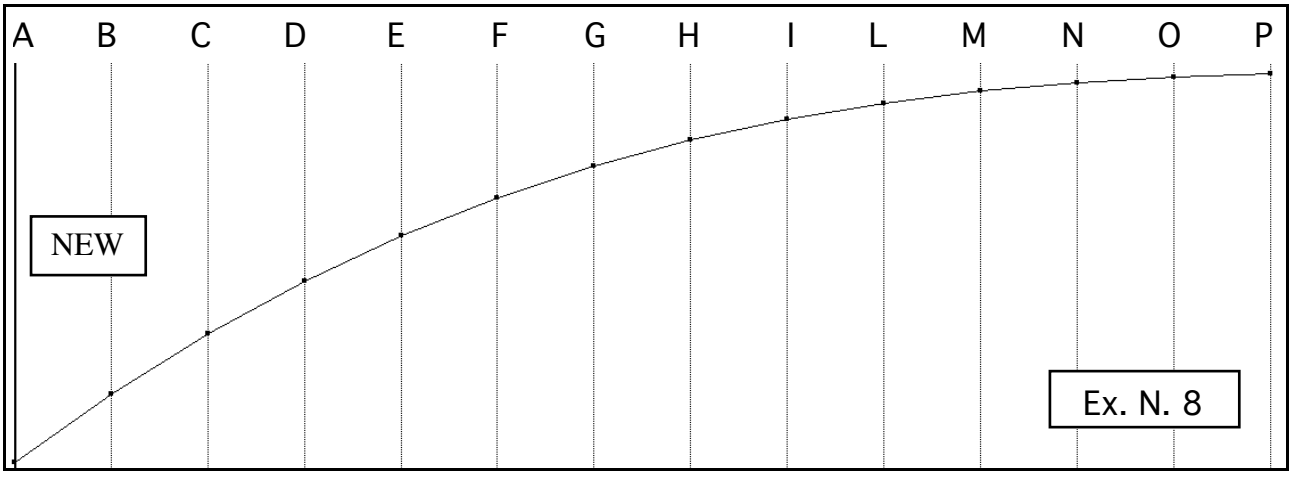
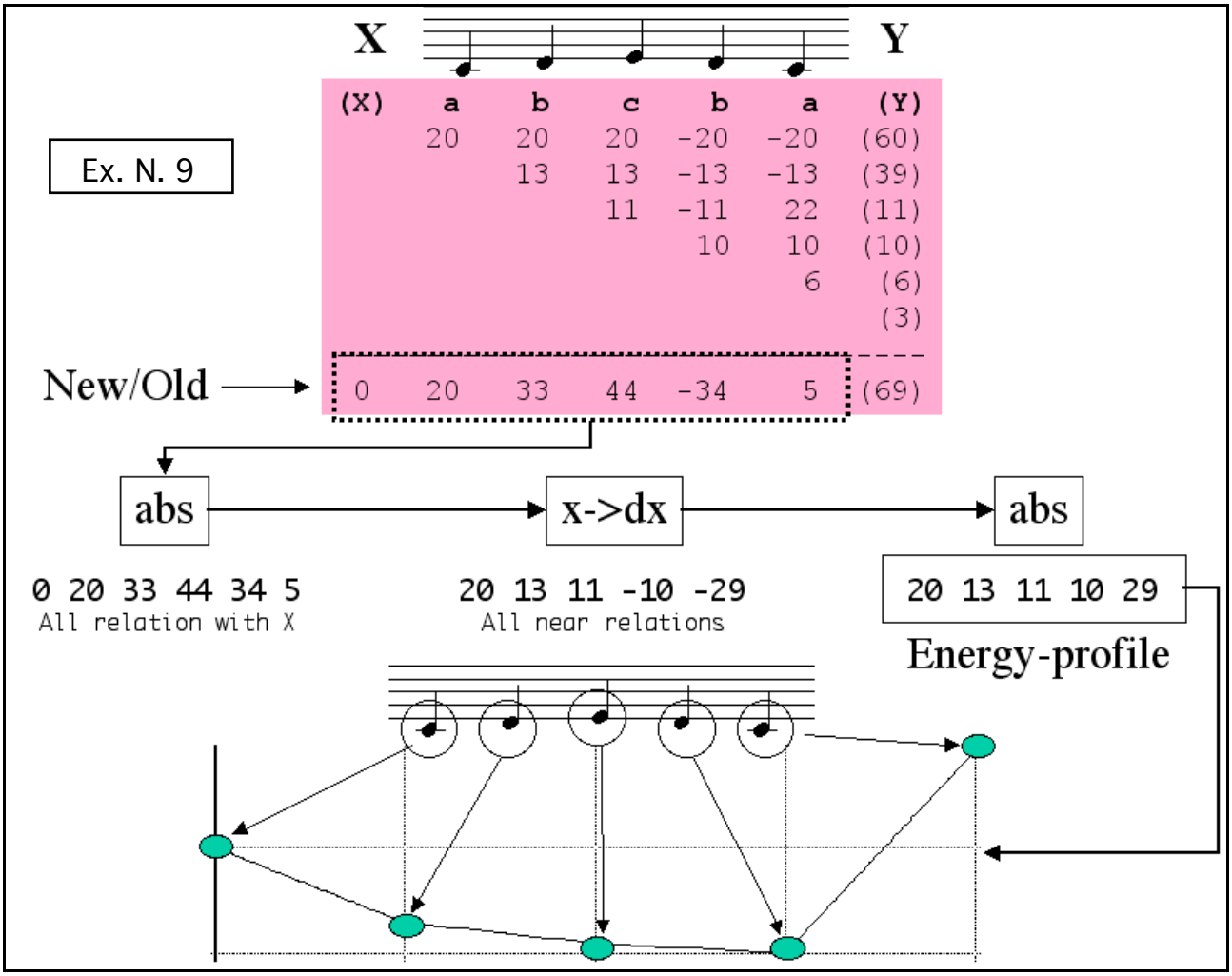
1 2 1 3 1 4
1 -1 2 1 3
1 2 3 2
1 1 1
1 1
1
+= 17
+= 11
+= 10
+= 6
+= 3
+= 1
17 17 -17 34 17
11 -11 22 11
10 10 10
6 6
3
17 28 -18 72 47
NEW/OLD analysis
Ex. N. 6

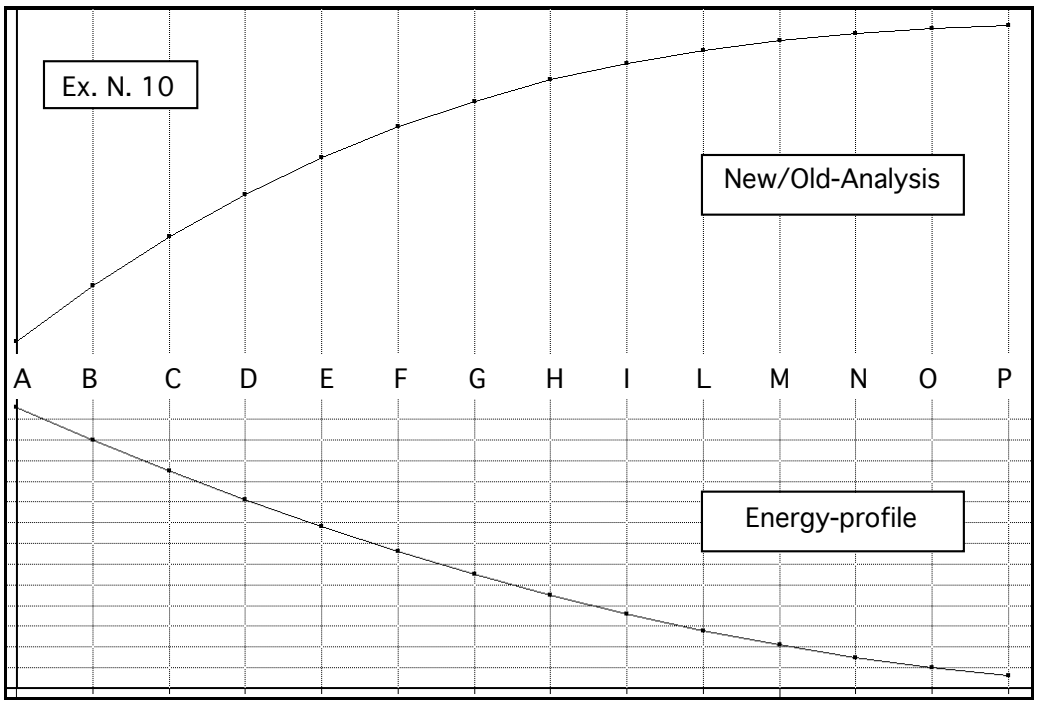

new
old
Ex. N. 7

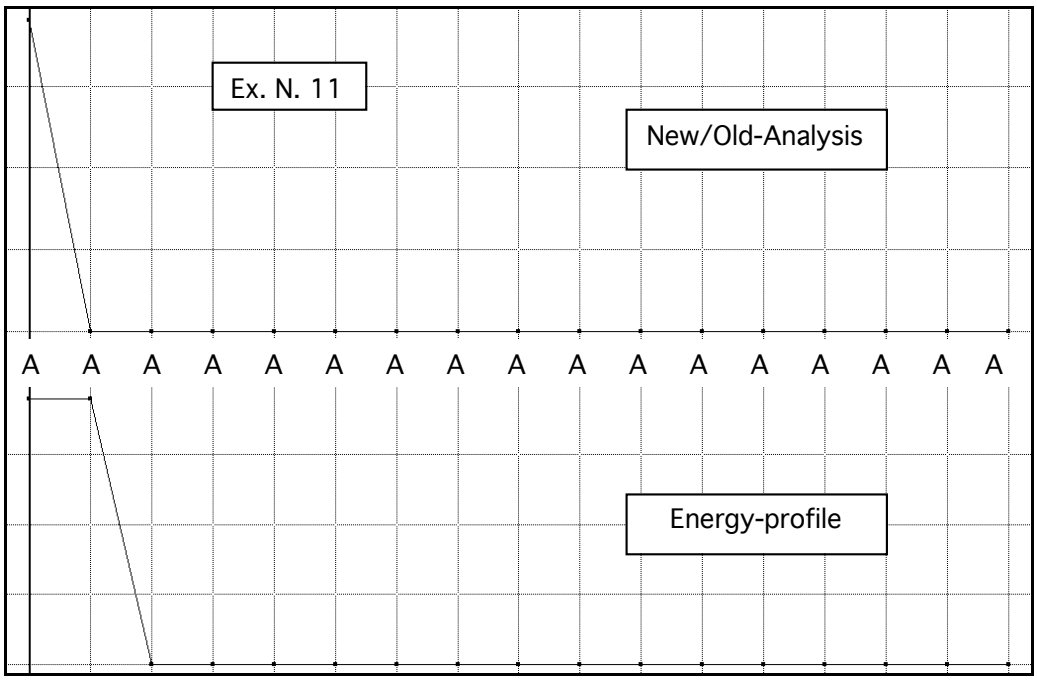

A B C D E F G H I L M N O P
NEW
Ex. N. 8

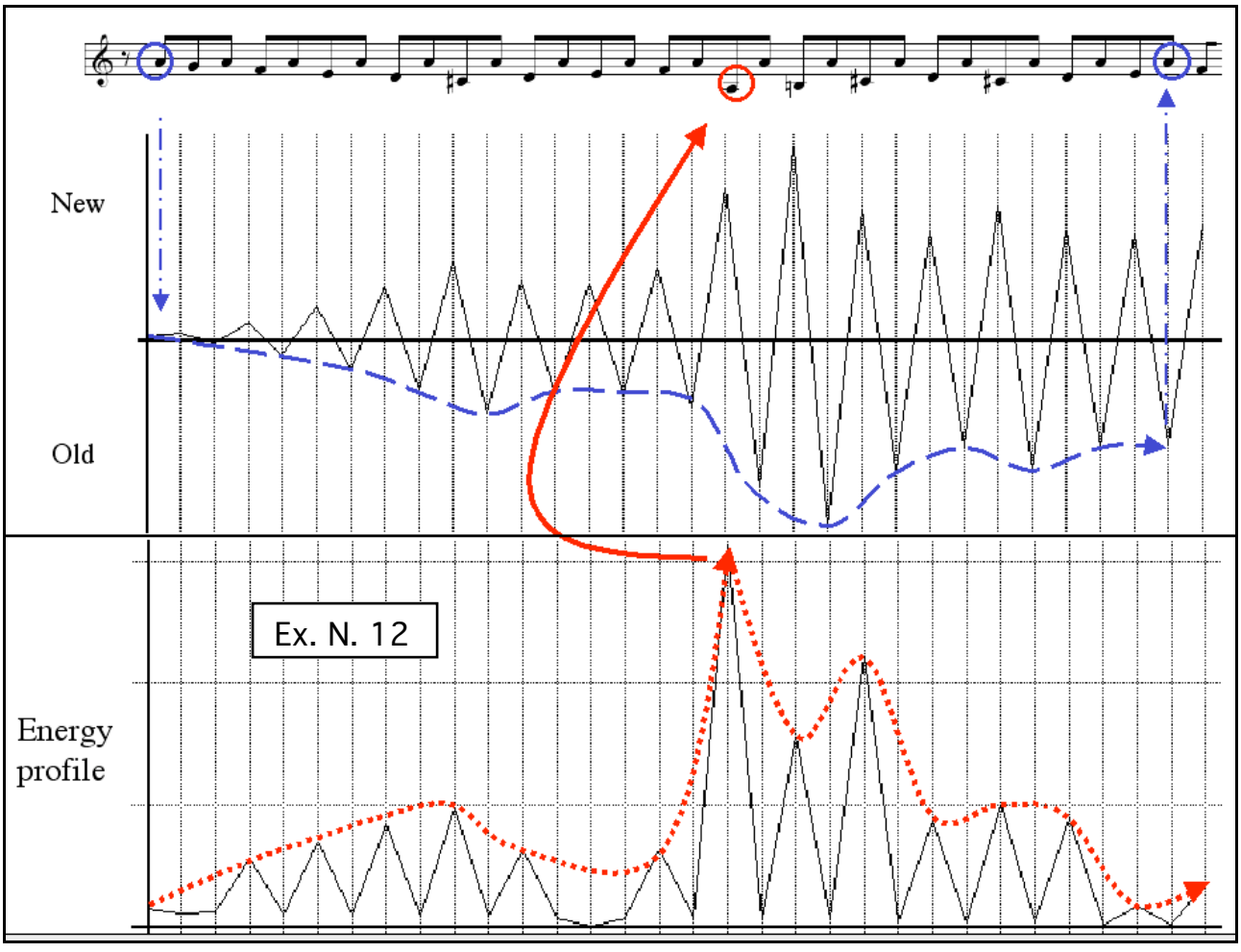
Ex. N. 9

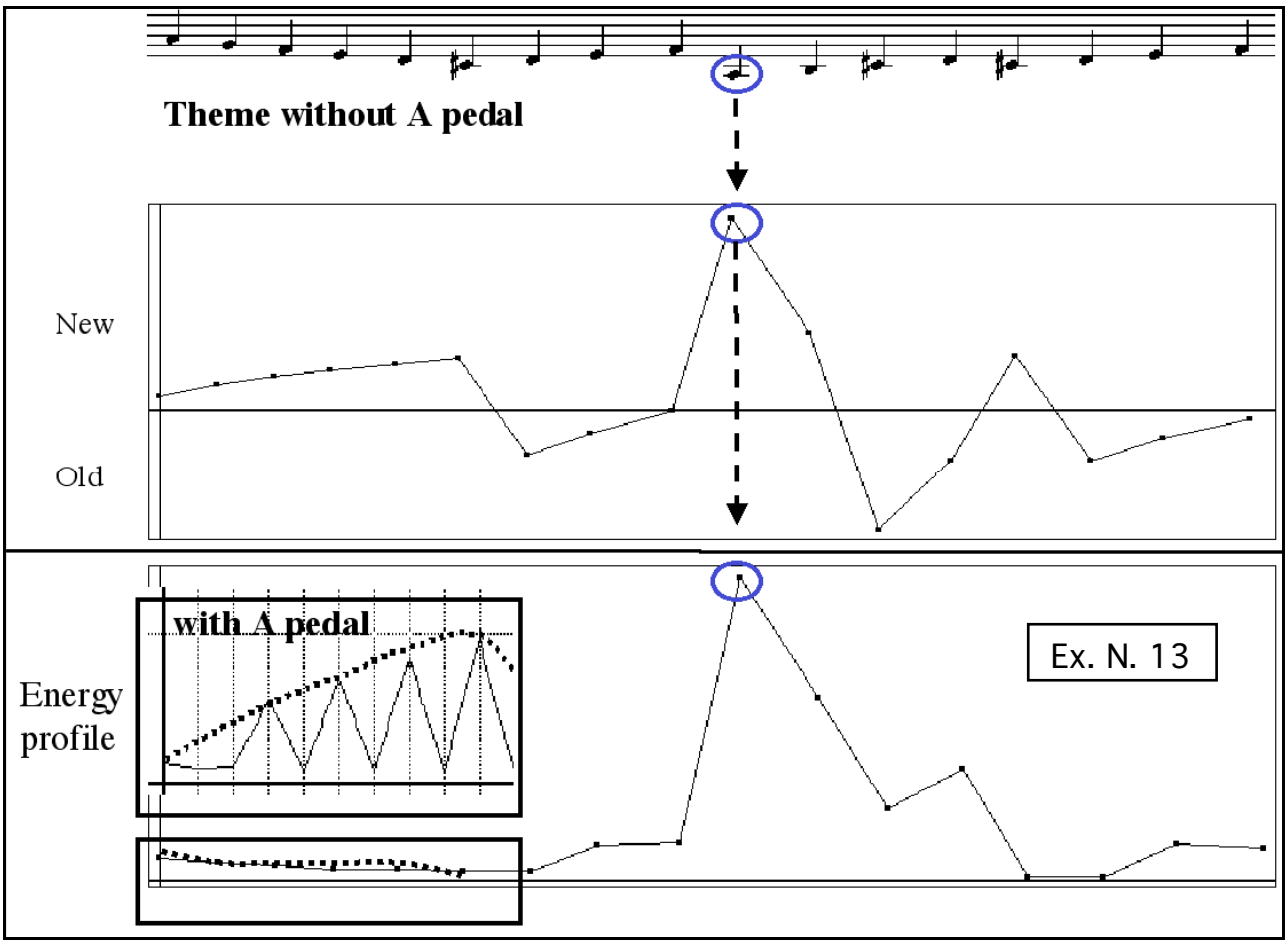

X
Y
(X) a b c b a (Y)
20 20 20 -20 -20 (60)
13 13 -13 -13 (39)
11 -11 22 (11)
10 10 (10)
6 (6)
(3)
New/Old
0 20 33 44 -34 5 (69)
abs
x->dx
abs
0 20 33 44 34 5
All relation with X
20 13 11 -10 -29
All near relations
20 13 11 10 29
Energy-profile

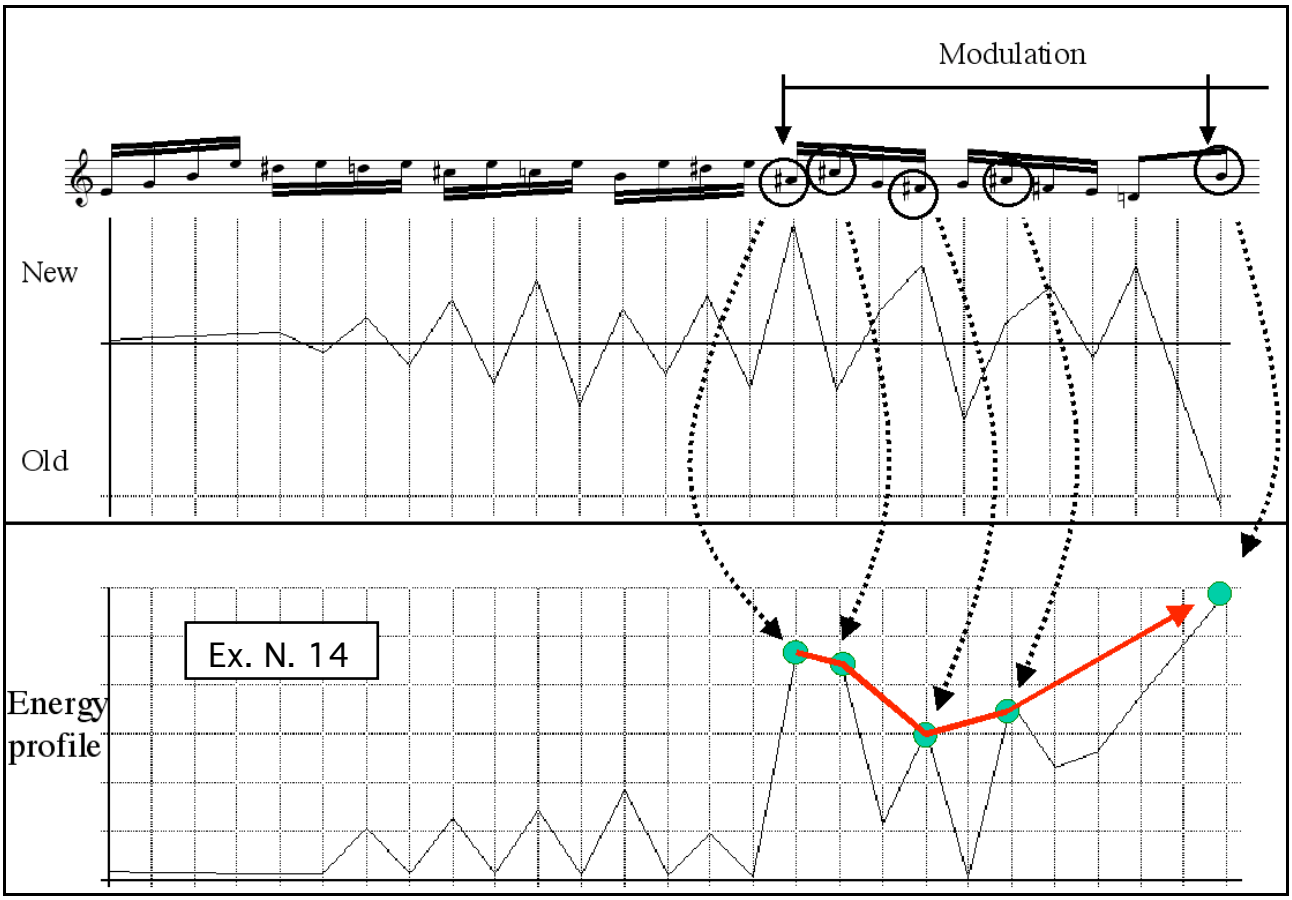
Ex. N. 10

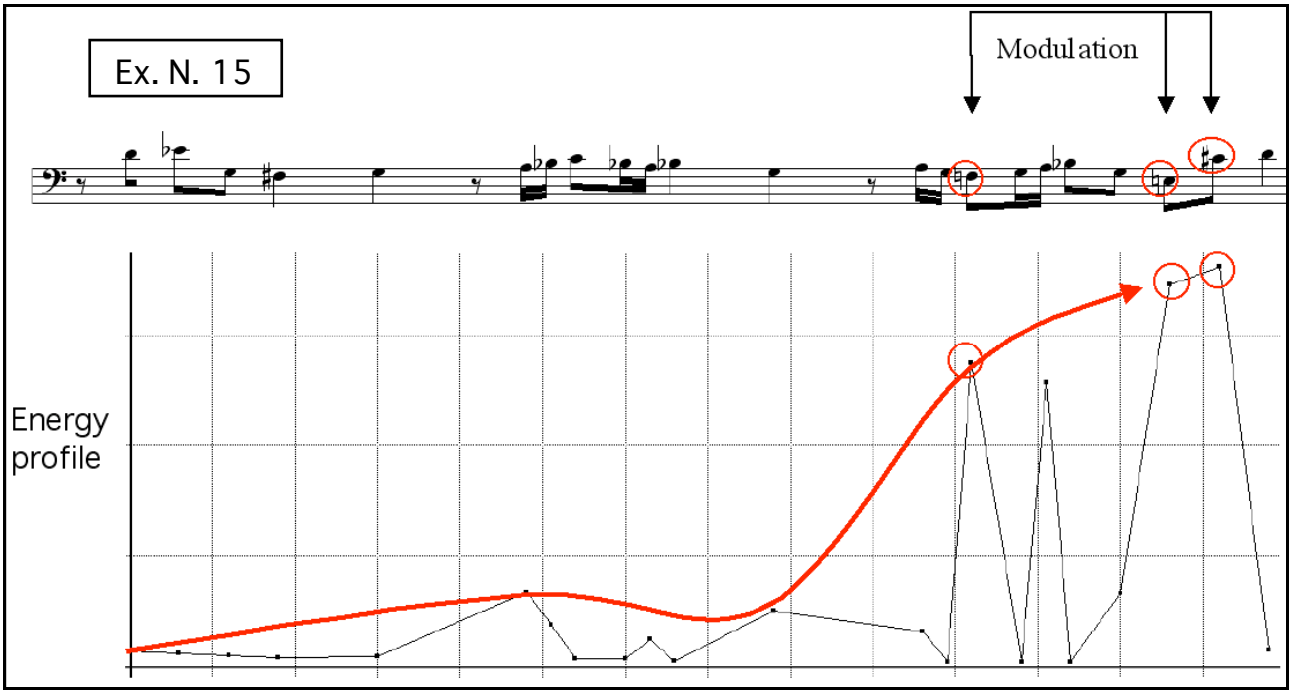

New/Old-Analysis
A B C D E F G H I L M N O P
Energy-profile

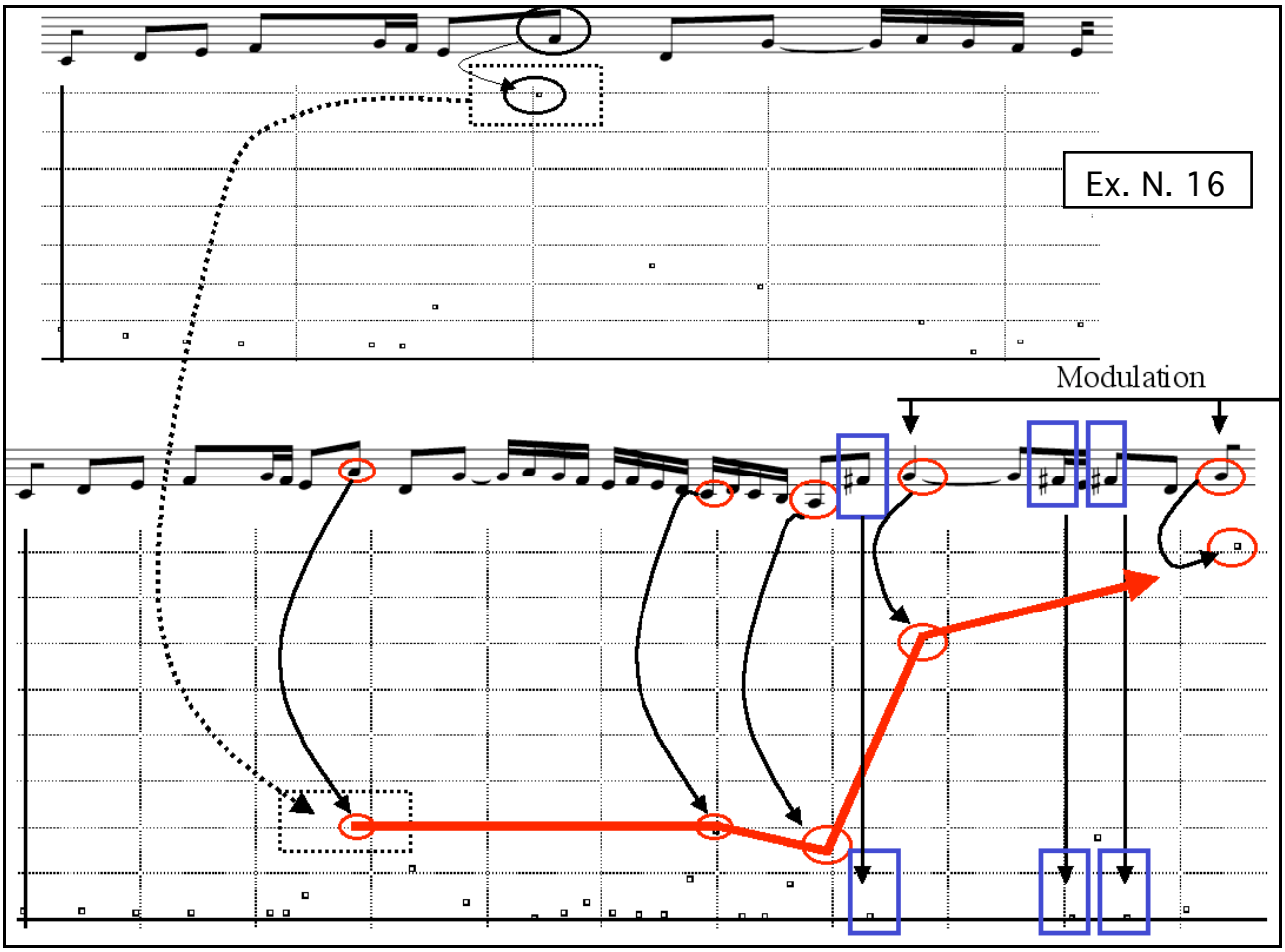

Ex. N. 11
New/Old-Analysis
A A A A A A A A A A A A A A A A
Energy-profile

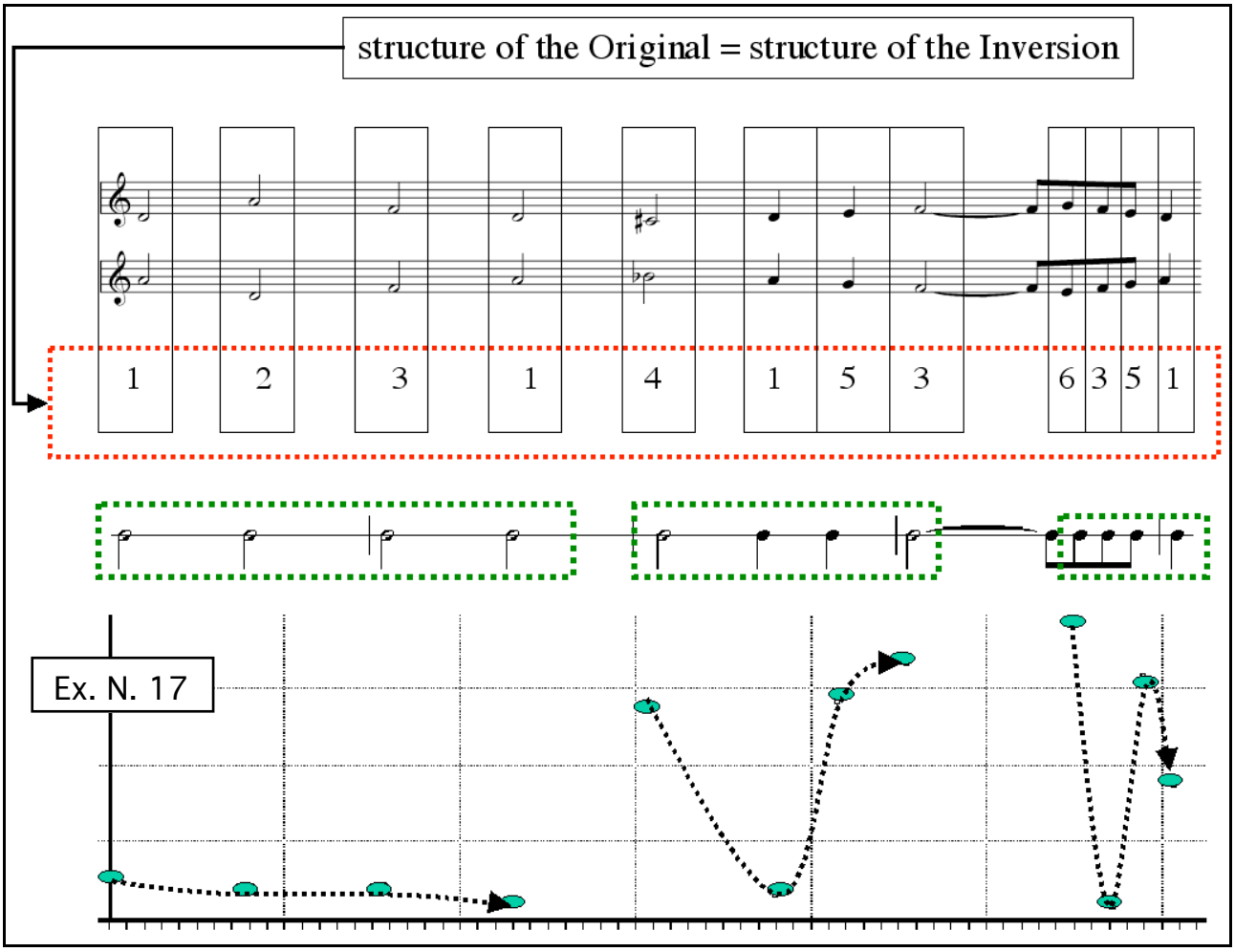

New
Old
Ex. N. 12
Energy
profile


Theme without A pedal
New
Old
with A pedal
Energy profile
Ex. N. 13


Modulation
New
Old
Ex. N. 14
Energy profile


Ex. N. 15
Modulation
Energy
profile


Ex. N. 16
Modulation


structure of the Original = structure of the Inversion
1 2 3 1 4 1 5 3 6 3 5 1
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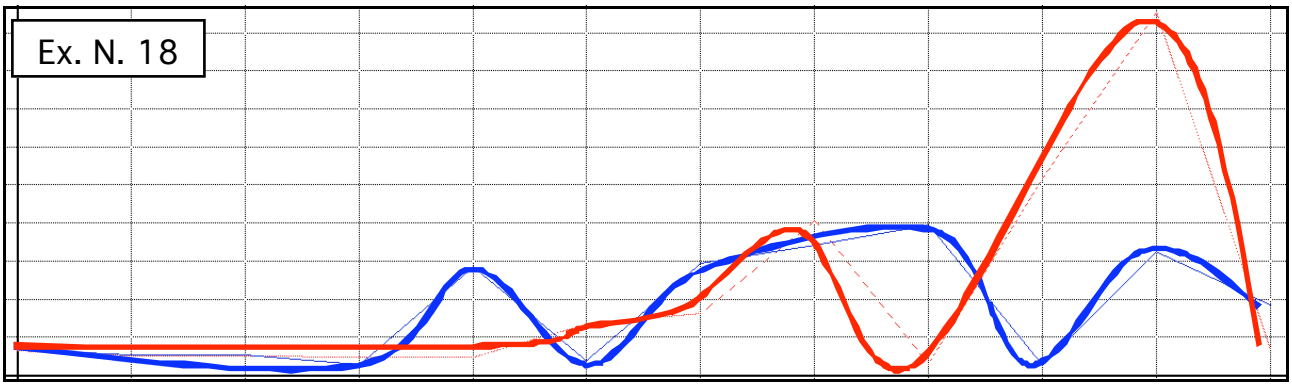
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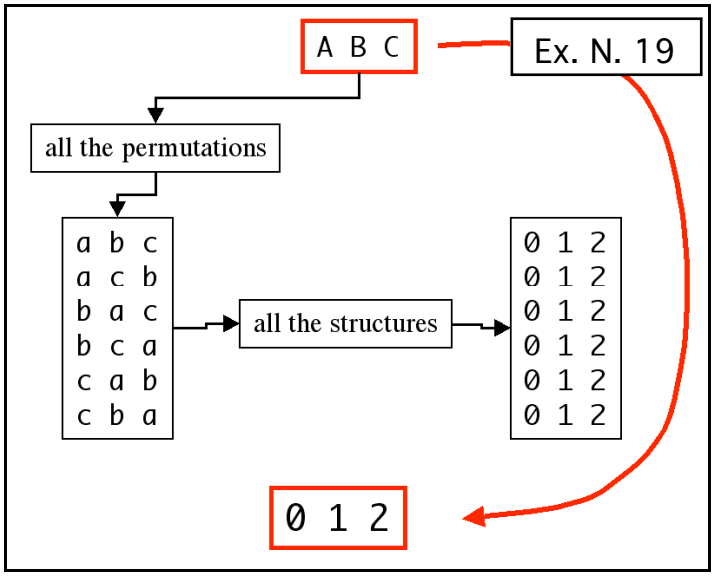
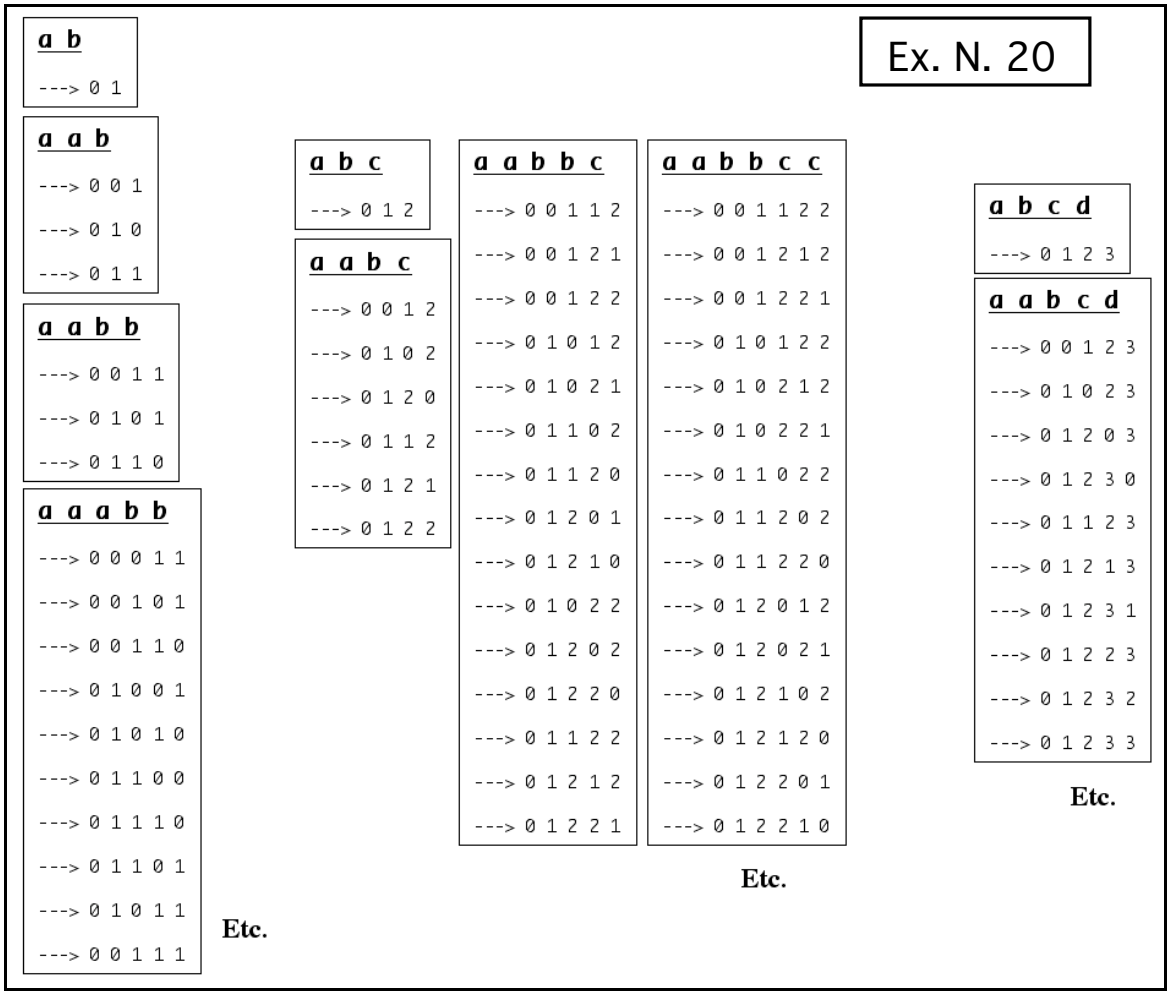
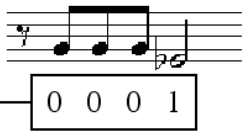

A B C
Ex. N. 19
all the permutations
a b c
a c b
b a c
b c a
c a b
c b a
all the structures
0 1 2
0 1 2
0 1 2
0 1 2
0 1 2
0 1 2
0 1 2

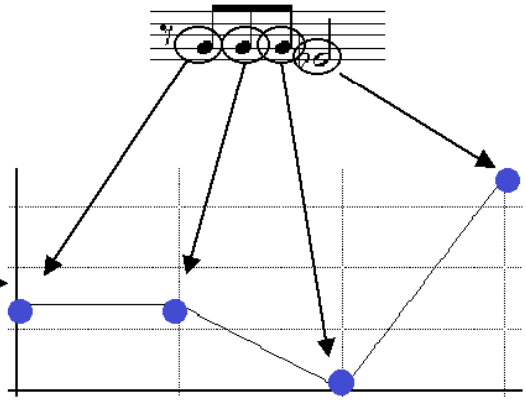

Ex. N. 20
a b
---> 0 1
a a b
---> 0 0 1
---> 0 1 0
---> 0 1 1
a a b b
---> 0 0 1 1
---> 0 1 0 1
---> 0 1 1 0
a a a b b
---> 0 0 0 1 1
---> 0 0 1 0 1
---> 0 0 1 1 0
---> 0 1 0 0 1
---> 0 1 0 1 0
---> 0 1 1 0 0
---> 0 1 1 1 0
---> 0 1 1 0 1
---> 0 1 0 1 1
---> 0 0 1 1 1
Etc.
a b c
---> 0 1 2
a a b c
---> 0 0 1 2
---> 0 1 0 2
---> 0 1 2 0
---> 0 1 1 2
---> 0 1 2 1
---> 0 1 2 2
a a b b c
---> 0 0 1 1 2
---> 0 0 1 2 1
---> 0 0 1 2 2
---> 0 1 0 1 2
---> 0 1 0 2 1
---> 0 1 1 0 2
---> 0 1 1 2 0
---> 0 1 2 0 1
---> 0 1 2 1 0
---> 0 1 2 0 2
---> 0 1 2 2 0
---> 0 1 1 2 2
---> 0 1 2 1 2
---> 0 1 2 2 1
a a b b c c
---> 0 0 1 1 2 2
---> 0 0 1 2 1 2
---> 0 0 1 2 2 1
---> 0 1 0 1 2 2
---> 0 1 0 2 1 2
---> 0 1 0 2 2 1
---> 0 1 1 0 2 2
---> 0 1 1 2 0 2
---> 0 1 1 2 2 0
---> 0 1 2 0 1 2
---> 0 1 2 0 2 1
---> 0 1 2 1 0 2
---> 0 1 2 1 2 0
---> 0 1 2 2 0 1
---> 0 1 2 2 1 0
Etc.
a b c d
---> 0 1 2 3
a a b c d
---> 0 0 1 2 3
---> 0 1 0 2 3
---> 0 1 2 0 3
---> 0 1 2 3 0
---> 0 1 1 2 3
---> 0 1 2 1 3
---> 0 1 2 3 1
---> 0 1 2 2 3
---> 0 1 2 3 2
---> 0 1 2 3 3
Etc.

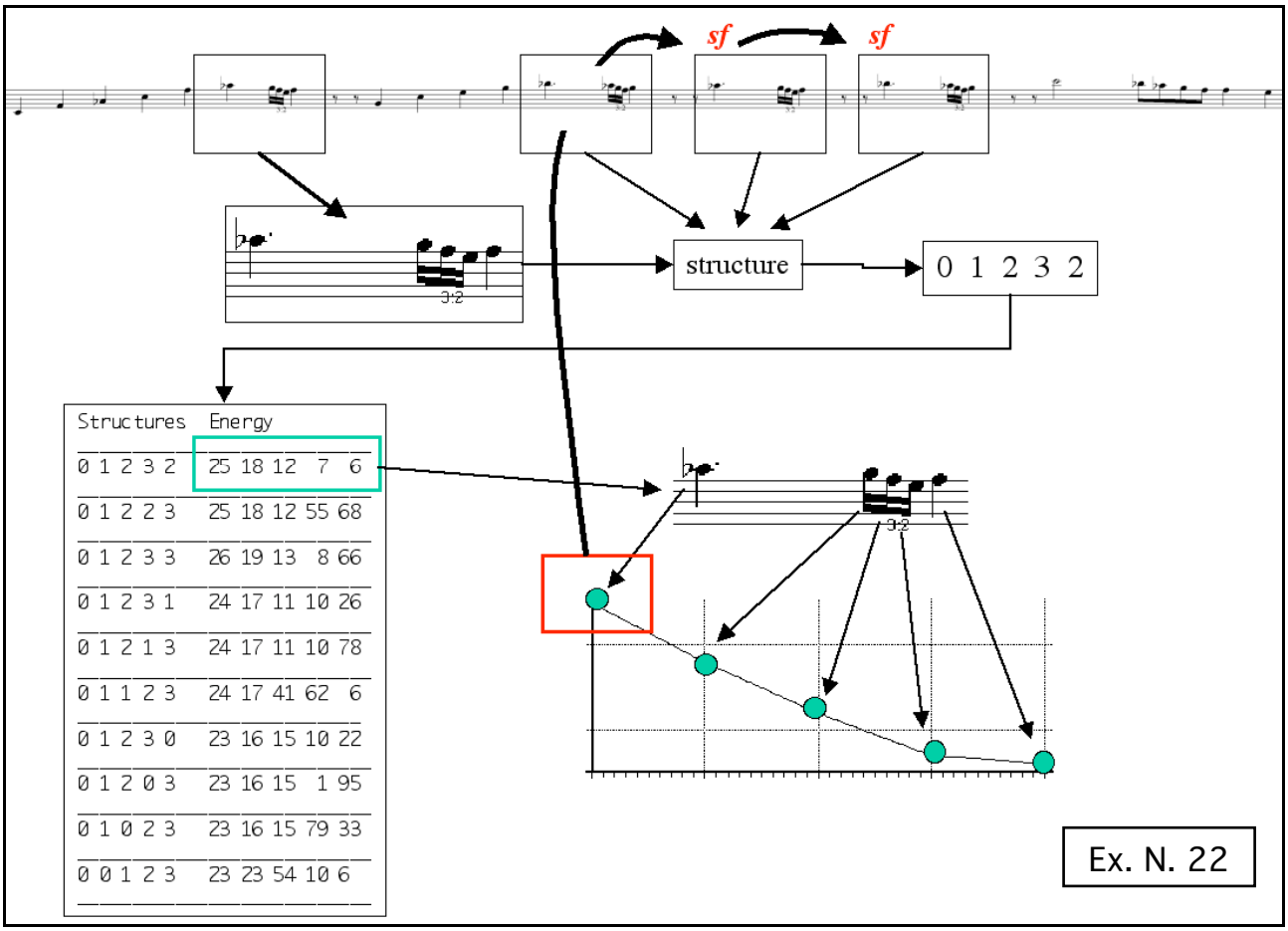
Ex. N. 21



0 0 0 1

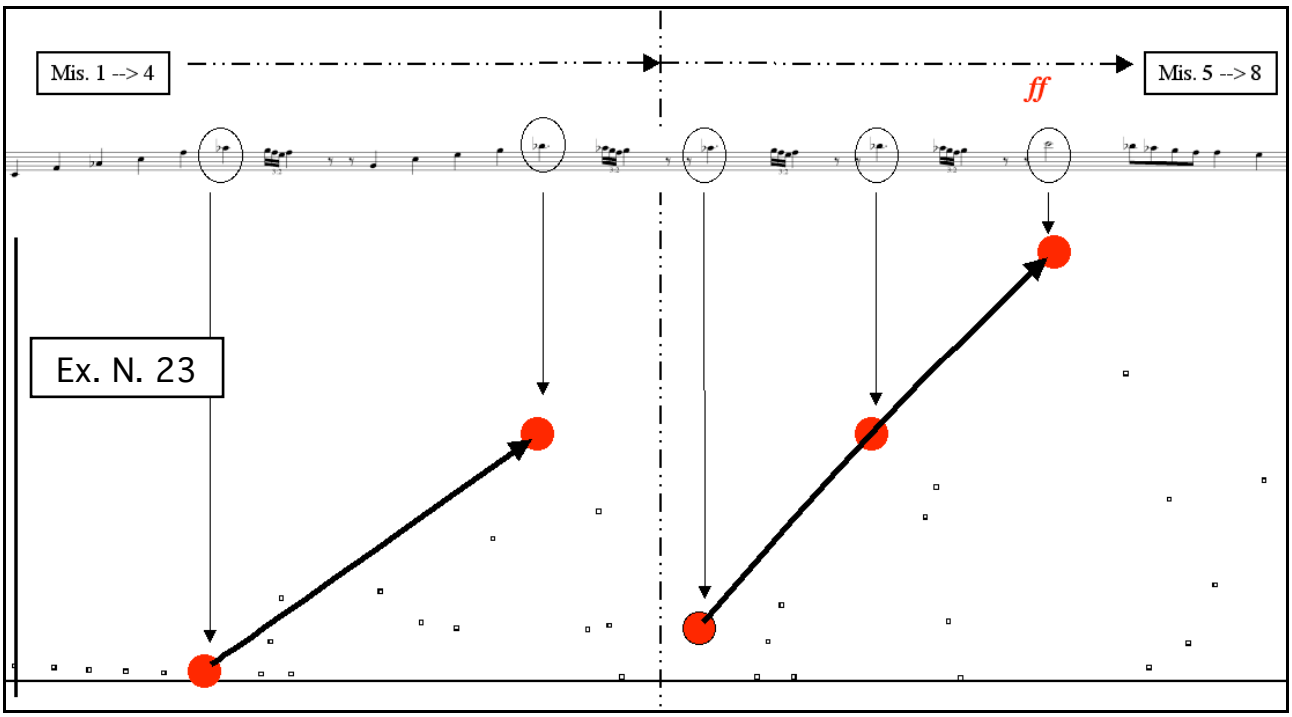
Structural permutations	Energy-profiles
0 0 0 1	14 - 14 - 0 - 35
0 0 1 0	14 - 14 - 29 - 6
0 1 0 0	14 - 8 - 8 - 14
0 1 1 1	16 - 10 - 26 - 0

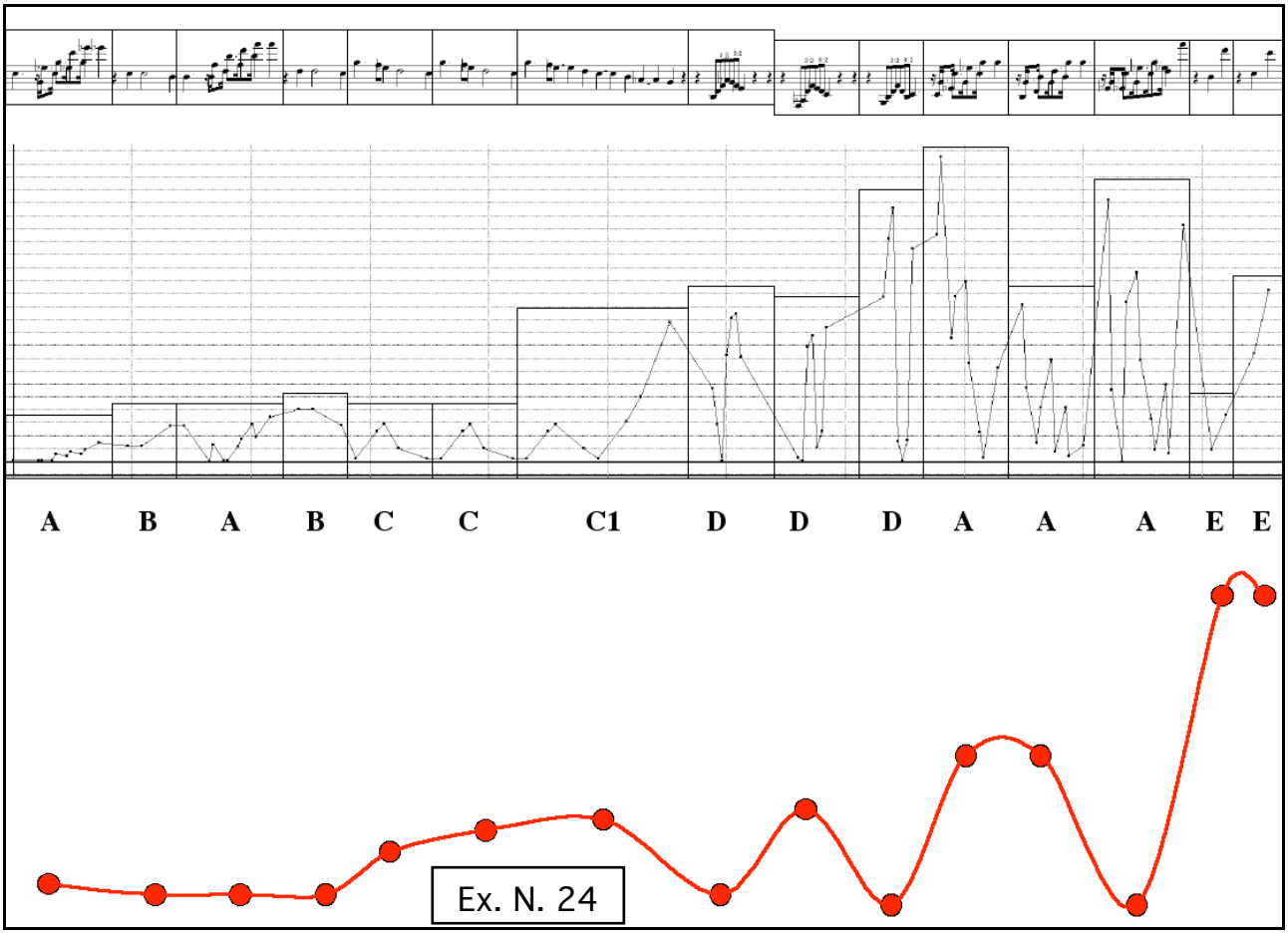


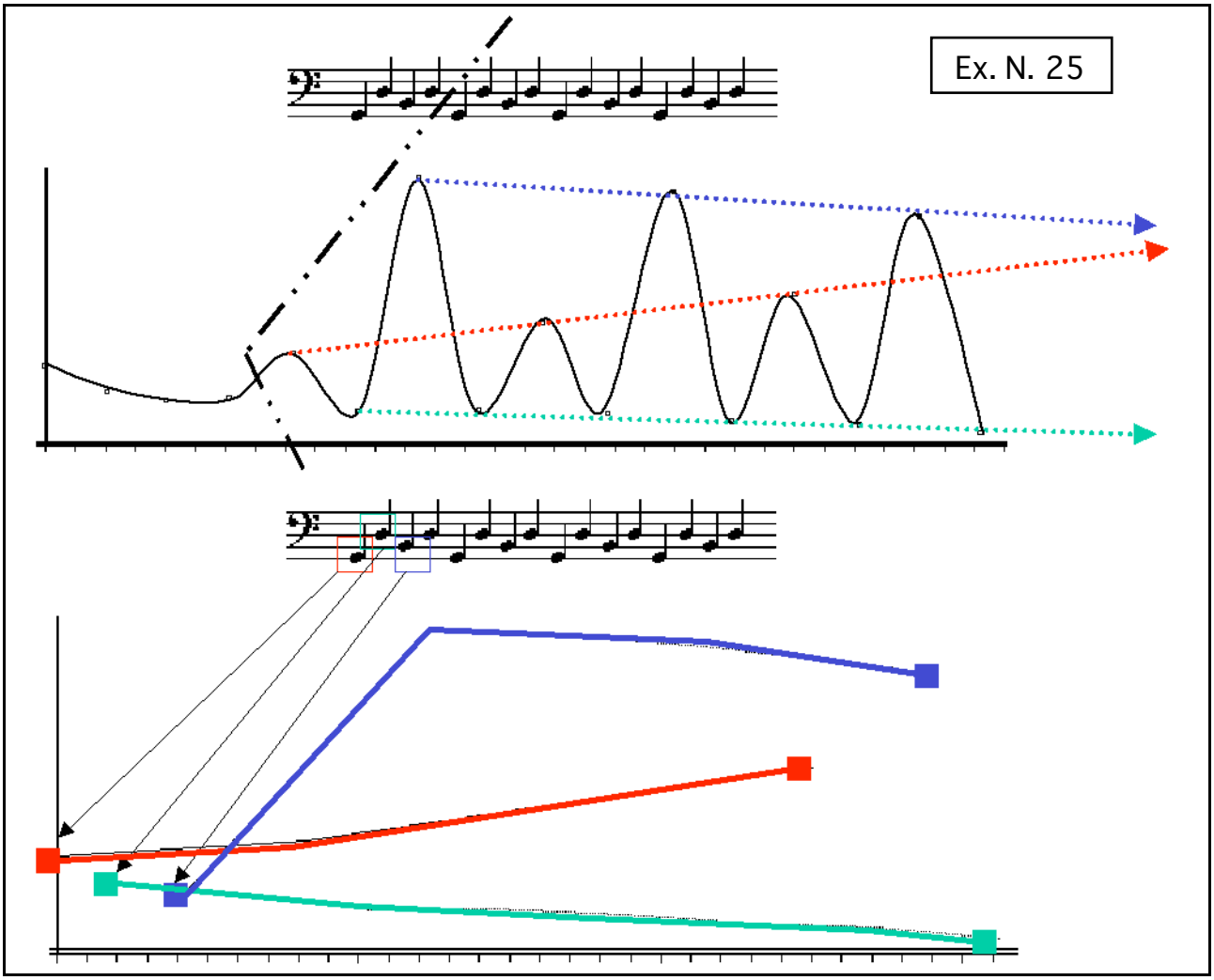


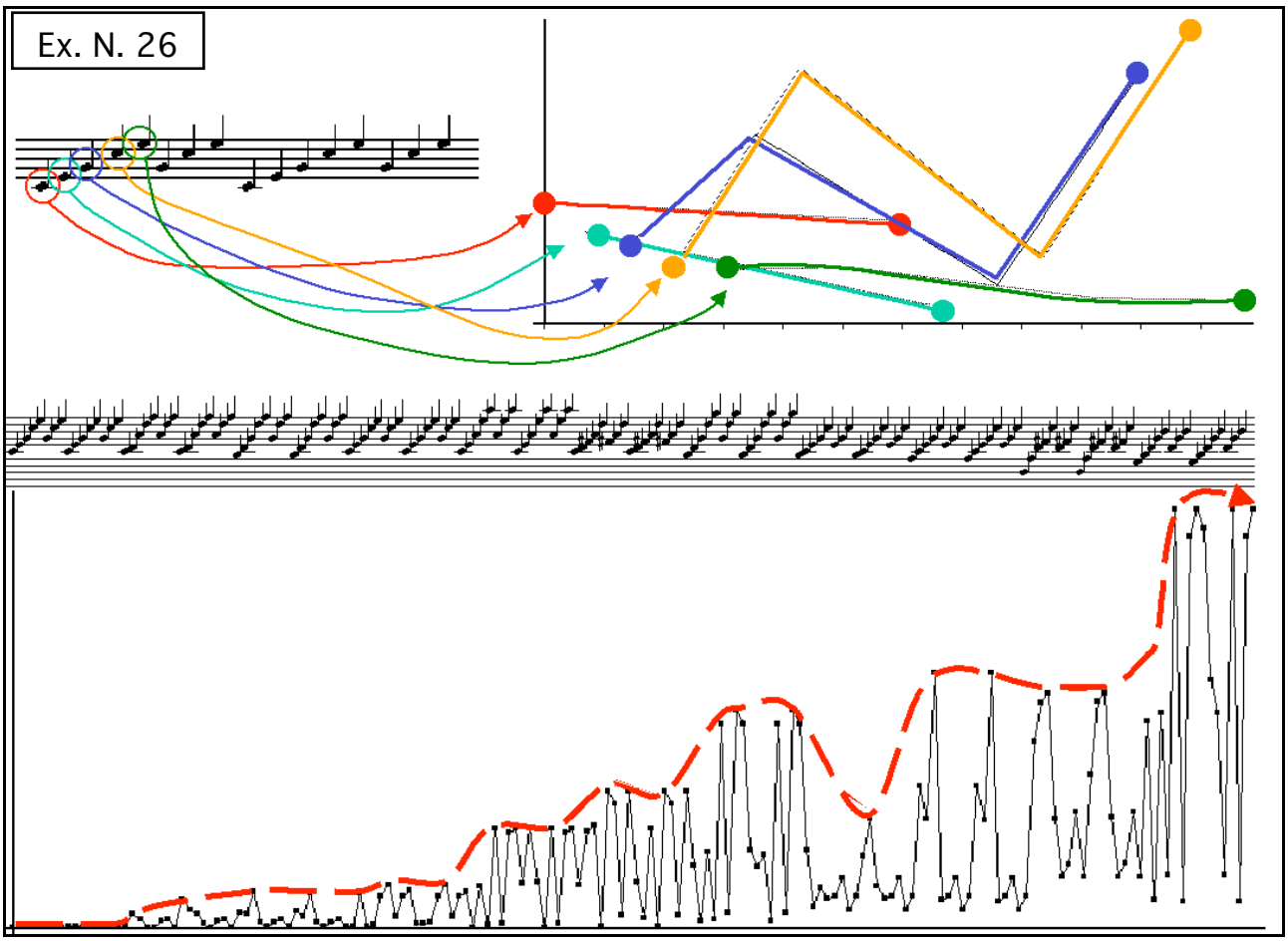
Structures	Energy
0 1 2 3 2	25 18 12 7 6
0 1 2 2 3	25 18 12 55 68
0 1 2 3 3	26 19 13 8 66
0 1 2 3 1	24 17 11 10 26
0 1 2 1 3	24 17 11 10 78
0 1 1 2 3	24 17 41 62 6
0 1 2 3 0	23 16 15 10 22
0 1 2 0 3	23 16 15 1 95
0 1 0 2 3	23 16 15 79 33
0 0 1 2 3	23 23 54 10 6

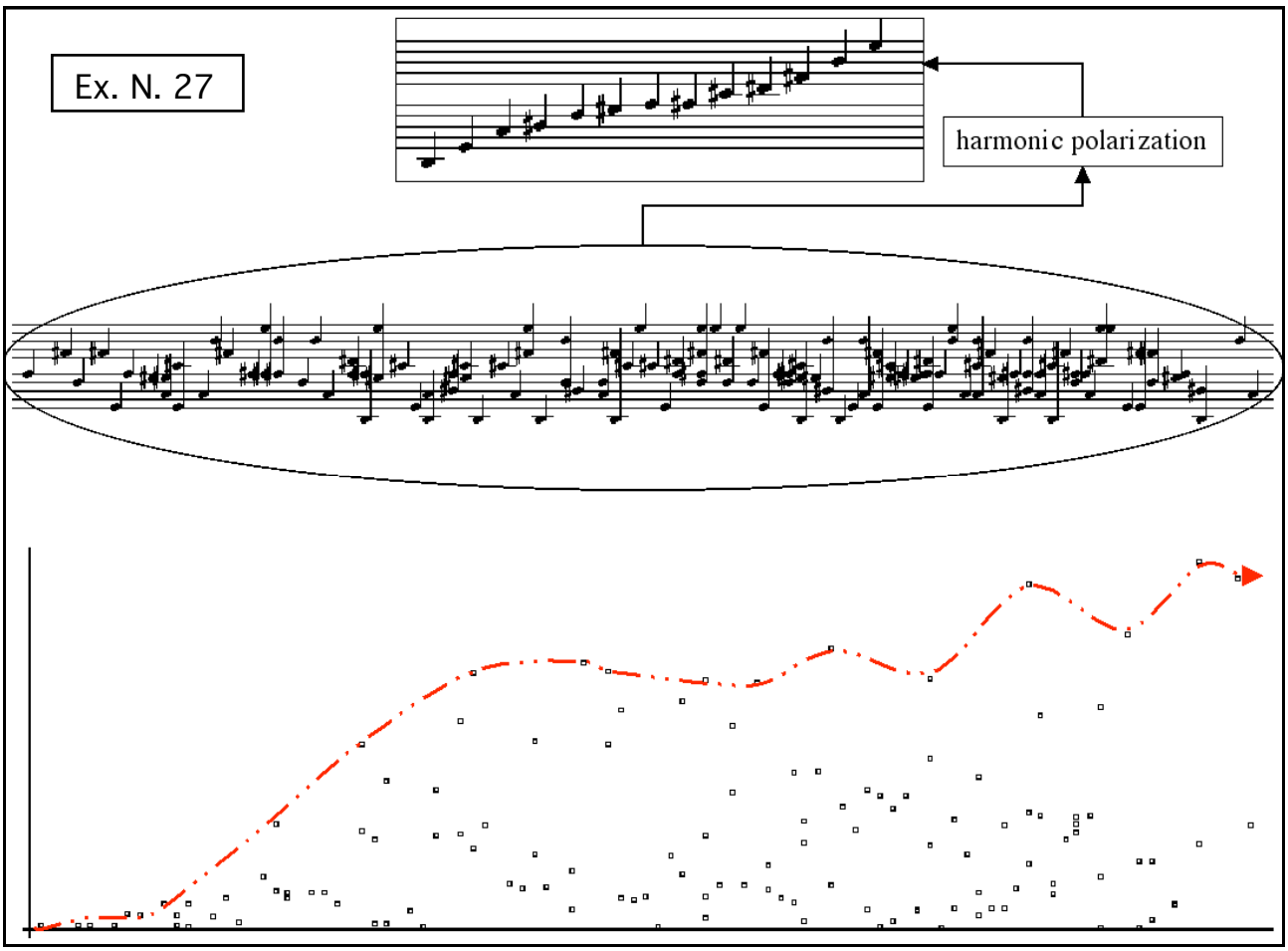
Ex. N. 22

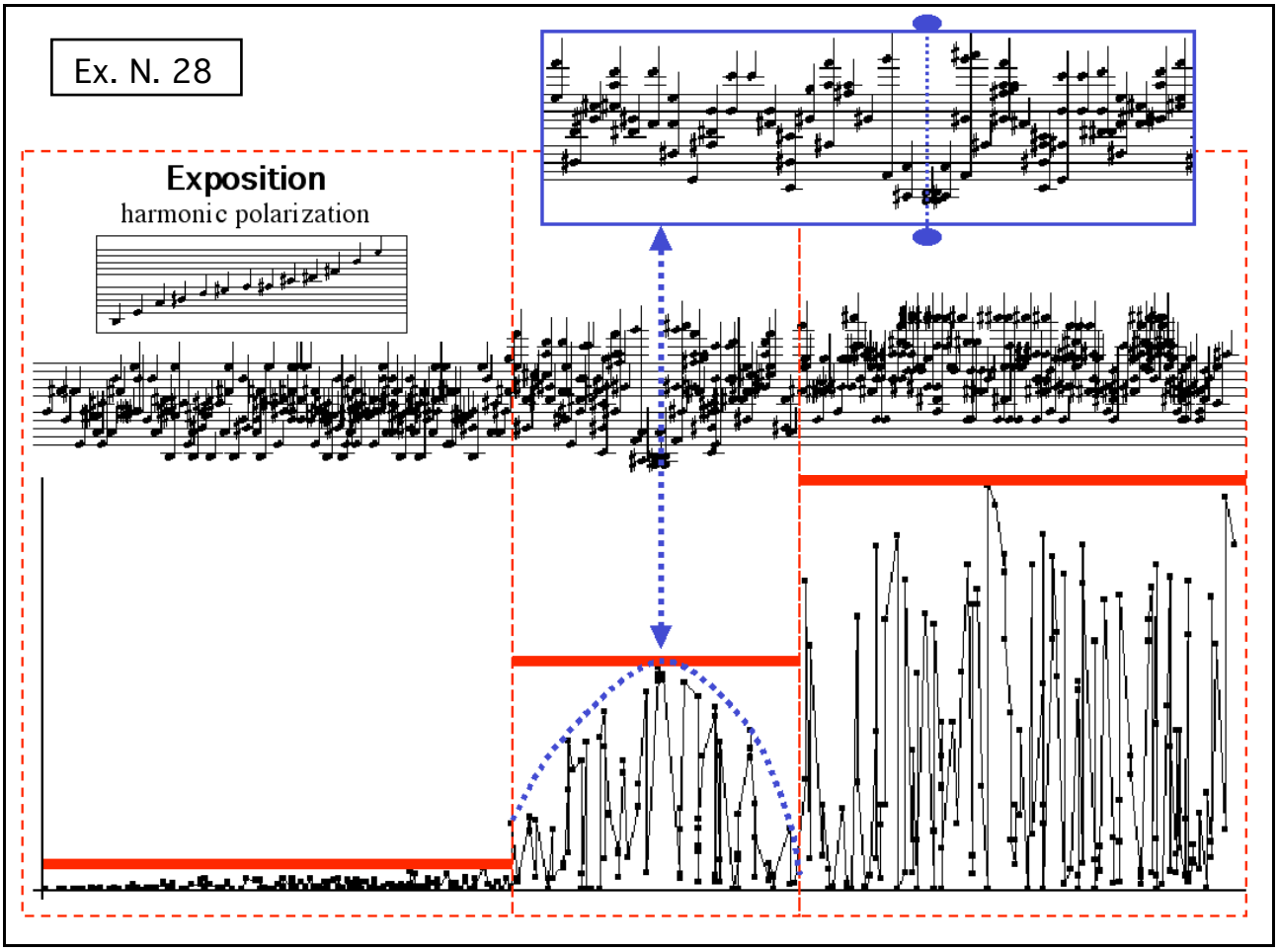

Mis. 1 --> 4
Mis. 5 --> 8
ff
Ex. N. 23

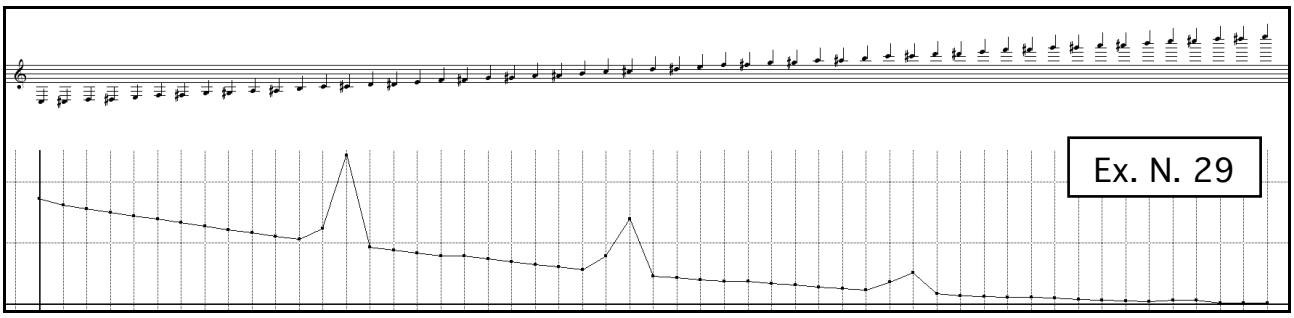

A B A B C C C1 D D D A A A E E
Ex. N. 24

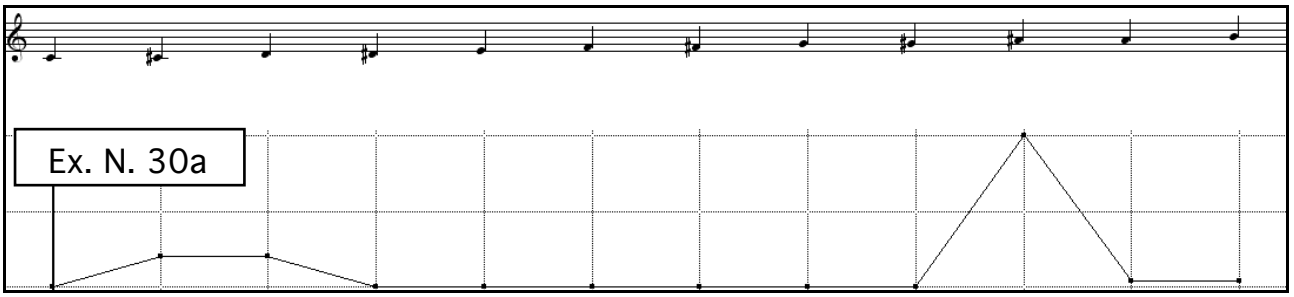

Ex. N. 25

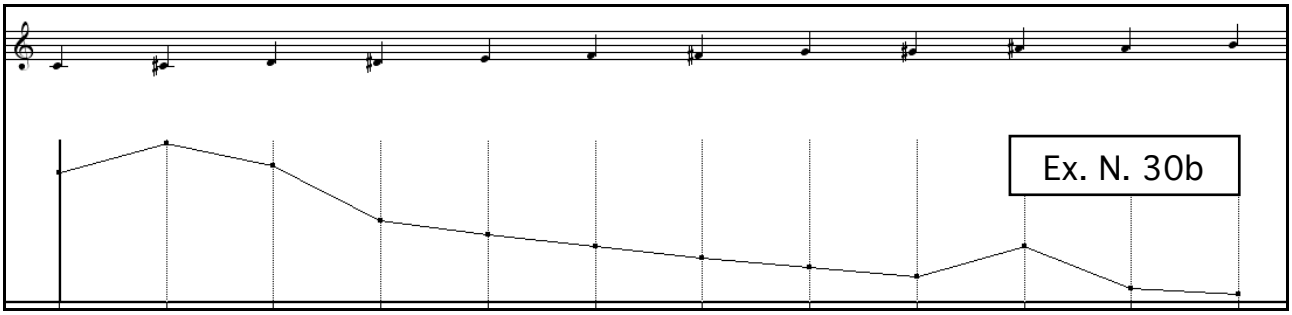

Ex. N. 26

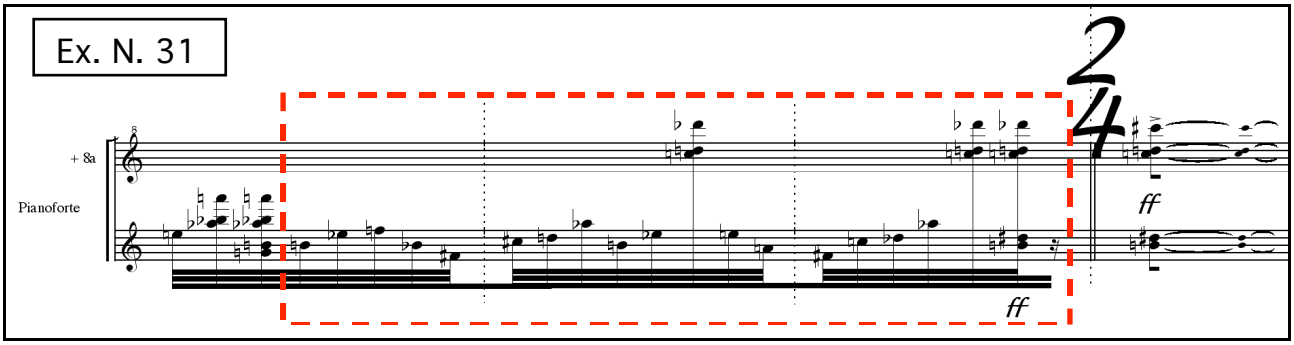

Ex. N. 27
harmonic polarization

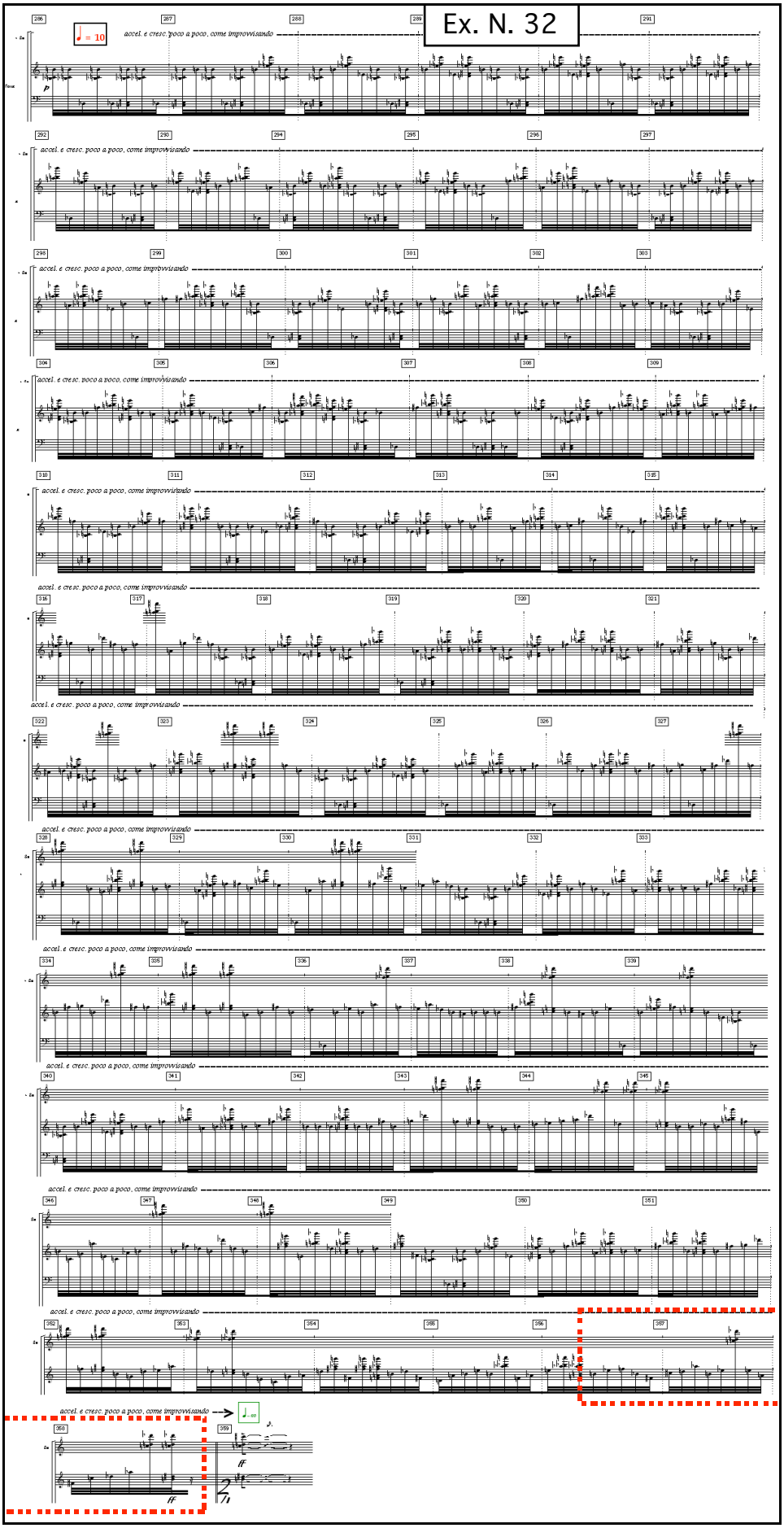

Ex. N. 28
Exposition
harmonic polarization


Ex. N. 29


Ex. N. 30a


Ex. N. 30b


Ex. N. 31
+ 8a
Pianoforte
ff
ff


Ex. N. 32
accel. e cresc. poco a poco, come improvvisando