Geometric Image Modelling of the Musical Object

Michel Naranjo and
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ABSTRACT

Contemporary music is often thought of in terms of musical objects where tonic notes, appropriately clustered, give a mass corresponding to height and tessitura criteria. A mathematical characterization of a musical phrase permits various visualization techniques of the figure. In accord with philosophical concepts, the pattern is perfectly represented by an envelope which is a tangent surface at a set of notes in a polyphonic score. Two image models are discussed in this paper. The first is based on the B-spline surfaces smoothing a discrete musical event set in the space: height-duration-timbre. The second performs the Discrete Fourier Transform signature of the digital musical signal.

Since Pierre Schaeffer's works, contemporary music is often thought of in terms of musical objects. Schematically tonic notes appropriately clustered do not give a chord, but a mass corresponding to height criteria and to a tessiture more or less fair [1]. Ligeti's second quartet, for example, can be seen as "a large moving shape of jagged texture and opaque tonal mist". Stephane Goldet translates this as "a pure music of tessitura, smoothed surface moving like a lava flow which little by little curdles . . . ", where "Ligeti breaks with the traditional discontinued register which exists between one instrument and the other and establishes the timbral tessitura notion where every timbral individual expression is exhausted" [2].

On account of the sound richness found by new musical material frequently associated with traditional orchestral instruments, the composer often needs tools that are necessary in structural description and monitoring. Philippe Manoury thinks the aid of Artificial Intelligence and cognitive science is indispensable [3]. Scientists easily sympathize with Marvin Minsky's suggestion that music is an ideal subject for the study of human knowledge representation [4]. It is not by chance that the first examples used to illustrate the perceptual rules of pattern came from music.

The Pattern, the Rhythm and the Image

The connection between pattern concepts and rhythm is ancient. Benveniste finds its etymological roots in Greek antiquity: Plato divided the primitive significance of pattern into a spatial, stable pattern (which later became the 'Gestalt notion' or figure) and a fluid pattern, or 'order in motion', which became the word 'rhythm' [5]. In terms of images, the figure is perfectly represented by an envelope determining a tangent surface on a set of discontinuous events. They define within this surface the singular points and that one fixes their continuity [6]. Rhythm provides motion in image. This metaphor introduces a relation between music and drawing. Using mathematical rules like philosophical concepts, the composer Iannis Xenakis abstracted patterns and then used them in musical and architectural creations. In "Metastasis" (1954), he introduced a simple relationship between drawing and music. In Brussels in 1958 this graphic musical imagery was transmuted into architecture in three-dimensional space where the lines of glissandi generated hyperbolic-parabolic surfaces on the Philipps Pavillion [7]. The assistant composer machine UPIC (in French: Unité Polyagogique Informatique du Centre d'Etudes de Mathématiques et Informatique Musicale) resembles a drawing board connected to electronic equipment capable of translating into sounds any graphic design (point, line, curve) traced on the drawing board with a special electronic pencil. The sonic equivalent of the draw-

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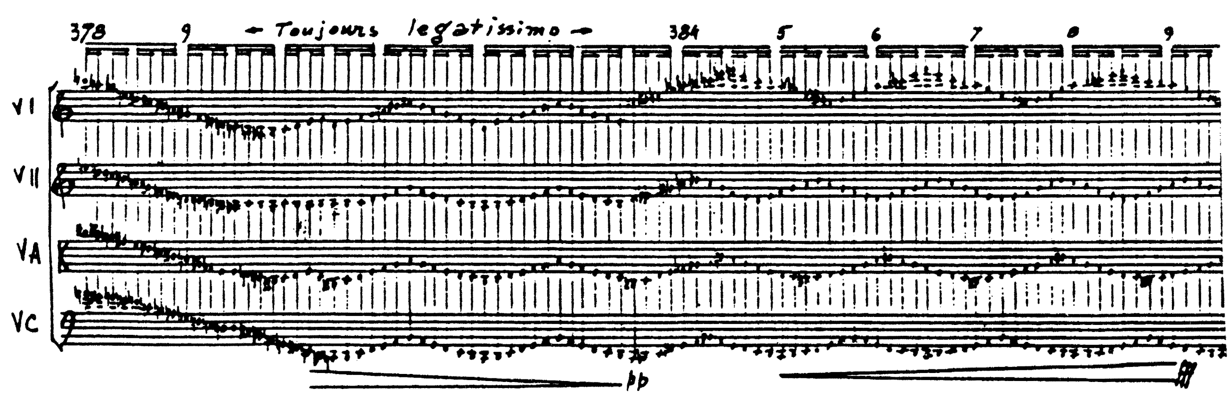
Fig. 1. "Tetras" by Iannis Xenakis, measures 378–389 (Salabert Editor).



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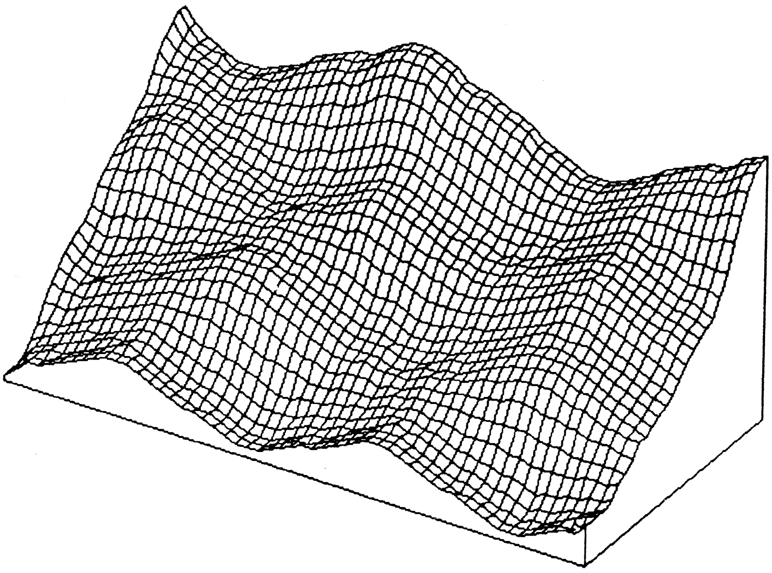


Fig. 2. Perception of mass of the string quartet.

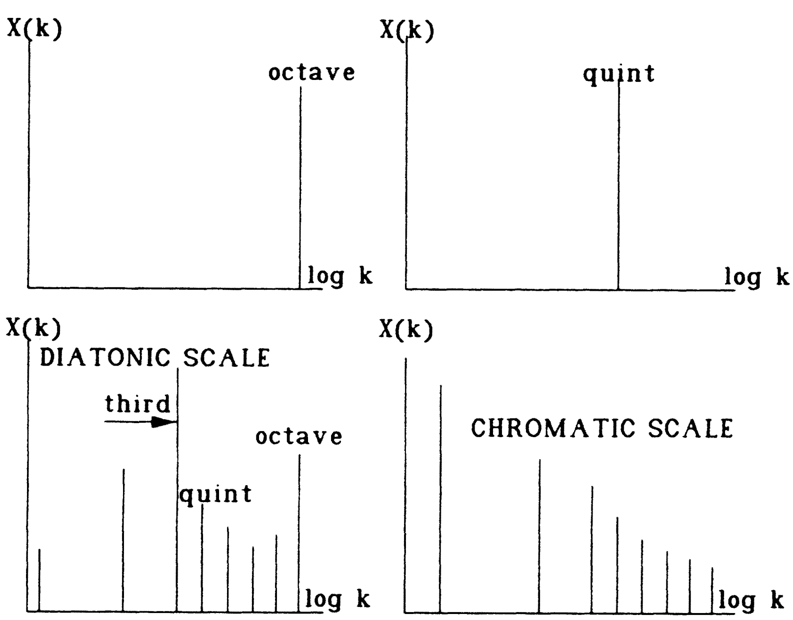


Fig. 3. Discrete Fourier Transform of an octaver, quint, diatonic and chromatic time-repetition.

ing is immediately calculated by the machine and made audible, permitting instantaneous control of the sound and sequence that have just been drawn. It is not, therefore, a matter of transforming the drawing into music, but actually conceiving the music graphically. The UPIC user quickly learns how to establish a relationship between the sounds and becomes capable of drawing these curves according to the sounds wished, even if the operator is a child.

Graphic Representation of Musical Knowledge

The recent evolution of graphic systems permits us to realize new composers' assistants where the plane representation is substituted for the 3-D space. A. Bogornovo and G. Hauss analyze the 3-D surface generated by two variable functions in order to control the resultant waveforms [8]. C. A. Pickover implemented a 3-D representation of melody patterns using topographic spectral distribution functions [9]. The dynamics of musical structures existing between several successive notes or sounds are being visualized by J.P. Boon and A. Noullez using 3-D schemata [10]. Musical aspects of fractal geometry are studied by B. Degazio in applications to automated musical composition [11].

In our representation system the images that we manipulate are synthesized using digital signal processing concepts; a melody is a signal in the plane: height-time, and a polyphonic phrase is a 2-D signal in the space: height-timbre-time. The composer introduces into the computer keyboard a set of discontinuous sound-components such as note sequences, their duration and their timbre. For instance, a phrase from Xenakis' "Tetras" (Fig. 1) is introduced line by line and each note is represented by three symbols: name-octave-value. The software transforms this string of characters into real points in the height-time plane and the timbre is given by the number of the line. David Ehresman and David Wessel show us that timbre can be classified by function of proximity criteria in a plane: spectral variations (brightness)–temporal evolution (attack) [12]. We believe it exists for an instrumental set, given a particular axis where all instrumental representative points are projected.

For reasons of simplicity and considering the timbral proximity of a string quartet, we have classified this timbre as a function of the register utilized in the partition. So the polyphonic phrase given in Fig. 1 is transformed into an array of points:

$[V_{ij}]$ where:

V_{ij} is the MIDI code of the note played during the

ith elementary duration by the

jth instrument.

In the example in Fig. 1, the elementary duration is the triple quaver and

$j = 1$ for violin 1,

$j = 2$ for violin 2,

$j = 3$ for alto,

$j = 4$ for cello.

This array of points constitutes the singular elements set of the phrase, and a smooth surface gives the continuity of the figure. We have used a B-spline algorithm [13] in order to obtain the parametric surface

$$Q_{44}(u,v) = \sum_{i=0}^{m} \sum_{j=0}^{n} N_{i,4}\,(u)_{j,4}(v)V_{ij}$$

where:

m is the total number of timbres,

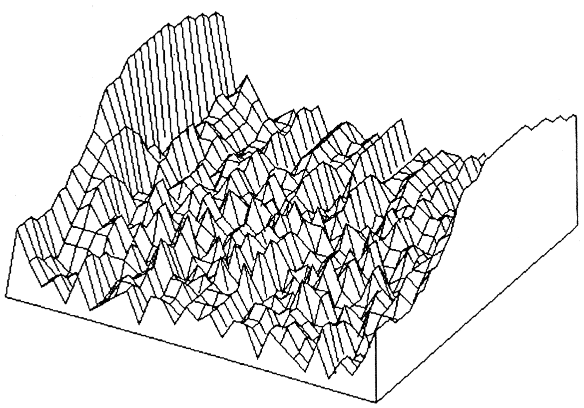


Fig. 4. Discrete Fourier Transform of "Tristan's Solo" by Wagner.

n is the total number of elementary durations,

$N_{i,4}$, $N_{j,4}$ are the order 4 basic functions for a cubic approximation of, respectively, the scale timbre and the scale duration given by the following recursive procedure [14]:

$N_{i,1}(u) = 1$ for $i \leq u \leq i+1$

$N_{i,1}(u) = 0$ otherwise.

$$N_{i,k}(u) = N_{i,\,k-1}(u) \cdot \frac{u-i}{k-1}$$

$$+ N_{i+1,\,k-1}(u) \cdot \frac{i+k-u}{k-1}$$

The synthesized image generated by the phrase given in Fig. 1 from measure 385 to measure 389 is given in Fig. 2. This image is a translation of the perception of mass where it exists as a shifting in the wave heights of the different instruments.

It is possible to utilize an inverse B-spline algorithm which gives us the singular geometric points of an image. In musical composition these points can be the height of the sounds. We shall use this representation for manipulating the musical phrase: first, detecting any particular line or curvature; second, manipulating the detected line or curvature as any rotation or translation; and, third, generating a new image derived from the initial image but made using the transformed line or curvature. This final work is now in progress [15].

Graphic Spectral Representation of the Musical Phrase

There are many instances where signal processing involves the measurement of spectra. For example, in speech recognition problems, spectrum analysis is usually a preliminary step to further acoustic processing [16]. Development of a comprehensive theory of spectrum analysis is made difficult by the fact that nearly all such measurements are taken over finite time intervals, and the length of this interval is usually determined through intuition and experience. In music, this difficulty is avoided because of the discrete nature of composition and because the elementary duration of a partition can be a basic sampling.

The Discrete Fourier Transform (DFT) is a mathematical function that performs the operation of breaking down a digital signal, such as a digitally recorded sound, into its spectrum. The DFT of a finite duration sequence of M heights is defined as

$$\{x(m)\},\ 0 \leq m \geq M-1$$

$$X(k) = \sum_{m=0}^{M-1} x(m) e^{-j\left(\frac{2\pi}{M}\right)mk}$$

$k = 0, 1, \ldots, M-1$ spectral scale sampling.

Figure 3 gives the DFT of an octaver, a quint, a tierce and a diatonic scale repetition. This experimentation shows the increased ray number and permits the spectral axis rating.

The image given in Fig. 4 is synthesized using the DFT of Wagner's melody "Tristan's Solo" (English horn). The third dimension is obtained by windowing the partition through a rectangular function.

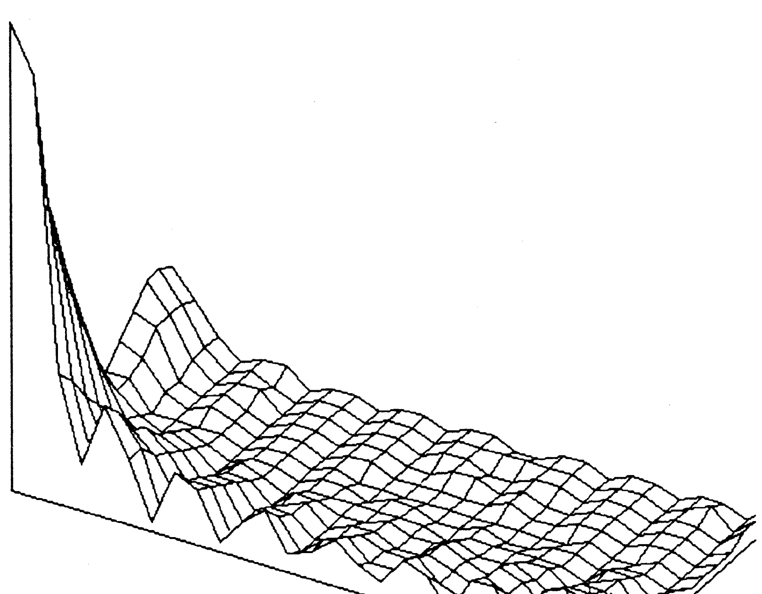
This result is comparable with images synthesized by Pickover but with analogic definition of the Fourier Transform [17]. Our transforms are computed with a radix 2 FFT's algorithm which reduces the computation time [18]. Our investigation continues toward a 2-D DFT transforming polyphonic phrase:

$$X(k,l) = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} x(m,n) e^{-j\left(\frac{2\pi}{M}\right)mk} e^{-j\left(\frac{2\pi}{N}\right)nl}$$

with a height sequence (M basic durations and N timbres),

$k = 0, 1, 2, \ldots, M-1,$

Fig. 5. This synthesized image represents the Discrete Fourier Transform of the "Tetras" phrase given in Fig. 2.



$l = 0, 1, 2, \ldots, N-1$.

We have illustrated this formula with the synthesized image of Fig. 5, which represents the DFT of the "Tetras" phrase given in Fig. 2. The chromatic aspect of the partition explains the important border rays.

Conclusion and Future Applications

Today Computer Science permits fundamental world transformation. Thus, musical research must be multidisciplinary in order to progress in this and other art forms concerned with scientific discipline.

Our research, materialized by a geometric representation of the musical object, could result in the realization of an assistant composer machine. Beyond the space representation height-timbre-time, it will be possible to introduce new dimensions: rhythm and dynamic exploration of the graphic possibilities of color and motion. This new composer's assistant is another step towards introducing the camera to the musical creation process [19].

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