MINOD to MIDI conversion was very fast and took about one minute for Bach's score and a few seconds for that of Beethoven's. To compare similar parameters of other recognition systems see (Bliestan & Baird, 1992, Fujinaga, 1988, Ingaki et al., 1992, Kato et al., 1992).

6. CONCLUSIONS

The paper describes MIDISCAN - a recognition system for printed music notation. Music notation recognition is a challenging problem in both fields: pattern recognition and knowledge representation. Music notation symbols, though simple and well characterized by their features, are arranged in sophisticated and confusing ways in real music notation, which makes recognition task highly difficult and still open for new ideas, as for example, fuzzy sets application in skew correction and stave location. On the other hand, the aim of the system: conversion of acquired printed music into playable MIDI format, requires special representation of music data. This representation should be adequate for both: source - notation oriented, and target - performance oriented music data. Regarding further development of this system, the effort should be put on following tasks: improving recognition methods, extending class of recognized objects, improving and extending music representation format.

See also (Aikin, 1994, Computing, 1994, Homere, 1994, Lindstrom, 1994) for reviews of MIDISCAN.

REFERENCES


A computer-aided object-oriented analysis

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Most of analytic tools developed during this century are exclusively devoted to pitch structure. It is however an evidence that, at least since Debussy, forming and linking complex abstract sound-objects are two decisive composing features. This paper exposes the basis of a computer-aided information and evaluation method which may bring out significant data for an objective analysis of the formal functions of these sound-objects. The Prelude La Cathédrale engloutie, by Debussy, exemplifies the way this method can contribute to high-level structure understanding.

1. The goal

Most of analytic tools developed during this century are exclusively devoted to the basic low-level components of music writing: pitches (or pitch classes). It is however an evidence that, at least since Debussy, forming and linking complex abstract sound-objects are two decisive composing features. Musicology and music theory generally approach object-oriented formal structures in a empirical way, ascertaining, without demonstrating, that they depend on the laws structuring pitches, considered as the most important, or, indeed, the unique formal dimension. This paper exposes the basis of a computer-aided method of information and evaluation of the components of the musical score which may bring out all the necessary data for an objective analysis of the formal functions of this sound-objects. Restricted — at least for the moment — to the piano literature, it is aided by a set of algorithms realized inside the Patchwork environment developed at the IRCAM Institute, Paris 1, as part of a PhD research on the 20th Century piano music.

2. The score reading

The source score has to be previously segmented in a sequence of units, basically defined by an homogeneous content; this homogeneity may be mainly due to the invariance of (most of) its elements, or to continuous teleological changes. The segmentation process is reached through a continuity break scanning of the score, at any desired level: macro-formal steps (texts, forms,ata), interruptions of pedal sustains and/or phrase slurs, continuity breaks in intensities, registers, rhythmical outlines, densities, etc. These rupture criteria do not depend on the thematical/periodical structure (phrases and other time-groupings), although coincidences may be founded, especially at higher hierarchical levels. Nevertheless, independence is fundamental to check connections between the object-level organization and (lower) ones. Each unit is thus a sole (written) sound-object [See fig.1 for a segmentation sample of the last bars of Debussy’s La Cathédrale engloutie]. Once segmented, the score is stored in several Midi files (one per segment, i.e. one per sound-object) to be exported to Patchwork [see, in the sample Patchwork window (fig.3), the Midi-import patches and Midi-object storage].

3. The sound-objects evaluation

Each object is analysed by a set of specific algorithmic patches, we name *interpreters*, connected in a hierarchically structured "frequency-modulation" bidimensional network [fig.2], where qualitative evaluations (in round boxes) modulate quantitative ones (square boxes), producing "synthetical" interpreters at a subsequent level.

The “8” dimension is exclusively concerned with achronic aspects of the musical writing: inside the "SPACE" sub-group of evaluation patches, the *AMBITUS* single interpreter calculates the range-filling rate of
the source file (related to the whole range of the piano), a quantitative value; and the REGISTER algorithm computes the number of filled registers (we count seven acoustic-defined registers in the piano), a qualitative distribution choice of the composer [the fig.3 shows how the SPACE interpreter do work]. The synthetic value of this two interpreters (SPACE output) is then submitted to minute analysis of vertical tone distribution (i.e. equidistant — or-and/or harmonic interlucic object-construction models), perceptual and/or cognitive consonance/dissonance, density rate. The second-level synthetic output value (SPECTRUM) is only retransformed if the EXOGENIC interpreter is active (for instance if the sustain or una corda pedal is used, or any global sound transformation, as in the pieces for prepared piano by John Cage). The last output value (collected in the S-box), rate of the achromatic sound complexity for the source object, is only a part of the analysis of the observed segment of the score.

The "T" network value rate acts as a qualitative modulator of the S contents and properties, according to the way the composer has distributed them in the object time-span. While the SPAN algorithm group quantify the relative duration of the object, by comparing it to the longest one (or the whole piece or section), the T-FILL group evaluates some decisive aspects of the sound-object: the time-density rate (the most frequent observed value in the source), the linearity rate (based on a equidistant onsetning model — the most regular rhythmic distribution of register intervals), the pitch-direction (a relative real number, function of the global directe condition of pitch-profile), a.o. As for the S dimenion, T-FILL is a quality modulator of SPAN, producing the final T value (collected in the T-box), which interacts with the S one to give a synthetic global sound-complexity rate for the source object (fig.2).

A whole segmented piece can be stored in a Patchwork sequence of buffers, as showed in fig.3 (left side, sample for 10 objects). A Patchwork specific set of boxes allows the connection of one or several evaluation patches, as desired. The output data is a numerical list for each connected interpreter. Each list correspond to the sequential evaluations of the connected sound-objects [see fig.4]. This lists contain significant information for analytic purposes, as it will be shown now to conclude.

4. The output data and the formal analysis

The fig. 5 and 6 are graphic representations of part of the lists table of the fig.4. The first graph displays the results of the evaluation of four interpreters for the last five sound-objects of La Cathédrale engloutie [see the musical score fig.1]. It shows how the composer realized the formal kinetics of the end of this Prelude by dialectically linking various parameters of the sound-objects: the progressive increase of the sound-space object (towards the end of the piece), the growing evolution of tone-density grid (which becomes more and more harmonic, the lowest the harmonic rate, the more harmonic the pitch distribution, the become more and more harmonic), the slight scattering of the pitch-density rate [space-density rate reads (0.45, between object c39 and o40), the slight scattering of the pitch-density rate [space-density rate reads (0.45, between object c39 and o40)]. It must be observed, too, that the vertical pitch-content tends to 0.32, 0.34, 0.45, 0.62, 0.75 (for the sequenced).

HARMONICITY algorithm reads: (0.29, 0.33, 0.12, 0.00, 0.09) for the sequenced.

The fig.6 shows the kind of relevant analytic data the program may return. It appears that Debussy, in this Prelude, systematically correlates the harmonic distribution of tones to the range-filling rate, in a way that the narrow-spaced objects have a strong wide-spaced objects tend to simulate an harmonic structure. While narrow-spaced ones have a strong

1 Patchwork is an interactive environment for computer assisted composition. It consists of a set of tools that help the composer generate and manipulate musical objects. Because of its ability to provide and to interact with the musical knowledge, it may allow the critical processing of information.

2 For a more comprehensive study of the space organization in this Prelude, see GUIQUE, D. (1995):

3 The software, although still in an experimental phase, is freely available for Patchwork owners.

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fig. 1: The final section of Debussy's La Cathédrale engloutie, segmented in five object-units (c39 to o43).
fig. 2: the upper-level network of the patches. S = "spatial" (i.e. achronic) evaluation group; T = "temporal" (i.e. diachronic) evaluation group; O = the source/target object (a MIDI file).
Fig 4: a listing cutout. O = label for the source files (i.e. the 43 sequential objects of La Cathédrale éclatée); int = intensity (i.e. MIDI velocity, scaled (0.0-1.0)); amb = range-filling rate; reg = register-density rate; reg-d: this density (as integer corresponding to the number of filled piano registers); space = average value (amb x reg); s-dens = space-density density (cont. next page)
Categorial Grammar and Harmonic Analysis

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Abstract

It is rather commonplace in everyday conversation to refer to the "Language of Music". However, we believe the whole apparatus already built for the analysis of natural language has not been yet as thoroughly used for the analysis of musical phenomena as it could have been. In this paper we present some initial ideas towards extending the application of this apparatus for the better understanding of "Music as Language".

In this paper, we apply some techniques from Categorial Grammar to represent a simple problem of music theory, which we believe nevertheless to be of widespread interest: functional harmonic analysis. We propose an encoding of the harmonic functions of chords as syntactic categories, and show how the generation of proofs of "harmonic well-formedness" of cadences can be implemented and used as a tool to verify and to display the functional harmonic structuring of cadences.

Keywords: music analysis, harmonic analysis, categorial grammar, syntactic calculus, substructural logics.

1 Introduction

It is commonplace in everyday conversation to refer to the "Language of Music". Indeed, the study of musical phenomena as linguistic objects has been developed by many authors (see e.g. [Be84, Ho80, Le83, Sc89]). In this article we present some initial ideas towards extending the application of this apparatus for the better understanding of "Music as Language". More specifically, we employ techniques from Categorial Grammar to represent a rather specific and simple problem of music theory, which we believe nevertheless to be of widespread interest: functional harmonic analysis [Br76].

The aim of Categorial Grammar [Be87, Be90, Be91, Lam58, Lam89] is the analysis of syntactic well-formedness of sentences. The fundamental concept underlying Categorial Grammar is that of syntactic categories, which are classes to which words in a sentence must belong. Syntactic categories can be organized as formulae of some substructural logic – e.g. the so-called Lambek Calculus [Lam58] – in such a way that syntactic well-formedness can be checked via an appropriate proof theory related to the logic.

In this paper we propose an encoding of the harmonic functions of chords as syntactic categories and show how the generation of proofs of "harmonic well-foundedness" of cadences can be implemented and used as a tool to verify and to display the functional harmonic structuring of cadences.

In section 2 we briefly review the concepts of Lambek Calculus that we need to use in the rest of the paper. In section 3 we introduce our encoding of harmonic functions of chords as syntactic categories, and show how they can be used to check and to display the functional harmonic structuring of cadences. In section 4 we present a simple FINLOG implementation for checking the harmonic well-foundedness of cadences and displaying functions of chords.