A Program for Topographic Analysis of Musical Texts
P. Grossi, G. Bertini

Summary

It may be interesting and useful, from the musicological and didactical point of view, to analyze the content of a musical text, or a part of it, at fixed instants (or points) and in an appropriate way, with the aim of studying and comparing harmonic, melodic, rhythmic or other structures.

The program described here operates in an interactive way on an adequately codified text previously stored in a file managed by a pre-existing musical software.

Information taken at a number of selected points of the text can be visualized on the video, printed on paper or heard by means of a real-time synthesizer. As an alternative, the result of a first analysis can be stored and re-processed later.

The selection standards of the information at different points of the text vary according to the result desired.

Apart from the description of the analysis program, a brief explanation is given of the type of code used in coding the text and the ways of execution of some of the musical software commands used during the analysis.

A demonstration will be given during the conference on the use of the program on a terminal linked to the CSHOC Institute of CNE in Pisa.
Introduction

1. Musical Tomography or Stratigraphy

New information control techniques acquired through the progress in informatics have enabled the designing and creation of logical instruments (currently defined as programs) to execute tasks which are costly for man with respect to time and application, with the rapidity and trustworthiness that electronic computers offer.

Besides, these techniques give a strong stimulation to imagination and inventiveness which, in the field of music, are important factors at all levels, from composition to performance, to didactics and musicological studies. Musicological analysis is one of the many topics taken up by a number of scholars for different objectives. Interesting works done with the help of the computer can be read, for instance, from existing literature, on the formulation of a music generation grammar, starting from a set of adequate analysis criteria of classical texts.

At present, a series of musicological analysis programs are being developed at CNUCE for various purposes (ANAL1, ANAL2, ANAL3, etc.).

The musical analysis program we are presenting here is ANAL1 and was designed and realized to analyze musical texts, or sections of them, by continuous or discontinuous points, according to different requirements to be decided every time.

By point, we mean an interval of time. It is basically a harmonic analysis even if, with the operational properties of the program and other existing routines, thematic and rhythmic studies on the text can be carried out.

In fact, at present, ANAL1 is structured and called in the same way as other routines, within an existing musical software, the Taurus (1, 2), installed at CNUCE in the last few years. A brief description of this software is given later. For the reading and storage of musical texts, existing routines and data structures of this software are used. Obviously, other resources of Taurus are also used, like management routines of a musical text library, processing routines and commands for sound execution on an audio terminal piloted by the computer.
ANAL1 and other musico-logical study routines ANAL2 and ANAL3 which will not be presented here, can easily be generalized and used to analyse texts codified and stored in different ways, after simple modifications of the program.

It is therefore necessary to return briefly to the operational properties of the routines used for the analysis and describe the type of code used to store the musical texts.
2. Some comments on the musical software used in the analysis procedure

The musical software TAURUS, mentioned in the introduction, forms the working environment of the analysis procedure. It can be considered as a musical language in absolute analogue to any type of computer and system of sound synthesis. It has a group of instructions used for the reading, storage processing and playing of musical texts, and for the automatic generation and management of the library.

At present, TAURUS is implemented on a large computing system and is structured in a version compatible with the physical properties of the audio terminal TAU2 (3). The terminal is linked on line to a computer system in time-sharing and can generate simultaneously 12 notes distributed among three outputs, each with dynamically programmable timbre. Harmonic additive synthesis is used with basic modification time of the volumes of the 7 formats up to the visible limit of the thousandth of a second.

TAURUS and TAU2 form a polyphonic, polyphonic system for real-time production of computer music, both for experimentation and didactic purposes.

Figure 1 shows a simplified diagram of the data structure in the processing program with which some TAURUS commands used in the analysis procedure interact: TEXT (EDR), SAVE, LOAD, CHAIN, INSERT, PLAY.

TEXT: The text is part of a group of commands for deterministic composition. Musical pieces can be stored by means of an alphanumeric keyboard. The notes are specified with the desired couple frequency and duration. The frequency is specified by the serial number of one of the 255 fundamental sounds of TAU2, or with a Latin or English name, with the numerical code, or with a frequency obtained from those available, while with the alphabetical code, only the frequency of the well-tuned scale can be obtained.

The duration is indicated by a real number, either a whole number or a fraction with 100 as the denominator. In practice, the duration is expressed in hundredths of a second.

The validity range of all the parameters (for the timer and the volume of the 3 available audio channels on the TAU2 as
well) are given in the Appendix.

In the following an example is given of the assignation of a series of notes of a voice of a traditional text.

**FLAD** - starts executing the conversion of the assigned text with the command YAT in the code of TANUS and reorders all the parameters locating these in suitable matrices in the work area of the storage of musical pieces (see figure 1).

**SAVE** - stores in the library all or part of the data of a musical piece found in the musical pieces area of TANUS.

**LOAD** - calls from the library the data of a piece or of a part of it and stores them in the musical pieces area.

**CHAIN** - calls from the library the data of one piece or of a part of it and concatenates then to existing data in the musical pieces area.

**INSERT** - calls from the library the data of a piece or of a part of it and overlays the existing data in the piece area with these data.

**PLAY** - sends the data of a text in the musical piece area, by means of an adequate code, to the audio terminal TAU2 to have them converted into audible signals. With this command, it is possible to apply dynamically (in real time) modifications to all the sound parameters, e.g. modulations of the volumes of the harmonics by means of tables containing pre-established wave forms, already available in the library or established by the user.

SAVE, LOAD, CHAIN, INSERT require the base or the sigla of the piece concerned and together with PLAY, accept specificative and/or limitative parameters according to the indications given here below.
A, B, C = channel area
F, D = fundamental frequency of musical notes
D = length of musical notes
T = formant volume (timbre)
V = intensity

Fig 1 - Simplified scheme of the data structures and main commands of TAUMUS used for analysis.
<table>
<thead>
<tr>
<th>Command</th>
<th>Name</th>
<th>Operational Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLAY</td>
<td></td>
<td>E, VOCI, P1, P2, P3, P4</td>
</tr>
<tr>
<td>SAVE</td>
<td>name/</td>
<td>ditto</td>
</tr>
<tr>
<td>LOAD</td>
<td>name/</td>
<td>ditto</td>
</tr>
<tr>
<td>CHAIN</td>
<td>name/</td>
<td>ditto</td>
</tr>
<tr>
<td>INSERT</td>
<td>name/</td>
<td>ditto</td>
</tr>
</tbody>
</table>

where the parameters have the following functions:

- **E** when used, orders the program to consider the values assigned to P2, P3, P4 as hundredths of a second, when excluded, such values indicate sound indexes.
- **VOCI** indicates the musical voices concerned. By default, all the voices of the piece are considered.
- **P1** indicates how many times the command is to be executed. By default the value 1 is assumed.
- **P2** indicates the starting point of the execution of the command. It can be considered as sound indexes or as hundredths of a second (with **E**).
- **P3** indicates the end of the execution of the command. It can be considered as sound indexes or hundredths of a second (with **E**).
- **P4** indicates the pace or the periodicity of the execution of the command. It can be considered as sound indexes or hundredths of a second (with **E**).

P1, P2, P3 are specified by integers; P4 can be specified by one or more integers. In this last case, i.e., when the functional features of P4 (P1, P2, P3) are concerned, it is possible to assign several values which are used alternatively to include or exclude parts of the piece concerned. In this case, the values can indicate groups of sounds of parts of the piece in hundredths of a second (with **E**). As each indexes as one record can contain can be assigned (max. 12 characters).
Examples:

1) **TH21 - EDIT**

   - Octave number
   - Duration
   - Volume
   - Tone

   A1 = J T 3, 4, 5, 6, 7, 8, 9, 10
   V1 5 24 56, 12 428 56, 24 47 A
   | | | | | | | |
   | Tone | Volume |

   Voice Harmonic vol. Pause name of the note

   The first six notes of the following text are assigned to the first voice of audio channel A, using the English code. A timbre and a basic volume are also assigned to audio channel A.

   \[ j = 120 \]

   \[ \text{\includegraphics[width=0.5\textwidth]{music_notes}} \]

2) **LOAD name2, 1001, 5024, (30, 55)**

   Transfer from the library of 30 hundredths/sec of the piece and exclusion of 55 hundredths/sec. from 2002 to 5024 hundredths/sec. of the chosen piece.

3) **SAVE name1... (2, 5, 7)**

   Storage in the library of 2 sounds, exclusion of 5, storage of 7, exclusion of 2, storage 5, etc...

4) **PLAY1... (3)**

   Storage of 3 sounds and exclusion of the same number from the beginning to the end of the text stored in the musical piece area.
3. ANALYZE Procedure

The tonographic analysis routine requires the definition of the points of study in terms of hundredths of a second. It operates on the text in the musical piece area of TAU2S, fetch the data, store them in another area of the storage and eventually transmit them to output where they are visualized or printed, according to the case. The points to be analyzed have to be represented by whole numbers separated by a comma and can occupy only one record (max. 150 characters). The operation of analysis can be repeated as many times as it is desired and every time with different values. The analysis is carried out in two ways:

a) Call from the library: the text or a part of it, specifying to the compiling routine ANALYZE the points to be analyzed, i.e., hundredths of a second, and identifying their exact temporal positions in the text.

b) Call from the library only the data of the text relative to the points to be analyzed (using the $P$ parameter of the command LOAD, following the ways described above) and asking the routine ANALYZE to analyze the data in terms of serial numbers of the points called.

In this last case, plastic texts can be done on the piece analyzed, by multiplying beforehand the duration of every event (point) analyzed by an adequate factor, to obtain a correct listening by means of an execution command of TAU2S, PLAY.

As an example, we are giving the outputs of the results of the analysis of a text (HOLDING variation, from J.S. Bach's aria) called from the library done in the above two ways.

The commands are followed by an explanatory comment preceded by several asterisks.

The display table of the result of the analysis gives in abscissa the basic scale of the well-tempered system, which is available on the TAU2, represented by the English code. The spaces between the letters indicate the alterations of the half-tone, while the number of the octave is placed above every letter. The stressing interval of the text (in hundredths of a second) and towards the letter is given in ordinate.

In every line, the voicings operated in that determined
Instant are given, indicated by their respective serial number (from 1 to V) and positioned in correspondence with the frequencies associated to them.
APPENDIX

We are listing here the sound parameters which can be introduced by the alphanumeric keyboard and called from the library of the TAU2-TAU202S system. The the validity range is also indicated.

Voices (A, B, C)

Musical notes which can be specified separately. They range from a minimum of 1 to a maximum of 12 and can be executed simultaneously. They are indicated with A1, A2, B1, B2, C1, C2 and have to be followed by the pair frequency and duration (f, t). If t is omitted, the last assigned value is taken.

Frequency (f)

If f < 525, f, positive whole number, or F in Latin code for English Bach.

f = 0, absence of sound for the corresponding voice; the values of frequencies f(t) generated by TAU2 are:

32, 78.5 (F) 510-425 Hertz with the basic interval ratio of 2 = 1.01943, i.e., one sixth of the tone of the real tempered scale.

Duration (t)

(}\) t = time number, whether whole number or a fraction in hundredths of a second.

T/48 indicates the durations of the notes in the piece area and send the data to TAU2 together with the relating values p, t/3031. The execution time of the sounds is calculated by TAU2 with t = D x t, where ΔT is the period of digital tonemeter, 15 T999HS, with the interval of 1 ms. Normally ΔT = 10 ms.

Wave form (T)

If A1, A2, ... AN, 0SAFST, A1, positive whole number.

AFi = 0; the ith format is absent; for every ΔT at least one AFi ≠ 0. AF1 = fundamental frequency value.

For every voice, the TAU2 hardware generates automatically the first 6 harmonics of the fundamental.

The wave form is defined for every audio channel specifying the relative values AFi of the 7 formats within a range of 7 values, to which correspond signal levels appropriately distributed on a scale in dB. If the set of f is omitted, the previous value is taken.
Volume (V)

\[ V_1, V_2, V_3, \text{ positive whole number.} \]

\[ 1 = 0, \text{ absence of sound for the corresponding audio} \]

channel; the intensity of the signal of output of every

audio channel can therefore be adjusted within \( 10 \) values of volume.

R.B.

During execution of the text, all the parameters (typically \( \text{\texttt{V}} \) and \( \text{\texttt{c}} \)) can be modified by means of algorithms and/or

envelope models available in the library of TAUMUS, or

provided by the user (commands \texttt{PLAY MODULATION} and \texttt{\texttt{c} \texttt{\textit{options}}}). For example, it is able to get "time varying spectra" with intervals of \( 0 \) sec, without limitations of

\texttt{time}.

References

1. G. Grossi - Modalita' operative del TAUMUS - Software di

gestione del TAU2. Collana "Studi Musicali", CNR del


2. T. Bologna, G. Grossi - Modalita' operative del

TAUMUS. Software di gestione del TAU2 (seconda edizione).

Collana "Studi Musicali" CNIC del CNIC, Fissa, pota Interme-

no, 156, 1979.


Terminal for Computer Music Experimentation. Proceedings