Computer-Graphic Tools for Music Analysis

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Abstract
A set of computer-graphic tools that help to analyze musical data visually in an intuitive and informative manner is described. We use DARMS-encoded compositions and a computer score representation designed for various analytic applications. The approach is flexible and accurate; many different types of information can be extracted easily and displayed with precision.

Introduction
The use of graphic techniques to illustrate aspects of musical scores dates back at least to Alfred O. Lorenz (1924), who used graphs to show the modulatory scheme for Wigner’s Ring Cycle. More recent examples are found in the seminal work of Cogan and Escot (1976) and various writings by other authors, e.g., Berry (1976), Howat (1983), Bernard (1987), and Roeder and Hamel (1989). In most cases these graphs were produced manually, a process that is time-consuming and prone to inaccuracies. Sound spectrum photographs (Cogan, 1984) and computer-generated sonograms (Waters and Ungvary, 1990) have also been used for visual documentation of musical structure. Although powerful, these techniques are quite specific in their utility and limited in flexibility.

Our approach uses DARMS-encoded compositions and a computer score representation (Brinkman, 1986 and 1990) designed for various analytic applications. The approach is powerful, flexible, and highly accurate, since many different types of information can be extracted easily and displayed with precision. The data, derived directly from the score structure, is passed through a program filter that generates a PostScript description of the graph, which can be displayed on a computer screen or printed on a high-resolution laser printer. The technique is extensible, and little new code is required to produce each new graph type. The following pages contain samples of our graphs; space limitations preclude presentation of all graph types.

Pitch Space and Time
Since music exists in time, it is impossible to perceive its structure all at once. Even the printed score shows only small portions of a large work on each page, and the vertical relationship among various instruments is only implicit to an expert score reader. A good graphic representation enables us to perceive many aspects of the musical “shape” of a composition. One type of graph that can be helpful plots pitch on the vertical axis and time on the horizontal. Figure 1 shows this representation of the first 26 measures of Béla Bartók’s fourth string quartet. The ticks on the vertical axis represent C in each octave from C₂ to C₇ (the third tick up from the bottom is C₆ or “middle C”). Each tick on the horizontal axis represents one whole-note unit of time. This graph is somewhat like a sonogram, except that it is derived from the score rather than from acoustic sounds, and

![Graph of Bartók's Fourth String Quartet](image.png)
only the fundamental frequency of each pitch is shown. The composer's utilization of acoustic space is clear but the individual lines are not, since it is impossible to differentiate the various instrumental parts and the rhythmic structure is difficult to follow.

Figure 2 is the score excerpt in what we call a Pianoplot. Here the lines representing pitches in each instrumental part are connected except across rests (we also introduce a short space between repeated notes). The musical structure and voice leading become much clearer, and features such as rhythmic interaction between parts, voice crossing, and points of imitation become obvious. Repetitive figures such as ostinatos are immediately apparent. This type of graph is similar to Cogan's "line drawings," but since they are generated by computer, music of great complexity and entire movements can be represented easily and accurately. We have graphed pieces by composers from Bach to Berio, and have found that stylistic differences are remarkably apparent in the visual representation.

Figures 5 and 8 show two complete movements—the fugue from Bartok's Music for Strings, Percussion, and Celesta (hereafter MSPC), and the first movement of Webern's Symphonic Op. 21. The general shape and many features of each movement can be seen much more easily than with a conventional score, since all pitches are in the correct vertical position relative to each other. We have found that even people who do not read music can follow these graphs while listening to the music, and that the visual representation helps to clarify many features, since the entire movement can be seen as a unit and details can be examined in any order desired. The subject entries, entries, and wedge design of MSPC are immediately apparent. One can also differentiate areas of relative motion and status, and can clearly perceive Bartok's technique of opening up gaps in registral space and then filling them in. The intentional symmetry in the codas is also clearly visible. Figure 6 is a pitch-space plot of MSPC. As each new pitch enters, a line is drawn to the end of the excerpt at the appropriate height. This graph shows how Bartok systematically opens up and fills in the chromatic pitch space.
which are clearly differentiated in the graph by changes in articulations, register, and axis of symmetry. For example, the first canon uses more short, detached notes, is at a lower register and is symmetrical about the horizontal axis on A_4. In the second canon more notes are connected, the register is higher, and the second half is a free retrograde of the first half, i.e., there is symmetry around a vertical axis.

Pitch-Class Distribution
There are many ways to plot pitch-class content in a piece. In short excerpts, pc integers can be placed above each attack point in a PartPlot. If we are not interested in voice leading, but do want to see register, we can plot pcs in register as in Figure 10, which shows clearly that the pitch classes in first canon of Webern’s Op. 21/I are registrally fixed and symmetrically disposed around pc 9. Another perspective is obtained by plotting pcs against time without regard to register. Figure 3 shows that in the beginning of Bartók’s fourth quartet the aggregate is completed quickly, followed by long stretches in which certain pcs are absent. In this graph horizontal lines indicate duration and pc integers indicate attack points. Alternately, pitch-class content, as a function of time or duration can be plotted using bar graphs. Again, the graph can be limited to specific parts or temporal portions of the score. The bar graph is also useful in visualizing tessitura if pitch frequency is displayed as a percentage of the total number of notes, arranged from high to low.

Rhythm, Dynamics, and Other Parameters
We have already seen that PartPlots show the rhythmic interaction between parts. We can also show the composite rhythm of all parts or selected parts of any musical segment. Figure 9 shows the composite rhythm of the first movement of Webern Op. 21; the different activity in the three double canons can be discerned. Figure 7 shows that the dynamic shape of MSCP/I reinforces the wedge-shaped compositional design. We have also used graphic techniques to show the row distribution in twelve-tone music. For example it is a simple matter to separate the canons in each double canon in the Webern movement, and then to display each row form separately.

David Huron (1989) proposed semblant motion and
onset synchrony as quantifiable measures of texture. The first group consists of contrapuntal motion into two types in which the pitch motions are either positively correlated (parallel and similar motion) or negatively correlated (contrary and oblique motion). The second is a measure of rhythmic diversity measured as the proportion of synchronous onset pairs. While his technique assigns a pair of values for embattled motion and onset synchrony to each member of several bodies of literature, we believe that these measures can be graphed separately as a function of time, and that this pair of graphs would be a useful addition to our arsenal of graphic techniques. We are also investigating approaches to a general measurement of textural density, and exploring various measurements of dissonance.

Conclusion

Graphic techniques are applicable to a large body of literature. Graphics can help us perceive the general textural, registral, and gestural "shape" of a composition. This overview, taken before (or after) the detail work of segmentation for other purposes whether set-theoretic, harmonic, or Schenkerian analysis, helps one to get a broad view of the composition and its gestures.

References