A Computer Project in Harmony Analysis

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For many theorists, a goal of computer-assisted music analysis has been to provide the results of conventional analytical techniques, such as harmonic analysis, with the speed and accuracy made possible by advanced technology. Such automation would dispense with routine work, leaving the analyst free for musical study on a higher level. More important, the use of a computer as an objective tool to test musical theories can introduce some quantitative evidence regarding topics subject to debate.

But before computer judgments will be accepted by the musical population at large, they must first prove themselves in less controversial settings, such as traditional harmonic analysis. The project described in this paper began with a seemingly innocuous request from an adviser for a small harmonic-analysis program as part of a larger package of analytical routines. Since then, the author has written two programs for harmonic analysis, one based on a strictly algorithmic approach, and one on a heuristic approach (Overs).

Previous research related to computer-assisted harmonic analysis reveals a gap between our intuitive and intellectual understanding of common-practice harmony. Normally, this gap has been accommodated
in computer work either by having a programmer limit the music studied (Bermant & Olive) or by accepting a faulty analysis in certain circumstances (Culbre, Jackson). Strangely, the source that best illuminated this problem was not an analysis program, but rather a composition project (Rothgeb) where John Rothgeb used a computer to harmonize unfigured masses according to eighteenth-century treatise rules. His conclusion was that these rules alone did not result in good solutions, largely due to insufficient consideration of tonal context.

In any simulation of a human thought process, there are two basic approaches. One, called algorithmic, involves a step-by-step, rigorous procedure that always yields the correct answer. A practical drawback of this method is that in many real-world situations, an algorithmic solution takes too much time. For example, in a one- or two-voice composition, all combinations of consecutive notes would have to be studied before the best interpretation was selected.

The algorithmic program demonstrated in this paper, strictly based on textbook definitions, leaves no room for error in non-modulating major music in which the entire chord is presented at once, with no non-chord tones. In doing so, a mathematical model of harmonic structure analogous to a music-theoretical model has been constructed. As an illustration, the following test examples, each composed in order to present different possibilities of diatonic chords, secondary dominants, other chromatic chords, and non-chord tones, will be examined.

Fig. 1 shows the first progression and its computer analysis.

This example, in C major, 4/4 time beginning on a dominant, is a straight-
Forward example of four-part harmony. Containing no notes that are
not in a chord, this passage was the basic test of program accuracy.

In the computer printout of results (shown in Fig. 1 below the
music), disordered chords appear in a form similar to their traditional
representation. Altered chords whose roots are notes in the scale
are indicated by the roman numeral, and Arabic numeral, if any, followed
by the shape of the chord in semitones above the lowest note. For
example, the second chord in the second measure, IV (G3F7), is an
altered IV chord with a shape of G7F7, i.e. three semitones and seven
semitones above the lowest note. Slashes stand for barlines, e.g.
"/ 1" marks the beginning of the first measure.

In the second test piece (Fig. 2), there are added complexities.
The piece has a key signature, begins on an upbeat, and is written
plastically, with from two to six notes in a chord. In addition,
there is a C-flat octave in measure two that does not belong to any
chord. This octave receives no roman numeral since it is not part of
a recognizable chord to the program. In the parentheses following the
dashes are the actual notes in the chord, reduced to within two octaves
of the lowest note. In reality, this chord is the combination of a
chord and a passing tone in the bass.

We have seen then that there is a logical basis for the basic
structures of harmonic analysis, and that this logic can be trans-
formed successfully into a computer program. However, it would be
unwise to arrive at the conclusion that an algorithmic solution exists
for music outside of a constrained subset since so many variables are
involved, many of which are at present determined intuitively by the
human analyst. In fact, by the time the program had reached its present level of complexity, it was actually taking more time than an experienced analyst would. It seemed, therefore, that while an algorithmic representation of harmonic practice was in itself a valuable contribution to music theory, a rigorous procedure was not an accurate simulation of human analytical thought processes.

The next program to be discussed presents a heuristic approach, that is, provides shortcuts that work most of the time. In using this program, the objective was to read in real music, and then print the same analysis that a musician would produce. Since modulation was outside the scope of this study, chords are labeled with letter-name root, quality, and inversion.

Results varied with the complexity of the music, with the best results coming from basically chordal textures. Even with a rather chordal Haydn Minuet, however, textbook rules alone proved hopelessly inadequate to create a harmonic analysis that would match a human's conclusions. For example, there is little question that the excerpt in Fig. 3, Haydn Minuet Op. 76, No. 3, measures 1-5 (Haydn), consists of two measures of C-major chords, one measure of G-minor chords, a measure of C-major chords, and a return to C-major chords.

For the computer, however, it was not such an easy matter. First, the opening four notes are unaccompanied. Should they be eliminated, possibly resulting in a missed chord, and then suggested one? At the other extreme, should all be considered chord tones, resulting in a C-major-seventh chord? We might instruct the
computer to ignore melodic neighbor configurations, but what if the
B were a chord tone?

Based on this measure and others, we arrived at an interesting
and new theory regarding the aural perception of sonorities. Namely,
for whatever reason, the listener expects to hear certain sonorities
rather than others; sounds that are expected need only be hinted at,
while unexpected chords must be clearly presented. From our research
with three whole pieces of music (one Baroque, one Classical, and one
Romantic), we found that the strongest chord is not the major triad,
as might be expected, but rather the major-minor (dominant) seventh
chord. Using just triads and seventh chords based on the major triad,
there seems to be a continuum from the major-minor seventh chord, which
need only be hinted at before being recognized, through the major triad,
which will be perceived unless there is a minor seventh above the root,
to the major-major seventh chord, which must be presented in such a
way that the seventh has no melodic explanation or lasts a long time.

While there is a danger of finding too many major-minor seventh
chords using the method outlined above, the overall results are superior.
For instance, in measure four, the final major-minor seventh chord is
questionable because of its short duration but is still within the domain
of acceptable answers for a person. On the other hand, analyzing measure
one as a major-major seventh chord would not be an acceptable human
answer.

A different problem encountered with computer applications to
harmonic analysis is the analysis of sonorities that cannot be arranged
in thirds, e.g., measure five, beat one. As a result of this measure
and others like it, a great difference was found in analyzing accepted
and unaccented non-harmonic tones. Specifically, the accented non-
chord tone displaces a chord tone and is often rhythmically simult-
aneous with chord tones. To handle accented non-chord tones, the
figured-bass concept of including chords containing accented dissonances
in the harmonic vocabulary was helpful. For example, the $\frac{7}{4}$ figure in
figured basses represents a triad with an accented dissonance. Similarly,
the chord tables for this program include $\frac{7}{4}$ and other such combina-
tions.

Upon finding an arrangement of notes corresponding to a potential
chord with an accented dissonance, the program searches for a possible
resolution following it. In Fig. 3, the resolution occurs in the second
chord of measure five. Note that the analysis itself does not mention
the accented non-chord tone since the labeling of non-chord tones is
not a function of this program.

In conclusion, the heuristic program reveals that music can devi-
ate from the theoretical model either by providing inconclusive evi-
dence (e.g. incomplete chords) or too much information (e.g. non-chord
tones). In addition to the features demonstrated here, other aspects
included in our model were duration, metric strength, harmonic rhythm,
root movement, bass movement, and the context of the chord before and
after a sonority in question.

In short, both the algorithmic and heuristic routines demonstrate
the complexity of harmonic analysis. Textbook rules worked fine in the
bothos of newly-composed test pieces but failed when applied directly
to actual music. Two main conclusions surfaced: first, traditional
rules do not provide sufficient consideration of the listener's expec-
tations; second, there is no established theory of organizing music
into harmonic patterns. For example, the traditional definition of
a non-harmonic tone is based on a given chord, but what if the chord
itself is unknown, as in actual analytical problems?

Armed with nothing but standard definitions, one is prone to
attempting to solve one situation with two unknowns. Hopefully, the work
described here will have benefits beyond computer applications. On
inspection, many problems faced with computerajar problems encountered
by students learning harmonic analysis. A more rigorous simulation of
analysis should help, therefore, in theory pedagogy.

A third conclusion is that rather than have the computer give
each chord one label, the program could provide for alternate analyses
of analogous passages. Then another program, assigning Roman numerals,
could select the possibilities making the most sense in the total con-
text. A more practical albeit less rigorous variation of the above
is to have an analyst eliminate unlikely solutions after examining
the possibilities provided by the program.

Overall, computer applications to harmonic analysis has revealed
how inadequate the traditional rules of harmony are per se. Yet, this
work has proved revealing if only because it underlines how little
we understand principles taken for granted by many. It is our hope
that future research will pursue this matter further.
References


