FORMANT REGIONS OF HARMONIC SPECTRA AS A MODEL FOR QUARTER-TONE CHORD VOICINGS

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ABSTRACT: This paper proposes a method of quarter-tone harmony that is derived from the analysis of harmonic spectra in which chord voicings are modeled on the formant regions of acoustic instruments. Furthermore, it proposes a method for creating an expressively fertile quarter-tone language using chord voicings of fixed register (after Boulez), in which electronic instruments are integrated with acoustic instruments. While this method of quarter-tone composition is related to French spectral composition, it differs from that school with respect to the following: it does not posit additive synthesis with harmonically rich instruments through the employment of spectrally derived harmonics, as it is highly debatable whether one can create the spectral fusion necessary for additive synthesis to occur, in such instances. Rather, spectra are used as a model for quarter-tone chord voicings. By using harmonic spectra and their formant regions as a model, one creates a harmonic language that makes musical and cognitive sense. The ultimate goal is to create a quarter-tone language that is expressively rich and (psychoacoustically) coherent.

The initial work for this method of quarter-tone harmony was developed using the object-oriented programming language MAX and the Yamaha SY77 synthesizer at the Center for New Music and Audio Technologies, University of California, Berkeley.

INTRODUCTION: Twentieth century Western music has seen the employment and development of many systems of microtonal tuning. Compositionally, microtones, rather than having a harmonic function, have been most commonly used by Western composers as a melodic ornamentation device. This frees the composer of the rather formidable task of having to compose and control microtonal harmonies. The most important issue of composing microtonal harmonies is the question of what to use as a model for chord voicings. Through the analysis of harmonic spectra and their formants, one can develop a model for microtonal chord voicings. Furthermore, through the analysis of harmonic spectra, a method for controlling subjective brightness in orchestration may also be developed. Using both spectrally derived harmonics and spectrally derived orchestration, a greater control of the integration of acoustic instruments with electronic instruments will be achieved.

HARMONIC SPECTRA AS A MODEL FOR QUARTER-TONE HARMONIES: By looking at how microtones occur naturally within harmonic spectra and their formant regions, one is supplied with a multitude of possible voicings for microtonal harmonies. The effects of microtones in such a harmonic context is best illustrated in the following example where a chord derived from the first eleven partials is heard first in semi-tone tuning, then in quarter-tone tuning and, finally, in eighth-tone tuning (Murail, 1991) (Example 1). Notice that the closer the tempered pitches come to approximating the actual frequencies of a harmonic spectrum, the less musically dissonant the spectrally derived chord becomes. Next, by taking a more chromatic chord derived from the middle formant regions of a low piano 'C' (48,399 Hz) (Example 2) and, again, listening to it through the same changes in tuning, one hears a similar lessening of musical dissonance occur. While it would be ideal to be able to perform the frequencies of a spectrum in a

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sporadically derived harmony exactly, one must compromise on the degree of tuning refinement. This compromise is due to the unpredictabilities of instrumental performance. That is, in most instances a quarter tone tuning should be possible in instrumental performance, whereas, in more rapid music, one should stay within the traditional semi-tone tuning to assure intonational integrity. Example 3, shows how close an approximation to the actual frequencies in the spectrum a quarter-tone tuning will give. The frequencies of the quarter-tone tunings were derived from the following equation by using $A = 27.5$ hertz as a base frequency:

$$\text{Frequency} = \text{Base Frequency} \times 124^n$$

(where $n$ is the number of 1/4 tone steps between the base frequency and the derived frequency).

Nevertheless, in compositions that use electronic instruments with acoustic instruments, one could integrate an eighth-tone tuning of the electronic instruments with quarter-tone tunings of the acoustic instruments. However, the danger of using too refined a tuning system with the electronics is that the amount of common harmonic tones available between the electronics and acoustics (in quarter-tones) will be greatly diminished. In such instances the pitches of the relatively rough quarter-tone tunings of the acoustic instruments may run the risk of contradicting the pitches within the more refined tuning of the electronics thus sabotaging any attempts for harmonic integration between the acoustic and electronic instruments. It should be stated at this point that the preference for using a quarter-tone tuning system comes directly out of instrumental practicalities rather than from a bias towards quarter-tone tunings.

Referring to the harmonic spectrum in Example 3, one sees the frequencies of several of the formants of a low E-flat (38.891 Hz) of the piano. Example 4 then takes these frequencies and rounds them off to the nearest quarter-tone. At this point we have the basic pitch material for part of a composition. The next step in composing with spectra would be to select various harmonies from the pitches contained within the formants of a spectrum.

**CHORD VOCINGS OF FIXED REGISTER:**

Using sporadically derived harmonies one can impose various types of compositional orderings to give consistency to the composition. One such imposed ordering would be to employ fixed pitch registrations — the freezing of pitches in a given register. This is a method borrowed from such serialists as Anton Webern and, more recently, by Pierre Boulez (Memorial for flute solo, two horns and six strings, and Derive for six instruments). In Memoriale, Boulez uses a symmetrical twelve-note harmony in which the pitches of the chord are frozen in the register between middle C and the B-flat an octave and a minor seventh higher. Boulez then composes various harmonies within this fixed register chord that are built around different rotations of a seven note row (Smith, 1991). These harmonies are also used as the basis for the melodic material of the solo flute part. Similarly, one can derive a series of harmonies from a spectrum which could, as with Boulez, provide the basis for melodic materials. In the opening two minute section of my piece Kyrie (for soprano solo, chamber orchestra and two Yamaha SY77 synthesizers) I derive six harmonies from the spectra of a low piano E-flat (38.891 Hz). The melodic material of the soprano is taken directly from the harmonies of the six chords. Example 5 shows the six chords. Chords two through five were derived by transposing the first chord onto each of the pitches in the first chord and then squeezing them into the chosen fixed register (D-sharp 5 to B5). The range of the fixed register of the opening section was selected because it gives regions where all of the instruments of the orchestra have some common register. The fixed register also serves as a practical aid to the soprano who should be able to latch onto her pitches through memory of where they occur registrally.

**CONTROLLING BRIGHTNESS IN ORCHESTRATION:**

Analysis of harmonic spectra may also give some clues about controlling subjective brightness in orchestration. That is, instruments which are perceived as sounding bright have harmonic structures in which higher partials are emphasized. This can be simulated in various ways with the orchestra. Using a string orchestra, for example, one can control the brightness in a very simple
way by emphasizing certain frequency regions, or by creating pseudo-formant regions (Smith, 1990), within the orchestration of a chord. This can be done simply by using the five types of bowed string timbres available (which, in order of subjective darkness to brightness, are: alto sul tasto, sul tasto, modo ordinario, half sul-ponticello and sul-ponticello) as well as five different subjective dynamic levels (pp, p, mp, mf and f). Example 6 shows how one can very simply shift a pseudo-formant region through a spectrally derived harmony. Analysis of harmonic spectra gives us the knowledge to predict the results of such placements of our pseudo-formant regions. Coupling this with the timbre space model (Wessel, 1979) one could simulate movements through a similar type of space through the use of pseudo-formants within the orchestra.

Traditional orchestration was concerned with contrasts between the dissimilar timbres of the different families of instruments in the orchestra. It was not until Arnold Schoenberg introduced the idea of Klangfarbenmelodie in the early part of the twentieth century that composers began to use sound combinations in orchestral color as a compositional device (Schoenberg, 1911). Pseudo-formants develop this idea by allowing one to move smoothly through, or step through, various gradations of subjective brightness. Such stepping is ideal for creating a convincing orchestral Klangfarbenmelodie.

An analysis of the electronic sounds that one wishes to employ compositionally will give one an idea for the placement of timbres in a way that will allow for a greater control of orchestral brightness. Likewise, an orchestration which best integrates electronics with the acoustic orchestra may be achieved by simulating the formant regions (through the use of pseudo-formants) of the electronic sounds in the orchestra.

CONCERNING HARMONIES DERIVED FROM SPECTRA AND SPECTRAL FUSION:
It is not my intention to use the orchestra or chamber ensemble as an additive synthesis engine by attempting to create new timbres through the employment of spectral harmonies, since it is highly debatable whether one can, at will, create the spectral fusion necessary for synthesis to occur, in such instances. This is because of the difficulties in performance of perfectly maintaining a steady pitch, or to have no fluctuation of pitch. Any fluctuation of pitch will cause a misalignment of the components in the attempted synthetic timbre and, at that point, timbral fusion will not be achieved.

CONCLUSIONS:
Through the analysis of harmonic spectra and their formants, one can develop a model for the voicing of cognate quarter-tones harmonies. Furthermore, one can impose such compositional ordering by fixed pitch registration to allow for greater compositional and expressive control in one's work. As well, through the employment of pseudo-formants in orchestration one can control the subjective brightness of orchestration. Last, through the combination of microtonal harmonic integration of spectral band harmonies and controlled orchestral brightness, one has the basic tools for the integration of live electronics with acoustic instruments.

REFERENCES:

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EXAM P L E 1

\begin{align*}
1/2 \text{ TONE} & \quad 1/4 \text{ TONE} & \quad 1/8 \text{ TONE} \\
\end{align*}

EXA M P L E 2

\begin{align*}
1/2 \text{ TONE} & \quad 1/4 \text{ TONE} & \quad 1/8 \text{ TONE} \\
\end{align*}

EXA M P L E 3

\begin{tabular}{|c|c|c|c|}
\hline
HARM & FREQ. & AMP. & 1/4 tone freq. \\
\hline
2 & 77.782 & .025709 & 77.8 \\
6 & 233.346 & .042035 & 233.08 \\
9 & 350.019 & .017177 & 349.23 \\
10 & 388.910 & .019107 & 399.00 \\
11 & 427.801 & .015331 & 427.47 \\
13 & 505.583 & .013980 & 508.35 \\
14 & 544.474 & .012126 & 538.58 \\
15 & 583.365 & .012126 & 587.33 \\
17 & 816.711 & .007725 & 806.96 \\
19 & 904.493 & .006613 & 905.79 \\
21 & 1011.166 & .004226 & 1016.71 \\
23 & 1088.948 & .003838 & 1077.17 \\
25 & 1127.839 & .003832 & 1141.22 \\
\hline
\end{tabular}

EXA M P L E 4

\begin{align*}
\end{align*}

EXA M P L E 5

\begin{align*}
\end{align*}

EXA M P L E 6

\begin{align*}
\end{align*}

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