Independent Portamento

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Many acoustic instruments create a harmonic series, a collection of sine-waves uniformly spaced in frequency. A listener aggregates such collections of sine-waves, or partials, into a single pitch. Some acoustic instruments allow portamento, the smooth glide from one pitch to another. For example, the violin and trombone. During acoustic portamento, each sine-wave transitions in parallel motion with the other members of the series. Of course, electronically generated sine-waves need not behave in this way.

A collection of pitches form a chord. For even simple chords, the composite collection of partials is large and complex. A sequence of chords presents a wealth of possibilities for each partial to transition between chords. Traditionally, acoustically, this transition is restricted to parallel motion of harmonic series. This thesis considers a collection of partials without acoustic analog: partials that transition independently between harmonic series. In so doing, chords a found to move in and out of 'focus'. At times the listener is able to aggregate partials into pitches and chords, while at other times the listener perceives an inharmonic collection of partials. Let this generalized portamento be "independent portamento."

Independent portamento disrupts the usual mechanisms of auditory stream segmentation. A listener may aggregate a collection of partials into a single pitch and then segment this pitch over time into a note, even if the collection of partials are gliding smoothly between various frequencies with no onset or offset to denote the beginning and end of the note. Individual partials can drift between pitches. Should a listener choose to concentrate on an individual partial, the listener will hear the partial disappear and reappear as it moves into and out of a harmonic series.

I. BACKGROUND

Previously I have explored similar ideas. In particular, for my 60×60 submission, *Partial Precept*, I used the vocoder analysis and resynthesis tool in Csound to resynthesize a recording of my speech such that the partials collapsed and expanded, moving in and out of a harmonic series. However, the flexibility of the vocoder tool was limited, and unwanted sonic artifacts were obvious.

For the present work I am using engineering software, MATLAB (for now, at least). This allows greater flexibility and does not compromise fidelity. Of course, MATLAB does not lend itself to expressive compositions, nor does it provide any facility for real-time performance. Nonetheless, I have developed a few tricks that allow MATLAB to sound less like a dentist's drill and more like a musical demonstration. It remains to be seen if I can move from 'musical demonstration' to 'music.'

Independent portamento first occurred to me while working on the Time-Frequency Visualization project. While working on that project, I was struck by how cluttered the spectrum of a chord usually is. Even for simple chords, for which a listener intuitively hears a few discrete pitches, the spectrum is densely cluttered with partials. If the dense clutter of partials is rearranged slightly, in just the right way, the listener may hear a completely different chord.

II. TRADITIONAL VS INDEPENDENT PORTAMENTO

With traditional portamento, a complete harmonic series smoothly glides from one pitch to another. Figure 1 shows a time-frequency image for two pitches (A440 and C♯556.9) that glide smoothly into two new pitches (F♯371.2 and D586.7). Each partial maintains the same position within a single harmonic series. At all times, two complete harmonic series are present. Hence a listener will hear two pitches that continuously transition to two new pitches.

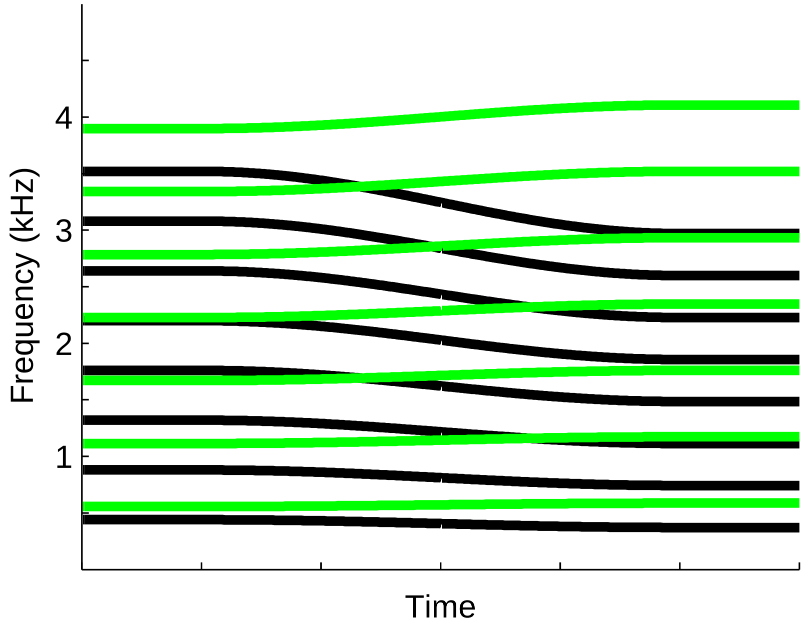

FIG. 1. An example of traditional portamento in which the pitch A440 transitions to F♯371.2 (black) and the pitch C♯556.9 transitions to D586.7 (green).

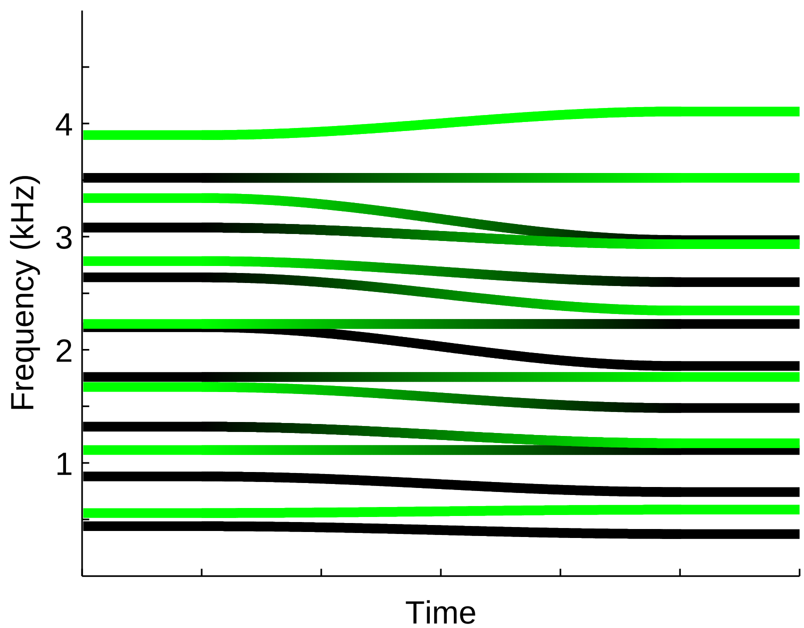

FIG. 2. An example of 'independent' portamento in which the pitches A440 (black) and C♯556.9 (green) transition to F♯371.2 (black) and D586.7 (green).

As a result of the parallel motion, several of the partials in Figure 1 intersect with each other. What if each partial was not required to maintain its position within a harmonic series, but instead could transition independently?

In particular, I am interested in 'lazy' and 'unaffiliated' partials. By 'unaffiliated' I mean that each partial need not remain within the same harmonic series. By 'lazy' I mean that each partial moves in frequency as little as possible: there is a set of candidate frequencies that each partial can choose from, and each partial chooses the nearest candidate.

Figure 2 shows the time-frequency image of the same pitches as Figure 1 using 'lazy and unaffiliated' portamento instead of traditional portamento. Note that none of the partials intersect each other. The partials are nearly stationary. Indeed, four of the partials are exactly constant (for example, the second harmonic of C♯556.9) equals the third harmonic of F♯371.2 equals 1,113.75 Hz, using just intonation). Each of these four partials begins the example associated with one harmonic series, and then changes affiliation to the other harmonic series. In spite of being constant, these four partials disappear into a pitch at either end of the example, and are only heard during the transition.

The coloring in Figures 1 & 2 indicate how a listener would aggregate the 15 partials into two pitches. Physically, the 15 partials are equivalent, the listener does the 'coloring.' In Figure 2, the regions where the color is neither black nor green indicate partials that are not aggregated into either pitch.

III. DEMONSTRATION

As it happens, it is difficult to synthesize a large collection of sine-waves that both move independently and adhere to a structure that is pleasing for the ear to aggregate and segment. And engineering software does not help matters. Nonetheless, I have rendered a demonstration that warrants a listen. A soundfile is posted at:

`http://www-personal.umich.edu/~nhadams/MAThesis`

This demonstration is a collection of up to 50 lazy and unaffiliated partials smoothly gliding between frequencies. Partials are turned on an off, and a rhythmic tremolo is applied, and that's it. Although simple in concept, writing the transition structure was tricky. The end result is hypnotic, potentially intriguing, probably annoying. This demonstration is algorithmic in that I did not choose specific frequencies or amplitudes. These decisions were relegated to a random number generator, and when I liked a result I saved the corresponding random seed. Frequencies were chosen from a fixed set, given by the harmonics of a repeating chord progression.

IV. HARMONY

The chord progression is from "Tempus Adest Floridum" ("It is time for flowering"), a spring carol first published in the 16th century, and used in the popular Christmas carol "Good King Wenceslas." The carol is not obvious during much of the demonstration, although near the end I let the rhythm of the tremolo sync up with the chord changes such that the tune becomes recognizable.

I chose this chord progression for several reasons. One, the chords are simple. The simplicity of the harmony contrasts with the inharmonic moments. This creates a different type of harmonic tension/release in which the tension is created not by a dissonant chord, but by the lack of a chord. Furthermore, the transition from tension (inharmonic) to resolution (harmonic) is entirely continuous. There are no abrupt changes to help the listener segment the auditory stream into events.

The use of continuous sine-waves, with no attack or decay, reminds me of pedal-notes in organ music. Solo organ music often consists of a powerful drone with melodies and harmonies embedded in it. Greek bag pipe music is another form of drone with accompaniment. Vast swaths of electronic music consist of a drone element with embellishments. The tune "Good King Wenceslas" is simple enough that the tonic pitch can be played continuously as a pedal-note without forming a strong dissonance. Thus it is easier to render a drone that appears simultaneously stationary and articulate a chord progression.

The tonic pitch is taken from the bell at St. Thomas Catholic Church on E. Kingsley St in Ann Arbor. For three years I lived within excellent range of this bell. St. Thomas often rang their bell, and the sound hung in the sky majestically. The fundamental frequency of the main pitch is about 411.3 Hz. For your listening pleasure, I appended a ringing of the bell to the end of the demonstration.

Just intonation is used: the ratio of any two pitches is a rational number. In this case, when multiple pitches are presented simultaneously, some harmonics overlap exactly. Hence the independent partials will sometimes collide and melt into each other, and reappear later when the partials to diverge.

V. WHAT NEXT: INSTRUMENT VS COMPOSITION?

In some sense, I view this work as developing an instrument more than writing a composition. The question becomes how to play the instrument? As is, the instrument is quite unwieldy, a clutter of MATLAB scripts. Much can be done to improve the programmability, although the instrument will never be playable within MATLAB.

With these thoughts in mind, here are the questions I have at this juncture:

- Who else has done this? While I can think of several prior composers and musical traditions that inform this idea, I am not aware of any other examples of this specific technique.
- Should I focus on developing the instrument, or focus on learning to play/program what I have? If I focus on learning to play/program the instrument as is, the I would first move into more adventurous harmonies, and then address the rhythmic monotony.
- Can independent portamento be implemented with real-time performance software? If I focus on developing the instrument, I will explore real-time options such as Pure Data or Max/MSP. I've had some experience with these programs, but not a lot. I'm not sure if the harmonic structure for controlling independent portamento can be implemented in PD. I'm also concerned about sound quality, as well as mathematical purity. PD and Max tend to be glitchy, and there are enough vagaries in the signal flow that I'm not confident the output of the instrument would truly be a collection of continuously evolving partials.

VI. BECAUSE I CAN: PHYSICAL FORMULATION OF PITCH

I have not used LaTeX since leaving Michigan. It is such a pleasure to use again that I am compelled to do some mathematical typesetting. Given a collection of k frequencies, $\mathbf{f} = [f_1, f_2 ... f_k]$, let $H(\mathcal{F}|\mathbf{f})$ be the logical function that indicates whether or not $\mathbf{f}$ adheres to a harmonic series with fundamental frequency $\mathcal{F}$. Specifically,

$$H(\mathcal{F}|\mathbf{f}) \triangleq \forall\, f \in \mathbf{f},\, \exists\, n \in \mathbb{Z}^+ : f = \mathcal{F}n \tag{1}$$

The event that a listener hears the pitch associated with fundamental frequency $\mathcal{F}$ when presented with a collection of frequencies $\mathbf{f}$ can then be defined as follows.

$$P(\mathcal{F}|\mathbf{f}) \triangleq H(\mathcal{F}|\mathbf{f}) \wedge \left(!\exists\, \mathcal{F}' > \mathcal{F} : H(\mathcal{F}'|\mathbf{f}) \right) \tag{2}$$

That is, $\mathcal{F}$ is the highest frequency that is an integer divisor of every element of $\mathbf{f}$.

Limitations of this formulation of pitch:

- Elements of $\mathbf{f}$ need not be exact integer multiples of $\mathcal{F}$
- Sparse collections $\mathbf{f}$ may be heard as separate pitches, for example $\mathbf{f} = [100Hz, 1kHz]$