Timbral Analysis:

Waveform, Spectrum and the Science of Music

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Abstract

The following is in one part, a study of several scientific aspects of music, namely waveform and instrumental spectrum, and in another part a detailed look into the monophonic instrumental spectrum of the flute and its relation to solo flute repertoire. Notwithstanding, this paper however is primarily a proposal for the development of a system of timbral analysis based on spectrum, waveform, and acoustic properties inherent of in the harmonic series and its relation to the characteristic, instruments, instrumental combinations, and music. The development of such a system of timbral analysis may provide several benefits to the applied and theoretical advancement of the science and art of music. 1) Provide a means of understanding waveform and harmonic spectrum of a sound source. Such an understanding of the very nature of sound may be used to determine pitch frequency, centricity, harmonic overtone content, as well as frequency spectrum and range of music. 2) May aid in the research and understanding of complex signal processing that may lead to advanced software applications designed to manipulate polyphonic music. 3) May allow solo instrumentalist the ability to isolate and study characteristic elements of human musicality inherent in performance. 4) May serve as a means of delineating formal structure in music. 5) May be used to create a comprehensive system of orchestration.

The 20th Century witnessed the invention of a plethora of new technologies and as a result, an explosion in the number of individuals who devoted their careers to music.[1] The advancement of recording, MIDI, and notation technologies provided composers, orchestrators, theorists, programmers, and performers with a multitude of new outlets for their work.[2] As the number of these outlets increased so too did the audiences attraction to them.[3] Consequently, music in the 21st century is increasingly characterized by the blurring of the boundaries that previously separated science from the art.

On the most basic level, sound must be described in fundamental principles of physics. On this planet, according to the laws of physics as we currently understand them, sound is produced by the vibration of an object, column of air, or string. The

[1] Strange, Allen. *Electronic Music Systems, Techniques and Controls.* Dubuque: Wm.C Brown, 1983.
[2] Anderton, Craig. MIDI for Musicians. New York: Amsco Publications
[3] Boom, Michael. *Music Through MIDI*. Redmond, WA: Microsoft Press, 1987.

vibrations rarefy and compress air molecules on a molecular level producing what we call a soundwave. This omnidirectional soundwave radiates away from the source of the vibration and travels at 1130 ft/sec in a room temperature environment. The soundwave is picked up by the folds of skin on the outside of our ears (a device that biologically severs as a means for humans to spatially locate the source of a sound). The tympanic membrane inside the ear then begins to vibrate in a sympathetic manner and directs the vibration to tiny bones in our inner ears that serve the function of being able to transform the vibrational impulse into electrochemical impulses used by human auditory cortex.

How the human brain processes these electrochemical signals is highly dependent on the type of sound (waveform, frequency spectrum and amplitude), environment (spatial location and envelope), anticipation of the listener (syntax and education), attribution and timbral association (personal experience), and overall aesthetic (social and cultural significance). Over the last decade, researchers in the area of music cognition have made great strides in the advancement of how a human being perceives sound and music.[4] Some researchers have determined patterns in relationship of sound/music and brainwave function. Others have identified formulae that can show a human electroencephalogram (EEG) and blood-flow responses to a given sound/music. [5] Individuals in areas of study such as music cognition and music therapy have even proven that music has the ability to alter brainwave patterns of an active listener.[6] Exciting advancements in regard to the science of soundwave/brainwave interaction are being made at an astonishing rate. Yet one area many of these studies seem to overlook is

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[4] Griffiths, Timothy et al., "Analysis of temporal structure in sound by the human brain." *Nature Neuroscience* 1:5 (September 1998)

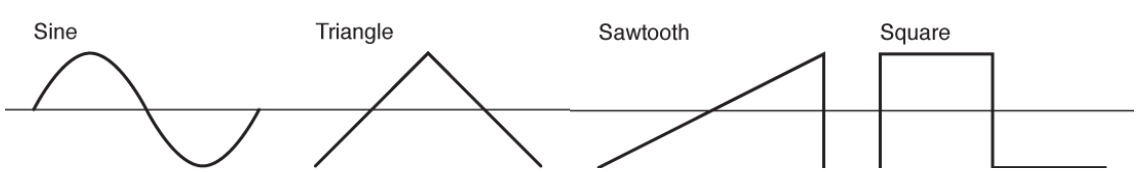
[5] Nakamura, Satoshi. "Analysis of music-brain interaction with simultaneous measurement of regional cerebral blood flow and electroencephalogram beta rhythm in human subjects." *Neuroscience Letters* 275 (1999) 222-226

[6] Lin, Yuan-Pin and Tzyy-Ping Jung. "EEG Dynamics during Music Appreciation." *First Annual International Conference of the IEEE EMBS* Minneapolis, Minnesota: September 2-6, 20099

the "type of sound" (i.e. waveform, frequency spectrum, and amplitude) or simply "timbre."

To understand timbre, we must first identify the basic construction of a soundwave, i.e. waveform, frequency spectrum, and amplitude. A waveform is the shape a soundwave takes while completing one cycle. (see figure 1) The frequency of a sound wave corresponds to the number of oscillations or cycles-per-second. One cycle-per-second is also known as 1 Hertz, abbreviated 1Hz. The frequency of the tone A4 is 440Hz, that is 440 cycles-per-second. To complicate matters further, waveforms may contain harmonic overtones and sidebands.[7] The sine wave is a pure waveform that contains no harmonic overtones. The clarinet produces a soundwave that is very close to a sine wave. A triangle wave contains odd numbered harmonics that dissipate rapidly at higher frequencies. The flute produces a soundwave very close to that of a triangle wave. The sawtooth wave contains odd and even numbered harmonics that dissipate slowly at higher frequencies. Reed instruments like the saxophone produce soundwave very close to that of the sawtooth wave. And the square wave contains odd harmonics that dissipate slowly at higher frequencies. Non-sympathetic waveforms from instrument combinations like the flute and oboe while unison produce a waveform very close to that of a square wave.[8]

Figure 1 – Simple Waveforms



[7] Appleton, Jon and Ronald Perera eds., *The Development ad Practice of Electronic Music*. Englewood Cliffs: Prentice-Hall, 1975.

[8] Howe, Hubert Jr. *Electronic Music Synthesis*. New York: WW.Norton and Company, 1975

The waveform, and thus, timbre of musical instruments are dependent on the construction of and material of the instrument. Mouthpieces, reeds, resonator shape, and nature of the vibrations in the object, air column, membrane or string all play a part of determining, and altering, the waveform of an instrument. Complex waveforms are formed by the interaction of several simpler waveforms and can be taken apart into their component waveforms in order to better understand their nature.[9] Figure 2a shows a complex waveform with three underlying component waves at deferring frequencies. These component waves are shown isolated in figures 2b, 2c, and 2d.[10]

Figure 2a – Complex Waveform

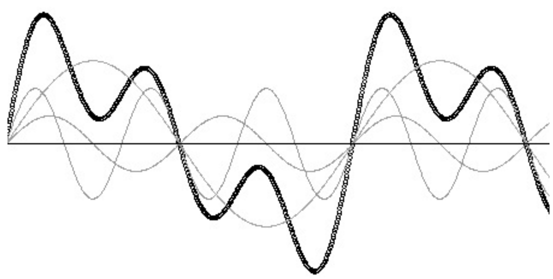


Figure 2b – Component 1

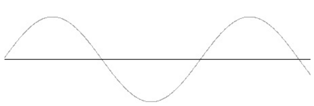
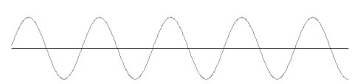


Figure 2c – Component 2

Figure 2d – Component 3



As a human, we perceive these waveforms not as individual components, but as a group. This tendency to hear and group harmonically sympathetic frequencies together is a natural process of the human brains ability to comprehend complex signals, and in the

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[9] Pellman, Samuel. *An Introduction to the Creation of Electroacoustic Music*. Belmont, CA: Wadsworth Publishing Company, 1994

[10] Askill, John. *Physics of Musical Sounds*. New York: Van Nostrand, 1979

case of this study, music.[11]

Research Methodology

In order to develop a method of using timbre and an analytical device, I first had the task of identifying and isolating characteristic elements of timbre. I accomplished this task by first acquiring a sophisticated software application developed by Cornell Laboratories Department of Ornithology Bioacoustics Research Program. The software named *Raven*, was designed to visually analyze the waveform, spectrum, and amplitude of bird song. Next, I systematically imported sound files of sampled orchestral instruments created using *Finale* and *Garritan's Personal Orchestra*. The sound files themselves were designed to provide a spectrogram of each orchestral instruments lower, middle and high registers using the tone "A" as a constant in each respective register. Additional spectrograms follow them indicating the extreme ranges of the instrument. (see appendix A).

As a means of supporting the data, I used second piece of software called *Baudline,* an advanced time-frequency analyzer with Fast Fourier Transform FFT spectrogram and digital signal processing, to a similar end. The data from this second experiment not only corroborated my initial spectrographic results, but also provided a higher resolution of the instruments waveforms and harmonic spectra. (see appendix B)

With the instruments basic timbre in visual form, classifying and categorizing the results would be the next logical step to developing a system of timbral analysis. Of course these initial results serve as a baseline reference, they are by no means comprehensive in their current form. Additional elements of timbre must be accounted for. Subcategories would need to be created that dealt with factors such as amplitude

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[11] Rossing, Thomas. *The Science of Sound.* Reading, MA: Addison-Wesley, 1982.

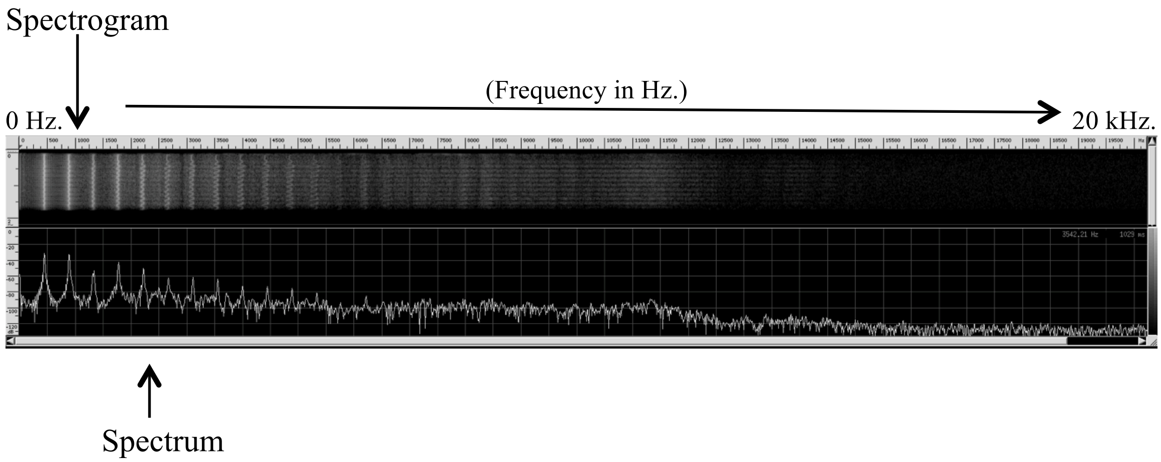
(dynamics), articulation, frequency modulation, and advanced special effects such as microtones, whistle-tones, glissandi, or key-clicks (among others) that are appropriate appropriate to the relevant instrument. Such an exhaustive undertaking is necessary to the development of a system of timbral analysis, yet unachievable for the purposes of this initial proposal. Nonetheless, armed with baseline spectrographic data of a large array of orchestral instruments, now came the time to isolate on aspect of this enormous subject for further study.

The Study – Flute, Waveform Spectrum and Solo Flute Repertoire

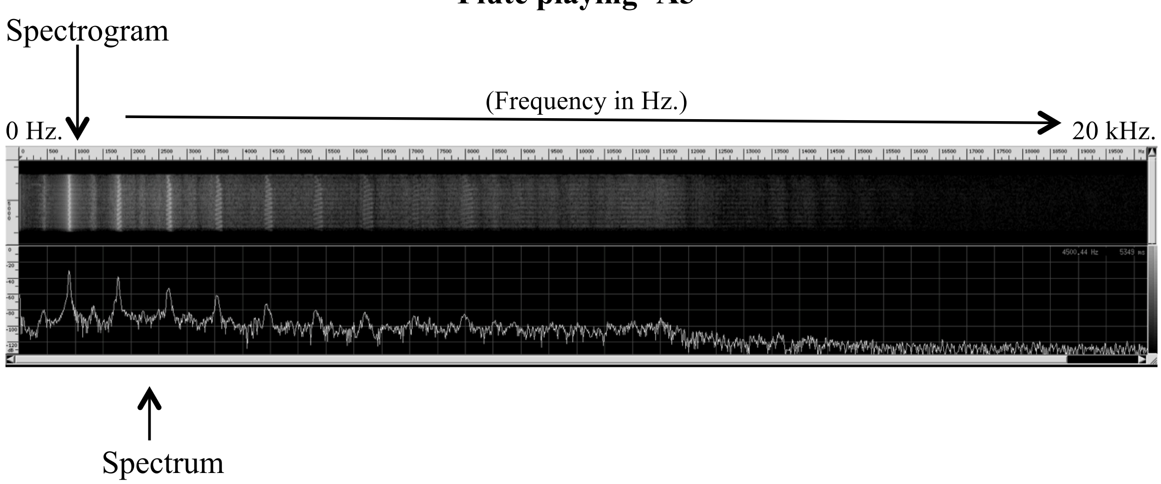
It was only natural to choose to isolate one particular monophonic instrument to use to determine the existence/non-existence of patterns and relationships between the waveform and the music in the effort to demonstrate the potential for the development of a subsequent comprehensive system of timbral analysis. So, why the flute? The answer, I chose the flute to study arbitrarily. Every instrument would need to be addressed eventually anyway, so the flute was just a matter of convenience. I wanted to study an instrument with a higher register, with an average harmonic spectrum, yet avoid a waveform that closely mirrors the sine wave, the clarinet being the latter. [12] The flute has all the characteristics I wanted, but with a waveform most like a triangle wave, and has a great variety of solo repertoire to work with. This isolated study represents only a tiny portion of the overall scope of such a system that will inevitably evolve. The following is the spectra and spectrograms of the flute, playing octave A's with the same amplitude in each of its registers.

[12] Backus John. *The Acoustical Foundation of Music.* New York: W.W. Norton, 1966

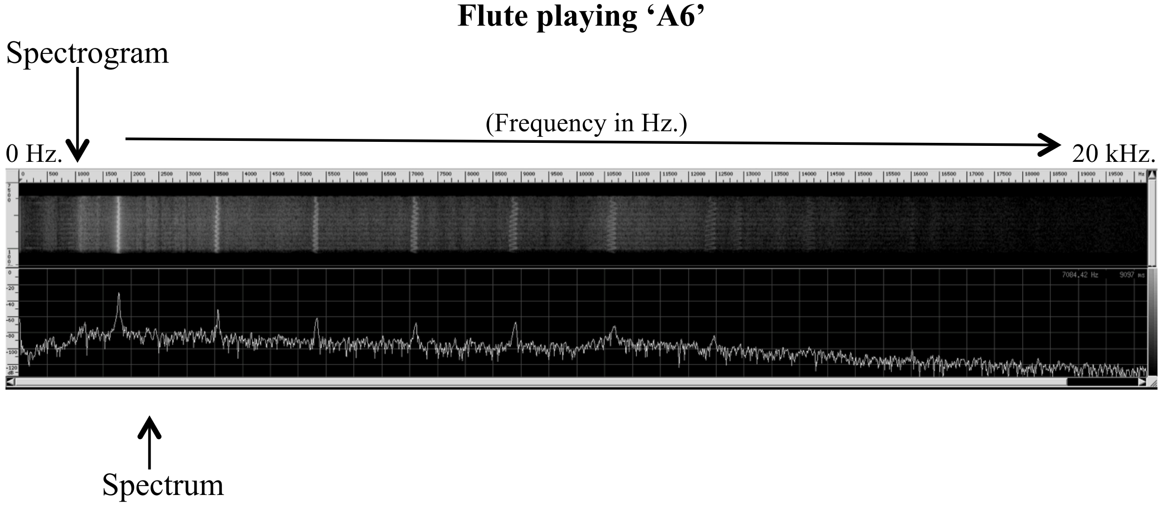
Flute playing ‘A4’



Flute playing ‘A5’

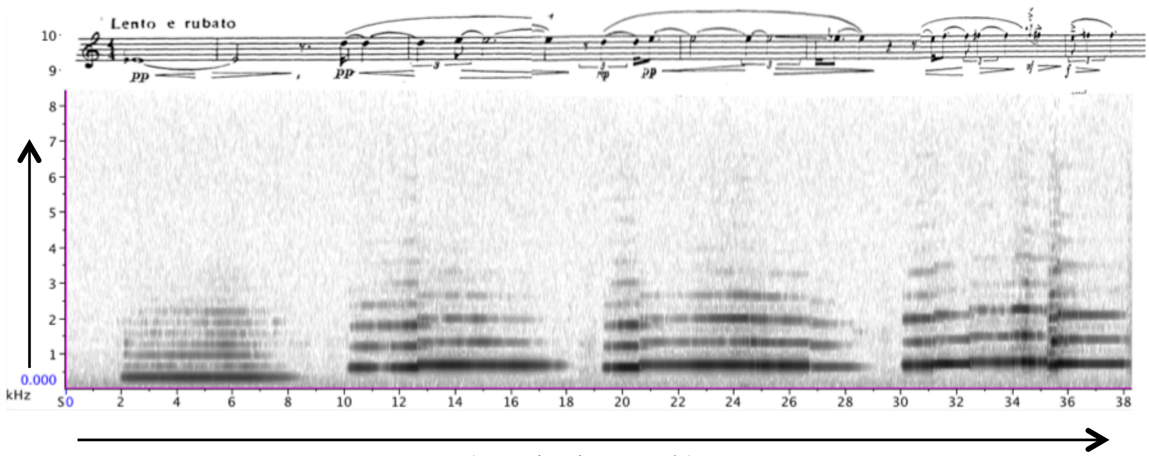


Flute playing ‘A6’



Note the overtones/sidebands as they change proportionally from over register to the next. The cutoff frequency, that is to say the harmonic overtone range, dissipates at approximately the same ratio as the fundamental. Also note the sub-harmonics (harmonics that appear under the frequency of the fundamental) are produced when the flute is playing A5 and A6. (For additional waveforms, see appendix B). Now that we have an idea of the spectral characteristics of the flute, lets look at how they appear in some music.

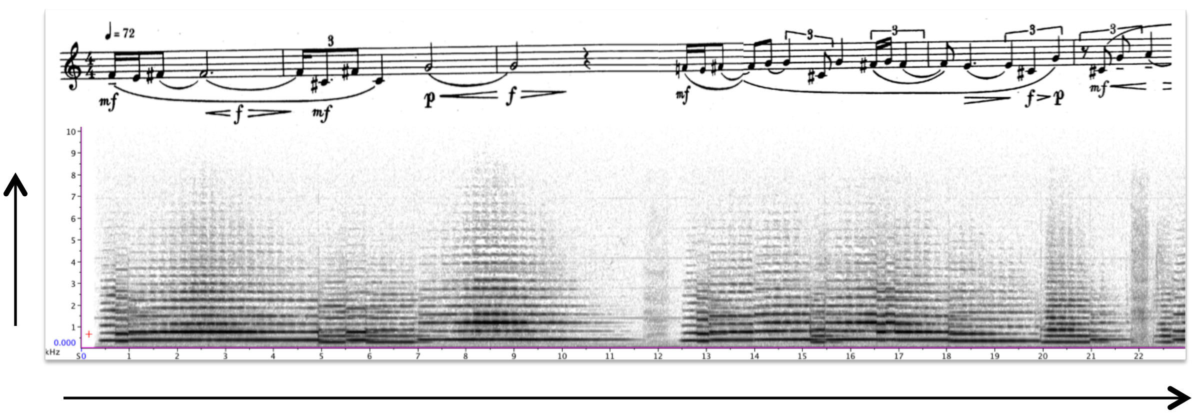
Figure 3 - Fukushima's, *Mei* mm. 1-8



(Duration in seconds)

An excellent place to start a musical timbral analysis would be with an example with long slow note values. In this case, we have selected Kazuo Fukushima's Flute Solo, *Mei*. The color of the spectrogram has been inverted to provide the easy visual identification of the spectra. Additionally, the corresponding measures of the score appear above the spectrogram (see figure 3). First observation, the flute's characteristic spectrum is clearly visible, as well as the long note values and changes from one frequency to another. You can see the first note value in the flutes lowest range appears in the expected spectra of the instruments lowest register, while the remaining notes appear in the instruments lower- middle register. In this example, the harmonic spectrum never exceeds 7 kHz. Furthermore, the dynamics such as crescendo and decrescendo are apparent in the spectrogram and correspond to the markings in the score. Another aspect that becomes apparent in the spectrogram is the phrasing and rests, indicated by empty space between note values. (additional spectrograms on this and other musical examples, see appendix C).

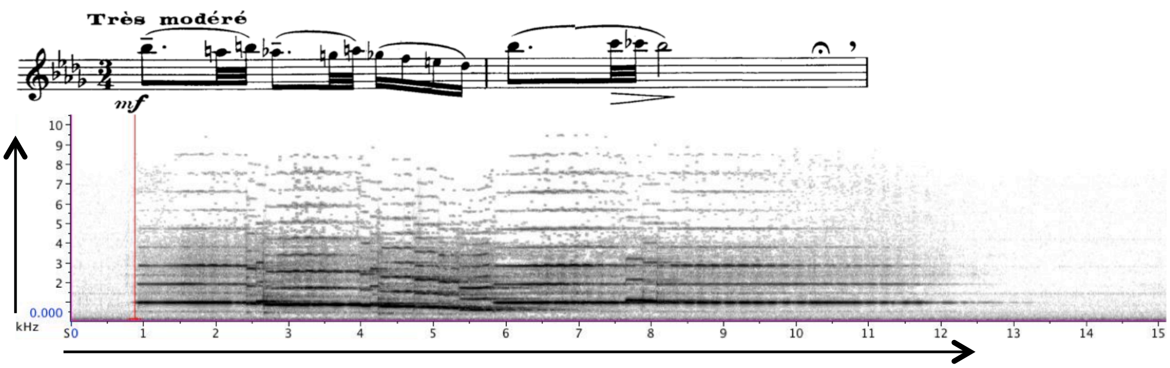
Figure 4 - Varese's, *Density 21.5* mm.1-6



(Duration in seconds)

In order to establish a pattern, we must study a number of musical examples. Another musical example that still contains mainly longer duration with a few shorter values is the flute solo *Density 21.5*, by Edgard Varèse. (see figure 4). In this analysis, you can still clearly see the long note values as they change from one frequency to another, but now you can see the quicker note values as they appear in the spectrogram. They appear as brief up and down "shifts." Note that the spectrum appears "truncated" due to the flute sounding in its low register. Also, once again the dynamics markings and crescendo/decrescendo are clearly correlates to the harmonic spectrogram. Phrasing and rests are also still easily identified. The flutes characteristic spectrum is clearly visible, although zoomed out a bit more to cover the harmonic range. This time the spectral range of the harmonic overtones is a little larger, although never exceeding 9 kHz. The extra harmonic range appears as though it may be attributed to increased amplitude, since the entire example is contained in the instruments lowest register.

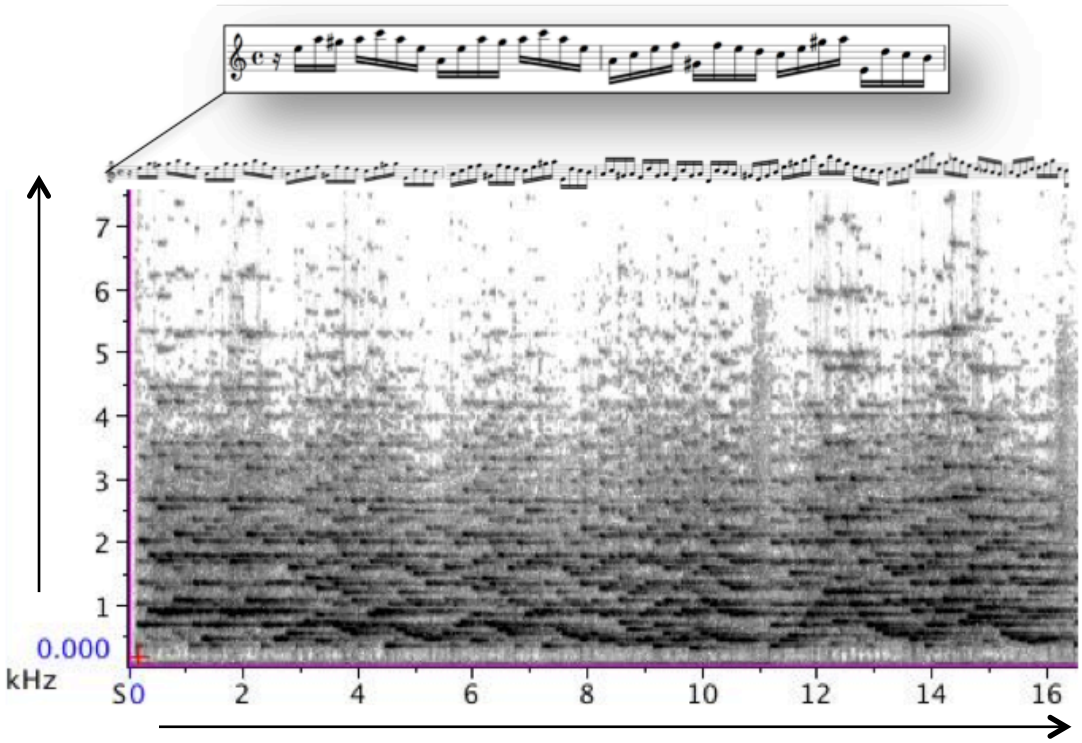
Figure 5 - Debussy's, *Syrinx* mm.1-2



(Duration in seconds)

Another musical example that still contains mainly longer duration with a few shorter values is Debussy's flute solo, *Syrinx*. (see figure 5). As with the two previous examples can still clearly see the long and short note values as they change from one frequency to another. Note that these frequency and rhythmic changes are still quite clear despite the highly chromatic passage and limited range. In this example the dynamics markings are sparse, but you can see the performers interpretation of the initial attack, sustained *mf,* decrescendo, subsequent fermata and final slope to end the phrase. The flute's characteristic spectrum is again clearly identifiable, this time in a higher register, yet also never exceeding 9 kHz. Unlike *Density 21.*5, the extra harmonic range in this example appears as though it may have more to do with the increase in register rather than amplitude.

Figure 6 - J.S. Bach's, *Partita in A Minor* mm.1-6

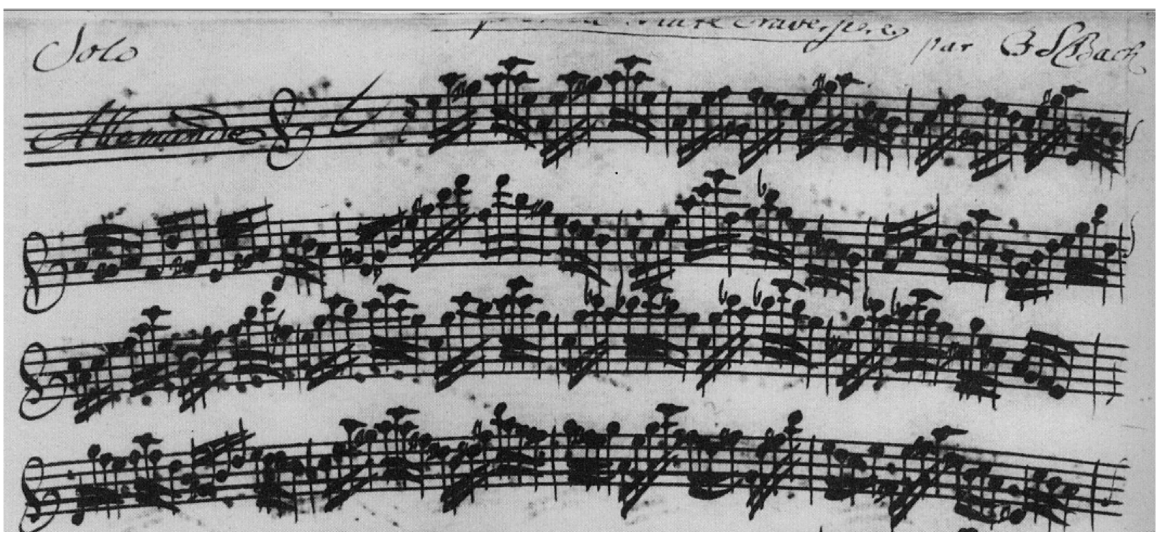


(Duration in seconds)

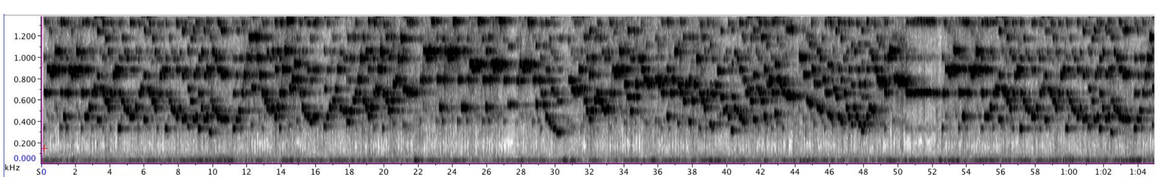
Now that we have seen a number of example that contain long and short note values, in the effort to be as thorough as possible, lets shift our attention to a musical example that contains a large number of frequently changing note values. J.S. Bach's, *Partita in A Minor* for solo flute is a perfect musical example that contains and abundance of short duration frequently changing notes (see figure 6). The spectrogram, on the surface may first appear to be chaotic. But with an increase in the resolution of the spectrogram a pattern emerges. You can see the fundamental frequencies near the low end of the spectrum; appear as short black "dots" that clearly show Bach's highly arpeggiated and rhythmically continual writing. Being a baroque musical example, dynamic markings are unsurprisingly absent from the score. However, it is possible to see the performers interpretation by looking at phrase structure and the spikes in the range of harmonics. Additionally, you can see the performers slight "pauses" between phrases, which appear as breaks in the continuity of the spectrogram. These breaks appear as "smudged" grey streaks, because they are essentially the natural reverberation of the previous notes played. This observation hold true for the previous examples as well, although some may be easier to identify than others. Even with an increase in the resolution of the spectrogram, the flute's characteristic spectrum is clearly visible, this time never exceeding 8 kHz. The extra harmonic range in this example also appears as though it may have less to do with amplitude than register.

On a side note, it is worthwhile to see the spectrogram of J.S.Bach's Partita in A Minor with his original manuscript. While the similarities in appearance are only aesthetic, they are still interesting to see.

J.S. Bach, Partita in A Minor, Original Manuscript

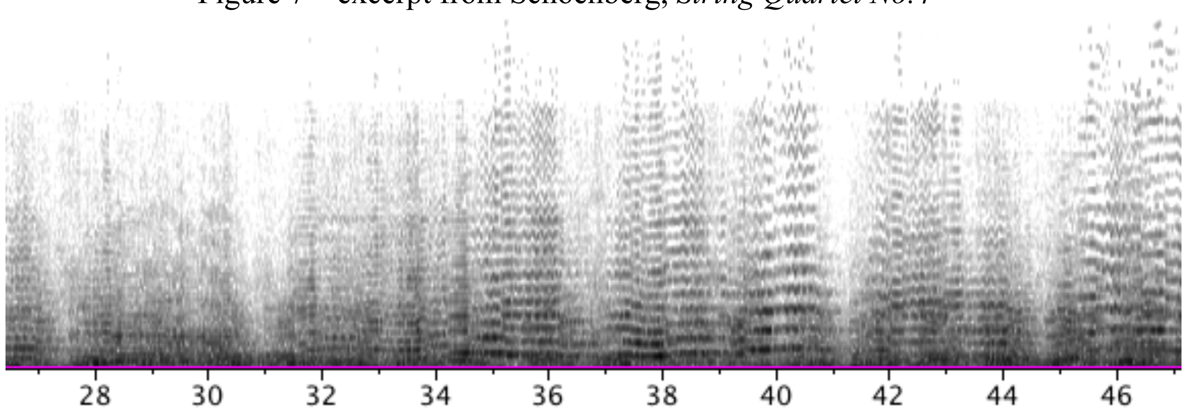


J.S. Bach, Partita in A Minor, Spectrogram



After studying a number of musical examples, some conclusion may be drawn about the flute. First, the spectrum remains consistent across differing compositional and performance styles. Moreover, the spectrum appears to be apathetic to the level of tonal or chromatic intervallic content. Perhaps such a system could be used to equally and effectively analyze tonal music, post-tonal music, or any range therein. Second, there appeared to be consistency in frequency, overtones, and overtone range across the musical examples. Therefore, as the frequency increases the waveform spectrum moves proportionally to include the higher frequency harmonics. Also, higher frequency harmonics may also be linked to an increase of amplitude even when the instrument is sounding in a low register where such high frequency harmonic would not normally be produced. In other words, the greater the amplitude, the more harmonics appear in the upper frequency bands. Third, phrases, cadences and dynamics are easily identified in the spectrogram regardless of register or amplitude. Perhaps this method may be used as a way to identify structure and formal characteristics of music. And finally, harmonic "beats" are produced by the interaction of non-sympathetic waveform overtones. These beats can be seen as a side-to-side wavering in the spectrum. The initial flute examples only reveal a slight "beating" of the monophonic sound sources with their own reverberation of the recording environment. Further study has revealed this phenomenon is significantly more apparent when studying the spectrogram of a polyphonic sound source. (for an example of harmonic "beating' see figure 7)

Figure 7 – excerpt from Schoenberg, *String Quartet No.4*



No study is complete without a brief look into the comparison to two different instruments playing the same composition (see figures 8a and 8b). To do this, we will brief revisit Debussy's, flute solo *Syrinx*. This time we have two spectrograms. The top spectrogram is *Syrinx* played on a trumpet and the bottom spectrogram is the same composition played on the flute (as we have seen before). Both instruments are sounding in the same register. Notice the complete difference in the waveform and spectrum. While the interpretation and tempo is controlled by the performer, and differs slight between examples, it is visibly clear that they are playing the same composition even though the waveform is noticeably different.

Figure 8a – Debussy's, *Syrinx* played on a Trumpet

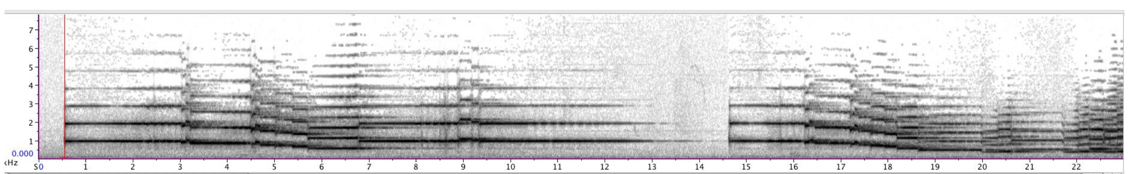
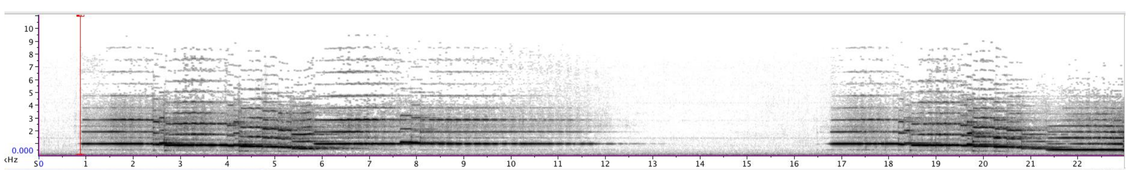


Figure 8b – Debussy's, *Syrinx* played on a Flute



Now that we have seen the waveforms of two differing instruments, it is important to see the waveforms of two identical instruments performing the same composition. (see figures 9a and 9b). These figures show two different players performing Fukushima's flute solo, *Mei.* As you can see both are clearly playing the same composition. Player one taking the passage a touch faster than player two and with greater harmonic range. You may ask, why should we look at the spectrograms of two performances on the same instrument? The answer, because this gives us a uniqe opportunity to explore the most ellusive aspect of music performance, the human element. Interpretation and musicality! Imagine instrumental performers having the ability to really break down the performance of one of an aspirational peer/mentor. Imagine being able to visually see all the subtelty and nuance that seperates the virtuosic from those who have yet to achieve such advances. After all, similar systems are currently employed by speech therepist and vocal performers. Perhaps this aspect of a timbral system of analysis could prove to be an invluable asset to instrumental performers as well.

Figure 9a – Fukushima's, *Mei* played on Flute player 1

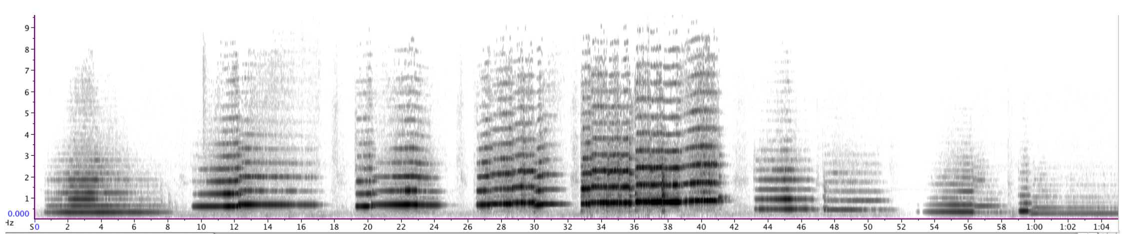
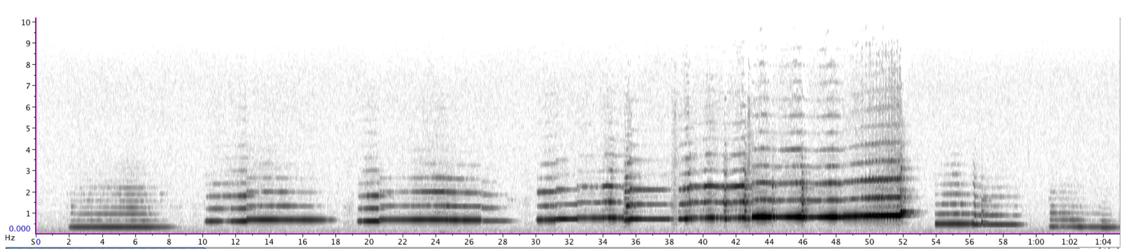


Figure 9b – Fukushima's, *Mei* played on Flute player 2



Now that we have identified the timbral characteristics of a flute, determined relationships as they exist between the instrument, notation, and music with regard spectral analysis in a monophonic environment. Lets briefly take a look at multi-timbral musical example. In this case, we will look at Heitor Villa-Lobos's, *Bachianas Brasileiras No.6* Duet for Flute and Bassoon. Before we look at the spectrogram and music, let us first make a point to understand the difference in waveform and spectra of the two instruments. Figures 10a and 10b show the spectra of the flute and bassoon. Remember the first three spectrums are octave A's in the respective instruments range, while spectra three and four are the instruments extreme low and high ranges.

Figure 10a – Flute

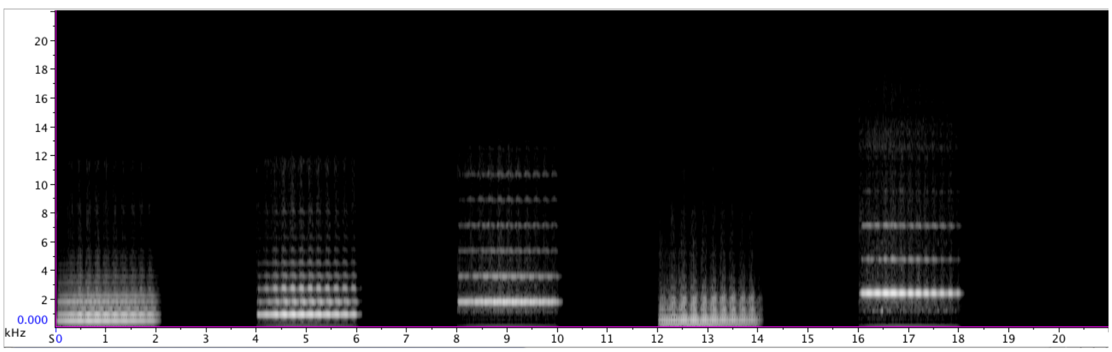
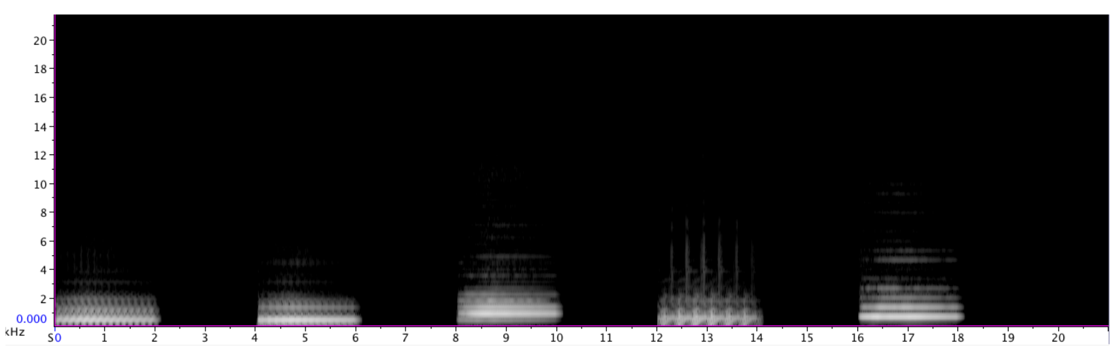
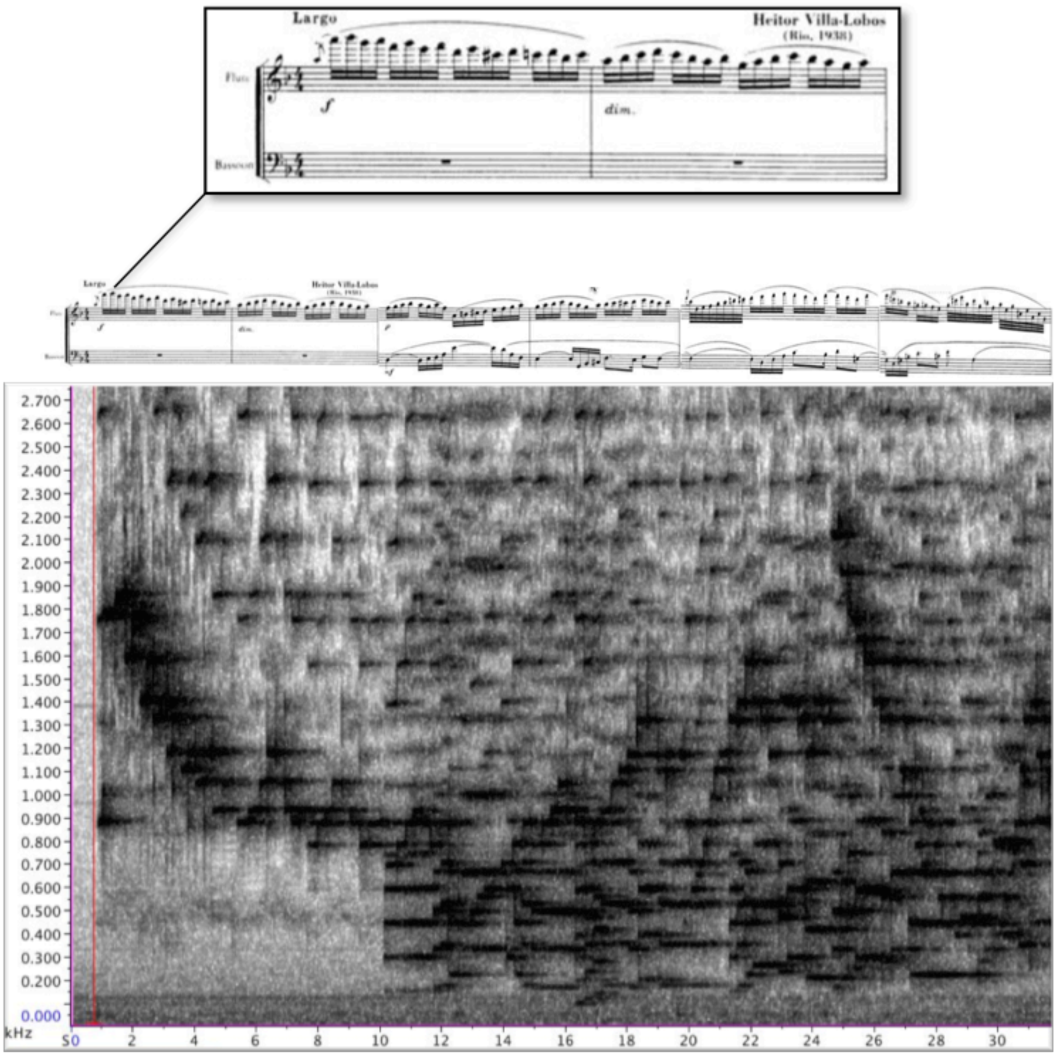


Figure 10b – Bassoon



With the timbral characteristics and differences between the flute and bassoon in mind, lets take a look at the opening to *Bachiana No.6* (see figure 11).

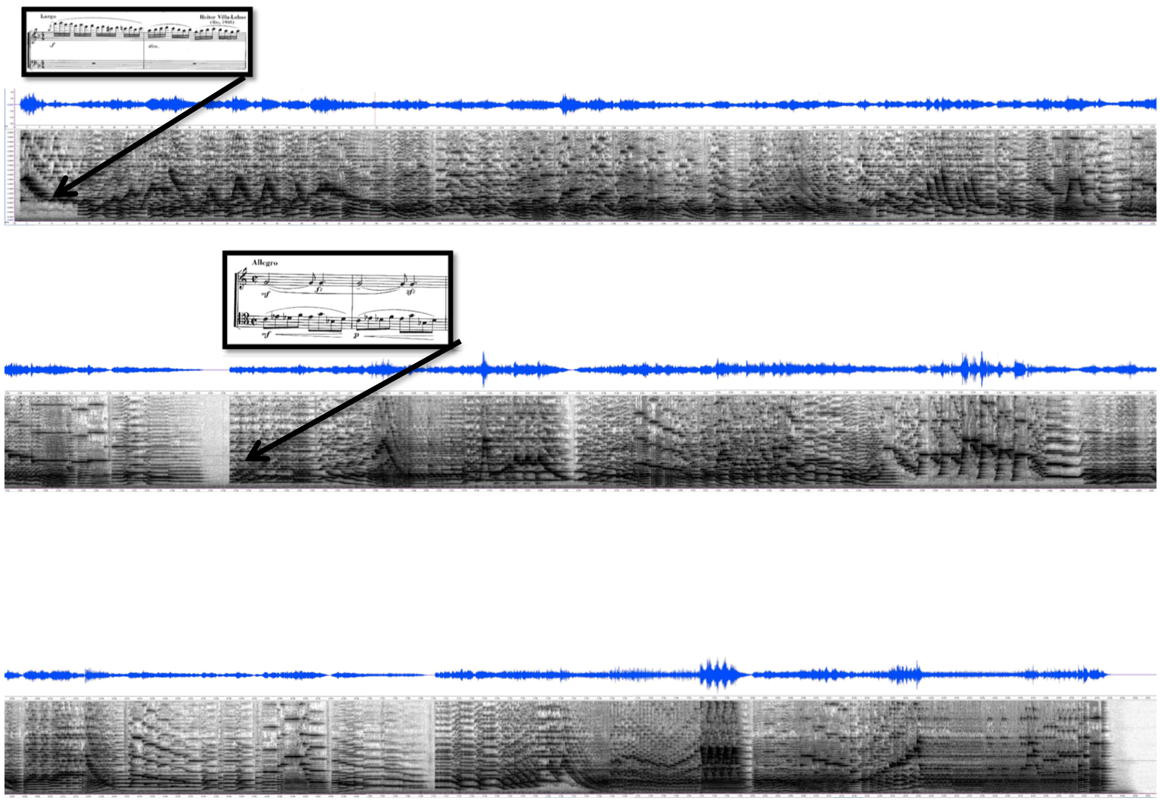
Figure 11– Villa-Lobo's, *Bachianas Brasileiras No.6* mm.1-6



As you can see, it is possible to follow the independent lines of the flute and bassoon. The flute enters for the first 2 measures solo, until measure 3 when the bassoon enters with a contrapuntal line and stays near the low end of the harmonic spectrum as the flute soars up and down the higher register in dramatic melisma. While this may appear to be a superficial comparison, it important to understand where such a observation could ultimately lead. Imagine sophisticated software applications that are able capable of isolating specific waveforms from a polyphonic audio source without destructively harming existing sympathetic waveforms. This would be possible by designing the software to use a comprehensive library of waveforms for frequency, range, tessitura, dynamics, articulation (like the category system previously proposed herein) which then actively cross compares the library of waveforms with those in the input source signal in order to avoid the destruction of sympathetic frequency spectrums of other instruments. Currently even the most advanced software uses the processes of band-pass and band-reject filters, which essentially isolate and/or remove all user-defined frequencies. These processes also inherently remove all fundamentals and harmonics that may be sounding in other instruments. As a result, it is currently impossible to isolate a specific instrument in a polyphonic signal. Perhaps this may not always be the case.

In addition to those discussed already, there are a few other potential assets from the development of a comprehensive system of timbral analysis. First, it may serve as a supplementary means of the formal analysis of structure within music. Since the example is fresh in our minds, lets look again at Villa-Lobos's, *Bachianas Brasilerias No.6* (see figure 12). This time we are looking at the complete spectrogram of the two-movement duet. Additionally, the amplitude waveform appears in blue above the spectrogram. Two places are marked with corresponding measures, both of which are the beginnings of each movement of the piece. Can you find some patterns that exist in the spectrogram? Remember from before what rhythmically active sections look like, and how long duration sustains appear in the spectrogram. Can you identify any phrases? Cadences? Perhaps the climax of the composition? There are definitely some interesting details than can be gleaned from this perspective. While using spectrograms to identify structure and form is beyond the scope of this paper, the proposal to develop such a subsystem is not.

Figure 12– Villa-Lobo's, *Bachianas Brasileiras No.6*



The final potential asset of the development of a system of timbral analysis is to serve as basis for a comprehensive system of orchestration.[13] Currently, composers, orchestrators, and arrangers use a great variety of information about instruments, groupings, ranges, tessituras, articulations, dynamics, performance forces, environments, available special effects, specific notation styles to name a few.[14] However, the most useful information to those who find themselves composing/orchestrating/and arranging

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[13] Rimsky-Korsakov, Nikolay. Principles of Orchestration. New York: Dover Publications. 1964 (orig. 1922).

[14] Adler, Samuel. *The Study of Orchestration*. 2nd ed. New York: W.W.Norton and Company, 1989.

comes from experience.[15] Experience offers what the current textbooks do not. It is one thing to be told a certain instrument combination should be avoided, and quite another to experience the faux pas first hand. Current textbooks may tell you to avoid these pitfalls, but they do not tell you "why." What if there existed a comprehensive system of timbral classification that was able to group similar sympathetic, conflicting, and apathetic waveforms and spectra with the intention of determining sub-categories based on range, tessitura, dynamics, articulations, intonation, and other applicable special effects like multiphonics, microtones, whistletones, and glissandi.[16] Figure 13 is a list of common orchestral instruments all of which have the ability to play the tone "A4." Next to the instrument name is the tone they are playing (in this case A4 of course) and a letter designation as to what register the A4 tone appears in the respective instruments range. (L = lower, M = Middle and H = High register). The purpose of the figure is to demonstrate what instrument may have sympathetic and apathetic waveforms and spectral properties from those who do not. Imagine a system that collated data on every instrument playing every tone, in every register, with every possible articulation and dynamic levels. What could we learn about orchestration with that data? Of course such a system could not, nor should it, replace the current model. It could however, complete it by giving those who are interested, an extra pallete of possibilities to work with.[17]

Figure 13– Orchestral Instrument List playing Unison A4's

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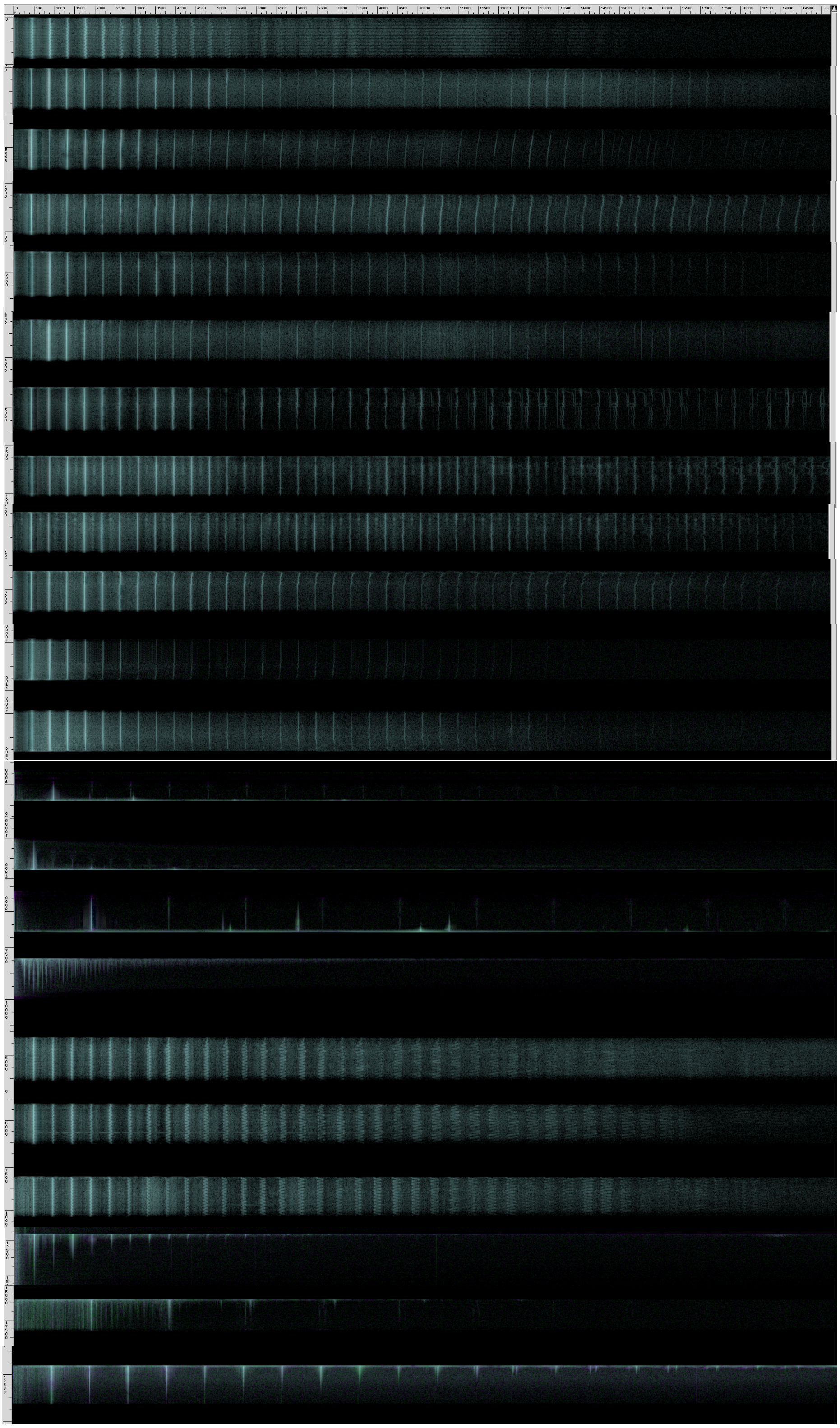
[15] McKay, George. *Creative Orchestration.* Boston: Allyn and Bacon, 1963.
[16] Bartolozzi, Bruno. *New Sounds for Woodwind*. London: Oxford University Press, 1967
[17] Schillinger, Joeseph. *The Schillinger System of Musical Composition.* New York: Carl Fischer, 1946.

> Henry Cowell, a contemporary of Joseph Schillinger describes *The Schillinger System of Music Composition* in the overture to the enormous treatise in the following words …
>
> *The Schillinger System makes a positive approach to the theory of musical composition by offering 'possibilities' for choice and development by the student, instead of rules hedged round with prohibitions, limitations and exceptions which have characterized conventional studies*."(Cowell, in Overture to Schillinger, xi)

Flute	A4	L
Oboe	A4	L
Clarinet	A4	M
Bass Clarinet	A4	H
English Horn	A4	M
Bassoon	A4	H
Alto Sax	A4	M
Tenor Sax	A4	H
Bari Sax	A4	H
Trumpet	A4	M
French Horn	A4	H
Trombone	A4	H
Xylophone	A4	L
Marimba	A4	M
Glockenspiel	A4	M
Timpani	A4	H
Violin	A4	M
Viola	A4	M
Cello	A4	M
Harp	A4	M
Piano	A4	M
Harpsichord	A4	H



Conclusion

The idea of spectral analysis is not a new one. A myriad of scientific disciplines employ a vast array of highly developed methodologies for spectral analysis specific portions of the energy spectrum, such as visible light wavelengths, and aural frequencies. Even the used of advanced scientific aural spectral analysis techniques is commonplace in recording and entertainment industries.[18] However, the use of timbral and spectral analysis in regard to the merging of the science and art of music has only recently has become possible. As with any scientific discipline, increased technology, and those who support it, allows for the development and use of tools that were unavailable to previous generations. Why should music be any different? Music is based on scientific principles, obeys the laws of physics and acoustics, and can be represented perfectly by mathematical language. Yet humans are so used to thinking of music as art, that music as science has gone underappreciated.[19] It is the duty of any theorist to provide new and novel techniques as they come available. A system of timbral analysis certainly fits that description. It would undoubtedly provide educators, theorists, composers, orchestrators, and performers, with a multitude of new methods, analytical tools and devices for applied and theoretical advancement of the science and art of music

[18] Nisbett, Alec. *The Technique of the Sound Studio.* New York: Hastings House Publishers, 1974
[19] Stravinsky, Igor. *Poetics of Music*. New York: Vintage Books, 1947.
"It was the Renaissance that invented the artist, distinguished him the artisan and began to exalt the former at the expense of the later."

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