

A Brief Treatise On Holistic Tonality

by Peter McClard

Prologue

All music theories seek to make sense of and codify the relationships created by variations of perceived pitches over time, usually in the form of timbre, notes, chords, melodies, harmonies, rhythms and structures. Because computers and digital audio processors have given us phenomenal control over the fine details of sound, a modern music theory must include the panoply of new possibilities. The long tradition of music theories going back to the Greeks, whose disciplined use of modes was geared toward inspiring nobility, has the goal of discovering or proscribing a set of rules by which music could be made more logical, harmonious and in often cases, more appropriate for exalting God in the service of the Church. It is my belief that traditional music theory in its entire academic splendor, does not adequately equip modern composers and musicians for the future where musical automation will greatly extend our reach and the music of the wildest imagination can be further brought to life, freeing us from the bonds of physical limitations.

Early theory such as put forth by Boethius¹ or Tinctoris², were concerned with resolving the imperfections of musical notes as the use of aliquot ratios such as 1:3, 2:3, 4:5, etc. caused octave inequivalence and dissonance (wolf tones) which was thought to be unholy and undesired but also easily avoided by singers. Early theories and treatises were essential to develop a formal notation of music so that it could be conveyed from place-to-place and generation-to-generation. Music scholars of those times proscribed the use of unison and parallel motion, which even though limiting, still produced sublime results such as Gregorian chant and leading to early polyphony such as that composed by Machaut.

Later theories began to expand into the world of polyphony where chords became more advanced over time and eventually counterpoint and complex forms of musical structure evolved. Polyphony remained relatively simplistic through much of the Middle Ages and up into the early Renaissance leading to the advanced musical theory of Rameau³ which was a turning point on the cusp of equal tem-

perament during the Baroque period which led to an explosion of complex music that endures as supreme examples in: Vivaldi, Scarlatti, Bach and others.

The Theory of Holistic Tonality builds upon other music theories, most notably that of Schenker⁴ whose work on harmony and counterpoint is far more comprehensive. However, Schenker could not have anticipated computers, synthesizers and fractal mathematics so his theories could not be fully extended into the modern era. In the sense that “ontology follows phylogeny,” Holistic Tonality is a recapitulation of prior music theories folded into a more elaborate DNA that should widen the possibilities for future musicians.

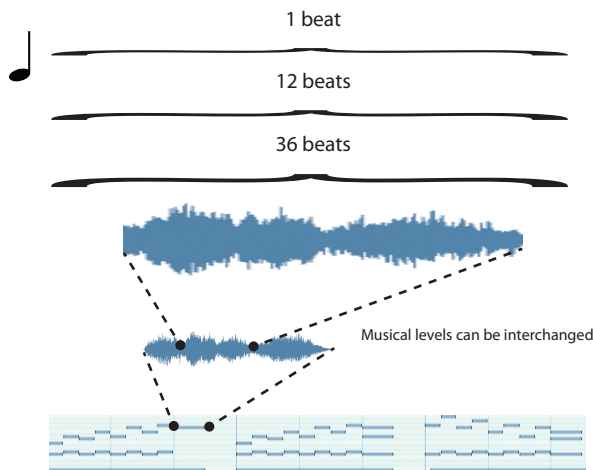
In all traditional phases of music evolution up until the mid 20th Century, musicians were generally limited to instruments which relied on the timbral qualities produced from naturally vibrating materials such as wood, skins, strings, or columns of air all of which were direct analogues of the most important instrument of all, the human eardrum (second is the human voice). In other words, as the string vibrates, so does the eardrum. In the end, all instruments causes the air between the instrument and the listener to be set into motion, culminating in the physical vibration of the eardrum which in turn converts the vibration, via a series of tiny bones and the cochlea, into electro-chemical signals to the auditory portion of the brain which then creates the sensation or perception of music.

Even modern synthesizers eventually drive the surface of a speaker cone (an even closer analog to the eardrum) or other device, which must vibrate according to the laws of physics. It is no surprise then that theories would center on vibrational patterns that would be perceived as harmonious or “pleasing to the ear.” It wasn’t until Helmholtz⁵ analyzed these vibrations more closely that it was understood that timbre was the sum of a complex “vibrational chemistry” where some quantity of overtone mixed with others to create a unique tonal quality such as that of a violin, flute or piano. Holistic Tonality simply states that: *All Music is Only Timbre.*

Another tenant of Holistic Tonality is that timbre operates relativistically according to time scale. The nature of Time itself remains to this day a mystery. It is even feasible within modern physics that all possible

music throughout the Universe is in the process of playing or has already played within the confines of the Grand Big Bang but that's another topic. Holistic Tonality seeks to first remove the human element from musical perception and suspend the bias we have for our time scale linked to the days and spans of our lives. Naturally, since we perceive time to flow at a certain pace, we will be attracted to musical events that occur on our scale. It is now known that some animals can better hear not only higher or lower pitches than us, but can communicate complex social messages in timbre. For example, a particular birdsong may appear to us as unified sound but nonetheless contains rich details of pitch and harmonic changes and conveys hidden messages to potential mates or adversaries. Rats have been discovered to laugh in a high frequency range that sounds to us like squeaks. One creature's squeak is another's laugh⁶. Time scale is critical to the perception of music but not to the musicality itself, which is independent of time scale.

Self-similarity of the Timbre Fractal



Indeed, going back to traditional music theory, it was the imperceptible “squeaks” of these higher frequencies that stealthily governed the need to have a Dominant or Subdominant since these were strong components of the overtones they were hearing and to this day dominate our musical timbres. Most overtones are perceived on a subliminal basis, no doubt linking us to our evolutionary ancestors that operated on a faster “speed of consciousness.” Very few people are aware of the individual tones that make up a timbre and we tend to unify these tones into a single sound. Holistic Tonality states that timbre governs or suggests structure, and that since traditional

timbres are structured in the classical Overtone Series, the larger structures that were suggested were similar to those found in the Human Music Catalog.

Holistic Tonality does not distinguish between *sound* and *music*. The *musical experience* is left to the listener (observer). No two listeners can experience the same music.

It is not until one starts to deconstruct the temporal aspects of musical structure that one can see clearly that timbre is equivalent to structure, if only on a different time scale. By understanding the relationships between timbre and structure, the modern composer is able to create new masterpieces where there are no boundaries between timbre and structure. In other words, one can compose timbre that freely morphs into musical structure, mixes with it, becomes it, and vice versa, larger musical structures which wind themselves into timbre on another time scale much the way fractals in nature and mathematics smoothly morph from one scale to another. In a sense, this is no different than what composers have always done using orchestration, dynamics and musical constructs to flow through time musically and tell their story to the listener.

To demonstrate this idea, I have formulated numerous experiments which have led me to classify a new class of musical structures I call: sonons, superintervals, hyperintervals, superchords and hyperchords. I have created software called HyperChord⁷ to aid me in these experiments and would encourage other musician/programmers to do likewise or use ready-made experimental software to conduct further experiments. In the end, dedicated hardware should be constructed which embodies the best ideas and controls and is worthy of a virtuoso. I would distinguish *ephemeral instruments* as those that would be mastered by a very few at a given time and *permanent instruments* as those that withstand the test of time and are responsive and logical enough to be worthy of lifelong dedication. So far there are no new 21st Century permanent instruments but it is possible. It may be awhile before a permanent hyper or meta instrument is constructed.

Nomenclature

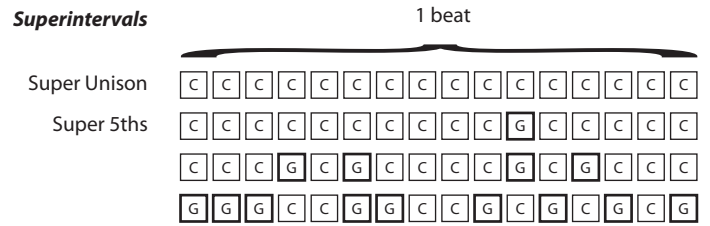
For simplicity, let us first use a simple, idealized synthetic voice that itself has very little color—essen-

tially producing a pure sine wave or something on that order. This *meta instrument* is also able to play a sequence of pitches at any speed but we must start with a fixed reference point so that we can make valid comparisons. Let's use 60 BPM as a reference tempo so that our quarter note is exactly one second. In the world of holistic tonality, traditional notation proves limited because within a one second span, hundreds of "notes" can go by so our quarter note is really only a durational placeholder for timbre.

First we play a one octave C Major scale in the span of our quarter note producing a now classic video game sound. This sound is a timbre. To prove this, change it to play 2 and then 3 octaves in the same span producing a totally different sound yet with similar *tonal characteristics*. Any musical scale can be used for this and each scale of course takes on the tonal characteristics of the scale: eg. chromatic, whole tone, gypsy, 19-tone, etc. Now, let us add another dimension of motion to the experiment by introducing a second "carrier scale." To do this we simply transpose our original C Major scale along a C Major scale, thus: C Maj, D Maj, E Maj, F Maj, G Maj, A Maj and B Maj, each time with the entire inner scale playing within our quarter note giving us 7 seconds of a C Major scale made of Major scales. This is a *hyperscale*. During these experiments it is important to swap in different scales and record the perception that occurs. For example, now play a C minor scale made of Majors and a C Major made of minors and a Minor made of Minors, etc. and record the differences perceived. Because there are too many permutations to consider and it will be left to future generations to catalog the possibilities, we must construct computer-based Hyper-Instruments⁸ or Meta-Instruments that can freely examine these and make them useful to current musicians and composers. All of these experiments should be sped up so individual tones are not perceived by the human ear but their effects are—very much like overtones behave.

Now let's simplify our experiment to examine the temporal chemistry when only 1 or 2 tones are used. Play a sequence of 32 C tones in our quarter note (technically 1/128th notes). This will produce a straight C tone. Now introduce at first 1 G tone in the sequence which will alter the timbre but it will remain a C tone. This is a *superinterval* (a *superfifth*). Introduce more G tones and in different patterns and

it will take on qualities of a perfect 5th yet no two patterns will sound identical because they do not have timbral equivalence.



Following this, the theory provides the following additional nomenclature and rules:

The smallest unit of timbre referred to as a *sonon*. A sonon does not have a fixed duration.

Sonons produce superintervals which produce hyperintervals which produce hyperchords .

All music is comprised of sonons which are the smallest musical units, or musical quanta.

Sonons are pure audio information but can be music.

1 cycle of pure sine wave is the simplest sonon possible. This is also the simplest timbre possible.

Sonons are not limited in complexity.

A sonon can be a timbre or can be a pre-timbre component depending on intent

Any consecutive or simultaneous sonons comprise a timbre. Sonons can be combined horizontally (melodic) or vertically (harmonic)

A *pitch* is a carrier frequency for a sonon. This can be subjective depending on the complexity of the waveforms present in the sonon

A composer's or musician's job, whether practical or artistic, is to create a sequence of sonon combinations with a given *envelope*.

An envelope is a *contour* for a timbre. One could call music a timbre-envelope continuum, but I use timbre to mean the same.

Those familiar with ADSR envelopes on synthesizers can appreciate these as named phases of a timbre: attack, decay, sustain and release. However in purely abstract terms, envelopes can have many more parts

and naming them all is a little like trying to name all the parts of the Mandelbrot Set⁹.

Introducing a parallel superinterval produces a *hyperinterval*.

Individual sequences of timbre can be considered *voices* though they don't have to use different sonons.

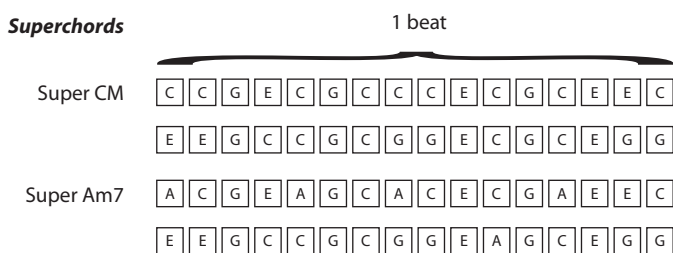
Two sonons are *identical* if the waveform of one can be time-stretched to match another.

Timbral equivalence occurs when identical sonons are used to create an identical pitch sequence. Two timbres are said to be equivalent if one timbre can be time-stretched to match another. *Timbral inequivalence* occurs when even a single sonon is different from one voice to another.

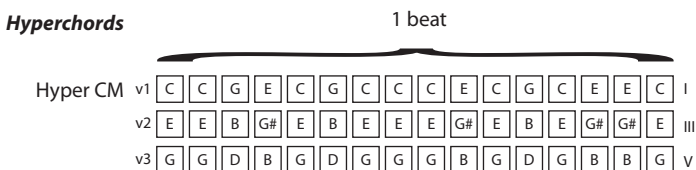
Unlike sonons (special timbre), two timbres are said to be *identical* if they are equivalent and have the same duration.

Timbral similarity occurs when two voices are composed of identical sonons, regardless of sequence or duration.

Using tones that form a triadic or higher order chords (as opposed to two tone intervals) produces a *superchord*.



Introducing 3 or more parallel superintervals produces a *hyperchord*.



Multiple parallel superchords also produce hyperchords.

Every timbre is a composition and compositions are

independent of time scale.

Timbre is said to be *natural* if it is produced without the use of electronic circuitry.

Timbre produced from electronic circuitry of any sort is said to be *synthetic*.

A *musical instrument* is anything that is used by musicians to generate timbre.

A *natural instrument* is anything that uses non-electronic means to generate timbre and the musician interacts directly with a natural, vibrating physical object (eg. flute, guitar). The human voice is a superior natural instrument and could be classified as a *biological instrument*.

A *synthesizer* is any instrument that uses electronic means to generate timbre and requires electromagnetic means to be heard.

A *natural synthesizer* is any instrument that uses mechanical or only electromagnetic means to actuate natural instruments by means of an abstracted interface, usually a keyboard (physical musical scale analog). An example of this is a keyboard which keys complete a circuit to cause a solenoid to strike a tuned stalactite (Stalactite Organ¹⁰). A piano is the prime example of a natural synthesizer, using an elaborate mechanism to translate the musician's motions into pad-strikes upon a string or strings. Other examples include harpsichord, organs and glass harmonica. Often cases, such instruments have additional inputs such as pedals or stops to reroute, augment or diminish the effect produced.

A *hyperinstrument* is any instrument that uses electronic or other means to multiply, enhance or otherwise alter a musician's interaction in real-time, usually via an augmented natural instrument or specialized controllers. It is feasible to create non-electronic hyper instruments such as the fabled (and hopefully never built) *Katzenklavier* that used a keyboard to transfer pain to a cat tails producing a complaining meow, supposedly tuned per different cats. Technically, any synthesizer is a class of hyperinstrument and hyperinstruments are a superclass of synthesizers.

A *meta-instrument* is purely electronic for the purpose of exploiting non-physical means of generating

timbre, though such instruments also must rely on a user interface to operate.

A *musician* is anybody who plays a musical instrument.

A *virtuoso* is a musician who demonstrates extraordinary skill either by innate abilities or from dedicating a large portion of his or her life to the mastery of an instrument or instruments. A society without virtuosos is *musically inactive*.

All rhythmic and dynamic structures in music are *envelopes* for timbre. Silence and rests are *null envelopes* and are only in the context of a given sonic unit. For example, if musicians rest on a note and someone in the audience coughs during that rest, the rest only exists in the composition-space of the piece but not in the performance-space. The cough is included in the timbre of the performance. Also, during a rest there may be reverberation, ambient or ancillary musician-generated sound such as breathing that is also in the performance-space.

Musical notation is a means by which timbre and envelopes are conveyed from one musician to the next. Roughly speaking, notes are analogous to sonons and dynamics to envelopes. Traditional musical notation is entirely geared toward the human time-scale and is not adequate for composing holistically.

A *composer* is someone who imagines, plans, evolves or discovers musical ideas and then uses a means of recording, such as musical notation or digital recording. Composers are often musicians and vice versa.

Traditional compositional structures such as: Sonata, Symphony, Opera, etc. are arbitrary formats for human-scale experiences. In holistic tonality, these are still considered timbres since on a different time scale there is fractal similarity between the parts and the whole.

Dissonance and *consonance* are subjective qualities or effects of music. One listener's consonance is another's dissonance though we know that physics and mathematics plays a strong role in this perception.

The *tonal quality* of music can be categorized as follows:

Tonal: music that makes more use of conso-

nance within the chromatic 12-tone scale.

Atonal: music that makes more use of dissonance within the 12-tone scale.

Microtonal: music that uses intervals smaller than the twelfth root of 2

Crosstonal: music that combines any of the above tonal qualities.

A *scale* is any ordered set of 3 or more discreet pitches and come in the following forms:

Octival: a set which repeats in each octave (linear)

Meta: a set which repeats over N octaves (linear)

Melodic: a set which changes per octave (nonlinear)

Algorithmic: a scale which pitches are calculated in real-time

Mixed: a scale which mixes different

Hybrid: a set which combines any or all of the above

A scale can be tonal, atonal, microtonal or combinations thereof. A continuum is not considered a musical scale, though it may share attributes. Some scales are only useful in the field of audification and musification (see below).

The first element of a scale is said to have an integer index of E_1 and the last is E_N .

The *minimum* of a scale is the pitch value of the lowest element.

The *maximum* of a scale is the pitch value of the highest element.

The *range* of a scale, expressed as an integer, is the difference between its lowest pitch index and its highest pitch index ($R = E_N - E_1$).

The *octave range* of a scale (R_O) is the number of octaves that can contain the scale. This can be expressed as an integer or as a floating point decimal for precision

The *domain* of a scale, expressed as 2 integers (equal temperament) or 2 floats where Middle C = 1.0, the first being the offset from Middle C of the scale's bottom element E_1 and it's top element E^N . The standard 88-key piano keyboard has a domain of $\{-39,48\}$. If the domain of the scale is above middle C then both numbers would be positive. Domain maps roughly into the traditional concepts of: Bass, Tenor, Alto and Soprano.

The *size* of a scale is the number of individual pitches it contains, S . Theoretically, scales can extend to frequency zero and infinity. However, for practical reasons they are limited to the range of hearing of the listener.

The *octavity* of a scale (O) is the average number of pitches per octave. This can be expressed as an integer or as a floating point decimal for precision. Meta scales can have an octavity < 1.0 . For example a Meta 9th has 14 half-steps per pitch. A *meta double octave* has an octavity of 0.5. A *meta octave* has an octavity of 1.0. The chromatic scale has an octavity of 12.

Audification is the process by which pure data or information is converted into audio. With computers it is possible to audify any data from any format, most commonly the: CD, MP3, DVD but also including images, video, text and more. Any data can be audified. Audification is governed by algorithms.

Musification is a similar process to audification but where data is converted into musical structures, mapped into scales and generally made more suitable to musical performance. Technically, musification and audification both produce timbre and are therefor the same, differing only algorithmically. I wrote a program called Pixound ¹¹which maps RGB information from images into scales and it makes extensive use of all scale types: Octival, Meta, Melodic and Hybrid. Because RGB are fundamental color components of our eyes, Pixound has a claim to musical permance for all future generations who wish to use color or light as a musical controller. Ideally, one would be able to seamlessly move between audification and musification, controlling musical output on several levels.

In the process of musification where data of higher ranges is mapped into scales of smaller ranges, *scale expansion* can be used. In this case, scales are padded

by repeating adjacent pitches (usually isometrically) to make data mapping more convenient. Increasing the octave range of a scale is another method but may produce undesirable low or high notes.

Any non-parallel superintervals, superchords or hyperchords comprise *supercounterpoint*.

Supercounterpoint is a subclass of timbre.

Any supercounterpoint can be composed but only synthetic timbres can be composed. Natural timbres cannot be composed due to quantum physics and chaos. Theoretically, one could use a quantum computer to compose hypertimbres which would be analogs to natural timbres.

Mixing any two or more supercounterpoints comprises a hypercounterpoint.

The effect of timbre on a listener cannot be fully controlled due to qualia ¹²therefor music will *always* be subjective.

We can never experience the full performance of music since we have only two ears with limited frequency response.

Timbre can be structured or unstructured, organic or synthetic, homogenous or heterogeneous.

Timbres can be composed of other timbres and, depending on the targeted time scale, can become recognizable compositions. *All compositions are timbre*.

Every musical composition is a drawn out timbre on one time scale or another.

The fractal dimension of timbre is a useful form of classification if precise enough.

The largest musical unit which is also a timbre is referred to as the Cosmosone (all sounds in the Universe). There is only one Cosmosone per Universe.

All music takes place within the timbre of the Cosmosone.

There are an arbitrary number of musical units including but not limited to:

Cosmosone: all sound in cosmos

Galactisone: all sound in galaxy

Stellasone: all sound in star system

Terrasone: all sound on Earth

Biosone: all sound in biosphere

Hydrosone: all sound in water

Urbasone: all sound in city

_____sone: all sound of that type

Imaginary music is free of the limitations of vibrational physics but there is no current way to bypass the timbral limitations of the eardrum and inner ear for physical music.

Imaginary music can only be heard by the imaginer until such time as consciousness can be shared.

All music has a fractal dimension which can be calculated (usually between 1.65 and 1.68¹³).

It is conceivable through timbral composition to create different musical systems which suggest different musical structures or emphasis. For example one could construct a system whereby the Dominant was not based on a perfect 5th but on a Tritone. But since the human ear is tuned to the 5th, we cannot fully appreciate such musical systems. The 12-tone equal temperament system is adjusted to our eardrums' timbral quality, though only approximately—except for octaves.

Octaves represent tonal equivalence in different time scales. Octaves apply to all vibrational phenomena including electromagnetic and matter. Physical matter can also be considered timbre. For example, water is a 2:1 ratio of Hydrogen to Oxygen which have a 16:1 atomic mass ratio. This is likely why water tastes like an octave sounds, very satisfying but not particularly interesting. Perhaps the ultimate vindication for Holistic Tonality is found in the cutting edge of physics, M-theory, which states that the Universe is composed of inconceivably small vibrating “strings.” This is sometimes referred to as String Theory. Even these tiniest of vibrations are governed by the mathematics of octaves.

Holistic Tonality is not based on equal temperament, which is merely a special case and it applies equally to all microtonal constructs.

Holistic Tonality incorporates established harmonic principles, though these become special cases within a general theory. The aliquot ratios of vibration are eternal mathematical truths yet they are only important as references and not as musical determinants.

Music is timbre applied to consciousness.

Music and timbre does not exist outside of consciousness. Outside of consciousness music is merely wave and particle motion through space-time.

Music and timbre can exist in an entirely imaginary realm because it requires consciousness of some degree to have imagination.

Cyclophonic music is a good example of Holistic Tonality in practice. Because sound is composed of waveforms propagated through the air, what better way to match this than using waveforms to construct all parts of the music? I wrote software called Cyclophone¹⁴ to demonstrate this concept. Cyclophone assigns multi-component complex waves to each parameter of music: pitches, rests, dynamics, ties and more. Each wave is assigned a fundamental frequency in *Cycles per Measure* or *Measures per Cycle* depending on wavelength, a phase and a y-intercept position. Then each harmonic of the wave including: f , $\frac{1}{2}f$, $2f$, $3f$, $4f$, $5f$ and Nf are assigned an amplitude and wave type: sine, square, triangle, etc.. When combined, these construct a myriad of complex and rich designs which are then directed to control what notes to play, when, how loud and whether to tie them with their neighbors. Each voice has up to 5 separate waves governing its overall behavior, not including any waves governing the sonic timbre itself. The music produced by Cyclophone is truly astounding in it's variety and all of it has a fundamental quality linked to the natural purity of its wave-based genesis therefor has musical permanence.

Holistic Tonality requires a new notation system.

A Holistic Composer seeks awareness of the context of each moment in a composition; it's relationship to the whole, the environment and even the history of the composer as well as the historical context. The holistic composer is responsible for every aspect of the timbre and envelope produced. A Master Composer would create a body of work that would be accessible on numerous levels, even including performances or perhaps an entire life's work con-

structured as a composition. While this is not practical, it is left to the future as a challenge or musical aspiration.

Numerous successful modern composers use a timbral approach to composition. In fact some such as Laurie Spiegel ¹⁵ or David First have created entire works that are slowly evolving, drone-like timbres. Phillip Glass, while not a timbral composer, is very textural; using repeating patterns with subtle changes that have a similar effect on the listener. Recently, a band called Bear In Heaven streamed their album, *I Love You, It's Cool* at 800,000% slower than the original (time-stretched) leaving the pitch at 100%. The effect was a stunning display of the timbral nature of music. Even at this speed, the music weaves a rich tapestry of ever-changing musical sound that perfectly matches the music played at normal speed.

In the future, when more mastery of the technique is gained, such compositions should be able to convey emotion on a scale and at a depth not yet achieved at least here on Earth.

It should not be construed from Holistic Tonality theory that any music is more or less inferior to another or that any music is primitive or modern but only that humans will constantly search for the next form of musical expression using the tools of the realm and the era. Nor should it be construed that a single drummer or flute player or any other instrumentalist should be required to explore computerization or synthesis and in fact I would greatly encourage the sublime mixture of any and all forms of musical expression without limit whatsoever.

It would not be right to merely say we have reached the end of musical possibilities and everything we do from now on will just be a variation on what has gone before. One can only wonder what the music of the 22nd Century (let alone the 30th Century might sound like but perhaps the ideas presented here will give the next generation a clue on where to begin the next phase of musical evolution. It is entirely possible that music of the future will be directly conveyed to the mind, bypassing certain physical limitations or that some strange, post-singularity ¹⁶cybernetic humans of the future will merely hear music on demand inside their quantum circuits

Footnotes

¹ Boethius' *De institutione musica*, between the years of 1491 and 1492

² *Diffinitorium musicae, Liber de arte contrapuncti* 1475

³ 1722 *Treatise on Harmony*

⁴ *Harmony (Harmonielehre, or "Theory of Harmony")* published in 1906

⁵ In 1863 Helmholtz published *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (On the Sensations of Tone as a Physiological Basis for the Theory of Music)

⁶ Larger creatures tend to respond to lower frequencies and smaller ones to higher frequencies, though there are many exceptions. By speeding up or slowing down other species' communications we can better understand them and they will tend to have the same fractal dimension as ours.

⁷ HyperChord 1986, TI-99, C-64 and later on Amiga 1988-1993, see review in *Electronic Musician* or *Computer Music Journal*

⁸ A term coined by Tod Machover for a class of instruments that generally enhance or transform musical output based on a given simpler input such as bowing of a cello producing more than a single cello tone. In a sense, all synthesizers are HyperInstruments since one may trigger extremely complex output by merely holding down a key or keys.

⁹ An infinitely complex form named after Benoit Mandelbrot, a mathematician who discovered fractal geometry.

¹⁰ Such as is found in the Luray Caverns of Virginia

¹¹ Pixound 1.0 was created for Amiga in 1988. Pixound for iPhone was released in 2011.

¹² The unique experience of reality and perceptions of an individual that can't be shared

¹³ PP Choudhury - 2009

¹⁴ *Cyclophone* 1999 came out of work I did on HyperChord and used pure waveforms to govern all aspects of the musical structure

¹⁵ *The Expanding Universe*

¹⁶ Singularity is a term coined by Ray Kurzweill to represent a rapidly approaching moment in time where computers will far eclipse the ability of the biological brain and even perhaps become conscious.