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RHYTHM IN ELECTRONIC MUSIC

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Introduction

Rhythm will be differentiated from its traditional definitions. I am not seeking a justification of beat-based or metered electronic music; I am not looking to revitalize the waltz. My aim is to generate alternative perspectives of rhythm and begin to formulate a new rhythmic organization particular to computer music.

The background of this paper is drawn from the context of contemporary concert music and in particular, the rhythmic concerns expressed by Edgar Varèse. His approach to rhythm will be addressed as a point of reference and departure.

Although rhythm is inherent in any time-dependent medium, it is not restricted to time-dependent mediums and therefore this term is used in a variety of contexts. For the whole of this paper, I present research of time dependent arts as well as plastic arts, in connection with computer music research, to organize historical and progressive views on rhythm. An inclusive survey of rhythmic inventions found throughout the arts and sciences will provide insight into the organization of sound and will examine and facilitate the following views particular to computer music:

- The internal rhythmic structure of sound, micro rhythm in micro sound, and microstructures.
- Multiple layers of sound objects as rhythmic structures, symmetrical textures, and possibilities with metric organization and geometric design as an integrated aspect of rhythmic form.
- The redefinition of measures in favor of masses, rhythmic complexity in algorithmic composition.
• Rhythm as force and the generator of form, dynamic systems, proportions, and growth patterns.

This paper is intended to be an offering for further experimentation, and a starting point to initiate conscious rhythmic intentions. A conceptual understanding will allow for individual operational experiments, and include my own experiments as a means of departure.

Context

The following documentation is a collection of perspectives on rhythm from instrumental composers and music theorists. The following documentation is chosen on the basis of significant turning points in rhythm theory, and categorized into subsections.

RHYTHM AND CULTURAL CONTEXT

FRANÇOIS-JOSEPH FÉTIS (1784-1871) was a Belgian composer and musicologist, but most influential as a critic and theorist. In 1832, Fétis presents his speculations on the future of music and rhythm, where he suggests that the developments of tonality in his period can be separated into what he called “The Four Orders of Rhythm”: unirhythmique, transirhythmique, plurirhythmique, corresponding to the possible variety within a single (uni) meter, the interpolation between meters of differing lengths (meters in transit), then multiple and compound (plural) meter—“the immense and new musical realm in which various rhythms and different metric systems can follow one another and be connected naturally to produce effects unknown at this time” (Arlin, pg 282), and finally to the balance between all these forms, the omnirhythmique, which was perhaps too much to foresee at the time, perhaps a process that “results in a most serious drawback by incessantly agitating the nervous emotions . . .” (Arlin, pg. 287)

The speculation of an omnirhythmique structure was perhaps too experimental for his conservative approach to theory. It took twenty years before Fétis could accept the idea that the five-beat measure would
fit into his *plurirhythmique* order (not as a compound meter divided as $2 + 3$), as he did manage to find an “absolutely quintal character” through his own compositional experiments. The constant intellectual battle with symmetrical necessities did not allow the five-beat measure much hope for further development with its uneven and irregular premise. Fétis struggled with five-beat measures until he concluded in 1852 that despite its “disturbance to a person’s natural feeling . . . handled with talent and circumspection . . . the five beat rhythm takes its place among the possibilities of variety that can be introduced into the rhythmic system of future music” (Arlin, pg. 282).

The Sufi tradition embraced the number five as the first circular number. In the context of this tradition, a sphere is “the most perfect shape as it has no beginning and no end and is symmetrical in all directions with respect to the center” (Ardalan, and Bakhtiar, 1979, pg 29), and this “quintal character” serves as the most common metrical base used in classical Persian music. The number five is an example of a specific preference, but exemplifies the cultural differences embedded in concepts of rhythm, accepted measured spaces and proportions, extending from music to architecture and religion—resulting in such resonant symbols as a dome or a steeple.

By the late 19th century, the music from cultures outside the European tradition became increasingly influenced by other cultures. European composers began to push the limits of western musical practice. Debussy, Ravel, Mahler and others, all played with folk or foreign ideas, lifting and reinterpreting material freely. Using these ideas and materials as though they were inventions was not uncommon in the early part of the twentieth century. In art, Picasso borrowed the cultural form of the African mask, which served as the basis for a lifetime of invention within the school known as primitivism, and sixty years later, in music, Steve Reich reinvented the Indonesian “loop.” Music from India, Africa, and Islam played a very important role in the evolution of rhythm in western music, although, most of these early western innovations of rhythm fall within this version of invention, which, more accurately, should be regarded as a translation of foreign rhythmic concepts.
SEPARATION OF RHYTHM FROM ITS STYLISTIC ORIGINS

THE MOST PROMINENT INNOVATIONS occur as the rhythm parameter becomes acknowledged on its own terms. Rather than treating rhythm as a musical element subservient to the traditional importance of harmony, counterpoint or melody, rhythm becomes elevated and more dominant. It takes its place as a facilitating factor for innovative musical experimentation, which coincides with the extensions or depletions of traditional harmony, thereby opening the opportunity for rhythm to regain some of the prominence that had been lost since the 15th century.

Chopin calculated complex rhythmic combinations as a means of notating rubato and temporal modulation, while Scriabin pushed these cross rhythms even further with more intentional structures. Scriabin’s more rationalized musical manner brought these rhythmic patterns to the forefront. Charles Ives “builds up musical moods which rely on rhythmical subtleties to an even greater extent than on tonal elements in their effect” (Henry Cowell, 1930, pg.108). What Chopin did with dramatic rubato and tempo changes, composers accomplished later with multiple tempos; resulting in polytemporal compositions, for example Charles Ives’ Symphony No.4, Stockhausen’s Gruppen for 3 Orchestras and György Ligeti’s Chamber Concerto for 13 Instrumentalists.

Igor Stravinsky carved and spliced his musical material to create asymmetrical rhythmic accents and shifting patterns and treated the meters and chords equally as static objects to be moved independently of each other. Through his juxtaposition of irregularities and displacements, nothing in his music falls into place traditionally. These innovations were deemed as “primitivism” for their combination of connotative styles and forceful use of accent. Syncopation, regular or irregular meters and accents were used in his compositions as individual components allowing for multiple rhythmic interpretations. Stravinsky is most recognized for rhythmic usage due to the infamous Le Sacre du Printemps (1913), although Les Noces (1923) with its stark folkloric colours and simpler orchestration may be a better example of the same musical intention.

Two weeks after the premiere of Le Sacre du Printemps, Debussy
premiered his last orchestral work, *Jeux* (1913), with the same ballet company, the Ballets Russes and Diaghilev. This work was overshadowed for decades as a result of the attention garnered by the notorious riots over *Le Sacre du Printemps*. If we look at *Jeux*, then we see more clearly why *Le Sacre du Printemps* caused such a scandal. Stravinsky’s music sounds like explosions of graceless right angles in comparison to the more delicate palette found in *Jeux*, although *Jeux* is equally rhythmically intriguing with ever changing timbral and temporal fluctuations throughout the piece.

The music of Conlon Nancarrow (1912-1997) is often considered the most rhythmically complex music ever written and it is almost entirely written for player piano, as this kind of musical complexity necessitates a machine to produce the it accurately. The studies for player piano include irregular time signatures and shifting tempi; in No.37 there are twelve different tempi for twelve different voices, while others consist of interlocking patterns unified by a singular tempo. The music contains a referential language from jazz to moments of bebop or brass band, which altogether make an intense ragtime, and yet ultimately leading to a musical language of its own. Nancarrow’s rhythmic intention also includes the direct application of classical Indian cyclical structures, and yet to such a complex degree that it is arguably impossible for instrumental musicians to reproduce.

Nancarrow’s music has an immediate uniqueness built from the fusion of more popular or folkloric forms with those of instrumental concert music, but this is clear when we consider only the surface levels. Rather than focusing on aesthetic concerns, my point here is to acknowledge these early inventions of rhythm as being innovative on a surface level; the composers built a provocative rhythmic language from the intensification or re-structuring of other conventional rhythm.

**PREDECESSORS OF RHYTHM APPLICABLE TO ELECTRONIC MUSIC**

Olivier Messiaen described an alternative in his *Technique de mon langage musical*, 1944. Being interested in rhythm, he studied 13th century
Hindu *deci-tàlas* and Greek metrical systems which he integrated into the core of his compositions, and eventually composed serialized structures that encapsulated these rhythmical ideas without quoting stylistically. Messiaen developed techniques such as *palindromic* rhythms, (possibilities in symmetrical patterns), *added values* (an addition to a duration making its value irregular), *rhythmic canons, augmentation and diminution* (the relationships produced by ratios such as three eighth notes to three dotted eighths and the exchanges of these over time), and finally the idea of *personnages rhythmiques*. This last technique is a further development on Stravinsky’s ideas of rhythmic cells, as each cell contains specific parameters, one of which is the designation of *mobility*. A cell that is considered mobile may decrease or increase in value, whereas an immobile cell will never change.

“*Most people believe that rhythm means the regular values of a military march. Whereas, in fact, rhythm is an unequal element, following fluctuations, like the waves of the sea, like the noise of the wind, like the shape of tree branches*”


The sense of temporality in Messiaen’s music is affected by his use of these techniques in proportional structures. An extremely slow tempo filled with rapid movement and the use of repetitive structural units can both convey the impression of suspended time. As the harmony is
treated as a static element, and the rhythm is treated like the detail of an ornate mosaic, the resulting sense of time flow is that each moment is vital to the form and yet does not suggest progression. As Messiaen continued to focus on aspects of rhythm, he moved the original interpretation from other musical traditions, and from pattern, symmetry, and durational values, he arrived at unmeasured musical movement, thus as described of *Quatuor pour la fin du temps*, “where more or less literally Messiaen put an end to the equally measured ‘time’ of western classical music” (Eyeneer Archives program notes).

The pitch and rhythmic structures in Anton Webern’s music can be discerned by ear, even though these structures are distributed between the instrumental or vocal part, and include structural silence enabling rests to take on an accented role. Each instrumental part facilitates another, as if they share the same colored glass in a fragmented kaleidoscope or the same arm in the structure of a snowflake. An internal organization is apparent in the pitch structure, but also hugely important to this music are the rhythmic cells and attention to durational proportions on the organization of structure.

Allen Forte has created a thorough analysis in his article: Aspects of Rhythm in Webern’s Atonal Music, *Music Theory Spectrum, Vol.2.* (Spring, 1980). Forte’s documentation includes a proportional graph for Webern’s *Sechs Bagatellen für Streichquartett, op.9*, movement 5, included here as an example of his analysis. In this graph, the vertical layers correspond to the instrumentation, nodes and solid lines determine onset, duration and offset, and the dotted lines signify the duration of silence. The smallest durational value in the piece is assigned to be the value of 1, as a means of having a common denominator so that all durational units can be compared. The analyses show geometric structures, with attention to numerical proportion, and mirrors, retrogrades and inversions, similar to the serial technique of pitch structures.

Webern is one of the composers whose thinking has influenced the development of computer music. The use of silence in his compositions is important (not as a Cageian *philosophical* musical moment) because it contains full structured intentionality. These silences are as rigorously defined as
Example 3. Webern, op. 9/5; proportional graph.

Proportion Graph by Allen Forte. Webern, op. 9, mvt. 5. Source: Music Theory Spectrum, Vol. 2 (Spring, 1980).
sound is and, considering that both are equally part of rhythm (the attack and release, or the on and the off) it is important that the duration between onsets is integrated into the structure as clearly as the duration of the sounds themselves.

Henry Cowell began writing *New Musical Resources* in 1917, in which he formulated a new and carefully applied theory of rhythm. By initiating a theory of rhythm as sound-vibration, he begins an important thread of research in electronic music, which will be discussed in more detail at the following chapters.

Brian Ferneyhough has denounced most of the ideas, previous to his own, regarding iterative rhythm and meters as either “temporal extensions” or “agogic pattern-making.” He suggests that the only use left for rhythm is in creating large scale articulations, and otherwise it is “at best anecdotal, at worst an actively debilitating factor” (Ferneyhough, *Collected Writings*, 1995). Ferneyhough addresses the concern of metrical use within the stylistic context, making it clear that a higher-level musicality is devoid of any such “negative features”, and contains none of such “residual patterns.” He also makes the point that within most contemporary music, the use of a metrical form, such as 4/4, has nothing more than a time keeping function.

*I start from the standpoint that a measure is not primarily a unit of emphasis, but a space, serving to delimit the field of operations or presence of specific sound qualities, of musical processes. The consistency of iterative pulses serves primarily to set off the limits, operative boundaries between one such space and another.*

*In my own music I have concentrated on the issue of interrelating iterative rhythm and metric structure through ratio relationships, which are individually quantifiable, and thus open to interaction in many diverse and complex ways.*

—Ferneyhough, *Collected Writings*, 1995
In 1996, Joshua Cody (artistic director of Ensemble Sospeso, New York) interviewed Ferneyhough, eliciting further remarks regarding the possibilities of metric functions in music:

*Meter represents a very useful form of middle ground mediational compartmentalization with respect to perceived time flow, and allows one to deal more delicately with aspects of fine-tuning in the prevailing realm of time-space analogy and its inconsistencies and ambiguities. I don’t really hear meter as a form of pulse hierarchization but rather as a quantified space to be experientially articulated and differentiated. I therefore assume that relative ratios between different-length measures are to some significant degree appreciable in and of themselves. That is certainly the basis for my pre-compositional operations, where I frequently compose out the entire metric structure of a piece in modified cyclic form, where each cyclic revolution undergoes some form of ‘variation’ much as if measure lengths were concrete musical ‘material.’*

. . . ‘irrational’ measure lengths, i.e. those based on beats expressed in terms of fractions of full beats in the prevailing tempo, thus giving rise to such time signatures as 3/10 or 5/24, are useful as local ‘dissonances’ serving to refocus attention and instantiate reassessment of the prevailing temporal perspective.

Ferneyhough has composed some of the most difficult notated rhythms ever written for live musicians; nevertheless, some virtuosi have proven it
possible to perform them. The kind of detail and complexity contained in his compositions is especially effective in his String Quartets, where it gives a forward movement together with an audacious, delicate quality. The concept of “local dissonances” in the metrical structure is problematic, as there is no point of reference to note any local consonance in the metric structure. However, Ferneyhough’s music does suggest the degree of articulation possible in temporal and numerical complexities that is suitable for the electronic composer.

THEORETICAL VIEWS ON RHYTHM AND THE EXPERIENCE OF MUSICAL TIME

FRED LERDAHL AND RAY JACKENDOFF (composer and psychologist) co-authored The Generative Theory of Tonal Music (1983). From the viewpoint of traditional music theory and cognitive science, it offered many innovations in the substance of rhythmic theory. The distinction between grouping structure and metrical structure is essential to Lerdahl and Jackendoff’s conception of musical rhythm. Metrical structure exists only at the musical surface and is articulated by an emphasis in the sound signal. The theory suggests that “grouping” is the basic component of musical understanding, and grouping structures (structural accents, phrases, resolutions, or abrupt changes) are experienced recursively by the listener as progressively larger musical units. The structural grouping and metrical grouping do not necessarily coincide; grouping and meter can be out of phase with each other or in different proportions. This counterpoint on multiple time scales provides structural syncopation (elision, driving the music forward), structural downbeat (collision, creating powerful accent), and a counterpoint of rhythmic structures, which occur when groups and structural accents stand in relation to metrical structures. The authors redefine the singular beat as an infinitesimal point in time corresponding to a point within a geometric shape, rather than a line that connects the points. Where the “time-span” is the line between the beats, beats then do not have duration, and the time-span is the duration or interval between them. A large-scale time-span can also occur when the metrical and grouping structures are filled with structural ornamentations.
Jonathan Kramer’s research into time and rhythmic structures, exemplified in his publication *The Time of Music* (1988), offers an extension of the previous ideas. As an introduction, Kramer writes, “If we believe in the time that exists uniquely in music, then we begin to glimpse the power of music to create, alter, distort, or even destroy time itself, not simply our experience of it.” In this way, he sees music as a series of events that not only contain time, but also shape it, and therefore we experience this musical time simultaneously with absolute time.

Kramer suggests that rhythm and structural rhythm are founding this shaped time. He describes the following theoretical temporal modes and considers them practically through an expansive treatment of metrical, grouping, and structural analysis of particular compositions. *Goal directed linear time* is a temporal mode when A goes to B, in the form of cause and effect, where the goal is achieved directly. *Non-goal directed linear time* also goes from A to B but may meander or behave subversively as it moves towards its singular goal. *Multiply directed linear time* describes the temporal continuum where there will be more than one linear goal. Also, as A will proceed toward B, the progression of C moving toward D may interrupt this progress for some time, but the individual linear goals will ultimately be completed. *Moment time* contains no fundamental linearity and is discontinuous. Kramer describes that “moments are often defined by stasis rather than process”, they may or may not be arbitrary, but will seem arbitrary. Finally, *vertical time* represents, complete and indefinite stasis of time, “untempered by progressions in time”, and is experienced similarly to that of viewing sculpture. This does not manipulate the listener by imposing subjective or characteristic qualities such as symbols or referential meanings, and the last remnant of linearity—any degree of phrasing—is gone. Essentially, this spectrum of temporal modes moves between two extremes: from a singular, goal driven experience, to a sense of timelessness and musical stasis. Usually, a composition moves through the spectrum of temporal modes, can be in more than one mode at a time, and rarely exists in one mode entirely.

The subjective quality of these temporal modes may be filled with contradicting perceptions that Kramer is careful to point out, but it
serves as the backdrop to his pursuit of a more complex understanding of musical time and rhythm. In the context of electronic music, it is important to recognize that these temporal modes are still relevant, and especially the latter, as there is much less possibility for such clear goal oriented music that is not organized around a harmonic language. Being able to describe musical stasis or musical momentum is useful for the composer; often this aspect of a composition continues to be treated solely as result of intuition.

Kramer looks into the practical musical elements as a means of determining these elements of musical time. “If musical time is subjective, malleable, and multiple . . . what does the precise measurement and comparison of durations really tell us?” (Kramer 1988, pg. 53) Kramer suggests that in tonal music, the motion shapes, or the experience of goals being achieved, distort our perception of duration. It follows that if one were to create shapes in music where non-linearity is the dominant force, then proportion will become the main force for musical coherence. Kramer justifies the need of a quantitative study of durations in moment time music for the following reasons: Moment time music is made of sections that are relatively static, as they are not given coherence through a context of progression. “The more static a passage, the more its perceived length agrees with its clock-time duration.” Therefore “in music lacking duration distorting motion within sections, the perceived proportional relationships between section lengths tend to accord with the ratios of objective measured durations.” (Kramer, 1988, pg.53)

Kramer draws from Lerdahl and Jackendoff’s theories of beats, pulses and metrical definitions, although he makes some notable differentiations. Again, beats points in time without duration, as is the point in space within a geometric shape, and the varying degree of accentuation of these time points creates the sense of meter. The difference between meter and rhythm in this case is that a meter is usually cyclic, whereas rhythm is in constant variation. “Rhythm is a force of motion, while meter is the resistance to that force.” (Kramer, 1988, pg. 83) Rhythmic accents and metric accents occur independently and do not necessarily coincide, the pulse as an accent is flexible and rhythmic, playing with that
force of motion. Joel Lester describes, “A metric accent . . . can occur on a rest; no event need mark it off. This is because meter is, in part, a psychological phenomenon. When a meter is first established, or is being reinforced, events must mark off or imply the metrically strong points. Once established, however, meter has a life of its own.”

CONCLUSIONS

INSTRUMENTAL COMPOSERS HAVE GENERALLY continued to use rhythm in either a stylistic manner or as a result of other complex musical concerns. The exceptions are those who would seek musicality with a more sonic oriented desire.

The dissection of rhythm and sound by separating and relating elements on multiple time scales begins a theoretical viewpoint of parametric organization applicable to the complexity of rhythm in electronic music.

The first reason for me to redefine rhythm in regard to computer music is that when, for example, the concepts of Indian classical music are translated into western traditional notation, the music does not work in the same way. A rhythmic language is developed in connection with sound, and this means that the language comes from the instruments that produce that sound. Therefore, with the individual properties of digital sound, that rhythmic language must be unique to the computer.
Inventions of Rhythm: Alternative Perspectives and Computer Music Applications

It is clear that the previous research is insufficient to the recent realm of musical activity in the concert electronic medium. The previous language used in the discussion of rhythm is unyielding to the innovative approach; Edgar Varèse proposed a new world of rhythm when he stated:

*Rhythm is too often confused with metrics. Cadence or the regular succession of beats and accents has little to do with the rhythm of a composition. Rhythm is the element of the composition that gives life to the work and holds it together. It is the element of stability, the generator of form. In my own works, for instance, rhythm derives from the simultaneous interplay of unrelated elements that intervene at calculated, but not regular, time lapses. This corresponds more nearly to the definition of rhythm in physics and philosophy as “a succession of alternate and opposite or correlative states.”*

—Varèse, Rhythm, Form and Content, 1959

This quote initiates several of my goals in the following sections: the need to revisit and revise basic concepts by inquiring into both artistic and scientific practices, the need to look at the means of holding a work or a sound together, to calculate moments of intervening elements, to discuss the elements of stability—all directed toward electronic music.

The thread of my research will not be chronological; instead I will
offer a survey crossing artistic and cultural practices. The inclusion of rhythmic invention found in visual arts, philosophy, sciences, etc. is an intention that aims to foster innovation. At the same time, the direct application of these ideas to known musical works and my own experiments is intended as a means of keeping in touch with the goal in mind. Rather than offering a lofty, free form philosophy of rhythm, the external sources are intended to shift perspective and move toward an operational context.
THE INTERNAL RHYTHMIC STRUCTURE OF A SOUND

In the context of computer music, the premise of rhythm will stem from an understanding of complex sound structures for which writings by Henry Cowell, Karlheinz Stockhausen, G.M. Koenig, and Curtis Roads are essential. The relationship between rhythm, frequency and microsound will expedite the primary means for a conceptual revision of rhythm, and this revision will be applied to the information in the following chapters.

HENRY COWELL: NEW MUSICAL RESOURCES

... rhythm is the moving impulse behind the tone, rather than the tangible thing having physical existence.

—Cowell, New Musical Resources, 1930

Cowell’s publication of *New Musical Resources* (1930) initiated an important revision of rhythm that is founded on early discussions of sound and frequency. He states that rhythm is not only related to, but also based upon the same properties as sound-vibration, and he proposes an organization of rhythm that correlates to the overtone series: a chromatic scale of durations, based on the relationship between the rate of cycles per second and the ratio equivalent subdivisions of a fundamental duration. This resulted in a system of consonant and dissonant polyrhythms, which are technically equivalent to intervals and chords, although on different time scales. Where the perfect fifth has a vibration ratio of 2:3 and the minor third is 5:6, every interval in the chromatic scale is one cyclic
micrometer against another. Cowell continues to use this idea as a mirror to the western harmonic system, with consonance and dissonance directly translated into “metric chords.” For example, a major triad in second inversion has an interval of a perfect fourth, and then a major third. According to his charts, this metrical chord, occurring in the duration of a common unit, would contain three layers of division—one into three, four and then five. Essentially, he recognized that harmony exists as a result of the variable rates of cycles per second occurring at the same time (micropolymeter), creating consonance if they line up regularly, and dissonance when these cycles line up less regularly and that the same principles can apply to subdivisions of rhythm. The twelve-tone scale has a largely consonant and limited set of possible cyclic micrometers, and therefore the extremes of these polyrhythms range from a ratio of $1:2$ as the most consonant, and $14:15$ as the most dissonant. From this perspective, western harmonic language is built on a system of cyclic polymeter, and the traditional use of meter is the static framework for these complex ratios in microsound.

Cowell introduced his theory of new tone combinations by saying, “Music is based upon, and is conditioned by, the physical laws of sound-waves. These laws disclose that musical tones have a relation to each other, which is measurable by mathematics” (Cowell, New musical Resources, pg.3). This still holds true when speaking of computer music, although the attention to particular relationships filters the musical language, which is then considered music. A tone and its harmonics exist as a result of repetition—the string which is set into vibration, will naturally begin to vibrate twice as fast in two halves of the original length, at three times the speed in threes, and onward in this manner. By investigating the relationships of the overtone series, Cowell looked into the periodic aspects of sound.

Using this concept to formulate a theory of rhythm does not incorporate the wider spectrum of sound that is filled with noise, irregularities and unequal measurements. The overtone series is an interesting structural phenomenon where complex dissonances are a result of periodic sound behaviour. By taking the physical laws of sound waves as the source for a language of rhythm unique to the computer, it is clear that
there is a larger realm of sound properties than that of the overtone series and purely acoustic sound properties.

“... all music is rhythm, variation of pitch is variation of rhythm, harmony are the blending of these rhythms... rhythm is nothing but the division of frequency plus an emphasis of that division.”

—Ezra Pound, 1910

This could be slightly revised, as all music is rhythm, variation of pitch is the variable rate of repetition... or the tempo of a regular pulse.

Most importantly, Cowell recognized that the rate at which sound vibrates relates the previously separated concepts of beats or pulses to sound vibration: “... a parallel can be drawn between the ratio of rhythmical beats and the ratio of rhythmical tones by virtue of the common mathematical basis of both musical time and musical tone.” (Cowell, *New Musical Resources*, 1930)

**Karlheinz Stockhausen: How Time Passes**

By 1955, Stockhausen had come to similar conclusions regarding the continuum between rhythm and pitch.

If the rate of beat is gradually increased beyond the time constant of the filter and the limits beyond which the ear can no longer differentiate, what started as a rhythmically repeated note becomes continuous... We see a continuous transition between what might be called durational intervals which are characterized as rhythmic intervals and durational intervals characterized as pitch levels.

—Stockhausen, 1955

Stockhausen takes these concepts further into his temporal theory with the publication of “... How time passes...” in 1957, which leads to important information on rhythm in relationship with temporal experience and compositional strategy.
Stockhausen suggests that the continuum of rhythm to pitch, as a concept of temporal spectra, occurs on multiple musical time scales. In one perspective, the threshold of perceived rhythmic intervals to continuous tone is approximately at 16 cycles per second, where rhythm is perceived between 6 and 1/16th seconds and continuous tone is perceived from 1/16 to approximately 1/3200 of a second (Roads 2001). Furthermore, the spectrum of a tone results from the microrhythm that exists over a fundamental period and on a larger scale, just as there exists the rhythmic spectrum over the fundamental duration of a composition.

The treatment of rhythm in the manner of pitch is reasonable considering this continuum and considering that they are both time based elements. As Cowell had searched for new rhythmical systems that would mirror pitch structures, Stockhausen also searched for a chromatic durational system within the aim of serial composition. These systems range from a series of twelve equally increasing durations, to a subdivision of a whole note corresponding to the overtone series. Stockhausen explains the contradiction that the inner structure of a continuous tone consists of the hierarchical organization of the overtone series, and that serial composition is organized non-hierarchically. If rhythm is to be treated in the same manner, with its fundamental duration and spectrum of subdivisions, it must also be able to be placed in any sequence or combination with differing fundamental durations and spectrums, of course adhering to a proportional series of these fundamental durations. Stockhausen eventually designs an equal-tempered duration scale where a whole note is designated to one of twelve tempo markings between 60 and 120 bpm, in which each difference in the tempo scale corresponds to the 6% difference between the semitones in the equal-tempered pitch scale. *Gruppen* and *Carre* are examples of Stockhausen’s solutions to composition and performance issues in the realization of these complex rhythm and tempo structures.

Once Stockhausen’s system of fundamental durations fulfilled the criteria for serial composition, he discussed further how there may be an internal rhythm inside that duration “which is like choosing a timbre by constructing an overtone series on a fundamental pitch” (Koenigsberg).
Curtis Roads adds to this thought in his discussion of Stockhausen’s early experiments:

“One can speak of a fundamental rhythm with harmonically-related rhythms superimposed. A periodic tone can be seen as having a rhythmic microstructure, with waveform peaks corresponding to its internal rhythmic intervals. The difference between meter and rhythm corresponds to the distinction on the microtime scale between fundamental tone and tone color, and one could just as well speak of “harmonic rhythm” as of tone color.”

—Roads, Microsound, pg.74

It is in this context that rhythm gains more interest and meaning than the issues which serial composition or instrumental music can offer. Cowell and Stockhausen demonstrate the struggle to make rhythm conform to a system based on periodic behaviour and acoustic sound properties. The idea of constructing timbre resides in the realm of electronic sound and digital control, but it is not necessary to apply strictly acoustical sound properties within a digital medium or to confuse periodicity with the definition of rhythm. The ability to perceive this aspect of sound could be regarded as marginal, but I believe that it is in this realm of sound that rhythm is prominently perceived. What we consider as meter, beat, accent, etc. are only surface levels, or stylish aspects, of musicality so that even within strictly beat-based music, it is not the beat that makes the music have rhythm. The musician that sonically moves in the performance, within the limits of a prescribed or improvised fundamental duration, is the musician with a strong rhythmic sense. The infinitesimal timbral changes, the fractional delays, or the slight bend or break of tone exist in any systematic construction of sound organization and overrides any musical style or compositional method. With or without live musicianship, electronic music proposes the ability to compose on all musical time scales with the utmost rhythmic inflection.
GOTTfried Michael Koenig: Summary Observations on Compositional Theory

G.M. KoEnig Summarizes Compositional Methods in Summary Observations on Compositional Theory (1963-1970) and differentiates the instrumental compositional procedure as one that “starts with the given instrument, producing particular sounds” from the electronic compositional procedure that “starts with the idea of the sound which then must be realized.” He continues that the construction of a sound then requires that a complex sound should be defined.

Koenig’s criteria for determining the complexity of a sound have two properties: the nature of the pattern, and the relationship between several patterns. Also, the number of distinguishable parameters, and the rule by which they are distributed throughout the pattern are significant to the complexity of the sound. A sine wave is used as an example of the minimum complexity of one pattern, for the period, or the pattern, consists of a symmetrical division of time and amplitude, and the complete tone is produced by the exact repetition of this pattern. Using only two parameters, the values are consistent with the symmetrical sine function and continue over the same period of time repetitively.

Points determine the parameter values of a sound, are scattered throughout the duration of the pattern, and are separated from each other by a time delay. The method of scattering will determine whether these points have periodic or aperiodic behaviour. These points in time, referring to the prominent changes within a parameter of the sound, create the

G.M. Koenig: parameter/time field

Example of a musical form unit.
horizontal complexity of one pattern. Each parameter field is characterized by the distribution method, the value limitations and restricting conditions, and by the number of points to distribute. This same procedure applies to the points in time, arriving at a sequence of algorithmically designed patterns.

Multiple parameter/time fields, which are superimposed, describe the structure of a sound, as there are always many parameters in one musical form-unit. In order to superimpose the parameter fields in this manner, the time field would need to be of the same durational value, a common time field, although further complexity is achieved if there are independent time fields. The points of one parameter may land on the same time point in time as another parameter, creating clusters of parametrical emphasis, or may all be separated, may occur in regularity or irregularity, creating vertical complexity. Koenig calls this complete musical form-unit a sound field.

In this definition of a complex sound, the basis for rhythm in electronic music can be determined. A sound field is a more useful term than meter. Considering Curtis Roads’ comment previously discussed that the distinction between meter and rhythm is analogous to the fundamental tone and tone color in microsound, in digital sound, it will be analogous to the time field and the distribution of parameter points. These points that are “any relevant alteration in the sound field serving to describe a pattern” (Koenig) can take the place of emphasis, rest, or accent. Predetermined sound fields may be organized in a static state, or in real time processing, the parameter field may also be constructed to choose values at a particular rate, or react to and depend upon the values of other parameter fields or live input, determining its accents and emphasis, as well as its time field, in real time, and thereby making dynamic relationships.

By examining the continuum of rhythm to frequency, only one example—the minimum complexity of a rhythmic pattern (a repeating pulse with a constant time interval)—is considered to be rhythm. On the other hand, the continuum between periodicity and aperiodicity within sound-vibration, producing noise and continuous tone, or random
pulses to a steady beat, and the fluctuation within this continuum, will achieve the complexity described by Koenig, and which I will refer to here as the internal rhythmic structure of a sound.

The sound object that lasts within the range of seconds is where the continuum of a continuous tone to an indefinite pitch or pulse is perceived. Regardless of whether a pitch or pulse is perceived, it is a continuous sound, and as Curtis Roads describes, “Pitch and tone are not the same thing. Acousticians speak of complex tones and unpitched tones. Any sound perceived as continuous is tone. This can, for example include noise” (Roads 2001). If rhythm is considered the movement between states, then any continuous tone (a sound remaining in one state) is the minimum complexity of rhythmical movement within the duration of the sound object. Therefore complex sound and rhythm as defined here, are the same.

Even on the micro timescale, it is possible to explore the internal rhythm as it creates timbre and moves even the shortest perceivable sound object. Considering sound scientifically offers further insight into the “wide range of transient, chaotic, and periodic fluctuations” (Roads 2001) that become integrated within this definition of rhythm. In the Varèsan sense, the inherent irregularities and transitory nature of sound are essential to this perspective.

Koenig continues to discuss the complexity of relationships between several patterns. These relationships may exist within one parameter as it changes over time horizontally, between two or all of the different parameters occurring simultaneously in one form-section, or between several sound form-sections.

_We shall speak of higher complexity if the individual values have many relationships to one another, and of lower complexity if only a few relationships are clear._

—Koenig, pg 35

In his examples of the different kinds of relationship, he suggests that if two sounds occur in succession and there is hardly any difference
between them, then this relationship is of low complexity. This is consistent with his example of minimum complexity, the periodic sine pattern, or its equivalent, the repeating time interval of a steady beat. Furthermore, sounds in direct proximity create a high sense of complexity and clear relationships, whereas continuous interpolation and overlapping may create difficulty in recognizing the relationships, and less complexity is perceived. Curtis Roads comments in regards to macro scale composition, “regular sounds/continuous sounds tend to get lost in consciousness, only noticed again when there are abrupt changes, or when they terminate” (Roads, Micsosound, pg.11).

_Pereception of sound-complexity depends on time: we only hear the complex relationship between two sounds if we remember both of them. Every sharp contrast interrupts our awareness of the respective average complexity. If the original pattern is not returned to after the interruption by the contrast, a new average value is approached: a new form-section occurs for the listener._

—Koenig, pg. 38

These suggestions can be useful within singular or multiple parameter fields on the micro scale, although perception of these is usually considered less prominent. As expressed earlier, it is on this level of sound that musicianship is most prominent, but more importantly, this analysis of relationship and complexity is integral to create terms for rhythm on a sound object scale where the precision and placement of sound objects in time becomes essential.

**SUMMARY: RHYTHM REDEFINED**

_The first revision of the term rhythm is discovered within one unit of time on a micro scale: it is the movement of particles acoustically, which result from the relationship of parameters which is rhythm, not whether it repeats, and not at which rate it may do so. A sine wave is clearly no more rhythmic than noise, just because the latter lacks repetition. The rhythmic structure of a composition is based on the same principles, namely the_
large scale of densities and sparsities marking an overall period of time—the composition.

The internal rhythmic structure of a sound is defined as the dynamic movement of an individual parameter and the relationship between several parameters occurring simultaneously within one time field. The behaviour of the parameters and the duration of the time field may repeat sequentially, may never return to this pattern, or will have individual characteristics moving between periodic and aperiodic behaviour as the sound objects progress. The movement between these states can be noted on multiple temporal scales, within one individual sound object, to the relationship between several sound objects, and to the form of a composition.

If a pattern does not change over time then the sound would be purely repetitive, and can be described as static. The more noise, the more irregularity in time interval, and the less repetition, will create a more dynamic, a more rhythmic sound. Most importantly, rhythm will be considered the state between these extremes; rhythm is itself the dynamic structure moving between periodicity and aperiodicity. The rhythm in a composition or a micro sound interacts with, dissolves and creates momentary, static activity, but rhythm does not occur if the musical behaviour remains in one static state. A completely, or even largely, random sound experience is perceived as “active” or “lively” at best, quickly lessening in degree of complexity, and missing the network of a total dynamic movement, which gives random behaviors a chance to actually have presence.

From this point, the term pattern is to be distinct from rhythm: a “pattern” is a static structure built from repetition, cadence or re-productive meter, while “rhythm” is a dynamic structure built from irregularity, correlative states, creating structural tension with a static form. This will be true on any time scale.
The results and possibilities of sound activity that is organized by systems of periodicity, functions of self-similar patterns, and their proportional measurement in time, will be examined in the following section. From repeating micrometers to complex symmetries, hierarchical systems of subdivided durational values, or proportional systems, all of which use repetition within a single pattern or between several patterns. In this chapter, seemingly simple concepts of periodicity are explored until patterns meet sound masses, where the essence of a discrete space returns to the continuous.

Repetition has commonly been used to create a strong psychological effect, it can be meditative or trance inducing, a group strengthening ingredient, a time keeping devise for synchronizing efforts, and it is also the premise of which some torture inducing techniques are based. Repetition will be considered within this continuum of periodicity, as it is situated in the extreme state of periodic organization.

There is a divide between popular, beat-based music and concert electronic music. Besides the emphasis on synthesis techniques, the most obvious difference is the degree of repetition and organization based on a pulse. A pulse is a musical choice, and there are plenty of examples where the steady pulse is pushed well beyond its foreseen purpose, where its subtleties attain a particular musicality, and it controls the internal parameters without demanding the listener’s attention—it can play a subservient or transient role, as momentary or continuous as one would like. The enjoyment of a dominating, organizational pulse in electronic music seems to divide the listeners who wish to be guided in their experience, and those that wish not to be.
Symmetry is deeply involved with traditional ideas of balance, and its power to communicate stability has been used for centuries in formal design. Temporal symmetries must unravel over time and are traditionally used to direct the attention with clarity, and guide the listening experience into frameworks of temporal expectations. In architecture, this result of focus and clarification will occur as well; if one needs to find the entrance to a building and the door is centered between two identical columns, the eye will be directed easily.

A repeating pattern within a repeating time interval, a steady pulse or a pitch, will be considered now as both having symmetrical and repetitive internal rhythmic structures. These formally periodic ingredients, a pitch and a pulse, have been traditionally used within symmetrical musical forms. From Cowell’s perspective, the colour and existence of the harmonic language is based on degrees of repetition and phasing combinations. Symmetrical architecture for sacred purposes that reflects repeating spiritual practices, or sonatas in 4/4 consisting of four measures per phrase, are two examples of repetition and symmetry embedded in symmetrical forms, and add up to what one would expect: in the extreme cases, the trance inducing quality, the powerful, mesmerizing quality of movement en masse, or in less extremes, simply—a musically orienting experience. As the material unfolds, the listener encounters similar material confirming memory and expectation, and the evolving experience will confirm where the music has been and will progress. On the other hand, a disorienting experience of sound organization is filled with irregular time durations, noises and unequal proportions, and as a result, there is more unconfirmed than confirmed information, providing the possibility for multiple perceptions, and, if guided at all, the attention of the listener will be guided in a more subliminal manner.

It will never be possible to describe music strictly in this way, as it is in
the nature of the medium to be transient, to cross temporal states (Kramer), and to remain subjective in this regard. John Cage suggested, while commenting on the paintings of Robert Rauschenberg, “We know two ways to unfocus attention: symmetry is one of them; the other is the overall where each small part is a sample of what you find elsewhere” (Cage, 1973). In this context, the intention is to say that guided listening is unfocused.

Regardless of these differing musical intentions, it will be shown that it is in between these areas where rhythm thrives: music exists only in a realm of risk, and so music will move forward through time by the nature of its devious subtlety—the addition of one thing and the subtraction of another, silence and juxtapositions, all of which veer from regularity to irregularity and vice versa, toying with expectations, memory, and the sense of timing.

**Loops**

THE MUSIC OF TERRY RILEY, Steve Reich, and Alvin Lucier has its origins in early tape loop experiments and tape delay/feedback systems during the early 1960’s. The music resulting from these experiments with phasing techniques ranges from distorting tape loop pieces to instrumental compositions, to installations including Lucier’s *Music for Pure Waves, Bass Drums and Acoustic Pendulums* (1980), all based on the use of simple, and very specific patterns moving in and out of phase. The sense of rhythm in this music, derived from looping and the harnessing of irregularities, is appropriately minimal, and is in favour of repetition.

Terry Riley described the origins of this discovery of the tape loop, while working with sound engineers in the creation of Music for The Gift (1963):

“He got it by stringing the tape between two tape recorders and feeding the signal from the second machine back to the first to recycle along with the new incoming signals. By varying the intensity of the feedback you could form the sound either into a single image without any delay or increase the intensity until it became a dense chaotic kind of sound. I enjoy the interplay
between the two extremes. This engineer was the first to create this technique that I know of, this began my obsession with time-lag accumulation feed-back.”

—www.loopers-delight.com/history/Loophist.html

Steve Reich and Terry Riley were mutually influential in the development of this music, but Reich’s background in philosophy and interest in the music of Ghana may have contributed to particular nuances in his compositional strategy. *Come Out* (1966) employs a vocal recording played on two channels, slipping out of phase with each other, splitting into more and more loops, ultimately leaving an unintelligible, distortion of previous patterns.

“In the process of trying to line up two identical tape loops in some particular relationship, I discovered that the most interesting music of all was made by simply lining the loops up in unison, and letting them slowly shift out of phase with each other. As I listened to this gradual phase shifting process I began to realize that it was an extraordinary form of musical structure. This process struck me as a way of going through a number of relationships between two identities without ever having any transitions. It was a seamless, continuous, uninterrupted musical process.”

—Reich, Writings about Music

Reich notes that a continuous sound is heard as a result of repetition and minimal variation within the progression. In performance, *Music for* 18
Musicians (1974-76), and other works of this nature, have a homogenous effect. The musician, who must physically activate repetitive onsets and syncopation, may experience this music as a “rhythmic” experience, whereas from the listener’s point of view, the entire unit is perceived as linear and unbroken. The composition has much in common with a fundamental tone, overtone patterns and the natural fluctuations similar to vibrato. It would be reasonable to expect a more dissonant quality to arise from the patterns moving out of phase, although this again is handled in regular proportions, leaving an overall consonant experience.

Jonathan Kramer suggested that musical time has “the power . . . to create, alter, distort, or even destroy time itself”, and that repetition is a means of stopping time.

Alvin Lucier’s I am sitting in a room (1970) must be mentioned for the particular use of repetition: the nature of the medium allows the sequence to crawl slowly into new forms, continuously changing, revealing its non-repetitive form, and revealing its uncontrolled state. The initial speech is transformed by the acoustical properties of the space, reinforcing the resonant frequencies of the room while gradually attenuating others; the room acts as a frequency filter. In the final stages of an originally forty minute looping process, the words are no longer recognizable. Piercing feedback tones scrape against each other and have taken the place of vowels, while the lilt of speech remains as the last remnant of the original phrases spoken. The process occurs steadily, keeping the sensation of an overriding, slow pulse due to the looping structure. At the same time, every sound is a variation of the previous so that the material is in constant renewal through variation. The regular unleashing of sonic material moves the process toward an inherent irregularity. The rhythm of the composition is the uncalculated element in this looping process, giving life to the work by the continuous forward moving and irregularity within the sound.

Feedback looping systems are essentially static forms, a pattern of cyclically re-feeding information, while the dynamic activity exists within the processing, determining interaction between the audio and signal processing. Consider the dynamic feedback systems of Agostino Di Scipio, as
he investigates the interaction between the room, the performer, and numerical values of signal analysis. He uses the term “circular causality” to describe the process of interaction rather than simply the reaction of a machine to its input. Rather, both sides of the interaction will behave dynamically in response to the information loop. By extracting particular features of the sound and by using this information to drive another control signal, which Di Scipio describes as sub-audio feedback or the feedback of control signals, the result is “a kind of feedback loop in the low frequency domain, or rhythm domain” (Di Scipio, Interview with Anderson 2005, pg.6).

What is implemented is a recursive relationship between human performer(s), machine(s), and the surrounding environment. Each action or reaction in any of these three elements has short- or long-term consequences on the whole, depending on the particular connections I design. Because it’s a recursive process, and because the recursive mapping of information from one element to another is far from being linear and void of noise, the overall process actually materializes a dynamic system. Let’s say it at least gets complex enough to blur any sense of a stable, recurrent input-output relationship.

—Di Scipio, Interview with Anderson 2005

Indian classical looping structures develop over the continual blurring and stretching between the boundaries of a melodic and metric looping pattern—the more a musician stretches the limits of this structure, the more rhythmically intense the experience. Similarly, by removing the perceptibility of the relationship between the input and the computer, the static quality of this loop is blurred for the listener, creating a tension with the listener’s expectations. Di Scipio’s Audible Ecosystemics are a series of studies where the computer and input are self-sufficient in their ability to co-exist, balance and compensate the input to output process. The structural pattern for Feedback Study consists of a sound processing loop where feedback initiates the system, continues to take in background noises, feeding the
computer, returning that sound back into the room after processing, of which some microphones will record once again, and onward in this manner. The DSP structure will extract information from incoming signals to regulate its own behaviour, to compensate in amplitude levels, and constantly restore balance between this delicate state of an almost simultaneous or instantaneous loop of producing and processing sound. The extremes will occur as the computer output interferes with the Larsen tones with frequency changes and noise, and the feedback will naturally build up while the computer must counter-balance and self-regulate the variable states. Di Scipio suggests that the musical form of this system has a major part to do with its capability of memory as there will be occurrences as a result of events from much earlier stages in the process: “It’s a sign of the system’s sensitivity to the external conditions and reflects the fact that the sound we hear at any given time is the outcome of the whole history of the system’s process” (Di Scipio, Interview with Anderson, 2005, pg.7). This complex looping process will ultimately accumulate to the point of its demise.

The *Background Noise Study No.3b with Mouth Performer* differs as the interaction is a more usual interactive loop between the performer and computer processing, but it serves as an example where a more dynamic tension is inherently built within the static form and the dynamic processing is itself the composition. In this case the performer places the microphone inside the mouth and attempts to make the least possible sound, a physical challenge due to the necessary and involuntary need to breathe and occasionally swallow, and in doing so, changes the shape of the vocal cavity and alters resonances. The computer processing takes these most miniscule sounds and applies discrete granular alterations and filters. The tension resides in the physical discomfort of forced stillness, and the need to make as little sound as possible, so that the system will not build too quickly and finish.

“... this fragility is an element that livens up the performance and instrumentalists may be more profoundly involved and made attentive by this risk of imminent failure” (Di Scipio, Interview with Anderson, pg.8). This is an example of simpler processing resulting in a more per-
ceivable, dynamic complexity. The rhythmic form, or the movement of temporal states, is built from a lively resistance to its process, a reluctance to move forward and to create variation, yet incapable of escaping.

**Symmetries**

“Symmetry is achieved through a balance of total impressions. A courtyard space may be required to balance a domed sanctuary space.”

—Ardalan and Bakhtiar

In the visual arts, and especially in the structural aspects of sculpture and architecture, the treatment of negative space is integral to the experience of form. The carved spaces of a sculpture are as integral to our vision as silence is to an aural experience. More importantly, certain architecture results from defining the space, rather than the space being a bi-product of its existence. Traditionally, acoustics have driven the form of a concert hall, but in electronic music the space is also designed within the medium.

La Alhambra, Granada
Source: private collections
In terms of sound and rhythm, the use of silence (a term used here to mean compositionally unintended sound) within the compositional object is worth considering. Webern provided earlier examples of structural silences and rhythmic cells that consist of durational rests, appropriate for complex patterns, symmetries and relationships for instrumental music. Considering this revision of rhythm, as the dynamic movement between altering degrees of periodicity, the rhythmicity of amplitude levels must also be considered. If the sound material largely continues in a high amplitude state, this will be considered a static state, and it is not difficult to remember the many torturous encounters with constantly unrefined amplitude levels. Amplitude has an obvious connection with emphasis or accents, and in this setting, an emphasis can just as easily be perceived with the surprisingly soft and subtle shift, or that of a silence, just the same as the deliberate hole in the canvas, or upon entering a room with no ceiling. In the realm of computer music, silence may be considered within the internal rhythmic structure of a sound field, and also may be integrated with large-scale compositional forms. Difficulties in the effective use of silence usually occur when less attention is given to its duration and proportion within the context of its placement in time. In these cases it can deplete the energy previously developed in the sounding material, rather than its potential to develop fineness of minimal sound and perception levels, or as accent and rhythmical uses.

Richard Chartier uses minimalistic cyclic patterns, constructed with carefully designed pause and silence to create transparent music of the slightest sounds, at times verging on the threshold of imperceptible amplitudes and frequencies.

Compositional focus often occurs in the space between the sounds.

\[\ldots\text{a faint rhythm is created and can provide a degree of structuring continuity to the piece, but as the work develops that rhythm is progressively fragmented and dematerialized into spectral remnants of its original. Knowable cycles can slowly develop, but within any discernment of pattern comes the}\]
particular auditory variance of the listener’s perception
—Chartier, www.3particles.com

*Afterimage* (2003) uses thin clusters of low frequencies that hover on the threshold of pulse and pitch, producing the simultaneous effects of cyclic polyrhythm and the pulsation of bending drones by quartertones. The consonant relationship within this layer is accentuated by pure tones at the upper limit of audible frequencies that are attacked like the sound of a pin dropping, all in equal measurements, at a tempo too slow to count, but essentially even and symmetrical. Silences occur not necessarily in total but are accounted for within each layer, creating a translucent texture of mirrored forms and empty spaces.

Including silence into symmetrical, durational patterns is complimented by a greater degree of complexity within the numerical relationships. Sieves can be seen as a powerful tool in the development of numerical patterns for time structures.

> In music, the question of symmetries (spatial identities) or of periodicities (identities in time) plays a fundamental role at all levels, from the sample, in sound synthesis by computer, to the architecture of a piece. It is thus necessary to formulate a theory permitting the construction of symmetries, which are as complex as one might want, and inversely, to retrieve from a given series of events or objects in space or time the symmetries that constitute the series. We shall call these series ‘sieves’.

—Perspectives of new music 28(1) 1990

“Towards a Metamusik,” Formalized Music

Xenakis proposed sieve theory for the creation of outside-time structures and numerical relationships. Sieves generate patterns of ascending numerical integers, which theoretically can be applied to several parameters but are most often applied to duration and pitch. Complexity is achieved through layers, offsets, intersections and unions of several sieve sequences. A complex sieve will create shifting and fragmented patterns,
creating an inherent irregularity and variation built from internal combinations.

Sieves are an invention of rhythm appropriate for the capacity of computer language and suggest the potential for rhythmic numerical sequences in electronic music. Using sieves as a source for durational structures does not prescribe cyclic structures; the sieve can be expanded into an endless list of numerical values, just as the combinations can produce endless variation. The combination of sieves can produce irregularities within one sequence of values or this combination can be split between several different parameters simultaneously. In this case, the unifying, numerical patterns allow temporal relationships within the parametrical counterpoint. This interaction can also interweave the numerical values of several sieves on differing timescales.

Xenakis used sieves as a generator of time structures in Psappha (1976), for solo percussionist. The initial phrase shows a complex sieve with indices 5 and 8, creating a cyclical structure made of forty units. Referring to the “metabolae” (shifts or changes) found in the poetry of Sappho, (Harley, 2004 pg.94), Xenakis offsets the sieve to begin at different indices, blurring the periodicity of the original forty unit cycle. The sieve is a mediator between numerical structure and musicianship, pushing the borders of pulse and rhythmicity.

In this context, the meaning of polyrhythm extends: rather than complex subdivisions of a fundamental unit of time, polyrhythm can also mean the counterpoint of several rhythmic constructions (Harley 2004, pg.94), occurring simultaneously and in simple or complex relationships. This permits patterns and symmetries to exist only in the largest temporal scale. As irregularities are perceived in moment form, the arms of each rhythmic layer branch onward into macro periodicities.

The potential of sieve cycles and symmetries will not necessarily create relationships that are perceivable, as these structures offer labyrinth designs if one should desire. In the case of multiple sieve structures, periodicity will not create synchronous, temporal events, but serve to maintain coherent, internal relationships.

The results of what Xenakis introduced, as “complex symmetries”,
Psappha: Opening passage showing rhythmic sieves.
www.iannis-xenakis.org/partitions/

may also be imperceptible or non-existent symmetries. Depending on the degree to which the numerical pattern has been transformed or combined, this system is less about perceivable symmetries and more about patterns, a means of scattering numerical values across the parameter
field, and allowing the numerical aspects of rhythm to move beyond simple relationships.

Patterns

THE NUMERICAL PATTERNS THAT are used in computer music are embedded in the construction of every sound; it is the fiber of the medium. These numerical patterns are usually intended as structural and generative material, rather than concerned with the perceptibility of patterns and durational relationships.

Gary Miller (mathematician and physicist, Canada) suggests that in a broad sense, mathematics is about patterns.

“... let us say that a pattern is a ‘passing over’ of its partial features or aspects. A piece of music passes over all its notes, silences, and passages. These notes and passages are the aspects of the piece of music regarded as a pattern. A pattern is always whole. In this case, it is the whole piece of music. Moreover, the notes and passages are themselves patterns. A graphic image, say a painting, passes over all the regions of the image, all the lines, tones, colours, figures and textures that make up the image. Whether a static pattern of a picture, or dynamic pattern of a song, the pattern is what it is by virtue of the way it ‘goes over’ its aspects. The way it goes over its aspects is the way these are fitting together to give the whole. Thus, we could have used the more cumbersome phrase a fitting togetherness instead of the term pattern. Let us call a static pattern a form.”

—Gary Glen Miller

Rhythmic patterns have a very different connotation. As rhythm has been differentiated from pattern, it will be useful to consider the boundaries of a pattern, and how we perceive patterns. While listening to electronic music, the following information can suggest why one will be inclined to experience a coherent progression, and also, the natural disdain from coherent tendencies. Studies in rhythm and pattern perception provide statistical information and suggest similar associations that can be applied while listening to electronic music.
According to Paul Fraisse (Rhythm and Tempo 1987), the grouping of information into patterns is the result when any difference is introduced into an isochronous sequence of elements. The difference can be as subtle as a change of timbre, amplitude levels or change of frequency. To test the duration of one grouping, people were given a different number of sounds to produce as a pattern. The more sound events to assemble in one group, the more frequently sounds were used in succession, and the fewer sound events, the less frequently. Even when more complicated patterns suggested subgroupings, the maximum duration did not exceed 5 seconds.

The differences in these sounds that form a group will shift our perception of where these patterns exist in the music. The onset of a pattern will commonly be indicated through an increase of intensity and lengthened duration, while the conclusion of a pattern will usually be indicated by another longer duration, including a portion of silence at the end. This silence will not conclude a pattern if it is not in tempo with the preceding durations. The range of amplitudes that describes an accent is not so obvious to the listener, but the awareness that it either is or is not an accent, except if accents occur within 5 seconds of each other. In this case, the listener will start to group the accents by their intensity.

These results are strong indications of how patterns are constructed and the way we organize information. Stretching the boundaries of symmetrical design, patterns or periodicities to the point where it is not perceivable is a choice, but these ideas are useful as a boundary to create perceivable patterns, or to create patterns that reside in the outer limits of this perception.

Fraisse explains that humans actually have difficulty in producing arrhythmic patterns. When asked to improvise a pattern that was not synchronous to a pulse, the tendency was that people would continue to produce an interval nearly equal to the previous. This may be due to the nature of musical patterns that one is exposed to, and Fraisse shows in a chart that describes prominent 18th and 19th century composers whose works consist largely of two durations, at a ratio of 1:2 (eighth to quarter or sixteenth to eighth note values). It is interesting that durational patterns,
consisting of more than two intervals and thereby introducing something beyond long and short, cause confusion. Any salient feature of a sound will disrupt this fragile notion of an organized pattern and grouping structure.

With the desire to understand the rhythmicity of irregularities found in the complex sound experiences of electronic music, it is necessary to understand the threshold of static patterns, and as well, the degrees of confusion and expectancy. Fraisse quotes J.G. Martin (1972, pg.150), “Inherent in the rhythmic concept is that the perception of early events in a sequence generates expectancies concerning later events in real time.”

Peter Desain’s (De)Composable Theory of Rhythm (1992) is a theory that introduces a formula of temporal expectancy. The events that occur in the past will project expectancy of future events on a sliding scale where the most recent event will carry the greatest degree of expectancy. By decomposing the rhythmic pattern into individual durational components, it is possible to determine the expected onset and duration of several possible intervals to follow. This can be used to predict structural ideas, for example, the perceived meter, the overall context of an irregularity, or the degree of repetition. Inversely, by expectations of future events, the past events will also be revised in memory.

“Its decomposability into simple components that model perception of time-interval pairs is attractive, not in the least because empirical results for simple stimuli can be ‘plugged’ into the theory to yield predictions for more complex temporal patterns” (Desain, 1992, pg.452). This theory is useful for creating coherent, non-linear patterns. Breaking the rhythm into its individual components allows an understanding of how complex rhythmic patterns can be coherent, where degrees of expectancy can create interplay between reinforcements and surprises. The interesting aspect of this theory that connects with the rhythmicity of electronic music is that instead of considering that a pattern either exists or does not exist, rather, a pattern constantly exists, and is more akin to the concept of patterns in mathematics. This formula slides over time, generating new expectancies with every present moment, renewing the set of relationships with past events.
Research into the perception of temporal patterns and expectancies can initiate parallels to the perception of electronic music, and offer a consideration to the degree of discontinuities and irregularities that are chosen. When patterns are not considered, irregularities are composed regularly, and the rate of which an unexpected event occurs is often highly expected.

**Meter**

To revise the concept of metrical music is useful once it is explored as an extension of rhythm. Rather than regarding it as a rule over the division of lower level rhythm, it can have a life of its own:

> Metrics in sound can be defined more nearly to the meteorology definition of “entrainment”: a phenomenon of the atmosphere, which occurs when one wind flow captures another.

—Wikipedia

Meter was discussed earlier in regard to Koenig’s description of a sound field, which is potentially a more useful way of listening to and constructing metrical ideas in computer music. The internal rhythmic structure of a sound may or may not be in relationship to the total duration (its time field) and can possibly be in relationship with preceding or following time fields. This allows the notion of meter to have a much less dominating character and, again, can be as complex as one would like.

Meter can be considered the temporal partitioning of musical behaviour into clearly defined sound objects. The relationships within that meter will carry the traditional implications, such as symmetry, repetitions, inversions, etc., but even these do not suggest that a sense of traditional meter will be returned. Once these parameters are all treated rhythmically, it can provide an interesting compositional tool, full of fluidity or irregularity. There may be no repetition of these time fields, rather the possibilities of juxtaposition and counterpoint of time fields become clear in this regard. Koenig described the possible relationships between several sound fields, categorizing in terms of complexities and determining that the more relationships developed between the individual sound fields, the greater the complexity.
Meter was described as the time parameter of a sound field and pattern as the construction of parameters that occurs inside that duration. As there may be as many parameters that make up the individual sound field, and many simultaneous sound fields, there can also exist a dynamic metric relationship.

The metric component of a piece may be considered similar to geometric design and programmed to mutate internally and on multiple time scales. In this sense, meter will be a mobile form, and as Jonathan Kramer described, compositions in the mobile form are those that can be put together in numerous ways. Literally, a score that has many options, of which the performer will make choices and create the sequence and combinations of composed materials or directions as he/she desires. In computer music, this mobile form is the nature of the instrument. Computer programming can be used not only to scatter these parameter values but also to design metrical relationships, which algorithmically put together the options in various ways that can be unique to each performance.

Choreographer William Forsythe offers this idea in the descriptions of his own work and methods for improvisation, which he developed with classical ballet dancers. By studying the points and geometrical relationships innate to classical ballet, he pushed the idea of planes, lines, and curves to a new level that developed a language for dance improvisation, incorporating bridges, transporting lines, dropping curves, only to touch the surface of his concept. In the photograph, Forsythe is demonstrating a “parallel shear”, and suggests that the shape may be applied to a series of attractions and repulsions, of which he demonstrates. This is a visual analogy to metrical complexity: the bending and stretching of a measure and improvisational ability provided by the computer.

By moving from a point to a line to a plane to a volume, I was able to visualize a geometric space composed of points that were vastly interconnected. As these points were all contained within the dancer’s body, there was really no transition necessary, only a series of ‘foldings’ and ‘unfoldings’ that produced an infinite number of movements and positions.
I actually began to produce movement based on recursive algorithms.

My own dances reflect the body’s experiences in space, which I try to connect through algorithms.

So there’s this fascinating overlap with computer programming.

Phases of movement shifting through parts of the body, and about their visible duration and rates of decay ‘that’s dance.

If you look back over the last couple of centuries, the dominant paradigm for what I call the temple arts—music and dance—has been counterpoint. Now once you begin to analyze the nature of an event carefully, as we did with ballet, you begin to see completely new possibilities for counterpoint.
By looking at the metrical shapes in classical music and unhinging all is parallel lines, symmetries, metrical orders, extracting the metrical shapes within a meter and mixing alternating proportions, a metrical language for computer music could provide this same well-defined sense of timing. The possibility for counterpoint within this language is apparent in the relationship between sound objects, but also can be used to create and fracture a metrical space within the parameter of one sound.

The result of Forsythe’s simultaneously measured and unmeasured system is a fluid dance where each line is susceptible to transformation or reinterpretation. The meaning of each element within the shape can shift, which is like a meter whose beginning, end, and inner pattern are all variables, of which the choices depend on the entire language, making continuous and complex relationships.

“Shapes in geometry and numbers in arithmetic . . . display two ways patterns occur. In one way, the continuous mode, lines, curves and solid figures continue on to extend from place to place. They may be continuously changed and continuously moved. In contrast to the continuous, patterns occur as well in the discrete mode. In the discrete mode patterns occur from discrete units combined and acted upon in discrete steps.

Formally, symbols are discrete units and are combined and acted upon in discrete steps. Ordinary algebra, is then itself, in the discrete mode even though it is used to describe the real number line, which is in the continuous mode. This interplay between the discrete and continuous is displayed again with equations and curves. Equations may be graphed, and curves may be described by equations. Analytic geometry, as well as calculus, is then about patterns that develop through the interplay of both modes. Following this manner, mathematics can be noticed to be a landscape of patterns built upon patterns.”

—Gary Miller
Alexander Calder’s mobiles hang in a delicate state of equilibrium. Built from a series of wire cantilevers with objects hung at either end to counterbalance each arm, the structure is a design of counterpoint and compensation, while being weightless enough that natural air movement in a room will cause its continuous motion. Furthermore, each wire is able to rotate in relation to other wires, and once in motion, the movement is meant to suggest a virtual volume. Between the possible positions to stand and view these sculptures, and the internal variation of all possible rotations occurring at such a slow rate, the possible variety of visual combinations should last a lifetime, and there would be no two perspectives exactly the same.

The temporal form of this sculpture suggests musical forms similar to the repetitious cycles and phasing patterns, or the complex patterns derived from periodicity in microsound. Here is where periodicity creates complexity and where the repetitions of discrete components create a continuous form.

**SUMMARY**

AFTER REGARDING PERIODICITY AS one extreme on a total continuum between periodic and aperiodic temporal behaviour, rhythm was defined as the dynamic movement between these states.

Common elements of static rhythmic elements such as loops, symmetries, patterns and meter were discussed, and aspects of irregularity and dynamicism were found in each case. Although the traditional view
of rhythm is founded on the periodic organization of discrete sound objects, it has been shown that repetitious patterns of discrete sound material will often return a continuous overall form.
INTERLUDE: THE DISCRETE AND THE CONTINUOUS

From the viewpoint of philosophy, music and mathematics, the terms ‘discrete’ and ‘continuous’ are discussed as being dependent on the existence of each other. Before continuing into a search of aperiodic rhythm, this interlude is intended as an exploration of the rhythmical significance existing within this duality.

“We encounter two contrasting kinds of objects: on the one hand, the indivisible, separate, discrete objects, and on the other, the objects which are completely divisible and yet are not divided into parts but are continuous. Of course, these contrasting characteristics are always united, since there are no absolutely indivisible and no completely continuous objects. Yet these aspects of objects have an actual existence, and it often happens that one aspect is decisive in one case and the other in another. In abstracting forms from their content, mathematics by this very act sharply divides these forms into two classes, the discrete and the continuous.”

—A.D. Alexandrof from Miller 2005

The term stria is used in a variety of contexts, including muscular tissues, the markings left by a glacier on rock beds, or the small black and yellow stripes of a wasp. It is used to describe a number of similar and parallel linear marks, grooves or ridges. In A Thousand Plateaus (1980), French philosophers Gilles Deleuze and Félix Guattari consider music in regards to what they call the smooth and the striated.
It can be said that space is susceptible to two kinds of breaks: one is defined by a standard, whereas the other is irregular and undetermined, and can be made wherever one wishes to place it. In this case, the principle behind the distribution of breaks is called a “module”; it may be constant and fixed (a straight striated space), or regularly or irregularly variable (curved striated spaces). When there is no module, it is “statistical”, with two aspects: whether the distribution is equal (nondirected smooth space) or it is rare or dense (directed smooth space).

—Deleuze and Guattari, 1980

This is reminiscent of Jonathan Kramer’s temporal modes, and although the authors use different terms of their research, this summarizes much of the discussion within the previous chapter. The “module” is easily transferable to the concepts of electronic music, as this module is the compositional procedure used to carve up the silence into sound objects. Returning to the concept of rhythm as the movement between these states, even the shortest, complex sound could, for example, travel between regulated to random distribution and come to rest in a limited, statistical state.

In the simplest terms, the authors describe the definition Pierre Boulez used to exemplify these different musical spaces: in a smooth space-time one occupies without counting, whereas a striated space-time one counts in order to occupy . . . “He makes palpable or perceptible the difference between nonmetric and metric multiplicities, directional and dimensional spaces.” (Deleuze and Guattari, 1980) The primary interest is in the communication between these two kinds of space, the alteration or juxtaposition of striated with smooth, the melding of stochastic distribution with that of intuitive choices, or how a smooth texture may develop from the regulated space.

After categorically defining the differences of this continuum, it is stated that the existence of either extreme is only possible in mixture, as the smooth space is in constant translation with the striated space, just as the striated space is constantly being pulled and returned to a smooth space.
Returning to the simple opposition, the striated is that which intertwines fixed and variable elements, produces an order and succession of distinct forms, and organizes horizontal and vertical planes. The smooth is the continuous variation, continuous development of form; it is the fusion of vertical and horizontal planes in favor of the production of properly rhythmic values, the pure act of the drawing a diagonal across the vertical and horizontal.

—Deleuze and Guattari, 1980

Koenig describes a fluid sound structure particular to electronically produced sound, as a sound that is indivisible into smaller sound events (The second Phase of electronic Music). He arrives at this thought through comparison of the instrumental sound event to the electronic sound object. The individual note of an instrumental composition would not be considered a form in and of itself, as the mechanical instrument has already prescribed the nature of its sound. Therefore, an instrumental musical form is the result of an organization of these individual sound events. As the electronic composer must define the entire character of the electronic sound, any electronic sound is already a result of a processing and formation. Koenig concludes that this inseparability of a sound from the work as a whole dissolves the boundaries between several sound forms, and behaves much differently than sound forms of instrumental music:

...the(electronic) sound form is the internal turned to the outside, an object, a variable acoustical element. This electronic sound embodies something fluid, streaming, similar to a river, which constantly produces an eddy. Its development is stopped by invisible resistance, and accelerated by the constant gravitational force. In the same way the acoustical shape of a variable electronic sound is the perceptible result of unrecognizable causes.

—Koenig, The second Phase of electronic Music, Book 2, Page 324
Koenig also experimented with complexity as a result of superimposing periodic structures, and both of these concepts, the fluid sound structure and the complexity derived from periodic patterns, can be seen as compositional starting points for *Terminus* (Zu Terminus, pg.59-62). *Terminus* (1962) exemplifies this duality of a discrete and continuous sound organization.

The initial material consists of a long sound made of five sine wave glissandi, with variable starting frequencies and a limited frequency spectrum. The rhythm inside this sound is created by the continuous irregularity of changing speed and direction within each glissando.

After transpositions and amplitude modulations, this sound is then spliced into discrete sound objects, literally from continuous threads of sound material into individual pieces of tape. The reorganization of these sound objects can be seen in the diagram on page 56.

Relatively simple relationships are used in the temporal organization, as each splice is arranged in relationship with the preceding and following sounds. The onset and duration have a regularity and common underlying pattern of being organized in proportional ratios by powers of two. This regularity of temporal form returns the discrete splices back into a continuous state.

The continuous transformation of original material develops by transposition, amplitude modulation, filtering, reverberation, chopping, cutting and synchronization, and is organized by a generation diagram of discrete processes. The individual processing transforms one fluid sound structure into another, introducing elements of fragmentation where it had been smooth, just as reverberation of impulse structures introduces traces of continuity where there had been none before. Superposition of the impulse structures can become so dense that the impression of the continuum is continuous. The processing can be seen as a pattern of transformation followed by synchronization, a process in itself that assures an irregularity and cyclicity at the same time, altogether a forward momentum that moves progressively away from the original source material. Furthermore, Koenig layers three different periods of amplitude modulation and specifies the approximate ratio of $0.3 : 1 : 4$. Shifting
Terminus, splicing arrangements of d4 a-1, a-2, a-3
and offsetting the layers develop these cyclic layers of periodic amplitude modulation into further complex relationships.

The second section of part one uses layers of periodic organization similar to the amplitude modulation, although periodicity is used here in the control of impulse patterns. Pulses diverge and coalesce; repetition and suggestive metrical relationships vanish as quickly as they appear, just as irregular, linear patterns split into dense cyclic textures.

Koenig’s compositional process in this work can be described in all its stages and time scales as the duality of the discrete and continuous: the constant transformations that distort periodicities, the complexity of superimposed periodic patterns that distort repetitious behaviour, and the synchronization of variants into complex sounds, the splicing of fluid sound forms into distinct blocks of sound, of which are finally superimposed and juxtaposed with a temporal regularity in the final formal construction. The treatment of discrete and continuous sound is embedded in the sounding material, signal processing and compositional procedure.

In visual terms, Pieter Brueghel the Elder (c.1525-1569), a Dutch/Flemish artist, uses colour and shape to move the eye in a combination of clockwise and counterclockwise movement, punctuated with angular turning points to create the sense of a fractured wholeness. This

Pieter Brueghel the Elder (c. 1525-1569) The Wedding Dance
Piet Mondrian Tableau I 1913
work is a static object that creates an illusion of movement for the viewer. Mondriaan creates a painting that is an illusion of architectural stability, but then creates a second layer of carefully controlled colour shapes that force the eye to move relentlessly over the surface seeking a resolution that can never be achieved. This work is a static object that creates an illusion of stillness and is an actual dynamic visual experience for the viewer.

**SUMMARY**

THE DUALITY BETWEEN THE DISCRETE and continuous object are integral to the concept of rhythm and to the manner of listening to the rhythm found in electronic music. From the processing of sounds, to the organization of the piece, material is in transition from measured and counted spaces to smooth, overall forms.
MAGNETS AND MASSES

This chapter will express rhythm from the perspective of microsound and sound particle organization. The ideas of density and sparsity commence a look into aperiodic concepts of rhythm. Operational techniques for controlling microrhythm, and stochastic grain clouds are discussed, finally leading to measurement and proportion on a larger scale. Through non-linear rhythm, a discrete space is found.

IANNIS XENAKIS: LA TOURETTE

XENAKIS WORKED IN THE STUDIO of Le Corbusier from 1947 to 1960, during which time, La Tourette, the Dominican monastery situated near Lyon, France, was designed. Xenakis applied concepts of rhythm to the windows of the façade and cloister.

The solid, rectangular form is interrupted by vertical windows on both sides of the building, opening the inner spaces to a specific design of light and shadow. The glass panes were set directly into the concrete and the distances between them is the core of Xenakis’ design, creating the impression of an undulating motion, known as the “Pans de Verres Ondulatoires”. The external lower walls were composed of concrete and glass of different widths, and as daylight enters through these windows, the floors are in constant rhythm between light and shade.

The solution to the design was, “an intuition that would prove to be of major significance for his further compositional approach: he considered the problem on a more general level, above the individual elements, by replacing the concept of rhythm by that of density” (Sterken, 2007). Xenakis then drew a table of the window casings where the spaces
between the windows are no longer concerned individually, but rather as a number of casings per length unit. The result is similar to the compressions and rarefactions of sound waves, with natural irregularities and abrupt changes. The multiple layers of this “undulating” or oscillating effect, creates a polyrhythm of windowpanes. As an image, the eye travels through each of the three layers, becomes attracted by another level and so on, creating a total undulating movement. If this were in sound, the listener travels between the layers being attracted by emphasis, in a constant flux of transitions between layers. The design of these windows gave a more dynamic quality to a static, and stark rectangular form. The window design was intentionally irregular within individual layers, very similar to how Varèse described rhythm as “elements that intervene at calculated, but not regular, time lapses” and as structural, “correlative states”.

In regards to Xenakis’ principle “the stacking of several independent
layers of duration whose proportional relationships may vary throughout the piece—would become the cornerstone of the complex rhythmic polyphony in many pieces by Xenakis.” (Sterken, 2007, pg. 37) Sterken suggests here that at each layer of the structure, from the individual areas of densities and sparsities within a layer, to the proportional relationships between the layers, creating a total dynamic movement on each layer is what creates “complex” rhythmic polyphony.

Applying his attention to the correspondence between music and architecture, Xenakis introduces an innovative logic in compositional structure and to the problems of mathematics and symmetry involved in both architecture and music. Symmetry is not only characterized by geometric regularity, or as metered regularity, but also now used as durations containing probabilities within proportional relationships. This can be seen as an extension of symmetry or as an organization of irregularity, a dynamic and transient movement on multiple scales.

The movement of light inside the building is essential to understanding the extent of rhythmical intention. In this instance, the rhythm is the dynamic movement of light against the composition of windows and larger composition of the interior space. The static, architectural structure is the measured space remaining still over time, while the light and shadow is constantly changing in counterpoint with this static structure. When considering the rhythm of architecture, it is common as it is in music that one sees repeated and sharp patterns as a “rhythmic” architecture. This is an example of a higher-level rhythm, one that is interwoven throughout the design and moves over time.
DENSITY AND SPARSITY AS RHYTHM

THE CONCEPTUAL UNDERSTANDING and technical means to develop a sound controlled by individual grains was envisioned by Varèse, and now serves as a complex tool for the development of rhythm.

*When new instruments will allow me to write music as I perceive it, taking the place of the linear counterpoint, the movement of sound masses, the shifting of planes, will be clearly perceived. When these sound masses collide the phenomena of penetration and repulsion will seem to occur. Certain transmutations taking place on certain planes will seem to be projected onto other planes, moving at different speeds and at different angles.*

—Edgar Varese, New Instruments and New Music
(From a lecture given at Mary Austin House, Santa Fe, 1936)

Stockhausen mentioned fields of sound masses containing events that are not precisely specified, that may not be individually perceptible, and mass-structures with statistical qualities of *opacity* (Stockhausen, 1957, pg. 32). Since the 1950’s the development of statistical, particle based sound masses can be found in numerous electronic works, but it was the early work of Xenakis that brought forth the concept of stochastically controlled sonic grains, densities and sound masses in both electronic and instrumental mediums.

A sound mass can be determined by its qualities as a cluster of sustained elements, or a mass of micro events behaving in a constant or evolving manner. A cloud texture uses statistical designs and will evolve over time with examples such as amplitude fluctuations, internal tempo changes, density and spectrum (Roads 2001). Cloud textures may be combined, transformed, or may collide and the internal rhythm can be related to these external movements over time.

The density of a cloud is an important variable to be considered with regards to rhythm, as a cloud can dissolve from a solid sound mass into pointillist textures. The timing and directional changes of this motion, as
well as the sparse pointillistic texture can be considered with rhythmical intentions.

According to Jonathan Kramer, “duration distorting motion” is accomplished by the goal oriented temporal systems, and the music that lacks this duration distortion, such as music derived from nonlinear systems, will rely more heavily on proportional time relationships to distort musical time against clock time. Stockhausen addressed the idea of time relationships and comments that without any proportionality, the result is a continuous temporal disorientation (Koenigsberg).

MICORHYTHM AND PARTICLE SYNTHESIS

THE ESSENCE OF MICRO RHYTHM resides in the grains that make up a sound wave. The behaviour of compressions and rarefactions, and the diversity of periodic or aperiodic fluctuations, will discern the fundamental rhythm of a sound. This shifting of particle densities is informative in all time scales of sound objects; it is the dynamic movement within any given period of time.

“To granulate means to segment (or window) a sound signal into grains, to possibly modify them in some way, and then to reassemble the grains in a new time order and microrhythm”

—Curtis Roads, Microsound pg. 98

In the context of granular synthesis, microrhythm is the arrangement of sonic grains, and can include the relationship between the linear patterns of grain duration and delay time, or can be the movement of time-varying frequency bands and densities of thousands of grains, or the shifting timbre within the duration of one grain. Granular synthesis is an attractive technique for experimentation in rhythm as it utilizes both the possibilities of sequential, percussive grains and the dynamics found within a sound mass: granular sound objects, from a fraction of a second to several seconds, inherently have complex rhythmic internal structures.

It is important to differentiate rhythm from pointillism. If the musical texture is made up of short grains at low density, one may begin to
hear fleeting moments that allude to metrical relationships, giving the impression of obscure, pattern making. If the density bears no correlation to other parameters, and remains in this state, the sparse scattering of sonic grains can be considered pointillism.

Roads differentiated between *Synchronous* and *Asynchronous* granular synthesis as a means of differentiating between two main categories, similar to periodic and aperiodic behaviour:

*Synchronous* suggests the periodic patterns discussed in earlier sections as the grain emission will be regular and follow one another in sequence. Lower densities will create slow, regular pulses, and if occurring simultaneously with more than one synchronous stream, looping, phasing, and metrical or polyrhythmic characters can occur. In a single stream, frequency to tempo ratios are made clear by a density per second, offering the possibility of intricate relationships between the extremes. A continuous tone will result from a high-density of regulated grains per second, and this tone production may change, dynamically varying between pulses and tones. The grain duration may change independently from a static, high-density value, creating a microrhythm in the formant of a tone. The bending of continuous tones may be controlled rhythmically by grain emission tempo changes within narrow limitations. The threshold of perceiving pulse or pitch is as fascinating as the threshold where the tempo of a pulse stretches slower to the point where sonic events are no longer perceived as a pulse. Stockhausen suggested 6 seconds as the limit of pulse perception. Synchronous streams with a density of 0.01 per second will generate subliminal pulsing patterns. Variants of all these examples can be implemented to include deviation in the duration between grain intervals. If this deviation is regulated or highly limited, two granular streams are enough to produce typical metric syncopation, whereas unlimited random deviation would produce continuous irregularities.

*Asynchronous* granular synthesis is the term Roads uses for the non-linear, stochastically derived sound mass, made up of time-varying grain duration, density, frequency band, amplitude, and spatial dispersion. Algorithmic control of the time-varying relationship between these
parameters brings attention to the wealth of rhythmic control made possible by this technique. Each parameter can be designed with formed, internal directionality, and can depend on the values derived from other parameters, resulting in a programmable improvisation of aperiodic rhythmicity on the micro scale. When considering these parameters in regard to Koenig’s conception of the complex sound, and imagine the density parameter of a grain cloud to be juxtaposed onto the frequency band parameter, between these two streams of values there can be unlimited variation within the temporal relationship. This sound would achieve a rhythmic quality once the extremes of individual parameters are employed with agility, and with meaning as to their correlative choices with another parameter. The motion within these clouds can then determine larger scale sequences and relationships between clouds in counterpoint.

The sounding results of synchronous granular synthesis naturally create a more homogenous quality, and has more in common with the looping and phasing music discussed earlier than with aperiodic rhythmicity. On the other hand, the sounding results of asynchronous granular synthesis naturally make a noisier texture. These rough timbres and aperiodic fluctuations of nonlinear grain patterns withhold a realm of rhythm applicable to a multi-temporal, and non-linear organization.

**MULTIPLE LAYERS AND TIMESCALES**

NON-LINEAR RHYTHM EXISTS WHEN stochastic operations guide the temporal activity of a sound. The music of Horacio Vaggione exemplifies this networking of layers, timescales, transient patterns and discontinuities, and describes a strong capacity for rhythm in electronic music.

In Vaggione’s *Ontological Remarks on Compositional Process* (2001), he describes the plurality of operational systems that can be employed in simultaneous timescales.

> Since the different time-levels present in a musical situation strongly interact, morphologies can circulate from one level to another. However, such circulation cannot take place, in many
cases, except under non-linear conditions: as noted, some types of representation that are valid on one level cannot always retain their pertinence when transposed to another level. Thus, multi-level operations do not exclude fractures, distortions, and mismatches between the levels. To face these mismatches, a multi-syntactical strategy is ‘composed.’ Object-oriented programming strategies . . . can help to encapsulate diverse syntactical layers into a multi-level entity (an object) able to integrate a given compositional network.

—Vaggione, 2001

Schall (1995) is an example of a work that utilizes polyphony of non-linear rhythm and thereby creates a compositionally active timbre. The initial sound material is made from piano samples, and the processing diverges from infinitesimal grains so short in duration that only bright noise is audible, to the recognizable pianistic glissandos, and sharp keyboard attacks.

Vaggione stratifies each sonic layer, and by frequent fragmentation, the figures become intertwined with the internal structures of each other, perceptually connecting an onset of one sound with the continuity of another. There are no reverberations that harness the agility of these interacting sounds and therefore the entire texture remains translucent. Alternatively, resonance is created through the use of irregular patterns that behave like processed decays. The translucency is important to this work, and necessary for aperiodic rhythm to be clearly articulated, especially as it is the fragmented layering that creates this experience.

Through the discontinuity of individual rhythmic layers, one figure will appear juxtaposed with a figure from another layer, and create a combined layer of positive and negative sound forms: instead of silence, layers create negative spaces for each other.

The frequency range is used as a static element throughout the piece. The individual layers of high, granulated sounds and low accents provide structural elements, returning at irregular intervals, but providing repeated associations with synchronicity or dispersion. Amplitude is also
used as a structural, static form. This parameter is important for the ability to perceive individual layers as well as the dynamic shifting between layers. The amplitude acts as a piston, creating a constant movement of foreground to background by highlighting the infinitesimal in one instant and the mix of reverberating patterns in another.

_This polyphony, coming out of the (complex) nature of time itself, can only be composed by favouring contrast, detail and discontinuity._

—Sedes, 2005

Returning to the earlier discussion of pattern, it is important to consider Vaggione’s own words in regard to the organization patterns in the context of electronic music:

_The production and transformation of musical patterns is, in my compositional work, based on operations of fragmentation and agglutination of objects of all sizes; several time scales are worked out simultaneously, including those belonging to the microtime domain (which I try to link to the level of the note by means of several strategies using sonograms, synchronizing waveforms, pitch-to-MIDI conversion, and so on). One important feature of this approach is that the patterns are not only considered as an ensemble of parameters but also as entities that can be manipulated in the sense of their parts._

—Vaggione 2000, pg.4-5

Methods of grouping structures are suggested in _Schall_, as sonic figures create a sense of pattern. The element of rhythmic expectation exists with discretion, and on all layers, the figures exist equally in complete variation and fragmentation. This material is arranged in such a way that its pattern and repetitive quality is in the sequential arrangement of sound objects on every scale. For example, at 3:06 the highest glissandos start to descend, with subtle repetitions and irregular, overlapping sequences.
Arriving at the lowest frequency by 3:44, a multilayered pattern is initiated into agile variation on all timescales. Moving in and out of sync with each other, the rhythmicity is apparent in this work as the unison timing found within one instant is juxtaposed to the dispersion between figures in another instant.

The aspect of simultaneity in this work has a fascinating musical result. The lowest, accented frequency arrives in an irregular sequence, but its sparse reappearance gives the impression of a downbeat. It is possible to imagine that in this music rhythm has been turned inside out. The downbeat and timbre are inversed; the prominent punctuation of time is created by sparse moments of colour, while the timbre and microtextures are given a rhythmic clarity, constantly in the foreground.

**Attraction and Repulsion**

The most dynamic element of rhythm can be described in its largest scale, its interaction and role in the formation of a composition. As the holder of events over time, rhythm is a magnet moving around other magnets, attracting and repelling between fine lines, causing collision and elision.

In the early stages of Xenakis’ theory of granular synthesis, he suggested that a sound grain could be described as a vector, with amplitude, frequency and time values. Within a cloud of grains, each one can then be prescribed to have directionality, and is what Curtis Roads named *Glisson Synthesis*. Roads paid attention to the added glissando effect, and to the magnetization patterns made possible by this directionality of frequency: from the initial frequency each grain may depart in a glissando, consisting of a shallow or deep range of deviation, may be unidirectional, bidirectional, converging to a centre frequency or diverging. (Roads, 2001, pg.123). By adding the time parameter, this provides further magnetization patterns that can be applied to every kind of grain cloud, whether dense, sparse, grains with glissandi or not. Magnetization can be applied to more parameters than that of frequency.

Consider the following possibilities: grains can be attracted to a point in time, to a semi-periodic pattern of time intervals, or in multiple layers
where time points of attraction are in counterpoint. The opposite could be employed, as repulsion to these time points, repulsion to periodic behaviour, and a combination of these as sequence or counterpoint, ensuring the attraction of one texture against the repulsion of another texture. These possibilities can also be applied to simultaneous parameters within one sound, such as an attraction to density while a resistance to higher amplitudes at altering or coinciding time points, where the specific counterpoint of time points creates variation in the outcome of these probabilities. This concept of magnetization carries the strength of true rhythmic movement, and serves as a strong metaphor to describe the intensities and dynamics of which rhythm is responsible.

The compositions of Xenakis carry their weight over time because the forms often include an attention to specific measurements of time and duration. The forms determine when to hover in a continuous block of time and when to diverge into complex, contrapuntal systems. These aspects of music are not unique to the composer, as it is this pull and release, this sense of magnetism, which is innate to the performance of music; it is the musician whose work it is to stretch timbral fluctuations between altering pitch values or whether to resist arrivals or to linger in decays. This is rhythm in the sense of dynamic tension and volume: points of gravity that harness random behaviour.

In *Metastasis* (1954), Xenakis used these concepts on a larger scale, where the attention to numerical process and temporal proportion is used to attempt a sonic model of

Naum Gabo 1890-1977
Linear Construction No. 2 1970-71
Source: www.fusionanomaly.net/naumgabo.html
volume. This volumetric sound results from the interaction of straight lines creating large and curved sonic structures, a sound that can be likened to the sculptures of Naum Gabo (Sterken, 2007, pg.41). Gabo created curves that push and pull on one another, giving rise to a form that is the result of all of the forces that bring the form into a balance under tension. Within the form, there are collection points for stress and other points that disperse that tension, so that the form is visually and actually an experience of a never-ending energy exchange. The desire to reveal the inner workings of a form combined with the use of new materials and processes is evident in these works.

With attention given to this magnetism on several time scales, the resulting body of sound should avoid a sense of decoration. The inner movement of individual parameters will result from macro scale attractions and repulsions, causing the surface textures rather than creating or adding an artificial surface layer. In architecture, the structure creates the form, but surfaces can be either caused by the process or they can be subjectively chosen and have little or no relationship to the form of the building. Although it is entirely subjective, the symmetrical and complex designs that cover the walls of Islamic traditional architecture have a

Metastasis, Iannis Xenakis Source: www.sonicsonline.org/ver4/GS.htm
non-obtrusive effect as surface. The curvature in the calligraphy seems to reflect the numerical proportions of the largest structural arches and domes. Returning to the physical aspect of sound, when the surface texture reflects the form, as in the case of many works by Xenakis, a mirror is inherent in the form and an asymmetrical and aperiodic form will be held up as if it were a physical structure needing to physically stand and hold its weight.

Non-linear, dynamical systems controlling particles or parameters of a sound can be considered and studied as rhythmic organization. These processes can carry out a three-dimensional representation of a form that grows from its mathematical structure. These structures can get smaller and larger simultaneously, and most importantly, can be considered as rhythmic spirals rather than lattices, branching off with its own volition, into looping structures or variants with respect to previous conditions.

The crystal is characterized by both a definite external form and a definite internal structure. The internal structure is based on the unit of crystal which is the smallest grouping of the atoms that has the order and composition of the substance. The extension of the unit into space forms the whole crystal. But in spite of the relatively limited variety of structures, the external forms of crystals are limitless. Crystal form is the consequence of the interaction of attractive and repulsive forces and the ordered packing of the atom.

—Varèse, Rhythm, Form and Content, 1959

Rhythm and temporal constructions that are a result of a spiral organization can be likened to Jeff Pressing’s idea of temporal cyclicity in music. If a temporal form is recursive or cyclic, it must be graphed in the form of a spiral moving upwards in time, making reference to the previous points in time on the y-axis, rather than linear time being graphed on the x-axis. Complex cyclic forms can make use of asymmetrical patterns, can branch off into linear subsections, in synchronization or adrift.

In the sense of attraction and repulsion, rhythm is a tension form.
RHYTHM AS FORCE; THE GENERATOR OF DYNAMIC FORM

THE PREVIOUS TWO SECTIONS HAVE brought together a diverse collection of examples where rhythm has been divided between periodic and aperiodic organizational systems. It was unavoidable that any musical form strictly remained in either one of the previous sections and now these extremes come together as conclusion: looking at rhythm as the generator of form; from the form of the micro sound object, to the form of a piece, the elasticity and movement of music over time, where rhythm is structure as force is growth. The term force is used here to describe rhythm for its strength and direction of action.

Musical forms are evaluated by the systems that produce them, such as the outside time structures or the algorithm that controls parametrical behaviour. These are the growth marks that will remain at the final stages of a musical form, whether its form increases in duration while remaining static over time, or whether it proceeds to bring about a gradually increasing complex form, improvised or devised. The rhythmical form is recognized by its procedure of producing or changing motion, preventing change in motion, or maintaining rest. This force can be in connection with other forces, one system of rhythm acting with another, and together combining to act upon the creation of form over time. Recursion, cellular automata, sieves, algorithmic composition, all may be considered the forces at work, and can be devised to move between time scales or remain as a propelling operation within one scale.

“In short, the form of an object is a diagram of forces.”
—D’Arcy Thompson *Growth and Form*, 1917

*Growth and Form*, by D’Arcy Thompson, was an influential work published in 1917, where he described the mathematical and dynamical principles applicable to natural forms, as well as introducing biology to mathematicians. Thompson’s analysis includes the surface tension of cellular forms, the dynamics of pressure acting upon and within a soap bubble, thereby stretching its form to develop and burst, to symmetrical forms of bone structure, limits of equilibrium, or stress-diagrams of ani-
mals. All these are imaginable analogies to the possible growth structures of computer programming, and can correlate to a diagram of rhythmical forces acting upon a musical composition or interaction system. This can also be described as physical modeling with the attention to timing, and constraints in the sense of internal time structures.

The properties that occur during the process of a splash of milk are the diagram of forces that make up its form.

![Instantaneous ‘splash’ of milk. Harold E. Edgerton. Source: On Growth and Form, D’Arcy Thompson, 1917.](image)

Depending on the height of which a pebble of liquid is dropped, a dip or hollow will develop on the surface liquid, of which a crater rises around. The edges of this crater become fluted, grooved, and then have a tendency to break off or release another droplet. The remaining edge of the crater retreats, sending a column straight up from where the drop fell, and releases variously sized droplets back up into the air. The column will sink down and circular ripples will move from its centre and dissolve. This happens on a very short time scale, similar to a mallet dropping toward a surface from a chosen height, falling with its weight, size and effort of its musician, landing on a variable surface that sends a splash of sound into the air, and can also be analogous to the onset and resolution of a composition.
If we can discuss *fluid* forms, discrete and continuous sounds, then the movement between these stages can be described, with mathematical articulation, as the rhythm behind the overall form.
Before it was possible to commence a technical implementation of rhythm that is applicable and provocative in the context of electronic music, it was necessary to redefine this musical parameter for the following reasons:

The understanding of rhythm has been dominated by the underlying concepts of instrumental music, which does not apply to the resources available to the electronic composer. The complex, subtle rhythms and strange articulations of timing that do exist in computer music can be studied as *rhythm*, and previously, this has only happened if there was a pulse or pointillist quality. By redefining this parameter, it can be possible to include the rhythmic innovation that has previously been developed, and begin further operational experiments in the implementation of rhythm, ranging from microsounds to compositional form and dynamic transitions.

Rhythm turns out to be the main parameter and a difficult parameter to articulate, as it describes the entire continuum of how sound is organized over time on all time scales. Contemporary concert music tends to situate inside a sense of time in fluctuation and to the abstraction of musicality. The moment when a listener hears this musicality is when the listener moves into a dynamic rhythm, the term rhythm here being used in its largest and untamed sense.

As a final quote, rhythm has also been considered on the ‘supra’ scale:
It is well known that rhythm is not meter or cadence, even irregular meter or cadence: there is nothing less rhythmic than a military march . . . Drying up, death, intrusion have rhythm.

—Gilles Deleuze & Felix Guattari, A Thousand Plateaus)

Gilles Deleuze and Félix Guattari consider rhythm once again and describe a cycle between chaos, rhythms and milieus. In this context, a milieu is defined as the periodic repetition of the component in a block of space-time. This will be similar to the mundane and repetitious elements of life, or the milieu of a social environment. A milieu is susceptible to chaos as each milieu is threatened by ‘exhaustion or intrusion’, and Deleuze and Guattari suggest that rhythm is the milieus’ answer to chaos.

In my own symbolic terms, I intend that rhythm may now include noise.
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