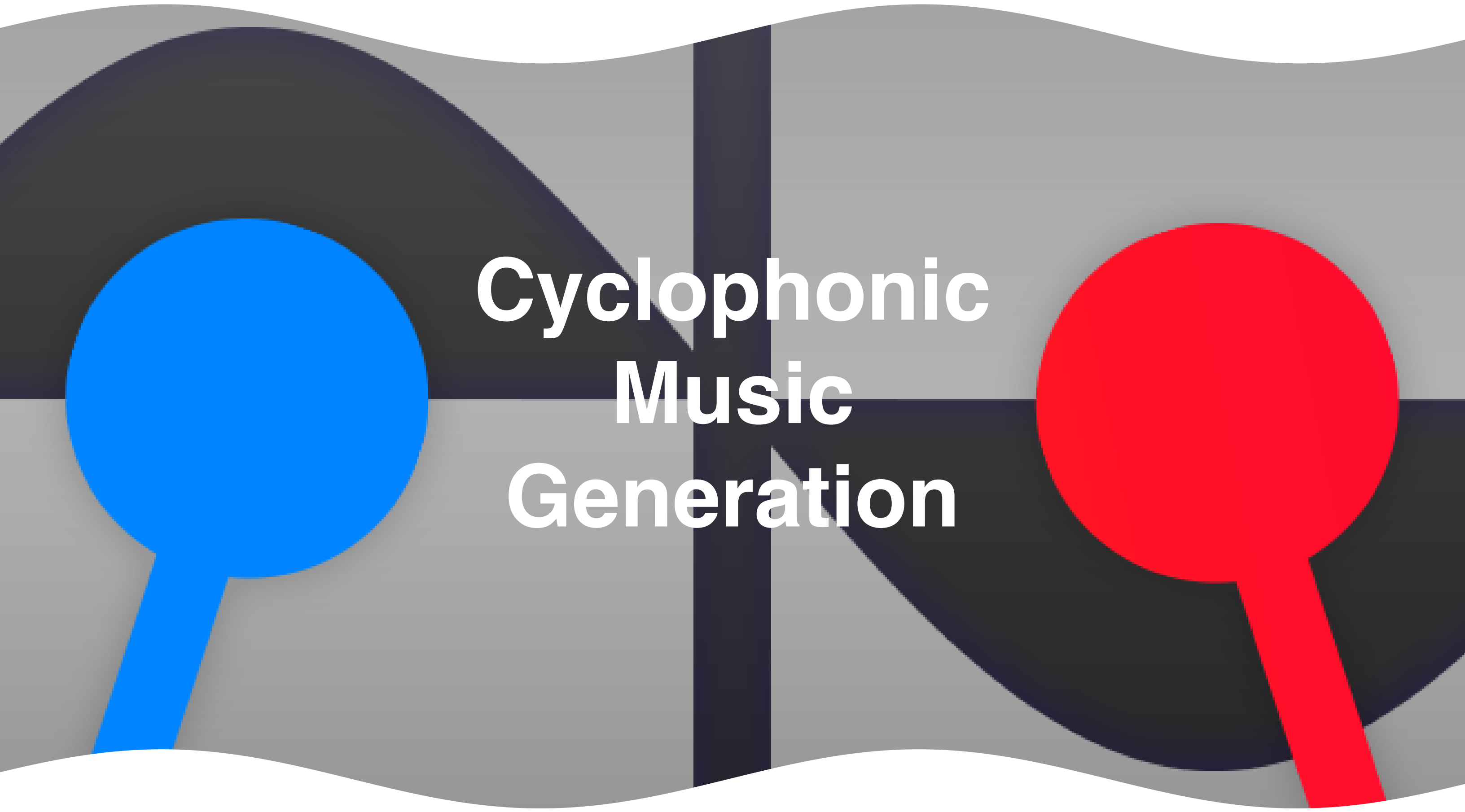
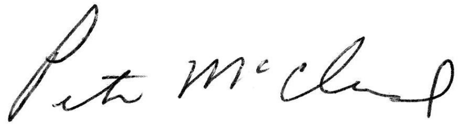


Cyclophonic Music Generation

Draft 1 7-11-15



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Introduction

The Cyclophonic Theory derives from a larger musical theory of mine called Holistic Tonality (http://www.holistictonality.org). Holistic Tonality theory states that all music is timbre (sound) on some time scale or another and that composers of the future will compose freely and smoothly between the audio and musical levels of what we think of as music. Cyclophonic Control of musical structure is a practical application of Holistic Tonality.

The word Cyclophone derives from the Greek words for *circle* and *sound*. It has been held as a nearly self-evident and almost spiritual truth that the circle is the most perfect geometric shape. It is associated throught History with concepts such as unity, wholeness, perfection and eternity and the planets themselves follow an elliptical path which is a tilted circle, creating the primal rhythms of Cosmic cycles. Gravity forces all matter into perfect spheres so that when we look up at night we see a perfect circle in the sky, the Moon or can be blinded by the perfect circle of the Sun if we dare to look. These spheres, in turn, rotate in perfect circles adding the diurnal rhythm we know as the day and the night—the Yin and the Yang. This is truly the most Universal symbol we have and it I would be willing to bet it is the same wherever there is intelligent life in the Universe. The one symbol all cultures can agree on is The Circle!

Naturally, mathematicians have studied all aspects and properties of the circle and it was one of the first shapes that could be well drawn with the use of a compass or a string. Out of the circle derives so many of mathematics inner jewels and perhaps its most important constant, π which represents the ratio between a circle's diameter and it's circumference. Pi is said to be a Transcendental number, a special class of irrational numbers. No one will ever know the actual value of Pi, only approximations. However, we don't need to know it for it to be most useful.

By inscribing a triangle inside of a circle and noting the relationships of the sides as the points are moved around, we saw the birth of trigonometry. The degrees of an angle are commonly measured in radians of which there are exactly 2π radians comprising the 360° around a circle. 180° = π. 90° = π/2. Degrees are a convenient way for us to represent radians and 360 is evenly divisable by many numbers for example 2, 3, 4, 5, 6, 8, 9,10 and 12. The relationships of the sides of the right triangle where the hypoteneuse (the side opposite the right angle) is the radius of the circle have been well known for millennia, perhaps most famously in the Pythagorean formula of $a^2 + b^2 = c^2$. However, trigonometry gives us another tool to make association between the *angles* of the triangles and the length of the sides in the form of Sines and Cosines. By plotting these lengths as the angle changes, we produce another one of Nature's most perfect forms, The Sine Wave.

The Cosmic Wave

At the heart of cyclophonic music is the simple Sine Wave: $f(x) = \sin x$. This most useful of functions can be easily manipulated to include frequency (how fast the waves repeat) and amplitude (how high the waves go) like so: $f(x) = A\sin Fx$, where A = amplitude and F = frequency.

By its very nature, the wave is rhythmic and sometimes this is even referred to as the sinus rhythm. Rhythm is the most primal and essential part to music. The drum was undoubtedly the very first instrument and to this day is widely accepted as the core instrument in any culture. But even without a drum, everything we do has a rhythm—whether it's the wake/sleep cycle, our heartbeat or a melody that is only recognizable because of its rhythmic pattern. The simplest, most obvious representation of rhythm is the up and down of a sine wave. This is what can be called a *perfect rhythm*, one that perfectly and uniformly repeats at a given frequency. However, just like water, the perfect liquid, is devoid of interesting taste, perfect rhythms are not particularly interesting.

Fortunately, the Sine Wave has a simple solution for that: simply add sine waves together of varying frequencies and amplitudes to produce more interesting rhythms like so:

$$f(x) = A_1\sin F_1x + A_2\sin F_2x + A_3\sin F_3x\ldots$$

In mathematical terms this is referred to as a Fourier Series. The use of such additive sine waves is widespread in the moderm world from electronics, engineering and signal processing to audio and synthesis. This is no surprise because sound Waves are exctly that, waves that propagate through the air to vibrate our eardrums that also vibrate in wave-like patterns.

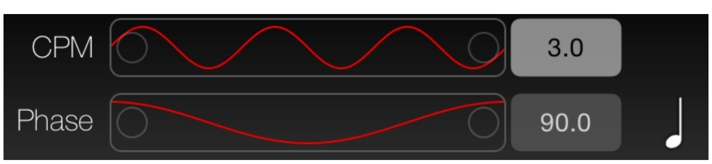
What sets Cyclophonic Theory apart from audio synthesis is the level at which the waves are applied. Instead of applying these waves to control the timbre or sound, as synthesizers do, the waves are used to control the parameters of musical structure such as what notes are played, their durations, rests, dynamics and more. The exact same waves that control sound, can be made to control music.

Sines have another useful property that we can take advantage of—that they vary periodically between minus 1 and 1.

Cyclophonic Frequency

Most music we are familiar with has a beginning and an end, just like we do. In music we measure time in beats and measures. This makes music understandable as it relates to the passage of time and literally gives us a *measure* to guage how much musical time has passed or will pass in a given piece of music. We have created a system of music notation that includes the Time Signature that tells us how many beats of what duration will pass in a given measure. Common time is 4/4 where exactly four quarter note beats pass for each measure.

Frequency in waves is commonly measured in Hertz (Hz) and is expressed in terms of cycles per second. A 440 means that a string would have to vibrate 440 times per second to produce the A 440 pitch. This is convenient for sound waves but musical waves happen at a much lower frequency (LFO) and within the context of musical measures. Therefor, in cyclophone theory frequency is measured in **Cycles per Measure (CPM)** for frequencies >= 1 and **Measures per Cycle (MPC)** for frequencies below 1 and > 0. Negative frequencies are not used and zero frequency has no meaning or represents stasis. This gives us the necessary connection to the musical structure and a way to relate what we are doing to traditional musical notation.



The frequency we set as our CPM is sometimes referred to as the Fundamental Wave. Everything in cyclophonic music is related to the Fundamental Wave, or the CPM.

$$f(x) = A\sin CPMx$$

CPM is not to be confused with Tempo, often expressed in **Beats per Minute** (BPM) since the same Cycles per Measure can be played at any tempo and they are completely independent.

Cyclophonic Phase

All waves must begin somewhere between 0 and 2π and then will repeat at some point determined by their frequency. This determine whether a wave starts at zero or at a peak or a trough or somewhere in between. Where it starts is referred to as the **Phase**.

Phase is simply added to the angle being calculated thusly:

$$f(x) = A\sin CPM(x+phase)$$

Cyclophonic Amplitude

The final component of cyclophonic control is amplitude. As you can see from the formulas shown, setting A to zero is multiplying by zero and of course produces zero. So in order to make our waves rise and fall in a rhythm, they require some non-zero amplitude.

By combining CPM with Phase and Amplitude, we are now ready to explore the many musical uses of these three simple parameters.

Cyclophonic Waves

As mentioned before, to get more interesting waves requires adding waves of differing frequencies and amplitudes. When waves are combined, each individual component is referred to as a **Partial**. This will be familiar to anyone who is familiar with the overtone series which is also a series of frequencies that are combined to produce a sound or a timbre. Partials in cyclophone theory are created with frequencies that are expressed as multipliers of the Fundamental Wave (CPM). The God of all multipliers is One. One is Unity. One is the Fundamental Frequency. The other gods of multipliers are the same ones that we see in the overtone series: 2, 3, 4, 5 and 6. Doubling or halving a frequency necessarily produces an **Octave**. In pure cyclophone theory, there is no limit to the number of partials one can add to produce the desired **Generator**. In practical terms, we can only comprehend so much at a time, so generally we use a relatively small number of partials. The Generator is the sum total of all the partials and then it's only a matter of what musical parameter the generator is assigned to control.

One other important wave parameter is used in cyclophonic music and that is the Wave's **Vertical Position (Y)**. This position is used to move waves up and down on the y-axis which becomes very useful and necessary when applying them to musical controls.

Without getting into the mathematics, let it also be said that another very important parameter of a given Partial is the **Wave Shape**. While sine waves are the purest form of wave, there are several common variations that any synthesizer enthusiast will be familiar with: Square, Sawtooth and Triangle. These different shapes are produced by changing the function of the sine wave to produce a different shape but they all make the same use of frequency, phase and amplitude and therefor are musically useful for cyclophonic purposes, just as they are in audio synthesis.

Cyclophonic Control of Music

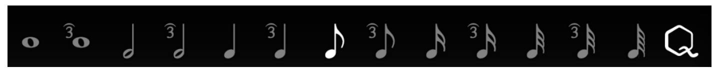
Once you have in place a means to generate waves of sufficient complexity, one only needs to let these waves perform their musical functions. This is achieved by assigning them to various musical (or audio) parameters. Each musical parameter should have it's own Generator (CPM, Phase and Partial Amplitudes) that operate independently of other musical parameters, though in many cases they are the same. For a given, musical parameter, there are natural limits. For example musical notes that we can't hear are of limited use so generally we limit them to the normal musical range one might find on a piano.

When a generator is assigned to a musical parameter, the limits and nature of that parameter are taken into account and the Generator is interpreted into the "language" of that parameter.

This results in two fundamental styles of interpretation:

- **Continuous control:** where the generator is continuously evaluated for its current value and then multiplied and placed within desired hi-lo limits to produce the desired output.
- **Discreet control:** where the generated is evaluated for a certain condition such as above zero or below zero, tapping into the periodic essence of the wave.

Some **Temporal Quantization** is generally applied in cyclophonic music in order to bring the results into a timing realm that fits with the desired musical feel. For example one generator may be evaluated every quarter note for a new value while another may be every 1/64th note up to CPU maximum. Essentially we must impose some sort of time grid on how often we sample a wave since we haven't yet invented an infinitely fast computer. The time grid tends to be put in terms of musical beat values in order to synchronize waves between the various musical parameters. The actual timing of this quantized sample rate is governed by the Tempo (BPM) and is calculated to a



normalized interval that represents a given beat value at a given tempo.

Functional Quantization is often required when interpreting a smooth, continuous mathematical abstract such as a sine wave into useful musical parameters. For example, notes are commonly used in the equal temperament scale and not as a sliding pitch (portamento or glissando). So it is sometimes required to reduce the wave into integer note values (aka. MIDI notes) rather than dealing with all the pitches between the notes.

Common Musical Controls

 **Note Waves**

When a generator is assigned to musical notes, it is used to change pitch like striking a different key on a piano. What pitch is evaluated depends on various other settings such as musical key, scale and range. there are no limits as to the temperament or frequency range of scales (also called Modes) used and it depends on the musical requirements.

Rest Waves

Rest Waves use a discreet interpretation of the Generator and by default produce a rest for all values greater than zero. In the above example you can see that the 4*x* Partial is given an amplitude of 25 and has the effect of carving out quarter notes in the Note Wave. The Rest Wave is entirely independent of the Note Wave and all other Musical Waves.

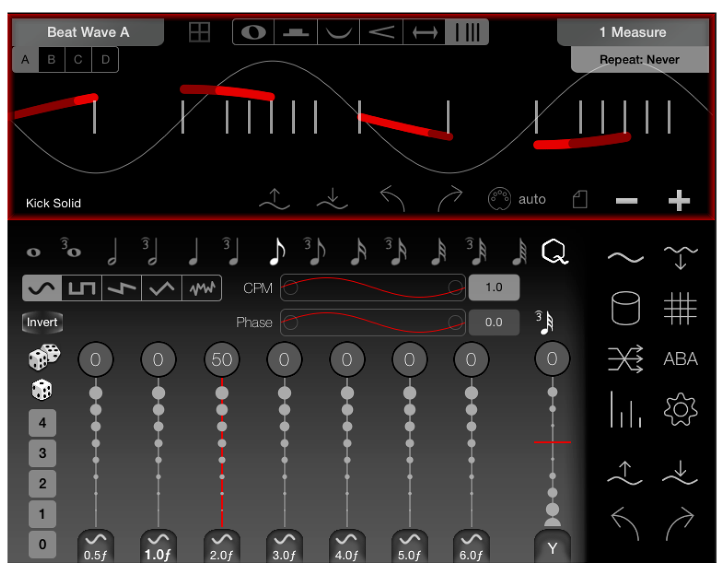
Tie Waves

Tie waves use a discreet method to determine whether adjacent notes are tied or untied. While it doesn't matter which method you use, the above method unties notes when the wave goes above zero. In that ties generally apply to the same note played consecutively, when the Note Wave is given amplitude, notes may become untied independently of the Tie Wave. However, in this Cyclophonic Control, there are A and B styles for the interpretation of the Tie Wave and in the B style, notes that are tied will not allow new notes to play during the tie period once the first note is played. I will cover Interpretation Styles below in more depth.

Dynamics Waves

The Dynamic Wave is a Continuous control type and uses the Generator to control musical dynamics or Velocity like hitting a piano key harder or softer.

Beat Waves



Beat Waves control the master Beat Value for a given

Voice based on the Wave's amplitude at a given time. This has the effect of creating rhythmic patterns that are independent of the other waves and create interference patterns based on the conditions of the other waves such as the rest, note and tie waves. There are many way once can interpret wave data into beat values so numerous Interpretation Styles should be provided in a useful interface.

Other Possible Musical Controls

The imagination is the limit when it comes to what you want to try and control using Wave Generators. Possibilities include:

- Note Duration
- Vibrato
- Accents
- Key
- Scale
- Harmony
- Counterpoint
- Rubato
- Slurs
- Tempo
- Pitch Bend

Common Audio Controls

While Cyclophonic Controls are largely aimed at musical structure, they are every bit as useful for audio control and Holistic Tonality theory requires that the many levels of music have no artificial boundaries between them. Therefor waves can and should be used to control the sound and spacial placement of the audio output.

Panning Waves

Panning Waves use continuous control to affect the left-right position of music al output dynamically creating interesting spatial effects.

Other Possible Audio and External Controls

There are no particular limits on audio and other such controls. Possibilities include:

- Surround Sound
- Effects
- Filters
- Various Continuous Midi Controllers
- Lighting
- Visual Effects
- Audio Glitching and Sharding
- Audio Pitch and Time Shifting
- Sample Manipulation
- MIDI Sequence Manipulation
- Audio Synthesis

Interpretation Styles

Each Musical and Audio controller has its own special considerations and leaves room for different ways to interpret or react to wave information. As such, one should include user options for different interpretation styles.

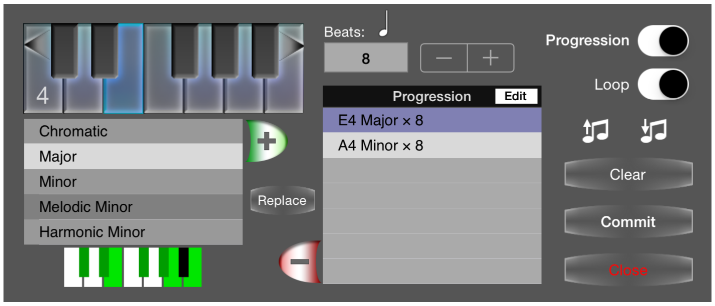
For example, one may desire for sounds that are played to complete entirely even though a new note has been triggered. This is often desired with percussion sounds which sound unnatural when they are cut off.

Or when a rest is encountered, you may also want to let the sound finish playing instead of chopping it off immediately (which you also may want to do). This produces a "softer" rest.

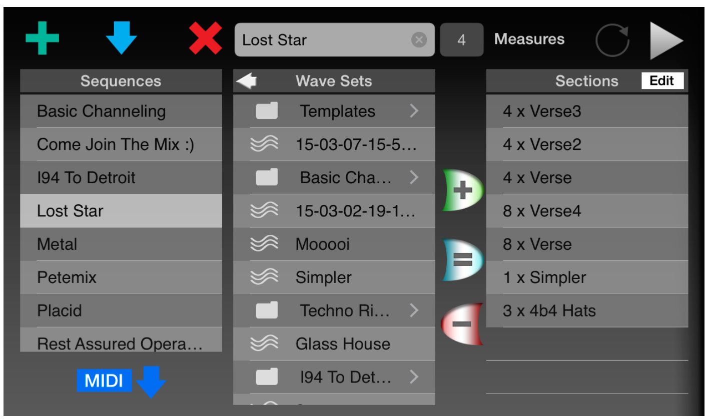
Dynamics and Panning can be calculated continously as though someone was controlling a slider or they can be calculated discretely on beat values only affecting the way a note plays but not how acts as it sustains.

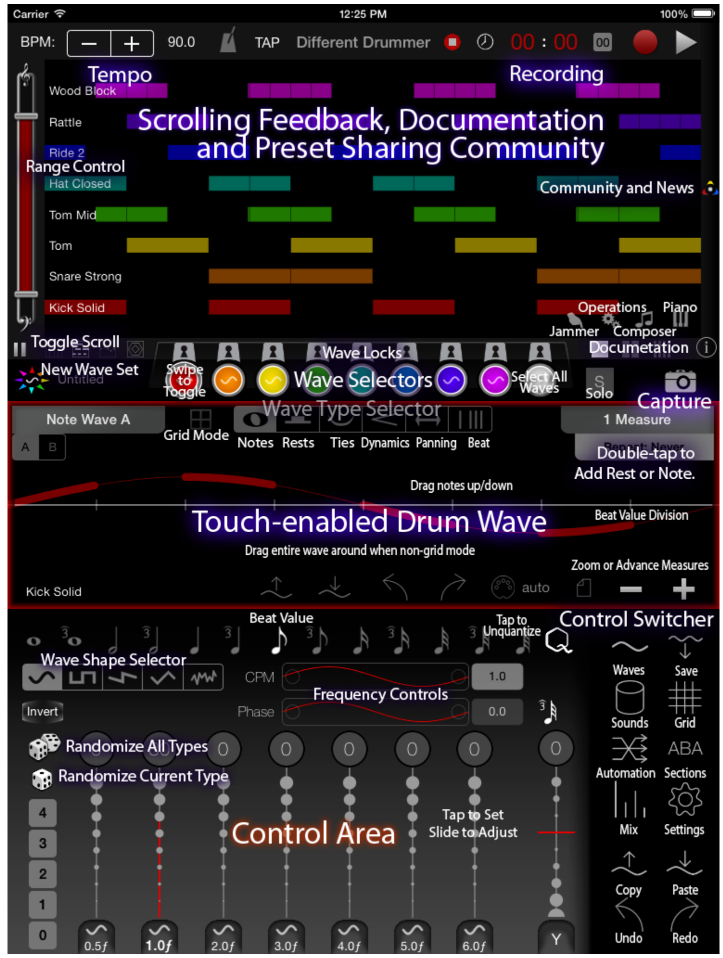
Beat Waves are open to tons of different interpretations where different amplitude levels (negative or positive) can be set to trigger various levels of beat division or multiplication.

Cyclophonic Composing



Each set of Generators comprise the state of a given Voice at a given time. Voices can be combined to create larger sonic tapestries. These in turn can be altered over time or swapped out entirely at a given time (sequenced). Other compositional techniques can be employed such as changing scales and keys and tempo to create a Master Composition for performance or recording purposes.





The Different Drummer Interface is only one example of a cyclophonic application

Cyclophonic Interfaces

The examples of interface shown are from my iPad app Different Drummer but by no means are the only way once might present the rich controls that Cyclophonic Music requires to be effective. One huge challenge is to make these controls as approachable by musicians as possible yet maintain the power and details that are possible. The interface of Different Drummer is intentionally “geekey” because it exposes a great deal of functionality. It is possible to abstract much of this away from the user and only allow them higher level controls but that is up to the individual programmer and their target audience. Touch controls such as on the iPad pose additional challenges as well as limited screen space so the most powerful version of a such an application would be found on a desktop both for the way windows and palettes are used and the raw CPU and RAM advantages.

There are many consideration when exposing a mathematical parameter in a friendly way. I have found there to be a continuous evolution of my own UI controls to make them more useful and obvious over time. For example I found sliders to be unwieldy for precise frequency control and so I replaced them with “scroll wheels” which I later found to be unnecessarily skeuomorphic (emulating a real-world object) and so I have replaced those with custom CPM and Phase controls, dedicated to the specific purpose. Likewise I have created dedicated amplitude controls which are more responsive and precise than the sliders they replaced. There will always be a trade off between ease of use and depth of control and it is always a challenge to find the proper balance.

Other Generator Models

Very much like audio synthesizers have fractured into a myriad of different schools of thought and methods, cyclophonic *music synthesizers* can do the same. For example, it would be very natural to introduce the concept of FM (Frequency Modulation) where the

Fundamental CPM Wave is itself governed by a wave, continuously changing frequency. The Beat Wave above is actually doing this in a certain way, changing the frequency of beats based on the amplitude of a wave.

Fractal Generators can produce very useful results and would generally have an entirely different set of controls than sinusoidal ones. Fractals may be the perfect tool to control all the levels of music and sound since sound contours are themselves fractal in nature.

Neural Networks can also be trained to compose in a given style and greatly aid us in the transitions between sound and music.

While these various methods would lead to fascinating results, the wave-based ones are the most likely to produce rhythms that are more relatable for dancing and entertainment purposes/

Analytical Techniques

By employing Fast Fourier Transforms (FFT) it is possible to work in reverse and interpret real-world audio into musical wave parameters. For example instead of trying to dial in the elusive parameters of a Samba beat, one might be able to have a program listen to an audio via microphone and find the parameters for you. In fact, this is slated as a feature of a future Different drummer.

Existing Applications

If you have an iPad, please have a look at Different Drummer which has been created with practical music production in mind with a dash of experimentation. It clearly demonstrates the principles of Cyclophonic Music production.

In Conclusion

It is obvious that there are few limits to this approach to musical creation and that to fully harness Nature's mathematical treasures is not only a life-long task but one that will take many generations to complete. The area of exploration is so vast that one program or programmer could never touch all the possibilities. After having created and used Different Drummer and Cyclophone for the desktop, there is no doubt in my mind that this should be a permanent addition to the musical vernacular and that Cycles per Measure will be with us for a very long time. In fact, I most certainly didn't invent this as I've used numerous audio plugins that use LFO (Low Frequency Oscillators) to control parameters such as panning or chorus depth. However, I am sure that changing the focus to include musical structure such as notes, harmony rests and ties will provide a huge palette for future musicians to dazzle us with!