John Chowning: Overview, Techniques, and Compositions

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MAT 276N | Winter 2009

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Introduction to Chowning

Purpose

The goal of this paper is to provide the reader with a broad overview of John Chowning's background, discoveries, techniques, and compositions. The intended audience is those with or without a musical or technical background. My educational and professional background are largely technical and my exposure to electronic music dates back a mere six years to 2003, so I personally gained much from the historical and compositional descriptions in this paper.

Introduction

John Chowning is one of electronic music's most significant pioneers and among the very first composers to use the computer to realize his ideas. Though best known as the father of FM synthesis, he has made significant contributions in the research of spacialization, psychoacoustics, and algorithmic composition. He is a master of analyzing and producing natural sounds, while his compositional work extends into new domains of timbre.

Though his technical research of heavy use of mathematical principles when composing may cause one to mistake him for a well-trained engineer, Chowning's work has only been for the purposes of musical composition. His desire to create new music drove him to the discovery of new technology, a prime example to argue the commonly seen separation between artistic and technical fields. This paper will give an overview of his background, research, techniques, major compositions, and conclude with a brief interview.

Background

Chowning's education was purely musical and for the most part traditional. He played violin as a child, then percussion as a teenager, eventually developing an interest in jazz during high school before attending the Navy School of Music. After military service, he obtained a Bachelor of Music at Wittenberg University in Springfield, Ohio. It was when he moved to Paris in 1959 to study with the renowned Nadia Boulanger, that he first heard electronic music including the works of Karlheinz Stockhausen and Pierre Boulez.

Upon returning to the states to obtain his PhD, he discovered that there was no computer music studio at Stanford and little interest in computer music within the states. An inspiring article regarding the possibilities of sound with computers in Science magazine led Chowning to contact Max Matthews, a researcher at Bell Labs and creator of the Music V programming language. Chowning installed Matthew's program on an IBM 7090 computer in Stanford's artificial intelligence lab in 1964. Chowning credits the interdisciplinary environment of the artificial intelligence lab for providing him with the resources he needed to teach himself programming, signal theory, and acoustical physics with no formal background. It was at Stanford that Chowning would conduct the bulk of his research in psychoacoustics, discover audio FM, and compose his major works of computer music. In 1975, Chowning became the founding director of the Center for Computer Research in Music and Acoustics (CCRMA).

Techniques

This section is meant to give an overview of the acoustical and synthesis techniques of John Chowning. While not all of the following techniques can solely be attributed to Chowning, he was certainly at the forefront of their usage. However obvious or practiced these techniques may seem in today's computer music, it is important that we look back to Chowning's time to discover the roots of modern practice.

Use of the Computer

One resource that the latest generation of musicians often assumes and takes for granted is the use of the computer in electronic music. Today, it is not uncommon for the terms 'electronic music' and 'computer music' to be used interchangeably, but in the 1950's and 1960's most electronic composers were working with tape recordings or analog synthesis rather than the extremely expensive and rarely available digital computers of the time. Yet, Chowning was one of the first composers to turn to the use of the computer in his music. "Music is a symbolic art," he says describing that musicians are used to writing their compositions on paper before hearing the results (Lehrman 2005). The transition from traditional notation to programming his ideas on computer systems that were far from real-time felt natural to Chowning and he comments, "I get a great deal of inspiration from computer programming languages." (Roads 1985) In a separate interview he tells us "the computer allowed us to touch an aspect of music which until then had been beyond the control of the composer… mainly the timbre… computers allowed us to get inside sound." (Arbor 2006) Chowning's last math course had been high school algebra and he had to beg for a passing grade in Stanford's "bonehead math" course at the age of 30, but he confidently states that the most important point in his learning was programming because it allowed him to go "directly from brain to output" using subroutines (Lehrman 2005). He is content programming for several hours a day so long as it is for the purpose of creating music. (Arbor 2006)

Acoustics and Psychoacoustics

Chowning desired to step outside of current musical and acoustical boundaries, but he took time to master and remain consistent with human perceptual and cognitive systems. He believes there is an inherent way that our aural perception system has developed over time, such as for hunters to perceive the distance of their prey or for babies to recognize the sound of a mother's voice. Chowning wishes to expand what is possibly musically within this intrinsic auditory nature.

Some of Chowning's early work, which would eventually lead him to his major discovery of audio-rate FM synthesis, was in sound spacialization. To conduct his research he used a 4-channel or quadraphonic setup in which four loudspeakers were arranged in a square around the listener. He referred to the area within the speakers as the listener sound space and the area outside of the speakers as the illusory sound space. His starting point for sound directionality was to divide the intensity between the two left and right pairs of loudspeakers in his setup by using signals of the same phase or delay (Pierce 1983).

Distance is the starting point spacialization. For example, one must be able to distinguish between a soft, near sound and a loud, far sound if their resulting intensities are the same. In addition to considering intensity, Chowning makes use of reverberation and Doppler shift to convey distance.

Reverberation was key in Chowning's implementation of distance techniques. He warns that one must be careful to give each loudspeaker channel its own reverberator with independent delay and gain. Distributing the reverberant signal equally on all channels risks masking the non-reverberant (direct) signal, thus reducing the perception of sound location and direction. He specified two types of reverberation when dealing with the distance of sounds: global reverberation- the part of the reverberant signal that is equal on all channels, and local reverberation – the part of the reverberant signal distributed between a speaker pair (Wells 1974). Chowning specified the equations below to relate reverberation to distance.

$$\text{Global Reverb} \propto \frac{1}{distance} \times \frac{1}{\sqrt{distance}}$$

$$\text{Local Reverb} \propto \left(1 - \frac{1}{distance}\right) \times \frac{1}{\sqrt{distance}}$$

We see from the above equations that reverberation becomes increasingly localized and therefore directional as the distance of the sound increases.

Global and local reverberation combine to create the overall reverberant portion of the signal. The most general factor relating the distance of a sound to overall reverberation is the ratio of the total reverberant signal to the non-reverberant signal (direct energy). While the energy of the non-reverberant portion of a signal falls off at a rate proportional to the inverse of the distance, the reverberant portion fades more slowly based on an inverse relationship to the square root of the distance (Pierce 1983).

$$\text{Local Reverb + Global Reverb} = \frac{1}{distance} \times \frac{1}{\sqrt{distance}} + \left(1 - \frac{1}{distance}\right) \times \frac{1}{\sqrt{distance}} = \frac{1}{\sqrt{distance}}$$

$$\Rightarrow \text{Total Reverberant Signal} \propto \frac{1}{\sqrt{distance}}$$

$$\text{Non-Reverberant Signal} \propto \frac{1}{distance}$$

These equations imply that the reverberation amount of a small space will remain somewhat constant with increasing signal distance. In larger spaces we can determine if a sound is somewhat distant based on a large ratio of reverberant signal to non-reverberant signal.

In 1972, Chowning wrote a spacialization routine as a front end for the Music 10 language that implemented graphical components so the composer could draw projected sounds pathways. This program considered both angular and radial velocities in its computations. Angular velocity is simply the rate of change of the intensity or energy of the sound, while the radial velocity takes into account the rate of frequency shift in the spectrum of the sound, known as the Doppler effect. Due to his lack of mathematics background, Chowning used a machine that plotted points at a constant rate to construct the algorithms he used in his program. If he moved the plotter faster then the points would be spaced further apart and vice versa (Lehrman 2005).

The Doppler effect was of deep importance to Chowning's work and describes an upward shift in frequency for approaching sounds along with a downward shift in frequency for sounds moving away from the listener. The Doppler effect is easily observed in everyday life such as the sound of passing cars on the street or the sound of a concert as you approach the venue. For a sound approaching at speed s meters/second, the frequency of the sound will be shifted upwards by a frequency $s/340$ (the speed of sound assuming sea level) (Pierce 1983). Thus, a sound approaching at a speed of 34 meters/second would raise the pitch by 1/10th of a Hertz.

A basic, yet often confused quality of a sound is its perceived loudness. While the intensity of a sound decays with increasing distance, Chowning's research was instrumental in showing that perceived *loudness* is a complex, multidimensional, and subjective property. He showed that loudness is related to several additional factors including vibrato, spectrum, and the amount of reverberation. Therefore, a sound with less intensity is capable of sounding louder than a sound with a greater measurement of intensity. Vibrato can be used to bring sounds forward and make them appear louder as we will explain in some of Chowning's later techniques. The previously discussed Doppler effect alters the spectrum of a signal making us think it is closer or further away and therefore perceptually louder or softer. Finally, reverberant spaces introduce a collection of echoes that add to the energy of a signal and can make it seem louder. Simply put, loudness is our perception of the intensity of the sound at its source regardless of our location (Chowning 2000).

Sound Segregation, Fusion, and Transformation

"Composers are making contact through the computer to a world of understanding about nature and science that is not a natural part of the musical education."

– John Chowning (Arbor 2006)

The practice of introducing small deviations in the frequency and amplitude of sounds is based on the sounds we find in nature. Only computers are capable of producing perfectly periodic sounds, for in nature sounds are quasi-periodic. Thus, to produce natural timbres, one must introduce patterns of variations in the frequency and amplitude components of a computer generated waveform. Chowning discovered two important uses for the micro-modulation of frequency known as vibrato. First, when working with a sound composed of multiple partials, adding small but equal amounts of vibrato to each partial leads to *perceptual fusion*, which is what causes our minds to perceive the partials as a single unified tone. Secondly, small, but non-equal amounts of vibrato applied to groups of partials leads to *source segregation* in which we are able to perceive separate tones or voices of sound. An excellent example of source segregation can be found in Phoné (1981) in which synthetic voices sound as mere tones until micro-modulation is applied.

In working with perceptual fusion and source segregation, Chowning was able to successfully emulate several quasi-periodic sounds in nature and traditional instruments. However, his true purpose was always "to use the computer to do that which we can not accomplish with natural musical instruments." (Arbor 2006) His discovery of FM synthesis when experimenting with vibrato rates would give him the method he needed to exploit timbre as an additional dimension to his compositions.

FM

"There is a whole domain of musical timbre which exists in nature but is largely chaotic… there is an orderly world that exists using the computer of the inharmonic partials."

– John Chowning (Arbor 2006)

The implementation of frequency modulation is relatively simple, yet developing a full understanding of its potential takes time and practice. This paper aims only to describe Chowning's relationship with FM. (See Chowning 1973 for a detailed explanation of FM along with instrument examples)

It was while working on sound spacialization and experimenting with high vibrato rates that Chowning discovered synthesis by means of frequency modulation (FM). He noticed that when the vibrato rate entered the audio domain (> 20Hz) various partials started to appear in the spectrum. In its simplest form, FM synthesis is accomplished by modulating the frequency input of one oscillator, the carrier, with the output of another oscillator, the modulator. However, multiple configurations of FM exist involving more than two oscillators. For example, Chowning's piece Stria used a configuration involving one carrier with two modulators.

Chowning discovered important relationships between the carrier and the modulator that determined timbre and if the partials would be harmonic or inharmonic. If the modulator's frequency is an integer multiple of the carrier frequency, then the resulting partials will be harmonic. Chowning also discovered that the modulation index, the ratio of modulation depth to modulation frequency, could be used to control the bandwidth of a signal over time by applying the amplitude envelope of the entire signal to the modulation index value. For a modulation index of value I, there will be $I+2$ audible partials. Thus, raising the modulation index controls the brightness of a sound. "The breakthrough for me was the realization that there is always such a strong coupling of bandwidth and intensity in most sounds, and that it is extraordinarily easy to implement that effect using digital FM synthesis." (Darter).

The ability to add inharmonic partials and change the bandwidth of a sound over time was not entirely new, for similar results were available with additive synthesis methods. The key difference to FM was its simplicity and ease of implementation. By simply increasing or decreasing the modulation index and carrier to modulator frequency ratio, one easily has control over a new dimension of timbre in the sound. Additive synthesis methods might require 16 to 17 oscillators to accomplish something that FM does using only 2 oscillators (Darter). Chowning says that with FM "nature is doing most of the work." (Chowning 1973) Though having only two oscillators may limit the number of variables for the composer to control, the "evolution of individual spectral components proves to be no limitation at all as far as subjective impression is concerned." (Chowning 1973)

Initially Chowning was able to create realistic clarinet, bassoon, and brass sounds with FM. Other characteristic sounds of FM are ‘clang’, ‘twang’, and ‘bong’ noises such as bells, drums, and complex harmonic and inharmonic textures like the human voice. The technique was licensed to Yamaha in 1975 and became the foundation for the incredibly popular DX7 synthesizer used on many recordings and soundtracks in the early to mid eighties. We have seen that Chowning found another way to emulate nature by “analysis through synthesis” with FM (Chowning 2000). However he states in his first major publication regarding FM that "applications are surely more numerous in the unknown timbral space.” (Chowning 1973) This statement leads us to examine his compositional work to observe a deeper usage of FM among other original techniques.

Compositions

Chowning’s compositional work makes direct use of his research in psychoacoustics and synthesis techniques. Though often focused on a single idea or narrative, the resulting structures of his pieces are incredibly complex yet well organized. Chowning explores the boundaries of our perceptual senses while focusing his efforts on using the computer to produces phenomena not heard in nature. However, the new dimensions in sound he explores are well balanced by his careful organization according to natural relationships such as the Golden Mean, Fibonacci Series, and Gestalt Laws. Chowning has a wonderful way of going completely against and with nature simultaneously and the results are nonetheless amazing.

Turenas

Turenas, completed in 1972, focuses on two of Chowning's most original techniques: the creation of a 360 degree sound space for the movement of sounds and the use of FM synthesis to create a variety of realistic tones and textures. In fact, Turenas contains only purely synthesized sounds created from FM synthesis. To realize his spacialization techniques, Chowning implemented his own subroutines for Doppler shift on top of the PDP-10 version of Music IV. The name Turenas, an anagram of natures, complements the usage of these techniques by referring to the way the sounds "tour" around the listener.

Though the purpose piece is more a study than a narrative, it is certainly no less inspiring, for it stands as a landmark in the demonstration of two important compositional techniques. Turenas was the first widespread composition to make use of spacialization and FM synthesis, and the theme of the piece focuses on the contrast between theses two new methods. The composition is divided into three sections of which the first and third focus on the movement of small, floating sounds in a 360 degree space, while the second section contrasts with strong and realistic instrumental tones.

Turenas begins immediately with highly spacialized insect-like sounds that surround the listener in a Lissajous pattern, a mathematical pattern based on the phase relationship between a sine and cosine projection. It was when initially drawing similar looking patterns on a plotting machine at Stanford that Chowning was approached by an engineer who mentioned the resemblance to Lissajous patterns. Lissajous paths have the property that their rate of change is slower when approaching a relative peak, a characteristic shared with natural motion in the sense that rate of change is much greater during acceleration than when reaching maximum speed. For examples, think about sprinters in a race or the acceleration of cars to a top speed. The actual shape of sound movement used in Turenas is known as a double Lissajous. This pattern occurs several times within the first and third sections, and the piece ends very much as it began with a final surrounding sweep of sound particles.

The use of FM in Turenas is showcased with the heavy bell sounds occurring throughout the piece and with the instrumental textures in the second section. From approximately 1:25 to 1:35 we hear an impressive timbral transformation from the tiny insect-like high pitches down to sounds resembling water droplets and finally into a powerful bell sound. After about 2 minutes into the piece, Chowning adds rich FM tones with tremolo and vibrato to the background of specialized particles. By about 3:30 we have completely reached the second section where the focus is on a variety of instrumental FM tones. In this section Chowning plays with FM's carrier to modulation ratio as well as modulation index to create several harmonic and inharmonic tones along with interesting timbral transformations between the two. Reverberation techniques are used more heavily in this section to indicate space and distance rather than the patterns of motion with Doppler shift in the first and third sections. At around 4:45 we feel the impression of tones fading away but maintaining their perceptive loudness as smaller more specialized sounds begin to take over once more. Using a rhythmic structure that may hint at Chowning's early jazz background, the piece eventually transforms back into a highly specialized series of shorter sounds. Actually, Chowning has mentions that much of Turenas was improvisational (Roads 1985). At about three quarters into the piece at 7:15 we hear the intense sounds characteristic of a high modulation index jumping from left to right channels. Perhaps these harsher sounds act to prepare us for the series of inharmonic and harmonic droning sounds that lead us to the end of the piece before spacialization takes over for the last time. Chowning also makes good use of subtle vibrato and tremolo to segregate the simultaneous tones sources during this time, and fills a gap in the low end of the spectrum with a pleasing deep bass sound around 8:45.

Stria

In 1977 John Chowning composed Stria, his most famous work. Like Turenas, Stria is constructed entirely from FM sounds, but rather than a study of spacialization accompanied by various improvisations, the Golden Mean is used as a strict theme that determines all aspects of the composition. Again, Chowning was working on a PDP-10 computer, but this time he used Music 10 (very similar to Music IV) and SAIL, the Stanford Artificial Intelligence Language.

Everything from the microstructure to macrostructure in Stria is related to the Golden Mean, 1.618. Stria is perhaps the most exhaustive study of this ratio in music, and once again Chowning succeeds in making use of mathematics as a narrative. The pitch scale used in Stria is based on a pseudo-octave with an interval ratio of 1:1.168 per octave instead of the traditional 1:2. Chowning chose to divide the scale into 9 equal divisions centered at 1000 Hz so that the scale remains somewhat similar to traditional 12-tone equal tempered tuning, but remains different enough so that it will not be interpreted as being simply out of tune. Moreover, the first frequency to occur in the piece is none other than 1618 Hz. Temporal relationships in Stria are also based on the Golden Mean. The work can be divided into several sections, and each section into several events all with durations related to each other by the Golden Mean. Additionally, the climax of the piece occurs at 0.618 of the entire duration.

Chowning makes use of timbre as dimension to composition by relating every parameter of FM to the Golden Mean or Fibonacci series, which has a close relationship to 1.618. The series is constructed by summing the previous term with the current term: 0, 1, 1, 2, 3, 5, 8, 13 …

Dividing the last term with its preceding term we see that the series comes closer to reaching the Golden Mean as it continues. For example, 2/1 = 2, 3/2 = 1.5 … 13/8 = 1.625 … 987/610 = 1.618. The carrier to modulation ratios along with the modulation indices for tones were set to 1.618 or ratios approaching 1.618 using numbers from the Fibonacci series. From our earlier discussion of FM we know that using 1.618 as a basis for carrier to modulator ratios rather than an integer accounts for the many inharmonic timbres heard in Stria. Chowning's FM implementation for Stria used Fibonacci numbers 1 and 2 for the number of carriers and modulators respectively.

Though much of the piece is based on the natural aesthetical properties of the Golden Mean, the other key elements of Stria's structure use the opposite of aesthetical norms in music. First, we notice that the duration of individual sounds is proportional to their frequency. This is contradictory to most music because low frequency sounds are typically used to drive the motion of a piece and thus have longer duration than higher frequencies. The result Stria produces by assigning longer durations to the high frequencies does sound strange initially, but eventually the macrostructure is realized with by the time the climax is reached on a low rather than typical high frequency. Along with duration, attack and decay times are proportional to the frequency of each sound as well. Chowning relies on the Gestalt principal of common fate to fill in the gaps left by reduced attack and decay for low frequency sounds. The principle of common fate is most often referenced to visual illusions in which the eye seems to complete a picture that is not completely drawn.

Starting with a subtle high frequency, Stria slowly adds tones in what feels like piercing lines of sound moving through time that accurately reflect the title's reference to striation lines in nature. Again we hear Chowning's mastery of vibrato to create a clear separation between tones and give the impression of antiphony. By about 2 minutes into the piece we can begin to perceive a slight trend moving towards lower frequencies. Sounds continue to fade in and out with slow attack and decays and at around 4 minutes we hear very effective use of reverberation along with minimal panning to give a sense of distance to the entering and exiting sounds. Around 5 minutes the piece becomes very quiet before louder low-pitched sounds enter to continue pushing the trend of downward frequency. The overall frequency rises briefly around 7:15, but glissandos quickly take over to move back down to lower frequency. The lowest pitches of the piece bring us to the climax around the 8:30. Glissandos are used again, but this time to move us back towards higher pitches. Mysteriously, at 10:56 we clearly hear a mid-range sound with incredibly short duration compared to every other sound in the piece, yet somehow this does not cause discomfort or interruption. One can only assume that the law of common fate keeps piece coherent despite this departure from the otherwise clear structural rules imposed by Chowning. By 14:35 we feel that the end of the piece has been reached as the pitch reaches a relative maximum. However, the frequencies begin to move downward once more and the purpose and trend of the remaining two minutes is unclear.

It should be noted that at least two versions of Stria exist. Chowning preferred a version lasting 15 minutes and 46 seconds. However, for my listening purposes a 17-minute version was used (ref) in which the climax occurs at 8:30/17:00, which equals 0.5 of the duration rather than at 0.618 of the duration. It is my assumption that the shorter version of Stria would be more preferable for me as well and account for the confusion I experienced with the final 2.5 minutes of the 17-minute version.

Though thoroughly organized and mathematically complex underneath, Stria moves us in simple downward and upward directions. Whether we are consciously or unconsciously aware of the underlying Golden Mean aesthetic, we cannot help but be captivated by the result of its sonic beauty. Furthermore, one may easily impose any personal narrative to the piece as it travels from mysterious high frequencies to dark lows and back to peaceful highs. While the overall timbre of Stria is relatively constant, Chowning's attention to detail is evident and the tones have natural sounding warmth that entertains one for the duration of the piece.

Phoné

Phoné was created from 1980-1981 and stands as the first major use of FM for vocal synthesis. However, Chowning once more uses his original techniques to achieve phenomena that only a computer could produce. Phoné stands somewhere in between Turenas and Stria in terms of structure and its use of timbres, but it stands out as an exploration of the possibilities of timbral transformations.

The piece begins with a quick series of short notes that seem to unwind into a purely electronic tone, but when small amount of vibrato is applied spectral fusion leads us begin to perceive the tone as vocal. Chowning works with many such transformations throughout the piece, and electronic versus human sounding timbres is definitely a major theme in Phoné. The transforming sounds shift to lower frequencies before the piece reaches complete silence around 45 seconds. The sounds fade in once more and by 1:20 we hear a transformation that ends with a clear and very realistic sounding voice. There is excellent usage of dynamic range in Phoné, which is effective in the composer's overall intent to start quietly, add pure tones, transform them into voices, and finally add unreal capabilities and transformations to the voices. One such transformation is a trumpet sounds morphing into a voice in 360-degree space at 3:30. Chowning as also determined the proper vibrato characteristics to separate voices and lead to a chorusing effect. At 4:47 a chorus of voice leads us to the first climax of the piece and then transforms into a brass sound. At 5:03 the motif signaling the start of the piece sounds followed again by pure, electronic tones slowing transforming in voices. The starting motif sounds a third time at 6:20 after which voices begin immediately, but this time slowing deconstruct themselves into their pure tonal components from 6:40 to 7:00. The piece builds again and we enter a full spectrum of timbres that finally lead to the largely reverberated, beyond-human basso profundissimo and second climax at 8:00. Another fading to a brief moment of silence at 8:40 and simple electronic tones transform to a chorus of voices, covered in a blanket of reverberation. After another brief return to silence we hear a mix of contrasting unreal, ultra-low male voices with very realistic soprano voices. At 11:49 and 12:05 we hear disguised versions of the starting motif, and the piece ends with a voice deconstructing its soft, almost unnoticeable electronic tones.

Other Compositions

Sabelithe was Chowning's first computer piece and officially the first ever piece to use FM synthesis. Sabelithe also makes used of moving sound sources as in Turenas, but the effects are not nearly as impressive since Chowning had not yet finished his program for Doppler shift. Sabelithe also began Chowning's experiments with timbral transformation using FM. From 4:50 to 5:10 we hear a drum morph into a trumpet.

Voices (2005-2006), is Chowning's most recent work. It uses the same scale as Stria and is realized using the Max/MSP language. Unlike his other purely electronic works, Voices is an electroacoustic piece featuring vocal accompaniment from a female soprano. Chowning uses a modern laptop computer and is interactive with the voice of the soprano triggering events on a laptop computer.

Conclusion

Turenas, Stria, and Phoné each have their own distinct themes while making exclusive use of Chowning's FM techniques. While some are more improvisational and others are strictly rule-based, all of his compositions reflect his research in acoustics and transformation of sounds. Chowning has succeeded in finding new timbres to use within our inherent perceptive and cognitive bounds- blurring the line between fantasy and reality while remaining aesthetically pleasing.

Interview with John Chowning (2009)

McGee: You came from a very traditional music background and learned programming, physics, acoustics, and signal processing in order to achieve your compositional ideas. What advice would have for those coming from highly a technical background trying to enter the world of composition?

Chowning: Knowing about music is really important. My math skills are really low-level. For example, I can understand both the FM equation and the trigonometric expansion, but I could never possibly derive the latter from the former. I learned about physics by simply asking lots of questions. The Stanford AI lab was a very special place with engineers, computer scientists, philosophers, linguists, so I could find an answer to almost any question…. but the lingua franca between all of us was programming.

A formal music background is very hard to recapitulate. Most of us as children go through the hard part… and I don't think I would recommend that… if you have some performance skills that is probably enough. Looking at things like how sounds are made… how AM and FM synthesis work and what values to use… then you really learn, and that I would recommend. There are also some perceptual issues… the ear doesn't like perfect symmetry … and understanding those issues has to do with understanding the internal dynamism of the art from the sound to formal structure.

McGee: You have referred to Music as a symbolic art in the sense that the composer writes or in your case programs a composition before being able to hear it. Now that much music creation software allows one to work in real time, do you think that is strengthens or weakens the creative process?

Chowning: It's easy for composers having traditional training to learn programming because they are used to representing music as symbols. [The method of creating music] is very individual. I always begin with a sound… and sometimes within the morphology of a sound I find the structure of a piece.

McGee: It is interesting that the narrative of Stria is based on mathematical relationships. You have shown an intimate relationship between art and science in the since that the Golden Mean was used as the creative foundation for that piece. Do you agree that the separation between art and technology is merely an illusion?

Chowning: Yes, and I've never been of the school where the Golden Section is this magical formula, but you find it in nature and it's true. It was a very practical application that generated a sound that I wanted to work with. [Because of the Golden Mean] I understood why I liked that sound.

McGee: Considering all of your work in spacialization, what surround setup do you see as the future in the performance of electronic music?

Chowning: I think the future for electroacoustic concerts is in movie theaters. Good ones have great sound systems that are tuned to the room… they are everywhere… you have a great display medium if there are visuals. They are culturally neutral… anybody feels comfortable in a movie theater while not everyone feels comfortable in concert halls.

Chowning Cheat Sheet

Here is a handy page of formulas and properties to consider for your own work along with brief notes on Chowning's major compositions.

Reverb:

Global Reverb $\propto \frac{1}{distance} \times \frac{1}{\sqrt{distance}}$

Local Reverb $\propto \left(1 - \frac{1}{distance}\right) \times \frac{1}{\sqrt{distance}}$

Local Reverb + Global Reverb = $\frac{1}{distance} \times \frac{1}{\sqrt{distance}} + \left(1 - \frac{1}{distance}\right) \times \frac{1}{\sqrt{distance}} - \frac{1}{\sqrt{distance}}$

$\Rightarrow$ Total Reverberant Signal $\propto \frac{1}{\sqrt{distance}}$

Non-Reverberant Signal $\propto \frac{1}{distance}$

Doppler Shift: An upwards frequency shift of $\frac{\text{speed of approaching sound (meters/sec)}}{\text{speed of sound (340 meters/sec at sea level)}}$

Loudness is subjective, multidimensional, and depends on intensity, reverb, bandwidth, and modulating effects such as vibrato and tremolo

FM

If the carrier to modulation frequency ratio is an integer then the sound will be harmonic. Non-integer ratios will lead to inharmonic sounds.

The Modulation Index controls the "brightness" of the sound. For an index, I, I+2 partials will be heard.

Turenas (1972) – 360 degree sound space with Lissajous patterns of moving sound

Stria (1977) – Based on several relationships to the Golden Mean (1.618)

Phoné (1981)– vocal synthesis and transformations with FM

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