ELETTRONICA TRIPTIKON

Bachelor Thesis
Intitute of Sonology, Koninklijk Conservatorium of the Hague
presented by João Manuel Marques Carrilho (Jonas Runa)

Contents :

III - *Informatics*

INTRODUCTION

The present bachelor thesis, oriented by Peter Pabon, is presented to the Koninklijk Conservatorium of the Hague by João Manuel Marques Carrilho.

The thesis is a triptych, studying *Theory*, *Iconography* and *Informatics*.

The first part (*Theory*) is an aesthetical compedium, subsidiary to different hermeneutic points of view. The second part (*Iconographies*) is ilustrated by a sample of musicographies of the student correlative to the theoretical enunciates of the first part. The third part (*Informatics*) relates to a formalized compositional system. The focus is there is on computer-assisted composition,

Electronic Music is a discourse as organized as any language (the sounds are codified previously in the case of written composition and codified in the moment in the case of improvisation)

The artistic object of this thesis (Electronic Music), consists in aesthetical information; that aesthetical message is the musical object itself.
Electronic Music is the substance or matter fixed in scores, computer programs or graphisms. It is a fundamentally technological area, so it requires a special kind of theorization : This thesis deals with it's technical and technological superstructures and the performative act. But it also pretends to demonstrate historically it's philosophical or conceptual nature.

I - *Theories of 20th Century Music*

I.1 – MICROTONALITY

FIG 1: Ivan Wyschnegradsky, ***Chromatic Drawing***
In 1940, Wyschnegradsky progressed towards an audio-visual work, rticularly with the use of color notation. In theory, he related the cyclic equilibrium of colors to the divisions of a tone: a 3-color cycle symbolizes the1/3 tone scale.

I.1.1 - *Transformations of musical languages*

Concepts only arise when thought is set in motion. The movement of concepts themselves generates languages. Languages reveal spiritual consciousness. Thought is not imparcial, it is bounded by movement to speed and feeling. It is only when inner time becomes autonomous that concepts can be formed, because if this autonomy does not exist, all thought is purely an immediate reaction to reality : Light – Color – Sound.

The historical study of the transformation of musical language is more important than the study of fixed historical periods, because it potentiates the comprehension of the transformation of musical consciousness.

Music has been for a long time an important social communication process, acting not simply from the inside of any society but also at the (macro) level of interactions between different societies at a large scale.
The psychodynamism in the art of music has always found a fantastic diversity of forms of expression. This process is continuous and generational. From the pre-literary age mankind has used *sound* in rituals and social ceremonies of diverse function.
Proto-writings (ideographic and/or mnemonic symbols, representing a meaningful language units) existed much before the development of a purely linguistic writing. They were visual elements deeply rooted in a spatial intuition (which dominates the visual perception). In ancient greece, diagrams were used to represent intervals, so that the eye could see what only the ear could perceive. It is in a logical tradition from Euclid (the "inventor" of geometry), that Descartes, with the help of algebra, formulated the *cartesian coordinate system*, an efficient spatial representation. The models followed for the organization of the *pitch space* in Descartes as in Rameau come directly from Pythagoras, and are justified as part of the *natural order of the world*. The development of *notation* is connected to this idea of a stable spatio-temporal system, in which both time and pitch have a regular metric. What this means in fact is a selection of some proeminent features of sound (but certainly not all), mostly it's periodical characteristics.
In 1739 Euler proposed a 2-dimensional model for the pitch space: one axis for just intonation and another for major thirds. The idea to give pitch two dimensions was important, it is not far from current psychoacoustic researches. For Schoenberg, *the bidimensional (or pluridimensional) space, in which musical ideas are exposed, constitutes a whole* (Style and Idea). In electronic music, many composers have refered to the composition as a multidimensional parametric space, meaning that each selected feature of sound will be organized according to an essentially spatial principle. It was in this sense that electronic and electroacoustic music have used Schoenberg's unified space. In this part we will follow the evolution of pitch spaces, also named *tone-systems*.

In general, any *tone-system* can be characterized by two factors: One is the number of steps within an octave. The other is the principle which organizes the relationships between the tones. The relationship of a *tone-system* to a specific *notation* is of great relevance. Certain cultures (ancient egyptian, and others) probably had a rationalized tuning system without possessing a special *notation*. Quite frequently the complete set of relations is an abstraction from melodic fragments and intonations.
Many music cultures do not posses a *tone-system* at it's basis. When this is the case, musical instruments are more likely to be motivation, rather than vocal music. The reason comes from the fact that if an instrument is pitched, it usually corresponds to a static tuning (scale), which should be able to communicate with other instruments, while the voice is more versatile in intonation matters. Musical instruments also can be the practical models of the theoretical systems, such as the Greek *canon*, *lyra* or *kithara*, the Persian *lute* (see Appendix 1) or the Indian *vînâ*. One can study ancient tuning systems by looking at the instruments used by any particular culture (see the egyptian, japanese and indian examples ahead):
In some *Old Mesopotamian* cuneiform tablets from the British Museum, remarkable discoveries have revealed ancient bablylonian scales which were probaly known also to the Sumerians and Assyrians. The tablets date from the time of Hammurabi, who had written the first known code of law. The babylonian scales are exactly the greek

modes (and the medieval eclesiastic modes). The tetrachord (credited to greek music theory but in fact used in mesopotamia and persia earlier) is a scale with intervals which add to no more than a perfect fourth. From a reference mode (e-f-g-a-b-c-d-e), the babylonians obtained seven others by a cyclic transformation process: to produce a new mode simply go down in parallel fourths and when you find the tritone raise the low note. Invesely, it is possible to lower the upper note in the tritone:

Tritone Tuned Upwards	*Tritone Tuned Downwards*
e f g a b c d e	*e f g a b c d e*
e f# g a b c d e	*e f g a b*b *c d e*
e f# g a b c# d e	*e*b *f g a b*b *c d e*b
e f# g# a b c# d e	*e*b *f g a*b *b*b *c d e*b
e f# g# a b c# d# e	*e*b *f g a*b *b*b *c d*b *e*b
e f# g# a# b c# d# e	*e*b *f g*b *a*b *b*b *c d*b *e*b
e# f# g# a# b c# d# e#	*e*b *f g*b *a*b *b*b *c*b *d*b *e*b

(The last step leads to a transposed version of the first in both cases)

FIG 2: 7 modes from ancient Mesopotamia
From the ancient Mesopotamia we inherited the following cyclic motions: 60 min/hour ; 24 hours/day ; 7 days/ week. It is quite interesting that we also inherited the 7-tone scale, and although the tunings are different, the *cyclic thinking* of changing between modes is exactly the same as the way tonal music changes between tonalities (thus it can be expressed in the same notation). The circle itself was divided in 360^{o} in ancient Mesopotamia, who used the sexagesimak numeral system.

It is extraordinary that this system is know for at least 3500 years. It is also remarkable that the tritone has been used since such a long time as a catalyst for changement (it is essential in tonal modulation, for instance: the tritone on the fundamental gives the leading tone of the dominant tonality).
All the babylonian modes were pythagorean in the sense that they only use the ratio 3/2 to build the *tone-system*. To say this is an anacronism because they existed before Pythagoras, who himself studied in babylonia a few years just before that civilization colapsed to the Persians. These facts point to the necessity of a complete revision of 99% of the music literature, which puts the greeks and their modes as the theoretical cradle of european art music. Lou Harrison, a composer who has been interested in a vast number of extra-european music cultures, was one of the people to bring atention to the relevance of the mesopotamian discoveries and to the fact that they may have passed to the Greeks.
The main concern should be to study what kind of interactions relate Babylonians, Egyptians and Greeks, and not to study them as closed systems. Pythagoras has not only travelled to Babylonia but also to Egypt, after an advice by Thales.

Ancient Egypt had a highly developed music used in religious cerimonies (using percussions, winds, strings...). By correlating the hole positions in different egyptian flutes one can speculate about the existence of a rationalized *tone-system*, which would unify and systematize a certain musical practice. The Egyptians probably got from Persia one 7-note scale, at least. They already used an old pentatonic scale, but after the New Kingdom, a similar version of our 7-tone a-minor mode became also quite popular.

In *India*, the Vînâ was the closest model to the theory, which in practice meant the usage of seven-tone scales which treated as modes (as for the ancient greeks). The 22 microtonal *srutis* are purely a "source" scale (in just intonation), from which modes of 7-tones each are born. Just intonation inevitably introduces differences between intervals (no *enharmonic equvalences*), a problem which would only start to be solved from the late middle ages. The indian modes are the same as the babylonian and the greek modes.

The *chroai* of *Ancient Greece* had some correspondence to the indian *srutis*. They were literally different *colors* (different possibilities of tuning) within the same scale.
From the greeks it is known that simple melodies are usually encompassed by a fourth or a fifth (corresponding to the third subharmonic or harmonic respectively). The fourth was related to the greek tetrachords. The fifth (almost alone) participated in the creation of tunings. There were two main tunings in the greek system, both coming out of the harmonic series: pythagorean and aristoxenian. The pythagorean uses the simplest of the ratios present in the overtone series disregarding unissons and octaves: 3/2. By superposing this interval on itself 12 times we are close to 7 octaves. This difference is called pythagorean comma (ratio of 1.013643). If all the fifths are reduced to the same octave we obtain a scale of seven tones in the 3-limit system (since the maximum prime involved is 3). The pythagorean comma means that from the 2nd on, all the fifths will be slighlty detuned in relation to a division of 7 octaves in 12 equal parts. Perceptualy a fifth maintains it's quality even if it is slightly out of tune, so there is only a problem when looking for *enharmonic* tones. The point was to build scales using the first intervals from the harmonic series, which assure a maximum of fusion between the tones. It would be pointless to have used the 1st or 2nd overtones (corresponding to unisson and octave) if a minimum of pitch differentiation was searched for. The scale associated to the perypatetic Aristoxenus used not only the 3/2 but also the 5/4, that is, the interval between the fourth and fifth harmonics (major third) :

1/1	9/8	5/4	4/3	3/2	27/16	15/8	*Aristoxenian*
1/1	9/8	81/64	729/512	3/2	27/16	243/128	*Pythagorean*

Note that in any of these cases, the distances between successive tones are not completely constant (the pythagorean uses only steps of 9/8 exept for one of 256/243), while in the harmonic series no interval is repeated, each is specific. The tunning curresponds only to one scale, but the greeks knew seven modi, or seven *colors*. These modes arise from cycles of tetrachords (*genera*), which could be filled in three different ways, although the diatonic seems to have been the dominant:

a. Diatonic 1 + 1 + 1/2 — c. Enharmonic 2 + 1/4 + 1/4

b. Chromatic 1 1/2 + 1/2 + 1/2

Each mode is created by combining two tetrachords. The modi obtained are the same as the mesopotamian already shown. In ancient greece they took the names of several local clans: Dorians, Phrygians, Lidians...
It is interesting that the greeks played the scales downwards, contrary to nearly all contemporary practice. We do not know exactly when this reversal occured, but there are many existing cultures which still following this ancient tradition (as in the singing of Navajo Shamans). During the Christian period a major confusion was generated due to the fact that they took the greek mode names and starting tones and

read them upwards, ruining the original system (perhaps because of a translation error!).
As argued by Dane Rudhyar (*The Magic of the Tone and the Art of Music*), in ancient Greece this descent meant the *involution* of Sound into particular material resonances, representing the action of a spiritual creative power. "Sounds transmit a collective subjective psychodynamism", that is way they were one of the ingredients in the *drama*, the expression of *Myths*. To be born in a modern society makes it dificult to grasp what this means. Consider the following example (also by Rudhyar): A acoustician studies the sounds of animals in the safety of a zoo VS. an indian who is travelling in a dark forest starts to hear animal sounds. In the first case, the scientist studies the sounds as physical waves, in the second, the indian listens to the psychology of the spirits of nature.
Nealy all books on greek music theory mention the descending tetrachord but very few attempt to explain the reason for it.

In *China*, Ching Fan (78-37 BC) noticed the pythagorean idea of approaching 7 octaves with 12 fifths, and expanded it: 53 fifths are closer to 31 octaves. The resulting 53 tone scale would be later used by Mercator, and the difference ibetween the fifths an the octaves became known as Mercator's comma (1.00209, about 5 times smaller than the Pythagorean comma).
The 12 ancient "Lu's" correspond to the 12 pythagorean fifths when projected into the same octave. As other asians cultures, the Chinese have used five tones per octave, also in different modi, for instance: c d f g a   d f g a c   f g a c d.
These steps were (as still are) the *natural* tone-steps for the Chinese. In our ears they sound as typical asian melodies because we have developed a large conceptual framework on "equal" intervals and produced so much music with that ideas that it made us listen in a different way. On of the chinese important instruments, the *Pipa*, comes from the instrumental family of the lute, as found in Egypt and ancient Mesopotamia, so not only the theoretical ideas have passed through!

The *Japanese* *Gagaku* is one of the oldest forms of harmonic music. Traditionally a modern program encompasses dance, intrumental and vocal pieces. From two of the instruments present in the *Gagaku: Biwa* (4-string lute similar to the chinese *Pipa*) and *Koto* (13-string zither), we can make observations about the subjacent organizing principle of the *tone-system*. The Koto was tuned using a 5-tone scale spread over about 2 octaves. This tuning was built out of two descending tetrachords using the the greek enharmonic principle. In the descending case : *c*   *a*b   *g*   *f*   *d*b   *c*.
(upwards: change *a*b into *b*b). Note that this scale is not the same as the pentatonic chinese, which was built from the diatonic tetrachords.
As I said there is always an interaction among different cultures, which can result in the dominance of one system (as the actual european) and the gradual disapearence of other minoritary ones, or in the combination of multi-cultural elements forming new hybrid *tone-systems*. Chinese music was known to the japanese from 300 AC, and by the 9th century there was an intese activity of both chinese and indian musicians in Japan. The *Nõ* drama appeared in the during the fourteenth century, and when it latter became almost exclusively aristocratic (17th century) it gave origin to the more popular *Kabuki*.

This new theatrical form new instruments, notably the *Shamisen* (3-string guitar), which was introduced from the Loochoo Islands (where it was received earlier from China).

In the beginning of the <u>*Middle Ages*</u> all the greek modes were still in use. The prefered *genera* was the diatonic system of 7 clearly distinguishable tones per octave, which could be remembered without difficulty. The situation progresses so that at the end only the ionian (major) and the aeolian (minor) modes subsisted, becoming the basis of western tonal music.
In the medieval modal epoch, *tone-systems* had to be adapted both from the need to extend the musical communication systems (example: coordinating a large group or an orchestra) or for integrating social rituals (such as the medieval church music, agricultural festivities...), leading to the eventual formalization of some tone-structure (and to a specific *notation*).
Several limitations were inherent to the greek tunings, such as the *syntonic comma*. These limitations mainly arise when there is a necessity to change between modes instead of having all the music in a static one, as ancient greece, where the diferent clans (dorians, phrygians...) presumably produced music each in their own mode.
If four pythagorean fifths (3/2) are superposed (81/64), that should lead to a major third (and 2 octaves). But the just major third (5/4) is smaller than that interval, the difference being the *syntonic comma* (81/80). A mode implies a determined hierarchical system, sugests a certain mood, or color. Any tone can be the third or the fifth (when considering several modes simultaneously), so the *syntonic comma* is a real practical problem which can be clearly hear. A particular tone is only defined by the intervallic context where it is located, but the ancient tunings did not take that into account, they predefined a static pitch space: *modulation* between modes was impossible.
Any scale derived from the intervals of overtones (except the octave itself) will never reach a multiple of an octave in a finite number of steps. From Pythagoras up ot the 18th century many proeminent music theorists and men of science have investigated all kinds of tunings and *tone-systems* which would reduce this problem.

In the mid-<u>*XVIth century*</u> , Zarlino and Salinas have invented ingenious solutions using 2/7 , 1/3 and 1/4-commas. This improved the system but was not a final solution; in any case it lead to the study of small intervals for which new instruments were required: the cembalo of Zarlino or the archicembalo of Vicentino (taken in the 20th century by Fokker). Salinas had also developed a tuning with 24 tones per octave (the *instrumentum perfectum*) which came from the desire to include all greek genera at once (diatonic-chromatic-enharmonic).

The most practical solution finally came at the start of the <u>*XVIIIth Century*</u> with Werckmeister. By simpy dividing the octave in exactly 12 equal steps, we are no longer limited by a specific mode. This may sound simple, but the ancient practices were linked to a sense of the mystical, such as the greek harmony of the spheres. *Harmony* did not mean to them to superpose tones, but to find a balance which reflects the harmony of the world and the skies. In *equal-tempered* no interval (except the octave) is expressed as a simple ratio: all deviate from the “natural“ order. It was necessary to step out of the traditional usage of simple numbers in order to increase the freedom of that same system into unexplored dimensions. The *Well-Tempered Klavier* and the *Brandenburg Concertos* (Bach) are paradigmatic examples of the

resources of enharmonicity. It is ironic such an “unnatural“ tuning system is in fact the simplest way to *modulate*, that is, to make use of a large number of scales within the same tuning, when so many centuries had been spent in search of the “harmonic“ system which would optimize the problem.
By this time the major/minor modes dominated completely, so with the introduction of *equal temperament* it became possible to organize a much larger emotional space, based on distance between tonalities. Any tonality implies relatives (major/minor) to which is it easier to modulate because they are “closer“ (they share a large number of notes with the original tonality).

The whole *XIXth Century* was a transitional period where the classical order slowly mutated. Beethoven and Wagner were among those who participated in the emancipation of chromaticism. There was much taken from the past, because inside any particular tonality all the old diatonic relationships were still kept. However, sudden modulations to distant tonalities (example: augmented fourth - *diabolus in musica*) and their chromatic juxtaposition were used without many problems.

In the *XXth Century*, the hierarchical principles of tonality broke down, starting with Arnold Schoenberg, who finally gave all the 12 chromatic tones the same intrinsic value.
This certainly did not mean the end of modality, which found expression in Debussy (example: whole-tone scale) and later in Olivier Messiaen (*modes of limited transposition*). However, what heappened since Schoenberg was a complete fracture of a unified system and the birth of a plurality of individual languages. Continuity lost it’s power to discontinuous processes. For Ligeti, for example, all elements are discontinuous, it is from them that one creates *continuums*. Busoni had asked for the expansion of the tonal system to no less than 18 tones per octave, but the classical notions of pitch were by the 20th century obsolete in themselves (at least since invention of the Fourier Transform and the extraordinary work of Helmholtz). The union of music to science has been a major contemporary tendency, as envisioned by Varèse.

“Pitch“ perception extends much beyond the european tradition and has been conceptualized differently. The separation and complete independence of musical parameters is purely theoretical. Outside the european tradition pitch is perceived in a different way. Microintervals represent a bridge between pitch and timbre. Many music cultures have used them as timbral inflections. Europe has taken a long time to develop theories that allow, at last, the complete subdivision of the pitch space in any imaginable way. An infinitely rich pitch *continuum* was one of the dreams of Ivan Wyschnegradsky.
The ancient greeks have introduced decisive new conceptions of the acoustic phenomena;
One of the major contributions that the european tradition can offer to the universal art of music is a system of polyphonic transposable intervallic relationships, a *temperament*.
Equal-Temperament (using microintervals) generalize the specific meaning this word has adopted by tradition. This research is perceptive, it is not subjeted to a specific aesthetic, such as the serial, (although it expands enormously it’s combinatoric possibilities: If the normal chromatic scale allows 12! series, then dividing the octave

in steps of 1/3-tone will produce 18! series). The 20th century microtonal composers were faced with four main problems:
1.Traditional european instruments were not built for the purpose of playing microtones. This was solved by adapting current instruments, manufacturing new ones or simply by inventing new techniques for existing instruments. This problem was essential, because without instruments composers could not hear their musical ideas and concerts could not be given.
2. In traditional notation, the minimum pitch difference is 1 semitone.
The initial concern was to sugest new symbols which were as close as possible to the traditional ones. Another solution was to create completely new symbols, which are as simple and understandable as possible, so that no doubt remains about their musical meaning. This is absolutely justified for instance if the octave is divided in an extremely large number of tones. There will be many new sounds to notate. It is completely impractical to notate a cluster of 48 tones 1/12-tone apart by writing every single one, as in traditional notation.
3.Traditional harmony relies on the stable principles of consonance and uses the tempered chromatic scale at it's basis.
Here the problem is multiple. On one hand, important scientific results (from psycoacoustics, physics, and so on) can be used to reach a new conception of consonance, and a new conception of the relation between harmony and timbre. The theoretical works focus both on exploration of all new intervallic combinations (Hába) and the pure conceptual invention.
4. The most important is the composition of works which validate aesthetically the intelectual and perceptual research.

Concerning the the creation of new instruments, Harry Partch can be considered a paradigmatic case where technique is completely at the service of musical invention and aesthetics. The researches of Partch into just intonation were multiple, from only 1 tone per octave to the 43 of the *Chromelodeon* (a kind of organ).
Ivan Wyschnegradsky and Alois Hába have been particularly involved in the third problem, creating new music theories for possible new structurations of the pitch space. Julián Carrillo has dealt with the same problem but integrating much more the physical aspects of sound into a theory of harmony. Of course all of these composers were faced with the problems mentioned, but their motivations were quite diverse. For Hába, the quest is directly related to biography: he heard microintervals in folkloric songs from his country.
Wyschnegradsky has mentioned a mysterious mystical experience which led directly to the work *The Day of the Brahma* (1916).

I.1.2 – *Ivan Wyschnegradsky & Alois Hába*

From the darkness of the night of Existence,
The dawn appears.
It's the divine torch of Consciousness,
the Spirit which rises from eternal sleep,
to follow his predestined path,
And in a creative growth,
Creating worlds, irradiating life,
In the creation of the forms and the worlds,
To manifest itself always more plentifully :
And in the end, when the Circle of Being is closed,
in an eruptive awakening, in a perfect manifestation,
To know one-self, and one's path
From the darkness of Nothing into the light of Everything.

(Ivan Wyschnegradsky, approximate opening text from *The Day of Existence* , 1916-1939, for reciter, large orchestra and mixed choir *ad libitum*)
Considered by Wyschnegradsky as his most important work, this piece first appeared under the name *The Day of the Brahma*, connected to a mystical experience which would influence Wyschnegradsky for the rest of his life. This is the work that oppened his way to microtonality: It is both his last half-tone piece and also the first deeper exploration into the *pansonic continuum* (especially the end part), thus it contains all the potentiality of his latter music. The voice (word) represents Comprehension, the music represents Emotion. In the nothingness between the tones, Wyschnegradsky arrived at a conceptual plenitude of sound, in a fluid and continuous state, which can be organized by the *principle of spatiality*.
The Day of Existence was played for the first time in 1978, Wyschnegradsky was then around the age of 85, and died the next year.

With Wyschnegradsky, a radical new conception of musical space is born. This idea remained his main orientation in life. Not a space given *a priori*, but one which has to be created, fabricated, invented. Physical space is simply the space where we heappen to hear the music. It cannot be reduced to musical space. In music (as other fields) we use spatial concepts as intuitions: (*high* and *low* tones, *intervals* meaning distances...).
No musical perception can ever occur without perceiving that which appears in a certain time and a certain space. Musical time has more similarity to physical time than musical space to the physical one. Musical time modulates the perception of physical time (thus qualitatively different from it), but both reamain a single dimension, experienced at different scales (rhythm of events, rhythm of sections, rhythm as form).
Musical space, on the contrary, has a multitude of *simultaneous* dimensions, the actual number being only limited by imagination. Time is thus able to *unite music to life*, as Wyschnegradsky puts it, precisely because it gives life to all the ideas from the domain of pure fantasy.
The absolute simultaneity of space leads us to the concept of *pansonority*. (All Sounding). This means the simultaneous sound *continuum*. In pitch spaces it represents an infinite number of sounds at infinitely small distances, and unlimited by low or high boundaries: a special *chord*. All this becomes extremely concrete by the *principle of spatiality*, which is a scheme of though to act on material, an organizing principle. (Varèse also gave superior importance to music as organized sound).
The interior space *is* the place for musical compostion, as ideas crystalize into sound or some representation (*notation*) according to the principle or scheme of *spatiality*.
Wyschnegradsky moved towards a *Spatial Plenitude*, a tendency which, for him, was visible in the pythagorean *music of the spheres* or the *musica mundana* (Boetius). The

evolution of musical language has taken Wyschnegradsky to a quite important point: sound becomes a function of space.

The *principle of spatiality* is specifically active in melody, harmony, poliphony and the actual instruments, as well as the divison of all sonic parameters. Theoretically, it develops from the old greek problematics of *continuity* / *discontinuity*, *movement* as well as from the greek questions on divisibility. Certainly this spatial scheme should be as close as possible to what it produces.
In practice, Wyschnegradsky has left Russia to be able to build and play a microtonal piano, and has even invented the term *Empirical Music* to explicit the experimental nature of his work. All the practical work is based on strong theoretical principles, as the notion of space in Wyschnegradsky extends to all dimensions: Research - Representation – Technique – Composition.
The *absolute sonic continuum* is a non-structured initial plane, from which the *principle of spatiality* creates all representations (structures). As no fixed representation pre-exists, one could think of a completely fluid mobilty, and apply the principle to all audible sounds and their temporal relationships. This constitutes the basis of *ultrachromaticism*.

The absolute potentiality of sonic relationships (intervals) without the need for any hierarchy (such as tonality), giving life to all imaginable spatial *continuums* is the *pure material*. The non-existence of pre-existing representations implies *pure functions* which are not pre-established. *Ultrachromaticism* is thus the structuration of pitch spaces using *pure functions* on *pure materials*. The principle of spatiality is also a principle of division, but there is no point to divide indefinitely, the human hearing has certain limits for pitch perception. The point is to open perceptual spaces which were unkown to our ears, to reveal their vibratory intensity.

The methods of *ultrachromaticism* are mathematical. One divides sucessively certain pitch relationships (the octave, for example) and classifies particular arragements in function of their regularity. Many specific schemes have been identified and studied in detail. (Regular, Irregular, Semi-Regular, Non-Octavian, see below...)
Wyschnegradsky has spoken of a *systematization of topological spaces of relationships*.
To classify these new spaces, Wyschnegradsky defines *density*, *total cycles of intervals*, *volume* and *specific intervals*.
Density refers to the number of divisions of the octave. A 1/2-tone space divides the octave in 12 equally spaced notes and so it has a density of 12. A division in 1/4 tones has 24 notes to the octave, and thus a density of 24. In one octave there are 4 minor thirds (3 semitones each). If we divide each of these thirds in 11 steps each we obtain a space of density 44 (11 x 4).
Choosing a certain division one obtains intervals, which can be used to generate orbits (always superposing the interval to itself).
Total cycles of intervals are series of notes obtained in this manner until the orbit reaches the inital note and the process restarts.
The *Volume* is the number of octaves travelled to complete the cycle.
For instance, one major second cycle has a volume of 1 octave (and a density of 6) while a minor seventh cycle has a volume of 7 octaves (but the same density).

Each smaller division has intervals which are not shared with larger ones. These intervals are called *specific intervals*. The interval-cycle generated by such intervals contains all the possible notes in the subdivision, and not simply a part.
What this means, for example, is that a division of the octave into 24 steps of 1/4 tone has some interval-cycles which generate the 1/2-tone scale, but also some which are specific to that particular division.
There are 8 interval-cycles specific to 1/4-tone (density 24) :

Scale	***Density***	***Nº Specific Interval-Cycles***
1/2-Tone	12	4
1/3-Tone	18	6
1/4-Tone	24	8
1/6-Tone	36	12
1/12-Tone	72	24

The cycles of fifths and fouths are central to classical theory. They generate all 12 notes of the chromatic scale without repetition, and have been used extensively for tonal modulations. They are specific interval-cycles, just as the minor second (which generates all 12 notes in a volume of 1 octave), and the major seventh (which takes 7 octaves to complete the cycle). It is interesting to note that in the 1/12-tone system (72 notes per octave), all the specific intervals are 1/12-tone alterations of the intervals in present in the half-tone scale.

For Wyschnegradsky the diatonic scale has no privelige whatsoever, although it was many times justified by theorists and composers, especially when explaining the first harmonics. But some micotonal systems integrate small harmonics much better than the tempered half-tone scale:
A 1/4-tone division integrates the 11th harmonic, because 11/8 is close to 2^(11/24).
A 1/6 tone division integrates the 7th (and also the 13th) harmonics, because 7/4 is close to 2^(29/36).
A 1/12 tone division integrates the 5th harmonic, because 5/4 is close to 2^(23/72)

Wyschnegradsky himself (in *Law of Pansonority*) asks us to give up the notion of scale for that of space, even though they are quite similar. Scales relate to traditional theory as spaces to *ultrachromaticism*. Diferent spaces are *continuums* of different sizes.
If the distance between the tones is constant, the space is *Regular*, otherwise the space is *Irregular*. Even in spaces which are *Irregular*, some internal order may be in action, and in such cases they are called *Semi-Regular* (for example a pattern of two different intervals which repeats). *Semi-Regular* spaces as thus *periodic* spaces.
Ultrachromaticism is based mostly on *Regular* spaces, but in any case, all these *continuums* find no representation in traditional theory and thus require the creation of new symbols:

FIG 3: Ivan Wyschnegradsky, *Notation of continuums*
These half-moon shaped objects had also different colors. One can see that the inner density of such shapes is decreasing from left to right. Compare the simplicity of the half-moons to the the work it would take to write all intermediary tones in traditional notation. Add 72 steps of 1/12-tone and you will reach the octave. But taking the interval 7/12-tone it will take you 10+2/7 steps, hence the fractional density.

One of the inventions of Wyschnegradsky which makes him extremely original is the concept of *Non-Octavian* spaces. In such *continuums* one makes use of reduced octaves (7ths) or extend octaves (9ths). All transpositions and modulations will be made having these intervals as reference, and not the octave.
For example, we can reduce one octave (6 whole tones) by steps of 1/12-tones until a major seventh is reached, or expand it using 1/12-tones until a minor ninth:
Reduction of the octave : { 6 - 1/12 , 6 – 2/12 , ... , 6 - 6/12 }
Expansion of the octave : { 6 + 1/12, 6 + 2/12 , ... , 6 + 6/12 }
The regular space of 1/12-tone has a density of 72 to the octave. If the same space is reduced to a major seventh, the result is 66 steps (divided into 33+33, 22+22+22...). The 7th+1/12 is divided in 67 steps, the 7th+2/12 in 68 steps, and so on until the 72 steps of the octave.
An interesting consequence is that Non-Octavian spaces will have a *fractional density*.
The octave can never be divided into an integer number of such intervals. The fractional value is obtained dividing the total number of tones in the interval-cycle by the volume (number of octaves until that cycle is complete). In the 7/12-tone space, the total number of tones is 72, while the volume is 7 octaves. The density is thus 72/7, or 10 + 2/7, as shown in Fig 2. If we extend our initial definition of density to allow the “octave“ be contracted or expanded, then we can say that the space of 7/12-tone has *relatve* density 12, although the absolute density is still fractional.

The above mentioned spaces (regular, irregular...) are specific, they reveal some level of division of the total pansonic continuum. The difference between space and continuum in Wyschnegradsky is very subtle. An extremely rarified continuum may degenerate into a chord, in an extreme case, a chord of octaves. A specific space maintains it’s identity even if it is “empty“. Perhaps *space* is meant more as a scheme of thought, and *continuum* as the concrete result of the principle of spatialization (division) of the material.

Wyschnegradsky has analysed the affinities and connections between continuums. This analysis brought him to rules, from the point of view of densities and volumes. Several connections between continuums are conceivable, especially if they share a common property. For example, two continuums can have the same density and diferent volume or vice-versa. They can also share the same number of notes for a complete interval-cycle. By contracting a continuum with a large number of notes into a smaller one we use what can be refered to as *negative melodies*. This means we remove notes from the original continuum to arrive at the new one. Since the outer notes of a continuum are more perceptually relevant, by sucessively removing one note at a time in the lower (or upper) part, we create a *negative* sucession always decreasing in volume. *Condensation* and *rarefaction* are simple ways of linking continuums. A space of 12 notes in half-tones can be condensated to one of 24 in 1/4-tones. Other more complex methods are also possible.

Ultrachromaticism is a general method, applicable not only to pitch spaces but also to rhythm (temporal equal temperament), intensity and timbre. A virtually infinite number of structures can be created. An irregular continuum of timbre (for example, each note of a chord is played by a different intrument) can be combined with a regular rhythmic continuum in a non-octavian space.

The notation of continuums is open to pure ingenuity, since no standard is in common practice. For continuums in pitch and rhythm, the standard notational symbols were mostly kept but extended and adapted. Wyschnegradsky is interested in the transformation of traditional symbols as a part of the general transformation of musical language. The notation of timbres is a difficult subject. While the three parmeters of pitch, rhythm and intensity have an associated gradation (a scale which can be clearly identified), timbres are essentially qualitative, apparently impossible to reduce to a single quantitative dimension. Wyschnegradsky proposes to keep traditional notation and have all the timbres separate as different "instruments", just as in a score for an instrumental ensemble, but refering here to the whole audible *pansonic continuum*.

The notation only serves the purpose of transcribing ideas, but in an actual piano, for example, there was no possibility to hear the micro-intervals using only the keys. From the colaboration of Wyschnegradsky with Alois Hába a particular kind of piano was born. Wyschnegradsky's idea was to extend the keyboard, having two sets of strings at a quarter tone distance. Latter in his life he would compose even a piano with 3 keyboards and 3 sets of stings. In this extremely peculiar instrument (it only existed in his own private house) the 3 sets were so close toghether that an incredible resonance could be heard. (There are some radio interviews where Wyschnegradsky plays his instrument).
In practice it was almost impossible to find such a piano for a concert, and in fact the concerts with music by Wyschnegradsky have unfortunately been very sporadic. After many dificulties, he finally defined a principle which would be applied in all the latter work: Instead of building a new piano it is better to use several normal pianos tuned at the necessary distance. For 1/4-tone systems, use 2 pianos 1/4-tone apart, for 1/6-tone systems, use 3 pianos at a distance of 1/6-tone from each other...
Following Wyschnegradsky's principle, we need 6 pianos to use 1/12-tone systems.
The ascending accidentals in that system are notated as:

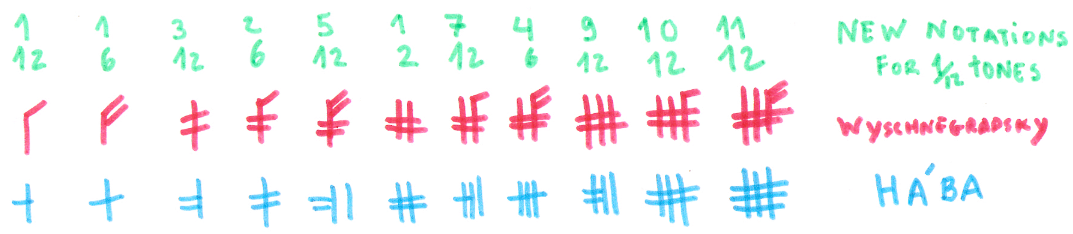


FIG 4: Ivan Wyschnegradsky / Alois Hába , *Invented notations for 1/12 tones ascending accidentals* Clearly both composers were trying to develop new notations from traditional ones. In the case of Wyschnegradsky one can notice the association with rhythm: larger alterations get smaller "rythmical" labels, in a cyclic fashion. Both propose the same new symbol, but for different alterations (9/12 & 10/12).

It should be clear that the system of Wyschnegrasky is not serial. He was also not fond of any particular *avant-garde*... Basically what he and Alois Hába did was simply to *systematize something that was on the air but nobody had done it*.

Hába was a major figure in microtonality of the early 20th century both as theoretician, composer and pedagogue. His openness led him to amplify the postulates of the previous czech theoreticians Skuhersky, Stecker and Novák. His main axiom was: *Any sound can be combined with any other sound from any other system. Any chord of two or more sounds can be combined with any other chord from any other system.*
His aproach is based on the old greek tetrachords, but applied to small intervals. Harmony is not treated functionally, but in two separate dimensions: As a single simultaneity (chords & clusters) and as the result of parallel modes in different ranges (polytonality & polymodality). Each division (1/4-tone scale, for example), is treated as a referential set from which subgroups can be extracted. These subgroups can latter be treated as modes (which means that they are not an exact transposition), and superposed to created chords. His book *New Treatise of Harmony* is a vast collection of all the possible combinations of the divisions in 1/2, 1/3, 1/4, 1/6 and 1/12-tones according to the principles just mentioned. Hába could already hear the 1/4 and 1/6-tones in traditional Moravian songs (which would have a long lasting influence on him), so he tried to open the compositional world to this existing but unexplored possibilities. In 1921 he presented at Donaueschingen a string quartet in quarter-tones, and finished in 1929 his full quarter-tone opera *Mother*. Hába met Wyschnegradsky in Germany(1922). Latter both would be in conctact with Julián Carrillo, the other main herald of microtonality.

Traditional spirits are unable to hear new music with new ears (Ivan Wyschnegradsky)

I.1.3 – *Julián Carrillo*

Julián Carrillo (1875-1965) was an absolute pioneer in microtonality. In him we find an instinct for the logical and the scientific, linked to an extraordinary sense of hearing.
Just as Stockhausen has mentioned the fact of *dreaming* pieces of music, Carrillo has spoken of dreaming a scale of 400 tones.
Although he, as Wyschnegradsky, were interested in escaping from the traditional way of hearing and dealing with pitches (by allowing all pitches to become musical), their motivations differ considerably. While Wyschnegradsky was highly mystical and philosophical, the *pansonic continuum* being a kind of transcendental existence without limits giving life to all sounds, Carrillo was inspired mainly by physical and perceptual experiences.

One of his main thesis, *Music as a system of culture, not a system of nature*, shows the actuality of his thought. While working at New York University in 1947 he discovered something that would get him nominated for the nobel prize in physics (1950).
Being a violinist, he was interested in the production of harmonics by divisions a string.
By placing the fingers on certain *nodes* (physical points without variation of pressure) it is possible to produce certain harmonics. But the node is physical, not mathematical.
In an ideal string the wavelength is much much larger than the thickness of the string. The mechanical impedance raises the overtones from the ideal mathematical case. Note also that if the node is below halfway, the frequency of the bowed part will be more than twice the frequency of its base note. Other physical factors are also relevant. Although he did not win the prize, his work completely reformulated the node law. The most important is the fact that Carrillo searched for a new scientific result because he *heard* things which were not compatible with the node law coming from 2000 year old Pythagoras:

$$f = \frac{n}{2L} \$ \sqrt{\frac{T}{m}}$$

FIG 5: Pythagoras, *Calculaion of the vibration frequeniy of a string*
Using only his ears, Julián Carrillo detected that the first harmonic of his violin sound was higher than the formula of pythagoras which had remained unchallenged. This discovery represents one of the movements towards the musical integration of the infinity in pitch, and the rejection of traditional music theory.

where f = frequency, L = length of the string, T= tension of the string, μ = mass per unit length. n = the number of the harmonic.

This scientific research came also after a long musical process which originated with the discovery of the *Sonido 13* (13th Sound). The first discoveries date back to 1985, while experimenting in the low G string of a violin. By moving a razor beween tones low G and A, Carrillo became enthusiastic: *Muchos sonidos!* (Many sounds!). He was hearing intervals as small as 1/16-tone. The name *Sonido 13* became a symbol for this

microtonal acoustic awareness, a true revolution in terms of sonic perception. The number 13 is only symbolic, representing a number larger than the octave, and in fact Carrillo has reached even 96 subdivision of the octave, from the earlier experiments of *Sonata casi Fantasía* (1925) to *Fantasía Sonido 13* (1930), for complete orchestra in 1/4, 1/8 and 1/16-tones, and many others.
The rejection of some pythagorean principles is coherent with the use of equal-temperament. Carrillo, as Xenakis, or Wyschnegradsky, envisioned a generalization of the use of temperament itself. This means any equipartition of any reference interval (usually the octave). The smallest step in an equipartition of the interval M in N parts corresponds the Nth root of M: $(\sqrt[N]{M})^{Step}$. (Step = nº of unitary steps)
This knowledge alone already allows the analysis of the Non-Octavian spaces of Wyschnegradsky or the frequency organization in *Studie II* (1954), by Stockhausen.

For string instruments it was possible to give instructions both for the performance and for the composition using microtones. Carrillo established several general "principles". In a group of string instruments, it is easier to produce microtones with the low ones. If only one string instrument is available, use the lowest strings using the lowest finger positions.
Other instruments require small adaptations, and Carrillo has been involved enhancing the microtonal possibilities of flutes, trumpets, trombones, guitars, mandolins, violins... He also constructed several microtonal zithers and invented his own harp-zither.
The piano is an important example of the practicality of the mexican composer.
Wyschnegradsky and Hába had constructed a piano with a special keyboard, adapted to the microtonal necessities. The problems to build the instrument and to difficulty to find people who could play it was a real drawback to the expansion of live microtonal music.
Wyschnegradsky had eventually solved the problem by always employing at least two pianos and a general principle.
Julián Carrillo took the exactly oposite approach to Wyschnegradsky and Hába. For him, one should not change the keyboad, which is customized to the hand, but change the tuning of the strings themselves. He thus constructed and patented 15 *metamorphic pianos*, each one tuned differently from whole-tone to 1/16-tone (In 1958, at the Brussels World Fair, the pianos won a gold medal). The ambitus of the piano becomes, of course, a function of the specific octave subdivision used. In quarter tones we have half the ambitus of the normal diatonic scale.
The problem for Carrillo was thus notational. The player *reads* something which if written in traditional notation *sounds* completely different.
Apparently it was not so difficult to adapt to this system, but Carrillo also devised new notations for the pitch parameter which were simpler and did not require many years of academic training.

In his method for notating pitch, spatial verticality is not abandoned, but two factors are considered: *Lines and Numbers*.

Lines represent octaves, *Numbers* are used for the total number of tones available within one octave, and notated (0, n-1).

Assuming the existence of two octaves, the numbers can cross the line (lower octave), or be above the line (higher octave). 7 octaves are contained in three lines and four spaces.

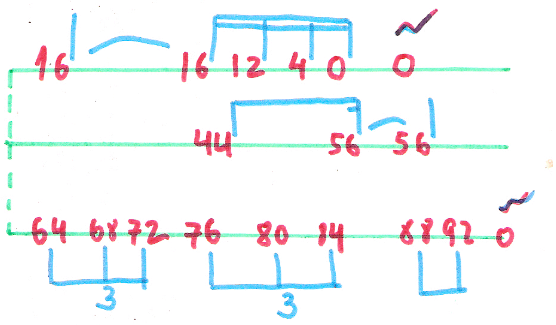


FIG 6: Julián Carrillo, *invented pitch notation for music in 1/16 of tone*
Carrillo's idea of notating pitches as numbers pre-dates the invention of midi (0-127), as well as all other numerical representations in electronic music.

Another innovation refers to the measurement of time. The meaning of the time signature is changed, by lack of precision. The numerator rather indicate durations (is seconds), and the denominators refer to the number of aliquot parts which divide the duration.

Contrary to Hába, who was extremely interested in the modal combinatorics, Carrillo exploits temperament in still quite unexplored ways. The *metamorphic pianos* give the opportunity to *modulate the temperament*, exposing their full potential. This modulation occurs from the piece *Concertino* (1948), for 1/3-tone piano and orchestra.

The distance between two sounds represents an emptiness. The *Sonido 13* symbolizes the search for this space inbetween the tones, for an unlimited number of possible chords.
After the death of Carrillo two of his students have realized the dream of a music for 400 tones per octave: *Cromometrofonia No.1* and *Cometa*, 1973, for harmonic harps, are intensive perceptual experiences where the ear is presented with extremely subtle micro variations of pitch in time.

I.1.4 – *Harry Partch, Ratios & Consonance*

The important for Harry Partch was to emotionally capture an ancient and primitive tradition. This implied the participation of music, dance and drama. The maximization of the power of theatre to add meaning to life leads Partch to make use of all possible elements which might enrich the drama. In most of his works, the human voice is essential (speech included). He was close to Wagner in the vision of an autonomous drama (see Apendix 2):

I declare aloud that the error in the art genre of Opera consists herein: that a Means of expression (Music), has been made the end, while the End of expression (Drama), has been made a means.
(Richard Wagner, *Prose Works* , as quoted by Harry Partch in *Genesis of a Music)*

Partch was thus not favourable of a "purist" view of music, represented to him by the *abstract* tradition of Bach and Schoenberg (although the *Pierrot Lunaire* is considered an exeption). The suspicion in relation to that tradition led him to build completely new instruments, to adapt old ones, to make use of scales and intervals not in current fashion and, most importantly, to create his own alternative conception of *corporeal* music.
It is precisely the spatio-corporeal element what liberates a musician (usually thaught in the *abstract* tradition) into a magical dancer-performer-musician-reciter.

The second principle of thermodynamics is similar to one of Partch's main concepts.
The scientific principle states that entropy is constantly increasing. Partch's concept states that the evolution of musical intervals has *progressed from the unison in the direction of the great infinitude of dissonance*.
What distinguishes Partch from Wyschnegradsky or Hába is this theory on consonance, expanding from musical ideas on ratios. He is not far from Julián Carrillo in the use of overtones, but just intonation would become, in Partch's case, the basis of his harmonic language. The fundamental principle for Partch is that intervals expressed by small number ratios are more consonant. The *Chromelodeon II* is a reed organ of 88 keys where the central part is tuned using small number ratios excluding unissons and octaves. It was built from the musical need of constant tones, not simply to test the scale (43-tones/ octave). Microtonal spaces of 43 tones per octave are found in at least two of Partch's organs and many other instruments contain the implications of that number and more. This is certainly not the only scale he used : In *Castor & Pollux* (1952), the octave contains 19 tones. The instruments built by Harry Partch are so original that it is at least worthwhile to mention the different types: Percussion (Marimba, Bamboo, Metal, Glass, Bells), Strings (Adapted viola & guitar, Kitharas, Harmonic Canons), Reed Organs and Small Hand Instruments.
Partch has chosen for his *Monophonic* system the 11-limit. (In general, an x-limit system is a tone-system where the highest admissible prime number in the ratio is x). The many scales concretized as musical instruments are thus, in Partch's case, build of units such as 11/9 , 11/7 or 20/11.
The major triad can be obtained from the harmonics 4-5-6. In the same manner, the minor triad can be obtained with subharmonics 4-5-6. Harry Partch has extended the major and minor concepts in *Otonality* (ratios with common denominator) and *Utonality* (common numerator), respectively. *Otonalties* rise in pitch by increasing the numerator, *Otonalities* by decreasing the denominator. When these ratios are

restricted to the 11-limit system we get the *Expanded Tonality Diamond*, a basic resource in Partch's monophonic system:

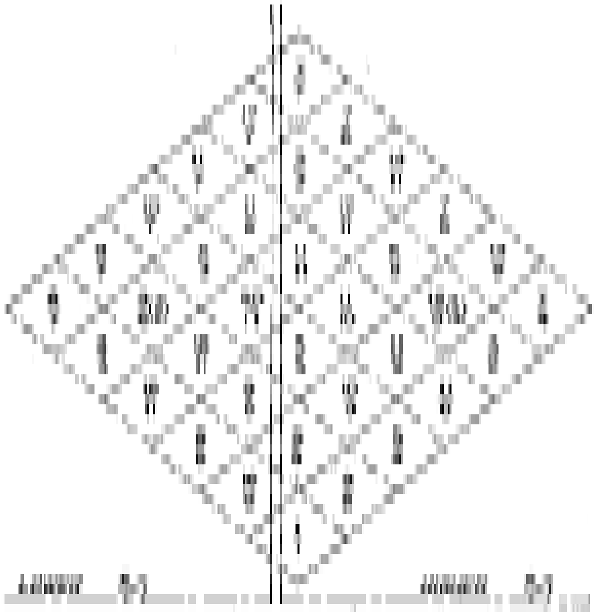


FIG 7: Harry Partch, *The Expanded Tonality Diamond*
The *11-limit tonality diamond* represents intervals of maximum consonance. 90º diagonals keep the denominator identity (the lower otonality is 1/1 – 9/8 – 5/4 – 11/8 – 3/2 – 7/4). –90º diagonals keep the numerator identity (the lower utonality is : 8/7 - 4/3 - 16/11 - 8/5 - 16/9 – 1/1).

The system is not able to modulate, nor capable of parallel transpositions. It is incompatible with the tempered system, but one could speculate it is probably better, at least for music which is simpler harmonically: each of the intervals is unique and relevant. In the tonality diamond above we can see 6 *Otonalities* and 6 *Utonalities* (based on 1-3-5-7-9-11). They constitute the most consonant intervals in the 11-limit system, or in other words the ones which give the strongest sense of tonality (centered in 1/1). In the 5-limit system the otonality is a major chord, and utonality a minor one. As the limit increases, more and intervals are added to the existing ones, filling the empty picth space. Considering only Otonalities, starting from the 27-limit we encounter intervals close to 1/3-tones. A 36-limit Otonality will divide the octave in 18 tones using intervals in the area between quarter-tones and half-tones:

$$\left\{1, \frac{33}{32}, \frac{17}{16}, \frac{35}{32}, \frac{9}{8}, \frac{19}{16}, \frac{5}{4}, \frac{21}{16}, \frac{11}{8}, \frac{23}{16}, \frac{3}{2}, \frac{25}{16}, \frac{13}{8}, \frac{27}{16}, \frac{7}{4}, \frac{29}{16}, \frac{15}{8}, \frac{31}{16}\right\}$$

This is the first of several Otonalities (chords) of maximum consonance which use intervals smaller than 1/4-tones, obtained using the *monophonic* system. Harry Partch, however, didn't need to go to the 36-limit to compose with microtones. The gaps given in the 11-limit (7/6 – 6/5, for instance) can be filled with a multiple of a number in that limit (3 x 9 = 27, for instance, in 32/27 , then 7/6 < 32/27 < 6/5).

The composer Clarence Barlow has extended Partch's principle : one should account not only for the smallness of the number involved in the ratio but also for it's divisibility.

This is supported by the fact that during western music history the numbers 8 and 9 were always preferd to the smaller 7 in the creation of intervals. 8 and 9 involve less prime factors than 7, which means they create intervals potentially more "consonant". While this is certainly a relevant expansion, the concept of pitch itself is changed:
It's possible to say that pitch perception occurs in at least three ways, considering the development of psychoacoustics. The intervallic hearing of ratios is the active field of tonality. This kind of pitch perception is usually divided in chroma and position, by allowing equivalences at the octave. The chroma represents the circle of tones (colors), in which the octave is divided. The position expresses the octave in which the tone occurs.
But the ear itself has a certain limit to the perception of pitches, which is not linear thought the frequency area. If two sine waves are closer than the critical band (they activate the same part of the basilar membrane), they are not perceived separately, but as one sound. One could also take a noise band and a sine wave and progressively reduce the bandiwidth until the noise did not mask the sine any longer. That would correspond to the critical band. The point of all this is that there is at least another dimension to pitch in which abstract ratios physically interact, giving rise to roughness and changes in the timbral perception. Note also that the perception of speech does not depend on intervallic hearing, but on the correct recognition of formants and language intonations. We still perceive, however, if a voice is "low" or "high".

Consonance has thus to be considered in at least two different fields: In an intervallic sense, small and highly divisible numbers will produce the highest perceptual "affinity".
In a timbral sense (when each note of the intervall is given a real spectrum), the actual roughness comes if the sound contains partials which lie inside the same critical band. Noise has many frequencies close together which cannot be distinguished individually, only statistically. Just as music theory has searched for consonant intervals, the actual practice has developed instruments whose spectrum is harmonic. In harmonic spectra the intervals will decrease in size with frequency, so at the low frequencies (smaller critical bands) the intervals will be larger and at the high frequencies (larger critical bands), the intervals will be smaller.

Imagine that you play a major third between A (440 Hz) and the C# above (554 Hz). The distance between the fundamentals is 114 Hz, larger than the critical bandwidth in this area which is around 100 Hz. At least these two highly energetic frequencies will be clearly distinguished. Compare this to playing a perfect fifth in the lowest octave of the piano: The distance of A (27.5 Hz) and E (41.2 Hz) is 13.7Hz, much smaller than the minimum 100 Hz necessary to individually percieve any two frequencies. This process could be extended to higher piano harmonics. The low fifth will sound much more dissonant than the major third, showing that consonance is not simply a consequence of the ratios composing an interval.

This is valuable knowledge for composers interested in microtonal spaces. Each frequency area implies a different response to small intervals from the part of the ear.

The dissonance is maximum at about 1/4 of the critical bandwidth. In terms of microtones this can be seen in:

MAXIMUM DISSONANCE INTERVAL
(≈ 1/4 CRITICAL BAND)

OCTAVE	1	2	3	4	5	6	7
1/2 - TONES (12/OCTAVE)	11	6	4	2	1	1	1
1/4 - TONES (24/OCTAVE)	22	13	7	4	2	2	2
1/3 - TONES (18/OCTAVE)	17	10	5	3	2	2	2

FIG 8: Maximum Dissonance Intervals
A low A (27.5 Hz) of the piano is taken as a reference for the calculation of the most dissonant intervals in all 7 octaves in terms of different microtones. We can see that in the three higher octaves of a piano, the minor second (1 semitone) is close to 1/4 of the critical bandwidth, while in the low tones this takes an interval of almost an octave.

I.1.5 – *Microtonal Spaces & Electronic Music*

Electronic music been able to question tradition in many essential aspects.
One of them certainly relates to the sonic *continuum*. On one hand, it became possible to extend the microtones to the limits of audibility but, most important, the concept of pitch itself has opened to new significations. The technological nature of electronic music has been linked to the scientific study of sound like no other music of the european tradition.
No longer musical parameters are exclusive and separate, and pitch is no exeption.
Missing fundamentals, pure tones, multiple tone sensation *(inharmonic sounds)*, unpitched sounds and so on and been extensively explored in electronic music.
The phenomenon of beatings is a revealing example.
While largely ignored by traditional music theory (and even avoided in a quest for *consonance*), it has been studied by physics. Technological devices have appeared in which this parameter can be controlled with precision and musicality.
The whole world of discoveries from human hearing such as the bark scale has definetively shown the deficiency of pitch class reductions and other theoretical devices.
Not only a fifth remains it's character even if it is slightly of tune with the harmonic (3/2), but a fifth in the lowest octave of a piano sounds *more dissonant* than a third in the middle, precisely because there the *critical band* is much smaller, and so the notes (although a fifth apart) create a sensation of roughness.
One can now change continuously from the pitch area to other areas of perception, such as noise. Noise is part of the sonic *continuum*. This is a *qualitative* continuum, is has ceassed to be countable. The spectral envelope has enormous influence on the perception of pitch. Risset has proposed the distinction between tonal and spectral pitch.
Phonetics and the general study of the voice has had an enormous influence in contemporary music and particularly in electronic music. The formants (peaks of the spectral envelope) come from the study of the voice but have been sucessively been applied to the study of many musical instruments. These resonances, or colors, are present in traditional music theory only as commentaries of treatesis on orchestration, and completely outside any formalized pitch theory.
Although mutated and transformed, *pitch* remains a fundamental aspect of human hearing, essentially a spatial intuition of ordering things in high / low scheme.
Stockhausen is one of the first ones to make use of a tempered division of the octave using electronic sounds. In *Studie II* (1954), the octave is divided in 25 equal steps while *Gesang der Jünglinge* uses 60 tones per octave. *Gesang der Jünglinge* (1955-56) was also one of the first pieces to include actual spatialization as a compositional element.
John Cage with Lejaren Hiller, in *HPSCHD* (1967-69) for harpsichord and computers used scales up to 56 sounds.
Xenakis, by nature mathematically oriented has done his own formalization of pitch spaces using the concept of *sieves*. In *Pleîades* (1979), the metallophones are set in an 19-tone scale using irregular steps of 1/3-tone and 1/4-tone.
The *sieve* formulation, however, is not so far away from the *modes of limited transposition* of Olivier Messiaen or from the *ultrachromaticism* invented by Wyschnegradsky. The notion of continuum in Xenakis is obviously as important as the other composers, as so many of his works explore glissandos in pitch space.

Many of this are controlled by statistical methods, representing temperatures, densities, ...
The *UPIC* system allows direct visual control of frequencies (almost as a sonogram), so Xenakis explored the pitch continuum also from a spectral point of view.
Jonathan Harvey, in *Mortuos Plango, Vivos Voco* (1980) has used a tuning derived directly from the fourier analysis of a bell. This is envisioned in the *Traité des objets musicaux* of Pierre Schaeffer where the sound of a gong is “reduced“ to a piano chord.
George Benjamin, in *Antara* (1987), uses computer microtonal transformations of a pan-flute to create sample sounds which are controlled live by two synthesizer keyboards, interacting with other instrumental players.
Kaija Saariaho has integrated the computer both in structure manipulation as well as sound analysis and synthesis. With the software *Iana* she is able to extract the “most perceptual“ partials from recorded sounds using the principles of *Terhard Analysis*.
The composer Clarence Barlow has been engaged both in computer music as well as the theoretical research of musical ratios and microtones. *OTOdeBLU* (1990) explores 17-tones for two player pianos. Barlow has explored modal scales containing microtones as well as a kind of “fourier synthesis“ of phonetic timbres realized in an instrumental score (*Im Januar am Nil* 1984). This piece, however, does not take into account individual spectra of the instruments (only fundamentals), in resynthesizing the phonetic elements. This surely functions against the musical intentions of this composition.
The french composer Pascale Criton represents an extremely valid development in the conception of *ultrachomaticism*. In *La ritournelle et le galop* (1996), written for guitar tuned in 1/16 of a tone, microtonality helps to reveal a new sonic world, where micro inflections give unsuspected possibilities to timbral and pitch control on the guitar. She has also used the micro-intervallic pianos of Carrillo, conceived to modulate from one temperament to another while keeping the richness of the acoustic sound.
Parallel to her compositions, she has developped musical applications of *Phase Spaces,* which allow both morphological analysis as well as sound synthesis. These spaces have been usefull to analyse multiphonic sounds as produced by wind instruments, for instance. The poetics of *ultrachormaticism* found new paths in contmeporary music because of it’s openness to integrate new discriptions of the reality of sound and because of it’s rejection of *a priori* axioms. Perhaps the full potential of the *pansonic continuum* will be revealed in the future electronic music.

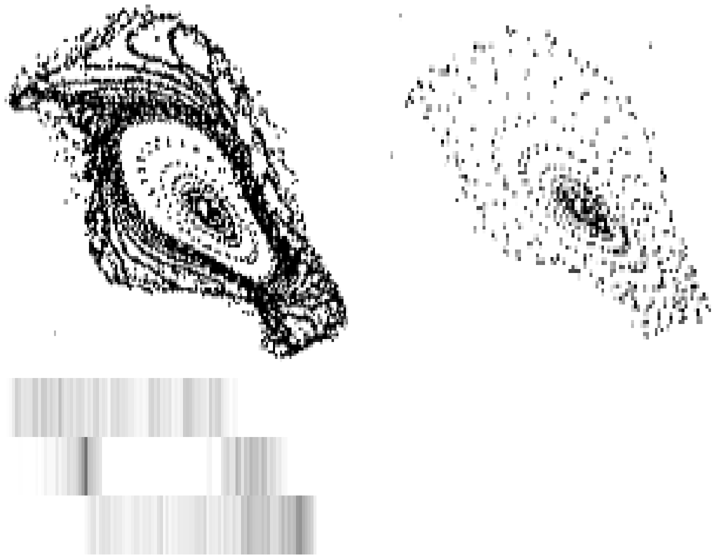


FIG 9: Pascale Criton, *3-dimentional Phase-Space representations of a Saxophone transient*
Phase Spaces conceptually originate in mathematics and physics. Here they show the mobility of energy in a saxophone signal, trajectories representing a morphological sonic space in continuous transformation.

I.2 – MUSIQUE CONCRÈTE

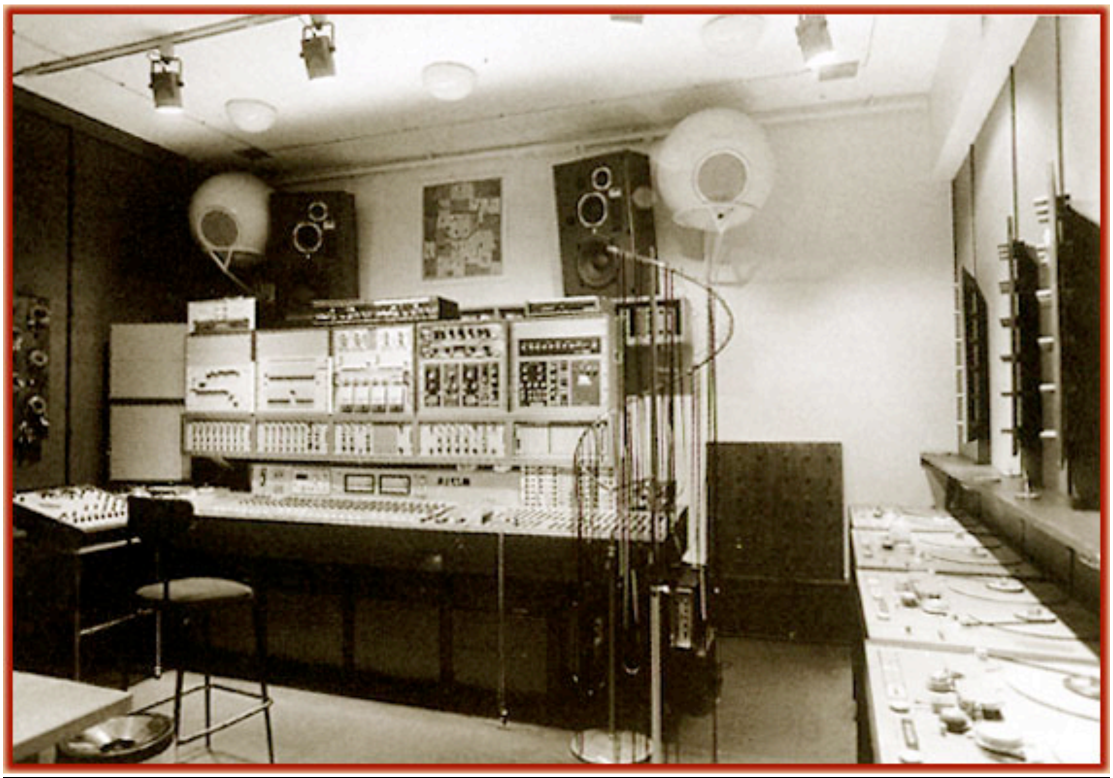


FIG 10: The French Studio for Musique Concrète in Paris

I.2.1 – *Pierre Schaeffer and the Traité des Objects Musicaux*

If *Concrete Poetry* was from the beginning an international movement, we cannot say the same about *Musique Concrète*, which started as phenomenon completely localized in the Paris Radio under the direction of Pierre Schaeffer (1948).
It's theoretical/aesthetical basis can be found in the *Traité des Objects Musicaux* (1966), from Schaeffer himself.
One of the revolutions of sonic concretism, the invention of the *microphone* (for instance, the one by Thomas Edison in 1876) was explored by many sound poets, as John Cage or Henri Chopin. The microphone in itself as a musical instrument was taken to a very high artistic degree for the first time in *Microphonie I* (1964-65), by Stockhausen.

It was, however, with Pierre Scheffer that musical concretism has gained it's monumental historical/aesthetical importance in the development of 20th century music.
The compositional methods of this new music were revolutionary and can be better understood if one follows the internal phases of a musical composition.
Musique Concrète starts from the material (Schaeffer himself refers a return to acustic sources). After a first contact with the materical, which now means any sound that can be recorded with a microphone (and not simply the traditional instruments), follows a

phase of intense experimentation, mostly consisting of transformations of the material using electronic means. Finally the composition involves selection, organization and montage of the transformed material.
This method is different from the traditional one, that starts (according to Schaeffer), from a certain conception (which is necessarily abstract), going to an interpretation by live musicians. For *musique concrète*, there is no need of live musicians because this is music intended for a loudspeaker system. This is an enormous change.
All *music notation* was also put into question, and although most composers of *musique concrète* use either no traditional notation or even no notation at all, there are some, as Stockhausen, which have taken a serious look at the subject, starting a process that seems more and more vital today : the precise notation of musical timbre.
Considering the oposition between traditional and concrete methods, Schaeffer points out immediately to the relationship between the two: the imagination of a composer using traditional instruments can be extensively enlarged by some work on the studio, using concrete (fixed, or prerecorded) sounds and the methodologies of *musique concrète*, just as a deep study of the sound of orchestral instruments and their function in traditional music can be iluminating to a composer working in the studio.
All this leads to a new comprehension of the sonic and musical phenomena.

Schaeffer clarifies that the *Traité des Object Musicaux* deals exclusively with thematerial (sound objects), and not with their organization in structures or forms (because that study alone would require another treatise).
He starts from the material, but his thought prevents him from being helpless when facing it. He reveals, on the contrary, the influence of Husserl and phenomenology in general. Even the notion of *object* (a point of aplication in the phisical world) is opposed to *idealized objects* , as abstract categories, languages, or even music itself, when considered independently of it's concrete realization.
The consciousness that I have of the objective world already implies another, different from me, as a subject. An object presents itself as the pole of identity of particular experiences, and by thus transcends the identity which surpasses particular experiences. (Husserl, *Formal and Transcendental Logic*).
Schaeffer gave great emphasis to the *transcendence of an object*, due to the common reaction of declaring it completely subjective. One should also look at his effort to unite exterior world and compositional world, while justifying a fusion between social/musical sound. Schaeffer's argumentation is mostly focused on the auditory phenomena, and starting among others from binomial relationships such as *objective/subjective, abstract/concrete, permanent/variable, sonic/musical, ...*
he arrives at four fundamental types of listening:

Écouter means an activity which we cannot avoid, a continuous submersion in any kind of sonic activity.
O*uir* refers to a more active participation from the part of the listener towards what is being heard.
Entendre (or directional listening) means that the listener is focusing on certain sonic characteristics , in other words, it means that the listener knows *a priori* what he will focus on while he listens.
Comprendre is a combination of directional listening with interpretation: in this kind of listening one tries to *understand* what is being heard.

Besides the four types of listening, *musique concrète* uses three other important postulates;
The first is *primacy to the ear*. Any limit or evolution of new music should be linked to the way our hearing organs behave. Such atitude stimulated not only musical investigation but also the investigation of sonic perception and the conception of the ear as a "complex microphone". For example: the fact that we can hear a low sound while listening only to higher harmonics was studied in detail by Schaeffer. Modern research on cognition, interpretation and the connection of the brain to the ear are also linked to his original concerns.
The second postulate is a *preference for acoustic soureces* , to which our ears have been exposed since the beginning of mankind and that have conditioned our ways of perceiving to an enormous degree.
The thid implies *the search for a language*. This is one of the recurring points in the treatise and what it really aims at is the creation of a completely new musical *solfège*.
Schaeffer also mentions Jacobson's *Law of Alternances* , or *Law of Languages:*
The possibility to subtitute one term for another, equivalent in one aspect but different in another
From the four elements of the *solfège*, two of them (*Pitch* and *Rhythm*) have gained proeminence in traditional scores because they can be notated precisely, while the other two (*Intensity* and *Timbre*) are only approximative. Another feature of the new *solfège* is that it relates *durations* and *timbres* in the following manner:
Durations are the color of *rhythms*, just as *timbres* are the color of *pitches*.
Pitch resists short durations, since it's perception starts as soon as the sound is longer than 5 miliseconds. *Pitch* is a prerequisite for *timbre*, and so the perception of *timbre* requires much longer durations. For sounds shorter than 5 miliseconds, we always hear the same *click*. Schaeffer was clearly interested both in the *limits* and the *thresholds* of hearing perception.
If any sound is available as material, then the discription or classification of sounds should be as general as possible. There is always the error of analyzing and taking out of context, but Schaeffer takes the risk and presents his own *Scheme for the classification of sound objects* (*Traité des Objects Musicaux,* pg. 442).
Morphology and *Typology* try to represent two opposing poles:
To study the inner structure of one sound (*form/matter*), and it's variations is to study it's *morphology*. One finds, for example, that a structured sound (such as low piano note) resist better to filtering both than a sine-wave (which does not resist filtering) or noise, that is, that we can still perceive the same origin or some similarity in character in the filtered/unfiltered spectral structures. But the diversity of sound sources is immense, and so one has also to consider *Typology*, dealing with different kinds of objects.

In the *solfège de l'object sonore* , one is advised to a systematic and repeated listening to different kinds of objects. In each repetition, perception should be confronted with new elements unoticed previously. The purpose is not repetition for repetition, but repetition as a method to become increasingly aware of the inner structure of the sound. One should also remember here the sentence of David Hume:
Repetition does not change any of the qualities of the repeated object, but it changes something in the mind that observes it.

Repetition in *musique concrète* is thus one of the keys to understand which compositional path should be taken, and this strategy is a completely novel experience in relation to traditional composition.
The basis of a new problematic are clear:
If any sound already has an inner structure, what are relationships of this structure to one which was conceived by a mind for the purpose of musical composition?

I.2.2 – Acousmatic Music

Many composers had acces to Schaeffer's studio, from Pierre Henry (his main collaborator from the start), to Stockhausen, Boulez, Bayle, Parmegiani or Luc Ferrari. Ferrari already had some contact with Edgar Varèse, and had a quite personal aesthetic which was clearly different from the one envisaged by Schaeffer: for instance in *Musique Promenade* (1969) or *Presque Rien* (1977), he used recordings not of isolated musical objects but of complete sonic athmospheres, preceding the study of *Acoustic Ecology* introduced in Canada by Murray Schafer.

However, the major development of *musique concrète* was called *Acousmatic Music* (where the sound sources cannot be identified), although the most important aspects of this music (and usage of the term acousmatic in music) had already been introduced by Schaeffer and are thus interior to the context of *musique concrète*. Note that already for Schaeffer, the *object sonore* is disociated from it's physical production body.
Acousmatic music is thus a subtypology of *musique concrète*, but it has extended it's methodologies, particularly in the domain of spatialization.
Idealized and realized by the composer François Bayle, the *Acousmonium* tranforms performance into an "art of projected sounds". The idea came from the Schaeffer/Henry problem that at concerts (for example in *Symphonie pour un homme seul*) the stage/hall becomes simply a larger version of the studio. The *Acousmonium* is based on an arch-structure, with distant but sufficiently numerous loudspeaker to give a credible acoustic image from any phisical location.
Bayle is the most important theoretician of *acousmatic music*.
His interests range from the *spatial theory* of Paul Virilio, to Merleau-Ponty, to Jules Verne while establishing the basis for the aesthetic in *Musique Acousmatique, propositions ...positions* (INA-GRM). All of them are, for Bayle, heroes of the "Spatial Odissey".
Bayle presents three distinct "spatial" categories specific to electroacoustics:

1. Distance : a gesture, (the spatial-temporal distance between sounds creates an object of perception - Apparition / Disappearance)
2. Presence : a context, (the form of the sound in itself, that is, consired in it's own vibrational / spatial constraints).
3. Body (the technology gives life to a sound as if it was inhabited by a living body)

I.3 - Elektronische Musik

The radiophonic studios should undoubtly be considered the doors to electronic music. Schaeffer was, besides composer and theoretician, a radio technician.
The Paris experiments from the late forties were immediately followed by the creation in Cologne, of the studio of the WDR, and latter by the *Studio di Fonologia Musicale* (italian radio), in Milan 1954 (Luciano Berio and Bruno Maderna).
The WDR studio was founded in 1951 by the musicologist Herbert Eimert in colaboration with Robert Beyer, a sound engeneer working for the radio.
The aesthetics associated with the music coming from this studio are so different from the french that to understand them we must go back to one of the major composers of the century, Arnold Schoenberg. The motivations of Eimert were completely based of the dodecaphonic conception of Schoenberg, who had put into question the use of *hierarchy* in compositional systems and was aiming at a total *democratization* of musical materials. Eimert believed in electronic means as the ideal context to the full development of the Schoenberg's idea (Even more than the instrumental medium)
Olivier Messiaen, which had his own *modal thinking* (linking him to Debussy, for instance), developed a system of modes, *Modes of Limited Transposition*. He also made links between these modes and rhythm (non-retrogradable rhythms, ...). (Messiaen, *La Technique de mon Language Musicale*)
It is very likely that he was using a modal approach to the musical parameters in his piece *Mode de Valeurs et intensitées*, but Boulez and others interpreted it as the extension of the Schoenberg serial technique to all musical parameters: Integral Serialism was born.
Thinking in terms of parameters continues today to be fundamental strategy of electronic music, although it's original connection to integral serialism is usually ignored. The original WDR studio reflected not only the aesthetics of Schoenberg but also those of Anton Webern, for instance in his application of serialism to the composition of microstructures.
One of the main points was to compose the sound *in itself.* This was the first true compositional concern with *sound synthesis*, and so Beyer named this music *Elektronische Musik,* which adequately describes it's aesthetics.

The idea was first based on the Fourier principles developed in acoustics by Helmholtz: any sound can be decomposed in sinusoidal waves. Using simple equipmnt such as the *Melochord,* it was possible to record and mix such waves. There were also some primitive filters, which allowed for the second kind of synthesis method available: *subtractive synthesis*
Werner Meyer-Eppler had worked before with the *Melochord* in Bonn University before he joined Eimert and Beyer in the creation of the WDR studio. His knowledge included acoustics, phonetics and information theory.
One of the most proeminent problems was that synthetic sounds (addition of sine-waves) were too static, especially when compared to acoustic sources, rich in inner variation. The problem was that sound synthesis was by then mostly a vertical procedure (unlike counterpoint, for example, which is strictly horizontal)
This opening to the *Vertical* (that is to *Timbre Composition*) was coming at least since Edgar Varèse, a visionary which has touched many further aesthetics.
Many composers of great value have worked in the WDR studio, such as Pousseur, Kagel, Ligeti, Koenig or Stockhausen.

I.3.1 – *Karlheinz Stockhausen*

One of the major composers to work in the studio was Karlheinz Stockhausen, who had already studied and with Meyer-Eppler before coming to the WDR. Stockhausen is an extraordinary case since he had also worked with Messiaen and even Schaeffer's studio in Paris.
Stockhausen desired to compose the sound in itself, and apparently Schaeffer saw no interest in that (remember his postulate about the preference for acoustic sources) so he dismissed Stockhausen.
By the time of Cologne, the young Stockhausen would write:
For a given work (X) only sounds of character (X) are required, because those sounds are the result of a compositional process.

After a detailed analysis of many of the musical instruments existing at the time in the *Musée de L'Homme*, Stockhausen composed his own timbres, the first experiments consisting mostly in the addition of sine waves tuned to a predetermined frequency scale. (for instance , *Studie I,* 1953)
It is important to understant that just as an old record player allowed to change the speed of a recording, in a studio this could be done continuously, and in fact *Transposition* (with time stretch) is a transformation method of extreme importance both for the WDR composers and Schaeffer and the *musique concrète* composers.
As Stockhausen argues, if we speed up a recording of a Beethoven symphony in such a way that it lasts only one second, we get a sound with a characteristic timbre whose inner structure was composed by Beethoven. In the same way we could extend another sound (captured by microphone), to a duration of one hour, to get a "music" whose structure is coming out of an arbitrarly short sound.
Stockhausen's attempt is to unite all musical time, from *Form* (long durations) to *Rhythm* (medium durations) to *Timbre* (extremely short durations).
If we accept his statement: *There are no sounds in time, Time is in the sounds*, then we are lead to the view of musical composition as consisting of many times existing in the many overlaping or sucessive sounds.
For Stockhausen, Electronic Music should always justify the new means. The sensation of new sounds is purely an exterior aspect, and the goal is rather to have new experiences through electronic music. In a lecture about *Kontakte,* he gives four criteria specific of electronic music composition:

Criteria A : Changing between different *Areas of Perception*:

1. The perception of *Pitch* (the ability to hear melodies and harmonies).
2. The perception of *Timbre* (considered here the color of sounds)
3. The perception of *Rhythm* (meaning proportions of durations)
4. The perception of *Form* (larger durations)

Criteria B : The *Composition/Decomposition* of sounds
Criteria C : The superposition of *Spaces*, crossing and overlaping each other, leading to a *listening in depth*
Criteria D : The continuum between *Sound/Noise*.

There are three major types of forms presented by Stockhausen, the *Narrative* or *Dramatic* Form (which is the basis of the traditional ideas of development), the *Sucessive* Form, advancing by *the principle of contrast*, or by blocks. Finally there is the *Moment* Form, where there is no relation both to Memory (no relation to the past,

a kind of zero-order Markov Chain) or to hopes in the future, but only the present is the compositional focus.
One of the most interesting aspects directly involved in electronic music is Stockhausen's distinction between the *Rhythm of the Sound* and the *Rhythm of the Bar*. Since in acoustic music the sounds come from traditional instruments and are thus predetermined most of the time, the work to be done is more at the level of the "rhythm of the bar" while in electronic music, where extreme attention is given to timbre and inner structure, the "rhythm of the sound" becomes in many cases the most proeminent atribute.
In the composition of *Gesang der Jünglinge* (1955-56), Stockhausen combined both approaches (*concrète* and *elektronische*) showing after all that Music is not a slave of any particular methodology.

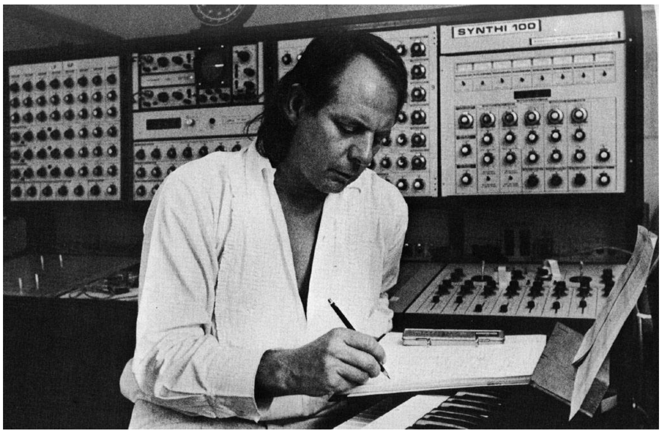


FIG 11: Karlheinz Stockhausen working in the Studio.

<u>I.4 – Tape and Computer Music</u>

I.4.1 – *Tape Music*

By the time when Ussachevsky and Otto Leuning visited both the French and the German radios, they had already started their own kind of electronic music in the USA (*Tape Music*, the name was chosen by Ussachevsky).
One of the first historical records of *tape music* is a public concert in the *Museum of Modern Art* in New York, in 1952. Those initial experiments quickly led to the creation of the *Columbia-Princetown Electronic Music Center*.
Other americans were of great importance to electronic music, as Pauline Oliveros (for example in *Bye Bye Butterfly*, 1960), or Gordon Mumma, both individually and in collaboration with John Cage and/or David Tudor. Mumma was also active in the *Sonic Arts Union* with other composers interested in the electronic medium : Alvin Lucier, David Behrman (and his the *brain music)* among others.
The american *Minimalism* of Steve Reich, was at it's origin, using techniques of *Tape Music: It's Gonna Rain* (1965) or *Come Out* (1966). Others as Terry Riley developed analog systems allowing the composer/improviser to transform sound in real-time. In Riley's case, the systems consists on the accumulation of several *delay lines*.

I.4.2 – *Computer Music / Parametric Music*

One of the greatest american contributions to the development of electronic music was the rigorous study of the musical application of a computer.
The computer has brought unknown possibilities completely outside the scope of other electronic devices : *Theremin* (1920), *Trautonium* (1928), *Ondes Martenot* (1928), *Hammond Organ* (1935), ...
All procedures for the generation of electronic sound are called *Sound Synthesis*. Up to the time of the appearence of computers, most of the synthesis methods were based either on *additive* or *subtractive* models.
The computer, as a completely programmable machine, can contain those and many other *synthesis models*, working in an abstract, generalized environment of information streams.
Something quite new was the fact that the complexity of the computer program is limited only by the imagination and craft of the programmer and by the computational speed limits of the machine.
The computer does not simply contain (potentially) all synthesis algorithms, it has replaced all of the old studio equipment, performing in seconds certain compositional strategies that would take months to realize in an Analog Studio.
Another use of the computer is that of assistent to musical composition. Here, the major figures are Xenakis and Koenig, although there are experiements as early as the *Suite Iliac* (see below).
In *Computer-aided composition*, the computer is used to symbolically manipulate several musical *parameters* (pitches, intensities, instrumentation, ...). These *parameters* are subjected to algorithmic processes of great complexity (for instance, the use of probabilities by Xenakis), but lead eventually to a musical score, clear enough to be played by a musician.

There are thus at least two “scores“:
-*operational data* (for the computer)
-*traditional score* (for the musician)

The idea of controling musical varibles individually came from integral serialism. In electronic music this means the control of individual *parameters* , which do not have to be simply the traditional ones, as pitch or rhythm. Some of main parameters in an electronic sound are it’s *temporal envelope* (dynamic variation of intensity) and it’s *spectral envelope* (dynamic variation of timbre), parameters considered approximative by Schaeffer, but which can be dealt with precisely in the computer.
Maxima of temporal envelope correspond to energy-peak intensities just as maxima in the spectral envelope correspond to energy-peak formants, or resonances. The study of those formants was born in connection to the human voice, but it was successfully extended to musical instruments and even to electronic sources (*Formant Filters*, and so on).
Another of the main possibilities of the computer is the rigorous control of *automation*. In the electronic domain, each *parameter* (intensity, for instance) can be controled both manually &/Or algorithmically and simultaneously reproduced and transformed to a high detail. This procedure can be extended to a large number of parameters and that is, in fact, one of the basilar methodologies in electronic music which is still actual today. Systems were developed to deal with a great number of parameters (using techniques from areas as Artificial Intelligence, Chaotic Systems, Genetic Algorithms, ...). This was an important advance because the original serial idea that musical variables are completely independent was a mistake. Today we have a different view, that each variable also affects others, such as in the experiences of S. Stevens: when the intensity of a sound changes, the perception of pitch is also altered.

I.4.3 – *Computer Music at the Bell Laboratories*

The first musical experiences with computers were aiming mostly at *Sound Synthesis*, and took place in the Bell Labs, around 1957. Edgar Varèse visited the laboratories (1959-60) and even organized public auditions of those early sonic experiments. One the earliest compositions coming out of Bell Labs is the *Iliac Suite* (1957), which interestingly was not dealing with *sound synthesis* but with the generation of *parametric data* for computer-generated string quartet. The piece starts with strict *cantus firmus* rules (as formulated by Fux) , which were previously programmed using a computer.
In 1968, Max Mathews and John Pierce arrived at a paradigm (*Music V*) which would influence most of the procedures coming after it. In any programm of this type, the composer is confronted with two essential aspects. Electronic composition is separated in aspects connected to *synthesis* (or instrument building) and data (*score*) to control the synthesis methods (electronic “instruments“).
In the aspects of synthesis, the architecture should be modular, allowing for many kinds of possible connections among basic modules (building blocks).
James Tenney was one of the composers invited to test the system.
Some of the 1965 experiments of Ferreti antecipate another usage of the computer: real-time interaction between musicians and computers.
One of the most proeminent composers to work in the Bell Labs was Jeadm-Claude Risset, who worked on *analysis* and *synthesis* methods and was also interested in psychoacoustics. Starting from the computer study of a trumpet sound (1966), he

eventually collected a catalogue for computer-synthesized sounds (1969), which although it's evident link to the original system remains one of the very few attempts at such a catalogue.
In *Mutations* (1969), Risset explored the relationship between harmony and timbre: when simultaneous, several notes can fuse into a unique timbre (as in the inharmonic sound of a Bell), if sucessive, those notes assume an essentially melodic character.
Fm Synthesis (John Chowning, 1973), was by the time a revolutionary method:
It was possible to have a large collection of complex timbres, both harmonic and inharmonic, and even to have sounds going from one state to the other. This was far more efficient than adding many sine waves, one by one, so synthesizers as the *DX7* have popularized the method. Chowning himself has used *FM* , for example in *Turenas* (1972).

I.4.4 – *Xenakis*

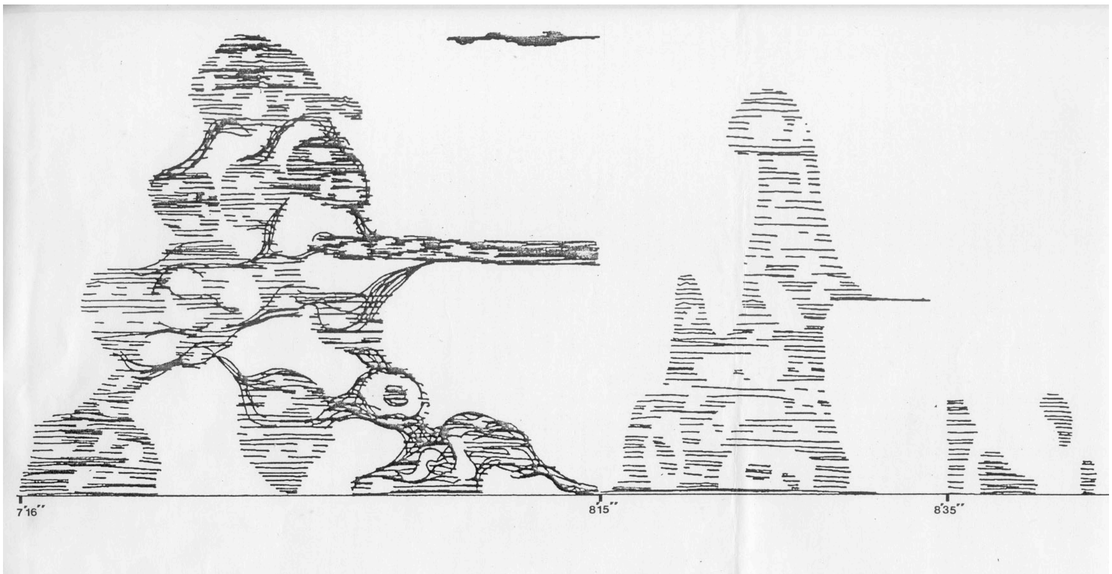


FIG 12: a part of the score of Mycenae Alpha, by Iannis Xenakis,

One of the great minds in computer synthesis was certainly Iannis Xenakis.
He has introduced advanced mathematical methods in the most diverse areas of musical composition (acousric, electronic, electroacoustic,...). In the domain of *Sound Synthesis* he is credited with *Dynamic Stocastic Synthesis*, dealing with probability distribution (density) functions to generate electronic, complex dynamic sounds.
His work with *Le Corbusier* and particularly at the Phillips Pavillion of 1958 was very important historically, and even today it is almost impossible to find multimedia work of such artistic value.
Another of Xenakis ideas lead to the creation of the *UPIC* system, which implies a new and more intuitive conception for the composition of electronic sounds. Similar in shape to an architect's table, the *UPIC* system allows the user to draw lines or any other shapes which will be transformed into sounds.
Another synthesis method of the proliferous Xenakis was *Granular Synthesis*. Although Gabor had already introduced the notion of *grain*, Xenakis has taken it to a statistical sense, both in instrumental and electronic music.

This notion of *grain* is an important issue, since it puts into question ideas about what is the smallest element in a musical composition.
In *Elektronische Musik* it was mentioned that the synthesis methods used in the WDR studio were mostly "vertical" procedures. Synthesis for Xenakis is far more "horizontal". This means that the important thing is the dynamic control of sound. It makes sense to Xenakis since his whole compositional question in always : How to go from point A to point B?
Regarding the *formalization* of music, to which the computer is an essential tool, Xenakis has written extensively about it both in *Musique / Architecture* and in *Musiques Formelles*.
(see the chapter III.1.1 – *Compositional Systems* for more information about *formalization* in music).
His attack on serialism was completely justified, because the tendency to generalize lead Xenakis to view serialism as a particular problem inside a larger problem:
How to deal with the combinatorics of a finite number of elements?

I.4.5 – *The Human Voice and Electronics*

Luciano Berio and Bruno Maderna had already composed works of major importance for voice and electronics (in collaboration with Cathy Berberian) such as *Thema (Ommagio a Joyce)* (Berio, 1958). In relation to the synthesis of the human voice, some of the developments include aplications of LPC methods (a kind of filter that tries to predict the immediate future of sounds), by Charles Dodge or *Formant Synthesis*, which is at the core of the *Chant* system in Ircam. The whole piece *Vers le Blanc*, 1982 by Kaija Saariaho consists in a continuous change from one chord to another, and during this process many types of formant modulation are applied. In this piece, Saariaho was using the *Chant* system and nothing else.
The brazilian composer Flo Menezes (associated to *Maximalist Music*) has derived an entire *musical form* from the phonological structure of a given word (naming it *pronontiation form*).
The human voice can be separated in it's excitation and resonance. Vowels correspond to resonant areas which remain perceptible even if the fundamental frequency changes (more or less independent of how low or high the voice is speaking or singing). But the technique could apply to other sounds, for example an excitation caused by the slide of the bow in a cello or the resonace we get if we hit it's body with a short impulse.

Finally one could mention all the methods related to *Analysis/Resynthesis* (using a Phase Vocoder or any FFT methods), which first decompose a sound in many small waves. The composition/decomposition of sounds was one of the criteria presented by Stockhausen for the composition of electronic music. In the computer, the decomposition allows a large variety of mutations and timbral combinations. If some characteristics of one sound are used in another sound, we are dealing with *cross-synthesis*, and if this is done in the spectral domain, then it is possible to obtain quite smooth transitions and transformations of sounds amonf themselves, going continously from the timbre of one to the next.
In the classic example, a speaker/singer is fed to a synthesizer.

Today one of the major applications of the computer is precisely it's interactive aspects playing in *"real-time"* (see the section on live-electronics). This use finds it's musical roots in works which have used analog transformations, such as *Mantra* (Stockhausen 1970), for two pianos, two *ring-modulators*, wood blocks and crotales, or *Con Luigi Dallapiccola* (Luigi Nono, 1979)

I.4.6 – *John Cage*

The presence of Varèse and Schoenberg in the USA has stimulated considerably the music in these countries, from Morton Feldman, who used to daydream about Varèse, as a child, to John Cage, who was a student of Schoenberg.
Cage declared *Noise* to be musical (as Varèse had previously done), and predicted it's future importance in all music and in electronic music in particular (*The Future of Music : Credo*, 1937). To trace a history of *Noise*, it would be necessary to go back at least to the russian and italian *futurists*.

With a completely personal aesthetic, John Cage touched electronics in every field he could, from recorded sounds on tape, to live amplification of acoustic situations (for instance the amplification of street traffic or of people moving and talking inside a building) to the amplification of "small" sounds (for example the amplification of his own troat while drinking juice)
Beteween 1967-69, Cage colaborated with Lejaren Hiler in the composition of *HPSCHD*, for harpsichord and computer generated sounds.
During a lecture, Cage tells a story about one of the greatest thoughts he ever got from Schoenberg:
In a lesson, Schoenberg asked the students to present several solutions for the same musical problem. After solving several of them, Cage said, with some confidence, there aren't any more solutions, to which Schoenberg replied:
What is the principle underlying all the solutions?
Cage only found the answer after the death of his teacher:
The questions we ask ourselves are the basic principles of all the solutions.

I.5 – MUSICAL SPACE

I.5.1 – *Which notion of space?*

The notion of space has gained an *operational function* in contemporary music.
Space can be generally used to discribe the interelationships among functional categories which allow us to think the complexity and the nature of the sound.
It is true that *any electronic sound requires a space*, but especially with the increasing use of computers, this fact should lead to new theoretical perspectives, giving *space* more than a critical and operational value in musical representations.
Just as perspective in painting, space has become the means of rational construction (It is necessary to keep some distance to our own referential logic in order to arrive at an aesthetic, which in any case is always the point of arrival, never of departure).

By the end of the 19th century, there was the *spatial symphonism* of Mahler.
In the 20th, space was used for the first time as one of the structural foundations for all dimensions of both musical language and compositional process. The composers who truly influenced the notions of musical space are few : Varèse, Xenakis, Stockhausen and Luigi Nono.

I envisage musical space more as something open than as something closed. In any case i don't desire any a priori control.
(Edgar Varèse)

I.5.2 –*Architectural dimensions*

The architectural dimensions of sound spatialization are almost ideological : the experience of the multiple raditiations of a church-organ, the spatialization of choirs in religious rituals, *cori spezzati ...*
This is also true in contemporary music, for instance : in the spatialization of timbre in spectral music (Radulescu, Grisey, Murail)

Many decades ago Stockhausen defined 11 points for a "modern" concert hall:

1. Circular / Squared Space : Orchestral groups can be placed both surrounding the audience and/or in the among of the audience.
2. A large number of movable platforms
3. A ground plane
4. No fixed chairs. The configurtion should be modifiable.
5. The possibility to connect microphones and loudspeakers around the walls and ceiling
6. Balconies at different heights for small instrumental groups
7. A few doors which are not an obstacle to a circular placement of orchestral groups
8. Electrically controlled resonance, able to adapt to each situation
9. Studio outside the hall for loudspeaker reproduction and recordings.
10. Lightning of the room independant of transportable lamps for music stands
11. Seats of wood

I.5.3 – *Models of Spatialization*

Models of Spatialization:

A. With Electronics
   a. With Computers
      i. With simulation of spatial trajectories
      ii. Without simulation, fixed spatial positions
   b. Without Computers
      i. Tape
      ii. Live Spatialization/Distribution of sources
B. Without Electronics
   a. Groups of instruments placed anywhere in the hall
      i. Fixed spatial configurations
      ii. Dynamic spatial configurations
   b. Spatialization inside one configuration, with all instruments localized

A recent example including computer-control of spatial trajectories is the piece *Cosmic Pulses* (Stockhausen, 2006/2007) where 24 melodic loops (containing 1-24 notes), each with individual rotations, tempi and trajectories, are spatialized in 8 loudspeakers (24 x 8 = 192 tracks). Two faders were used for tempo variations and two faders for the pitch glissandi. In total, Stockhausen composed 241 different trajectories in space:

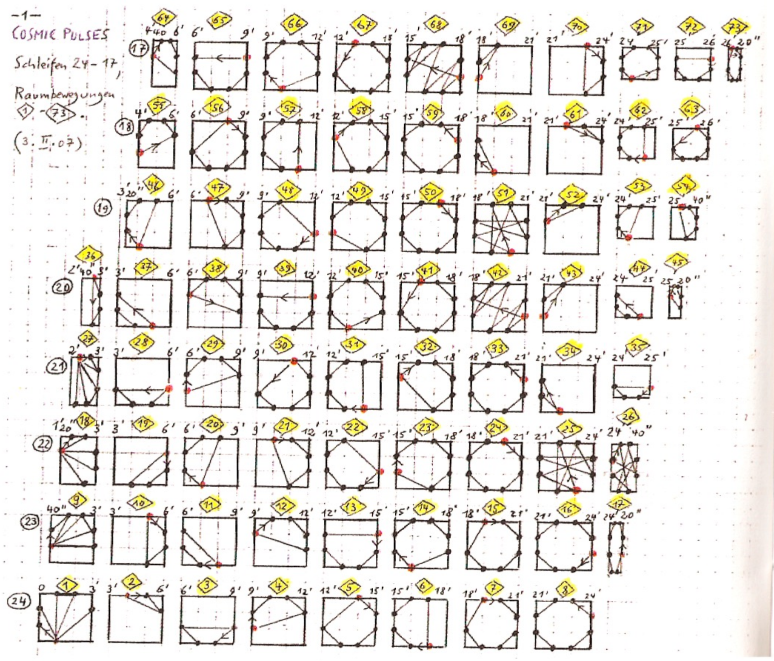


FIG 13: Karlheinz Stockhausen, the 1st page of the 241 different trajectories in space in Cosmic Puls

I.5.4 – *Spatialization and Rhythm*

Our ears are *microcosmos* of the outer spaces. The spatialization of rhythm means that each spatial/musical point is given rhtyhmic independence, something which heappens normally in daily life.

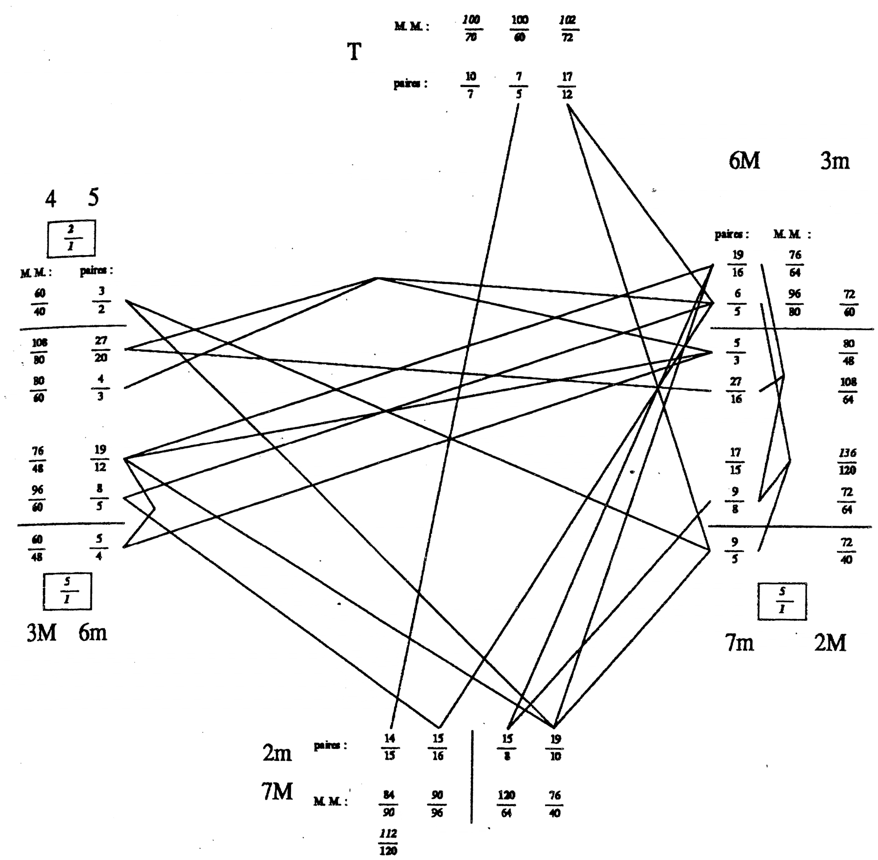


FIG 14: Emmanuel Nunes, *Spatialization of rhythm in Tif'ereth* (1978), for six instrumental groups and six soloists.
Each poin in space is related to a certain metronome mark, assigned to a particular instumental color.

Other examples of the use of space could include:

1) Ligeti (a unified approach to space) , for instance *Volumina* (1961-62), *Atmosphères* (1961) or *Apparitions* (1958-59)

2) Mauricio Kagel has used the concert hall as performance area (for example *Dressur*), as a musical instrument (for instance in *Pas de Cinc,* for walking musicians) or as the place for a sound installation (for example in *Ornithologica multiplicata*, 1968, for exotic and continental birds). He has also made movies using quite strange scenarios...

<u>I.6 – IMPROVISATION AND LIVE ELECTRONICS</u>

In electronically processed music, (or *Process Music,* here meaning any musical creation using real-time processing of sound*)*, the computer also plays a major role in establishing a relationship between acoustic and electronic instruments. It stimulated the proliferation of sonic devices with diverse and specific music explorations: First, with the synthesizers; then the sequencers; then the samplers (in the 80's), linked to the art of concretism; until their combination in big *cibernetic machines* of music. The computer was the most important instrument for the formulations of *mimetic music* (laptop, live improvisation) where timbres, sound textures and rhythmic combinations can be electronically simulated. Take as an example the simulation of the sound of a trumpet (using *physical modelling syntesis,* for instance) or the string section of a symphony orchestra or even the human voice.
In the 1980's *interactive music* gained proeminence, from a scenario where electronic instruments are connected via *MIDI* and the sounds electronically manipulated and transformed in *real-time*, to the satelite transmissions of Nam June Paik.

But the last word on the subject can be given to Max Mathews in his text *The Computer as a Musical Instrument* (in *Musique en Project*, 1975, pg 69):

We live in revolution. The music we hear comes in it's majority from electronic devices – record players, radio, TV. Electronics has invaded not only reproduction but also recording – from the multitrack recording to total electronic synthesis, passing by reverberation. The electric guitar raises enormously the possibility of discourse in the game of a category of musicians. The next step, new instruments – the most impressive of them will be the computer, alone or with other electronic equipment. In the future computers will have the role of improvising machines, machines allowing everyone to express himself without the necessity of studying for many many years.

In the short history of *computer music*, we find inventors of synthesis methods, programmers, ... which will become oracles for musicians dealing with live-electronics, most of them as simple users of systems for which them have to scientific knowledge. Improvisers of live-electronics are thus manipulators of technological creations, built either by themselves or someone else...
The hyperspecialization of recording studios, fixed or mobiles, was quickly solicited by improvisers.
The correlations can be: simply electronic (with or without prerecorded material); between acoustic instruments and live electronics (with or without prerecorded material). This originates five subspecies of creative activity in live-electronics:

1. Midi interaction in instrumental pieces
2. Analog Processing (for instance *delay*) in instrumental pieces
3. *Real-Time* sequencing, multitrack and instrumental improvisations.
4. Multimedia interactive works requiring several *real-time* processes.
5. Digital operations with pre-recorded material &/Or Multimedia.

I.6.1 – Electronic Interaction

The sound technician has also gained a major role in the development of a live improvisation. The most recent artistic and multimedia function in today's experimental live-electronics is that of the *Tonemeister*. Just like the acoustic jazz orchestrator, he transforms timbrically, texturally and structurally the work of musicians. The *Tonemeister*, while codifier of sounds, will be one of the instrumentalists-improvisers in the future of improvisation (for instance, Walter Prati, Marco Vecchi and Joel Ryan have used real-time processing in the Electro-Acoustic Ensemble of Evan Parker).
This Technician/Musician can also use his musical personality just as any Jazz musician.
Computer-assisted improvisation is a *work in progress* which clearly marks the figures invented by the players and also transforms them in real-time, an actualization of the myth of the mermaid. Any of the live-electronics musician is really acting in an "android" (a kraftwerkian man-machine) world, both in relation to systems of composition and of improvisation.
Since the advent of computers and voltage control in the 1960's possibilities have been given to generate and manipulate all kinds of artificial sounds.
The musicians dialogue, interpenetrate their solos via *MIDI*, and in real-time, from the simultaneous computational action (the analog source can be a saxophone going to a microphone connected eventually to a loudspeaker); It becomes possible, among other gestures, to deform timbral textures;
A group of soloists can used electronic models, workstation, the powerfull synclavier, fairlight, emulators, eventide, kyma... but all that technological world is already a point of escape, since all the *life* in improvisation can volatilize in abstractions or complex automation procedures of self-programmed or other high-tech devices.
This question is similar to the microwave in cooking; the dinner is already served. All that is left is to heat it and actualize it quickly, fast-food ready for consumption.

The sampler is the digital substitute of the tape recorder and it has raised the pallete of discontinuities. The sampler as an advanced concretist technology gives us a whole universe of sounds and musical segments, and is a common presence in improvisation involving sonoloplastic treatements. It has been used usually simply as a device for textural decoration but has known new light and even ascended to the first rank of musical digital devices.

The improviser of computer music is an *android* in the sense that his music cannot be executed exclusively by one musician and his human gesture, it corresponds roughly to the union of at least two intelligences, natural and artificial. Computer-assisted improvisation deals thus with technical and symbiotic elements, a forest of interconnections Man/Machine.
The technique of *Drone* , a continuous figure, with legato motives sometimes repeated, comes from the beginning of electronic music itself, and today it is easy to find it in the discourse of *mass musics* for *laptop*, with a functional action similar to that of the *Basso Continuo* of the Barroque or the rhythm section in Jazz.

Initially, *groove* meant an improvisatory activity assuming the computer as an instrument, from one hand the action (keyboard, mouse, ...), from the other, self-determination and control.

The praxis of clasical electronic still holds today, and it is possible to find a regime of installation without players in music intended only for loudspeakers.

Kinetic Music has evolved: from the aesthetical positioning of loudspekers to the movements of sound in space, determined by the computer, creating a virtual reality of space and movement.

Art relates more and more to nanotechnology: it is significant the progressive instrumental miniaturization in the scene of New Improvisation.

As a *post-modern* situation, (anoucing in vain the colapse of tonal music), the improvisation using live-electronics should is opened to new opinions, acepting incompatible regions, plurality ... as the Zen garden with rocks where everyhting is relative. It is the case of music for laptop, popularized.

Improvisation using live-electronics is being propelled by the acousmatic phenomenon, where acoustic sources are hidden from the eyes and unrecognizable to the ear.

The art of improvisation in it's post-modern configuration is the apropriation of sound objects, notes or noises from daily life deviated to fluxes of diverse conotation. It sets itself in a new objectivism : Quotation, Mixture, Invention of objects agitaded by the logic of an absurd though, pregnant with emotionality. It's rhythm is abstract, determined only by the obscure laws of mechanics and electronics or by instable pulsations of some human action.

I.7 – NEW LANGUAGES

From the *autophonic* musics from the beginning of the millenium (example: Aeolian Harp, where the wind sings), we have evolved to a mechanical and machine construction (example: the Barroque Organ, a paradigm for power in music). Today with the *automatic music* of a groovebox or *cibernetic musics* : emphasizing spectro-morphological investigations, algorithmic processes, mimetisms, robotics, sound synthesis, community distribution using the *Internet* or other telematic networks.
Music can be characterized by new technological inventions, technical experimentations, graphical formulations and by the scientific outlook of contemporary classical composition or the aesthetics of new music :
- Technological applications of amplification, high fidelity, ambience or reverberation of sound
- Portability and Miniaturization of instruments and electronic devices
- Coordination of the acoustic output by specialized producers and engeneers.
- Generative grammars in music (*Serialism* is one of them, as polytonality, modalism or microtonality)
- Invented theories of intervals, rhythms, harmonies, textures, ...

Some of the projects of today's music include :
Aleatoric Music (determined by chance)
Graphic Music (dependent on design)
Conceptual Music (where the idea dominates the sound substance itself)
Electronic Music (made of artificial or studio materials, without live-musicians)
Live-Electronics
Electroacoustic Music (*Mixed music,* acoustic & electronic, with live-musicians)
Artificial Voices and particular vocal techniques
Anti-Music, with destructive effects...
The construction and/or hybridism of instruments with more recent codified techniques
Numerical Notation, and mathematical calculations of any kind
Musique Concrète, which uses the microphone as an instrument
Percussion Music, with specific notation for this instrumental
Prepared Piano , or an experimental "preparation" to other kinds of instruments.
TextKomposition, where the score is presented as a poem or in prose
Minimal Music, new simplicity, and the logic of repetition, with illimited influence of the late pop rock music...
Science-Fiction conceptions in *computer music*
Real-Time Interaction and virtual sound
The use of fractals, in a game of infinite sonic recursions.
Brain Music, using brain waves to control the sounds
Timbre Composition, no longer requiring neither the image of mechanical action nor the principle of identification

New electronic music has adopted the new *interart* vocabularies (painting, installation, sound sculptures, cinema, video, performance art, dance, ...):
-Multiple discourse and poly-art in *happenings*
-Musical Theatre, instrumental dramatization
-*Post-Modern Opera*, metanarratives, quotation and neoclassicism
-*Video Music*, audiovisual synesthesia

-*Underwater Music*, (Michel Redolfi, for example), which has transformed the acoustic conditions (music does not have to be exclusively transmitted in air).
-*Multimedia Metalanguages*
-Concerts transmitted via satelite where the musicians can be at an arbitrarly large distance from each other...

The Music of the 20th century has left us an infinity of fascinating projects for the 3rd millenium, which has just started.

I.8 – CONCRETE POETRY / CONCRETE MUSIC

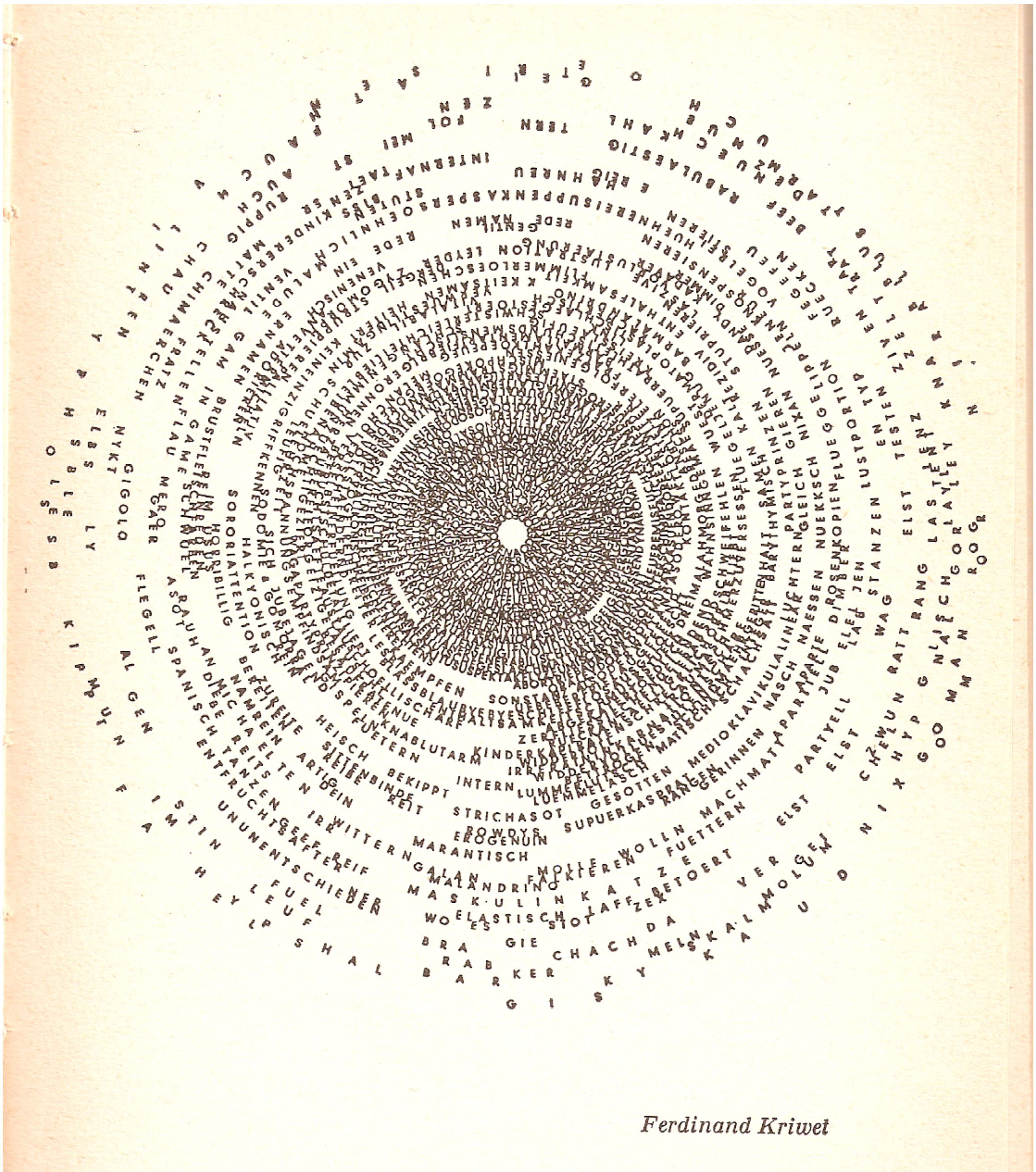


FIG 15: Ferdinand Kriwet, ***SehTexte***
The Visual Poetry of Kriwet: Individual linguistic elements are spatialized with decreasing density from the center, as in a galaxy . Circular groups of letters imply continuity between the spatial-linguistic and the spatial-visual. From abstract rotating words we pass into a purely visual experience, a maximum concentration of multi-meaning elements. The reader may become part of this rotatory movement, inverting thus his usual linear way of reading.

We must find a sort of unique language half-way between gesture and thought
(Antonin Artaud, *Pour un théatre magique*)

This radical statement of Artaud concerning the autonomy of theater and it's liberation from text, emphasizes that theater requires the *expression in space,* and precedes much of the new poetry appearing under such movements as Concrete Poetry, Visual Poetry or Phonetic Poetry.
Theater as a vibratory action on sensibility is free from the purely textual message.
All articulations, gestures, lights, sounds, and so on are an integral part of the magical means of theather.

The new poetries are no longer codes of thought, they originate in the consciousness of the potentialities of language.
In fact, as for Walter Benjamin, all intelectual activities can be conceived as a language.
In this sense, there is a language of music, painting, poetry or religion. It is the principle in those activities oriented towards intellectual communication. Language extends to any spiritual domain.

It is in this spirit that poetry opens up to other arts :

Phonetic Poetry	Music
Visual Poetry	Painting
Multidimensonal Poetry	Sculpture
Mechanical Poetry	Architecture

These new poetries have roots in Rimbaud, Mallarmé, Pound, Cummings and others as well as in information theory and certainly in the strucutral linguistics of Saussure.

The phenomenological principles taken from Husserl by Pierre Schaeffer and the notion of musique concrète itself finds a clear parallel in poetry. Both Abraham Moles and Max Bense refer to the fenomenological concept of text. Moles was an influential figure for his work on informational theoriy of aesthetic perception. Bense, a poet and a theoretician of the movement. Contrary to the musique concrète, this poetry was from it's starting point international, with leading figures from Brazil, Germany, Japan, Sweden, France, Portugal and so on.

Two fundamental phases can be observed:
Concrete Poetry: Language not only as regular communication but the association sign/word to matter. Insitence on the material , the actual black signs independent of the linguistic content.
Spatialism : The notion of space in poetry becomes extremely typographic. The movement of matter is converted into spatial energy. This spatial evocation is both symbolic and literary, creating an aesthetic form. (Abraham Moles)

Spatiality and Concrete Poetry break with the normative organization of linguistic symbols.
Concrete Poetry uses its materials functionally and not symbolically. These materials are nothing but themselves. (Max Bense)
Simultaneity of verbal and non-verbal communication becomes possible, as language is seen as a set of symbols to manipulate. From the readable, we come to the functional, the sensitive, the perceivable.

Everything is organized no longer serving a semantic principle, but an aesthetic one. This aesthetic information does not have a meaning, it transmits it's own realization (Max Bense). Permutations and irregularity of metric can already indroduce aleatoric elements.
In fact permutational art has been linked with poetry in a systematic exploration of all kinds of symbolic games, both linguistic and visual.
Many spatial and permutational techniques are applied: letters and words are given movement, reduced, atomized, repeated, transformed... Poetry participates in the invention of new symbols, in the visual and acoustic composition of linguistic elements.
These languages generally aim at a formal simplification.
As an example, Gomringer considers the *constelation* the simplest possible kind of configuration in poetry which has for it's basic unit the word, enclosing a group of words as if it were drawing stars togheter to form a cluster.
The word is broader than it's meaning (Kruchenyk)

Phonetic poetry (sound poetry) explores the sonic possibilities of the voice, either live or on tape. A poetry that extends to the mouth and to the ear. Phonetic elements can be recognizable or not. This poetry arises from the premisses of Artaud already evoked: *To use language in a concrete and spatial way*. Poetry as sound, not just as syntax. A scream is emotially penetrant when heard and reveals the space it originated in. All kind of electronic transformations are also allowed in this art.
Kostelanetz dismisses *Philomel* (1963) by Milton Babbit from being sound poetry because most of the the sounds are pitched, but at least regarding the human voice, there is no certain distinction of music from sound poetry. A clear distinction is the following:
Certainly the *Sprechgesan* of Schoenberg emphasized the word rather than the note, but rooted in the field of music. Inversely, Kurt Scwitters, in *Ursonate* (1922-32) constitutes an impressive early example of sound poetry as such, where the text is organic and full of musicality, where every articulation counts for the aural sensation it creates. Only more than thirty years later would Steve Reich subject the human voice to tape manipulation:
It's gonna rain (1965) and *Come out* (1966). Both deal with social issues. In the first the voice of a preacher named Brother Walter is duplicated in slightly different loops, so they gradually in and out of phase. The second is based on a real recording of a riot in Harlem in 1964: *I had to, like, open the bruise up and let some of the bruise blood come out to show them* ... someone trying to pass through the police forces in search of medical help...

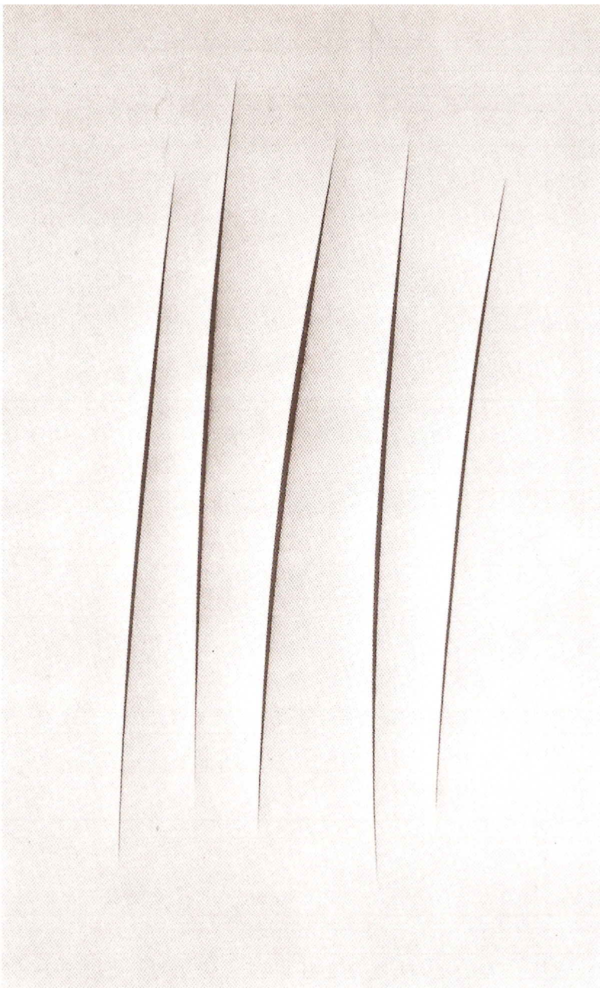
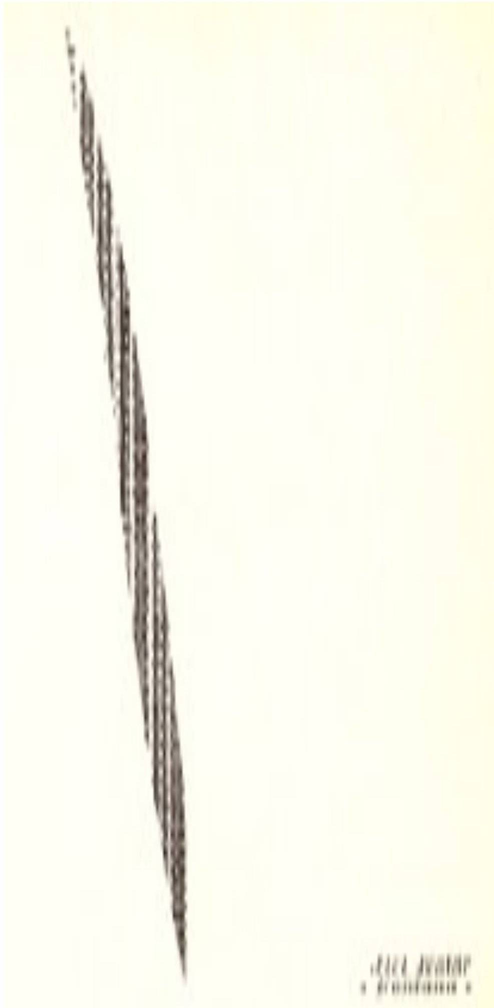



FIG 16: Lucio Fontana, ***Concetto Spaziale – Attese*** **(1963)**
FIG 17: Jiri Kolár, ***Fontana***

Between Painting and Poetry: In the series of paintings named *Concetto Spaziale*, Fontana explores the canvas in an extremely spatial and concrete way. Cuts made directly on the canvas play with it's essentially material aspect. Perspective no longer has to be imagined, it is real and spatial. Perceptually, a hidden spatial dimension emerges through the cuts.
In the visual poem of Kolár, letters of the word "fontana" are repeated vertically and cutted in a similar shape to *Concetto Spaziale*. Here it is not only the physical space that it suggested through the "cut", also the linguistic one. The word has gained spatial movement which emphasizes it's meaning. This movement originates a visual global form, immediately detectable to the eye. Visual sensation, movement and internal linguistic meaning are thus self – referent.

From the first studio of electronic music in Italy, there has been an interest in the study of the human voice. The Studio di Fonologia Musicale was founded in Milan in 1955 by Bruno Maderna and Luciano Berio. They were not only interested in the voice as artistic expression but also in it's rigorous scientific study. Bruno Maderna had already composed several works for the voice, such as *Studi per "Il Processo" di Kafka* (1950). Starting from phonemes by Hans G. Helms, Maderna has also composed *Invenzione su una voce* , an electronic elaboration on the voice of Cathy Berberian, and *Le Rire* (1964). Berberian has extended many vocal techniques. Her realization of Cage's *Aria* (1958) was inspiring to many composers. She has crossed the borders of musical style, recording not only contemporary music, but also music of popular origin, and even The Beatles.

Luciano Berio has made some of the most extensive researches on the human voice done by a composer. In *Circles* (1960), he reveals areas between music and phonetic poetry based on a text of Cummings. Texts by Proust, Sanguinetti and Machado are integrated in *Epifanie* (1961). Working in the Studio di Fonologia Musicale, he created vocal musique concrète on the work of James Joyce : *Thema (Ommagio a Joyce)* (1958) . *Visage* (1961) and *Sequenza III (per voce femminile)* (1966) are realized with Cathy Berberian, and new vocal notations are invented.

Since the fifties, experiments have been made in the Bell Laboratories in the area of computer-synthesized speech. Although these experiments were mostly scientific, some composers have seeked impossible worlds for the normal human voice by using the computer. Charles Dodge has worked with the voice consistently, being able to integrate knowledge from speech physiology to acoustic phonetics. In his own musical version of Beckett's radio play, *Cascando*, speech is given definite pitch by analysis / resynthesis.
Lansky has also used speech synthesis in *Six Fantasies on a Poem by Thomas Campion.*
The work of Trevor Wishart has been far more organic, either improvised or in computer transformations of the voice. In his book *On Sonic Art,* Wishart discusses utterance as a biological phenomena, the possibilities of the human voice, phonemic objects, language, as well as the phonetic poetry of Schwitters already mentioned.

Alvin Lucier, in *I am sitting in a room* (1970) has treated the voice in a very spatial way. As a recorded fragment is played back and re-recorded again in the same room, the physical space begins to be revealed. The experiment is taken to a point when the sound of the voice is no longer recognizable. Only the resonant frequencies of the space itself are left, and the room has become an instrument. In fact this piece can be seen as a continuous transition from the sound of one voice filtered by one space, to the resonances of that space, modulated by the original voice.

John Cage has touched poetry as everything he did. The methods to compose music are no different than the ones to compose poetry. The way of saying something should suggest what is being said, in a transition from language to music. Cage is interested in a demilitaryzation of language, by freeing it from syntaxt. Words loose their usual sense to be able to express something else. It is in this spirit that Cage owes something to Gertrude Stein. But perhaps his favorite writter was James Joyce.
In *Roaratorio : An Irish Circus on Finnegans Wake*, composed from 1976 to 1979, sixty-two tapes are played simultaneously to irish traditional music. The tape material comes from Cage's own book, *Writing for the second time on Finnegans Wake.*
Series re Moris Graves started as a series of texts to accompany an exibition of drawings of Moris Graves, a painter and friend. In *Art is either a complaint or do something else* and *What you say* (1979), Cage has recorded sentences of Jasper Johns which are subjected to computer chance operations. Each output is printed in the form of a Mesostic, in itself a kind of visual poetry much used by Cage.
In *Empty Words* the approach is even more extreme. There are four parts in which the complexity is always reducing. The first part ommits sentences, the second ommits phrases. The third ommits words and in the fourth we are only left with letters and sounds. The performance of *Empty Words III* in the Teatro Lirico in Milan in the 2th of december 1977 has transformed itself into an authentic riot.

Indeterminacy consists of 90 stories from the books *Silence* and *A year from monday*. These stories are read by Cage himself while David Tudor plays extracts from the *Concert for Piano and Orchestra*. To all this, some of the tapes of *Fontana Mix* are added. They are quite explicit of Cage's interiority and philosophical thinking, his approach to music.
A particular aspect is the timing of the reading. At extremely slow speeds, speech comunicates not the ordinary, perhaps something Zen. *Diary: How to Improve the World (you will only make matters worse)* is an anarchic work of art. In it, the typography determines the electronic realization. Typography controls both the stereophonic distribution and the level of Cage's voice. Loose ideas about philosophy, anarchy, experimental and electronic music move in a sonic image lasting 6 cd's...
The nature of the revolutionary work done by John Cage can not be fully apreciated under the scope of sound poetry, but at least these examples show how far away Cage was from "being a composer" in the traditional musical sense.

As Henri Chopin, several poets were developing their individual style of reading, where the sound itself is their identity. John Cage is a paradigmatic example. The several recordings of Henri Chopin are inventive in their combination of electronics and phonemes. François Dufrene explored poetry in the form of histerical sounds, also in a very characteristic way.
Pierre Boulez has used texts of Henri Michaux in *Poesie pour pouvoir* (1958).

Language has been divided: semantics, semiotics, aesthetics.
While semantics deals with the understandable and universal and semiotics theorizes on symbols and their relationships, the aesthetic dimention becomes decisive in artistic languages. In poetry the symbols contain the semantic information (as the notes of a musical score), which has to be distinguished from the aesthetic information. The aesthetic message is transmitted as the symbols come to life, either when heard as sound (music) or read as text (poetry). By using only one symbol and transforming the typography and the visual look, it is possible to keep the semantic information while changing the aesthetic one. Concrete poetry with spatialism extend the division prose-rhyme, because not only the sounds of words are correlated (as with rhyme), but also the meanings, forms (geometrical shapes), colors, and so on usually cooperate to create a unique linguistic work of art. To investigate the relationship between form and meaning we could either look for a variety of forms with the same meaning or for a variety of meanings related to the same form. Many concrete poets refer to language as realization (as opposed to communication), a language that has ceassed to be alegoric and has become material and has opened to multiple significations. In music, Stockhausen speaks about multi-meaning forms (UCLA Lectures). All this reveals that the main problem of language is not one of meaning, but of immediacy.
The original problem of language is it's immediacy. (Walter Benjamin)
Benjamin associates this immediacy with the *magic* of language, which implies it's infinity.
The spiritual message which some language transmits cannot be limited from outside that particular language. The immediate aesthetical transmission is only equal to a linguistic one from the point of view that both are communicable. Language becomes it's own communication medium.

The painter Francis Bacon has declared to know what his paintings mean only formally. Otherwise *they mean nothing, exept what people want to read into it.* The notion of a *content of language* is put into question, but not it's communicative essence. The fact of naming things in an essential linguistic dimension. But in concrete poetry, the *sign* as a process of nomination aproaches the aesthetical process itself (Max Bense). While mathematics invents a complete symbology which should be as understandable as possible, poetry allows the double, multiple meaning which gives rise to subjectivity. Simultaneously, common language is renewed by the invention of words in every new generation.

Particularly interesting is the work of Ferdinand Kriwet. In *Apollo America* , a radio piece from 1969, Kriwet puts together recordings from the media concerning the first landing of american astronauts on the surface of the moon. In this piece as in *Voice of America* one can hear an acute perception of that time. Kriwet reveals the media from the inside, working directly with the means of mass communication. The emotionally charged discourse of radios becomes sound poetry, but also a radical social observation.
Texts written by Kriwet include *POEM-PAINTINGS*, *PUBLIT* (Public Literature) and *SEHTEXTE* (Visual Texts). Publit attempts to free literature from the book. The literature in book form constitutes no problem. However, Kriwet explored literary *notice-boards, house fronts, hoardings, signs, lorries, etc* which *remember their ideographical origin, their status before the creation of phonetics. Literature in book form is significant only when especially composed for it.*
... to stimulate new experiences in language and to convey and extend consciousness of reality, as far this manifests itself as a current of thought in language.
(In *Concrete Poetry: A World View* ,1968, Indiana University Press)

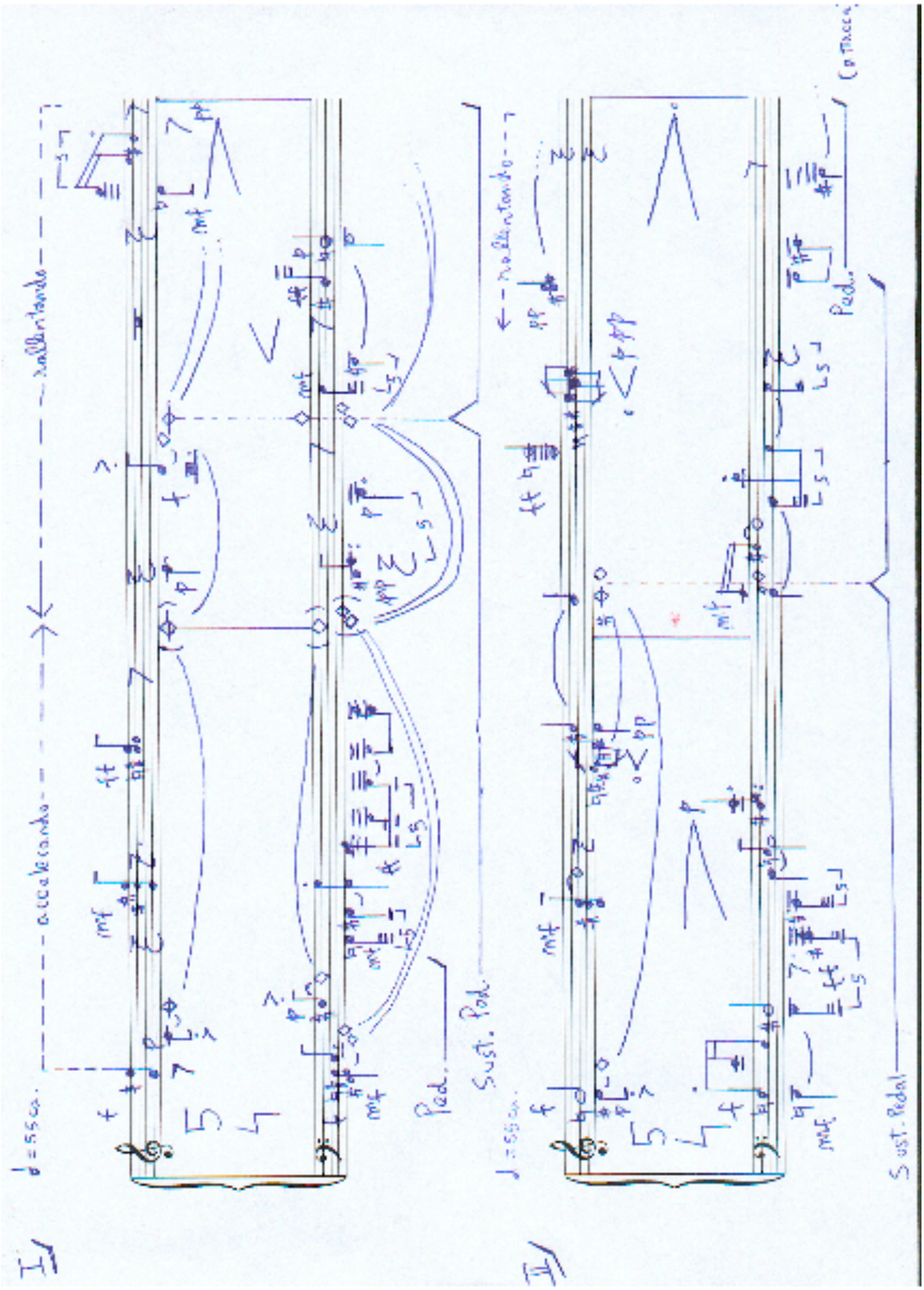
The visual poetry (SehTexte) is still linguistic, but it is open in form. No clear development is suggested. To the first look the poem assumes the form of a *sign character*, which remains it's global appearance. For Max Bense the *sign* is the aesthetic process itself, which requires a new *sign* or nomination. Already in Wittgenstein we find an extreme importance given to nomination in language. In the SehTexte the semantic content is less explicit than in the Publit, but Kriwet himself speaks of the impossiility to eliminate semantics completely.

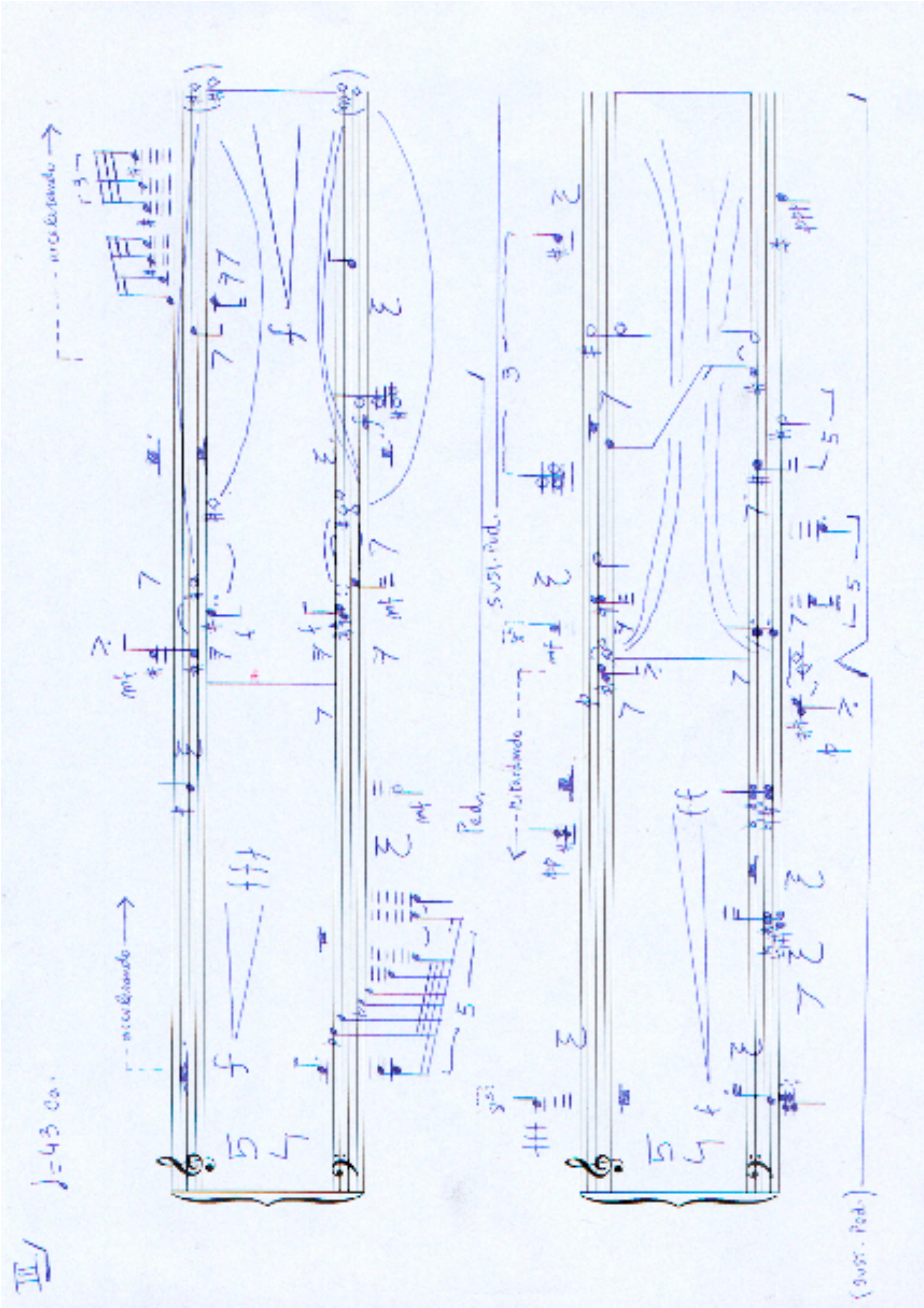
FIG 18: Ferdinand Kriwet, *Visual Text XIV* (1964)
This poem has the same immediacy as real traffic lights during the night. The 3-dimensionality is created as words and letters become volumes. Some words (as *tense* or *sight*) seem static, while others (as *drive*) appear distorted clearly because of spatial movement. The colors allow different words to superpose in space and still maintain their unity.

II - *Iconographies*

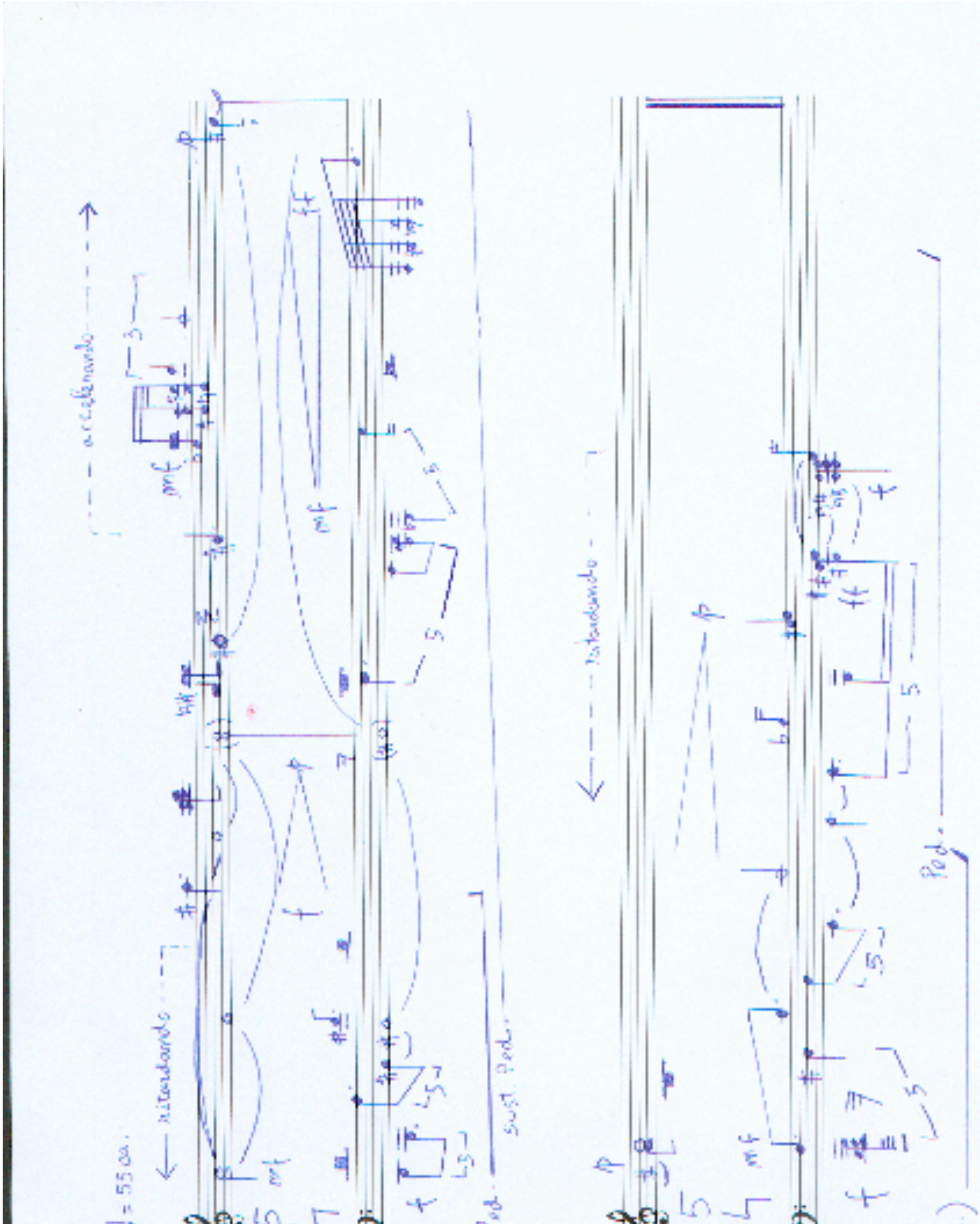
II.1 – MUSICAL SCORES

II.1.1 – *Fluxo,* for Piano Solo





III/
♩=43 ca.
accelerando
ritardando
Ped.
sust. Ped.
(sust. Ped.)



ritardando
accelerando
ritardando
Ped.
sust. Ped.
(Sust. Ped.)

II.1.2 – *The counterpoint of species,* for Flute and Electronics

NOTATION:

GRADUAL CHANGE FROM PITCHED SOUND TO A SOUND WITH PREVALENCE OF BREATH (with LITTLE OR NO PITCH)

SOUNDS PRODUCED

FINGERING

INDICATES A "SWEEP" OF THE SPECTRUM FOR A SINGLE FINGERING. THE SOUNDS PRODUCED ARE NATURAL HARMONICS.

OR FLTZG.

FLUTTER TONGUE. SEVERAL SPEEDS ARE USED, SOMETIMES WITH ACCOMPANIED GRAPH: FLTZG LENTO. IN THIS CASE, THE RESULT SHOULD BE A SLOWLY MODULATING AMPLITUDE, FADING IN AND OUT.

KEY-PERCUSSION

"QUASI-PIZZICATO" (TONGUE WITH NO SUBSEQUENT BREATH PRESSURE)

"TONGUE-RAM" (VIOLENTLY CLOSE THE HOLE OF THE MOUTHPIECE WITH THE TONGUE WITHOUT EXPIRING AIR)

MOUTHPIECE POSITIONS: ■ = TONGUE IN MOUTHPIECE | ⊡ = BLOCKED BY LIPS

□ = NORMAL PLAY | ⊔ = MOUTHPIECE AT DISTANCE

FLUTE TURNED OUT AS FAR AS POSSIBLE

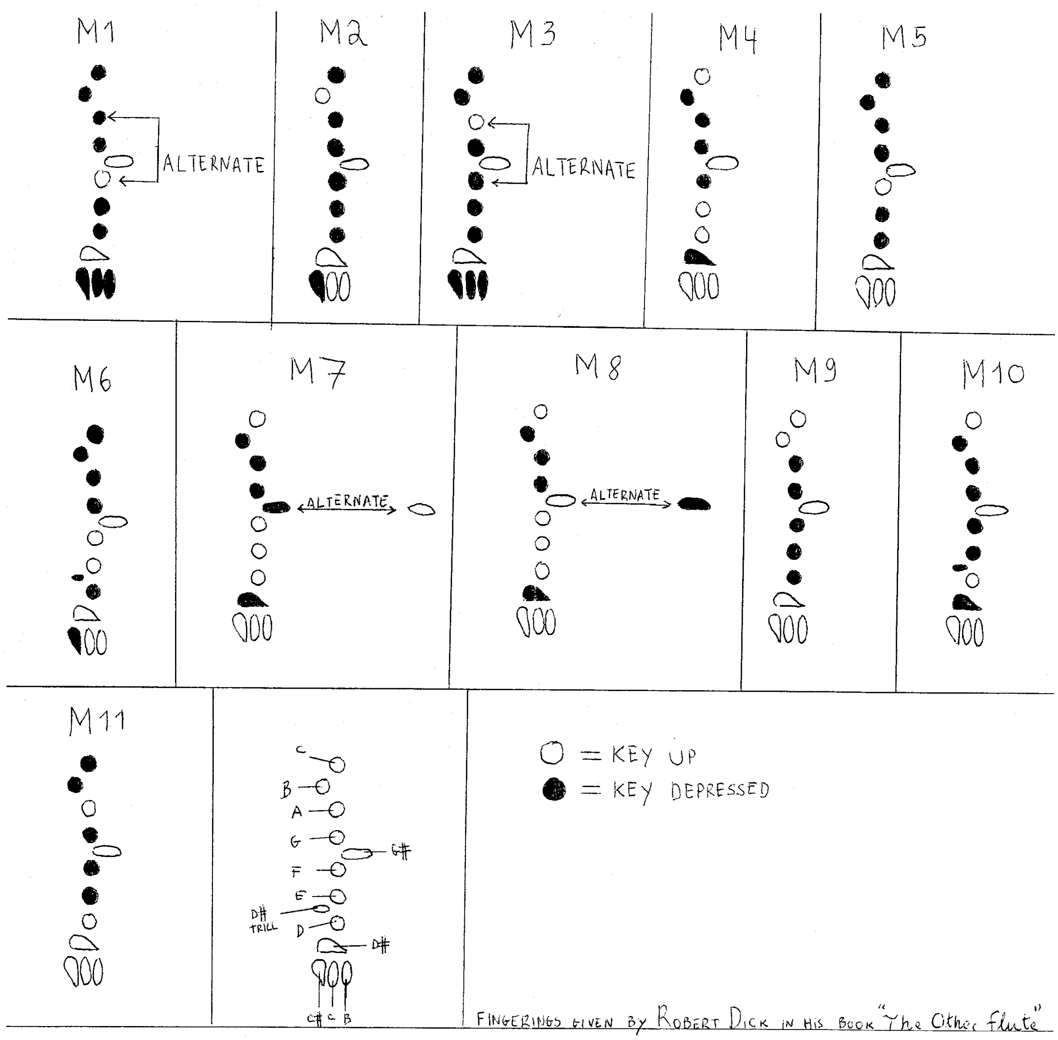
FINGERING [i] [u] FLUTE TURNED INWARDS AS FAR AS POSSIBLE

VOWEL SHAPE OF THE MOUTH

"JET WHISTLE" (PRESS LIPS AGAINST EMBOUCHURE PLATE SO THAT NO AIR ESCAPES AND BLOW DIRECTLY INTO THE FLUTE. THE RESULTS ARE RESONANCES OF THE TUBE)

SING AND PLAY IN UNISON | SING AND PLAY SIMULTANEOUSLY AT THE SPECIFIED INTERVAL

A.F. = ALTERNATE FIN…

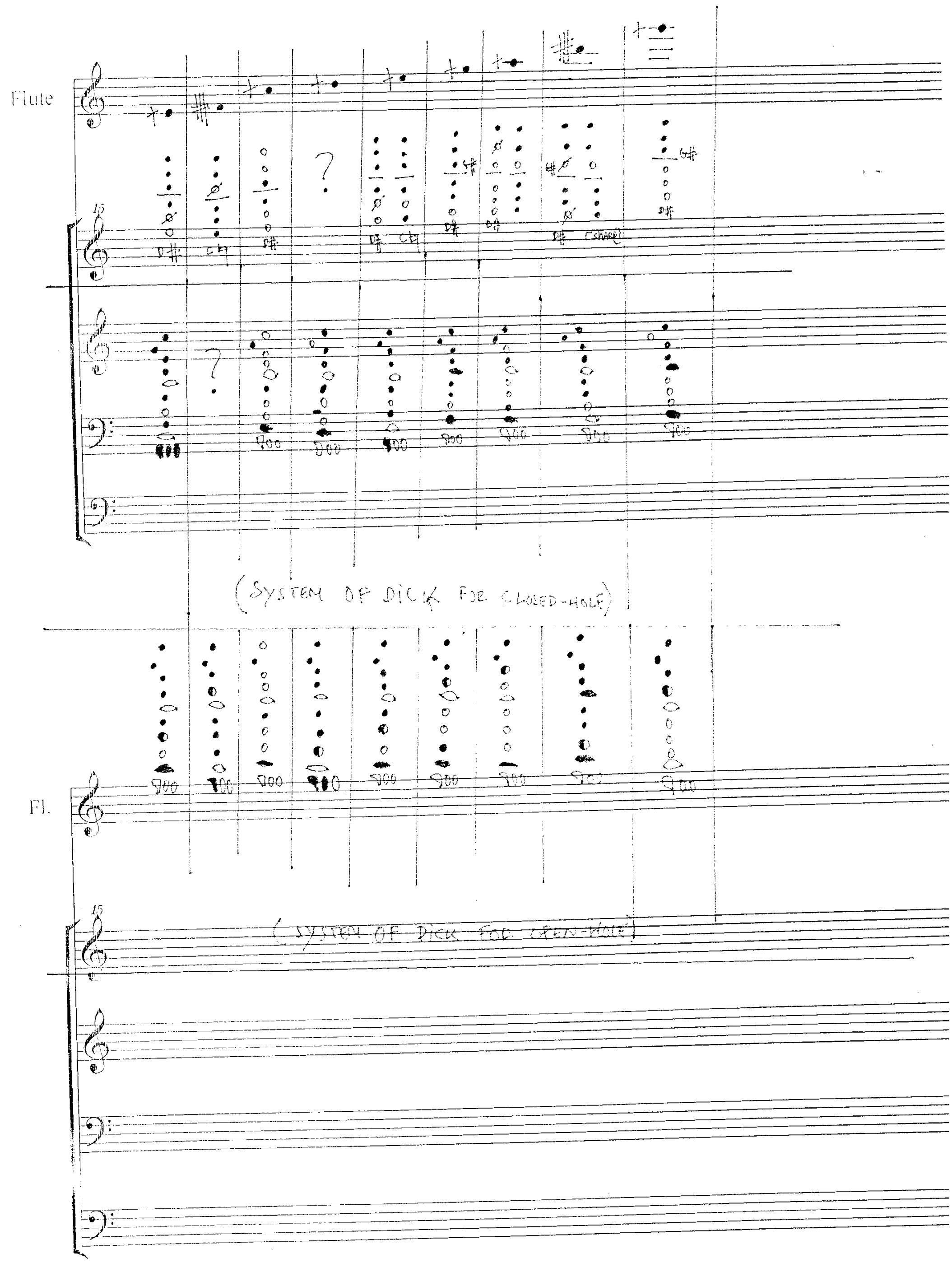


MULTIPHONIC FINGERINGS

FOR [illegible] FLUTE

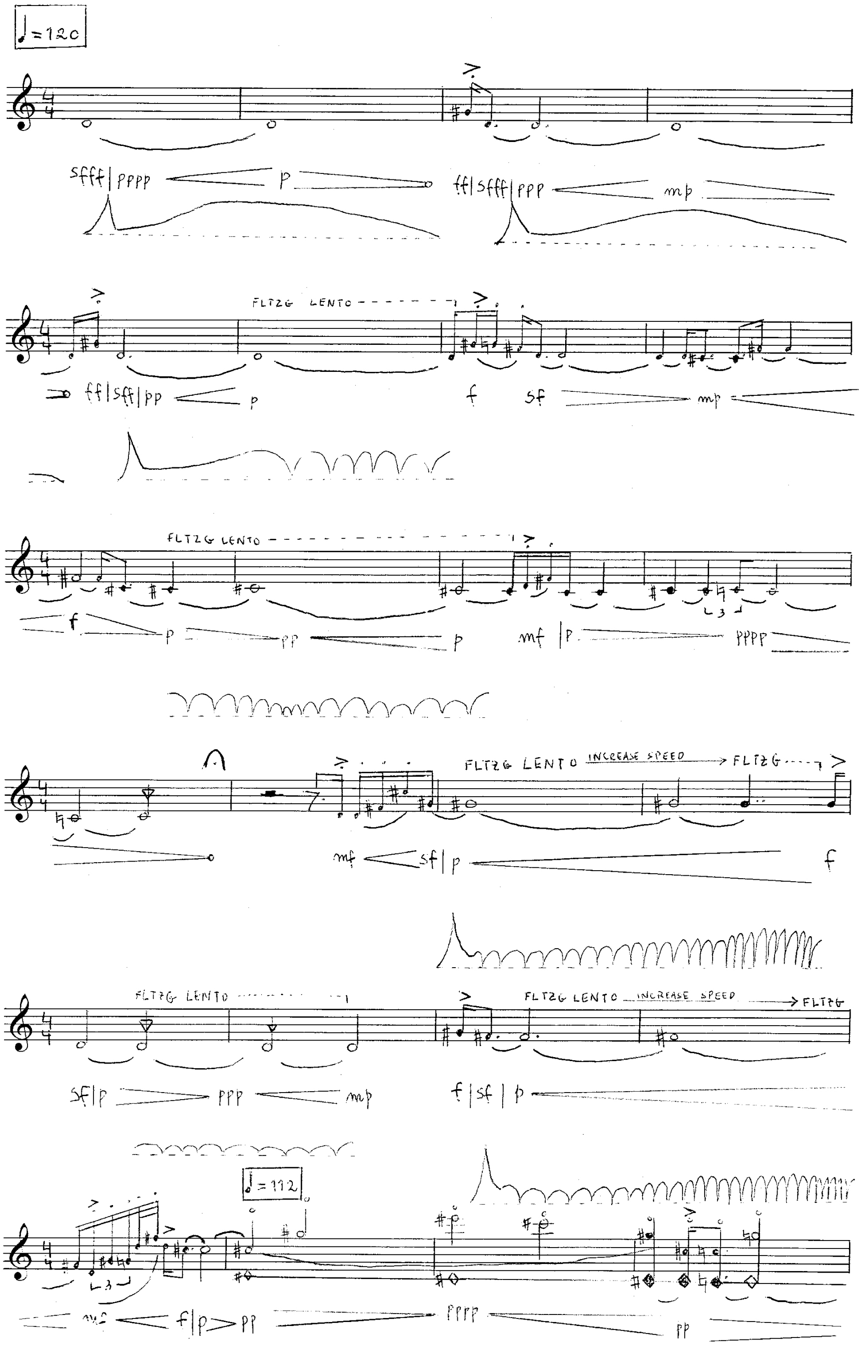
WITH B FOOT

[FINGERINGS FOR QUARTER TONES] (SYSTEM OF HOWELL)



ALTO FLUTE IN G

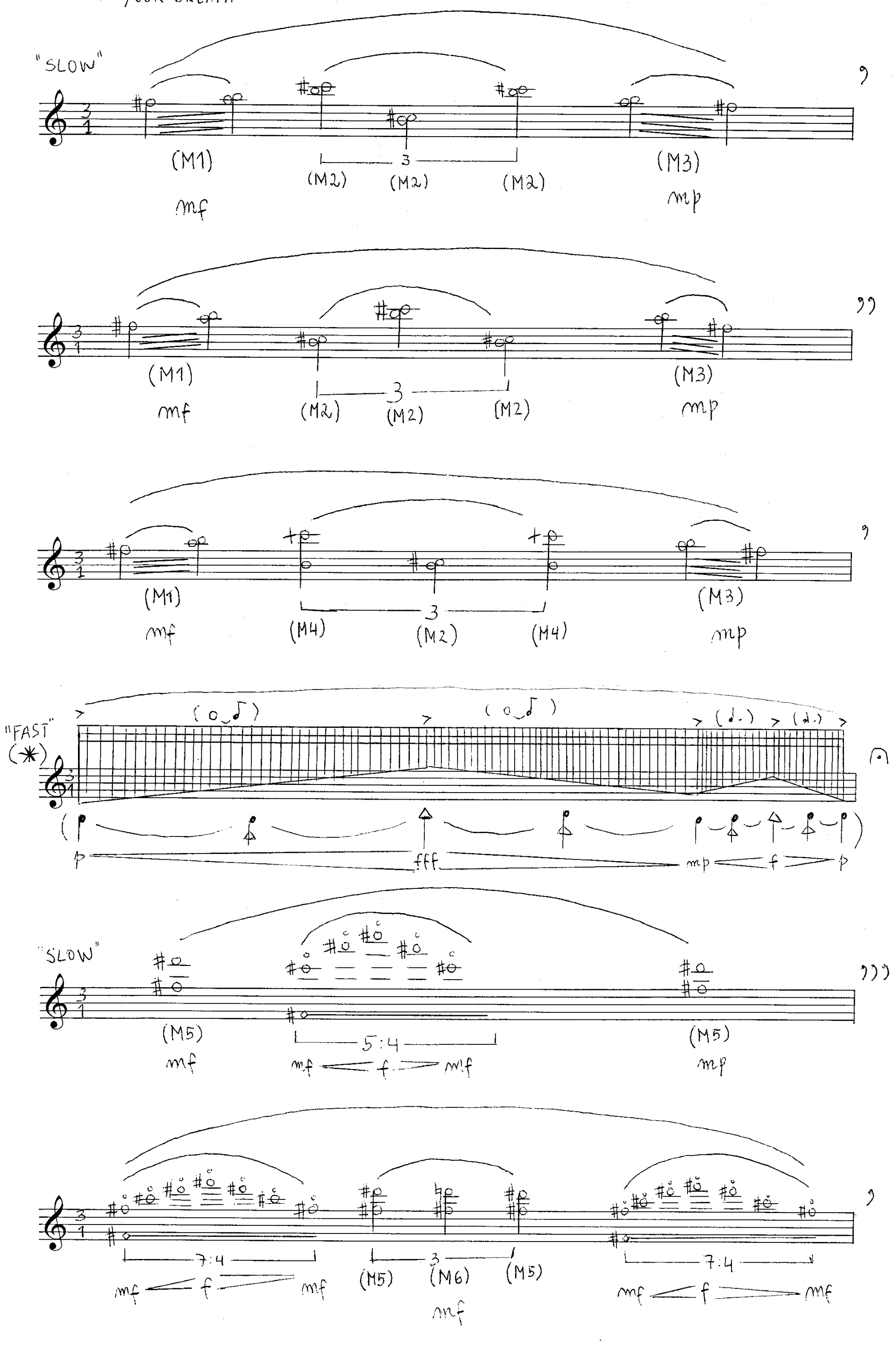
JOÃO CARRILHO

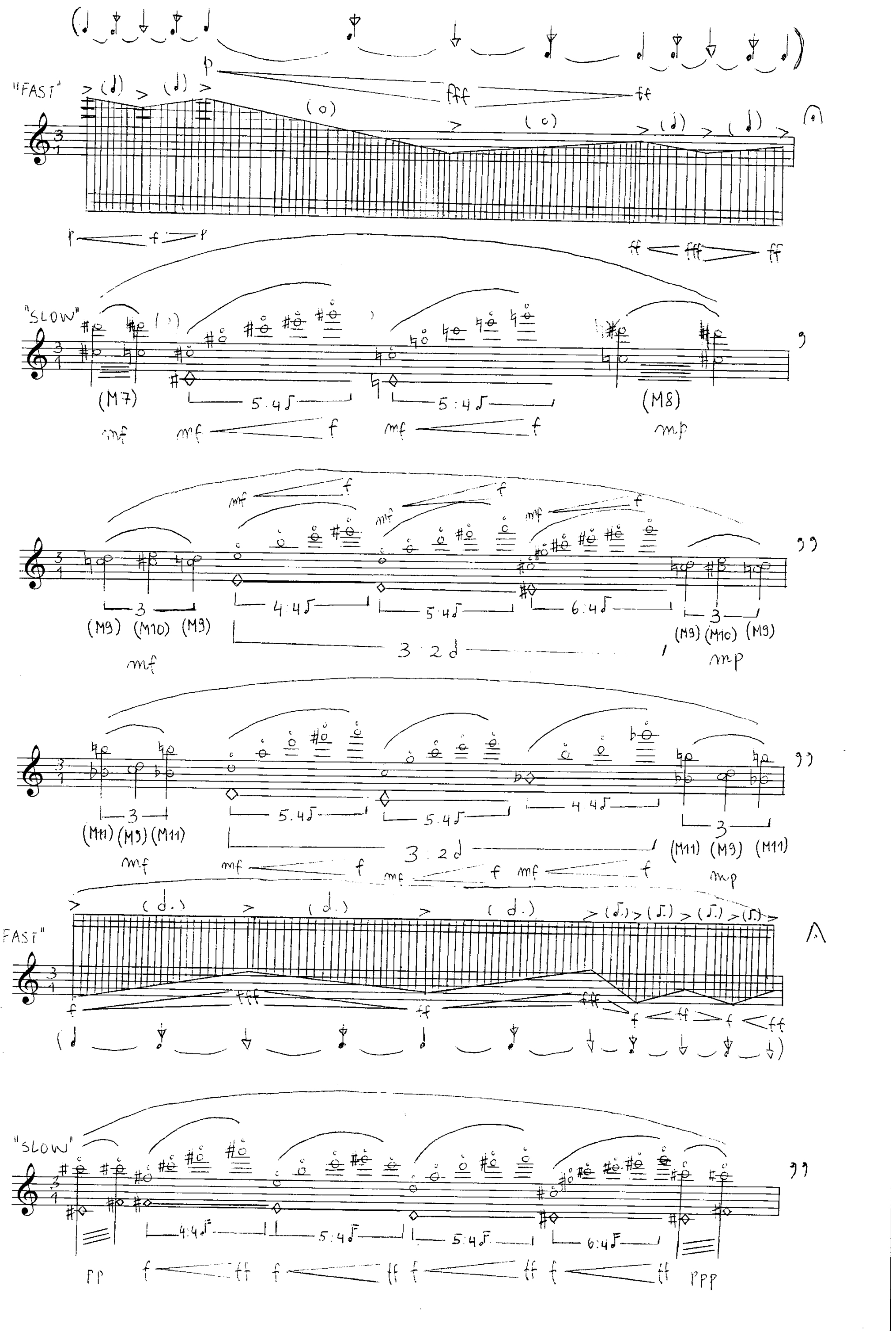


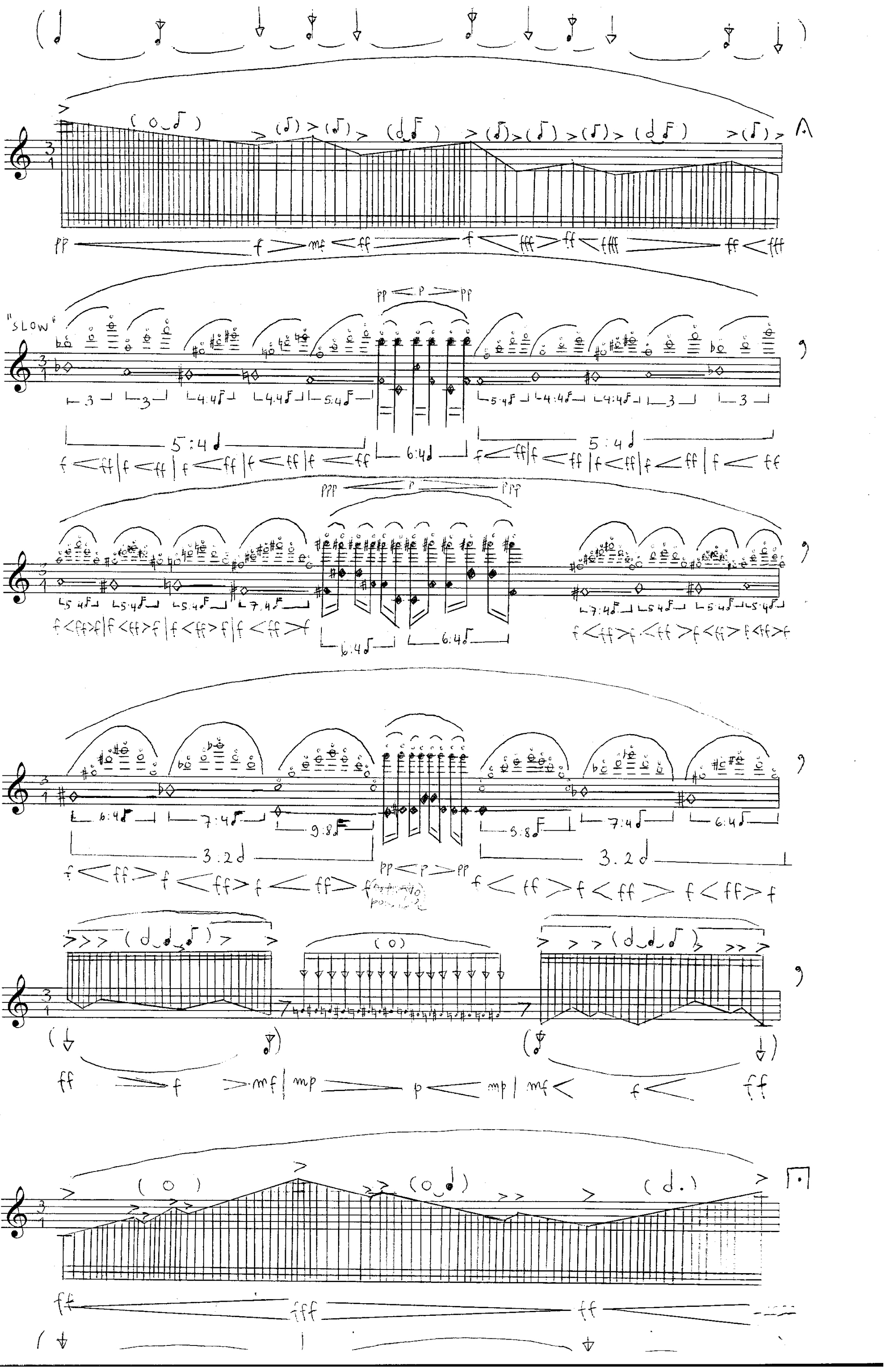
JOÃO CARRILHO
2007

ORD. FLUTE IN B

FOLLOW YOUR BREATH

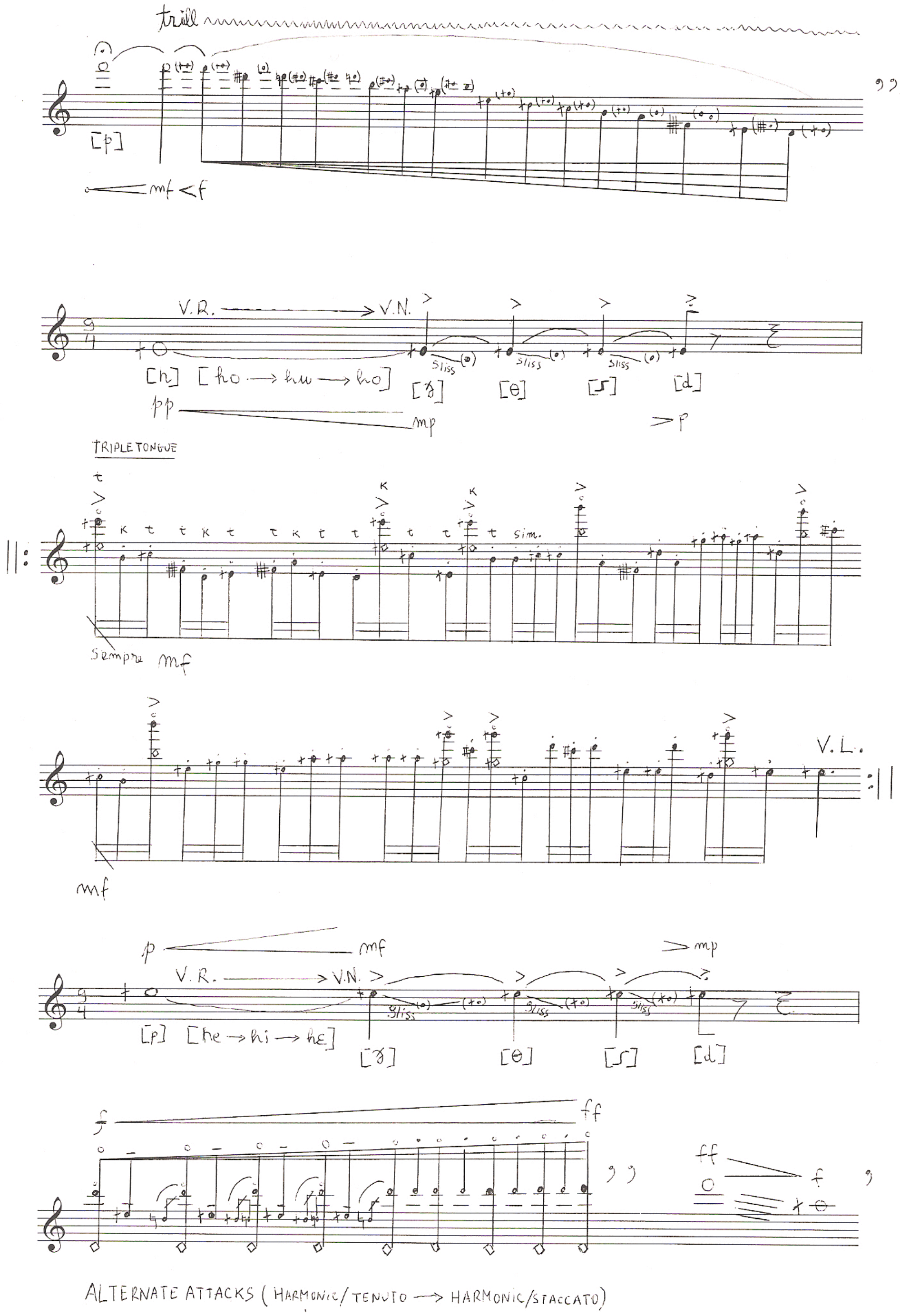


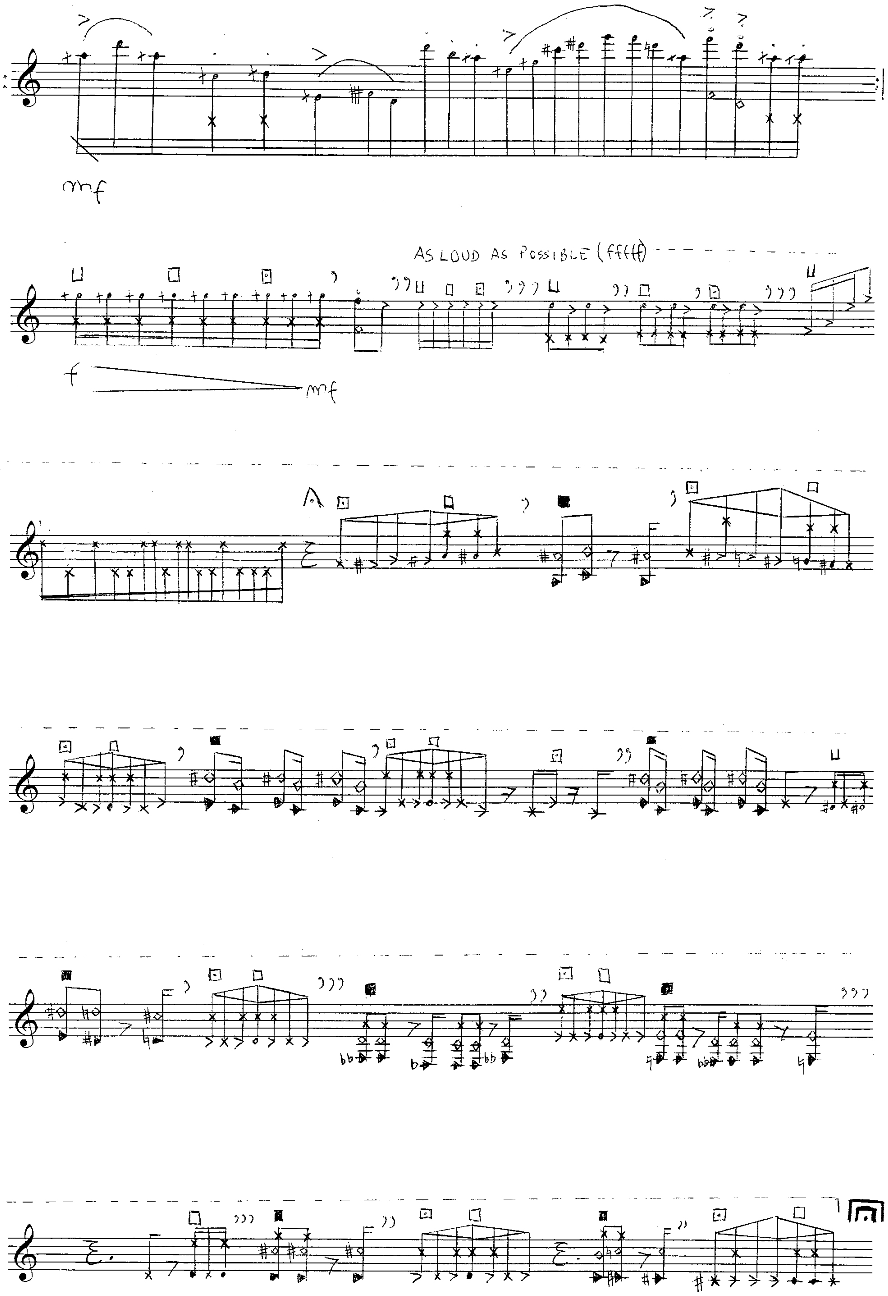

"FAST"
"SLOW"
(M7)
(M8)
(M9) (M10) (M9)
(M11) (M9) (M11)
"FAST"
"SLOW"

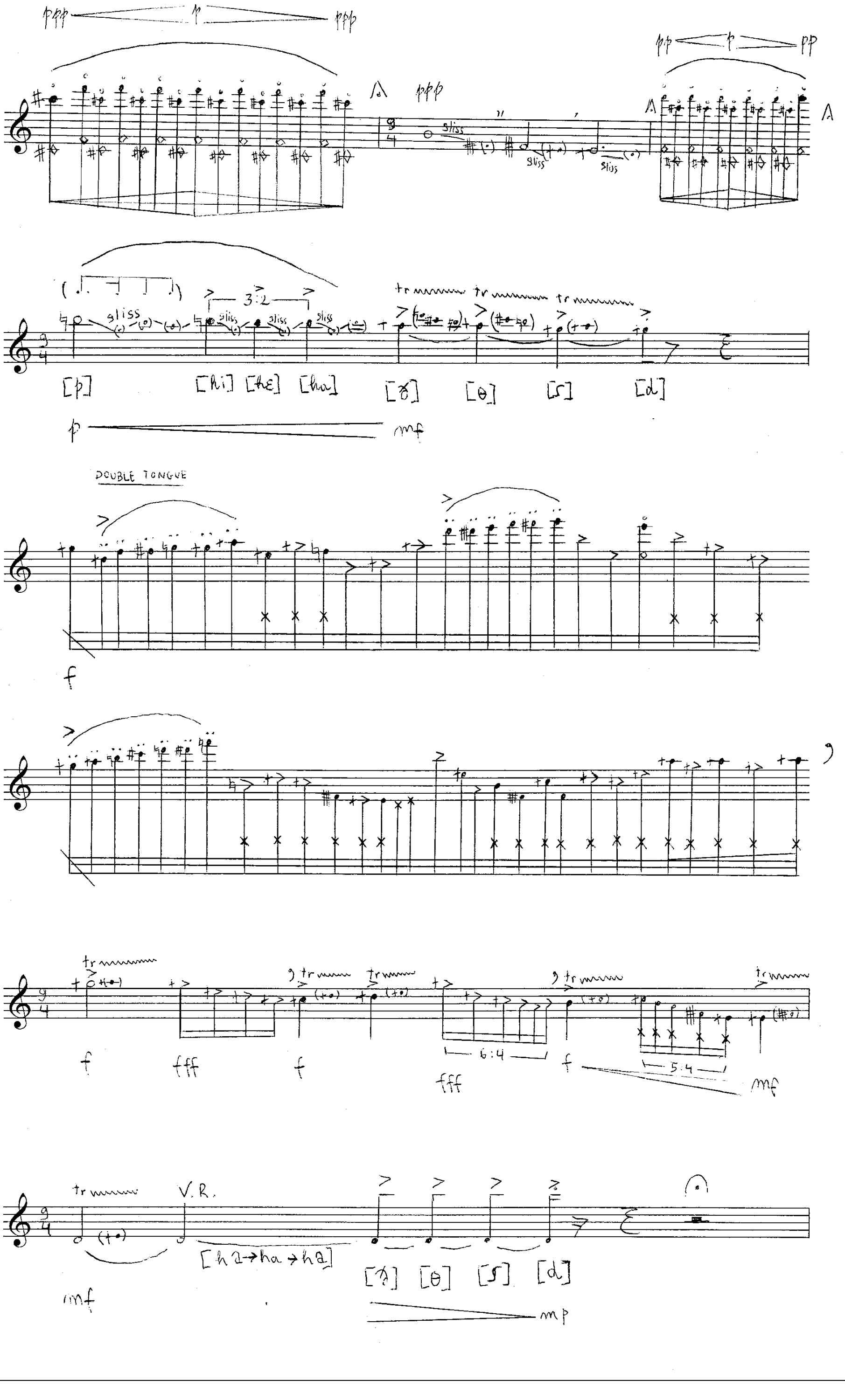

"SLOW"

PICCOLO

JOÃO CARRILHO
2007




mf
f
mf
AS LOUD AS POSSIBLE (fffff)


gliss
3:2
DOUBLE TONGUE
6:4
5:4
V.R.

III - *Informatics*

III.1 – COMPUTER- AIDED COMPOSITION USING *MATHEMATICA*

III.1.1 – *Compositional Systems*

First Metaphor : - *CLASSIFICATION OF ANIMALS* from the chinese encyclopedia, Celestial Emporium of Benevolent Knowledge (as quoted by Borges, in The analytical Language of John Wilkins)

- 1.those that belong to the Emperor,
- 2.embalmed ones,
- 3.those that are trained,
- 4.suckling pigs,
- 5.mermaids,
- 6.fabulous ones,
- 7.stray dogs,
- 8.those included in the present classification,
- 9.those that tremble as if they were mad,
- 10.innumerable ones,
- 11.those drawn with a very fine camelhair brush,
- 12.others,
- 13.those that have just broken a flower vase,
- 14.those that from a long way off look like flies.

Intelligence is an ability to discriminate, to distinguish. The "game" of composing music is always at the middle of two activities: *Invention* (foresee) / *Discovery* (start a process).
In Classical composition, there were always systematic processes, having *Classification* and *Representation* as proeminent atributes.
While traditional notation reveals the formalized aspects of *Representation*, the classifications of each composer can vary. The above mentioned metaphor for the classification of animals suggests more the creativity of it's author than any practical use for it.

In music composition, the practical use of any classification is to order and render fruitfull the composer's creative process. If the compositional process is systematized in function of a *general conceptual framework*, than we can speak of a *Compositional System* : a collection of *operational* techniques acting on musical material. In the field of traditional composition, these *operational techniques* are expressed as *writing techniques* (for example, techniques specific to a *choral* or a *fugue*). An *operational technique* is simply a useful direction in the compositional process. It can range from the most strict determinism, and rule-based systems, to vague ideas or indeterminate principles. *Operational techniques* are used to shape the material in the context of a piece.

Musical Information Organisms are an example of a *compositional system*.
They appeared linked to research on conginitive psychology and have interested composers as Boulez, Manoury or Stroppa.
The metaphor is a biological organism with complex behaviour.

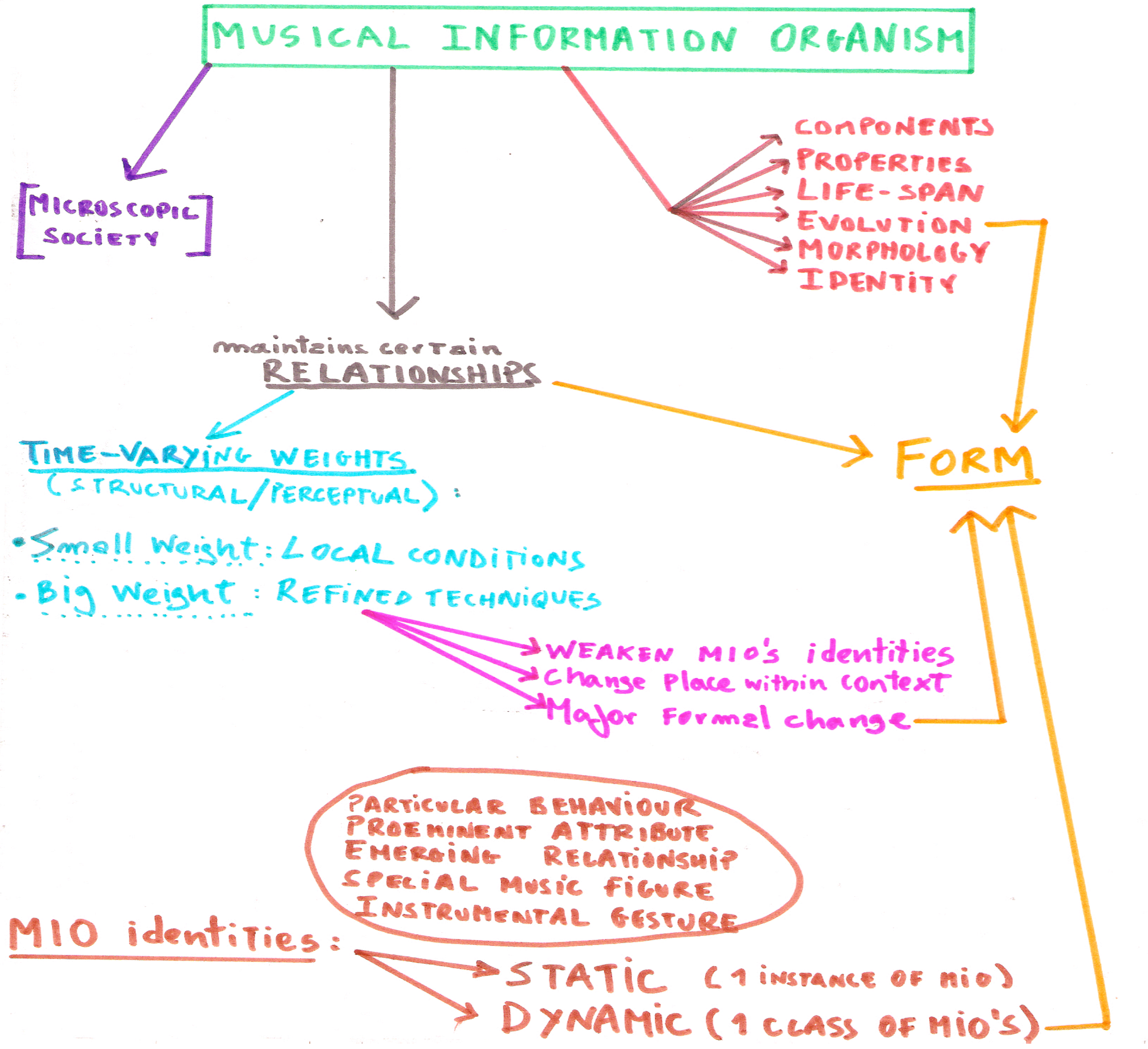


FIG 19: A schematic discription of a *Musical Infromation Organism*
The basic level of musical composition is a MIO Identity (a particular behaviour, an instrumental gesture, ...) and not any pre-compositional material, such as pitch or rhythm tables. This identity is intself a microscopic society, with components, properties, a life-span, and so on, maintaining certain relationships in time. A piece of music is considered as a macrosociety of such organisms, and the composer as someone who studies it's sociology.

III.1.2 – *Compositional tools in Mathematica*

My musical use of the computer has 3 different contexts:

1) computer-aided composition
2) sound transformation, montage and electronic composition
3) improvisation and live-electronics

I have programmed an environment using *Mathematica* to deal with the first of these contexts. It is a part of my research for a personal *compositional system*.
The functions are grouped in a *mathematica package*.

There are 4 main sections in the program:

INITIALIZATION

CONTROL

COMPOSITE RHYTHM MATRICES

SIMULTANEITY STUDIES

The most general methods are the micro/macrotansformations found in the *Composite Rhythm Matrices* section, which use modules found previously, either in the *Initialization* or the *Control* sections.

The main idea behind the programming is **TIMING,** because it is time which unites all other perceptions

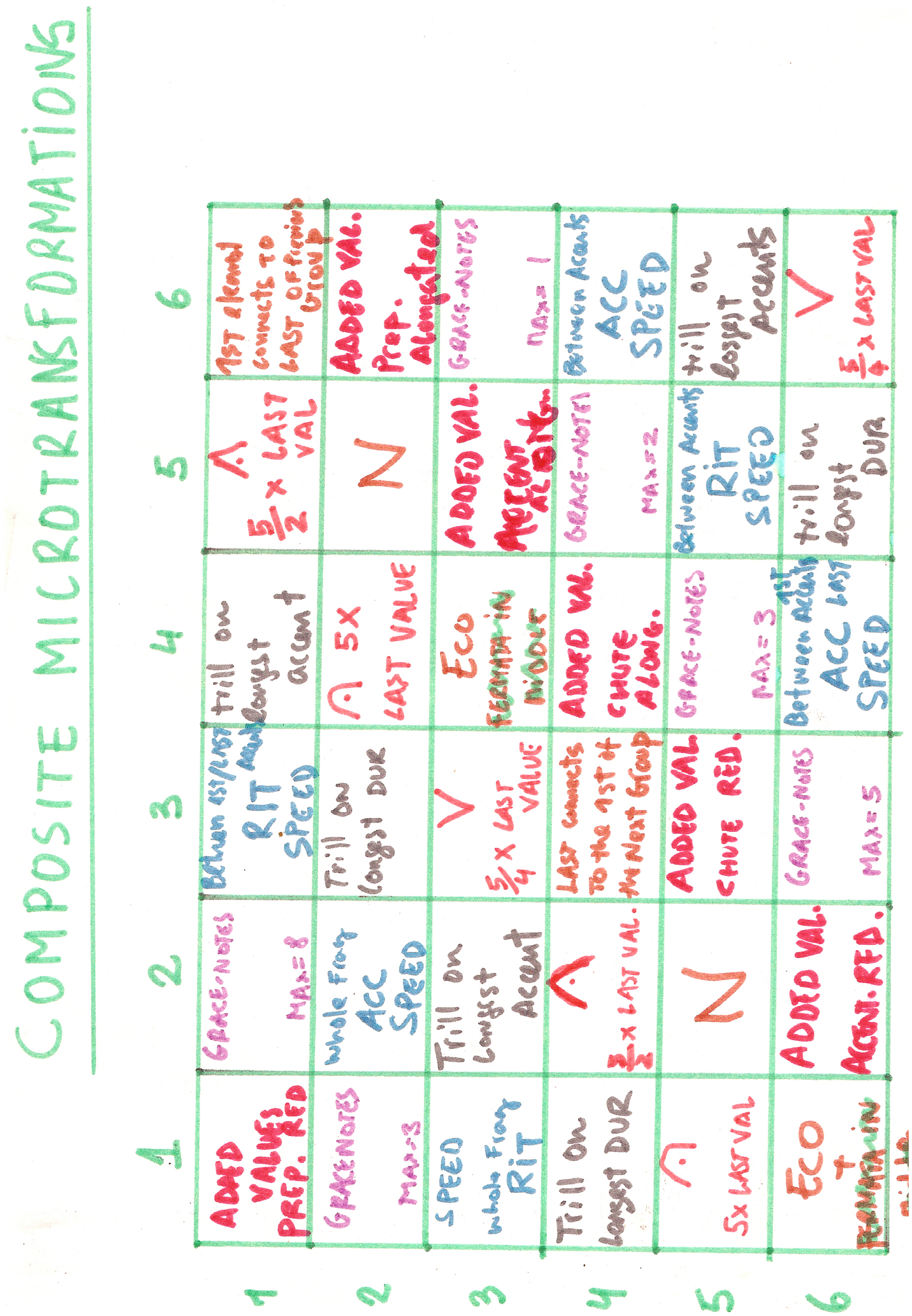


FIG 20: A schematic representation of the Macrotransformationa Matrix found in chapter III.2.3.1

III.2 – DOCUMENTATION

III.2.1 – *Initialization*

NOTE : In this documentation the functions are in bold, and their parameters come either afterwards (in parenthesis) or immediately below.

III.2.1.1 – *Packages*

<<Graphics`Graphics`
<<DiscreteMath`Combinatorica`
<<Statistics`DataManipulation`
<<Statistics`MultiDescriptiveStatistics`
<<Statistics`DiscreteDistributions`
<<Statistics`ContinuousDistributions`
<<LinearAlgebra`MatrixManipulation`
<<"~/Musica.m"
<<Miscellaneous`Music`

III.2.1.2 – *Global Variables*

TempoMarking (rythmic unit , BPM) can go to Text Files or CSound Scores .

PperQ= DIVISION OF MIDI FILE = N° of TICKS PER QUARTER NOTE

Dynamics (ppp - fff)

TempoMarkings: (LARGO = 40 to PRESTISSIMO= 220) BPM

TEMPO MARKING (rythmic unit,BPM refers to TEXT FILES

PperQ=DIVISION OF MIDI FILE=N° of TICKS PER QUARTER NOTE
DYNAMICS

TEMPO MARKINGS
Largo 40-59
Larghetto 60-66
Adagio 67-72
Lento 73-78
Andante 79-88
Moderato 89-109
Allegro 110-129
Vivace 130-149
Presto 150-190
Prestissimo 190-220

DYNAMICS :

ppp=34	pp=40	p=48	mp=56	mf=64
f=80	ff=100	fff=127		

III.2.1.3 – *Importing and Exporting*

To WORK only with MIDI CC it is fine to use:
Event Sequence [Controller [cc (i), value(i) , channel (i)], step (i) , {i, imin, imax}, PPQ]

PROPTOMID
l = List of Proportions to be Converted to N° of Ticks (Integer) according to the global variable PperQ = Internal Division of Midi File = N° Ticks / quarter note

MIDIEXPORT
lm = List of MIDI Commands
outname = output file name

MAKENOTES / MAKECHORDS
lr = List of Rhythms
lp = List of Pitches/Chords
lv = List of Velocities
lc = List of Channels

A MIDI FILE GETS INTO A SEQUENCE FILE, consisting of:
-start time
-pitch
-amp (127=original volume)

PROPTOSEC:
l = List of Proportions to be Converted to Seconds, according to the global variable TEMPO MARKING
DisplayCSound (For Displaying what kind of tables we put in CSOUND)

NormToCSound (Convert a list of amplitudes from normal to CSound type Norm=(0-1) CSound=(0-32767))

EXPORTCSOUND:
lf = List of Functions
lp = List of Parameters
scorename

III.2.1.4 – *Mathematica to Lisp*

MtoL = Convert a List from Mathematica to Lisp Notation

III.2.1.5 – *Recsale / Shake / Lens / Interpolations / Correlations*

ReScaleL :
l = Input List
ref ={min,max}

ReScaleM :
l = Input Matrix
lref = {{min1,max1},{min2,max2},.......,{minn,maxn}}

Shake :
l = Input List
d =Length of partitions in which l is subdivided. Each partition is randomly permutated

simi (Correlation)
l = Input List
sim = Similarity Degree (-1,1) of the output

interpr (Interpolation):
ir = List of Initial Values
fr = List of Final Values
ip = Interpolation Parameter (1 = Linear >1 = Exponential <1 = Logarithmic)
n = N° of Steps

NOTE : Length[ir] should be = Length[fr]

Lens :
lin = List of Initial Values
fp = Focal Points (Min,Max)
ip = Interpolation Parameter (1 = Linear >1 = Exponential <1 = Logarithmic)
n = N° of Steps

III.2.6 - Conversions

mtof , mtob , ftom , ftob , btof , btom functions to convert from Midi <> Frequency <> Bark

FR: Filter Repetitions in a List

CriticalBand : Gives the critical bandwidth for a given center frequency

cton & ntoc : convert midi notes between numerical and alphabetical classification

III.2.2 – *Control*

III.2.2.1 – *RHYTHM*

III.2.2.1.1 – *Single Rhythms*

These functions can be used to transform/generate single rhtyhms, they are used with the command **Single***, where * is a number from 1 to 4:

1 - ADDED VALUES l = Input Rhythm
typeA = 0/1 : Precipitation of Accent/Retard of Accent VS. Random position

typeB = 0 : RANDOM typeB = 1 : NOTE
typeB = 2 : SILENCE typeB = 3 : POINT

2 - TABLE OF AUGMENTATIONS/DIMINUTIONS
l = Input Rhythm
maxfactor = the max expansion/compression in relation to the original \ : <= 10

3 - INEXACT AUGMENTATION/DIMINUTION OF A RHYTHM (l, maxfactor, typeA, typeB)

4 - RECURSIVE INEXACT AUG/DIM (l, n°recursions, maxfactor)

NON - RETROGRADABLE RHYTHMS :

NonRetro : Generate a Non - retrogradable from a given rhythm

GenNR : given a base of possible values construct different non-retrogradable and sort them by total duration -
type 0 : random values from the base
type1 : random values from Table of Augmentations)

III.2.2.1.2 – *Ornamentation*

These functions can be used to add ornamentation to a list of rhythms.
They are used with the command **Ornate***, where * is a number from 1 to 6:

1-SPEED: (CREATES ACCELERANDOS & DECELERANDOS)
l = INPUT RHYTHM
f = SPEED FACTOR TO APPLY
s = Starting Ryhtmic Value
e = End Rythmic Value

can also be used to modify chords (expand or compress)

2 - ARPEGGIO :
lr = LIST OF RYTHMS
la = LIST OF ARPEGIOS

3 - GRACE NOTES :
lr = LIST OF RYTHMS
lg = LIST OF Nº of GRACE NOTES
ls = LIST OF SPEEDS (< 1 decelerando ; 1 = const ; > 1 accelerando)
lc = LIST OF CENTERING NOTES

4 - GRACESPPEDC :
Same as GRACE NOTES but with constant speeds

5 - RHYTHMIC INVERSION : retains the first value but inverts the proportion of all other values to this one

6 - GROWTH:
Implies a change in the feeling of the beat: (slower or faster, with some relation between the rhytms)
lr = input rhythm
up = the rhythm is moved right / left (1 / -1)
ad = the rhythm is augmented / diminuted (1 / -1)
n = nº of steps to shift

III.2.2.1.3 – *PolyRhythms*

These functions can be used to transform/generate polyrhtyhms. They are used with the command **PolyR***, where * is a number from 1 to 7:

1 - RHYTHMS WITH DIFFERENT DURATION (repete todos os ritmos até regressar à fase inicial)

2 - RHYTHMS WITH IT'S OWN VARIATIONS (O ritmo é repetido e sobreposto às aumentações/diminuições)

3 - RHYTHMS WITH IT'S RETROGRADE (o retrógado pode ser introduzido com delay)

4 - CANON OF RHYTHMS (rhythms in parallel with delays = negative offsets)

5 - CANON BY ADDED VALUE (rythm vs a variation of itself in cannon)
type = 0 : Simple Compression Expansion
type = 1 : Inexact AugDim

6 - CANON OF NON - RETROGRADABLE RHYTHMS
(base of possible values, nºfigures in NR, construct non - retrogradable and put it in CANON)

7 - RHYTMIC PEDAL

III.2.2.1.4 – *Structures*

Generate structures or distribute the actual voices in a new number of voices.
These functions are used with the command **Structure*** , where * is a number from 1 to 6:

1- METERS / BEATS
c = list of meters
b = list of nº of beats in each meter

c >= b <= slow down
c<=   b >= speed up

2 - CELLULE REPEATED AND RANDOMLY DIVIDED
barsg = Nº of BARS OF GENERATING CELLULE
barsmultiple = TOTAL NUMBER OF BARS (should be a multiple of generating nº of BARS)
z = EACH whole note IN THE CELLULE CAN BE DIVIDED IN BEATS OF A MAXIMUM OF 1 / Z
beatlist = EACH BEAT CAN BE SUBDIVIDED IN ANY VALUE FROM BEATLIST
timesignature : ALL BARS HAVE THE SAME LENGTH AND THUS THE SAME TIME SIGNATURE

3 - SPREAD RHYTHM AMONG VOICES (Voice Take over Rhythmic Value)
ld   = LIST OF DURATIONS
lv   = LIST OF BASIC DURATIONS MULTIPLIER FOR EACH VOICE max = Total Nº of bars
ts = TIME SIGNATURE

4 - REMULTIPLICATION (blur by repetition)
lr = INPUT RYTHM
ld = LIST OF DISTANCES BETWEEN REPETITIONS IN RELATION TO THE TOTAL DURATION OF INPUT RYTHM (= 1)   (SHOULD CONTAIN VALUES >= 0)
lrep = LIST OF NUMBER OF REPEATED RYTHMS IN EACH REPETITION
lspeed=LIST OF SPEED BALANCE (ACC/DIMIN) OF EACH REPETITION

5 - REMULTIPLICATION WITH OVERLAPS -> CREATE SEVERAL VOICES (blur by repetition)

6 - CUMULATIVE VOICES
l=pattern to be repeated
n=n°of output voices

III.2.2.2 – *SCALES*

III.2.2.2.1 – *Microtonal Modes of Limited transposition*

These functions extend the ideas of Olivier Messiaen into the microtonal or to any desired step sizes:

MESSIAEN :
modunit = { modulus (in MIDI) , unit (semitones) } mode = This mode of limited transposition has a maximum of mode transpositions
degree = Several Solutions can be found, the degree in the solution n°
minmax = { start (in MIDI) , end (in MIDI)}

LISTENMESSIAEN : Export a Midi File with notes up & down in the chosen mode

MESSIAEN COHERENCE : Intersection of 2 modes

III.2.2.2.2 – *Scales employing specific step sizes*

findweights:
CREATE SCALES OF M NOTES WITH MODULUS = TOTAL, using available step sizes
steps = list of steps to be combined
tot = total
m= n° of steps to archieve total fweights : same as above but for every sublist of original patterns (minimum 2 patterns)

basecycles : Gives the basic cycles (= scales)

cocyclic : From one basic scale give the related scales

III.*2.2.3 – PITCH*

III.2.2.3.1 – *Harmony*

Harmonicity:

totdis (chord)
Give DISSONANCE of a chord (assuming harmonic spectrum)

newtotdis (chord,np)
Give DISSONANCE of a chord (assuming harmonic spectrum with np partials)

newtresh:
(GENERATE ONE CHORD)
a = lowest possible midi pitch
b = highest possible midi pitch
v1 = lowest possible dissonance
v2 = highest possible dissoanance
n = n° of notes in the chord

GN :
(Mutation of the input Chord with controlable random deviation of lowest and highest note plus the dissonance)
l = INPUT CHORD
nota = ± Max Rand deviation of lowest & highest pitch
dis = Max Rand Deviation in Dissonance

GNiter:
(iteration version of the above, with the same parameters plus the number of iterations)

Wa :
(WALKS IN DISSONANCE CONTROLING:
ls = STARTING CHORD
o = output
p = list with PITCH DEVIATION of LOWEST and HIGHEST NOTE compared to the previous chord
q = list with DISSONANCE DEVIATION of Next CHORD compared to the previous

Chord Evolutions:

sdr: (chord)
Give The SURFACE / DENSITY / ROUGHNESS of a Chord
SURFACE = Range in Semitones ;DENSITY = Average notes per semitone ;
ROUGHNESS = Measure of how regularly spaced the chord is.

Inv : (chord, direction)
Generate a NEW CHORD and keep the same intervals that compose the chord
direction = starting point will be a (possibly octave tranposed) note of the original (at position direction in chord)

addn : (chord)
Generate a NEW CHORD by adding notes from the input

remn : (chord)
Generate a NEW CHORD by removing notes from the input

givenewchord: (l = input chord)
Generate a new chord using **Inv**,**Addn**,**Remn,**:

recgivechord:
(Generates chords recursively, using the **givenewchord** function)
li = input chord
n = total n° of chords

nextc:
(l = input chord, h = ± dissonance, s = ± surface, d= ± density)
Generates a new chord with control over the increase/decrease of dissonance, surface and density

recnextc: same parameters as **nextc** plus the n°iterations

ChordEvol:
Generate an evolution of chords
(l = input chord, lh = list of dissonances, list of surfaces, list of densities)

III.2.2.3.2 – *Melody*

TONAL CLARITY: given a certain KEY (= note), and a scale, give the priority of the notes in the scale for max tonal clarity, i.e. how far they are from the harmonic series of the KEY. This method is used in a statistical sense.
K=Input Key
S=Input Scale
TC= Tonal Clarity (0-1)
Ol=Length of output

GenShapes:
Generate melodic shapes using Sine, Triangle, Square and Sawtooth waves as basic functions. The parameters are the N° of inflections in a generated shape (dimensionality) and the discontinuity degree (continuous means the inflections start and end at the same point)

ComputePitch: (start, lgliss, out, n)
Generates controllable random walks in the pitch *continuum*.

III.*2.2.4 – SERIAL TECHNIQUES*

AI : Generate an all-interval series (no parameters required)

AIQ : (input series)
test if a series is an all-interval series.

DerivedSet (input series)

R, RI, IR (input series)
give the Retrograde, the retrograde of the inversion, and the inversion of the retrograde, respectively

tonerow (input series)
constructs a matrix according to the principles of classical serialism.

InternalV (input series)
Gives the internal intervallic vector of that series

III.2.2.4 – ARTICULATIONS, ENVELOPES AND DYNAMICS

EvlCyclic : repeat an envelope n times

AttDec / EvlDecay : generate envelopes of type attack/resonance based on the LogNormal distribution
N= Max Length of the envelope

III.2.3 – *Composite Rhythm Matrices*

III.2.3.1 – *Microtransformations*

Applytransformations (list of rhythms, list of accents)

This is a general transformation method that can be applied to single durational values (each one has it's own velocity value) or matrices of 6 x 6.
In either case the result is a *Composite Microtransformation Matrix*, which should contain all the possible transformations on a single list of (rhythm,dynamics) that:

a) do not change the total duration substantially
b) are exclusively monophonic

To build the transformations, several modules from *CONTROL (III.2.2)* have been combined. Among them :

a) Added Values, consisting of accelerated/retarded attacks and/or endings
b) Grace Notes
c) Accelerandos
d) Trills
e) Ecos
f) Null

III.2.3.2 – *Macrotransformations*

Applymacrotransformations (list of rhythms, list of accents)

This is a general transformation method that can be applied to single durational values (each one has it's own velocity value) or matrices of 6 x 6.
In either case the result is a *Composite Macrotransformation Matrix*, which should contain all the possible transformations on a single list of (rhythm,dynamics) that:

a) change the total duration substantially
b) are not exclusively monophonic

To build the macrotransformations, several modules from *CONTROL (III.2.2)* have been combined. Among them:

a) Non-Retrogradable
b) Recursive Inexact Aug/Dim
c) Rhythmic Inversion
d) Meters/Bars
e) Null
f) Meters/Bars (using the messiaen modes as rhythm patterns)

III.2.3.3 – *Structural Operators*

III.2.3.3.1 – *Inner Nesting*

WuoRhythm (input rhythm)
type 1 : each value of the rhythm becomes a multiplier to the whole rhythm (total duration is changed)
type 2 : each value of the rhythm is subdivided with rhythm itself (total duration is not changed)
type 3 : each value of the rhythm is subdivided with rhythm itself, and each value is again subdivided with the original rhythm (total duration is not changed)

WuoRhythm2 (structural rhythm, perceptual rhythm)
Means that the "perceptual rhythm" will be distributed in time according to the structural rhythm
note that these functions give strange things if you use input rhythms that contain trills or grace notes for the structural rhythm

III.2.3.3.2 – *Distribution Functions*

DFUN :
rr = LIST OF REPETITION RATES (How often a certain element repeats). The list is converted to 1 BAR
fact = TOTAL Nº OF BARS
offset = STARTING BAR

VIEWDFUN : *x axes = dfun* *y axes = ones*
To graphically visualize the distribution function

III.2.4 – *Simultaneity Studies*

THREE WAYS TO DEFINE DURATION OF EVENTS (two variables become independent):

DUR (x) = OFF (x) - ON (x) (controlling *onsets* and *offsets*)
ON (x) = OFF (x) - DUR (x) (controlling *offsets* and *durations*)
OFF (x) = ON (x) + DUR (x) (controllin *onsets* and *durations*)

Here we are only dealing with timepoints (they can be interpreted as ON, OFF, TMS (time of maximum sample), MID (mid duration of soundfiles), ...)

SimulOverl = {Nº of simultaneities between lists, Overlap (0-1) of l2 in relation to l1 (100% overlap if l2 is completely contained in l1)}
l1 = Starting Rhythm
l2 = possibly staggered rhythm

CASE A: MAXIMUM SIMULTANEITIES WITHOUT TIME-STRETCH (only delays):
MaxSim[l1,l2] = The genesis-function-choice to order l2 in relation to l1 considering max simultaneity and overlap

OrdSim[l1,l2] = All possible TIME-SHIFTS of l2 (l1 is remains equal) ordered according to : {maxsimultaneity , overlap} (part 3 of output)

MSim[l1,l2] = Gives the particular time-shift of l1 or l2 with maximum simultaneity :
OUTPUT = {{lx, ly}, {{Nºsimultaneities, %simultaneities},Overlap}}

CASE B: MAXIMUM SIMULTANEITIES WITH TIME-STRETCH

MaxSimTS[l1,l2] = The genesis-function-choice to order l2 in relation to l1 considering max simultaneity and overlap, allowing TIME-STRETCH of l2

OrdSimTS[l1,l2] = All possible TIME-SHIFTS of l2 (l1 is remains equal) ordered according to : {maxsimultaneity , overlap} (part 3 of output) , allowing TIME-STRETCH of l2

MSimTS[l1,l2] = Gives the particular TIME-SHIFT-STRETCH of l1 or l2 with maximum simultaneity

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Curriculum

JOÃO Manuel Marques CARRILHO

Born : Lisbon, Portugal 14 of November 1981
ID card: 11905520
Adress in Portugal: Rua da Imprensa Nacional, 83-2º dto
1250-124 Lisboa
tel: 213974828

ACADEMIC
1. Courses

1999-2001: Physics at Instituto Superior Técnico, Lisbon, Portugal
2003-2004: Sound Engineering at Restart school, Lisbon, Portugal
2001-2003: Mathematics at Instituto Superior Técnico, Lisbon, Portugal
1985-1997: Conservatory Course. Studied Violin with Leonor de Sousa Prado, Piano, Flute, Music Theory, Music History and Acoustics. Many concerts of solo, ensemble and orchestra performances.
2004–2008: Sonology, composition, performance and electronic music at the Royal Conservatory of The Hague, The Netherlands. Composition teachers: Konrad Boehmer, Clarence Barlow
2007. Scuola di Musica Elettronica, Venezia, Italy
2007 – Contacts with the Fundazione Luigi Nono and Nuria Schoenberg-Nono
2007. participation in the electronic symposium in Cologne, in the presence of composers as Koenig, Barlow, Niblock …

2. Seminars

Mathematics/Physics:
Supralight velocities, Instituto Superior Técnico, 2000
Diagonal Seminars, Instituto Superior Técnico, 2001-2002
Electromagnetism and differential forms, Instituto Superior Técnico, 2001Modern Algebra, Instituto Superior Técnico, 2001
Music:

Louis Andriessen, Centro Cultural de Belém, 1997
Carla Bley & Steve Swallow, Centro Cultural de Belém
Agostino di Scipio, Micro-time sound design, Coimbra 2003
Barry Truax, Coimbra 2003
Emmanuel Nunes, Lisbon 2004
Robert Ashley, The Hague, 2005
Gottfied Michael Koenig, The Hague, 2005
Curtis Roads, The Hague 2005

2007. with Jorge Lima Barreto o duo ZUL ZELUB for piano, & computer music

WORKS

Abstração, for solo violin 2003
Self-Projection VS. Self-Invasion, text pieces for any instrument 2004
Two miniatures, for string quartet 2004
Schizo-Garden, for violin & live electronics 2005
Perspective, for tape 2005
Numerology I, for computer generated sounds 2005
Numerology II, for computer generated sounds 2005
Fluxo, for solo piano 2006
Timescapes, 6 islands for piano & live electronics 2006
The counterpoint of Species– para flauta e electronica 2007
(first performance at the conservatorio Benedetto Michelangelo in Venice, 2007)

HUMAN LANGUAGES

Introduction to Arabic, Sociedade de Lingua Portuguesa, Lisbon 2001-2002
4ºlevel of French, in Instituto Franco Português , Lisbon 2002
7 years of study of English

TEXTS:

Musica e Filosofia – a musica árabe desde Avicena (editado em 2007 na revista Atlantida, Açores, IAC)
Musica Electronica – para revista ORO Molido, madrid, 2007
Microtanalidades, 2008, para a revista Atlântida, Açores, no prelo

COMPUTER LANGUAGES

General purpose:	C, C++, Lisp
Scientific:	Mathematica
Artistic:	Max/Msp, Pure Data, CSound, Supercollider

COLLECTIONISM
500 circa : Books – Music, Physics, Philosophy, Mathematics and Poetry
10000 circa music records – Classical music, Ethnographic, Jazz, Rock, etc...
500 circa music scores – mostly of 20th century music

ZUL ZELUB

"Zul Zelub" is an electroacoustic musical partnership founded in 2005 by Jorge Lima Barreto and João Marques Carrilho. The duo takes a radical conceptualist approach growing out of a theory of "unrealised energy" – purely mental investment of memory and intention – inaudible entities – secret, unexpressed, musical aspects, the desire for the insubstantial, inner voice, parapsychic force generating no matter, conceptual anticipation and abandon, virtual formulation as in a dream. This theory has been carried from abstract to reality and taken beyond its metaphysical mindscape in the CD, in prelo, also called "Zul Zelub", in improvisations for piano solo, electronics and computer live.