PIETRO GROSSI
Selected writings

edited by Marco Ligabue

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Introduction

Marco Ligabue

In addition to musical and artistic works, Pietro Grossi left a large number of writings that illustrate and document his thoughts about music and its relationship to technology. These writings – which have already been published on other occasions and are now, the most part, out of print – aim to bring his work and the cultural, social, and aesthetic climate in which he was active to a broader audience. His work conveys fully that multi-faceted character, which found expression in many projects of the purest pioneering spirit, initiating the spread of a series of transformations in the field of musical thought and expression that still today call for greater attention and evaluation. Luciano Berio and Bruno Maderna's pioneering experiments in electronic music at the RAI Phonology Studio in Milan, where for a brief period Grossi studied the new possibilities in the field, were quickly digested and re-worked in a personal and original key. The activities of S 2F M (Studio di Fonologia Musicale di Firenze) bear witness to this, activities which, by the way, would lead more or less directly to the founding of official centres of electronic music throughout the country. The first such department was founded in 1965 at the 'Luigi Cherubini' Conservatory in Florence, thanks to Pietro Grossi's donation of the S 2F M studio equipment that up until then had been kept in his home. Due in large part to Enore Zaffiri and Teresa Rampazzi, who both gravitated to S2FM for a period, other official experiments were born in Turin and Padua, experiments included in this number of the journal in the sections dedicated to the two musicians.

Grossi's thought and activity soon developed well beyond the first experiments and moved toward applications of information technologies to music, taking off in a direction that very few shared in theory and practice; in fact, almost no one, including many of the pioneers. Among the earliest at an international level, the first Italian experiments in computer music began in this way, thanks in large part to Grossi's work with the Istituto CNUCE (today the ISTI) at CNR and the design and implementation of the first music computer, the hybrid TAU2, described in detail in the Graziano Bertini's contribution. Beyond its practical and operational interest, the TAUMUS software developed for the TAU2 proved to have important aesthetic implications for musical discourse in its conceptual and organisational structure, implications which today find confirmation in the direction Grossi had imagined and predicted forty years ago.

The selection of articles included here propose to trace definitively an intellectual and creative itinerary that was able to quietly and consistently make contributions by calling into question the future of music as form and expression, as well as by creating new coordinates for its existence and social significance. In this regard in particular, we would like to draw attention to *Automazione e musica: verifiche e previsioni*, *Sulla computer music*, *Musica in tempo reale*, *L'istante zero della musica*.

Pietro Grossi's original collected writings are reproduced here in their entirety and in chronological order by date of composition in order to make it easier for the reader to follow the development alluded to above.*

* All the writings by Pietro Grossi here published are from: Pietro Grossi, *Musica senza musicisti. Scritti 1966-1986*, ed. by L. Camilleri, F. Carreras, A. Mayr, CNUCE/CNR, Pisa 1987.

[1] *S 2F M*

NOTICE 1

Music produced from November 1965 to January 1966 by the S 2F M (Studio di Fonologia Musicale di Firenze – Musical Phonology Studio of Florence) team during an electronic music course at the Music Conservatory, Florence.

RESEARCH HZ

use 10 geometric series

1° term	ratio
80	2
110	1.9
140	1,8
170	1,7
200	1,6
230	1.5
260	1.4
290	1,3
320	1,2
350	1,1

sinusoidal wave

RESULTS

combinations of 8 fz of each series according to the binomial coefficients

$$\binom{8}{1}, \binom{8}{2}, \binom{8}{3}, \binom{8}{4}, \binom{8}{5}, \binom{8}{6}, \binom{8}{7}, \binom{8}{8}$$

average duration per 10” combination.

THE WORKS QUOTED HERE ARE AVAILABLE TO ORGANISATIONS AND INDIVIDUALS

Firenze, Piazzetta delle Belle Arti, January 31, 1966

[2] *Report on the foundation, objectives and activities of S 2F M*

I founded the S 2F M (Studio di fonologia musicale di Firenze – Musical Phonology Studio of Florence) in 1963 and provided it with the equipment that permitted the execution of works high technical and artistic quality. This equipment is constantly being added to and improved so as to increase production, the most significant stages of which are summarised below:

1963 Presentation in Florence of the Studio's first work

1964 1) performances in Turin, Padua, Ferrara, L'Aquila, Rome of first works
2) presentation of the studio and its activities at the Festival of Contemporary Music in Venice
3) participation at the first International Colloquium of Electronic Music in Gand where I represented Italy

1965 1) conferences on the direction of research, study, and production with performances in the following Italian cities: Turin, Bolzano, Trento, Rovereto, Padua, Trieste, Florence, Genoa, Terni, Rome, Naples, and Palermo
2) broadcasting of research work from radio stations in Hiiversum, Lugano, Stockholm, Sydney and selected cities in the U.S.A.
3) participation in the exhibit "La casa abitata" at the Palazzo Strozzi, Florence, with sonorisation in select rooms and the stand of the architect Ricci
4) collaboration with Bruno Munari on an exhibit in Milan

1966 Milan: Ideal Standard: organisation of audiovisual events in collaboration with the MID group**,** exposition duration: one month

In addition, the studio has collaborated in Florence with the Association "Vita Musicale Contemporanea" (founded and directed by me) for performances of electronic music, providing the most up-to-date and comprehensive reviews of the current production of various studios around the world. (Paris, Cologne, Munich, Gand, Warsaw, New York, Tokyo) with which S 2F M maintains close contact.

In 1965 the Studio's equipment was offered to the Conservatory of Florence to use in a course on electronic music. The offer was received with great interest by the director, Maestro Veretti and the Minister of Public Instruction, who authorised the course, the first of its kind in Italy and one of the very few in the world.

[3] *Electronic music in Italy*

The activities of electronic music in Italy have been unique, lively, stimulating, in continuous transformation, and projected towards distant, aesthetic-operative goals with moments of exploration that have at times outstripped these very goals; a development which has benefited from the contribution of every centre in the world.

A statistical analysis puts Italy today in first place in Europe and in second place in the world behind the United States, in terms of the proportion of research centres to the general population with studios in Milan, Turin, Padua, and Florence. To these studios should be added the two courses in Turin and Florence, private and public respectively, along with the constant increase in individual activity in both the technical and creative fields, especially at the present moment.

The use of technical equipment puts us among the first – from the Milan Studio, equipped in 1955 with the most state of the art electronic instruments to the most recent creations on synthesisers and the use of computers.

The same can be said of the aesthetic achievements, which range from brilliant, individual achievements dating from the very beginning to team experiments aimed at taking on the most subtle challenges, challenges which have been gradually elucidated with the availability of new technologies and new acoustic discoveries.

The founding of the Phonology Studio in 1955 at the RAI in Milan marks the beginning of Italian activity in electronic music. The then director of the RAI, Mario Labroca demonstrated openness and foresight, contributing in a decisive way to the realisation of the first concrete results when he entrusted the Studio to Luciano Berio and Bruno Maderna.

These two composers were immediately able to make studio among the foremost and most active in the world, along with those in Paris, Cologne, and New York, by following their experimental approach, learning from them, and hence, developing their own direction, a direction free of conditioning by Paris and Cologne and, if anything, closer to New York for its daring use of acoustic resources, while true to a strong stylistic commitment to the European musical culture of the post-war period.

That initial direction was enough to determine the work of several musicians working at the studio, like Vlad, Castiglioni, Bucchi, Sifonia and others later, such as, Nono, who still develops, transforms, and gives shape to the acoustic texture of his theatre there. The abundant bibliography of the Milan Studio activities between 1955 and 1960 is an important confirmation of the intensity of Italian productivity in that period.

The first signs of increased the interest in the area of experimentation in electronics applied to music came in Rome around 1960. Vittorio Gelmetti, Antonio De Blasio, and Gino Marinuzzi, Jr. managed to produce some work on their own equipment, as in the case of Marinuzzi, as well as on the equipment provided by the Istituto Superiore delle Telecomunicazioni (Higher Institute of Telecommunications), as in the case of Gelmetti and De Blasio.

We can see a noticeable distancing from the spirit that reigned in the experimental studios as shown by the work of Gelmetti in *Treni d'onda a modulazione di intensità*. In this work the line of strong rhythm and timbre contrasts in rapid time is now abandoned in favour of subtle transformations of acoustic densities with pre-defined and limited width. In this way the immense acoustic possibilities available are valorised and underscored.

In 1961 Pietro Grossi composed programmed or algorithmic music for the first time in Italy.

He carried out the first investigations or research with electronic instruments with the intent of starting a work strategy that completely countered those already in existence in its objectives: to acquire sound events different from one another and, therefore, «music as experimentation» and meaningful communication thanks to the logical instruments used to carry out the analysis. The choice of the sound field for analysis and the system of analysis are determined by the need for flexibility and consequentiality in a larger research project. In order to develop and continue this process, Grossi founded the Studio of Musical Phonology, S 2F M, in 1963 in Florence and together with young musicians like Italo Gomez, Jon Phetteplace, Albert Mayr, Riccardo Andreoni, they went ahead with composing and disseminating electronic music. Since that time annual performances in Florence – and sometimes in other cities – have insured that Florence has maintained a singular pre-eminence in knowledge of the most important production of many experimental studios.

From 1965 on S 2F M made its equipment available for a new course in electronic music instituted at the Conservatory of Florence thanks to the support of the director of the Conservatory, Maestro Antonio Veretti.

Grossi is the teacher of the course.

This course has a unique feature: the admission of students from other departments even if they have no musical background. The experience to this point has been positive and has confirmed the hypothesis that a profound division in working and, as a consequence, teaching techniques exists between instrumental and vocal music based on performance virtuosity and electronic music in which the difficulties of execution are turned over almost exclusively to electronic instruments.

In 1964 and 1965 two other private studios began in Turin and Padua following the Florentine example. Both of these studios follow a working method similar to that of S 2F M.

The SMET (studio di musica elettronica di Torino – Electronic Music Studio of Turin), founded by Enore Zaffiri, brings together a number of young people, offers a private course, and follows a sensible methodology of elaboration based on pre-determined data shaped by geometrical figures. This provides a structural guarantee that validates the research.

NPS (Nuove Proposte Sonore – New Sound Proposals) in Padua brings together four Paduans from different backgrounds: the musicians Teresa Rampazzi and Serenella Marega, the painter Ennio Chiggio, and the physicist Memo Alfonsi. The point of departure for their work is a simple or complex acoustic event. The characteristics of this event are developed progressively within the limits of parameters suggested by those of the initial event itself.

The two studios also circulate information such that, along with the activities of S 2F M, most of Italy can consider itself informed about the developments in electronic music.

The "Collage", of new dada orientation, can also claim representation in Italy through the work of Gelmetti, the Florentine Giuseppe Chiari and, of late, Aldo Clementi. Their work guidelines vary in degree of intervention and, thus, in the modification of the recorded 'acoustic object'.

"Live Electronic Music", so called for its extemporaneous creation, which takes place in the very moment of performance, and thus, before the listener, or at the limit, produced by the very listener, does not have an assiduous following, except among a group of Americans working in Rome.

Despite its differentiations, in such intense activity devoted to undertaking new tonal, formal and operational challenges, let's not forget the electronic instrument which nowadays increases exponentially human faculties in every field: the computer. In fact, since May 1967, an Olivetti-General Electric computer, the GE 115, has been used for performance. Its phonic and rhythmic resources have been exploited by means of effective instructions, which apply the data of a programme written by an Olivetti employee, the technician Ferruccio Zulian, for producing 1300 frequencies. Under Gross's supervision, S 2F M has begun experimenting with having the computer perform classical pieces by Bach, Paganini, and Webern and programming other types of research.

Without a doubt, the contribution of the computer to research and experimentation can now proceed at a level of verification, reliability, and speed unavailable to us up to now. This important step toward higher levels of automation in music puts Italy up with few other countries where such experimentation with the computer has begun – the United States, Canada, The Netherlands.

[4] *Special course in electronic music*

In 1965, with the collaboration of S 2F M (Studio di Fonologia Musicale di Firenze – Musical Phonology Studio of Florence) a special course devoted to electronic music started at the 'Luigi Cherubini' Conservatory of Music in Florence. The first in Italy and one of the few in the world, the course constituted the beginning of a kind of teaching in great demand, as witnessed by the interest of the younger generations.

We can say that the process of updating and integration of teaching techniques required by the extension of activity in the area of electronic music began in 1965 with official approval.

The development of the work program took into account the profound differences between the practise of traditional music based exclusively on artisanship from that available through the use of today's electronic equipment, which even at a basic level, obviates the need for virtuosity.

The direct and immediate contact with the equipment and knowledge through experience of the peculiarities of the available sound sources make up the most essential and profound part of the programme of study. The practical part of the course is organised around individual and teamwork. The following program collection outlines strictly defined areas of research – following a rigorous set of procedures dictated by the equipment used – and created by working groups or the entire team. The methodology, which underpins this organisation, is aimed at acquiring different kinds of acoustic phenomena and, as such, each bearing an original message, i.e. study to know, learn, and enrich the informative power of the world of sound. Individual study has also followed the same ends drawing, in most cases, on group experiments for material of original sound sources to carry out further research. The full range of possible transformations of a tape recorded sound event can be used with methods and for objectives in a lay context that in their purer applications diverge from the praxis of the casual choice.

The course was followed by an average of 25 registered students per year with the excellent assistance of Albert Mayr and Riccardo Andreoni.

At the end of each course the work created during the year is presented, along with the performance of works created at the various experimental studios and historical-artistic news about the studios for information and training purposes. As of last year a mathematics and physics course has been created in conjunction with the electronic music course.

Research: 3 T B M N

Beats

[see graphic at p. 26]

Note: differencies between extreme numbers are omitted.

The different order of the differencies of the same value is not relevant to perception; for this reason, only one version is realized for groups of constituted by the same frequencies.

[see graphics at pp. 27-28]

Research: D N S T

Density

11 intervals to which are added 1, 3, 7, 15 intermediate frequencies

The intermediate frequencies constitute some arithmetical progressions

[see graphic at p. 29]

Wave shape:

The research was completely carried out by a sine wave and repeated by a square wave.

Timing:

30” every density

Volume:

- 15 dB every frequency

Research: P L S

Impulses.

Sound events sequences organized in the time domain by an impulse generator variable in time and duration.

Timing of the impulses

White noise filtered by Krohn-Hite filter

Positioning of the two scales of the filter

[see graphic at pp. 29-30]

Chords of 8 frequencies with geometrical intervals

12 sequences were realized for every time-list which duration is 20” each, divided by pauses of 20”.

The time-lists overlap each other following the order given by the column, spaced by one sequence. Ex.:

Research: C B

Combinations given by binomial coefficients

[see graphic at p. 30]

of 10 sequences of 8 frequencies each obtained by geometric progression with the following ratios

[see graphic at p. 30]
Number of the combinations for each sequence:
8 + 28 + 56 + 70 + 56 + 28 + 8 + 1 =255
Duration of every combination: 30”.
Sine wave shape.

Research: O M
60 permutations of the 20 frequencies of the *Musical Offering* theme by J.S. Bach
theme’s frequencies ordered from low to high
[see graphics at p. 31]
Order of the frequence elements in the first permutation:
1, 2, 2, 3, 3, 3, 3, 4, 4, 4, 6, 6, 6, 7, 8, 8, 9, 10, 10, 11.

The other permutations are obtained shifting the numbers from right to left, i.e. each number shifts one position after an complete cycle of the number at his right. Ex.: 10 shifts one position every 20 positions of number 11.

Each permutation is placed in a different frequency zone, as follows: the number 1 of each permutation coincide with the frequence given by the following table of 60 well-tempered frequencies divided in 12 groups:
[see graphic at p. 32]
the use of each group is linear; ex.:
[see graphic at p. 32]
Timing:
Time for each element or frequency 30”.
Succession timing of the elements in seconds:
[see graphic at p. 32]
A succession timing lasts for a complete permutation
1) the groups a, b, c, d, e, are used following the order given by the binomial coefficients:
[see graphic at p. 32]
Es.: *a, b; a, c; a, d; a, e; b, c;* etc.
2) the elements ordering of each group is given by the permutation of five elements
Succession timing of the permutations in seconds:
1,3,7,13, 19, 29, 37, 43, 53.
a, b, c, d, e.
For the utilization rules see paragraphs 1) and 2)
Sine wave shape.
Volume:
-10 dB

[5] *The electronic computer*

The time when one single generation will be able to make music for dozens or maybe hundreds of future generations seems to be approaching.

This statement might seem incredible, amazing, and science fiction-like. But it is only the natural result of observations, studies, and updated and realistic estimates about the possibility of using for musical purposes the latest equipment scientific progress has given to musicians.

We know from experience that often every estimate that seemed reckless at the moment, everything that seemed futuristic and strange as it was developing, has later been recognised for the historic reasons that led to its appearance.

So what is the instrument that could revolutionise musical activity to its roots? The electronic computer.

Today this tool exists, is being used, and can now include itself, among the most valuable and innovative tools available to man, perhaps comparable to the discovery of fire or the invention of the wheel.

It has already become irreplaceable and indispensable in science and commerce in the twenty years since its appearance. And now people are starting to use it in the arts, like drawing, music and literature.

Apart from those ritual displays at every symposium or conference of little melodies or marches created by programmers on computers to surprise or entertain the audience, there are examples of complete or partial application.

Complete, if the whole process, from programming to the realisation, is done on the calculator; partial, if the programs are used to compose instrumental or electronic pieces created on the equipment usually used by the musical phonology studios.

Until now partial use has been exploited for musical research into the substance and form of sound (convincing examples are those of Hiller and Isaacson in Urbana, Illinois USA; Xenakis in Paris and Grossi in Florence, Italy).

At any rate, to return to the *Divertissements* we just mentioned, we can't overlook their meaning because they have shown that, even if at an embryonic level, the computer can be used as a musical instrument because it creates sound. All musical parameters can be made with this instrument: height, duration, timbre and volume.

The range of frequencies varies according to the computer's characteristics. Better performance allows a wider range of sounds (one of the latest computers, Olivetti-General Electric GE 115 recently used by Grossi as a 'performer', has a range of 1300 frequencies). Duration values are practically unlimited. The other two parameters, too, timbre – i.e., sound composed of chosen partials – and volume can be tuned to a fine level that couldn't be obtained with other instruments.

The possibilities offered by the computer, together with the electronic equipment already widely used in the music phonology studios, help realise the capillary control of a limitless world of sound until now unimaginable.

The computer's magnetic memory and easily storable punched cards allow us to carry out systematic and wide ranging research, in addition to the repetition (theoretically infinite) of each relevant programme. These are all characteristics with which the computer sits alongside magnetic disks and tapes, but with qualitatively superior requirements.

Thanks to its constant evolution, even the most difficult objectives – such as polyphony – will certainly be reached.

Production and distribution centres of will give the user a wide selection, along with the possibility of modifying pre-set programmes.

The amazing speed of computing processing down to billionths of a second is at the base of the astonishing results.

Since the advent long ago of the gramophone and records as means of producing and preserving sound and through the work of music phonology studios in the last 20 years, we have reached the age of automation. We find ourselves faced with new urgent problems and ask ourselves questions of practical, educational, and aesthetic import.

Technology works hand in hand with artisanship, the exclusive basis until today of all musical activity. These activities will work together at first and then will begin to compete. What will the future hold?

It is not yet possible to hypothesise about the future. Certainly everything we've learned is giving way to a process that seems irreversible.

[6] *Experiments with computer music*
in collaboration with General Electric

In May 1967 the first experiments in computer music in Italy were carried out by the S 2F M in collaboration with General Electric Information Systems in Italy.

The trials were carried out at General Electric's research centre in Pregnana Milanese. The GE-115 computer was used both as the sound source and performer. No other conversion equipment or electronic apparatus was used. The sound generated directly in the computer's central unit circuits was recorded by cable onto a magnetic tape.

The possibilities offered by the computer for the frequency and time parameters were examined, studied, and put into practice.

Three programmes were prepared for these experiments, which were used in part or in their entirety according to the kind of research and results.

The programmes were written by Ferruccio Zulian (G.E.) and used by Pietro Grossi (S 2F M) for playing Bach, Paganini, and Webern works and for studying new sound structures. In particular, Domenico Cesa-Bianchi (electronic engineer) and Dr. Giovanni Rapelli (G.E.) worked on the project, while Riccardo Andreoni, Mario Baroni, Albert Mayr and Aurelio Peruzzi (S 2F M) collaborated on the codification of the scores.

Z3 music programme (PMZ3)

Pmz3 executes 1488 instructions, corresponding to an equal number of frequencies of 8 alphanumeric characters each, divided into 7 subroutines.

A specific printout shows the available frequencies and their machine code.

The first 4 letters of each instruction, that are fixed, determine the vibration that in microseconds ranges from 143,3 to 15301,3 that in frequencies is 6978,3 and 65,3. The difference between one vibration and another is 12 microseconds.

The remaining 4 alphanumeric characters, which may vary, show the number of repetitions of that same vibration and so they determine the duration of the corresponding frequency up to a maximum of 65.536 periods; the minimum length is 1 period.

Another instruction of 6 alphanumeric characters – 2 invariable and variable – carried out by an eighth subroutine, doesn't produce an audible vibration and so it is used as a pause.

The instruction generates a period of silence of 1/309th of a second. The number of this instruction's repetitions determines the duration of the pause.

Recalling a particular instruction of pmz3 the number of vibrations of each frequency can be increased or decreased.

A1 programme (PA1)

Processing permutations with repetition (dr). In the computer's peripheral memory, pa 1 has stored a series of elements made up of pmz3 instructions based on the dr formula of combinatory calculus. This formula produces every possible combination of the given elements. The maximum number of elements that can be processed is 16.

Pa1 recognises any one of the following pairs of instructions: sound-pause, pause-sound, pause-pause.

The choice of duration and frequency values of each element and component is free and independent from those pre-established for other components of the same process provided they fall within the manageability range of pmz3.

An example of the operational capabilities of GE-115 with Pa1. The dr of 5 elements at 5 by 5 correspond to 15.625 elements -275.000 alphanumeric characters are processed and recorded on the peripheral tape memory in 40 seconds.

A2 programme (PA2)

Searching and selection of permutations. Pa2 searches and extracts any permutation already registered in the computer's peripheral memory with Pa1.

Pa2 accepts from 1 to 99 different search variables of 3 digits with a + or – sign. The search starts from a previously selected permutation and continues until the number of permutations specified earlier along with the values of the variables is reached. The maximum number of permutations is 99.999.

The permutations selected are stored in another peripheral unit and the resulting data is elaborated with pmz3.

A sample search.

G Program result

The G tables list 70.859 permutations divided into 4 sections.

Section I: 2943 dr of 109 groups of 3 elements whose time values are showed in the table 1. Each group has only one frequency from 317 to 549. Each element has 2 periods of sound and the remaining pause.

Section II: 7371 dr of 164 groups of 3 elements that altogether include 492 consecutive frequencies in ascending order and taken from pmz3's program results starting from frequency 317.

Section III: 31-000 dr of 124 groups of 4 elements of 496 frequencies of pmz3 'fanned out' as in chart 2. For each element there are 10 sound periods and 1 pause.

Section IV: like the previous section with the variation of 1 period of sound and 10 pauses per element.

TABLE 1 WORK G SECTION I

all the combinations inside the following table were used to define the duration ratios among the elements of the dispositions

every value x 5 indicates the number of periods for element

example

combination 1 2 3 = 5 10 15 (2 sound + 3 pause, 2 sound + 8 pause, 2 sound + 13 pause)

combination 3 by 3 of the first 10 numbers of the natural series

[see graphic at pp. 38-39]

TABLE 2 WORK G SECTION III and IV

Coded frequencies in the table of the pmz3 fan-shaped

[see graphic at p. 39]

[7] *Automation and music: verification and predictions*

Computers are the latest tools in the musical world. They supplement the wide range of electronic instruments used in the electronic music studios and increase their potential.

The contribution made by computers to improving human ability to operate in the field of sound – as in every other field of human activity – is demonstrably enormous and continues to expand because of the rapid evolution of logical electronic circuits.

It is absolutely necessary to stay abreast of the evolution of objective musical reality as it is driven by the continual influence of technological progress and understand the consequences without hesitation; in order to clarify as well as possible the way music has diversified in the electronic era we live in.

So we are talking about passing from a 'manual' stage to an 'automatic' one, while maintaining the necessary balance between the terms thought and instrument.

A computer can play 15.625 sounds in forty seconds.

This means that a composer could have 1,406,250 sounds available in one hour and 11,250,000 sounds in 8 hours.

This is the most recent and one of the most important musical experiments completed to date using the computer as direct performer or musical instrument.

A few words about the use of the computer for the musical aims mentioned above.

We know that a large number of electric vibrations circulate inside the computer – in all of the circuit components, these vibrations are generated during its use.

A programmer, who knows the functional characteristics of the computer at hand, writes a set of operations able to produce all the audible vibrations possible inside the central unit.

The composer can choose from a variety of operations those that best suit his work and program the computer by communicating the appropriate instructions via punched cards.

The resulting sounds are transmitted via cable and then recorded on magnetic tape.

In short, these are the operations needed for using the electronic calculator as a performer.

Incidentally, the programme used recently for experiments in Italy permits the use of 1500 frequencies or sounds that may take 65.000 different durations.

Let's go back to what I was talking about before – that in 40 seconds a computer is in a position to play 15.625 sounds – to make clear that programming to perform doesn't mean it makes sounds, only that it processes, records, and stores data in its memory on disks or tapes, also called peripheral memories. Performance occurs when an operator transfers data to the central unit so that it can be used. The storage and transmission speed is 60,000 characters/second, i.e. about 390 sounds per second. To use an analogy with classical music, we could say that the time used for the processing and storage is the same as that used to write the score; the time used for the transfer and execution corresponds to the performance.

Now let's make a comparison. Beethoven's 9th Symphony is made up of about 250.000 sounds, the computer can prepare five pieces of equal complexity in 1 hour and forty in 8 hours.

Furthermore if we consider that what has been accomplished up till now has been fairly simple in the way of any first contact with new systems or equipment, it's fair to imagine that future technical-working refinements will bring even greater results than those achieved at present.

Finally, it's important to note the figures referring to processing time are valid only for the present time.

Rapid progress in computers requires continuous re-examination of the different situations as they come up. For example, by next year we predict a two-thirds reduction of the time used in the experiment described at the beginning of this article.

The electronic calculator is the most recent and most sophisticated instrument developed for musical practice. It is the latest of a long series of which thermoionic or electronic valves were the initiators.

Since then the instruments connected in some way to electronics – amplifiers, filters, microphones, loudspeakers, etc. – started to be used in the music, altering the long established balance between composers, performers, and listeners.

This change, limited to the relationship between performer and listener until the use of magnetic tape, has affected creative ability since the introduction of this new instrument. It is so important because, in addition to substantial improvement in radio transmission and recording, it marks a period of sonic and working achievements never before realised. Just think of the immediate control of the sound event chosen by the composer and its production, which corresponds perfectly to what the composer – who, at the same time, is the performer – had in mind.

Through the use of magnetic tapes, tape recorders, frequency and white noise generators etc., our control over the whole range of sounds spreads and becomes stronger at the same time as we achieve freedom from manual manipulation or performance virtuosity. Until the use of computers – a recent event in practical terms – we can speak of semi-automation or of a period that bridged the gap between working by hand and true automation.

With the introduction of computers we are truly entering a new phase of knowledge and use of the world of sound.

The beginning of a complete change in the structure of the music field developed and consolidated throughout the centuries on foundations we are familiar with and which until now was considered unchangeable, has today become a reality.

The performer has been replaced by the electronic equipment which, because of its astoundingly powerful growth, will introduce the listener to new sound dimensions he never imagined possible and whose variety and accessibility will be available in any place at any time.

In fact, the recent application of so-called remote terminals, which, as we know, allow us to use the computer at a distance of tens, of hundreds, of thousands of kilometres, suggest fabulous possibilities.

Today automation goes hand in hand with manual practice. But what will the juxtaposition of two such different ways of working mean?

Personally, I doubt that these two systems will remain in equilibrium considering the age of our centuries-old baroque instruments and their acoustics**,** which tell us so little after so much use, for the prospect of gains, so unconceivable until now – like the elimination of the hard manual work imposed by traditional technique and consequently the possibility of greater refinement of intellectual processing, the goal human beings aspire to in the end. After all, human beings are really concerned about the creative process and are happy to leave the machines to execute their programmes and put into practise their ideas.

In conclusion the observation that the availability, in any place and at any time, of a practically infinitive amount of micro and macro sound structures through computers that work in time-sharing with remote terminals and general achievements made in cybernetics, lead us to underscore certain concepts that can be summarised as follows: progressive loss of all forms of specialisation; temporary value of all experimentation and achievements, learning and teaching approaches; total flexibility of choice as no longer dependent on the decisions of a few specialists.

Finally, the absolute need for joint collaboration between experimental centres has emerged instead of outdated and useless competition. These centres will probably decrease in direct proportion to the increase in their working potential until the predictable realisation of the use of satellite-centres developed for any acoustic need in orbit around the earth.

The future history of the working process in music, as in other sectors of human activity, corresponds to a pyramid whose base is made up exclusively of hands-on ability and the top by the total automation of «everything for everybody, effortless and valueless», as the sociologist and psychologist Renato Famea incomparably sums up the human condition awaiting us in the near future.

[8] *On 'computer music'*

Computers offer the possibility of resolving problems of total automation in every branch of music, from musicology to composition and performance, and thereby greatly contribute to the future of the world of sound.

When human beings have the means to work at such a level of complexity and perfection that they can extend knowledge and skills quickly and immediately that today enable him to put into practice daring projects one after the other and they are forced to continuously readjust the reasonable limits of their possibilities and the updating of these means, we have to agree that the general problem linked to every human activity – handed down from the past or created in the present – can't find solutions to today's needs without considering the possibility of taking advantage of the most technically advanced opportunities. Not taking advantage of them would imply a useless and, therefore, damaging waste of time and energy in an activity that goes against history, economy and humanity.

Music isn't an exception. The 'self-operating' techniques and corresponding methodologies, that are essential correlates of those techniques, are finding application in different fields: composition, phonic and musicological research, allowing the operator, at best, to free himself completely from any manual task, such as score writing and performance, and substituting him in a wide range of decision-making stages. Different applications follow at operative, organizational, aesthetic and socio-didactic levels that require a re-examination of the previous structures of musical practise, on the basis of all the elements provided by the new reality of today's 'technotronic' age; this age that empowers man, asking him to take tremendous responsibility for making his most fantastic wishes a reality.

The importance to musical practice of the evolution during time of its instruments can be summarized in the following way.

Origins to the 19th Century

Musical creation and production pass from a primitive stage to a more complex technique without changing some basic characteristics.

Composition: we move from writing scores by hand to printing.

Performance: instruments played manually have no automatic mechanism and so stay inert if left by the performer. *Limits of operation in the world of sound*: 'well-tempered' interval system and rhythmical and phonic possibilities conditioned by the musician's performance abilities.

Listening: Consumption occurs only in the time and place of the performance. The listener cannot interfere with the choice and performance of or place from where the message is sent.

The invention of new instruments and their progressive improvement doesn't change the way they are played or the composer-player-listener relationship.

20th Century

Continuation of manual dexterity in both composition and performance techniques. Similarly, at each stage of musical practice, the automation process is initiated and characterized by the use of instruments that preserve the sound message (record) and broadcast it everywhere (radio). The next development in automation is the introduction of frequency generators, tapes, filters, synthesizers etc. and, more recently, *computers* into the musical practice.

This rapid *excursus* emphasises a very important moment: the use of 'self-operating' instruments that replace man in every step of the working process, from the idea to its performance through various moments of choice, combination, and control of the parameter values of sound. The significance of this achievement goes beyond the remarkable fact (which was, in fact, unexpected in this particular field, despite a by now generalised, conceptual assimilation) of liberation from manual labour, to face the issue of renewing the structures of 'musical society', its hierarchies and rituals. These structures were untouchable and irreplaceable until the appearance of the first instrument able to replace man as performer, the record; but then they gradually fell apart thanks in large part to the continuous creation of new and more advanced equipment scientific progress could offer to the musical field. And the rapid rate of innovation of this equipment is increasing continuously.

The gradual technological metamorphosis the musical field is going through is evident and can be recognised at each stage.

Leaving aside all research before the advent of the record, which left a negligible mark due to a lack of technological support, the real beginning of replacement of human work and physical presence occurred after Thomas Alva Edison's famous invention of the *record*. The record could preserve a message and reproduce it whenever and wherever the listener chose. It changed considerably the relationship between performer-listener from an economic, aesthetic and cultural point of view! Economic, because of the limited cost of records compared to the enormous number of possibilities for listening at a technically acceptable level; aesthetic, for the generally high quality of performance and for the possibility of immediate comparison between different interpretations and evidence of past performances. This last point has favoured a faster technical-aesthetic path, showing the limitations in time of the validity of the interpretations[1], and stimulating the performance technique. From a cultural point of view the wide spread circulation of records permits the promotion of a wide range of musical messages.

As mentioned above, the prerogatives of the *radio* go hand in hand with those of records. Radio also allows a large number of listeners to enjoy listening at the same time. As far as performances are concerned, both records and radios cause a decline in musical activity on the part of music lovers and in the need for live performances, thereby reducing the importance of traditional places for listening to music: concert halls and theatres. Finally, the introduction of tapes in recording and radio broadcasting techniques has created more competition with live performances due to the high quality in recording and reproduction equipment**.**

It is now evident that musical institutions – especially opera companies and symphonies – cannot sustain this kind of competition and will inevitably be at a disadvantage. Only the inertia of a strong tradition and other factors, which don't have anything to do with music, will permit continuation, beyond the limits of society's real needs, of activities that have been surpassed by the events that are modifying human lives. In fact, it is enough to examine the availability of records and national radio stations – including cable radio – and reflect on the situation of music at the beginning of the century, or just twenty years ago, and we can see how much music performance and appreciation has changed.

Tapes and the other electronic equipment mentioned above, some of which work automatically, allow the composer – for the first time in the history of music – to make, listen to and modify right away the sounds created[2]. The composer can record them on magnetic tapes thanks to the greater flexibility of the new electronic instruments for alteration and juxtaposition of sound that make up the equipment of the experimental music studios since 1945. The result: availability of total sound, disengagement from the 'well-tempered' system, elimination of the performer as interpreter and mediator between composer and listener, and finally, a means to overcoming the limits of human performing abilities. In this way, the composer sees the realization of his goal of perfect performance of his ideas and the public, whose sensibilities have been progressively trained by the quality level attained by the record and radio broadcasts, can listen to products that are qualitatively perfect. Finally, the simplicity of production operations extends the working opportunities in the music field to a high number of aspirants who are culturally evolved but with none of the qualifications that are fundamental for manually produced music.

After all, when the *computer* appeared, it brought with it the possibility of resolving complete automation problems in every possible branch of music, from musicology to composition and performance. Studies are being carried out and experience in this

[1] On this topic, it is important to recognise the exception posed by Toscanini's still vibrant and unsurpassed performances.

[2] The prerogative of having works produced for their own instrument, formerly extremely rare and reserved for a few virtuoso composers.

area is accumulating and, together with the overwhelming qualitative improvements of the means, the outcome will be an important contribution to the future world of sound. With the introduction of this means, the dynamics of techniques, concepts and educational and artistic choices, which require the operator and user to re-examine continuously the changing reality deriving from the development of electronic equipment, present us with a much quicker working pace than before gradually requiring man to adapt to the new tools and their control without hesitation or uncertainty. Studies in the computer music field are increasing at a rapid rate. Centres of electronic computing and automation are experimenting and improving techniques and systems, while teaching methods designed to prepare teams of experts and programmers for this kind of job are being developed. At present, there are educational programs in Urbana (Illinois), Princeton (New Jersey), Utrecht (Holland) and Florence (Italy). The course in *Florence* began in February 1969 at the Music Conservatory and is offered in collaboration with the Centro Nazionale Universitario di Calcolo Elettronico (CNUCE) of Pisa.

Such rapid changes in the instrumental field lead us to believe that experience and demonstration have their greatest historical importance and justification only when they are being carried out; so programming, also limited in time, has to take into account the estimated rhythm of technological evolution as the programme itself is being developed. We are witnessing a stimulating event: universal availability, through different channels, radio or via cable, of an infinite number of micro and macro sound structures that can be put together – according to the listener's taste – through simple tools such as keyboards, switches, remote terminals or photocells. Numerous channels deriving from one or more highly efficient distributive centres will be able to reach any environment and give each person a wider selection in the area of his choice. So, in this way composer, player and listener will be one and the same person.

The total disintegration of specialisation and the individual ability to create any sound combination will, as a consequence, necessarily lead us become increasingly disinterested in other peoples' choices or, at least, interested on at the level of mere curiosity, more in the methodological than in the aesthetic sense. We can already see this, in a minor but obvious way, in the relationships between experimental electronic music centres and derives, in fact, from the relative ease with which each centre can achieve respectable results thanks to the high quality of electronic equipment now available.

Future prospects do not include anymore science-fiction scenarios. All the tools exist and are waiting to be used, somewhat like a Meccano set. Obviously, conceptual and organizational more than economic difficulties still persist (because the costs will be ridiculously low and can't be compared to those traditional music institutions will have to sustain.) This slows down the progress of studies and experience, consequently slowing down an unavoidable process, while an awareness of the problem, in the event that the gap made itself felt in this sector also, with the idea of arriving at a point that here, as in other sectors less intractable in economic and organizational terms, Europe could establish a priority.

At any rate, an examination of the past, the present, and speculation on the future of music, in light of the evolution of the instruments available for making music, indicate a pyramidal movement whose base is made up of impressive, capillary manual work up to the top with the most perfect 'self-operating' system (computer – satellite – two-way radio) universally available through intermediate stages of automation represented by technical achievements of everything from the old phonograph to the computer. The sociologist Faema's felicitous conclusion[3], «all for all with no effort», referring to humanity's future condition, naturally includes music, now enjoying one of the most exciting moments of ineluctable metamorphosis.

[3] Renato Famea, *Lo sconcertante mondo di domani*, Centro Nazionale di Studi sulla civiltà moderna (National Centre of Studies on Modern Civilization), Venice 1966, p. 114.

[9] *Music in real time*

Those who work in the arts must be aware of their historical moment, have with a clear vision of what now belongs to the past, a sense of the present from which to formulate hypotheses for the future given the revolution we're witnessing today.

Of course, we can't do this without some shock and without accepting the trauma of renouncing some of the principles and values that shaped us, but that no longer seem to belong to the present.

This can be said of all different areas of culture and so we need to extend it also to music, which seems to be, of all the arts, the most closely linked to a generic concept of romanticism on an institutional level.

So we will not tire of asking all those who work in music – who demonstrate a real lack of interest in experimentation, ignoring the importance of the new instruments man has at his disposal – to consider in this sector, and from an interdisciplinary point of view, think about the contribution they can make to the development of civilization.

History teaches us that every step in human progress is characterised by the use of more and more powerful tools; not using them would mean thwarting a priori every possible creative effort in any activity.

Among one of the rare exceptions of musicians who understood the core of this problem, we would like to mention Hermann Scherchen, a gifted artist, who was never a creature of habit as a conductor, but was, in fact, so dedicated that, probably for this reason, felt the constant need to examine the evolution of music. So this man, who in 1954 built an electro-acoustic research lab in his house in Gravesano, told me how he was personally involved in initiatives similar to mine and that we both should now realize that we were spending uselessly because our equipment would soon be replaced by the computer. This statement was prophetic, but at that moment electronic tools were the only instruments we had on hand and were a necessary step.

Again in 1963, when he was leaving, Scherchen invited his students at the Accademia Chigiana in Siena to consider the possibility of not using traditional instruments anymore. At the time, this caused a scandal without however, once the seed was sown, stimulating them to have those second thoughts, which the authority of the person involved and the spirit of the age, should have encouraged.

But the situation today proves that Scherchen was right. Study centres for applying the technological advances to music started popping up everywhere. We've covered new ground in a short time. And the pace is picking up. And it's just as apparent that at each stage progress has created the context for questioning values, relationships or rituals connected to traditional music. This is evident from a quick analysis of the evolutionary process we're talking about.

The invention of the record replaced human work and physical presence – the performer – in the reception of music, initiating the process of freedom from manual work that is a logical part of our civilisation. Furthermore, records allow the listener to preserve and reproduce a message when and where s/he likes.

Radio, magnetic tapes, and other means created by electro-acoustic technology have made a great contribution to possible fruition, both because they provide a wider range of choice and penetrate all social levels. For this reason, they serve a much more powerful cultural function than traditional music institutions. Their intervention has been such as to alter significantly the relationships between the equipment and the public.

And if we want to consider the advantages brought about by the records, radio and tapes for musicians and music lovers, we would note the technical quality of recorded performances, the possibility of immediate comparison between different interpretations and, lastly, the conservation of past performances make it possible to satisfy the most demanding listeners as well as draw inspiration for further study and re-evaluation, since they highlight the wear and tear of certain messages.

In particular, tapes allow the composer to put his thoughts into practise immediately and have not only eliminated the presence of the performer but have also eliminated mediation.

We often here people say that we lose the advantages of direct participation with these new means, but this isn't true if we consider the relationship between composer and performer.

In effect, at first composers accepted mediation by performers in stride. But they have created texts that were increasingly more and more complete, thereby reducing the margin left to the performer.

After all performers who are least affected by the passing of time are those who in their interpretations have aimed for extreme objectivity. From this point of view, Toscanini's performances are considered exemplary.

Stravinsky is an important example because he wanted to interpret his own works himself to give performers a model of his intention and he didn't hesitate to take a stand against those performers who, instead of putting themselves at the service of the music, adapted it to their own demands to highlight their own personal qualities.

We could object that recent musical trends like aleatory music, new dada, etc… seem to take the performer back to the glories of the past to the degree that he's often put in the role of composer. But these cases represent a breaking point to show the loss of forms and the inadequacy of traditional instruments; so in a certain sense they prepare a situation that is emerging due to the invention of equipment offered by modern technology.

There is no doubt that, under pressure from the instruments we're talking about, we need to question traditional practice in both the production and appreciation of music. In fact, there are various questions, for example: what is the point of live performance when the quality of recorded music is definitely better? What is the point of attending concerts or musical performances in general, if only an *élite* bound to a bourgeois habit with little connection to reality participates? Today human beings are used to receiving messages, not searching for them, because they buried every day by a huge amount of information wherever they are. The need to reach a meeting place to enjoy music evidently means bucking the trend. We shouldn't think this ensures the defence of individuality, rather this will be ensured by the custom of exercising our own choices from all the information we receive.

For example, if we consider what was the social role of theatre in the past, we note that, in addition to being a source of pleasure, it was not only very important for the message communicated in the performance but also a meeting place for the social and cultural *élite* that identified with the political, social and cultural forces present in different periods. But today many other channels of information are used to send messages to an infinitely wider social base, as is the situation today. Since they are more modern, they have prerogatives the theatre can't compete with. Of course, music performances are not an exception to what we've said above, so today any attempt to penetrate different levels of society with traditional performances, is too late and, for this reason, out of date; just as it borders on the utopian, compared to possibilities today, to use theatre in general – and music in particular – for communicating political content; today, when a public from the most varied cultural extraction can receive messages of any kind at home and enjoy music of high quality.

No doubt any considerations that involve the function of musical institutions will necessarily reflect on music schools responsible for educating new instrumentalists. Evidently, they have to re-examine their goals and organization. These schools were founded to create a particular class of professionals whose education was concentrated on long and hard exercises on musical instruments, as well as lessons on musical theory and related subjects – the courses of general education still aren't adequate today beyond the compulsory education level. These schools risk inevitable decline if they aren't able to take on the responsibility that automatically follows from the new realities in music and that requires that they take into consideration the new reproduction equipment for music, electronic equipment, and especially, *computers*, which due to their extraordinary potentiality, permit total automation in all branches of music, from musicology to composition and performance.

Computers urge us, as never before, to be aware of the need for new, dynamic concepts in theory and practise. Our civilization is undergoing an acceleration that doesn't allow for hesitation or uncertainties. As such, the musician is left little but the choice of the most advanced equipment, what can lend modernity and meaningfulness to his work. In short, *the computer*.

Today *computer music*, born soon after the invention of *computers* and developed in constant relationship with them, is the product of the experiences of many operators, who started intense research in various EDP centres around the world.

So from Hiller's isolated research in Urbana and Barbaud's in Paris, today we have a worldwide network of active centres, in New York, Tokyo, Los Angeles, London, Urbana, Albuquerque, Utrecht, Paris, and Pisa. At the CNUCE (Centro Nazionale Universitario di Calcolo Elettronico)[1] in Pisa, the project has been formulated with the intent of developing an overall solution for problems related to the automation of sound production and intends to offer future users a wide range of choices for producing music by using computer terminals. In other centres, researchers are developing other methods and programmes, which could be summarised as follows: either the elaboration of individual scores on the *computer*, which can then be performed on other instruments, or monitoring of other electronic instruments by the *computer*, such as synthesisers, filter chains, ring modulators, tape recorders, or, lastly, processing and direct execution.

The contribution *computers* have brought to the extension of human capability in the field of sound, as in every other field of human activity, is indisputably immense. We can now wander in the infinite fields of sound, free from the difficulties imposed by traditional technique. It speeds up immeasurably production time, makes it possible for everyone to develop and express his/her own creativity in music, and always provides meaningful information. Furthermore, because of the innovation in the so-called generations of logical systems, research and results improve constantly.

For this reason, in working with *computers*, we need to be aware that all our experience is historically important and will necessarily be rapidly surpassed. This is why it represents only a moment in a continuum of activity that develops in direct proportion to the incredible increase in the potential of the machine that creates it.

If we compare the traditional working practice, based on performance on what are basically inert instruments, and automated computer processes, it is obvious that in the time, for example, a performer can tune his instrument, the computer can process data on thousands of sounds that naturally can also be performed according to the commands it receives with a precision beyond human capabilities. It's worth considering the time people need to learn how to perform elementary music on traditional instruments, time also required by people who have special musical and instrumental aptitude. For centuries these performers have had to devote the best years of their lives to long and tedious manual exercise, while today's instruments offer those who are motivated in the field of music the possibility to reject the condition of inferiority if they don't have time for general, cultural education, thus compromising their individuality and social contribution.

So now, through the capabilities of the computer, we can hope to find some of the answers to our questions and we can propose partial solutions to other problems that come up in the development of society.

Computers give us music in real time; this is no doubt the most shocking innovation they offer. By means of terminals, extremely simple instruments to use – now within the reach of everyone, if not of families as they will be in the future, at least of

[1] National University Centre of Electronic Calculation.

institutions – anyone nowadays can programme, produce, and listen to music with unprecedented range of choice. We can go from the reproduction of classical works to the creation of any sound product. These extraordinary possibilities, whose limits today will no doubt be overcome quickly by the evolution of research, render the attitudes of those who, in order to enjoy music, have to depend on other people's choices to do it completely out of date.

We are now faced with the new fact that many aspirants have the chance to work in music, given the elementary nature of the instruments we can use to create music. These will depend on individual taste, to correspond to the desire to return to the past or express individual creativity by working in an extremely simple way on equipment that will inevitably become familiar.

For this reason, *computers* can potentially become a very effective teaching instrument that can used in all types of schools to teach music to young people of various ages, resolving the age-old problem of how to teach music to young people following various courses of study.

At last, if we look to the future, computers will offer great opportunities for enjoying leisure time.

In this direction, last autumn the first demonstrations of the work in this field in Italy took place, first in Venice during the Festival di Musica Contemporanea (Contemporary Music Festival), then in Rimini during the I Biennale internazionale di metodologia globale della progettazione (Ist International Biennial of Global Planning Methodology).

Here, for one week, in a pavilion set up by IBM and CNUCE in Pisa, the public could work on a terminal connected with a 360 IMB computer in Pisa and, by using commands provided by a pre-set programme, could hear the musical response right away.

Similar experiences occurred in the same period in Como during the Autunno Musicale (Musical Autumn).

These last experiences, having to do with the use of a terminal, an international priority, widely confirm what we have been predicting.

And, in reference to these experiments, it has been noted that the attitude of some well-known critics, who, evidently completely unaware of the character and problematic implications of this experiment, thought they could speak in qualitative terms and even use absolutely inappropriate terminology for this phenomena they observed, asking themselves if this was 'art'. So they underscored one more time an inability to free themselves from traditional models, while instead it would have been opportune to reflect on the meaning of these experiences, on their future, on how they could be part of an interdisciplinary vision, on proposals that could help resolve some basic problems that have emerged with the evolution of society, like that of leisure time. In fact, we should be talking about issues now officially widespread and in the process of being studied. Instead, we have seen that those who are officially responsible for information have sometimes heard, without having second thoughts, about the possibilities man today has of using instruments that make us think that auto-information, auto-creation and auto-formation are already realities.

Naturally, auto-creation elicits the issue of personality development in man, of the development of taste and of a new position towards aesthetics, so for this reason it involves teaching.

There is comfort in some perspectives indicated by various sociologists of this vision of the future education of young people who should leave space also to music. They describe a society characterised both by permanent instruction and research and by greater entropy in the life cycle, i.e. of the passage from one activity to another.

Therefore, it is clear that in youth, man will have to experience many different disciplines to enter already at that early age in what will be the spirit of the future professions and he will have to convince himself that what he learns can't be considered definitive. Then, again in the fullness of maturity, leisure time, deriving from the increase in automation, will allow him the possibility to become more cultured and refined.

The opinions expressed here probably puzzle many musicians even those who work in *computer music*. I think that they are borne out by the evident transformation in today's society, to which we would be wise to open our eyes.

Today we virtually have the possible solution to all of our problems. We have the means but not the appropriate structures. We must be aware of this and we should act remembering that our generation is responsible for the ones to come.

[10] *Computer music in real time: the Pisa experience*

1. *Playing a computer in real time*

What do we mean when we say that a piece of music is performed «with the computer» or, even, «by the computer?» Let's imagine we have a synthesiser with a keyboard and a control panel with a series of switches, levers, sliders, joy-sticks. The complexity of the music we would be able to create with this equipment will depend essentially on two factors:

a) our ability on the keyboard

b) the speed and precision with which we are able to manipulate commands on the control panel

A fourhanded performance (two on the keyboard, two on the control panel) would certainly improve the situation, but it cannot really offer substantial changes.

However, we can achieve major innovations if we bring the computer into play. By connecting the new 'instrument' to the synthesiser and instructing it in how to perform, it can direct the keyboard and the control panel (or, better, the corresponding oscillators and various circuits) with a control complexity, speed, and precision much superior to those of a human performer.

In this sense, we can say that the computer takes on the role of the performer, in part. Let's say 'in part' because obviously we cannot expect personal or inspired interpretation of the score from a machine, but only a simple, perfect execution of the sequence of commands programmed previously in the memory.

Having got over certain limitations connected with manual operation, let's turn our attention to the limits of the instrument, the synthesiser.

The ways sound is synthesised, i.e. the techniques we use to obtain the functions that represent fluctuations of audio signals in time, starting from the simplest, are many and a synthesiser can hardly incorporate all of them. It is even more difficult to find a synthesiser that could potentially manage new methods of synthesis research might come up with. Given its programmability, the computer isn't limited in this way. In fact, if it is programmed correctly on the basis of certain synthesis formulas, it can execute the entire process of sound realisation without having to manage an external synthesiser for this purpose, arriving at the final stage of digital (numeric) representation of the audio signal. A simple digital/analogical converter (DAC) transforms the series of numbers (samples) generated by the computer into sound. We could speak of a 'hybrid' method when the process of synthesis is carried out by analogical equipment external to the computer and controlled by it and of a 'completely digital' method when the audio signal, in its 'sampled' representation, is provided directly by the computer.

Given the mass of calculations required, computers that use programmes for the digital sound synthesis are not always able to supply the DAC the series of signal samples at a speed sufficient to guarantee good quality sound (at least 32,000 samples per second.). In this case the samples are first calculated and memorized, at a slower rate, on appropriate memory supports (mass storage such as disks or magnetic tapes,) then sent at high speed to the DAC for execution in 'differed time'. Obviously it is a significant disadvantage not to be able to listen right away to the acoustic result of an elaboration.

Instead, we say that the computer plays in 'real time' when the calculation time and the musical performance time are superimposed, or at least alternating, so that the first is transparent to the listener. The processing of a signal sample for the DAC (digital synthesis) or of a control command for the external synthesiser (hybrid synthesis) is carried out at high speed in the interval of time between the sending of one sample or command and the next, without interrupting the sound. It is easier to arrive at a performance in real time with the hybrid method as the computer is freed up from the work of synthesising.

The TAU2, described in the following section, is an electronic device for the synthesis of sound in real time based on the hybrid method.

The possibilities for using the computer as a musical instrument are certainly not exhausted by the examples outlined up to this point. The more general function of the electronic computer is, in fact, as the name implies, to compute data. Once criteria to represent musical scores (code) inside a computer are established, beyond being memorised and being immediately executable, these can be manipulated and elaborated in ways which by hand with paper (pentagram) and pencil would require long periods of time and greater risk of error. An elementary example: a classical score in a given key, once memorised, can be transposed by the computer into any other key in a fraction of the time required for a human being to type in this command. The possible manipulations at this level are, a priori, practically infinite, but are possible only after providing the computer with specific programmes. One of these programmes is the TAUMUS, described in the next section.

In short, we have seen how the computer can be considered an instrument for 'making music' in three ways:

- the computer as an automatic performer of scores on an external instrument
- the computer as performer and instrument, simultaneously, i.e. as a generator of sounds
- the computer as a means for computing musical structures and performing them

It is not reasonable to assume that the application of computers to music aims to gradually replace instruments, the performer, the orchestra, the composer, and even, as some have objected, the listener, to arrive at a paradoxical situation in which we have machines that play, on the one hand, and machines that listen, on the other, while human beings are completely excluded.

The computer should be considered a tool, like a powerful 'musical instrument' that human beings alone can use in a creative way to extend their faculties of thought and expression and to give musical form to their ideas.

2. *The TAU2 – TAUMUS System*

The TAU2-TAUMUS system is one of the important achievements of the Pisa working group – a set of electronic equipment (hardware) and computer programmes (software) that enable the memorisation, composition, re-elaboration, and performance of music in real time. Based on the hybrid method (see section above), the system uses an audio terminal, the TAU2, specifically designed and built for the purpose in 1974-75 at the IEI, for the synthesis of sound, and the programme TAUMUS, hosted on the IBM 370/168 system of the CNUCE for the processing of the music.

The TAU2 can be understood as a musical instrument on which the sound structures elaborated by the TAUMUS are executed. At the same time TAUMUS creates and manipulates musical pieces according to the instructions or COMMANDS indicated by the user via alphanumerical keyboard of the terminal (typewriter or video) connected to the computer.

2.1. *The TAU2 audio terminal*

The TAU2 is a polyphonic and poly-timbre instrument that executes music in real time under the control of a general purpose computer.

The TAU2 is made up of a completely digital interface and control unit, that receives 'musical instructions' containing the acoustic parameters from the computer and exchanges with it the commands necessary for the correct transmission of musical data and a digital-analogue unit (audio unit) that produces signals in audio band according to the binary coding of the parameters provided in sequence by the control unit.

Let's list briefly the musical capabilities of the terminal leaving aside other operational features.

The audio signals are obtained by summing a certain number of sinusoidal signals with frequencies in a harmonic ratio with the fundamental and dynamically and individually adjustable amplitude by means of the appropriate musical instructions from the TAUMUS programme containing the parameters in the proper order:

– Fundamental frequency of the notes to produce (F)
– Amplitude of the harmonic components (A)

– Intensity of sounds (I)
– Duration of sounds (D)
– Special effects (ES)

The TAU2 uses a range of 324 frequencies from 32,4 to 16.425,1 Hertz (9 octaves) whose base interval ratio is 1/6 of a tempered tone, enough to induce when heard an almost continuous sensation of the variation of tone.

The durations of sounds are adjustable by software in multiples of ms and can be reduced by hardware in multiples of 1 ms by means of a manual regulator placed on the TAU2 control panel.

In order to simulate different sources distributed in space, TAU2 generates sound in three distinct channels simultaneously. From each channel up to four notes can be emitted at the same time, each automatically composed of the first seven harmonics (28 distinct signals emitted together per channel.)

The shape of the wave of each channel can be defined by a precise command, called a timbre command, by controlling the amplitude of each 'formant' within seven amplitude levels, with 27 dB dynamic range.

By software the general volume of the channel can be regulated within 15 intensity levels (29 dB.)

Taking into consideration all the possible dynamics for the parameters mentioned above, up to 2^{21} spectral combinations per channel are possible. Several other different timbres can be obtained by using special sequences of commands during the execution of a piece. In the same way by adjusting the intensity levels, modulations of the sound envelopes can be obtained.

The choice of timbres (a sequence of timbre commands) and the form of the envelopes (evolution of the intensities) can be created from several models previously stored in the TAUMUS archive memory or the research and programming of the shape of the wave most appropriate for his piece can be left to the freedom of the user (composer.)

2.2. *Brief note on the TAU2*

The design and construction of the TAU2 date from '73-74-75. The structural and functional characteristics were chosen taking into consideration the components available at that time for the automatic performance of polyphonic pieces in real time and allowing for limited calculation time on the computer, so as to be able to experiment in musicology, music teaching, computer music production in the most efficient, easy, and immediate manner possible. Furthermore, the choice was made to not aim to imitate instruments or traditional synthesisers, or to experiment with new models of synthesis. Attention was turned to the acquisition of an extensive range of values of the acoustic parameters and their complete programmability via software. Therefore, the principle of simple additive synthesis and sinusoidal components was adopted.

Original circuit design was found for the audio unit as well as a cache memory for the interface with the computer and a special arrangement of the control unit.

These choices influenced the performance so that the following possibilities were available:

– harmonic synthesis with variable spectra within short time intervals
– audio signal with complex modulations and no interruption for pieces of any length
– execution of a sufficient number of notes to produce polyphonic pieces of music without needing 'play-back';
– musical execution independently of the transfer speed of the commands from the computer that therefore can be shared with other users
– the ratio between music computing and execution time is kept within the limits of a few computing (even complex) seconds for one minute of executed music on the TAU2. The last two properties make the use of TAU2 still valid, since it is possible to exploit in real time the powerful resources of the 370/168 system of CNUCE (for instance, its archive and tele-processing) to which the terminal is actually connected in the same way as a normal output device.

2.3. *The TAUMUS programme*

TAUMUS is a programme, hosted at the moment on the IBM 370/168 system, which interprets and execute the instructions or COMMANDS individually indicated by the user via a terminal (video or typing) connected to the system. The user can indicate three principal functions via the TAUMUS commands: COMPOSITION, RE-ELABORATION, ARCHIVE MANAGEMENT of pieces. In order to carry out these functions TAUMUS has been allocated two major memory areas:

OPERATIONAL AREA and ARCHIVE. The operational area is the place of all processing of sound material. It can handle pieces with up to 12 voices (given the structure of the TAU2) and a maximum (at the moment) of 2000 sounds per voice. After having undergone re-elaboration, the sound material stored in the operational area can be saved in the archive or sent to the TAU2 for performance. Recalling a piece from the archive to the operational area or composition of a piece (directly in the operational area) could cause (at the user's command) deletion of previous content in that area.

The archive can store pieces of up to a total of approximately three million sounds. That limit can be superseded by the use of peripherals like tapes or disks (mass memory). At the moment, the archive contains more than one thousand texts among pieces from all periods and styles, 'timbre models' to use in sound modulation processes and experiments of various kinds, and represents, for the dimensions and methods of use, probably a unique example in its genre.

The TAUMUS commands could be seen as a set of tools for the management and transfer of the information stored in the operational area and the archive.

Table 1 lists the TAUMUS commands in relation to their functions.

– Composition of sound structures can be executed using two different criteria. Text assignment makes possible the codification and memorisation in the archi-

ve of pieces taken from already defined texts (for ex. classical scores); Self-generation implies the automatic generation of sound structures by the programme (and immediately performed by the TAU2) by means of generation processes based on random numbers controlled by the user at various levels.
- The commands for re-elaboration enable the user to modify the sound material in the operational area whether it is the result of earlier compositions or has been taken directly from the archive. The values of the acoustic parameters of the notes (timbre, frequency, duration, volume) of the piece, or their order, can be modified in various ways.
- The commands for management of the archive allow the TAUMUS user to manipulate pieces already archived and send them to the operational area in various ways. For example, it is possible to cancel pieces, load more than one in sequence in the operational area, or load voices from different pieces and superimpose them, and so on.

It is also possible to use that function in automatic. By using specific commands, in fact, the user can execute a series of pre-arranged pieces randomly selected from the archive by the programme. The performance of each piece is followed by a set number of variations using, always randomly, the procedures of the re-elaboration commands. In this way, TAUMUS simulates the user, who selects archive pieces, modifies and performs them without interruption.

3. *An example of a 'music session' at the computer*

Seated at the terminal, having taken care of a few preliminary operations, the user finds him/herself in the 'TAUMUS environment': s/he can begin to interact with the computer and compose pieces of music using the programme commands. These examples show a selection of commands and their results in music.

For the purposes of exemplification, I use the first 8 measures of the theme of the last movement of Beethoven's Ninth Symphony and, for the MIX command only, the first 8 measures of the theme of Ravel's *Bolero*.

N.B. The parameters associated with the commands were chosen with the aim of obtaining results that can be codified on a pentagram and understood easily rhythmically. The examples were executed using the value of the first at 72 hundredths/sec.

Examples:

A) execution – examples of execution with alternating blocks (N hundredths/sec executed and hundredths/sec cancelled)

PLAY Z|,,,(54
ESEMPIO 1
PLAY Z|,,,(45

ESEMPIO 2
PLAY Z|,,,(36
ESEMPIO 3
PLAY Z|,,,(27
ESEMPIO 4
PLAY Z|,,,(18
ESEMPIO 5
PLA Y Z|,,,(63
ESEMPIO 6

+ Character Z informs the programme that the numeric values are in hundredths of a second

B) modifications

1) raising of a fifth of the text with alternating blocks of 63 hundredths/sec
EXAMPLE 7
2) progressive raising of frequencies of a half-tone for each sound + raising of the previous sound
MODIFY F| + (0,78)
EXAMPLE 8
3) modification of the interval ratios from the 10th to the 22nd sound
SCALE |. 1,10,22
EXAMPLE 9
4) alternating backward execution following given parameters
1,,,(6,5,7,4,3
EXAMPLE 10
INVERT F
5) specular inversion of frequencies
EXAMPLE 11
6) random re-ordering of sections of the piece of 108 hundredths/sec, numbered from 1 to 11
SHUFFLE Zl108
EXAMPLE 12
7) alternating sequence of 2 sounds of Beethoven's theme with 3 from Ravel's theme
MIX 12,,,3
EXAMPLE 13

C) automatic processing – example of creation of a 4 voice structure of 5 sec. duration

CREATE
random? (programma)
NO (operatore)
assign options (programma)

LA|5|FA|,,, 176, 73,,3|DA|,,,200,20,,
201* (OPERATORE)
EXAMPLE 13

[See musical examples at pp. 61-63]

4. *Conclusions and perspectives*

The TAU2 audio terminal and the TAUMUS programme were, and are still, used in various activities from teaching to demonstrations to concerts, from musicology research to composition.

From 1977 to today the system has been presented in many introductory courses for Conservatory, University, and High School students. The courses have been organised in such as way as to enable the participants to work independently at the video terminal within a short time, dialoguing with the machine using the TAUMUS commands, codifying, composing, modifying, and memorising short sound structure.

The musical possibilities of the system have been presented on various occasions with demonstrations and concerts held by Pietro Grossi, and during radio and television broadcasts. Among which:

– the demonstration at the Conservatory of Santa Cecilia, Rome (1977)
– participation at the events of the Como Musical Autumn Festival (1977-1979)
– the seminar in Musical Informatics at the 'G. Verdi' Conservatory, Milan (1978)
– the two days of "Permanent Listening" (created by RAI radio connection between Pisa and Florence), with meetings and round table discussions during the 41° Maggio Musicale Fiorentino, 1978)
– the performance (transcription for computer) of the *Art of the Fugue* by J.S. Bach during the Estate Fiesolana, in Pisa and Rome (1979)
– participation in the International Festival "Ars Electronica", Linz, Austria (1979)

plus various demonstrations in Milan, Genoa, Leghorn, Siena, Pisa. The last demonstration record of computer music issued by the Musicology Department of the CNUCE in April, 1979 is another example of the possibilities of the TAU2-TAUMUS system. It contains examples of automatic and semi-automatic composition, adaptations for computer of scores for traditional instruments, automatic variations on pieces by classical, modern, and contemporary composers and more. The following people collaborated on the final project: A. Belfiore, T. Bolognesi, P. Grossi, A. Mayr and T. Rampazzi (all of the pieces are performed by the TAU2). In particular, we would like to remind readers that *Aegror* by Alfonso Belfiore, contained on the album, won second prize at the International 'Luigi Russolo' Competition for young composers of electro-acoustic music (Varese, September 10-23, 1979.)

Another important application of the system is that of research in the fields of composition, musicology, and acoustics. Among the musicians who have used more or less frequently the Pisa resources, we would like to remember Mario Milani, Teresa

Rampazzi, Albert Mayr, Alfonso Belfiore; Robert Cacciapaglia, the D.O.C. group (Collina, Melli, Nencini, Stefi) of the RAI in Milan, Ingrid McIntosh, Noel Zahier, in addition to, naturally, Pietro Grossi, the primary inventor of the entire system. TAUMUS and TAU2 were then used by researchers in the Musicology Department of the CNUCE for the analysis of timbre, experiments in psychoacoustics, and by university students for thesis in Physics and Computer Science.

If, on the one hand, TAU2 still remains a valid instrument for music research and, as such, is still used in many circumstances, on the other hand, the rapid evolution of technology has made it possible to build ever more compact and efficient audio terminals. In this regard, a micro-programmed, completely digital board, particularly oriented to the synthesis of sound using the 'frequency modulation' technique, which will soon be able to work alongside the TAU2, is in the final stages of development at the I.R.O.E. in Florence (an Institute of the C.N.R.).

A research area that has been explored in Pisa with notable interest involves the automation of musical processes and, in particular, the simulation of composition based on the use of randomness

Randomness is an ingredient contemporary music has been looking into with increasing interest. Just think, for example, of certain improvisations by avant-garde jazz musicians like Cecil Taylor, or of Iannis Xenakis' 'stochastic music', or the numerous contemporary scores that include aleatory behaviour in certain moments on the part of the performer.

It is difficult for human beings to compete effectively with the computer in simulating randomness. Just try to pronounce quickly a series of unconnected words: you will realise rather soon how hard it is to produce each word distinctly (in meaning or in tone) from its predecessor. The computer has no such problem; it can simulate random behaviour of the… finest quality. But there's more. The theory of stochastic processes teaches us how infinite are the variety of random possibilities and how, among these, some have more 'musicality' than others. The melodic phrases generated by the computer, with their obvious hierarchical subdivision in sub-melodies, are just the result of chance (of a special domesticated variety of randomness called «$1/f^x$ noise»). Who would have ever thought?

Therefore, just as it has demonstrated itself to be a musical instrument of enormous utility for the study of the universe of timbre, so the computer is showing itself equally useful in the exploration of the world of random structure (or behaviours,) what can enlarge (like a rich variety of timbres) the range of prime resources on the composer's pallet. However, this field of study is still largely unexplored and, therefore, it is difficult to place limits a priori on its possible applications. The not unreasonable hope is that research of this type (just like other studies that revolve around computers, like artificial intelligence) can help human beings formulate ever more novel ways of making music, while at the same time continuing to show the power and versatility of the computer as a musical instrument.

[11] *Combinatory calculus as a tool in composition*

The musical life of the 20th century has encountered along the way fundamental and pressing problems to which the specialists, musicians, have had to devote all their creative energy. The dominate need for change, accelerated by the pressure of rapid social change in which technological development has brought itself to bear, has required a review of every single moment in music, be it creative, didactic, performative, analytical, organisational.

Of special interest for composers were the phonic substance and form problems.

With reference to the latter topic this article aims at showing a possible working tool derived from the mathematical disciplines, i.e. combinatory computation.

Its application to the development of sets of phonic parameters of 'U' sounds of complex musical structures and to other cases where the musician deems it necessary can help in design, build and control sound structures based on new formal logics.

This article describes the analysis of the different possibilities for development that combinatory computation offers a description of the operational possibilities of the routines of the musical programme TAUMUS and some application examples of these routines.

Combinatory computation is a branch of the set theory that deals with the number of possible groupings that can be obtained with a fixed number of objects by taking into account the following 3 possibilities:

– choosing all of them in a certain order (permutation);
– choosing some of them in a certain order (disposition);
– choosing some of them without considering the order (combination)[1].

[1] In the original Italian the definition and demonstration of three possibilities mentioned above are reported in detail; see p. 66-71 for a full explanation

FUNCTION COMBINA (CM)[2]

Its task is to re-elaborate a piece or part thereof in memory using combinatory computations. Given a finite set of elements, several groupings are possible considering the three possibilities of taking them all in a certain order (permutation), part of them in a certain order (disposition), part of them without order (combination). If one or more elements are repeated, the groupings are called with repetition otherwise simple.

The function COMBINA examines all these possibilities taking into account a set of I elements[3] that can be of two types:

– single sounds or single acoustic parameters;
– sections of the piece;

Consequently, we have two different formats of the instruction type:

FORMAT 1 – processing of acoustic parameters or single sounds:
CO<PA><CV> I p_1 , p_2 , p_3, p_4

<N><N><N><N>
R R R

Variable symbols – are included in parentheses:

<PA>- means ACOUSTIC PARAMETERS marks a sequence of one or more of the following symbols:
F frequency
D duration
T timbre
V volume

<CV>- means CHANNELS[4] and VOICES A sequence of letters (A,B,C) and numbers (1,2,3,4) indicates respectively the channels and the voices affected by the command

Note: Only the specified channels are taken. If no channel is specified all channels are considered. The same rules apply for the voices, as soon as a channel is indicated, whose numbers must be written immediately after the letter of the channel they refer to.

[2] COMBINA is a routine of the TAUMUS programme aimed at automatic development of sound structures. It is actually designed to process data for the audio-terminal TAU; this routine, with minor changes, can be used to process any kind of information.

[3] The limit of the number of elements is determined by the operational capabilities of the main programme associated with the routine and/or of the system where the processing is performed.

[4] The present description of the routine, referring to the processing of the acoustical parameters and to the groupings of the musical voices in channels, is based on the operational features of the audio terminal TAU2.

p_1- selects the order of the sub-sets generated by the combinatory computation. If omitted, the order of the sub-sets will result from application of the computation formula; that is, the sequence of the groupings will be obtained following the line of reasoning for the generation of all possible cases. If employed with any value, the random order of the sub-sets will be obtained.

p_2- indicates the element of the set from which the processing will start. By means of this parameter and the following one the sub-set of all the elements of I that the function will examine is set.

p_3- indicates the other extreme of the selected interval within set I.
If p_2 and/or p_3 are omitted they take by default the values 1 and N respectively where N is the last note of the piece or the last hundredth of a second if constant Z is used to sub-divide the piece temporally in hundredths of a second.
p_4- operates a further action on the sequence delimited by the values assigned to p_2 and p_3. It indicates the pace whereby the acoustic elements of the set I are selected.

Variable N underwritten to any parameter indicates the maximum value that the parameters can assume. N is the number of elements that the grouping operation will consider and will be specified later in FORMAT 3. Variable R underwritten to parameters p_2, p_3, p_4. leaves to the programme the choice of the values for the parameters themselves. A pseudo-random number generating routine provides the requested data.

If p_2, p_3, p_4 are not employed the number of sounds specified in FORMAT 3, (N), will be considered, and only the first N sounds of the piece are processed.

The parameters are separated by character «,» if one parameter is omitted a sequence of two consecutive commas is required: If all three parameters are not specified no separation character is necessary.

If instead of single sounds, sections of a piece are considered, FORMAT 2 is valid.

CO Z <CV> / p_1, (p_2^1, p_3^1), ... , (p_2^9, p_3^9)

<N><N><N> <N><N>

Mandatory parameters:

Z - is mandatory in this format because the piece is sub-divided hundredths of a second and the resulting intervals of time will be considered for obtaining the groupings.
At least a couple:
(p_2^i, p_3^i)- represents the couple under examination: the first parameter indicates the hundredth of a second that marks the beginning of given element and the second parameter is the last hundredth of a second of the element.

Optional parameters:

p_1 - as for format 1 it indicates how the grouping must be selected; if omitted the order of the generated sub-sets will derive from the combinatory computations.
OBS – the numbers underwritten with 2 and 3 are used to connect to format 1 to mar each the first and the last sound; in this case the first and last hundredth of a second of the section of the piece to process.

– in general, the sections considered do not span the whole piece; the sections of the piece not selected for processing are cancelled using format 2.
– computations that require more than 2000 sounds per voice are interrupted when such a threshold is reached. This threshold is imposed by the TAUMUS programme.

Formats 1 and 2 are employed for the selection of the elements. Format 3, that will be examined shortly, has the function of orderly grouping the sounds according to combinatorial choices. In fact, given one of the first commands, the programme will send the message ASSIGN and will wait for information about the formula, the number of the elements of the sub-sets and other parameters that will set limits. Format 3 (after the message ASSIGN):

C

PR<N><K> / p_1 , p_2 , p_3

D <N><N><N>

Mandatory parameters:

C,P,D,R - indicate the type of combinatorial processing selected by the operator to process the sub-sets. They are employed in the following way:
1) C - simple combinations
2) P - permutations
3) D - simple dispositions
4) CR – combinations with repetitions
5) PR - permutations with repetitions
6) DR - dispositions with repetitions
N - is the number of the elements of set I to which the function COMBINA is applied
K - is the number of the elements of each sub-set
OBS - if K equals N it can be omitted and in such a case the dispositions coincide with the permutations-
K must not be greater than N.
Both must be positive, whole numbers other than zero and not greater than 9.

Optional parameters:

p_1 - if employed, this parameter indicates the first sub-set from which the choice of the selected groupings is verified.
p_2 - indicates the last of the generated sub-sets where the choice must end.
p_3 - is the pace used to scan the set of the groupings.
OBS - if omitted p_1 and p_2 take the default value 1: that is the sub-sets are selected starting from the first with pace 1 and taking them all.

– if p_2 is not specified this parameter assumes by default the number of the sub-sets given by the formula and therefore all the sub-sets will be considered;
– in this case also the parameters are separated by commas and the same rules of format 1 apply if one or more parameters are omitted.

OBS - if the number of sounds to be processed is less than N, no processing will take place.

– if the number of sounds to be processed, as defined by the parameters, is a multiple of N the number computations will be equal to the ratio between the number of sounds and N. In fact at the beginning the first N sounds will be processed then, since at least a number greater or equal to N is left, another grouping of N element is made.

APPENDIX

Given the first 7 sounds of a melody by Verdi the simple permutations of 4 sections in hundredths of a second are required, assuming that the crotchet value is 100 hundredth of a second.

Commands: COMBINA ZI, (1,175) (176,350) (351,525) (526,700)

[See illustration at p. 75]

[12] *Ground zero moment in music*

Today, music has reached a moment of radical change in its history, existence, and development. It is at its 'ground zero' moment and by ground zero I mean a period of time that could last a century or two, i.e. an 'instant' in the history of society and music. This is my conviction after my work with the computer, or rather at the terminal. I am a musician (cellist and composer) and for the past twenty years have been involved in *computer music*, which I arrived at after a period of experimentation in the area of electronic music.

And I must say that I have made some very interesting discoveries, even disconcerting for their novelty. I make deductions from my personal experiences, which are not necessarily absolute truths. It is well known that today music is still a manual, artisan activity. Artisanship of a very high level, if you will, but still artisanship, that requires considerable human endeavour to produce results. When a person sets out to study one of the instruments I call 'inert' – with respect to those I call 'operative', automatic – s/he must undertake a hard apprenticeship with little certainly of reaching his/her goal.

The situation is very different with 'operative' instruments. Even before the computer, we used to use equipment that enabled us to work more easily: sound generators, tape recorders, microphones, etc. In fact, I would date this 'ground zero' moment from Edison, a little more that a century ago, i.e. from the moment when technology and its powerful equipment entered the field of music. Already with the gramophone it became possible to listen to any musical or vocal recording, where and when anyone wanted, something that freed music from a sort of servility. With the radio, sound and musical events of whatever kind were made available to millions of people.

A further step forward was made with the invention of magnetic wire and then magnetic tape, thanks to which, on the one hand, the recording industry made a giant qualitative leap and, on the other, so-called *tape music* was born, to which some people who had never dealt with music before devoted themselves, for example, engineers like Schaeffer in Paris, Eimert in Cologne and others.

With tape music came to be composed directly, eliminating the barrier of performance: no longer mediation by the performer in the transmission of the musical message. Not only, but from that moment, the listener him/herself became the master of direct intervention in the message.

Already twenty-five years ago, I was in close contact with all the researchers involved in electronic music, and we exchanged taped recordings each with a title and an author.

And each time I got something, I was very happy to listen to what the other person had done. But I could also get hundreds of other pieces out of that tape by making use of the technology available at the time: variable speed tape recorders, filters, even scissors. Already we saw the prospect of freeing ourselves from the message, which earlier had been rigorously fixed on music paper and performed according to precise rules. Each tape-recorded phonic message became the point of departure for creating many others.

With the advent of the computer the work potential increased immeasurably, bringing us total independence from others. I would say that the computer freed us from the creativity of others and heightened our own. From the beginning of my work on the computer, I noticed that I could get the best result possible from the instruments available and immediately. Given a text, I could hear a perfect performance right away. From that moment on I became another person, who enjoyed a work potential that even I couldn't imagine. I created a 'digital' music library at the CNUCE (Centro Nazionale Universitario di Calcolo Elettronico – National University Centre for Electronic Calculation) in Pisa where I work, an archive that includes Bach's *Art of the Fugue* and *The Well-tempered Clavier*, Paganini's *Capricci*, Stravinsky's *Rite of Spring* and many other works. For now the coding process is manual and rather complex. However, we are developing an optical reading system for musical texts, which will enable us to work much more easily. Now, once the text was codified and stored, I could perform it however I wanted to, since the information processed on the computer can be manipulated in many different ways. So, from a set of information making up a classical, contemporary, or even extemporary piece created by the computer itself, it is possible to make an infinite series of transformations.

All of this profoundly changes the way we think about music in general. The first is that today performance by hand might have no meaning any longer. To obtain a good traditional performer, we have to choose from hundreds of thousands, by a process of elimination until we find the one we're most satisfied with. But now with the computer – even with a home computer; there are already some that can handle eight or even sixteen voices – any of us can perform previously memorised pieces of music however we want. This is an experience I have every day. I go to the computer and perform *The Rite of Spring*, a *Capriccio* by Paganini, or Gershwin's *Rhapsody in Blue* and so on however I want. I do that with no problem at all and I can manipulate the piece the way I want. This is a new situation: I free myself from the performer.

Of course, I still live this situation on a personal level; but I think that I've begun to live the future of music in doing this.

What does it mean to perform? It means to study hard one of the instruments – beautiful, without a doubt – something I devoted myself to before these new experiences, but which belong to a period that is about to complete its cycle. I think it's insane to knock oneself out to work at an instrument in order to make sounds, when we have the means today to create what we want right away. At the Music Conservatory in Florence where I teach, we felt the need to introduce a scientific high school to motivate students to continue their studies after high school so that they would reach adulthood with a decent cultural preparation. In fact, not all the students do; some do, some don't.

With the 'operative' tools available today, each of us can create his/her own music at home alone. The world of music we've known up to now, with its rituals, restrictions, exclusivity, selection, differences between listeners, composers, and performers, will now have to change radically.