Programmed Music
Personal Experiences and Work

The invitation to take part in this year's Seminar reached me so late that there was no time for me to prepare a seminar. So I was given the option of reporting on my own work, relying on such supporting materials as could be got together at short notice.

I decided on some biographically tinged notes relating to the time I worked at the Cologne Electronic Music Studio, as well as a description of some of the problems of automated composition in a voltage-controlled studio, and with the computer.

Since I didn't have any written notes, I have been obliged in retrospect to rely on my memories of the days in Vicenza. Inevitably this report will encompass subjects that I didn't lecture on, and will pass over many things that may have struck the participants of the course as important. I can only hope that there is a sufficient degree of overlap for this summary to appear more or less relevant. The three following sections correspond to my three meetings with the participants.

1. The "classical" electronic studio

My experiences with electronic music began in 1954; after supplementary studies at the Music High School in Cologne, I had the opportunity to work in the electronic studio of the West German Radio: Previously I had heard lectures by Werner Meyer-Eppler about electronic sound-patterns and, in late-night programmes on West German Radio, examples of the work at this radio studio.

This rather superficial information provoked me on the one hand to criticize the aims and working methods of the first "electronic" studio (in contrast to the musique concrète studio in Paris), on the other hand, it pricked me on to draft a first electronic score. Once I had a thorough look round the Cologne studio, however, I saw that I was going to have to throw this score away as being unrealisable, and follow a different path. And thus it was that my first electronic composition *Klangfiguren I*, which was actually left unfinished and later withdrawn, came into being.[1]

Strictly speaking, my first effort wasn't exactly unrealisable; but I soon saw that – as in the case of instrumental music – there had to be a sensible relationship between the technical demands and the musical result. In the electronic studio, this relationship presents in a way quite different to that which arrises in instrumental music. It struck me that, contrary to the opinion genrally expressed at that time, the means for structuring timbre were limited and by no means brought every conceivable timbre within the composer's (or technician's) grasp. Timbre, as soon became apparent, is a concept belonging to instrumental music, and it rests on the fact that each particular musical instrument is characterised by its own more or less invariable and unmistakable timbre; and in fact, timbres aren't named by means of a special terminology, but simply with the names of the appropriate instruments. Finally, apart from a few exceptions, timbres don't have an autonomous role to play in traditional instrumental music; they are tied to a context, namely a contrapuntal-harmonic context, in which timbres are given the role of differentiating between "voices", or else of fusing them into harmonic

[1] G. M. Koenig, Studiotechnik, die Reihe 1, Universal Edition, Vienna 1955.

functions. One can see what a strong influence this instrumental concept of timbre had on the beginning of electronic music from the attempts of Stockhausen and others to construct electronic timbres in accord with the criteria for instrumental ones, namely by basing them on the relationships of overtones and their relative loudness.[2] These "artificial" timbres – such at any rate was my impression of them – were certainly stimulating, because they were "home-made" and new, but were strangely dull in comparison to the "real" ones; they seemed far less well suited to act as carriers of a musical context, to lend it transparency, to trace outlines, as opposed to remaining as mere blobs of colour. Conformation of this observation may perhaps be found in a conclusion which many other people have come to, on the basis of the same or similar criticism: it's not so much the spectral make-up of a sound that typifies is, as the attack transient – which would take us back to instrumental music.

Actually, the technical resources in the early days of the Cologne Studio were frankly primitive. Anyone who has set foot in a modern studio will find it difficult to imagine how compositions like Stockhausen's and Pousseur's first pieces, or those of Hambraeus, Evangelisti, Krenek or Gredinger could have been realised at all.

When I entered the studio there was only one sine-wave generator, and this wasn't even in the actual studio, but in the servicing department; the connection had to be effected each time in the main switching room of the radio station, and then two assistants were able by means of a telephone link to record individual notes for subsequent synchronisation into sounds. Necessity is the mother of invention: technician Schütz thought up a new arrangement of the tape heads which made it possible to operate continuously with tape-loops (the arrangement, in the direction the tape ran in, was: play-back, erase, record); at each rotation of the loop, another note was added to the spectrum.

The use of tape-loops, which was far more widespread than the above example might suggest, shed a penetrating light on the relationship mentioned earlier between technical demands and musical result. That is, the tape loop represents a form of mechanisation which is by no means just a matter of technical actions, but intervenes radically in the process of composition. Even the recording of sound on tape, which can be replayed at any time, forwards or backwards, or at a different speed, and can moreover be cut up and then reassembled out of little bits of tape, represents a presentation of musical material which scarcely permits comparison with an instrumental score.

The latter, not unlike an architect's plans, represents a general plan, the execution of which is not only entrusted to specialists (instrumentalists, singers, conductors), but also leaves the specialists with a certain degree of freedom as regards its evaluation, comprehension, and elucidation ("interpretation"). This is possible because all the symbolic particulars of the plan remain within the composer's range of experience: known instruments, physical actions while playing the instruments, length of breath, temporal coordination of all actions in "real time" etc. On the other hand, it would be impossible for a composer of electronic music without a very detailed knowledge of the fields of mathematics, electro-acoustics and psycho-acoustics, as well as of the technical equipment in the appropriate studio, to describe what is vaguely called "the sound he imagines" in terms of physical magnitudes such that it could be "realised" (not "interpreted") faultlessly by studio technicians or computer programmers.

[2] Karlheinz Stockhausen, Nr. 3 Elektronische Studien I und II (1953-54), in: K. Stockhausen, Texte zu eigenen Werken, zur Kunst Anderer, Aktuelles. M. DuMont Schauberg, Cologne 1964.

So in practise the composer realises his electronic work himself, and thus is forced to translate every acoustic or formal idea into a technical production model which is not only appropriate to his idea of the sound, and economical (studio time is in short supply!), but also satisfies the standards for electromagnetic recording as conceived by people like the demanding producers of major recording companies.

This aspect of mechanisation drew my attention from the start. I suspected that between the individual events in a composition, even the individual data within a sound, on the one hand, and the circuitry in the electronic studio (with which not only single sounds but also entire sound structures are more or less automatically produced) on the other, there existed connections which made it possible to project one of these spheres into the other. Serial composition technique, which emerged only a brief while before the beginnings of electronic music, and indeed Schönberg's twelve-tone technique, represented "equipment" for reproducing similar (or at any rate equally valid) results on the basis of similar working instructions. So mechanisation can be understood as a typical studio product of the attempt to present the experience of individual composers, and even for a whole era, as prototypes of musical activity.

I am well aware that the development of electronic music over the last quarter of a century has done nothing to promote such a theory and that after promising beginnings, it's far more the traditional form of musical life that has gained the upper hand, the composer being able to satisfy the demands of the market only by uninterrupted individual production. For this reason, the original distance between electronic and instrumental music has largely disappeared, whereas precisely this difference might, under other circumstances, have led to deeper insights into the structure of instrumental music. Ideas and experience of the kind I have mentioned constantly accompanied my work as a composer in the Cologne studio, as they did later at the Institute of Sonology.

2. The programmed Studio

In 1964 I was invited to the State University in Utrecht, to fill the vacant position of artistic director of the electronic studio (later called the Institute of Sonology). My last electronic composition in Cologne bore the title *Terminus*; not so much because I saw the Cologne period coming to an end, but because, after a variety of attempts (particularly in *Essay*), I decided to give up any further attempts to realise a truly continuous sound (as opposed to an assemblage of single sounds which could be produced individually) with the means of the "classical" studio. I intentionally use the word "sound" because, as acoustically structured time, it embraces the momentary timbre as well as the momentary pitch or dynamic, even silence. The Utrecht Studio immediately offered the opportunity to develop a new studio equipment and design new studio rooms.

An important part in all this was played by the technique of voltage control, which has since become widely known through the spread of the synthesizer. Without going into technical details, one can at least say that for the purpose of voltage control, the guiding hand of the composer (to adjust pitch, volume, or the range for filtering) is replaced by a variable direct-current voltage; this voltage is either produced by generators or derived from audio signals (demodulation). In this way, any succession of actions can be laid down, "programmed", in advance.

Prototypes for musical activity are best suited to the forming of variants (see also section 3). I had already taken the first steps towards trying to realise this, albeit with the limited means of the classical studio, in my earlier electronic compositions (and also in instrumental works). A new basis now offered itself in the voltage-controlled studio, particularly through the use of a Variable Function Generator designed by Tempelaars.[3] In what follows, I shall describe the basic features of my series of works *Funktionen*.

The starting point for the *Funktionen* ("Functions", 1967/69) was a stepwise DC voltage signal, produced with the Variable Function Generator, which was not only intended to produce basic sounds, but also to serve in shaping groups of sounds by means of ring modulation, rhythmicising, volume curves, filtering and reverberation. The basic sounds were recorded direct on tape, the control signals only after frequency modulation of a sine-wave signal between 1 kHz and 10 kHz. The control signals for the ring modulation lay between 100 Hz and 1000 Hz. A number of variants of each basic sound and each control signal were produced; since the stepwise output signal was not to be infringed upon as regards the sequence of voltage levels, the formation of variants was restricted to the speed with which the whole period of 48 steps was scanned (transposition of basic sounds) or by their "rhythmicising" through aleatoric triggering of the individual steps (control signals of variable temporal density). Where only switch functions were to be programmed (switching on or off of filters or reverberation), the highly differentiated step signal was replaced by a comb-shaped signal.

By the end of the first working phase, there were tapes containing (a) different basic sounds in several variants: the stepwise basic signal; a sine-wave signal, frequency-modulated with the aforementioned signal; an impulse signal, produced by a slow scan of the basic signal; (b) control signals derived from the stepwise basic signal, for ring modulation and envelopes; (c) comb-shaped control signals for switching functions. Each basic or control signal was recorded for long enough for up to a minute of material to be taken from it later on.

The second working phase consisted of the production of sound-structures with the aid of the sound – and control – materials already produced. For this purpose 36 patches were used ranging from the unchanging basic sound to complicated manipulation by means of ring modulation, filtering, reverberation and rhythmicising. The patches indicate how the desired pieces of equipment are to be combined. The tapes on which material had already been recorded were distributed amongst an appropriate number of tape recorders (maximum of four), rewound forward to the desired variants, and started simultaneously; the controls signals were frequency-demodulated.

In the third working phase, the results of the second were cut into the desired length, and spliced to one another. By this means four tapes were produced for the four tracks of the definitive version. However, before the second working phase began, the following questions had to be answered: (a) which patches are to be used for the production of sound structures? and (b) which variants of the basic sounds and control signals (insofar as these are required) are to be fed into each patch? – Before the beginning of the third working phase, there were two more questions: (c) how long shoulds the individual sound structures be? and (d) what order should they occur in? – These questions were answered by chance decisions, using a

[3] Stan Tempelaars, A Double Variable Function Generator. Electronic Music Reports 2, 1970. Institute of Sonology at Utrecht State University.

computer program. So an example from the "score" for the production of sound structures and the final montage looked like this:

13) PATCH 18, PULSE 8, FILTER 1, REVERB (21), RING 28 (21), DURATION 175
14) PATCH 11, MEL 7, RING 6, DURATION 50
15) PATCH 1, BASIC 12, DURATION 22
16) PATCH 12, MEL 10, RING 19, FILTER 1, DURATION 922

This means: Sound 13, Patch 18, Filter setting 1, volume control for reverberation with variant 21, Ring modulation with variant 28, Volume control for ring modulation with variant 21, Duration 175 cm (about 4.6 seconds). In Patch 18, a pulse-like basic sound (succession of clicks) is filtered and ring modulated; before the ring modulation, reverberation is mixed in. The instructions for sounds 14 to 16 are to be interpreted accordingly.

After the synchronised recording of the four tape tracks of sounds, a fourth working phase proved necessary. The fact was, that all the sound structures based on sequences of impulses came out substantially softer than the continuous sounds, and tended thus to be masked. A final overall regulation of the volume created balanced dynamics between the tape tracks.

This kind of production method makes the formation of variants much easier. The patches can be produces rapidly, and different basic sounds and control signals fed into them. One can test how strongly the difference between various patches (= number and type of manipulations) affects the basic sound, and to what extent systematic deviations in the control signal are effective. And one can also reproduce the overall form of a composition under changed conditions.

The first version within this series of works (*Funktion Grün*) was produced in one week; the simultenous production of several variants could probably have reduced the working time to a few days, so that within a few weeks a fairly large number of comparable "pieces" could have been realised (*Funktion Grün* lasts slightly over eight minutes). An experiment of this kind could show to what extent the listener's experience of something like the form is influenced by the actual patch, its sequence, its duration, or the feeding in of different control signals. At the time, I didn't have time enough to carry out these experiments; instead I composed further versions (*Gelb, Orange, Rot* – yellow, orange, red – the "colours" are just to distinguish pieces; they don't have any synaesthetic significance), so that I could at least play with the global divisions of the overall form. In *Funktion Grün* (green), each patch occurs once only in each track; in *Funktion Gelb* the overall form was divided into three sections, in *Orange* into four, and in *Rot* into six sections. The sections are distinguished by the predominance of particular patches which occur only sporadically in the other sections. Thus it is *Funktion Grün* that seems to make the greatest demands on the listener; but it turned out (in so far as this could be investigated to date) that the listener clutches at every straw in order to get his bearings in the continually changing sound environment, and thus may possibly find a richer structure in "non-articulated" pieces (so long as they aren't too long) than in clearly "articulated" ones.

In ending this chapter, it may be observed that the *Funktionen* were conceived primarily as aesthetic objects. In order to carry out a systematic investigation of the questions posed above, one would have to have imposed drastic limitations in all respects.

3. Music with the computer

During my last year in Cologne, I took a computer course at the University of Bonn, my intention being to prepare myself for programmed sound synthesis. However, the computer in the mathematics department didn't have access to the necessary convertors; so as not to remain idle while awaiting technical alterations, I decided to start by going into the question of how far music could be programmed, limiting myself in this case to instrumental music. I found a starting point in serial music, as the historically most recent – albeit theoretically uncodified – method of composition. My own experiences as composer, several conversations with "serial" composers in the Cologne studio and at music festivals and, not least, the direction of a composition class at the Cologne Music High School gave me some standpoints from which to seek out basic compositional concepts. In the event, these basic concepts were of necessity so general that no concrete musical constellations could yet be derived from them. Specific data (for defining variables) can either be calculated by the program or put together by the user of the program.

The following basic concepts offered themselves: chance, rule, unrepeatability, repetition, regularity, irregularity, symmetry, transition, and the like. "Chance" is produced by a chance program which I call ALEA (a,z) and at each command delivers a chance figure between the limits a and z. "Repetitions" give rise to groups of similar elements. For this purpose there is a program GROUP (a,z,type,ga,gz); elements are chosen from between a and z, and the number of repetitions per element ("group size") from between ga and gz. "Type" indicates whether the elements and sizes of groups are to be chosen by ALEA or SERIES. SERIES (a,z) once again yields chance numbers, but with a check on repetition, so that no element between a and z is repeated until all have had their turn. "Symmetry" is understood to mean musical correspondences in the broadest sense. "Transitions" are possible between the limits of parameters (e.g. high-low, loud-soft), but also between regular and irregular constellations.

In my first composing program "Project 1" (1964-66), the specific data were largely produced by the program itself; only metronomic tempi and durations can – within limits – de defined by the user.[4] Each time the program runs through the computer, it produces another variant of the same structural model. Timbres are designated by the figures 1 to 9; the composer can interpret them however he wishes (as single instruments or groups of instruments). In the rhythmic sphere, 13 different durations as part of a metrical unit to be chosen by the composer are available; each part of a structure receives its own tempo and ends with a fermata. The harmony results from four 3-note groups which together constitute a twelve-tone series; the size of the chords at each point in time depends on the chosen duration. Four pitch registers are once again indicated with figures which the composer can then interpret. For dynamics, six values between pp and ff are available. Each variant consists of seven sections, and in them each parameter goes through three gradations of irregular formations, three gradations of regular formations, and one mixed form which endeavours to create a balance between the two principles. The usefulness of this program for experimental and didactic purposes was, however, overshadowed by the impossibility of defining changing data for the parameters, and different kinds of constructional principle for the formal development.

---

[4] G. M. Koenig, Project 1. Electronic Music Reports 2, 1970. Institute of Sonology at Utrecht State University.

My second composing program "Project 2" (1965-68) offers the composer diverse possibilities for influencing the structure of the result as he desires, be means of the input data.[5] The number of questions the composer has to answer is so large (63) that the resultant consequences can only be taken in after thorough study of a handbook and some practical exercises.

Basic ideas like symmetry and balance are here absent; on the other hand, the mechanisms for distribution and combination gain in importance. To start with observations about the distribution mechanisms:

Each parameter is defined by its elements, which are given by the composer in the form of a "list" (the parameters used are actually: instrument, harmony, register, interval of entry, duration, pause, dynamic, performance instruction). The list elements can then be combined in any way to form any number of groups (not to be confused with the groups of similar elements in the selection program GROUP, see above).

Finally, several groups (in an extreme case only one) are assembled into an "ensemble"; only from an ensemble are parameter-elements admitted into the score. Groups arise through the assemblage of particular instruments (strings, wind) or time values (long, short) or of particular notes into chords. The list of a parameter in its entirety can form a group, and so can a single element; so for example it would be sufficient to put one trumpet into the list, since it can be named several times within one group. The ensemble must contain at least one such group – there can also be several – and one and the same group can also occur several times over in the ensemble. This path from the list via the formation of groups to the ensemble requires automatic formation of variants; for before groups are combined into an ensemble for a second variant, the old list may be exchanged for a new one, unless one wants to regroup the same list-elements. The same applies to the next stage: though the ensemble is treated according to the same plane, its constitution is changed, unless one wants to treat the same ensemble according to a fresh plan. This manipulation of elements, from the list to the score, applies to nearly all the parameters mentioned above.

A further distributive mechanism results from the question: according to what criteria are groups to be transferred to the ensemble, and ensemble-elements into the score (lists and groupings are the business of the composer, who supplies the program with the appropriate data)? Here, as in the first distribution mechanism, the parameters remain independent of one another.

In "Project 2" there are three more programs for this purpose, in addition to those already mentioned in connection with "Project 1" (ALEA, SERIES and GROUP). RATIO (a,z) gives one the opportunity to select the elements between a and z several times over (in contrast to SERIES). To this end, each element is allotted a factor indicating its relative "weight", so to speak, TENDENCY (d,a1,a2,z1,z2) allows one to move a window over the elements, so that gradual transitions can be composed out; the elements visible in the window are controlled by ALEA. A transition can also be made up of several sections; a relative duration d is given for each section; the limits of the window, which can be controlled independently of one another, are designated a1 and a2 for the starting position and z1 and z2 for the end position. Finally, SEQUENCE allows the composer to determine the order of the elements himself.

[5] G. M. Koenig, Project 2, a program for musical composition. Electronic Music Reports 3, 1970. Institute of Sonology at Utrecht State University.

Combination mechanisms affect the parameters (which are fashioned into a hierarchy for this purpose) within one "voice", and subsequently between several voices. Within a single voice (i.e. for each note), for example, no pitch can be composed if a percussion instrument is involved, an conversely no percussion instrument can be selected if a pitch has already been prescribed.

There are reciprocal influences of this kind between almost all parameters; they ensure that the formative law of the parameter computed first ("main parameter") is put into effect without hindrance, whereas those parameters which are computer subsequently must adjust to it. The order in which the parameters are computed can be defined by the composer or left to chance (another important source for the formation of variants!). The combination of several voices calls for a decision on harmony (since the voices can either proceed with harmonic independency of one another, or have a common harmonic system) and an arrangement in the instrumental-parameter whereby several groups of instruments are either mixed or kept separate.