SIMULATION OF FUMCTIONS OF COMPOSER AND MUSICOLOGIST ON ELECTRONVIC COMPUTER

R.kh.Zaripor

Institute of General and Pedagogical Psychology, Academy of Pedagogical Sciences, USSR, Moscow

A method of simulation on an electronic computer la described, In which a set of formalised rallies of parameters is flsad in correspondence to a certain research, object. The following computer programs are constructed for the composition of song melodies, harmonization of melodies analysis of harmonizations (this programme aots as an examiner) and composition of musical reflations. The latter realises a component of heuristic activity - transposition of the invariant form (structure) to different contents. These programs oonfixm the hypotheses concerhing certain laws used by mam in oreatire work untuitiraly. To Make an objeotive eraluation of machine music and compare it with composer music a special experiment has been conducted by a method which eliminates the influence of the psychological set (bias) of the experts. Examples of computer melodies are giren in a musical notation.

8 1. In the study of certain psychological object the following problem arises s to what extent the knowledge of or Information on the object, produced consciously (e.g. obtained in a psychological experiment) is relevant to the understanding of this object. In other words, is this knowledge sufficient to imitate the objeot?

It is not always that in hie heuristic aetirity man uses only consciously-aroduced parameters. When dealing with fflcult problems he introduces subconsciously additional factors that he cannot be aware of, although they often play an essential role.

Xlectronic-conputer simulation is a reliable method of rerifying hypotheses concerning laws goreznlng research object. Simulation is reproduction or imitation of certain aspects of the objeot under study,' that is those aspects that interest the researcher. In computer simulation the machine program includes regularities obtained in analysis of experimental data. The computer, naturally does not use anything abore that, anything that is subconscious.

Simulation is carried out in three stagest

1) On analysis of the object the laws of its structure are found out. Besides, the laws and principles of the structure and development of the object may be formulated on the basis of hypothetical conceptions of this objects.

2) Synthesis is reproduction or imitation of the object on an electronic computer with the help of a program which includes the laws discovered on during analysis.

3) Estimation of the machine results consists in determining the extent of adequacy of the model to the study object, that is the extent of similarity between machine end hcaun actions or results. This is the only criterion of a) perfection of our algorithm, b) correctness of the adopted principles of simulation, and c) extent of knowledge of the study objeot. At this stage our ideas on the laws of the object are rerified.

Thus in electronic-computer simulation it is objectirely conflted Aether the machine (the program, to be more exaot) posseeses sufficient knowledge to imitate object on the study.

Stimulation should be distinguished from synthesizing, which is not intended to attain similarity with an object.

Experiments in simulating some functions of composer and musicologist on "Ural-2" and BEGM-6 computers were oondnoted in three stages correspondingly, further they are commenly described, tor more detailed information on the research methods and results the reader is referred to the author's monograph (1) and articles (2,3).

5 2. Let us examine a method of simulation of musical composition based on algorithm!aatiom of the laws and rules of composition* Simulation is based on a probability process subject to definite regularities.

The method of organization of the algorithm is based on the principle of hierarchy of rarioua musical concepts. Sereral conceptions must be introduced

Any musical composition is characterised (both syntactically and seswntically) by a certain set of parameters P_1, P_2,..., F_k..., embodying laws and means of composition. The parameters may indicates range of melody, measure, distribution of frequencies of interrais, nunber of degrees in an ootare, etc Every P_k

parameter assumes several values: P_{k1}, P_{k2}, ..., P_{kc}, ... The value of a parameter is a definite number or numerical structure, a concrete law of distribution of frequencies of interval, and set of chords - out of an aggregate of those permissible in the program. The type of composition means the qualitative characteristics, or certain distinguishing musical features typical of an aggregate of compositions (style, genre, emotional tenor, etc.). The type may be "dancing music", "Waltz", Strauss waltz", "width", "melodiousness", etc.

It will be established in analysing a number of coapoaitione of some type that not all the parameters are equally charactarlatle *of* the whole type. If a parameter assumes *only* one (eaaentlal) value we shall refer to it aa an easaatlal parameter, of which thereMay be several in every type of composition. If a parameter assumes different values in different compositions of one type it is lneseemtial and we shall call it an inessential parameter, An eseenvial parameter Tor dancing music is, for iaetaaee, the aeasure. which la la waits 3/4 and is Charleston 4/4 An exaaple of aa inessential paraaeter for waits la "amber of unstressed motea". An essential parameter for a Russian folk song is "sequenoe" (aovsment of the aelodic figure up or down by a few degrees with retainaent of the seme rhythm and interval relatione), with the value of "abaeaoe of sequence". Thus the essential values of parameters are the indispensable characteristics of the compoaltloaa of a given type.

$$\text{Let} \quad M = M(P_1, P_2, \ldots, P_k, \ldots)$$

be an ordered set of varioua parameters. The simulation of a T_o type of ooapositloa is baaed on the assumption: any type of ooapoaltloa is characterised by a definite set of valuea of parametara

$$Mc = M(P_{1ac}, P_{2bc}, \ldots, P_{kec}, \ldots),$$

where P_{kec} ia a definite value of paramater P_k salaotad from a multitude of permissible values. Inessential parameters are designated in zero values. Thus tha qualitative characteristics of the composition (Tc typa) is aat up in correspondence to a formal-quantitative characteristic (set of values of Mc parameters).

To simulate compositions of a definite To typa certain umbers - encoded values of parameters - are fed into tha corresponding cells of tha computer's memory. In this way tha computer la asaignad a certsin list of rules and maana of composition by which tha composition produced must be governed. The fixed coaa automatically "set-up" or form tha program. Out of all tha programmed valuea of each parameter only one, assigmed, value is selected, If tha value of a parameter was *not* given, than during tha setting up of tha program it la aalaotad from an aggragata of programmed values at random, that ia by maana of tha ganerator of random number*. It follows that not all of tha programmad law* are used in synthesizing tha given composition but only a part of them. This part is designated Mc sat, which determine* tha Tc type of tha composition. The programs developed by this principle illustrate the process of quantity (set of Talma* of parameter*) transforming into quality (typa of mulo).

Tha Me sat - list of tha laws and means of oomposltiom uwd by tha computer, that la tha structure of tha composition is printed along with tha machine composition. This makes it possible to conduct various psychological experiments in perception of music. It also allow* for solution In principle tha major problem of mu*icology - to find the relation between tha structure of the music and lt* Influence on the emotional state of the liatemar. Let us designate this thod M-method, for short.

Tha M-method of simulation is s of replacing tha direct analysis of tha stucy object (with unkmown characteristics) with a formalised analysis of the synthesized object (the laws and structure of which are known), that is to lise the method of analysis by means of synthesis. A special progrsm may be useed to add new values to the programmed valuea of parameter*, that la to extend the multitude of the preaet laws and meama of composition. This enables ua to synthesise compositions of new types - new synthetical structure end musloal styles, different from those analysed.

S 3. Tha principles of the M-method ware used in setting up tha following machine pro grama.

1. Oompoaitlon of melodies is simulated in the form of a musical period in key major or minor. The sounds of the melody smewer the rules of its four aspects: rhythmic, melodic, harmonic and structural. These rules establish the variou* durations, interval-pitch relation*, stable and unstable sounds of the scale, repetition* of melodic and rhythmic figures as well a* the segmentation *of* the melody into its separate const - ructs - phrase*, motifs. The selection of the form of composition (a period of 8 or 16 bare) ia motivated by a desire tc make a more detailed study of tha rules of the melody which is a finished musical piece of minimum extent (1).

2. A composition in song rhythm is programmed - a sequence of durations corresponding to a definite poetic metres a sequence of straamd and unstressed syllables of a poem. A combination of thl* progrsm with a program for composition

of a melody provides the possibility of simulation of sons melodies to a siren text in verse, or a song (see (1)).

3. The program of harmonization of a given melody in quadrivoiced chorda (trladsand seventhcbords in basic form and their conversions) imitates the solution of school problems. The programme covers study material of the one and a half semesters of music college- Such problems are solved in music college by means of the rules of harmonisation outlined in text books on harmony. However, the absence of precise definitions and constructive procedures makes the process of harmonisation largely intuitive. Bat in programming formal clarity must be introduced in the logioal interrelation of the varloue elements and means of harmonisation. Besides, the solution of the problem of harmonization is not unique, there is the problem of finding an optimal (by certain criteria) solution.

The structure of the algorytbm makes it possible to simulate different types of harmonization (for instance, different in the extent of comlexity) because a provision is made to a programme by arrangement of a set of values of Mo parameters, corresponding to the set of rules and means of harmonisation (see (1)).

4. The program for analysis of solutions of students' problams in harmonization and for detection of errors acts aa examiner and is a prototype of a reaching system. By "errors" are meant forbidden or undesirable sequences of chords or voices e.g. chord, nonsensical from the point of view of the program. When an error has bean detected its specifics and location in the composition are indicated The possibility of assigning a set of values of Mc parameters (that is a list of rules the violation of which in the initial solution is considered an error) provides for analysis of solutions of problems of varying degrees of complexity of harmonisation. In other words, the programme produces various requirement to students after one month of study or on completion of the whole term of study (see (1)).

5. The machine composes one-voice variations on s given musical theme. On the basis of musical material this program realizes one component of heuristic activity, in this oase, transposlbillty, a fundamental property of structure. Transposition or transfer of invariant forma is to be observed in transformation of any nature. In this is embodied the integrity of structure which cannot be broken up into elements.

Very often whan listening to a tune and its variation we detect the connection between them intuitively. This is so because the variation retains all the unchanged elements or the invariants of transformation. Bat in variation they are masked by the changed rhythm, meter, key and the melodic line itself. These masking elements often make the tune unrecognisable. The M-nethod of simulation identifies the invariants and the masking element a. as veil as the mechanism of transposition of inrarlanta in the variation of the meloay (see (2,3)).

Computer variation by the M-method makes it possible to reconstruct the meonanism by which the given composition was created, to follow step by step the whole process of transformation of the given theme into the given variation, and to demonstrate the intermediary results of the consequitlve stages of transformation and deformation of the melody (eee (3)). Figure 1 presents the melodies composed under this programme by BESM-6 computer of the Computation Centre. USSR Academy of Sciences. It will be noticed that melody No. 1 completely coincides (except for the first note in the last bar) with the popular "Molodyortknaya" song (from the film "Volga-Volga") by the Soviet conposer Danaevakl. The synthesis of this melody by the computer confirmed our assumptions concerning the nature of its oonneotions with the original theme, the ways of transformation of this theme into the melody of the "Molodyoahaaya", as well aa concerning the mechanism of creation of melodies of this syntaetioal structure (the melody of a popular song), lor it is only by this process that a machine melody coinciding with the given well-known melody could hare been produced.

S 4. The proximity (or similarity) of the machine result and the study object is the criterion of perfection of the algorythm and the degree of knowledge of this object. What is important is not the absolute quality of the machine results (of musie, for one) but a maximum degree of coincidence of these results with the object in the respects being studied during the process of simulation. The problem or evaluation of the machine results and of their comparison to the object simulated is a very complex one, especially in the case of works of art. Evaluation here is influenced by many factors, ncluding public opinion, readiness to contradict, and particularly psychological aet or Mas. that is a prejudice against the work being evaluated.

The author has devised a method of sociological examination of evaluations made by listeners of machine music. The problem of evaluation of machine compositions and their comparison with composer musie can only be dealt with on the basis of a questionnaire. This problem is tied in with listeners' psychology, that is their inability to evaluate the compositions objectively if they know beforehand

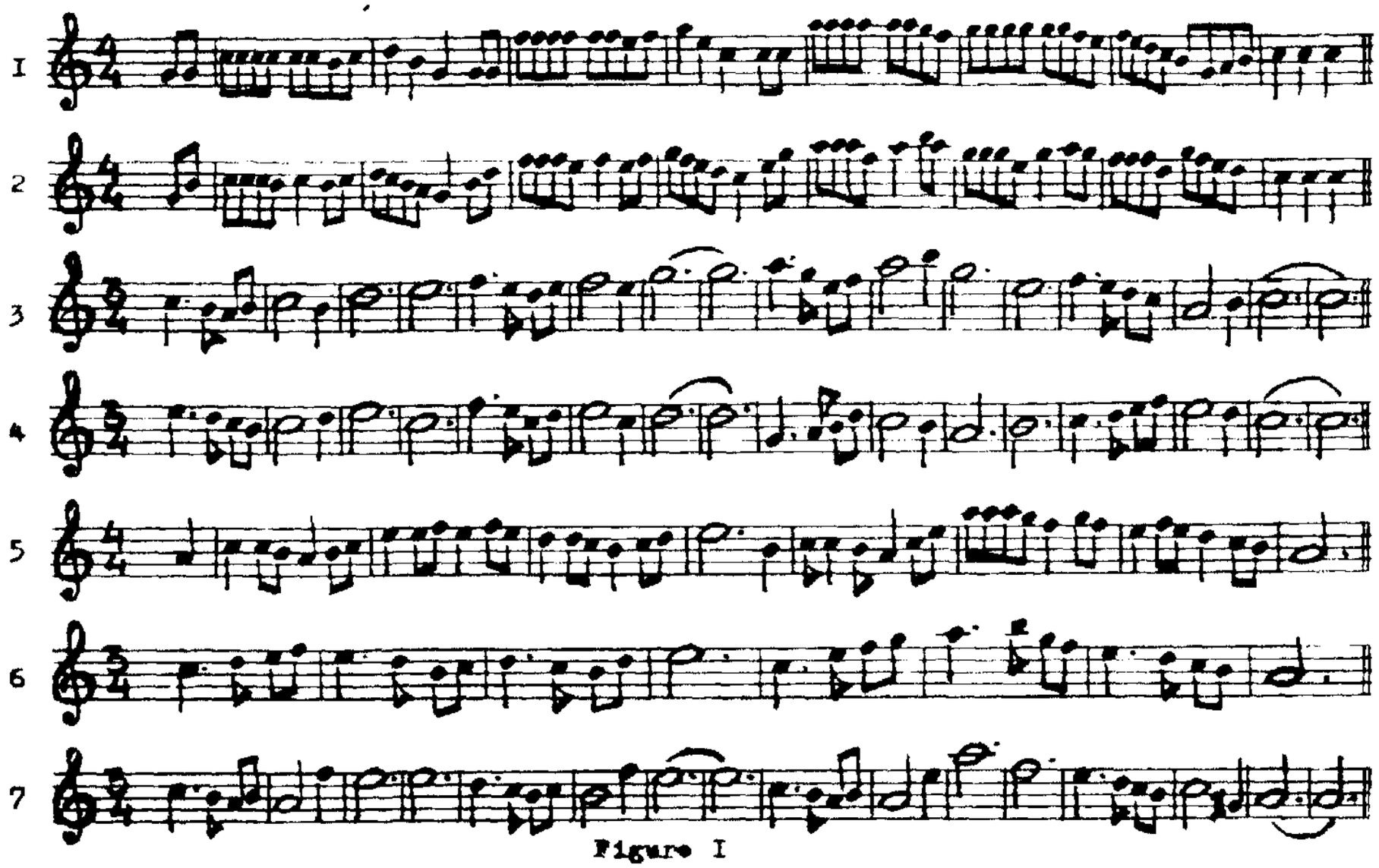

Figure I

that melody No. 1 is machine-produced, and melody No. 2 was composed by man. J Just as it ie impossible to appraise objectively a popular melody. Psychologically it is quite natural. Therefore to be able to make an objective comparison the listeners must not know what they are evaluating at the given moment, machine* or man-produced music.

A special experiment is needed to make a sociologically objective evaluation of the computer's compositions and compare them with the objects of simulation. The purpose of the experiment is to eliminate the psychological set (bias) of the experts, to confuse them so that they will not know what they are dealing with, whether it is a work of the computer or man. Besides, that experiment is also to obtain an objective evaluation of machine compositions as compared to composer's works, that is to indicate their quality.

Melodies of well-known Soviet composers published in selected song books and melodies composed by "Ural-2" computer under the above programme were selected for the experiment. The melodies were played in an arbitrary order, unknown to the listemters who were to evaluate them by a five-point scale and write the number of points in the blanks of the form. The experiment was conducted in different socio-musical groups with approximately the same level of musioal education. They were students of the Moscow Power Institute, students of the Gneslns Music Teachers Training Institute, participants in the symposium "Problems of Artistic Perception*' (the sitting of the symposium was concerned with music perception). senior-grade school pupils, mathematicians, participants in the Methodlogical Seminar of the Steklov Institute of Mathematics of the USSR Academy of Sciences and the Computation Centre of the Academy, employees of cultural establishments and others - more than GOO people in all. A similar experiment was also conducted *on* the basis of a programme broadcast by the home service of Radio Moscow on August 25, 1973.

Just as in any sociological study objective conclusions were made on the basis of averages of subjective evaluations of the participants in the mass experiments. The processing of experimental data yielded different characteristics (see (1)). The adopted method was found correct as it made it possible to eliminate the psychological bias we have mentioned. It was established in a series of experiments that the machine compositions scored more points (by various criteria) than composer music. The following table shows how melodies were evaluated by one criterion by the musically well-educated group of students pf the Gnesins Institutes

	Evaluation				
Author	5	4	3	2	1
Machine	76	253	204	22	5
Composers	61	213	247	31	8

Am = 3.67; Ac = 3.51

The table gives the number of 5-; 4-, 3-, 2-, 1-point evaluations of the machine and composer melodies: *Am.* and Ac are average evaluations of the melodies.

The results of this experiments prove the following facts in computer simulation of some types of music, such as composing melodies of popular songs, the results obtained by the machine are not only comparable to human works but are even superior to them in quality. This is indicative of the fact that the mechanism of creation of such forms of music has been studies to a very high degree, and proves the correctness of the chosen principles of simulation.

It is important to bear in mind that the melodies of professional composers used in the experiment are the result of human professional activity which is called creative.

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