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The Intonational System of Azerbaijani Modes: a Study with the Use of Computer Technologies

Интонационная система азербайджанских ладов: изучение с применением компьютерных технологий

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Abstract. The perception of Azerbaijani frets when performed on evenly tempered instruments is based on the property of human consciousness to generalize different phenomena, recognizing their common meaning. Azerbaijani frets form a stable image in consciousness, and the pitch of the 12-step uniform temperament completely determines the individuality of the frets and their differentiation. Acoustic measurements related to the pitch intonation of Azerbaijani music (both traditional and compositional), with the study of their microintonation schemes, as well as the timbre characteristics of Azerbaijani folk instruments have so far remained out of the field of view of researchers and have not been the subject of special study. The article deals with issues related to the intonation system

Аннотация. Восприятие азербайджанских музыкальных ладов при исполнительстве на равномерно темперированных инструментах основано на свойстве человеческого разума обобщать разнообразные явления, распознавая их общий смысл. Азербайджанские лады формируют в сознании устойчивый образ, а равномерность «шагов» 12-ступенчатой темперации полностью определяет индивидуальность ладов и их дифференциацию. Акустические измерения, связанные с интонационной звуковысотностью азербайджанской музыки (как традиционной, так и авторской), с изучением её микроинтонационных схем, а также тембровых характеристик азербайджанских народных инструментов, до сих пор оставались вне поля зрения исследователей и не были предметом специального изучения. В статье рассматриваются вопросы, связанные

of Azerbaijani frets, with their existence in contemporary musical culture, cites the field of cognitive musicology, which allows us to present the intonation system of Azerbaijani frets in the form of a cognitive structure, which has significant prospects for their implementation in the field of contemporary musical research with the involvement of music computer technologies. A particularly important aspect is associated with an adequate representation of the range of problems under consideration in the system of contemporary musical education, which is also possible and very productive when using modern music computer technologies.

Keywords:

the art of music, ethnomusicology, synesthesia of the arts, fuzzy logic, knowledge base, music computer technologies

с интонационным строем азербайджанских ладов, с их существованием в современной музыкальной культуре, цитируется область когнитивного музыковедения, которая позволяет представить интонационный строй азербайджанских ладов в виде когнитивной структуры, имеющей значительные перспективы их реализации в области современных музыкальных исследований с привлечением музыкально-компьютерных технологий. Особенно важный аспект связан с адекватным представлением круга рассматриваемых проблем в системе современного музыкального образования, что также возможно и весьма продуктивно при использовании современных музыкально-компьютерных технологий.

Ключевые слова:

музыкальное искусство, этномузыкология, синестезия искусств, нечеткая логика, база знаний, музыкально-компьютерные технологии

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The problems of musical modes of different nations, the relationship of modality and tonality across historical eras and cultures are always relevant for musical scholarship. Azerbaijani modes, genetically related to the musical systems of the peoples of the East, occupy their own noticeable place in the multicolored palette of modal systems. Uzeyir Hajibeyli (U. Gadzhibekov, U. Hajibeyov) the founder of Azerbaijani composition school pointed out that Azerbaijani modes in their richness and diversity are worthy of great attention, and their harmonious "living system" makes it possible "to bring something new to the common cause of the world musical art." [1]

Uzeyir Hajibeyli figuratively wrote that the musical culture of the people of the Middle East reached its flourish in 14th century and had proudly raised as a twelve-columned, six-towered "structure" (dastghah) from the height of which one could view all four cardinal directions: from Andalusia to China and from Africa to the Caucasus. Due to the socio-economic and political changes that took place towards the end of the 14th century, fatal cracks appeared in this magnificent musical "structure" which eventually led to the fact that its columns and towers fell apart and it collapsed. The peoples of the Middle East used the valuable rubble of collapsed "palace

of music" and along with their own "mode building material" built their own "musical temple" in the style specific to each nation. [2] This valuable rubble served as the "mode building material" for the construction of a musical temple and of Azerbaijani music.

In modern musical culture, Azerbaijani modes manifest themselves in both traditional and European genres. Existing in their simultaneity in the not-too-distant time space as a living evolving system, they represent a unique opportunity to explore the life of these modes at various stages of development and follow the evolution of musical thinking from ancient oriental monody (mugham) to contemporary composing practices.

The modal system of Azerbaijani *traditional* music contains more than 80 modes involved with the mugham — the chief genre of Azerbaijani professional music of the oral tradition. The scales of these modes and their tuning are reflected in the scale of the tar, an Azerbaijani folk instrument, with the octave divided into 17 non-temperament tones. [3]

This tuning system is appropriate for Azerbaijani professional folk music. It can be described as an unequally tempered scale, in which the semitones, tones and intervals are available in several variants and differ from the 12-degree equally tempered one. In Azerbaijani traditional music the modes whose scales seem to be identical, may differ in sounding and have different names, since the mode and the key of the mugham are determined in regard to the tar. As F. Chelebiyev noted, if the mugham changes its place, i.e. the key, it will certainly acquire a new name, because the key is crucial in the Azerbaijani mugham. The same mugham passage sounds differently in different keys. Accordingly, the term "transposition" in conventional meaning of this word cannot be applied to mugham art. [4]

Fig. 1 shows the scale of the tar with frets spaced according to the mugham system of Azerbaijani traditional music (90, 24, 66, 104 cents) and the 12-tone equal temperament scale.

On the other hand, when U. Hajibeyli founded the modern theory of Azerbaijani modes he distinguished only 7 main modes to use them in the composers' music. He gave these modes the names of the most popular Azerbaijani mughams: *rast, shur, segah, shushtar, chargah, bayati-shiraz, humayun*, and he adopted European notation and twelve-tone equal temperament for the scales of these modes. [2] For notation, U. Hajibeyli chose the frets of a tar with the tunings that are closest to 12-tone equal temperament, while retaining the rest for mugham performance [5] (Table 1).

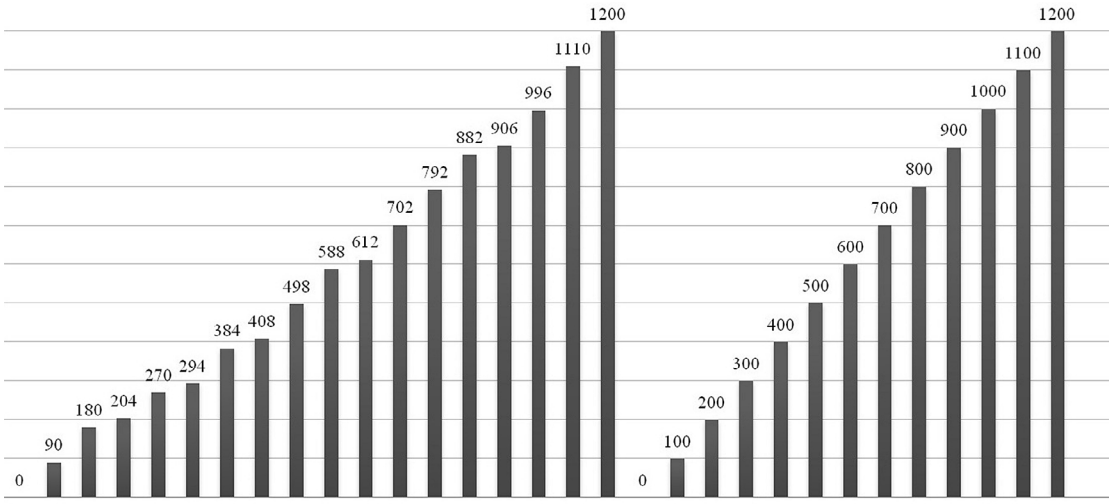


Fig. 1. The 17-tone scale of an Azerbaijani tar and the 12-tone equal temperament scale

Table 1. Notated and Non-Notated Frets of the Tar

Frets of the tar	Cents in the scale of the tar	Cents in the 12-tone equal	Difference with the 12-tone equal temperament	
			Notated frets	Non-notated (mugham) frets
1	90	100	–10	
2	180	200	+4	–20
3	204	200		
4	270	300		–30
5	294	300		
6	384	400		–16
7	408	400	+8	
8	498	500	–2	
9	**588**	**600**	**–12**	
10	**612**	**600**	**+12**	
11	702	700	+2	
12	792	800	–8	
13	882	900		–18
14	906	900	+6	
15	996	1000	–4	
16	1110	1100	+10	
17	1200	1200	0	

The zonal nature of musical hearing [6] existing not only in performance, but also in the perception of pitch, makes allowances for minor deviations of pitch. When we compare intervals of Azerbaijani modes with the Garbuzov's zones of melodic intervals, we can see that all the intervals of Azerbaijani modes including the mugham intervals (made up of the mugham frets) are correlated with the Garbuzov zones (Table 2). This means that European notation, as well as 12-tone equal temperament are both applicable to Azerbaijani modes. [7]

The functional relationship of the degrees of the modes are more informative than their exact tuning, which usually provides the fundamental basis for the study of modal harmonies and their classification. This conclusion allows to distinguish the macro-intonational schemata of the modes (related to the functional relationships) and the micro-intonational schemata (associated with the nuances of traditional performance and in-zone intonations). These are macrointonational schemata that allow to recognize Azerbaijani modes in European genres, which incorporate the 12-tone equal temperament, while their micro-intonational schemata preserve the authenticity tuning in Azerbaijani traditional music.

Meanwhile comprehension of the modal system of Eastern music is a difficult problem for those musicians whose ear is trained only on the basis of major and minor, in Eastern music such musicians hear only some general oriental intonations. The problem becomes doubly complicated if the modes are represented not only in the traditional but also in the European genres — as frequently occurs in the Azerbaijani musical culture. When analyzing Hajibeyli's opera *Keroglu*, Marina Frolova-Walker is forced to admit: "What we hear is the minor subdominant in a major key plus the alternation of tonic major-minor, another cliche of exoticism. While it is possible that a native Azerbaijani might detect in national characteristc features in *Keroglu*, Westerners are unlikely to share this perception." [8]

The *rust, segah, chargah* modes are to an equal degree interpreted by the European

Table 2. Intervals of the Azerbaijani Tar and the Garbuzov Zones

Interval	Size, *cent*	Difference with the 12-tone equal temperament	Garbuzov zones	Murham
P8	0	0		All mughams
P4	498	–2	472–530	All mughams
P5	702	+2	672–730	All mughams
P7	996	–4	966–1024	All mughams
M2	204	+4	160–230	All mughams
m3	294	–6	272–330	All mughams
M6	906	+6	866–930	All mughams
m6	792	–8	766–830	All mughams
M3	408	+8	372–430	All mughams
m2	90	–10	48–124	All mughams
M7	1110	+10	1066–1136	Rast
M7	1086	–14	1066–1136	All mughams
m2	114	+14	48–124	All mughams
M3	384	–16	372–430	Segah
m6	816	+16	766–830	Rast
M6	882	–18	866–930	Segah
m3	318	+18	272–330	Segah, Shur
M2	180	–20	160–230	All mughams
m7	1020	+20	966–1024	Rast
P5	678	–22	672–730	Segah
P4	522	+22	472–530	not used
P4	474	–26	472–530	not used
P5	726	+26	672–730	not used
m7	972	–28	966–1024	not used
M2	228	+28	160–230	Cargah
m3	270	–30	272–330	Shur, Dugah
M6	930	+30	866–930	not used
m6	768	–32	766–830	not used
M3	432	+32	372–430	Shur
M7	1062	–38	1066–1136	not used

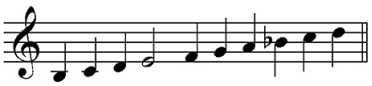
ear as *major*, while *bayati-shiraz, shur, shushtar, humayun* — as *minor*. This presents not only the individual problem of each individual musician — one can see here the global problem of understanding of other cultures, the general problem of cognition, the problem of methodology.

Ear training on the basis of major and minor scales, triads and arpeggios has developed resistant mode stereotypes, provides a static a sense of modal structure and ensures the confident recognition of different modes. However, sophisticated patterns of major and minor do not form the basis for understanding Azerbaijani modal structures. The structure and logic of Azerbaijani modes differ to a considerable degree from the major-minor system, and musicians who study Azerbaijani music encounter many phenomena unfamiliar to the European ear. [9]

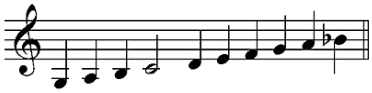
In the major and minor scales the sense of modality arises from the unilateral sequential step-by-step motion from tonic to tonic within a single octave, both upwards and downwards.

Unlike the major and the minor scales, these scales have more than seven notes. According to Uzeyir Hajibeyli's theory, [2] the modes in Azerbaijani music contain from 8 (as in the shushtar mode), to 11 notes (as in the chahargah mode).

The tonic of Azerbaijani modes is in the middle of the scale. For example, segah mode with tonic E [Ibid.]:



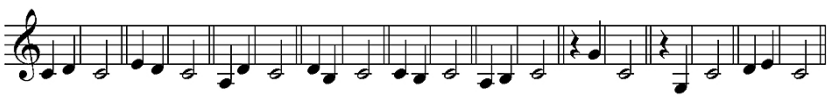
Modes and scales in Azerbaijani folk music are not based on the octave. One and the same pitch in different octaves assumes different positions and has different functions. These functions can be represented in the neighboring octaves by different pitches, for example, *b* and *b-flat*[1] in the rast mode with the tonic note *C* [Ibid.]:



The augmented second cannot be viewed as the mode indicator, as it may occur in different cases: either in independent modes or as a result of the creation of chromatic scales.

One of the main features of the Azerbaijani modes is that studying their scales is in for their aural perception. The structure of any of the Azerbaijani modes when it sounds distinctly separately does not make it possible to hear and fathom its individual features. Cadences play an important role in the task of distinguishing the particular individual modes in Azerbaijani music.

Examples of the cadences for each of the modes of the six main Azerbaijani modes *(rast, shur, segah, shushtar, chahargah* and *bayati-shiraz*) were provided by U. Hajibeyli in his treatise *The Principles of Azerbaijani National Music*. [Ibid.] Here is one example of a full cadence in the rast mode with *C* as the tonic:



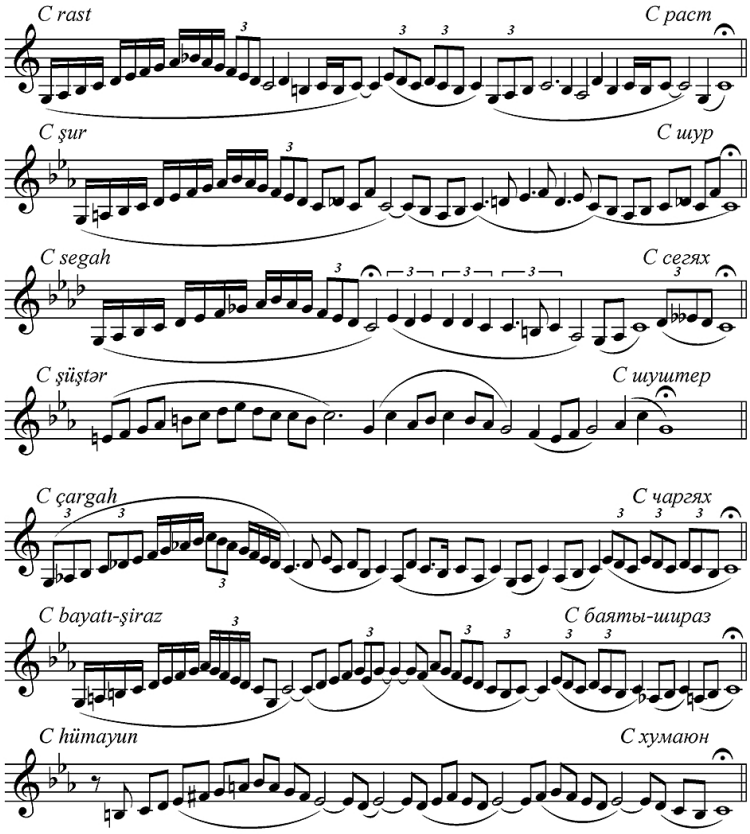
The study of the Azerbaijani modes traditionally involves discipline of modal hearing by developing the students' memories and enriching their vocabulary, i.e. the accumulation of melodic modal impressions and their fixation in the listener's consciousness. This is a long process, which involves the assimilation of a sufficiently large number of musical examples.

For the sake of studying Azerbaijani modes and developing modal hearing on this basis, the models for the seven chief modes have been created, as incidated in the *Practical Guide*. [5] The author of the guide provides a set of short modal improvisations for the sake of enhancing aural perception for the rast, shur, segah, shushtar, chahargah, bayati-shiraz the humayun modes (Example 1).

The mode models contain the necessary and sufficient information required for identifying the mode. These models unify the most typical intonational and metro-rhythmical features of each mode (including the particular scale and the various options of the cadences), thereby, helping determine the mode in the musical composition. They reflect the regularity of the modes in Azerbaijani music; they are concise, rhythmically defined and easily remembered because of their emotional coloring. On the basis of the mode models, the Practical Digital Guide for the Study of Azerbaijani Modes was also developed.

The mode models and musical examples were recorded with the use of the Finale multifunctional music notation program, which makes it possible to input both the music and the text and is supported by MIDI keyboards. The recorded models and musical examples may be saved both in the graphic .tiff format and in the .mus format, which makes it possible to listen to the musical text (using standard notation). To determine the mode of a musical example, it is sufficient to choose from the group of models with the corresponding tonic the particular one that

Example 1
Models of the rast, shur, segah, shushtar, chahargah, bayati-shiraz, and humayun modes



is intonationally suitable for the analyzed musical excerpt.

The guide consists of the following sections: Introduction, Mode Models, Learning, Testing, and Appendix.

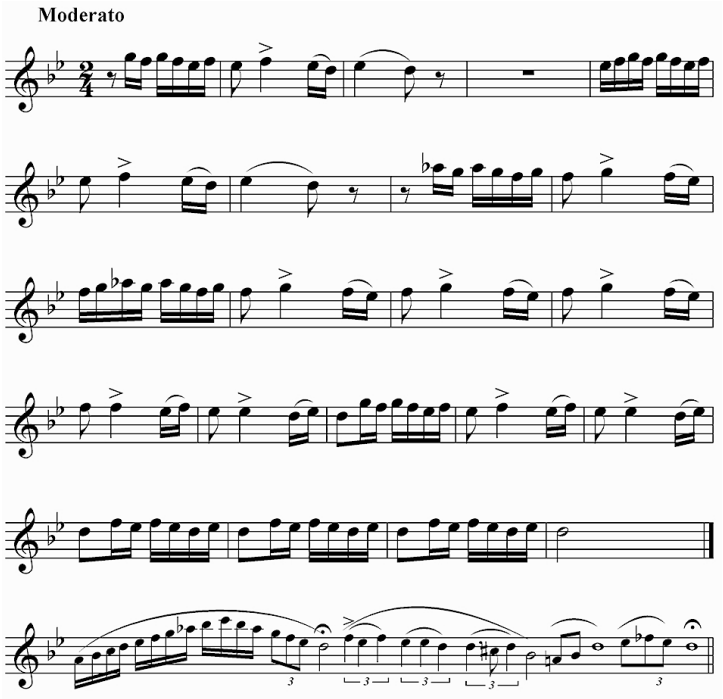
The *Introduction* presents the theoretical part which gives an idea about the contemporary manifestation of Azerbaijani modes, both in the European and in the traditional local genres. This section provides some insight into the modal system in Azerbaijani music, its scales and tuning present in traditional genres. The technique of teaching the aural perception of the seven chief Azerbaijani modes on the basis of models is also proposed.

The *Mode Models* proposed are grouped according to the principle of the same tonic and are arranged in chromatic order from each tone of the 12-note chromatic scale. With such a grouping present, it is easier to distinguish the distinctive intonational features of each mode, which also helps determine the predominant mode in a piece of music.

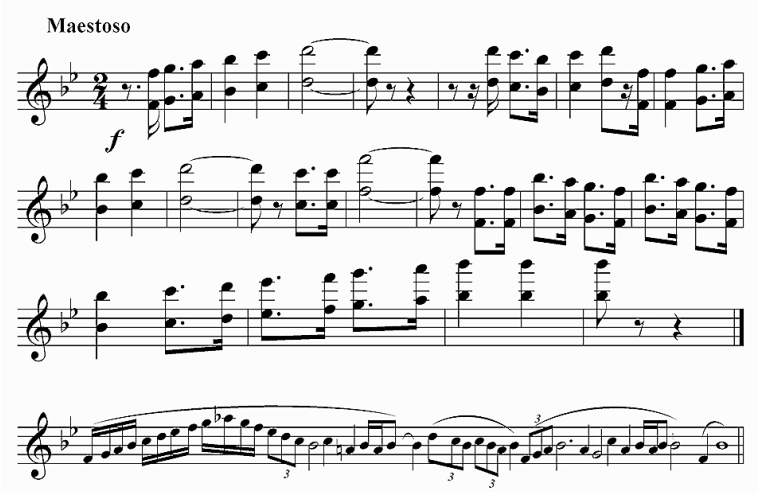
The section titled *Learning* presents about 80 musical examples systematized by the respective modes — *rast*, *shur*, *segah*, *shushtar*, *chargah*, *bayati-shiraz*, and *humayun*. Every example is accompanied by a model in the relevant mode and tonality. For the development of the musical ear, it is recommended to sing and perform each example accompanying it by the appropriate mode model (see Examples 2 and 3).

The experiments in musical composition on the release of artistic imagination, the new rules for organizing the sound material and sound forms, the new possibilities for creating sound, the alternative forms of performance practice,

Example 2
Overture to Uzeyir Hajibeyov's opera "Koroglu".
First Theme (D in the segah mode)



Example 3
Overture to Uzeyir Hajibeyov's opera "Koroglu".
Coda (B-flat in the rast mode)



the ratio of vocal-instrumental and computer music, the eatures of studio work — all of these present the characteristic manifestations of musical culture at the turn of the 20th and the 21st centuries which characterize the general structure of the elements included in the complex model of the semantic space of music, its individual states and subsystems, the functional dependence between the components of the model, the presence of elements of uncertainty in its structure and concrete-figurative content, as well as the reflection of the temporal parameters of music based on the processes of simultaneity (unification in simultaneity) occurring in musical perception. "The multitude of sound elements forming the musical fabric should merge together into an integral sound and musical form," as Karlheinz Stockhausen writes. [10] The multidimensional approach to timbre has led to the use of the concepts of "timbre space" and "motion in timbre space" (Arnold Schoenberg). [11] The listening activity becomes an integral component in such music, since the fabric of the composition is as improvisational as it could possibly be and includes random elements. There is a constant search for new paths in musical shaping.

These and many other circumstances have been the prerequisite for the formation of a complex field of knowledge and phenomena (musical, informational, technological, artistic, social, cultural, etc.), — namely, musical computer technologies (MCT).

In 2002 the educational and methodological laboratory *Music Computer Technologies* (EML *Music Computer Technologies*) was established at the Herzen Russian State Pedagogical University. EML Music Computer Technologies is a developer of a number of unique, promising areas at the crossroads of culture, art, computer science and information technology. The circle of interests of EML employees includes research on the problem of the interrelation of natural, technical and humanitarian sciences, the development of specialized software for computer musical devices and the use of this software in pedagogical processes in order to improve the system of music education and upbringing.

Thus, the most promising areas of application of musical computer technologies in the further study and development of a complex model for the semantic space of music are:

– within the field of developing mathematical research methods in musicology — building an intellectual system for cataloging and analyzing music of the peoples of the world with the extraction of musical knowledge in the conditions of uncertainty, inaccuracy and partial reliability of information, which, in particular, is reflected in a number of publications prepared jointly with a group of scholars from Azerbaijan [12];

– development of info-communication technologies and computing systems (knowledge extraction, artificial intelligence systems based on fuzzy sets systems, etc.) in order to create a single, maximally complete (and constantly replenished) and accessible catalogue of examples of traditional music, not only from various regions of Russia, but also from various countries, which would be convenient for scholarly research and musical creativity;

– the creation of conditions based on the use of musical computer technologies (including a technological base) for coordinating the activities of folklorist musicologists and ethnomusicologists, psychologists, musical acoustics and engineers in the field of information technology in music and cybernetic ethnomusicology;

– the creation of a melody identifier, a virtual sampler, computer music training programs, sequencers, software for the professional activities of a musician based on musical computer technologies;

– the development of a method for constructing models of subject areas which are difficult toformalize and the application of the developed approach to create a model of musical creativity based on the analysis of musical texts, the cyclic structuring of statistical data and structural analysis of

statistical information, making it possible to simulate the creation of texts which would satisfy previously obtained or manually set parameters;

– the development of a Russian software network which would solve many problems: the use of a Russian-made sampler for musical and educational purposes, the construction of a number of high-level training programs based on it, as well as professional work with arrangements. Such a tool would expand, in particular, the technical and artistic possibilities of teaching children and adults, forming a universal educational and technological model based on the use of musical computer technologies;

– construction of a computer model of musical artistic work, including the synesthetic patterns of music, which allows the analysis and synthesis of musical texts based on the probabilistic parameters of fragments of musical texts (the developed approach can be used in other difficult-to-formalize subject areas);

– creation of a hardware and software complex based on the use of musical computer technologies on the basis of traditional Russian musical culture, music of the peoples of Russia and the world;

– a serious and in-depth consideration of issues related to the formation and development of music informatics — a field of knowledge that, on the one hand, studies the specific features of musical activities with the participation of computer technologies, on the other hand, requires the interaction of musicians and specialists in the field of natural and technical sciences. It should be noted that the experience of conducting (in various forms) courses of musical informatics for engineers, programmers, researchers of natural science and technical profile, in Russia and in other countries, convinces that musical and theoretical knowledge is necessary for the activities of these categories of specialists in the field of computer science;

– development and research in the field of music pedagogy and musicology, musical informatics, computer modeling of musical artistic processes, timbre programming, the performing arts and arrangements on electronic musical instruments, artistry in the field of computer music, mathematical methods in musicology, etc. [13]

The scholars of the EML *Music Computer Technologies* scholarly group are also developing new approaches to organizing the educational process and conducting classes with a significant reliance on the use of musical computer technologies ("Musical Computer Technologies in the Digital Age School"), which is implemented in the following main areas: musical computer technologies in professional music education (as a means to expand creative opportunities); musical computer technologies in general education (as one of the means of teaching); musical computer technologies as a means of rehabilitating people with disabilities; musical computer technologies as a new direction in training specialists in the humanities and technology profile; musical computer technologies in the field of digital arts; musical computer technologies in the field of information technology in music, psychoacoustics and musical acoustics, musical and sound-timbral programming; musical computer technologies and sound design, sound production; musical computer technologies and musical sound engineering; musical computer technologies and performance on electronic musical instruments; musical computer technologies and creative work in music with the use of computers. Developments in these areas of research have also contributed to:

– consolidation of the professional community, unification of its leading artistic forces in choosing ways to implementing the spiritual and moral education of the younger generation, taking into account all the features of the socio-cultural process of modern development of our society;

– assistance in the development of new educational programs in the field of music and, in general, art education, based on the global capabilities of modern information technologies;

– development of existing state educational standards and other new scholarly and educational directions.

The synesthetic nature of musical thinking creates prerequisites not only for expanding and enriching the possibilities of music with the participation of computer technologies, but also for its entry into the sphere of other arts (which is convincingly confirmed by the practice of recent decades). It is significant, for example, that based on the experience of using the graphic method of composition ("composing music through drawing") with the participation of computer technology, Iannis Xenakis put forward the idea of educating "broad-profile artists" (in essence, of a synthetic type) endowed with fundamental knowledge in various fields of the natural and technical sciences (including computer science), as well as in the field of the "theoretical history of the music and the visual arts." However, this is a topic that requires a separate independent study, due to the scale and complexity of its problems (see, for example, [14]).

The approach to understanding the musical-historical process as a diachronous-synchronous continuum with the patterns of rhythms of artistry characteristic of it, the study of various processes using musical computer technologies, as well as computer technologies in general, has contributed to the expansion of the structure and enrichment of the diversity of properties of the model. [15; 16]

Based on the above, it can be concluded that the development of information technologies makes further improvements in the manifestations of the laws of such interaction of music, mathematics, and computer science, [17] but does not cancel these laws themselves, the understanding of which in their fundamental forms remains indispensable. It must also be taken into account that the "actually human" component in this interaction is more stable and does not evolve as rapidly as computer hardware. Meanwhile, as is rightly noted by many, "art itself, whether old or new, is ultimately created for man and man."

The field of computer science contains a lot of possibilities that have not yet been used (or used to a small extent) by music theory and practice — both with the participation of computer technologies and independently of them.

The developments outlined in this article are presented to its authors as a promising addition to the previously formed provisions and concepts in this area, which significantly complement the structure and properties of the complex model for the semantic space of music.

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