ISSN 1997-0854 (Print), 2587-6341 (Online) DOI: 10.17674/1997-0854.2018.4.055-064
UDC 781.1+378.1

IRINA B. GORBUNOVA, MIKHAIL S. ZALIVADNY

Herzen State Pedagogical University of Russia
Saint-Petersburg Rimsky-Korsakov State Conservatory
St. Petersburg, Russia
ORCID: 0000-0003-4389-6719, gorbunovaib@herzen.spb.ru
ORCID: 0000-0001-9599-5925, trifonov_e_d@mail.ru

The Integrative Model for the Semantic Space of Music: Perspectives of Unifying Musicology and Musical Education

The authors analyze the possibilities of examining the logical regularities in music by means of mathematical methods which have been formed for the most part in the 20th century. The proposed integrative model for the semantic space of music originated as a generalization of some analogous theoretical results obtained earlier by other researchers. The methods discussed in the article including, in particular, the basic ideas of such fields of research as set theory, the theory of probabilities and the theory of information, as well as the principles of soft computing, make it possible to elicit the premises of these scholarly branches in more traditional manifestations of music theory. The considered theoretical ideas and generalizations are remarkable as a basis for the precise study of various components of the system of musical thinking, including its synaesthetic area. The last of these aspects is important in the modeling of synaesthesia as a special case of virtual reality by means of computer technology and, thus, the use of music as a source of such realities. In connection with the ideas of direct inclusion of the visual range in music by computer means, such modeling becomes important not only for the synthetic forms of artistic activity with the participation of music, but also for the art of music itself. The authors of the article also touch upon some aspects of application of mathematical approaches to music in the sphere of musical education.

Keywords: mathematics and music, musical semantic space, music theory, musical education, music computer technologies.

For citation: Gorbunova Irina B., Zalivadny Mikhail S. The Integrative Model for the Semantic Space of Music: Perspectives of Unifying Musicology and Musical Education. *Problemy muzykal'noj nauki/Music Scholarship*. 2018. No. 3, pp. 55–64. DOI: 10.17674/1997-0854.2018.4.055-064.

И. Б. ГОРБУНОВА, М. С. ЗАЛИВАДНЫЙ

Российский государственный педагогический университет им. А. И. Герцена
Санкт-Петербургская государственная консерватория им. Н. А. Римского-Корсакова
г. Санкт-Петербург, Россия
ORCID: 0000-0003-4389-6719, gorbunovaib@herzen.spb.ru
ORCID: 0000-0001-9599-5925, trifonov_e_d@mail.ru

Комплексная модель семантического пространства музыки: перспективы объединения музыкальной науки и образования

Авторы анализируют возможности изучения логических закономерностей в музыке с помощью математических методов, сформировавшихся преимущественно в XX веке. Предлагаемая комплексная модель семантического пространства музыки возникла как обобщение ряда теоретических результатов, полученных ранее другими исследователями. Рассмотренные в статье методы, включающие, в частности, основные идеи таких областей исследований, как теория множеств, теория вероятностей и теория информации, а также принципы мягких вычислений, позволяют выявить предпосылки этих научных отраслей в более традиционных проявлениях теории музыки. Рассмотренные теоретические идеи и обобщения примечательны как основа для точного изучения различных компонентов системы музыкального мышления, в том числе и его синестетической области. Последний из этих аспектов важен при моделировании синестезии как частного случая виртуальной реальности с помощью компьютерных технологий и, таким образом, использования музыки как источника таких реальностей. В связи с идеями прямого включения визуального элемента в музыку компьютерными средствами такое моделирование становится важным не только для синтетических форм художественной деятельности с участием музыки, но и для самого музыкального искусства. Авторы статьи затрагивают также некоторые аспекты применения математического подхода к музыке в сфере музыкального образования.

Ключевые слова: музыка и математика, семантическое пространство музыки, теория музыки, музыкальное образование, музыкально-компьютерные технологии.

Для цитирования: Горбунова И. Б., Заливадный М. С. Комплексная модель семантического пространства музыки: перспективы объединения музыкальной науки и образования // Проблемы музыкальной науки. 2018. № 4. С. 55–64. DOI: 10.17674/1997-0854.2018.4.055-064.

The complex model of the semantic space of music combines different levels of musical semantics, including various aspects of musical logic and psychological patterns of music, among them, various forms of musical synaesthesia. One of the sources of this model (including the principle of an integrated approach to the consideration of fundamental laws of music [16]) was the theory and practice of complex analysis of musical works, which present one of the characteristic directions in the development of musicology existent since the first half of the 20th century. On the other hand, the proposed model originated as a generalization of some analogous theoretical results obtained earlier by other music scholars (Ernst Kurth, Boleslav Yavorsky, Charles Osgood, and Abraham Moles, Iannis Xenakis, Bulat Galeyev, etc.).

It must be noted that the logical laws of the structure of musical compositions has presented a subject of purposeful study by musicians since the first half of the 19th century (the theoretical works of that time disclosed elements of set theory, the nature of which, however, was not realized at that time, since mathematics and the theoretical study of music developed in many different ways: Adolph Bernhard Marx. *Die Lehre von der musikalischen Komposition*. Bd. 1–4. Leipzig, 1837–1846; Hugo Riemann. *Grundriss der Kompositionslehre*. Bd. 1–2. Leipzig, 1897).

The fundamental ideas which can form the theoretical basis for such studies are represented by a number of significant works (Rudolf Zaripov. *Cybernetics and Music*. Moscow, 1971; Alexey Losev. *Music as a Subject of Logic*, Alexey Losev. *From the Early Works*. Moscow, 1990; Sergey Eisenstein. *The Vertical Montage*, Sergey Eisenstein. *Selected Works in 6 Vol., Vol. 2*. Moscow, 1964, etc.), among which a special place is held by Iannis Xenakis's book "Musiques formelles" [25]. It outlines the links and parallels between the set theory and probability theory aspects of the study of the system of musical logic, which are concentrated mainly in the chapters that made up the first edition of the book (1963) (a more detailed analysis of this aspect of the problem is given in the works [10; 11]).

The information content of structures of musical logic is characterized by Xenakis on the basis of Claude Shannon's statistical information theory. Due to the "double"-probability theory and set-theory use of matrices (as in a game – the theoretic sections of the element of evaluation of the messages are clearly presented), there is also the question of synthesis of the different approaches to the study of information, which is undoubtedly of promising value. According to the authors of the article, as one of the steps towards solving this problem in relation to the area of musical logic, it is possible to use the system of "banal deductions" (respectively, the frequency of repetition of an element or a combination of elements) stemming from the values characterizing the variety of relations between elements in certain musical constructions, in the informational assessment of these latter (see, e.g., [3; 9; 10]).

Previously, the characteristic of the "pleasant character" of the consonances that are close to the concept of information (subjectively perceived diversity) was put forward in Leonhard Euler's book *Tentamen Novae Theoriae Musicae ex Certissimis Harmoniae Principiis Delucide Expositae* (Petropoli: Typographia Academiae Scientiarum, 1739), while the author of the book considered the various aspects of this characteristic feature, in particular, the results of combining the consonances in a particular key with the modulations from one key to another (discussed in more detail in [3]). As shown by later studies (see, for example: [1]), the concept of information is very important for the aesthetic evaluation of phenomena; at the same time, the meaning of this concept (as well as the Eulerian category of "pleasantness") is not limited to a purely logical area, it also includes more specific semantic content (Abraham Moles. *La théorie de l'information et la perception esthétique.* Paris, 1958; John Pierce. *Symbols, Signals and Noise. The Nature and Process of Communication*. London, 1962). In addition, the general philosophical meaning of the concept of information is revealed in its theoretical consideration and practical application, as well as the musical-aesthetical aspect (Rudolf Zaripov. *Cybernetics and Music*. Moscow, 1971).

The results of the use of mathematical methods in musicology in the first two thirds of the 20th century received a further impetus due to the emergence of the theory of fuzzy sets (Lotfi Zadeh. *The concept of a linguistic variable and its application to approximate reasoning*. Moscow, 1977; *Soft Computing. Third International Workshop on Rough Sets and Soft Computing.* San Diego, 1995), the appeal to which allowed identifying the prerequisites for its appearance in the theory of music. Thus, musicology and related sciences in the mid-20th century offered a number of promising ideas, containing ample opportunities for studying uncertain factors in the system of musical thought and partially ahead of the same ideas in the exact sciences. At the turn of the 1940s and the 1950s, music theorist and acoustician scientist Nikolai Garbuzov put forward the theory of the zonal nature of musical hearing, covering all the basic properties of sound (Nikolay Garbuzov. *Musician, Researcher, Teacher*. Moscow, 1980). According to this theory, each elementary logical unit of music corresponds in practice to a number of sound characteristics close to each other (pitches, durations, dynamics, timbres), together forming a whole aggregate entity, – namely, the zone. The boundaries of these zones change over time; their number may also change.

Around the same time a group of American composers (John Cage, Earle Brown, David Tudor, etc.) put forward a number of proposals to introduce factors of uncertainty into the logical structure of music, which later took shape in the form of aleatoric and sonoristic compositional techniques and became widespread throughout the world (see, for example: Edison Denisov. *Stable and Mobile Elements of Musical Form and their Interaction*; Edison Denisov. *Contemporary Music and the Problems of Technique Evolution in Composition*. Moscow, 1986; Mikhail Zalivadny. *Experiments on Applying the Regularities of Sight-and-Hearing Synaesthesias in Composing and Analyzing Music*, Mikhail Zalivadny. *Synaesthesia: the Unity of Senses and the Synthesis of Arts*. Kazan, 2008; Trygve Nordwall. Krzysztof Penderecki – studium notacji i instrumentacji. *Res facta*. Kraków, 1968. No. 2). Some aspects of these proposals are related to Garbuzov's zonal theory, but are more applicable to the performing side of music and suggest much wider boundaries of the zones of the pitches and durations of sound. Practical experience in the implementation of these proposals (the specific aesthetical characteristics of which are beyond the scope of this work) have contributed to the understanding of the elements of logical uncertainty present in the musical tradition (drums with an uncertain pitch, melismas, articulation, as well as the traditional system of dynamic shades).

In addition, the 1940s and 1950s witnessed the appearance of the method of the "semantic differential" by Osgood and his co-authors, who grew out of the study of the laws of the synaesthesia of sight and hearing (Charles Osgood, John Suci, and Peter Tannenbaum. *The Measurement of Meaning*. Urbana: Illinois, 1957). This method presents an important step towards the study of the field of musical-synaesthetic performances, due to their grouping based on scale steps of differences. In addition to the possibility of statistical generalizations of the data of synaesthetic perception of music by different listeners (which is also associated with the uncertainty factors of musical content), this method allows for an element of uncertainty in the structure of the scales themselves, which enables us to talk about the zonal nature of musical synaesthesia. Each differential (unit of distinction) in such a scale is represented by a line segment (between opposite concepts), which may also be interpreted as a zone of synaesthetic representations. The distinction itself of these representations is possible on the basis of both quantitative and qualitative differences and, thus, does not require mandatory equality of segments in size.

From the point of view of the logical organization of music, it is possible to modify this device when the bearers of the musical value are not segments ("differentials of semantic scales"), but points at their junctions, the location of which also allows certain fluctuations within a certain band (zone). This modification gives the scales of synaesthetic values of music elements a similarity with the existing scales of differences of these elements in music theory (a simple example of which is ascending pitch), also allowing different degrees of accuracy and, accordingly, fluctuations in the distances between individual elements (for example, the scale of intervals in the work of Sergey Taneyev *Mobile Counterpoint of Strict Writing*. Moscow, 1959). The original version of the method of studying synaesthetic patterns of music on this basis (with an open internal structure of scales and a qualitative difference of the elements of synaesthetic correspondences) was proposed in the 1970s by Galeyev in relation to the study of auditory-visual synaesthesia (Bulat Galeyev. *The problem of synaesthesia in art. The Art of Luminous Sounds*. Kazan, 1973).

The ideas and methods described above present the obvious prerequisites for the use of the apparatus (at the time of the generation of most of those ideas, which had not existed prior to that), fuzzy and "rough" (i.e. containing only the limit values included in the fuzzy set of values) sets in music theory (in addition to the apparatus of the theory of probability and mathematical statistics, which had previously been known and widely used already in the 1950s and 1960s). However, these do not give a complete picture of the forms of manifestation of the uncertainty factor already identified by that time, acting within the system of musical thought (including its synaesthetic sphere). More complex forms of this type are noted in the works of Ernst Kurth [21] and Joseph Schillinger [24], as well as other music theorists, devoted to the regularities of the spatial-auditory synaesthesia in melodic movement. Both of these researchers note the value of individual sounds of the melody as points that highlight the moments of change of the direction of the motion ("the boundaries of individual phases," "the highest points of linear curves"). In addition to that, Schillinger indicates the dependence of the nature of the lines in the included musical synaesthesia of visual representations of the articulation of sounds (curve – legato, broken line – non legato, point structure – staccato). The specific nature of curves or broken lines is not regulated, which makes it possible for us to speak (this is especially obvious in the case of curvilinear motion paths) about their "zonal geometry," as well as the fuzzy functional dependencies in the interaction of sound and visual elements [2] in the framework of musical synaesthesia.

The examined theoretical ideas and generalizations are remarkable as a basis for concise study of the various components of the system of musical thought, including its synaesthetic area. The last of these aspects is very important in the modeling of synaesthesia as a special case of virtual reality by means of computer technology and, thus, the use of music as a source of such realities. In connection with the ideas of direct inclusion of the visual range in music by computer means (Viktor Ulyanich. *Computer Music and the Exploration of a New Medium of Artistic Expression in the Art of Music: Thesis of Dissertation for the Degree of Candidate of Arts (Ph.D.).* Moscow, 1997), such modeling becomes very important not only for synthetic forms of artistic activity with the participation of music, but also for the art of music per se.

In connection with the development of music computer technologies (MCT) [6] as one of the most important areas of professional activity of the modern musician, it has become obvious that it is necessary to form an adequate theoretical understanding of music as a multilateral system, not limited to "logic expressed in sounds," as well as the fact that such representation is necessary for the training of modern musicians of various specialties.

With the help of the presented model, it is currently becoming possible to study in great detail the patterns of interaction between different levels of figurative content of music, which have not been previously subjected to wide systematic study, as well as the patterns of interaction of figurative and semantic spaces of the generators (composers and performers) and the recipients (listeners) of musical works. Thus, the author acquires rational justification and prospect of entering into a more multilateral semantic integral number of historical models of musical space (for example, circular models of sound orders and rhythms in the medieval theory of music of the Middle East [18, V. 3]). The compositional and logical aspects of this model in their obvious forms contribute to the identification of patterns of active and creative perception of music, which is essential for the formation of creative thinking in general. The features of the structure of the "auditory-visual area" of this model create the opportunities for practical computer-graphic modeling of musical structures with the use of methods of representation of three-dimensional spaces in virtual reality systems. The results of this presentation can be applied in the field of art studies, psychology, general and musical education.

The considered model can be applied as a structural basis for the systematic study and practical development of laws of musical logic (the contrapuntal, pitch, rhythmic, and volume-dynamic organization of music, its general composition patterns, etc.); it is possible to identify the subspaces appropriate to these laws, which do not contain the danger of their absolutization. In equal measure, this model can be used in the study and modeling of various forms of musical synaesthesia (including the use of computer technology), thereby significantly enhancing the prospect of the development of extraterrestrial domains of musical thinking to a degree comparable to that of the development of the musical sound system. It is also very promising and fruitful to apply this model in the field of complex analysis of musical works (including the extremely complex content and structure of the issues of perception and aesthetic evaluation of music) and the study of the ways of their existence in connection with the peculiarities of performance interpretation. Of particular interest is the issue of the output of specific results of musical modeling in other areas of knowledge and, ultimately, the practical transformation of the "virtual realities" created by music into a "true" reality, relating to the field of material phenomena and processes surrounding the man.

The development of individual compositional patterns, as well as their totality, contributes to the disclosure of the concept of harmony. Since the function of harmony is bonding, the connection of a certain number of elements to synergetically align them with each other to perform a common task, teaching students including those from specialized music schools using information technology, in the connection of computer and art, is of great importance in such a section of mathematics as the theory of groups. In a well-known work on the theory of groups devoted to the use of principles and methods of symmetry in various fields of art it is noted: "The concept of symmetry is included in art through the concept of structure. Art, as a figurative form of knowledge and modeling of the world, should reflect and really reflects its structural side. Structuredness is a fairly general law, a form of existence and movement of matter, and the products of scientific and artistic creativity are also subject to this law. It is well known that works of art such as fiction, poetry, music, painting, architecture, etc. have a complex artistic structure and represent an organic interweaving and interpenetration of different substructures of individual components of artistic expression" [17, p. 296–297].

It should be noted that these patterns partly find expression in contemporary music computer technologies (computer system UPIC by Iannis Xenakis, "The Singing Shamayl" by Bulat Galeyev, popular musical computer programs Cakewalk Sonar, Steinberg Cubase/Steinberg Nuendo, etc.).

We live in the era of the digital civilization and, at the same time, of a change of opportunities and means of teaching art and music, in particular. In the artistic sphere great dramatic changes have occurred, and new creative directions have emerged: "digital arts," "distant reading," "digital reading" (a term proposed by Franco Moretti), "music computer technologies," "media education," etc., requiring joint research of humanitarians and specialists in the field of digital technologies.

The knowledge of the secrets of sound production, sound creation, richness of timbre and acoustic influence of music is becoming more tangible for a true musician, it enriches his/her creative imagination, gives an incentive to artistic innovation. As already noted, at the turn of the 20th and 21st centuries, there appeared a new direction in musical creativity and music pedagogy, i.e. MCT, due to the rapid development of electronic musical instruments (from simple synthesizers to powerful musical computers) [19; 20]. In contemporary electronic musical instruments, the most complete and perfectly embodied centuries-old accumulated information technology in music and the art of music making. With the development of MCT and the media music direction in modern music education, a significant place has been occupied by the technological aspects of ideas about musical creativity and musical instruments (including music and computer); without a knowledge of these aspects, it is impossible for the performer to interpret musical compositions correctly. The outstanding pianist of the 20th century Josef Hofmann writes: "When a student pianist sufficiently mastered the material side, that is, the technique, an unlimited space, a wide field of artistic interpretation, opens up for him/her. Here the work is mainly analytical, and it requires that the mind, spirit and feeling, supported by knowledge and aesthetic flair, form a happy union that allows you to achieve valuable and worthy results" (Josef Hofmann. *Piano Performance. Answers to Questions about Piano Playing*. Moscow: Muzgiz, 1961, p. 31).

The existence of musical instruments, their sound, embodied in the musical sonorities, illustrates the fundamental ideas associated with the study of a complex model of the semantic space of music. The musician's attention is drawn to the study of the physical characteristics of musical sounds, the ways of their recording and playback, the explanation of psychoacoustic features of auditory perception of sound by a person, the basic principles of computer generation of musical sound, etc.

Musical instruments as one of the sources (conductors) of musical creativity are considered as synthesizers of musical sound in their historical development (from mechanical, acoustic instruments to modern musical computers) [3]. (Note that the importance of understanding the mathematical, physical and physiological analysis of musical sound for those involved in musical creativity, in the middle of the 19th century was revealed by outstanding German scientist Hermann von Helmholtz: Hermann Helmholtz. *On the Physiological Causes of Musical Harmony*, Vol. 2. St. Petersburg, 1896).

Much in this direction has already been thoroughly developed by Russian scientists. Let us touch, in particular, on the need to include in the system of modern professional musical education fundamental courses related to the study of the basics of musical acoustics, which today, with the active introduction of modern information technologies (IT) and MCT, has received an effective and qualitatively new development, it has determined much in the development of music science in general [4]. Today, courses of academic disciplines have been prepared aiming at forming the ideas of the contemporary musician about acoustics, musical acoustics, in particular, about the MCT and in general about IT in music and contemporary musical education.

In this regard, also of particular importance are the works of Yuri Rags. Working in various fields of music scholarship, including issues of musical aesthetics, research in the field of musical psychology (including the problems of musical synaesthesia), revealing the features of the interaction of the composer and art performing, asserting the role and place of new IT in music and musical education, developing the conceptual framework of the course "Musical Informatics," assessing the role of electronic and computer music in contemporary musical and artistic space, finally, deeply and substantively dealing with musical acoustics and defining its place in modern music education, the scholar simultaneously demonstrated his concern about the disunity in the organization of musicological scholarship (see, for example: [8; 14; 15]). He turned to this topic constantly, for many years, as if trying to find a tool with which to implement the process of combining disparate areas of music research. He writes: "We proceeded from the fact that the system of the art of music, which is one in its essence, should find unity in scholarly knowledge. With this purpose, one of the variants of the model considered was the model of a holistic system of studying the musical arts" [14, p. 40]. The missing component, namely, the instrument of the musician-researcher and the creator, with the help of which it is possible to combine into one whole the whole "multilayered musical culture" (the term of Zofja Lissa [22]), is, in his opinion, musical acoustics, directly studying the material of the "homogeneous medium" of music (a term by György Lukács [23, p. 352]), and thus designed to provide the necessary level of generalization.

In contemporary electronic musical instruments, the century-long experience of information technology in music and of the art of music-making is accumulated and embodied in the most perfect and complete manner. Discussing the role of IT in the contemporary musical-educational space and creativity, Rags notes that "now with the invention of sound recording, sound film, radio, television, with the development of sound engineers, as well as those who are engaged in computer music, music acoustics is becoming a more and more significant research discipline. On its basis it is possible to manage the complexity of the process of composing a musical work, playing and editing sounds" [14, p. 245]. Today, it is clear that the use of the IT has great potential for writing, performing, researching music and music education; that this process should not be feared, but rather should be supported and actively participated in. Too often asked the question, Rags replied, "What you need is to replace talented musicians by the 'machine,' to take art alive in one last plan, and thus lower the aesthetic value of the art of music. But in this regard, no one sets a goal for him/herself. It is known that the computer and electronic sound permeates present-day advertising, musical videos, television and radio broadcasts, films etc. Their quality is not always satisfying. Therefore, there is a need to prepare real professionals in this area who could really raise the artistic level of art. And educational institutions should not depart from the case, but, if possible, lead them" [15, p. 202].

Calling for a unification of musicians, musicological theories, and the knowledge of music, Rags also speaks about the need to unite musicians themselves: “To unite the interests of musicians working in secondary schools and in special music schools in all disciplines and at all levels of education (in children’s music schools, comprehensive schools or colleges, universities)” and “to use the rich opportunities of new IT and in the methodological development of the system of music education” [14, pp. 65, 67], to establish mutual understanding between representatives of different directions of musical and scientific research, the need for “more harmonious relations between them: one cannot exist without the other, and artificially created barriers between music and acoustics, which have arisen in educational institutions, will be unnecessary. In reality, these barriers do not exist” [Ibid., p. 83]. The scholar emphasizes the meaning and the role of musical acoustics in the synthesis of the different areas of musicological research: “The problem method of phonics at different periods of its development, the value of musical acoustics for different spheres of scientific knowledge of music and a lot of other issues, these problems constitute the content of future research that we believe, will be conducted jointly by musicians, including teachers, and acoustically” [Ibid., pp. 244–245].

The discovery of the connection between the auditory evaluation of space and its objective properties is a step towards a new stage in the development of musical acoustics, to the consistent formation of elements of a complex model of the semantic space of music, reflecting the current state of music science, as it allows the musician to understand the underlying principles of the formation of the sound image of the musical space in the process of creating musical compositions (see, for example: [5; 7; 13]).

Expounded in this article to the fullest extent, these ideas found expression in the course “Information Technologies in Music” [3; 9], which is one of the fundamental courses for preparing students in music departments of pedagogical universities, musical academies and conservatories, studying in the direction of “Music Computer Technologies.” The tutorial process for this educational program also includes the following disciplines of profile training: “Computer Music,” “History of Electronic Music,” “Technologies and Methods of Training (in the Disciplines of Profile Training: Music Computer Technology),” “Architectonics of Sound,” “Fundamentals of Studio Recording,” “Information Technology in Music,” “Technology of Musical Styles,” “Fundamentals of Composition, Instrumentation and Computer Arrangement,” “Traditional and Computer-Using Orchestration,” “Technology of Studio Recording,” “Methods and Practice of Teaching Electronic Composition and Arrangement,” “Methods of Teaching Playing an Electronic Musical Instruments,” “Standard Software of Professional Activities of a Musician,” “Theory of Traditional and Electronic Instruments,” “Musical Computer,” “Basic Electronic Musical Instrument,” “Additional Musical Instrument (Electronic),” “Electronic Synthesizer,” “Electronic Ensemble,” “Computer Music Workshop,” etc.

At the stage of primary vocational education, programs of profile, and pre-profile training for students of schools with in-depth study of the subjects of the musical cycle (the discipline “Music Computer Technologies,” “The Musical Computer as a New Instrument of a Musician,” “The Musical Computer Is my Friend,” etc.) have been implemented. Students of the system of additional professional education are trained in professional retraining programs “Teaching Musical Disciplines by Using Music Computer Technologies” and “Teaching Electronic Music Synthesizers,” as well as in programs of advanced training “Music Computer Technologies,” “Electronic Musical Instruments,” “Interactive Network Technology of Music Training” (the program “Soft Way to Mozart”), “Music and Informatics,” “Contemporary Methods of Teaching Music Disciplines by Using Music Computer Technology,” “Performing Skills on the Keyboard Synthesizer,” “Contemporary Methods of Teaching Music Disciplines by Using Computer Technology,” “Methods of Teaching Music to People with Disabilities (Vision and Hearing Impairment) Using Music Computer Technologies,” “Computer Music,” “Methods of Teaching Music Disciplines by Using Music Computer Technologies,” “Cloud-Oriented and Tablet Technology in the Teaching of Music Disciplines,” etc.

For the implementation of these disciplines a number of textbooks [3; 9; 12, etc.] have been prepared, which deal with the principles and forms of interaction of music, mathematics and computer science in their historical development (including the modern stage); they contain recommendations for the construction of the training courses on the use of mathematics and information technology in the field of music research and practical composition.

REFERENCES

1. Belov G. G., Gorbunova I. B. Muzyka i kibernetika [Music and Cybernetics]. *Muzyka i vremya* [Music and Time]. 2016. No. 11, pp. 25–32.
2. Gorbunova I. B. Audiovizual'nyy sintez: istoriya, sovremennoe sostoyanie, perspektivnoe znachenie dlya muzykal'noy teorii i praktiki [Audiovisual Synthesis: History, Current Status, Promising Value for Music Theory and Practice]. *Mir nauki, kul'tury, obrazovaniya* [The World of Science, Culture, Education]. 2014. No. 6 (49), pp. 456–461.
3. Gorbunova I. B. *Informatsionnye tekhnologii v muzyke: uchebnoe posobie dlya studentov vysshikh uchebnykh zavedeniy, obuchayushchikhsya po napravleniyu "Pedagogicheskoe obrazovanie": v 4 t.* [Information Technologies in Music: A Textbook for Students of Higher Educational Institutions Enrolled in the Direction of "Pedagogical Education": in 4 Volumes]. St. Petersburg: Publ. house of the Herzen State Pedagogical University of Russia, 2009. Vol. 1: Arkhitektonika muzykal'nogo zvuka [Architectonics of Musical Sound]. 2009. 175 p.; Vol. 2: Muzykal'nye sintezatory [Music Synthesizers]. 2010. 215 p.; Vol. 3: Muzykal'nyy komp'yuter [Musical Computer]. 2011. 411 p.
4. Gorbunova I. B. Informatsionnye tekhnologii v muzyke i kompleksnaya model' eyo semanticheskogo prostranstva [Information Technologies in Music and Integrated Model of its Semantic Space]. *Nauchno-tekhnicheskie vedomosti Sankt-Peterburgskogo gosudarstvennogo politekhnicheskogo universiteta. Gumanitarnye i obshchestvennye nauki* [Scientific-Technical Bulletin of Saint-Petersburg State Polytechnic University. Humanities and Social Sciences]. 2014. No. 4 (208), pp. 152–161.
5. Gorbunova I. B. Komp'yuternye nauki i muzykal'no-komp'yuternye tekhnologii v obrazovanii [Computer Science and Music Computer Technologies in Education]. *Teoriya i praktika obshchestvennogo razvitiya* [Theory and Practice of Social Development]. 2015. No. 12, pp. 428–432.
6. Gorbunova I. B. Muzykal'noe programmirovanie, ili Programmirovanie muzyki i muzykal'no-komp'yuternye tekhnologii [Music Programming, or Musical Programming and Music Computer Technologies]. *Teoriya i praktika obshchestvennogo razvitiya* [Theory and Practice of Social Development]. 2015. No. 7, pp. 213–218.
7. Gorbunova I. B. The Role of Musical Computer Technologies in the Training of the Modern Music Teacher. *Problemy muzykal'noj nauki/Music Scholarship*. 2014. No. 3 (16), pp. 5–10. (In Russ.)
8. Gorbunova I. B. "Estetika: informatsionnyy podkhod" Yu. Ragsa: aktual'noe znachenie i perspektivy ["Aesthetics: Information Approach" by Yu. Rags: Relevance and Perspectives]. *Teoriya i praktika obshchestvennogo razvitiya* [Theory and Practice of Social Development]. 2015. No. 2, pp. 86–90.
9. Gorbunova I. B., Zalivadny M. S. *Informatsionnye tekhnologii v muzyke: uchebnoe posobie dlya studentov vysshikh uchebnykh zavedeniy, obuchayushchikhsya po napravleniyu "Pedagogicheskoe obrazovanie": v 4 t.* [Information Technology in Music: A Textbook for Students of Higher Educational Institutions Enrolled in the Direction of "Pedagogical Education": in 4 Volumes]. St. Petersburg: Publ. house of the Herzen State Pedagogical University of Russia, 2013. Vol. 4: Muzyka, matematika, informatika [Music, Mathematics, Computer Science]. 181 p.
10. Gorbunova I. B., Zalivadny M. S. Concerning Mathematical Methods in Music Research and Preparation of Musicians. *Problemy muzykal'noj nauki/Music Scholarship*. 2013. No. 1 (12), pp. 272–276. (In Russ.)
11. Gorbunova I. B., Zalivadny M. S. Opyt matematicheskogo predstavleniya muzykal'no-logicheskikh zakonomernostey v knige Ya. Ksenakisa "Formalizovannaya muzyka" [Experience of Mathematical Representation of Musical-Logical Regularities in the Book by I. Xenakis "Musiques formelles"]. *Obshchestvo. Sreda. Razvitie* [Society. Environment. Development]. 2012. No. 4 (25), pp. 135–139.
12. Gorbunova I. B., Zalivadny M. S., Kibitkina E. V. *Muzykal'noe programmirovanie: uchebnoe posobie dlya studentov vysshikh uchebnykh zavedeniy, obuchayushchikhsya po napravleniyu 050100 – Pedagogicheskoe obrazovanie* [Music Programming: A Textbook for Students of Higher Educational Institutions Enrolled in the Direction 050100 – Teacher Education]. St. Petersburg: Publ. house of the Herzen State Pedagogical University of Russia, 2012. 195 p.
13. Gorbunova I. B., Chibirev S. V. Komp'yuternoe modelirovanie protsessa muzykal'nogo tvorchestva [Computer Modeling of Creative Process in Music]. *Izvestiya Rossiyskogo gosudarstvennogo pedagogicheskogo universiteta im. A. I. Gertsena* [Proceedings of the Herzen State Pedagogical University of Russia]. 2014. No. 168, pp. 84–93.
14. Rags Yu. N. *Akusticheskie znaniya v sisteme muzykal'nogo obrazovaniya* [Acoustic Knowledge in the System of Music Education]. Ryazan: Litera M, 2010. 336 p.
15. Rags Yu. N. Perspektivy razvitiya kursa informatiki v muzykal'nykh obrazovatel'nykh uchrezhdeniyakh [Prospects of Development of Informatics Course in Music Educational Institutions]. *Sovremennoe muzykal'noe obrazovanie – 2003: materialy II Mezhdunar. nauch.-prakt. konf. (9–11 oktyabrya 2003 g.)* [Contemporary Music Education – 2003: Proceedings of the II International Scientific and Practical Conference]. Ed. by I. B. Gorbunova. St. Petersburg: Publ. house of the Herzen State Pedagogical University of Russia, 2003, pp. 200–203.

16. Shveytser A. *Iogann Sebastyan Bakh* [Schweitzer A. Johann Sebastian Bach]. Moscow: Klassika-XXI, 2011. 816 p.
17. Shubnikov A. V., Koptsik V. A. *Simmetriya v nauke i iskusstve* [Symmetry in Science and Art]. Moscow: Nauka, 2002. 429 p.
18. D'Erlanger R. *La musique arabe, ses règles et leur histoire*. T. 3: Safiyu-d-Din. Paris: Geuthner, 1938. 525 p.
19. Gorbunova I. B. Electronic Musical Instruments: to the Problem of Formation of Performance Mastery. *15th PARIS International Conference on Education, Economics, Humanities and Interdisciplinary Studies (EEHIS-18): Int'l Conference Proceedings*. Budapest, 2018, pp. 23–28.
20. Gorbunova I. B. "New tool for a musician". ICASET-18, ASBES-18, EEHIS-18. *16th International Conference on Literature, Languages, Humanities and Social Sciences (LLHSS-18): International Conference Proceedings*. Paris, 2018, pp. 144–149.
21. Kurth E. *Grundlagen des linearen Kontrapunkts*. Berlin: Max Hesse, 1922. 532 p.
22. Lissa Z. O wielowarstwowości kultury muzycznej. *Muzyka*. 1959. No. 1, S. 3–22.
23. Lukács G. *History and Class Consciousness*. MIT Press: Print, 1971. 467 p.
24. Schillinger J. *The Schillinger System of Musical Composition*. Vol. 1–2. New York: Carl Fischer, 1946. 1640 p.
25. Xenakis I. Musiques formelles. *La Revue musicale*. Paris, 1963. No. 253/254. 232 p.

About the authors:

Irina B. Gorbunova, Dr.Sci. (Pedagogical), Chief Researcher of the Educational and Methodical Laboratory of Music Computer Technologies, Professor at the Department of Informatization of Education, Herzen State Pedagogical University of Russia (191186, St. Petersburg, Russia),
ORCID: 0000-0003-4389-6719, gorbunovaib@herzen.spb.ru

Mikhail S. Zalivadny, Ph.D. (Arts), Senior Research Associate, Saint-Petersburg Rimsky-Korsakov State Conservatory (190000, St. Petersburg, Russia), **ORCID: 0000-0001-9599-5925**, trifonov_e_d@mail.ru

ЛИТЕРАТУРА

1. Белов Г. Г., Горбунова И. Б. Музыка и кибернетика // Музыка и время. 2016. № 11. С. 25–32.
2. Горбунова И. Б. Аудиовизуальный синтез: история, современное состояние, перспективное значение для музыкальной теории и практики // Мир науки, культуры, образования. 2014. № 6 (49). С. 456–461.
3. Горбунова И. Б. Информационные технологии в музыке: учебное пособие для студентов высших учебных заведений, обучающихся по направлению «Педагогическое образование»: в 4 т. СПб.: Изд-во РГПУ им. А. И. Герцена, 2009. Т. 1: Архитектоника музыкального звука. 175 с.; Т. 2: Музыкальные синтезаторы. 2010. 215 с.; Т. 3: Музыкальный компьютер. 2011. 411 с.
4. Горбунова И. Б. Информационные технологии в музыке и комплексная модель её семантического пространства // Научно-технические ведомости Санкт-Петербургского гос. политехнического ун-та. Гуманитарные и общественные науки. 2014. № 4 (208). С. 152–161.
5. Горбунова И. Б. Компьютерные науки и музыкально-компьютерные технологии в образовании // Теория и практика общественного развития. 2015. № 12. С. 428–432.
6. Горбунова И. Б. Музыкальное программирование, или Программирование музыки и музыкально-компьютерные технологии // Теория и практика общественного развития. 2015. № 7. С. 213–218.
7. Горбунова И. Б. Музыкально-компьютерные технологии в подготовке современного педагога-музыканта // Проблемы музыкальной науки. 2014. № 3 (16). С. 5–10.
8. Горбунова И. Б. «Эстетика: информационный подход» Ю. Рагса: актуальное значение и перспективы // Теория и практика общественного развития. 2015. № 2. С. 86–90.
9. Горбунова И. Б., Заливадный М. С. Информационные технологии в музыке: учебное пособие для студентов высших учебных заведений, обучающихся по направлению «Педагогическое образование»: в 4 т. СПб.: Изд-во РГПУ им. А. И. Герцена, 2013. Т. 4: Музыка, математика, информатика. 181 с.
10. Горбунова И. Б., Заливадный М. С. О математических методах в исследовании музыки и подготовке музыкантов // Проблемы музыкальной науки. 2013. № 1 (12). С. 264–268.

11. Горбунова И. Б., Заливадный М. С. Опыт математического представления музыкально-логических закономерностей в книге Я. Ксенакиса «Формализованная музыка» // Общество. Среда. Развитие. 2012. № 4 (25). С. 135–139.

12. Горбунова И. Б., Заливадный М. С., Кибиткина Э. В. Музыкальное программирование: учебное пособие для студентов высших учебных заведений, обучающихся по направлению 050100 – Педагогическое образование. Санкт-Петербург: Изд-во РГПУ им. А. И. Герцена, 2012. 195 с.

13. Горбунова И. Б., Чибирёв С. В. Компьютерное моделирование процесса музыкального творчества // Известия Российского гос. педагогического ун-та им. А. И. Герцена. 2014. № 168. С. 84–93.

14. Рагс Ю. Н. Акустические знания в системе музыкального образования. Рязань: Литера М, 2010. 352 с.

15. Рагс Ю. Н. Перспективы развития курса информатики в музыкальных образовательных учреждениях // Современное музыкальное образование – 2003: материалы II Междунар. науч.-практ. конф. (9–11 октября 2003 г.) / под общ. ред. И. Б. Горбуновой. СПб., 2003. С. 200–203.

16. Швейцер А. Иоганн Себастьян Бах. М.: Классика-XXI. 2011, 816 с.

17. Шубников А. В., Копцик В. А. Симметрия в науке и искусстве. М.: Наука, 2002. 429 с.

18. D'Erlanger R. La musique arabe, ses règles et leur histoire. T. 3: Safiyu-d-Din. Paris: Geuthner, 1938. 525 p.

19. Gorbunova I. B. Electronic Musical Instruments: to the Problem of Formation of Performance Mastery // 15th PARIS International Conference on Education, Economics, Humanities and Interdisciplinary Studies (EEHIS-18): Int'l Conference Proceedings. Budapest, 2018, pp. 23–28.

20. Gorbunova I. B. "New tool for a musician". ICASET-18, ASBES-18, EEHIS-18 // 16th International Conference on Literature, Languages, Humanities and Social Sciences (LLHSS-18): International Conference Proceedings. Paris, 2018, pp. 144–149.

21. Kurth E. Grundlagen des linearen Kontrapunkts. Berlin: Max Hesse, 1922. 532 p.

22. Lissa Z. O wielowarstwowości kultury muzycznej // Muzyka. 1959. No. 1, S. 3–22.

23. Lukács G. History and Class Consciousness. MIT Press: Print, 1971. 467 p.

24. Schillinger J. The Schillinger System of Musical Composition. Vol. 1–2. New York: Carl Fischer, 1946. 1640 p.

25. Xenakis I. Musiques formelles // La Revue musicale. Paris, 1963. No. 253/254. 232 p.

Об авторах:

Горбунова Ирина Борисовна, доктор педагогических наук, главный научный сотрудник учебно-методической Лаборатории музыкально-компьютерных технологий, профессор кафедры информатизации образования, Российский государственный педагогический университет им. А. И. Герцена (191186, г. Санкт-Петербург, Россия), **ORCID: 0000-0003-4389-6719**, gorbunovaib@herzen.spb.ru

Заливадный Михаил Сергеевич, кандидат искусствоведения, старший научный сотрудник, Санкт-Петербургская государственная консерватория им. Н. А. Римского-Корсакова,
ORCID: 0000-0001-9599-5925, trifonov_e_d@mail.ru