



Apuntes Universitarios, 2020: 10(4), octubre-diciembre

ISSN: 2304-0335 DOI: <https://doi.org/10.17162/au.v10i4.486>


## Sobre la aplicación de modelos del espacio semántico de la música en el análisis integrador de obras musicales y educación musical con tecnologías informáticas musicales


### On the application of models of the semantic space of music in the integrative analysis of musical works and music education with music computer technologies

Irina Borisovna Gorbunova<sup>1a</sup>, Mikhail Sergeevich Zalivadny<sup>2</sup>  
& Irina Olegovna Tovpich<sup>3</sup>

Herzen State Pedagogical University of Russia, St. Petersburg, Russia<sup>1</sup>  
N. A. Rimsky-Korsakov Saint Petersburg State Conservatory, St. Petersburg, Russia<sup>2</sup>  
School "Music" of the Frunzensky district of St. Petersburg, St. Petersburg, Russia<sup>3</sup>

 Orcid ID: <https://orcid.org/0000-0003-4389-6719><sup>1</sup>

 Orcid ID: <https://orcid.org/0000-0001-9599-5925><sup>2</sup>

 Orcid ID: <https://orcid.org/0000-0002-7455-006X><sup>3</sup>

**Recibido:** 03 de febrero de 2020

**Aceptado:** 07 de junio de 2020

#### Abstract

In the second half of the 20th century, many music researchers demonstrated a steady interest in music categories as the space and time, whose fundamental nature and unifying (integrating) potential are obvious. However, despite the undoubted contribution to the consolidation of the findings, there was a need for further improvement in music studies, both regarding the content and the logical (including mathematical) research apparatus. This article considers these aspects of the comprehensive model of the semantic space of music in modern research theory and practice and its impact on the system of contemporary musical education.

**Keywords:** integrative model of the semantic space of music, music education, computer technologies in music

#### Resumen

En la segunda mitad del siglo XX, gran número de investigadores en el campo de la música demostraron un interés constante en categorías musicales como el espacio y el tiempo, cuya naturaleza fundamental y potencial unificador (integrador) son obvios. Sin embargo, a pesar de la indudable contribución a la consolidación de las conclusiones, era necesario seguir mejorando los estudios sobre música, tanto en lo que respecta al contenido como al aparato de investigación lógico (incluidas las matemáticas). En el artículo se examinan estos aspectos del modelo integral del espacio semántico de la música en la teoría y la práctica de la investigación moderna y su repercusión en el sistema de educación musical contemporánea.

**Palabras clave:** modelo integrativo del espacio semántico de la música, educación musical, tecnologías informáticas en la música.

<sup>a</sup>Correspondencia al autor:  
E-mail: [gorbunova7575@yandex.ru](mailto:gorbunova7575@yandex.ru)

## Introduction

In the second half of the 20th century, the theoretical works on music did not present classical musical theoretical systems as comprehensive and versatile as the systems developed in the first half of the century. These papers considered such categories as the space and time of music, whose fundamental nature and the unifying (integrating) potential are obvious. However, music scientists and researchers in related fields paid close attention to these issues only at the turn of the 21st century.

The existing developments in this direction made an undeniable contribution to the consolidation of the research findings. Nevertheless, there was an obvious need for further development of these issues, both regarding the content and the logical (including mathematical) research apparatus. We explored several models of the space of music that were created in the first (for example, by Kurt (1947)) and in the second half of the 20th century (the models of Osgood, Suci and Tannenbaum (1957), Stockhausen (1962), Xenakis (1971), and Galeev (1973)). The conducted analysis allowed us to unite them and create a comprehensive model of the semantic space of music. This work enabled us to consider the problem of the relationship of spatial and temporal characteristics of musical structures of various scales. A draft of such a model was presented by one of the authors of this article (Zalivadny) in 1987 at the workshop “The Synthesis of Arts in the Age of Scientific and Technological Revolution” held in Kazan as part of the All-Union School and Festival “Light and Music,” and later, in a more expanded form, by the authors of this article (Gorbunova and Zalivadny, 2018).

### *Literature review*

One of the authors of this article first used the models of the semantic space of music when teaching students of the Leningrad (St. Petersburg) State Conservatory. This work involved the models of Osgood, Suci and Tannenbaum (1957), Nazaikinsky and Rags (1964), Galeev (1973), some earlier ideas related to this problem (Eisenstein, 1940; Schillinger, 1978), as well as some provisions presented in the works of Riemann (1900) (for example, the idea of expressing “the dynamic side of affects” in music developing the similar position of Hanslik (1854)).

These findings were further explored in the scientific cooperation with the Department of Computing Systems and Networks of St. Petersburg State University of Aerospace Instrumentation, the Faculty of Arts of St. Petersburg State University, the Music and Computer Technologies Training Laboratory of Herzen State Pedagogical University of Russia, and St. Petersburg State Conservatory. The results of this cooperation were presented in a number of publications with the participation of the authors of this article (Alieva and Gorbunova, 2016; Alieva, Gorbunova and Mezentseva, 2019a; Gorbunova and Zalivadny, 2012; Zalivadny and

Burshtyn, 2005; Zalivadny, Burshtyn and Budeykina, 2007), as well as in the dissertation of the candidate of sciences defended in 2001 on the topic “Theoretical problems of the computerization of musical activities (an attempt of a integrative description)” (Zalivadny, 2001).

Some publications not only explore the general laws of the proposed model, but also provide examples of the application of these laws to specific historical material (from antiquity to the present time) (Gorbunova, 2016, 2017). These applications have confirmed the advantages of this model, demonstrating its promising potential of further application. Over time, however, it became apparent that to conduct further research in this direction, it is necessary to overcome the inconsistency in previous publications. This resulted in a collection of works “Comprehensive model of the semantic space of music” published in 2013 (Gorbunova, Zalivadny and Tovpich, 2016), as well as studies conducted at the Educational and Methods Laboratory “Music and Computer Technologies” of Herzen State Pedagogical University of Russia and some scientific articles and monographs, among which we would like to mention (Gorbunova and Zalivadny, 2017).

### **Materials and methods**

Understanding music as a message naturally led to the semantic interpretation of the phenomenon of the space of music (as well as the time of music). This does not exclude the possibility of studying its other aspects, for example, within the morphology of art. In turn, the semantic approach to the phenomenon studied explains the focus on the spatial aspects of music, since the psychological idea of the “seeming present” (in other words, “psychological now”) implies the exposure of the whole musical image, which is the starting point of its further evolution. The significance of the spatial aspects of music is also confirmed by subsequent processes of the simulations of the results of such an evolution.

When developing the mathematical apparatus of the proposed model, it was fairly difficult to establish correspondences to some specific logical and technological generalizations of music theory, which required modification of some original definitions that are widely used, for example, when teaching the courses of “Mathematical research methods in musicology,” “Music informatics,” “Computer and music technologies,” “Computer and music creative work,” “Sound and timbre programming,” “Music sound engineering,” and “Music programming”.

### **Results and discussion**

To determine the applicability of the comprehensive model of the semantic space of music (respectively, to test its effectiveness), we used the introductory section of Scriabin’s 10th piano sonata (vols. 1–38) as a representative example. In this analysis, we applied the tabular recording method (similar to the one described in the work of Nazaikinsky and Rags

“Perception of musical tones and the meaning of individual harmonics of the sound” (Nazaikinsky and Rags, 1964, pp. 93-98), as well as one of the analytical sections in S. Eisenstein’s earlier article “Vertical Montage” (Eisenstein, 1940, pp. 248-249). The columns of the table corresponded to measures, the lines – to various areas of semantics, including “the dynamic side of affect” (its spatial and kinetic basis), and the associated ideas of “warmth,” “lightness,” and “probabilistic thingness” of the corresponding musical constructions.

The conducted experiment confirmed the great potential of the models used, their contribution to the consistent identification and systematic reproduction of the synesthetic (and generally specific content) characteristics of music. At the same time, it was possible to determine the structural foundations of the semantic interpretation of the analyzed extract of Scriabin’s music by the composer himself (“forest,” sounds and emotions of the nature (Sabaneev, 2000, p. 263)). In turn, the analysis results indicated that it was necessary to further improve the structure of the models, which required, on the one hand, using the apparatus of modern mathematics (first of all, set theory (Zalivadny and Burshtyn, 2005; Zalivadny, Burshtyn and Budeykina, 2007)), and on the other hand, a more detailed study of historical traditions related to the theoretical consideration of the synesthetic laws of music. Here it seems viable to consider the approaches (from the project of “The Clavecin for the Senses” by Castel (1763) to the theoretical ideas of “Vertical Montage” by Eisenstein (1940, p. 192) and the characteristic features of some poetic translations of Baudelaire’s sonnet “Correspondences” (1970). According to them, *synesthesia should be interpreted as a score* (the lines of which correspond to different dimensions and groups of dimensions of the semantic space) and *as an ensemble*, ultimately – *as a keyboard system* (the latter consisting of the same components). It is also possible to draw an analogy with timbre banks (for example, on an organ or synthesizer), including those with a variable structure. An important distinguishing feature of these interpretations is that the main carriers of the meaning in them are (in the form of notes, keys, etc.) points at the junctions of segments of semantic scales (in contrast to highlighting the segments themselves like in the model of Osgood, Suci and Tannenbaum (1957)), which seems to be more consistent with the wider established traditions of professional musical theory and practice (Gorbunova, Zalivadny and Tovpich, 2014).

By studying the materials on the history of musical and synesthetic patterns we could identify a number of duplications in the analyzed extract of Scriabin’s sonata regarding the characteristics of some lines of the analytical table (the indicators of the “dynamic side of affect,” “warmth,” and “lightness”). Therefore, there is a possibility of a more flexible interaction (similar to the timbre side of orchestral musical compositions) between various psychological modalities and other components forming the comprehensive musical image. The examples of this flexible interaction that allows free emergence and disappearance of these components, as well as various transitions, “roll calls” and “dialogs” between them, are found

in traditional (written “in line”) samples of a comprehensive analysis of musical works (a representative example is the analysis of the episode “The Action of the Elders –Human Forefathers” from I. Stravinsky’s ballet “The Rite of Spring” by Asafiev in his “Book of Stravinsky” (1977, pp. 57-64)). It should be said that the structured “musical score” consideration of this area of musicology may become another significant direction of research on music theory.

Another important issue is the role of music computer technologies (MCT) in the creation of different “virtual realities” based on musical synesthesia and using such realities in art synthesis and the corresponding development of an integrated model of the semantic space of music both in music science (musicology) and in its applied aspects (Gorbunova, 2019; Mahmood, Al-Kubaisy and Al-Khateeb, 2019; Hassan, Al-Mashhadi, Hassan and Jawad, 2019). The most significant of these is currently musiceducation. In the future, this integrated model of the semantic space of music is to be developed by the Educational and Methods Laboratory “Music and Computer Technologies” at Herzen State Pedagogical University. Its employees have carried out extensive research and methodological work resulting in a significant contribution to the structure and content, as well as the application of the model studied. This includes a dissertation defended in the Educational Laboratory “Music and Computer Technologies” that explored various aspects of the application of a comprehensive model of the semantic space of music in the music education involving computer technologies, as well as studied the properties of this model and its application in computer simulation of musical creative work. As a few examples of research on this issue let us mention the works “Teaching information technology to future secondary schools music teachers in a pedagogical university” (Pankova, 2016), “Music computer technologies as a phenomenon of modern culture” (Romanenko, 2015); “Methods of teaching computer science through music computer technologies at the propaedeutic stage of general education” (Plotnikov, 2014), “Methods of teaching the basics of musical programming” (Kibitkina, 2011), “Approaches to implementing the concept of music and computer education in the training of a music teacher” (Kameris, 2007).

At the moment, the author of this article supervises dissertation research in the following specialties: 13.00.02 – Theory and methods of training and education (music, general and professional education); 13.00.02 – Theory and methodology of training and education (computer science, general and professional education); 05.13.18 – Mathematical modeling, numerical methods and software systems; 13.00.08 – Theory and methods of professional education; 05.25.05 – Information systems and processes; 17.00.02 – The art of music; 24.00.01 – Theory and history of culture (art history, cultural studies), these include:

*Candidate dissertations* “Methods of teaching music and computer science to students with visual impairment using MCT” (Voronov), “Integration of MCT and theoretical music

subjects as a means of teaching computer science to the students of Music and Education” (Yatsatkovskaya), “Methodology for the development of informational competence of music teachers in the system of continuing professional education” (Tovpich), “Training of music teachers of supplementary education for children to work in the educational information environment”(Davletova), “Development of general cultural competencies of students of a pedagogical university with MCT” (Balabanova), “MCT as a resource for overcoming formalism in the knowledge of music computer technologies of music teachers” (Bazhukova), “The concept of preparing a future teacher for spiritual and moral education of the youth using MCT” (Marchenko), “Organizational and pedagogical conditions for training college students to develop music culture of Yakutia with MCT” (Spiridonov), “Mobile technologies as a resource for advanced training of a music teacher” (Goncharova), “Digital button accordion performance as a sociocultural phenomenon in Russia: traditions and modern trends” (Petrova), “Software package for processing sound fragments in the MIDI format for the blind and visually impaired” (Govorova), “Computer modeling of the process of musical creativity” (Yasinskaya), “Development of a model of an intellectual system for analyzing and cataloging musical information” (Kiseleva).

*Doctoral dissertations* “Interaction of European and Far East cultural traditions of the peoples of Russia and China while mastering academic musical heritage with MCT” (Mezentseva), “Distance learning technologies in the system of modern music education” (Pankova), “Development of information and communication technologies and computing systems for creating a catalog of samples of traditional music and cybernetic ethnomusicology” (Chibiryev), “MCT in the context of the development of the cultural and educational environment of a comprehensive school” (Plotnikov), “Music and computer technologies in the contemporary system of musical education” (Kameris).

Next, let us name the main aspects of using a comprehensive model of the semantic space of music in modern pedagogical, scientific and methodological theory and practice. For instance, the comprehensive innovative educational system “Music and computer technology in the training of a music teacher,” developed in the Educational Laboratory “Music and Computer Technologies” of Herzen State Pedagogical University of Russia develops the principles underlying the methodological system based on a comprehensive model of the semantic space of music in modern education and leads to the formation of new subject areas in musical and pedagogical education, which is possible due to the emergence and development of MCT (Gorbunova and Kameris, 2019; Alieva, Gorbunova and Mezentseva, 2019b; Gorbunova and Zalivadny, 2019). These technologies enable the existence of some modern jobs for the musicians working with MCT (sound engineering, digital sound recording, sound design, sound production, performance on synthesizers and MIDI instruments), programmers, and the developers of electronic music systems (Gorbunova and Chibirev, 2019).

This methodology implies the use of music and computer technologies, specialized software, and a specially organized classroom, as well as an innovative approach to conducting classes based on group work and creativity. We created, obtained official recognition, and introduced into practice a vocational educational program “Music and Computer technologies” for training Bachelors of art education. Since 2004, students have been enrolled in various Russian regions and educational institutions. The following courses have been developed and conducted for students of music departments at pedagogical universities: “Computer music,” “History of electronic music,” “Technologies and teaching methods: music and computer technologies,” “Sound architectonics,” “Fundamentals of studio recording,” “Information technologies in music,” “Technology of music styles,” “Fundamentals of composition, instrumentation and computer orchestration,” “Traditional and computer orchestration,” “Studio sound recording technologies,” “Methodology and practice of electronic composition and orchestration,” “Methods of teaching an electronic musical instrument,” “Basic software for the work of a musician,” “Traditional and electronic instrumentology,” “Musical computer,” “Main electronic musical instrument,” “Additional musical instrument (electronic),” “Electronic synthesizer,” “Electronic ensemble,” “Music and computer workshop”, etc.

We developed and implemented a master’s program “Music and Computer Technology in Education.”

The students of the Faculty of Special Needs Education (the Department of Deaf Education) have been doing such courses as “Musical and computer technologies for the rehabilitation of people with hearing impairments,” “Musical and computer technologies for the rehabilitation of people with visual impairments,” etc. The following professional retraining programs have been developed:

- “Teaching music subjects with music and computer technologies”;
- “Teaching electronic musical instruments”;
- “Information technology in music and music education”;
- “Technologies for the creation and artistic processing of sound information”.

Applying the proposed methodology, the following continuing education programs have been created in the Educational Laboratory “Music and Computer Technologies”:

For music teachers in secondary schools and the teachers of music and art schools such courses as “Music computer and technologies,” “Methods of teaching music subjects with music and computer technologies,” “Computer musical creative work,” “Methods of teaching electronic musical instruments,” “Orchestration with electronic musical instruments,” “Distance musical education,” “Information technologies in music,” “Musical computer as a new instrument of a musician,” “Teaching music subjects with a synthesizer and a computer in children music and art schools,” “Information technology in music education,” “Musical

computer in a children music school,” “Sound design,” “Applied sound engineering,” “Fundamentals of musical programming,” “Modern methods of teaching music subjects with computer technology,” “Methods of teaching music to people with disabilities (visual, hearing impairments) using music computer technology,” “Interactive network learning technologies,” “Electronic musical instruments,” “The art of performance and orchestration with the piano synthesizer,” “Computer music,” etc.

For students of music schools, an elective vocational course “Music Computer (a new instrument of a musician)”, which enables to develop the creative potential of music students, expanding the range of musical instruments, familiarizing them with the application of information technologies in the field of music.

For sound engineers and sound producers we developed a professional retraining program “Technologies for the creation and artistic processing of sound information,” as well as advanced training courses “Musical sound engineering,” “Computer musical creativity,” “Technologies for creating audio-visual projects,” “Designing educational and methodological content for the implementation of distance music training,” “Management and marketing in distance music education,” “Digital technologies in modern concert practice,” etc.

### **Conclusion and outlook**

This article explores the basic methods of an integrative analytical study of music with the models of musical semantic space. It is obvious that further detailed research on the effectiveness of this approach (and similar ones) requires a more extensive study and the accumulation of larger volumes (arrays) of relevant analytical results. However, there is no doubt that one of the important goals of such studies is to ensure the systematic professional development of the non-sound areas of musical thinking to the level comparable to the mastery of the sound system of music.

The authors of the article are currently developing the main aspects of the comprehensive model of the semantic space of music and are exploring the potential of music and computer technologies in the development of various kinds of “virtual realities” based on musical synesthesia, and the application of such realities to solving problems of art synthesis.

Another relevant issue is the application of MCT in the integrative model of the semantic space of music when studying biorhythmics of a composer’s work, establishing the authorship of discovered musical fragments recorded within various information and symbolic musical systems (for example, hooks, Znamenny Chant, kontakion, cinnabar notes, and neume), and the restoration of the lost elements of musical works.



**References**

- Alieva, I. G. and Gorbunova, I. B. (2016). On the project of creating an intellectual system for cataloging and analyzing the music of the peoples of the world. *Society: Philosophy, History, Culture*, 9, 105-108.
- Alieva, I. G., Gorbunova, I. B. and Mezentseva, S. V. (2019a). Music and computer technologies as a tool for spreading and preserving musical folklore (on the example of the Russian Far East). *Music Scholarship*, 1(34), 140-149. doi: <https://dx.doi.org/10.17674/1997-0854.2019.1.140-149>
- Alieva, I. G., Gorbunova, I. B. and Mezentseva, S. V. (2019b). Music computer technologies as a worth-while means of folklore studying, preserving and transmission. *Utopia y Praxis Latinoamericana*, 24(S6), 118-131.
- Asafiev, B. V. (1977). *The Book of Stravinsky*. Leningrad: Musika.
- Baudelaire, C. (1970). Correspondences. In C. Baudelaire, *Flowers of Evil* (p. 20). Moscow: Nauka.
- Castel, L.-B. (1763). *Clavessin Pour Les Sens. Esprit, Saillies et Singularités du P. Castel*. Amsterdam, Paris: Vincent.
- Eisenstein, S. M. (1964). Vertical montage (1940). In S. M. Eisenstein, *Selected Works in 6 Volumes*, Vol. 2 (pp. 189-266). Moscow: Iskusstvo.
- Galeev, B. M. (1973). The problem of synesthesia in art. Art of luminous sounds. In Collection of Works of the Student Design Bureau "Prometheus" (pp. 67-88). Kazan: Kazan Aviation Institute.
- Gorbunova, I. B. (2016). Methodological aspects of the interpretation of the functional and logical laws of music and computer and music technologies: Systems of musical score. *Society: Sociology, Psychology, Pedagogy*, 10, 69-77.
- Gorbunova, I. B. (2017). Information, music, and computer technologies in music education. In I. B. Gorbunova (Ed.), *The Collection of Works "Contemporary Musical Education – 2016: Materials of the 15th International Research and Practical Conference"* (pp. 44-51). Herzen State Pedagogical University of Russia, St. Petersburg State Conservatory named after N. A. Rimsky-Korsakov.
- Gorbunova, I. B. (2019). Music computer technologies in the perspective of digital humanities, arts, and researches. *Opcion*, 35(S24), 360-375.
- Gorbunova, I. B. and Chibirev, S. V. (2019). Modeling the process of musical creativity in musical instrument digital interface format. *Opcion*, 35(S22), 392-409.
- Gorbunova, I. B. and Kameris, A. (2019). Music computer education concept for teachers: Raising the problem. *International Journal of Recent Technology and Engineering*, 8(2S4), 913-918. doi: <https://dx.doi.org/10.35940/ijrte.B1181.0782S419>

- Gorbunova, I. B. and Zalivadny, M. S. (2012). The experience of the mathematical representation of musical logical patterns in the book of J. Xenakis "Formalized Music." *Society. Environment. Development*, 4(25), 135-138.
- Gorbunova, I. B. and Zalivadny, M. S. (2017). *Music, Mathematics, Computer Science: Interaction Aspects*. St. Petersburg: Herzen State Pedagogical University of Russia.
- Gorbunova, I. B. and Zalivadny, M. S. (2018). The integrative model for the semantic space of music: Perspectives of unifying musicology and musical education. *Music Scholarship*, 3, 55-64. doi: <https://dx.doi.org/10.17674/1997-0854.2018.4.055-064>
- Gorbunova, I. B. and Zalivadny, M. S. (2019). Leonhard Euler's theory of music: Its present-day significance and influence on certain fields of musical thought. *Music Scholarship*, 3(36), 104-111. doi: <https://dx.doi.org/10.17674/1997-0854.2019.3.104-111>
- Gorbunova, I. B., Zalivadny, M. S. and Tovpich, I. O. (2014). An integrative model of the semantic space of music and the prospects for the interaction of music science and modern music education. *Scientific Opinion*, 8, 238-249.
- Gorbunova, I. B., Zalivadny, M. S. and Tovpich, I. O. (2016). *A Integrative Model of the Semantic Space of Music: A Collection of Articles*. St. Petersburg: Publishing House of Herzen State Pedagogical University of Russia.
- Hanslik, E. (1910). *On the Musical and the Beautiful*. Moscow: P. Jurgenson.
- Hassan, I. M., Al-Mashhadi, H. M., Hassan, K. R. and Jawad, H. M. (2019). IoT based multitasking games and entertainment arcade station using Raspberry-Pi. *Journal of Southwest Jiaotong University*, 54(3). doi: <https://doi.org/10.35741/issn.0258-2724.54.3.4>
- Kameris, A. (2007). *Approaches to implementing the concept of music and computer education in the training of a music teacher*.
- Kibitkina, E. V. (2011). *Methods of teaching the basics of musical programming* (Candidate thesis). St.-Petersburg, Russia.
- Kurt, E. (1947). *Musikpsychologie*. Berlin.
- Mahmood, M., Al-Kubaisy, W. J. and Al-Khateeb, B. (2019). Using artificial neural network for multimedia information retrieval. *Journal of Southwest Jiaotong University*, 54(3). doi: <https://doi.org/10.35741/issn.0258-2724.54.3.19>
- Nazaikinsky, E. V. and Rags, Yu. N. (1964). Perception of musical tones and the meaning of individual harmonics of the sound. In *Application of Acoustic Research Methods in Musicology* (pp. 79-100). Moscow: Music.
- Osgood, Ch., Suci, J. and Tannenbaum, P. (1957). *The Measurement of Meaning*. Urbana, Illinois: Illinois University Press.
- Pankova, A. A. (2016). *Teaching information technology to future secondary schools music teachers in a pedagogical university*.

- Plotnikov, K. Yu. (2014). *Methods of teaching computer science through music computer technologies at the propaedeutic stage of general education.*
- Riemann, H. (1900). *Die Elemente der Musikalischen Aesthetik.* Berlin, Stuttgart: W. Spemann.
- Romanenko, L. Yu. (2015). *Music computer technologies as a phenomenon of modern culture* (Ph.D. thesis). St.-Petersburg, Russia.
- Sabaneev, L. L. (2000). *Memories of Scriabin.* Moscow: Klassika-XXI.
- Schillinger, J. (1978). *The Schillinger System of Musical Composition*, Vol. 1-2. New York: Da Capo Press.
- Stockhausen, K. (1962). The concept of unity in electronic music. *Perspectives of New Music*, 1(1), 39-48.
- Xenakis, I. (1971). *Formalized Music: Thought and Mathematics in Composition.* Bloomington, London: Indiana University Press.
- Zalivadny, M. S. (2001). *Theoretical problems of the computerization of musical activities (an attempt of an integrative description).* (Ph.D. thesis).
- Zalivadny, M. S. and Burshtyn, L. N. (2005). A integrative model of the semantic space of music: structure foundations and education potential. In I. B. Gorbunova (Ed.), *Modern Music Education – 2005. The Materials of 4th International Scientific and Practical Conference* (pp. 24-29). St. Petersburg: Publishing House of the Russian State Pedagogical University.
- Zalivadny, M. S., Burshtyn, L. N. and Budeykina, T. B. (2007). Cartesian product of sets and composition of functions: Interaction in the musical space. In *Scientific Session of SUAI. Part II. Technical Science.* St. Petersburg: St. Petersburg State University of Aerospace Instrumentation.