

An Intellectual Cataloging System for Music of the Peoples of the World. A Transdisciplinary Approach Towards the Study of Musical Phenomena: Theory of Fuzzy Sets

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Abstract—The article is a continuation of a multicomponent comprehensive study aimed at identifying the problems of using a transdisciplinary approach, which forms an effective basis for the qualitative and quantitative assessment of musical phenomena using the resources of modern music and computer technologies and their impact on various fields of musicology. The authors of the article note the special role of research in the field of the formation of a transdisciplinary approach in the methodology of modern science, belonging to the prominent Russian musicologist Mikhail Sergeevich Zalivadny (1946-2023), who owns the leading ideas in the development of a comprehensive model of the semantic space of music. The authors note that the use of music and computer technologies in scientific research devoted to this issue serves as the basis for the possibility of creating new theoretical and experimental-practical means of studying music, including uncertainty factors in music investigated with the help of music computer technologies.

Keywords— Digital Musical Instruments, Information Theory, Intelligent Cataloging System for the Music of the Peoples of the World, Musical Computer Technologies, Transdisciplinarity, Synergetic Approach, Theory of Fuzzy Sets.

I. INTRODUCTION

The use of fuzzy sets in music, which — in terms of mathematical modeling — is a complex and poorly defined system consisting of many interacting subsystems, where fuzziness and subjectivity manifest themselves both at the acoustic, structural, semantic levels, and in genres and styles, composing and performing creativity, musical analysis and criticism, is a promising area related to the systematization of big data, classification, search and structuring of musical information.

Technologies based on a transdisciplinary approach to the study of musical phenomena and the theory of fuzzy sets, the emergence of which has led to a shift in scientific paradigms to research in many fields of knowledge, are in demand by modern streaming music services and online music applications, and recommendations for listening are based on them in accordance with user requests. Also, as the experience

of implementing new professional musical and educational directions shows, such as: master's degree programs *Digital Technologies in Music and Sound Design*, *Music Computer Technologies in Education* and bachelor's degree programs: *Music Computer Technologies* and *Information Technologies in Music and Sound Design*, the transdisciplinary approach determines the functional synthesis of methodologies and the creation of completely new educational concepts based on them, based on the priority influence of the synergetic approach on the strategy of teaching musical art.

The post-non-classical paradigm of modern science is characterized by the desire for the most complete knowledge possible. The key to this knowledge is synergy, a theory of self-organization that allows combining different approaches to the study of phenomena. A powerful tool here is the combination of quantitative and qualitative research methods within the framework of a transdisciplinary approach.

Transdisciplinarity involves going beyond individual disciplines to discover common patterns in the organization of any knowledge. It is obvious that the application of a transdisciplinary approach to pedagogy makes it possible to develop a new concept of education that meets the needs of modern society.

II. FUZZY SET THEORY AND ITS APPLICATION TO MUSIC THEORY AND PRACTICE

In the modern era, music computer technologies (MCT) greatly contribute to the development of musical creativity and methods of research and analysis of music.

A special impetus to this process is given by the theory of fuzzy sets, the emergence of which has led to a shift in scientific paradigms and approaches to research in many fields of knowledge.

The fuzzy approach, as emphasized by L. Zadeh (1973) [1], provides an effective means of describing the behavior of systems that are too complex and poorly defined in order to apply precise mathematical methods to them.

With the advent of the fuzzy sets apparatus, it became possible to quantify those phenomena that had previously either been taken into account only on a qualitative level, or required the use of bulky or crude models.

Over the following years, expert and intelligent systems have been created in a wide variety of areas when it becomes

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necessary to make decisions in conditions of uncertainty, inaccuracy, partial reliability of information, and its subjectivity.

What is the use of the fuzzy approach and the apparatus of fuzzy sets in music, which, in terms of mathematical modeling, is a complex and poorly defined system consisting of many interacting subsystems, where fuzziness and subjectivity manifest themselves at acoustic, structural, semantic levels, genres and styles, compositional and performing creativity, musical analysis and criticism? One of the first to start research in this area was P. Elsea (1995) [2], who examines in his articles the possibilities of the fuzzy set theory apparatus for formalizing dynamic shades, rhythm, meter, tempo, pitch, as well as making musical decisions. Demonstrating the various possibilities of using the fuzzy sets apparatus, P. Elsi operates in a 12-step uniformly tempered high-pitch sound space and does not use fuzziness at the acoustic level in any way.

At the acoustic level, the theory of fuzzy sets finds its correspondence in N. Garbuzov's concept of the zone nature of hearing ("zone theory"), which reflects the property of our hearing to generalize in one quality ("steps") sound phenomena that differ in their physical characteristics. Garbuzov defined the measure of this generalization — the area, which he called the zone. After conducting numerous experiments, the scientist identified the quantitative boundaries of the sound—altitude zones - the limits in which hearing relates different heights to the same level (Garbuzov, 1948) [3]. In the course of subsequent works, he comes to the conclusion about the ability of musicians to distinguish and use intra-zone shades that give the performance individuality and artistic expressiveness (Garbuzov, 1951) [4].

In order to define the concept of the high-altitude zone, we have introduced two new terms in the context of our research:

- The zone of auditory "imperfection", which is formed as a generalization of pitch differences that are not detected or "not noticed" by hearing;
- A zone of artistically conditioned intonation, which is formed as a result of high-pitch intonation caused by the musical context (Alieva, Gorbunova, 2016-2017; Alieva, 2017) [5-7].

The analogy between Garbuzov's and Zadeh's concepts is obvious: both are based on the property of consciousness to generalize quantitatively different phenomena in one capacity. As Galushka writes, Garbuzov, introducing the concept of an interval zone in relation to the musical system, was the first to apply the theory of fuzziness in a "naive form."

Galushka, considering the fuzziness in relation to the structure, gives a geometric interpretation of uniform temperament and the Pythagorean structure and represents the Garbuzov zones as parallel lines on a plane that limit the possible sound-pitch values (Haluska, 2000) [8].

Garbuzov's experiments also receive their mathematical expression in the articles by T. Leon and V. Liern (León, Liern, 2013). By presenting notes as fuzzy sets and using the apparatus of fuzzy sets, the authors explain the coexistence of the "real" system, in which musicians actually perform, and theoretical (Pythagorean, natural, evenly tempered), thereby

expanding the concept of a high-pitched system following Garbuzov [9].

In these works, only the zone of auditory "imperfection" is formalized, vagueness in relation to the zone of artistically determined intonation is not considered by the authors. Meanwhile, the study of the zone of artistically conditioned intonation and its formalization has a special informative value for music science

III. A TRANSDISCIPLINARY APPROACH TOWARDS THE STUDY OF MUSICAL PHENOMENA

Publications linking fuzziness and music rarely appear in musicological publications. Most of these articles are presented in journals and conference proceedings on computer science.

The implementation of a synergetic approach in the development of musical and artistic culture, involving the study of cultural and historical contexts, philosophy, ethics and aesthetics of various eras, is highlighted in the research of many authors.

Among the significant concepts characterizing the processes and phenomena associated with the application of synergetic methods to the analysis of complex musical-theoretical systems, we single out such as: the category of the "musical fund of synesthesia" (otherwise known as the "synesthetic fund of music") by Bulat M. Galeev, "intonational dictionary of the epoch" and "sound-rhythmic formulas" by Boris V. Asafieva, Albert Vellek's research. Determining the integrity of this approach to the study of cultural and historical contexts of aesthetics of various eras, the systemic, interdisciplinary (and sometimes transdisciplinary) nature of progressive (upward) development ("complication", "enrichment", "complexity", "transdisciplinarity") Determining the integrity of this approach to the study of cultural and historical contexts of aesthetics of various eras, the systemic, interdisciplinary (and sometimes transdisciplinary) nature of progressive (upward) development ("complication", "enrichment", "complexity", "transdisciplinarity") Mikhail S. Kagan, a prominent Russian philosopher and cultural critic, points out in his writings. The researcher considered the concepts of "complexity" and "innovation" as "umbrella" interdisciplinary terms widely used in modern natural science and socio-humanitarian research and determined by the development of social, computer and engineering sciences, as well as the development of synergetics of information processes [10]. Developing the ideas expressed, Russian scientists continue to conduct research in this direction, analyzing a number of approaches to problems related to the "challenge of complexity" in the 21st century, the peculiarities of the socio-humanitarian dimension of complexity, and the identification of the essential features of complex thinking itself.

The monographic collections of scientific papers *The Synergetic Paradigm* [11], which include the works of prominent Russian scientists – philosophers, musicologists, cultural scientists, sociologists, educators, representatives of natural and technical sciences – describe in detail the content of the synergetic paradigm as a model of cognition of the

world using interdisciplinary and transdisciplinary approaches that determine the functional synthesis of methodologies and the creation on their basis completely new educational concepts in the diversity of their manifestations in nature, spiritual and material culture of society. Let us note the continuing role in the development and formation of this scientific field of research, carried out with the participation of Mikhail S. Zalivadny, who proposed a comprehensive model of the semantic space of music for consideration. Later, this model was significantly developed in a whole range of scientific works with the participation of employees of the Research and Methods Laboratory *Music Computer Technologies* of the Herzen Pedagogical University Russia, among which we note the works [12-16]. A significant contribution in this direction was made by research and practical developments carried out on the basis of the RML *Music Computer Technologies* of the Herzen State Pedagogical University of Russia. The results of these studies have both scientific and theoretical, as well as scientific, practical and applied significance. Among such studies, we can single out the following works: *Musical Computer* (Gorbunova, 2007), *Research of Mathematical Models, Development of Algorithms for the Interface of a Software Package for Processing Sound Fragments in MIDI Format* (Chibirev, 2007), *Methods of Teaching the Basics of Music Programming* (Kibitkina, 2012), patent for the invention *Algorithmic Model the Process of Composing Sound Fragments in MIDI Format* (Chibirev, 2011), *An Integrative Model for the Semantic Space of Music* (Gorbunova, Zalivadny; 2016), *Intelligent Systems for Analyzing and Cataloging Music of the Peoples of the World* (Alieva, Gorbunova, 2016), *Music, Mathematics, Computer Science: Facets of Interaction* (Gorbunova, Zalivadny; 2017), *Music, Mathematics, Computer Science: An Integrative Model for the Semantic Space of Music* (Gorbunova, Zalivadny, Tovpich, Chibirev, 2024). Computer programs are currently being developed: *Fretless Polyphonic MIDI input Controller, Additional Keyboard for Fretless Polyphonic MIDI input Controller, Fine Tuning Algorithm for Fretless Polyphonic MIDI input Controller* (Chibirev; 2020 - 2023).

IV. MUSIC COMPUTER TECHNOLOGIES AND THE RUSSIAN ELECTRONIC MUSICAL SYNTHESIZER (REMS)

According to scientists from various fields of knowledge, at the present stage of the development of science, the transdisciplinary approach plays a key role in the design process of modern domestic software and hardware complexes. One of such projects carried out in our country, based on the use of MCT, is the creation of a Russian electronic musical synthesizer (REMS). with the timbres of traditional musical instruments of the peoples of Russia and the world, developed by the staff of the RML *Music Computer Technologies* of the Herzen State Pedagogical University of Russia.

New opportunities in the field of modeling the process of musical creativity using MCT have revealed new facets of the

interaction of music, mathematics, and computer science with the active involvement of the apparatus of fuzzy set theory (see, for example, in [14-16]) and led to the emergence of significant scientific results in this area [17; 18], which, in turn, is the basis for the development of such extensive fields of scientific and practical activity as:

- Formation of an intellectual music cataloging and analysis system, creation of an intonational catalog of music of the peoples of Russia and the world,
- Creation of a "gene music bank",
- Creation of a Russian electronic musical synthesizer (REMS) with the timbres of traditional musical instruments of the peoples of Russia and the world.

The work in these areas is currently being carried out jointly by scientists from the Russian Federation and the Republic of Azerbaijan: employees of the RML *Music Computer Technologies* of the Herzen State Pedagogical University of Russian and researchers from the laboratory *Research of Azerbaijani Professional Music of Oral Tradition and Their New Directions: Organology and Acoustics* of the U. Hajibeyli Baku Music Academy under the scientific guidance of member of the Union of Composers of Azerbaijan, Doctor of Philosophy in Art History Imina G. Aliyeva. The relevance of developments in this scientific and practical field of activity is also due to the need to take urgent measures to preserve traditional creativity in the context of globalization, and interdisciplinary dialogue creates conditions for developing a common strategy in solving scientific problems associated with research conducted in this area [19; 20].

V. CONCLUSION

The creation of a catalog of digitized recordings will contribute to the accumulation of fundamental knowledge in the field of musical folklore, their scientific understanding and systematization to solve a number of professional musicological tasks. The use of music computer technologies in scientific research on this issue, a new dynamically developing field of activity for musicians and programmers, serves as the basis for the possibility of creating new theoretical and experimental-practical means of studying music, including uncertainty factors in music that are studied using the tools of modern music computer technologies.

REFERENCES

- [1] Zadeh L.A. Outline of a New Approach to the Analysis of Complex Systems and Decision Processes. *IEEE Transactions on Systems, Man and Cybernetics*, SMC-3. 1973. Pp. 28–44. <https://doi.org/10.1109/TSMC.1973.5408575>
- [2] Elsea P. (1995). Fuzzy Logic and Musical Decisions. URL: <http://artsites.ucsc.edu/EMS/Music/research/FuzzyLogicTutor/FuzzyTut.html#Number>
- [3] Garbuzov N.A. *The Zone Nature of High-Pitched Hearing*. Moscow: Publishing House of the USSR Academy of Sciences. 1948. 86 p.
- [4] Garbuzov N. A. *Intratonal Hearing and Methods of Its Development*. Moscow: Muzgiz Publ., 1951. 64 p.
- [5] Alieva I.G., Gorbunova I.B. On the project of creating an intellectual system for cataloging and analyzing the music of the peoples of the world. *Society: Philosophy, History, Culture*. 2016. No. 9. Pp. 105-108.

- [6] Alieva I.G. Intonation System of Azerbaijani Frets in the Context of Contemporary Music Theory: dis. ... Doctor of Philosophy in Law. Baku, 2017. 236 p.
- [7] Alieva I.G., Gorbunova I.B. On Fuzzy Methods of Sound-Pitch Analysis in Music. *The World of Science, Culture, and Education*. 2017. No. 3 (64). Pp. 171-174.
- [8] Haluska J. Equal Temperament and Pythagorean Tuning: a geometrical interpretation in the plane. *Fuzzy Sets and Systems*. 2000. 114. Pp. 261–269.
[https://doi.org/10.1016/S0165-0114\(98\)00113-4](https://doi.org/10.1016/S0165-0114(98)00113-4)
- [9] León T., Liern V. A Fuzzy Framework to Explain Musical Tuning in Practice. *Fuzzy Sets and Systems*. 2013. 214, 51-64.
<https://doi.org/10.1016/j.fss.2011.08.007>
- [10] Kagan M.S. Selected Works: collection of scientific papers: in 7 volumes. St. Petersburg: Petropolis, 2005. Volume I. Problems of Methodology. 356 p.: ill.
- [11] *The Synergetic Paradigm: The Synergetics of Innovative Complexity* / ed. by V.I. Arshinov. Moscow: Progress-Tradition, 2011. 495 p.
- [12] Gorbunova I.B., Zalivadny M.S. Integrative Model for the Semantic Space of Music and Prospects of Interaction between the Science of Music and Contemporary Musical Education. // *Music Scholarship*, 2018. No. 4(33). Pp. 55-64.
<https://doi.org/10.17674/1997-0854.2018.4.055-064>
- [13] *Complex Model of the Semantic Space of Music: Collection of articles / Comp. I.B. Gorbunova, M.S. Zalivadny, I.O. Tovpich*. St. Petersburg: Publishing House of the Russian State Pedagogical University named after A. I. Herzen, 2016. 186 p.
- [14] Gorbunova I.B., Zalivadny M.S., Tovpich I.O., Chibirev S.V. Music, mathematics, computer science: a complex model of the semantic space of music: monograph. St. Petersburg: Lan: PLANET OF MUSIC, 2023. 384 p.: ill.
- [15] Gorbunova I.B., Chibirev S.V. Modeling the Process of Musical Creativity in Musical Instrument Digital Interface Format. *Opcion*. 2019. Vol. 35. No. Special Issue 22. Pp. 392-409.
- [16] Gorbunova I.B., Zalivadny M.S., Tovpich I.O., Chibirev S.V. Music, Mathematics, Computer Science: An Integrative Model of the Semantic Space of Music: monograph; 2nd ed., ispr., add. Saint Petersburg: Lan: PLANET OF MUSIC, 2024. 420 p.: ill.
- [17] Gorbunova I.B., Zalivadny M.S. A transdisciplinary approach to the study of musical phenomena: information theory and its impact on various fields of musicology. *Music Scholarship*. 2024. No. 2. Pp. 180-199.
<https://doi.org/10.56620/2782-3598.2024.2.180-199>
- [18] Gorbunova I.B. About Mikhail Sergeyevich Zalivadny (1946-2023). *Music Scholarship*. 2024. No. 2. Pp. 178-179.
- [19] Alieva I.G., Gorbunova I.B. Application of a Fuzzy Approach in Research of Patterns of Organization and Perception of Musical Text and Music Computer Technologies. In the collection: *Regional Informatics and Information Security. Proceedings of the XVIII Anniversary St. Petersburg International Conference*. Saint Petersburg, 2022. Pp. 281-285.
- [20] Gorbunova I.B., Zalivadny M.S. The Zone Theory of Musical Time and a Transdisciplinary Approach to the Study of Musical Phenomena. *Music Scholarship*. 2023. No. 3. Pp. 8-22
<https://doi.org/10.56620/2782-3598.2023.3.008-022>