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A Transdisciplinary Approach to the Study of Musical Phenomena: Fuzzy Set Theory and Its Application to Music Research and Educational Practice

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Abstract. The post-nonclassical paradigm of contemporary science is characterized by its striving for the most holistic knowledge possible. The cornerstone of this knowledge is synergy, a theory of self-organization that facilitates the integration of diverse approaches to the study of phenomena. The integration of quantitative and qualitative research methodologies within a transdisciplinary framework is considered to be a pivotal tool in this context. Transdisciplinarity means going beyond individual discipline boundaries to uncover universal patterns in the organization of new knowledge. Applying a transdisciplinary approach to pedagogy enables the development of a novel educational concept meeting the demands of contemporary society. This article continues a comprehensive, multi-component investigation aimed at elucidating the issues of employing a transdisciplinary approach, which provides a robust foundation for the qualitative and quantitative evaluation of musical phenomena through the application of contemporary music computer technologies (MCT) and their influence on various spheres of musicology. The authors highlight the significant contributions of the outstanding Russian musicologist Mikhail Sergeyevich Zalivadny (1946–2023), who formulated foundational ideas in developing a comprehensive model of the semantic space of music. The authors emphasize that the use of MCT in scientific research on this issue serves as the basis for creating novel theoretical and experimental-practical tools for studying music, including the exploration of uncertainty factors in music analyzed through MCT. The article also addresses issues related to the need for training specialists in various fields of activities associated with digital music technologies within the contemporary media culture space, as well as the formation of concepts corresponding to this innovative humanitarian-technological direction.

Keywords: Mikhail Sergeyevich Zalivadny, music computer technologies (MCT), music education, synergetic approach, fuzzy set theory, transdisciplinarity

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Трансдисциплинарный подход к изучению музыкальных явлений: теория нечётких множеств и её применение к музыкальной науке и практике образования

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Аннотация. Постнеклассическая парадигма современной науки характеризуется стремлением к возможно более целостному знанию. Ключом к этому знанию является синергия – теория самоорганизации, позволяющая соединить разные подходы к исследованию явлений. Мощным инструментом здесь является сочетание количественных и качественных методов исследования в рамках трансдисциплинарного подхода. Трансдисциплинарность предполагает выход за рамки отдельных дисциплин для обнаружения общих закономерностей организации любого нового знания. Применение трансдисциплинарного подхода к педагогике позволяет выработать новую концепцию образования, отвечающую потребностям современного общества. Статья является продолжением комплексного многокомпонентного исследования, направленного на выявление проблематики использования трансдисциплинарного подхода, составляющего действенную основу для качественной и количественной оценки музыкальных явлений с использованием ресурсов современных музыкально-компьютерных технологий (МКТ) и их воздействия на различные области музыкознания. Авторы статьи отмечают особую роль исследований в области формирования трансдисциплинарного подхода в методологии современной науки, принадлежащую видному российскому музыковеду Михаилу Сергеевичу Заливадному (1946–2023), который сформулировал ведущие идеи в разработке комплексной модели семантического пространства музыки. Авторы отмечают, что использование в научных исследованиях, посвящённых данной проблематике, МКТ служит основанием для возможности создания новых теоретических и экспериментально-практических средств изучения музыки, включая исследуемые с помощью МКТ факторы неопределённости в музыке. В статье также затрагиваются вопросы, связанные с необходимостью подготовки специалиста в различных областях деятельности, связанной с цифровыми технологиями в музыке в пространстве современной медиакультуры, а также с формированием понятий, соответствующих этому новому гуманитарно-технологическому направлению.

Ключевые слова: Михаил Сергеевич Заливадный, музыкально-компьютерные технологии, музыкальное образование, синергетический подход, теория нечетких множеств, трансдисциплинарность

Dedicated to the Russian musicologist Mikhail Sergeyevich Zalivadny (1946–2023), who played a leading role in developing a comprehensive model of the semantic space of music, which conditions the transdisciplinary approach to the study of musical phenomena.

Introduction

Since ancient times, philosophers, mathematicians, and musicians have sought and identified the intersections between the vast spaces of Music and Mathematics. In the contemporary era, the process of the evolution of musical creative work and methods of music analysis has been significantly facilitated by the integration of information technology into music, alongside developments in mathematical methods of musicological research, which had an effective impact on the development and formation of music computer technologies (hereinafter — MCT). A particular impetus to this process is provided by fuzzy set theory, the emergence of which has led to a shift in scientific paradigms and research approaches across numerous fields of knowledge. As emphasized by Lotfi Zadeh,[1] the fuzzy approach provides an effective means of describing the behavior of systems that are too complex or ill-defined in order to be analyzed with the help of precise mathematical methods. With the advent of the apparatus of fuzzy sets, quantitative analysis of phenomena previously considered only qualitatively, or requiring cumbersome or approximate models, became feasible. Over the subsequent years, expert and intellectual systems were developed in various fields, when address decision-making in conditions of uncertainty, inaccuracy, partial reliability of information, its subjectivity.[2]

Musical technologies based on a transdisciplinary approach and fuzzy set theory, which has driven paradigm shifts in research across various knowledge areas, are increasingly in demand by modern streaming music services and music-related internet applications, forming the basis for personalized listening recommendations in accordance with user requests. The implementation of new professional music-educational programs, such as master's degrees in *Digital Technologies in Music and Sound Design* and *Music Computer Technologies in Education*, as well as bachelor's degrees in *Music Computer*

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[1] See: 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*. IEEE, 1973, issue 1, pp. 28–44. https://doi.org/10.1109/TSMC.1973.5408575

[2] See: Alieva I.G., Gorbunova I.B. About unclear methods of analysis of pitch in music. *The world of science, culture and education*. 2017, no. 3, pp. 171–174. (In Russ.); Alieva I.G., Gorbunova I.B. The use of a simple approach in the study of patterns of organization and perception of musical text and music computer technologies. In: Regional informatics and information security: proceedings of the 18th Anniversary St. Petersburg International conference, October 26–28, 2022. (Алиева И.Г., Горбунова И.Б. Применение нечёткого подхода в исследованиях закономерностей организации и восприятия музыкального текста и музыкально-компьютерные технологии. В: *Региональная информатика и информационная безопасность: сб. трудов Юбилейной XVIII Санкт-Петербургской Междунар. конф., 26–28 октября 2022 г.*). St. Petersburg: St. Petersburg Society of Informatics, Computer Facilities, Communication and Control Systems Publ., 2022, pp. 281–285.

Technologies and *Information Technologies in Music and Sound Design*, demonstrates that a transdisciplinary approach fosters a functional synthesis of methodologies, enabling the creation of entirely new educational concepts based on them, based on the priority influence of a synergistic approach to the strategy of teaching musical art.

This article continues a multi-component, comprehensive study, [1; 2; 3; 4; 5] aimed at identifying the issues of employing a transdisciplinary approach, which forms an effective basis for the qualitative and quantitative assessment of musical phenomena using the resources of contemporary MCT and their impact on various areas of musicology.

Fuzzy Set Theory and Its Application to Musical Theory and Practice

One of the pioneers in this field is Peter Elsie,[3] who explores in his articles the potential of applying the apparatus of fuzzy set theory to formalize dynamic nuances, rhythm, meter, tempo, pitch, and musical decision-making. Demonstrating various applications of fuzzy set theory, Elsie operates within a 12-tone equal-tempered sound-altitude space, without addressing fuzziness at the acoustic level.

At the acoustic level, fuzzy set theory aligns with Nikolai Garbuzov's concept of the zone nature of hearing ("zone theory"), which reflects the human auditory system's property to generalize in one quality ("steps") sound phenomena differing in their physical characteristics. Garbuzov defined the scope of this generalization as a "zone." Having conducted extensive experiments, he identified the quantitative boundaries of pitch zones — the boundaries within which hearing associates various pitch values with a single scale degree.[4] In the course of subsequent works, he concludes that musicians can discern and use intra-zonal nuances, imparting individuality and artistic expressiveness to performances.[5] To provide clarity to the concept of pitch zones, we introduced two novel terms within the context of our research: the zone of auditory "imperfection" and the zone of artistically conditioned intonation.

The analogy between Garbuzov's and Zadeh's concepts is evident: both are based on the ability of consciousness to generalize quantitatively different phenomena into a single quality. According to Yán Haluška, by introducing the concept of intervallic zones in relation to musical tuning, Garbuzov was the first to apply the theory of fuzziness in a "naive form." [6] Haluška, considering the fuzziness in relation to the system, provides a geometric interpretation of equal temperament. Garbuzov's experiments also find mathematical expression in the works of Teresa León and Vicente Liern, [7] who, using the apparatus of fuzzy sets, expand the concept of a high-altitude system after Garbuzov. These works formalize only the zone of auditory "imperfection," while the authors do not consider fuzziness in relation to the zone of artistically determined intonation. Meanwhile, the study of the zone of artistically determined intonation and its

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[3] Elsea P. *Fuzzy Logic and Musical Decisions*. Santa Cruz, CA: Technical Report, 1995. URL: http://peterelsea.com/Maxtuts_advanced/Fuzzy_Logic.pdf (accessed: 03.08.2025).

[4] Garbuzov N.A. The zone nature of high-pitch-hearing. In: Garbuzov N.A. is a musician, researcher, and teacher: collection of articles. (Гарбузов Н.А. Зонная природа звуковысотного слуха. В: *Гарбузов Н.А. — музыкант, исследователь, педагог: сб. статей*). Moscow: Muzyka Publ., 1980, pp. 80–145.

[5] Garbuzov N.A. Intrazonal intonation hearing and methods of its development. (Гарбузов Н.А. *Внутризонный интонационный слух и методы его развития*). Moscow; Leningrad: Muzgiz Publ., 1951. 64 p.

formalization is of particular informative importance for musical science.

Publications linking fuzziness and music are rare in musicological journals. Basically, such articles primarily appear in computer science journals and conference proceedings on MCT. To provide an overview of this field, we refer to several studies where fuzzy sets are involved in formalizing musical and theoretical knowledge and address tasks related to interpretation, perception, and composition.

The article by Harro Kiendl, Tatiana Kiseleva, and Yves Rambinintsoa [8] is an attempt to "teach a computer expressive performance." The authors identified 150 rules for the artistic interpretation of Beethoven's *To Eliza* and developed a system based on the use of fuzzy logic methods, including the rules of fuzzy modeling, at the input of which is the score of the play, and at the output is a MIDI file. The authors acknowledge that, while the level of interpretation surpasses mechanical score reproduction, it remains significantly below the level of an experienced pianist. Josep Arcos also aims to train a music computer for expressive performance, but does so on the basis of analyzing and imitating live performances, controlling five different fuzzy expressive parameters: dynamics, tempo, vibrato, articulation, and attack. [9] (It should be especially noted that in Russia, already in the late 80s of the last century, domestic software products were developed aimed at modeling individual properties of a musical composition: nuance, agogy, tempo, etc. One of the first products is the "Style Enhancer" software from the NTONYX studio at the M.I. Glinka Novosibirsk State Conservatory. Later, this product was recommended as a module by the music software leader Cakewalk Pro Audio.)

Chandan Kumar, Sandip Dutta, and Soubhik Chakraborty [10] propose a musical cryptography algorithm based on fuzzy logic, using fuzzy rules to compose, harmonize, and orchestrate artistically satisfactory musical passages that serve as encrypted messages. Relatively recently, the *Endel* program appeared in the space of the so-called "creative technologies." This application offers an audio ecosystem that generates personalized sound environments for concentration, relaxation, or sleep, based on weather, time of day, heart rate, and user movement speed.

The *Amper Music Artificial Intelligence* project (2014) enables any user to create musical compositions in accordance with their wishes by entering keywords related to mood, style, structure, and duration. This program is in demand for creating background music for various programs, advertisements, etc. David Cope's *Emily Howell* software for composing music "having trained" on works by classical composers (Beethoven, Vivaldi, etc.), creates compositions in similar styles. The Mercury [11] software is focused on assisting in the creative process by offering recommendations and serving as an "adviser" to composers. The program offers numerous options for transitions between two melodies, harmonic sequences, rhythmic patterns, and it is capable of reading musical text and displaying the final result in MusicXML format. Javanshier Guliyev and Konul Memmedova [12] to make compositional decisions build relationships between composition elements (attributes) and subsequent conclusions using IF... THEN models and a set of rules. As an example, the authors present calculations involving two attributes ("loudness" and "pitch") with corresponding conclusions described by linguistic variables ("quality assessment"). Particularly promising are directions related to big data systematization and the development of streaming music services. The demand for such projects is confirmed by a review article by Hinyu Yang, Yizhuo Dong, Juan Li, [13] which includes 114 references reflecting

the results of studies from 2003 to 2017. For clarity, various methods of recognizing "musical emotions" are summarized in an informative table. A similar research objective was set by Russian scholar Sergei Chibirev, who conducts experimental studies among students and faculty of the Herzen State Pedagogical University of Russia (hereinafter — Herzen University), St. Petersburg State Conservatory named after N.A. Rimsky-Korsakov, participants of international scholarly conferences such as Contemporary Musical Education: *Creative Work, Research, Technology* and *Interdisciplinary Discourse East-West: 21st Century. Creative Work. Research. Technology. Education*, as well as the annual All-Russian Open Festival-Competition of Creative Work *CLARINI of the 21st Century*, involving teachers, students, graduate students, master's students, and doctoral candidates from various educational institutions in Russia and countries of the near and far abroad. [14; 15]

Music Information Retrieval (MIR) systems are typically focused on European musical culture. Abdoli Sajjad offers a search engine for Iranian music. [16] The researcher identifies distinctive pitch and intonational features of Iranian traditional music, characterized by its 24-tone equal temperament (according to Ali Nagi-han Vaziri [17]) and a system of seven primary dastgāhs and numerous gūshehs, organized according to the radif. The "notes" constituting a dastgāh were described by means of fuzzy sets of the second order. The classification is based on the difference in the sound-altitude ratios of the stages of the dastgāh scales, and for recognition, the musical sample is compared with its prototype dastgāh.

In the field of musical artificial intelligence (hereinafter — AI), developers are employing a wide array of advanced technologies for designing AI systems. Thus, Arshia Ulaganathan and Sheela Ramanna [18] propose the idea of granulating fuzzy information based on the automatic classification of musical genres. For classifying not only classical but also jazz samples, Francisco Fernández de Vega and Francisco Chávez [19] use a genetic algorithm (similar to natural selection) combined with a system based on fuzzy FRBS rules (Fuzzy Rule-Based Systems). The results take into account the rules of harmony and their relationship with a certain genre. In an article by Rodrigo F. Cádiz, [20] the application of fuzzy logic concepts to music is discussed, as well as a set of tools for using fuzzy logic in a real-time sound synthesis environment in Max/MSP; the author also demonstrates how fuzzy logic concepts can be used and implemented in areas such as algorithmic composition, sound synthesis through parameters, its defining characteristics, and a number of other parametric methods for creating computer music.

In the cited works related to MCT creative work, two primary directions are noticeable: first, when a developer creates musical compositions based on the selected rules of harmony and form, that is, from a "blank slate;" second, when information technologies enable composition by imitating an extensive database including well-known musical works and numerous samples. The latter approach often results in compilation work, which is, as a rule, discouraged in both the creative and the scientific communities. However, in computer creativity, this method proves to be highly productive, as exemplified by the aforementioned *AMPER* program, which released the first-ever AI-generated music album.

Implementation of the Synergistic Approach in Mastering Musical and Artistic Culture

The post-nonclassical paradigm of contemporary science is characterized by the pursuit of the most holistic knowledge. The key to this knowledge is synergy, a theory of self-organization that facilitates

the integration of different approaches to the study of phenomena. A powerful tool in this context is the combination of quantitative and qualitative research methods within the framework of a transdisciplinary approach. Transdisciplinarity transcends the boundaries of individual disciplines to discover universal patterns in the organization of any knowledge. Obviously, the application of a transdisciplinary approach to pedagogy enables the development of a novel educational concept that meets the needs of modern society. The implementation of a synergetic approach to the process of mastering musical and artistic culture, which involves the investigation of cultural and historical contexts, philosophy, ethics, and aesthetics across various epochs, is highlighted in the studies of many authors who, developing scientific theories significant in this direction, considered the synergistic paradigm as a model of comprehending of the world. Among the basic concepts characterizing the processes and phenomena associated with the application of a synergistic method to the analysis of complex musical and theoretical systems, we highlight the following: the category of "music fund of synesthesia" (otherwise – "the synesthetic fund of music") of Bulat Galeev, "the intonation dictionary of the era" and "sound-rhythmic formulas" of Boris Asafiev, and the research conducted by Albert Wellek.

Predetermining the holistic nature of the synergetic approach to exploring cultural and historical contexts of aesthetics across different epochs and analyzing the patterns of ontogenesis as a process of individual personogenesis, the prominent Russian philosopher and culturologist Moises Kagan emphasizes the need to "turn to the synergetic concept of self-organization processes in such systems" [21, p. 61] and he considers our consciousness and pedagogical practice to be self-developing systems: "It is becoming clearly insufficient to operate with those invariants that were found in the processes of self-organization of its [synergetics. — *I.G.*, *I.A.*] founders. This is evidenced by concepts already integrated into scientific discourse, such as 'self-governing system,' 'self-regulating system,' and 'self-reflective system,' as well as the growing need to comprehend an increasingly broad range of non-physical, anthropo-socio-cultural processes from a synergetic perspective." [Ibid.] In his works, Kagan also points to the systemic, interdisciplinary nature of the progressive (ascending) development of contemporary pedagogical theory, (its "complication," "enrichment," and "complexity").[6] As Sergei V. Busov notes in the article "M.S. Kagan's Synergetic Model of Culture in the Context of Philosophical Discussions on the Boundaries of Personal Freedom in the Second Half of the Twentieth Century," Kagan was "one of the leading domestic representatives of the systemic approach to analyzing the development of systems of varying complexity, asserting that such an approach required the application of the principle of historicity,

[6] See: Kagan M.S. Towards a synergetic interpretation of self-organization processes. In: Synergetics and synergetic historicism. (Каган М.С. К синергетическому толкованию процессов самоорганизации. В: *Синергетика и синергетический историзм*). St. Petersburg: Osipov Publ., 2005, pp. 113–125; Kagan M.S. A system synergetic approach to the construction of modern pedagogical theory. In: Cultural enlightenment in modern Russia: collection of scientific articles by participants of the round table "The Tenth Kagan readings" (May 18, 2016). (Каган М.С. Системно-синергетический подход к построению современной педагогической теории. В: *Культурологическое просветительство в современной России: сб. науч. статей участников круглого стола «X Кагановские чтения», 18 мая 2016 г.*). St. Petersburg: Asterion Publ., 2017, pp. 10–31.

as the 'historical approach' is an integral part of the systemic approach." [22, p. 75] Vladimir Arshinov underscores the transdisciplinary nature of the research carried out in this field, exploring in his writings the concepts of "complexity" and "innovation" as "umbrella" interdisciplinary terms, [23] widely used in contemporary natural science and socio-humanitarian research and determined by the development of social, computer and engineering sciences. The concept of "information synergetics" is introduced by Victor Tsvetkov in connection with the development of information processes. [24] Analyzing the "foundations of synergetics" and the "synergetic worldview," Elena Knyazeva and Sergei Kurdyumov examine core concepts, representations, and models of the "interdisciplinary theory of self-organization and co-evolution of complex systems," and a thorough cultural analysis of specific examples and phenomena from the history of culture and science, artistic and scientific creativity, "individual mental life and social practice" is carried out. [25]

Developing the ideas put forward, Russian scholars conduct research analyzing various approaches to the issues associated with the "challenge of complexity" in the 21st century, employing interdisciplinary and transdisciplinary approaches that facilitate a functional synthesis of methodologies and the creation of entirely new educational concepts in the variety of their manifestations in nature, the spiritual, and the material culture of society. We note such new transdisciplinary directions and concepts highlighted by the authors as: the interdisciplinary and transdisciplinary potential of the complexity paradigm, synergetic ontology as a set of processes of becoming within a single language of self-organization, [26; 27; 28; 29] symbolic attractors of the information society, [30] synergetics of complication and the transinstitutional matrix of innovation, [31] complication,[7] complexity of innovative transformations as an aspect of the ambivalence of social self-organization, [32] innovative complexity of self-learning systems, [33] and numerous other processes and phenomena related to the application of synergetic methods to the analysis of social reality and the transformation of socio-humanitarian knowledge under the influence of the synergetic worldview. [34] In the 7th volume of the collection The Synergetic Paradigm, dedicated to understanding the phenomenon of complexity and processes of innovative development, the authors demonstrate a variety of approaches to the problems associated with the "challenge of complexity" in the 21st century and "the opportunities that it opens for analyzing the processes of globalization, bioethical issues, economics, and engineering science," while also paving the way for studies due to the "comprehending of informational and communicative strategies of social synergetics." [35, p. 551]

In 2009, Klaus Mainzer's book *Complexity Thinking: Matter, Mind, Humanity. A New Synthesis* [36] was published, analyzing "the path traveled by knowledge from profound philosophical ideas, starting from Antiquity, the Middle Ages, and the Modern Era,

[7] See also: Gerasimova I.A., Burgete Ayala M.R., Kiyashenko L.P., Rozin V.M. Complexity and the problem of unity of knowledge. Issue 2: The multiplicity of realities in a complication world. (Герасимова И.А., Бургете Аяла М.Р., Киященко Л.П., Розин В.М. *Сложностность и проблема единства знания. Вып. 2: Множественность реальностей в сложностном мире*). Moscow: Institute of Philosophy of the Russian Academy of Sciences, 2019. 250 p.

to cutting-edge scientific research in fields such as nanotechnology, chaos theory, artificial intelligence, neuroscience, and advanced humanitarian technologies and, in the words of Charles Percy Snow, "a bridge is being thrown between two cultures – natural science and humanitarian." [Ibid., p. 2] Mainzer discusses interdisciplinary issues of modern science, due to the theory of self-organization, the development of synergetics, and its subfield, the complexity theory. In his introductory article *Synergetics: Crisis or Development?* [37] to the fourth edition of Mainzer's book, Georgy Malinetsky[8] notes that "many results and ideas of synergetics <…> shape the image of the future and aid in selecting pathways for development. These ideas live in society today. They transform the world by becoming elements of culture. <…> In the history of science, it unexpectably turns out that the complex and incomprehensible, in essence, turns out to be arranged quite simply <…> and vice versa, behind the apparent simplicity, researchers manage to uncover paradox and depth." [Ibid., pp. 15–16]

It should be noted that the concepts of "complexity" and "innovation," widely employed in contemporary natural and socio-humanitarian research as "umbrella interdisciplinary terms," have been predetermined by the results of research conducted in the field of exact and basic sciences. Among the significant studies in this field, special attention should be paid to the work of Rem Barantsev[9] who for many years tried to comprehend the processes and phenomena shaping the methodology of modern science and came up with the concept of semiodynamics, "which studies qualitative changes in holistic formations within a symbolic representation" [38, p. 413] and "is the closest precursor to synergetics" [see also: 39, p. 2].[10] Speaking about the interconnectedness of methods in these interdisciplinary research fields, which focus on the mechanisms of synthesizing holistic formations, the scientist emphasizes that the primary distinction lies in the fact that "semiodynamics is broader in scope, as it is not limited to self-organization processes, but narrower in method, since it is limited to a sign representation. However, this narrowness has precisely facilitated rapid progress in in the development of methods necessary for synergetics." [40, pp. 113–114] Highlighting the enduring significance of the conceptual and substantive content related to semiodynamics, which "considers general patterns in the development of symbolic systems," and noting that "the distinction between sound-based and hieroglyphic writing systems has

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[8] Georgy Gennadievich Malinetsky is a Soviet and Russian mathematician, Dr.Sci. (Physics and Mathematics), Professor, one of the leading specialists in Russia in the field of synergetics, risk management and future design, full member of the Academy of Military Sciences, head of the Department of Mathematical Modeling of Nonlinear Processes of the Keldysh Institute of Applied Mathematics at the Russian Academy of Sciences.

[9] Rem Georgievich Barantsev (1931–2020) is a Soviet and Russian scientist, mathematician, Dr.Sci. (Physics and Mathematics), Professor, the author of more than 400 scientific articles, a number of which present a virtuosic use of asymptotic analysis and classical methods of mathematical physics, USSR State Prize laureate, researcher and commentator on the scientific heritage of Alexander Lyubishchev, member of a number of international scientific organizations, including the Executive Committee of the International League for the Protection of Culture, St. Petersburg Mathematical Society, the Scientific Council of the St. Petersburg Union of Scientists, etc.

[10] See also: Barantsev R.G. Semiodynamics as a channel of synergetics. In: The Academy of Trinitarianism. (Баранцев Р.Г. Семиодинамика как русло синергетики. В: *Академия Тринитаризма*). Moscow, EL No. 77-6567, publ. 14453, 06/14/2007. URL: https://www.trinitas.ru/rus/doc/0016/001b/00161390.htm (accessed: 03.08.2025).

profoundly shaped the psychological, cultural, and historical trajectories of Western and Eastern civilizations," [41, pp. 37–38] Georgy Malinetsky, in his article *Rem Georgievich Barantsev: Accuracy – Simplicity – Scope of Application*, focuses on the "striking proximity" of the views of scientists from the humanities and natural sciences, namely Rem Barantsev and Yuri Lotman. He writes: "I have recently discovered with surprise that the outstanding culturologist and historian Yu.M. Lotman, in discussing symbols of cultures and historical periods, expressed ideas remarkably close to those of semiodynamics," suggesting that these scholars, working at the same time, could have formed a "creative alliance." [Ibid., p. 38]

In his article *What is Music in Terms of Synergetics*, Alexander Klyuev examines "the everyday coordinates of music from the standpoint of synergetics as a philosophical and ontological doctrine," [42, p. 125] emphasizing the objectivity of the process under consideration and correlating the evolution of the human psyche with a new stage of intensified integrative processes. The scientist notes that "from the perspective of the synergetic worldview <…> music, as an "ultimate" system — the "attractor of attractors" in the evolution of material systems — represents a super-attractor of the systemically evolving world." [Ibid., p. 128] Conducting music-historical and philosophical-ontological research, as well as relying on the works by other authors such as Moris Bonfeld,[11] Elena Knyazeva, and Sergei Kurdyumov, [34][12] Klyuev concludes that there exists a "possibility of the emergence of multidimensional meanings," which shape and condition the formation of a "model of systemic evolutionary growth, within which the place of music is determined." [43, p. 317] Since according to the scientist, "music represents the ultimate state of self-organization in the system-evolutionary movement of matter" on the basis of a unified semantic space: "synergetics – synergy", the prerequisites for interpreting musical creativity through a synergistic approach are created, implying an "absence of rigid determinism." [Ibid.] As Moses Kagan emphasizes, synergetic laws possess a "genuine universality" and therefore a "philosophical-ontological character," [44, p. 52] which is largely consistent with the ideas and statements of the prominent Russian musicologist Bonfeld[13].

Russian musicologist Nina Kolyadenko, who established the scientific direction and scientific school of musical synesthetics in our country

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[11] Bonfeld M.Sh. Music: Language. Speech. Mind. Experience in the systematic study of musical art. (Бонфельд М.Ш. *Музыка: Язык. Речь. Мышление. Опыт системного исследования музыкального искусства*). St. Petersburg: Composer Publ., 2006. 648 p.

[12] Knyazeva E.N., Kurdyumov S.P. The Foundations of synergetics: a man who designs himself and his future. (Князева Е.Н., Курдюмов С.П. *Основания синергетики: Человек, конструирующий себя и своё будущее*). 4th Ed., add. Moscow: LIBRIKOM Publ., 2011. 264 p.

[13] See: Bonfeld M.Sh. Innovative Aspects in the Discipline "Analysis of Musical Pieces". In: Contemporary musical education – 2003: proceedings of the International scholarly and practical conference, October 10–12, 2003. (Бонфельд М.Ш. Инновационные аспекты в курсе «Анализ музыкальных произведений». В: *Современное музыкальное образование – 2003: материалы Междунар. научно-практич. конф. 10–12 октября 2003 г.*). St. Petersburg: Herzen State Pedagogical University of Russia, 2003, pp. 78–81; Bonfeld M.Sh. Musicology as a subject of study: ideology and technology. In: Contemporary musical education – 2002: proceedings of the International scholarly and practical conference, October 9–13, 2002. (Бонфельд М.Ш. Музыкознание как предмет изучения: идеология и технология. В: *Современное музыкальное образование – 2002: материалы Междунар. научно-практич. конф. 9–13 октября 2002 г.*). St. Petersburg: Herzen State Pedagogical University of Russia, 2002, pp. 89–92.

on the basis of the M.I. Glinka Novosibirsk State Conservatory, focuses in her works on the need to explore the ways of "incorporating" the synergetic approach into the interpretation of musical texts. She argues that "the synergetic methodology in studying musical texts <…> can yield tangible results." [45, p. 17]

A significant contribution to the process of understanding the necessity of interpenetration of methods for studying the humanities, the exact, and natural sciences, and creating conditions for the development of a transdisciplinary approach to musicological research and modern music education systems, was made by the prominent Russian musicologist Michail Zalivadny. [46] The scientist plays a pivotal role in the development of a comprehensive model of the semantic space of music, [2; 47; etc.] the reliance on interconnected elements of which enabled a novel conceptualization of a wide range of phenomena and processes studied by musicologists in various fields of musical science and consideration of music as a unique form of artistic development of the world in its specific socio-historical context, as well as in relation to other types of artistic activity and spiritual culture of society as a whole. His dissertation, *Theoretical Problems of Computerization of Musical Activities: Experience of Complex Characterization*,[14] laid the foundation for the establishment and development of the MTC, which made it possible to look at the problems of preserving, researching, transmitting musical folklore, preventing its oblivion, and transforming folk music artifacts into a living, functioning organism, using innovative forms of work with sound, thereby expanding the possibilities of composer creativity. Continuing the ideas expressed by scientists about the need to implement a transdisciplinary approach to the study of musical phenomena, [1; 4; 5] we also note the significant contribution made by Zalivadny to the process of comprehending the role of mathematical research methods in musicology. [29][15]

Music Computer Technologies and a Transdisciplinary Approach to the Study of Musical Theory and Practice of the Music Education

As previously noted, information and digital technologies in music today find their application in various fields of musicology

[14] Zalivadny M.S. Theoretical problems of computerization of musical activities: experience of complex characterization: Dissertation for the degree of Cand.Sci. (Arts). (Заливадный М.С. *Теоретические проблемы компьютеризации музыкальной деятельности: опыт комплексной характеристики: дис. … канд. иск*.). St. Petersburg, 2001. 148 p.

[15] Gorbunova I.B., Zalivadny M.S. Music, mathematics, computer science: The facets of interaction. (Горбунова И.Б., Заливадный М.С. *Музыка, математика, информатика: грани взаимодействия*). St. Petersburg: Herzen State Pedagogical University of Russia. 2017. 296 p.; Gorbunova I.B., Zalivadny M.S. On the need to teach mathematical methods of music research in the system of contemporary musical education. (Горбунова И.Б., Заливадный М.С. О необходимости обучения математическим методам исследования музыки в системе современного музыкального образования). *Obshchestvo: sotsiologiya, psikhologiya, pedagogika*. 2015, no. 6, pp. 146–150; Gorbunova I.B., Hiner H., Zalivadny M.S. On importance of mathematical methods in music research and education of musicians. (Горбунова И.Б., Заливадный М.С. Хайнер Х. О значении математических методов в исследовании музыки и профессиональной подготовке музыкантов). *Universitetskii nauchnyi zhurnal*. 2015, no. 11, pp. 103–111; Gorbunova I.B., Zalivadny M.S., Tovpich I.O., Chibirev S.V. Music, mathematics, computer science: An integrative model for the semantic space of music: monography. (Горбунова И.Б., Заливадный М.С., Товпич И.О., Чибирёв С.В. *Музыка, математика, информатика: комплексная модель семантического пространства музыки: монография*). St. Petersburg: Lan' Publ.; Planet of Music Publ. House, 2024. 420 p.

(and art history), primarily due to the development of MCT,[16] which provide a robust foundation for the qualitative and quantitative assessment of musical phenomena. The range of works published in this direction is wide and diverse: the bulk of research is associated with composing, computer arrangement, musical sound engineering, sound-timbral programming, the art of performing on digital musical instruments and many other areas that are widely in demand and are extremely rapidly developing today.

The rich potential of MCT has significantly influenced the formation of new ideas for creating and developing musical and creative tools aimed at expanding the prospect of musical composition, arrangement, and performing skills on digital musical instruments.[17] The advent and development of new creating sound methods using electronics in the second half of the 20th century stimulated the emergence of novel musical, creative and performing phenomena, as well as the development of new educational areas, necessitating the active use of MCT as a tool, instrument, and new media-active environment for the 21st century musical culture.

The development of cybernetics and computer science in the second half of the 20th and early 21st centuries contributed to the processes of the logical systematization of patterns across various fields of human activities, particularly facilitating the formation of new research directions on the nature of musical logic, which formed the prerequisites for a semantic interpretation of musical space (as well as musical time). [1; 2; 48] In turn, the semantic approach to the consideration of the "geometry" of musical space led to the highlighting of the spatial aspects of music, which is associated with achievements in modeling the characteristic manifestations of these patterns in practice [14; 15][18] and which led, in particular, to a synergistic (and, in the future — transdisciplinary) approach to the study of not only musical and creative phenomena, but also the information and technological processes themselves.

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[16] See about this: Gorbunova I.B. The phenomenon of musical computer technologies as a new educational creative medium. *Izvestiya Rossiiskogo gosudarstvennogo pedagogicheskogo universiteta imeni A.I. Gertsena*. 2004, vol. 4, no. 9, pp. 123–138. (In Russ.); Gorbunova I.B. Music computer technologies in the perspective of digital humanities, arts, and research. *Opción*. 2019. Año 35, Regular No. 24, pp. 360–375.

[17] See about this: Gorbunova I.B. New tool for a musician. *10th International conference on advances in science, engineering and technology (ICASET-18), 15th International conference on education, economics, humanities and interdisciplinary studies (EEHIS-18).* Paris, June 20–21, 2018. Conference Proceedings. 2018, pp. 144–149; Gorbunova I., Belov G. On the premises of training in playing the electronic musical instruments. *Kazan Pedagogical Journal*. 2016, no. 2-1, pp. 8–17 (In Russ.); Gorbunova I.B., Davletova C.B. Electronic musical instruments in the system of general musical education. *Theory and Practice of Social Development*. 2015, n. 12, pp. 411–415 (In Russ.); Gorbunova I.B., Petrova N.N. Music computer technologies, supply chain strategy and transformation processes in socio-cultural paradigm of performing art: using digital button accordion. *International Journal of Supply Chain Management*. 2019, vol. 8, no. 6, pp. 436–445; Gorbunova I.B. Musical synthesizers: monography. (Горбунова И.Б. *Музыкальные синтезаторы: монография*). 2nd Ed., add. St. Petersburg: Soyuz khudozhnikov Publ., 2018. 224 p.

[18] See more details: Chibirev S.V., Gorbunova I.B. Music computer technologies: on the problem of modeling the process of musical creative work: monography (Горбунова И.Б., Чибирёв С.В. *Музыкально-компьютерные технологии: к проблеме моделирования процесса музыкального творчества: монография*). St. Petersburg: Herzen State Pedagogical University of Russia, 2012. 159 p.; Gorbunova I.B. The integrative model for the semantic space of music and a contemporary musical educational process: The scientific and creative heritage of Mikhail Borisovich Ignatyev. *Laplage em Revista*. 2020, vol. 6, no. Esp, pp. 2–13.

A number of studies note that the priority of the influence of a synergistic approach on the strategy of teaching musical art is now becoming increasingly obvious, which is due to the need to apply a transdisciplinary approach that takes into account multicomponent and multifactorial interactions between the components of subject knowledge included in the educational process and the implementation of the principles of openness, non-linearity and instability of the learning process within the context of its self-structuring and self-organization (see, for example, in the works of Elena Zhurova,[19] Aleksandr Koblyakov,[20] Galina Grushko,[21] Elena Kuprina,[22] and others). These conclusions align significantly with the results of studies conducted with the participation of the authors of the article. [1; 2; 3; 4; 5][23]

The rapid development of MCT necessitates solving problems related to the solving problems associated with taking into account and fixing their multicomponent functional aspects. Thus, the complexity (respectively — "multidomain") of the music structure has as its consequence the consideration of its role as a kind of "additional storage device" which is especially important in relation to the synesthetic characteristics of music and contains ample opportunities for their accounting and analysis using MCT in the process of computer modeling of musical phenomena, encoding musical information taking into account and on the basis of methods and means of a transdisciplinary approach to their study and methods of fixation.

A significant contribution in this direction has been made through research and practical developments carried out on the basis of the research and methods laboratory *Music Computer Technologies* of the Herzen University (hereinafter — RML *Music Computer Technologies* of the Herzen University). The outcomes of these studies hold both

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[19] Zhurova E.B. The semantic worlds of the music by Johann Sebastian Bach. The first book. (Журова Е.Б. *Смысловые миры музыки Иоганна Себастьяна Баха. Книга первая*). Moscow: Pervyi Tom Publ., 2020. 280 p.; Zhurova E.B. A Synergetic approach in the study of baroque musical art using the example of the presentation of the monograph "The semantic worlds of the music by Johann Sebastian Bach". In: Contemporary musical education — 2021: creativity, research, technology: proceedings of the 20th International scholarly and practical conference, December, 8–10, 2021. (Журова Е.Б. Синергетический подход в исследовании музыкального искусства барокко на примере презентации монографии «Смысловые миры музыки Иоганна Себастьяна Баха». В: *Современное музыкальное образование — 2021: творчество, наука, технологии: материалы XX Междунар. науч.-практ. конф., 8–10 декабря 2021 г.*). St. Petersburg: SATORY, 2023, pp. 237–244.

[20] Koblyakov A.A. Synergy and creative work: an universal model for removing obstacles as the basis of a new research strategy. In: The synergetic paradigm. Diversity of quests and approaches: collection of articles. (Кобляков А.А. Синергетика и творчество: Универсальная модель устранения противоречий как основа новой стратегии исследований. В: *Синергетическая парадигма. Многообразие поисков и подходов: сб. статей*). Moscow, 2000, pp. 243–261.

[21] Grushko G.I. Musical form as a nonlinear process. (Грушко Г.И. Музыкальная форма как нелинейный процесс). *Muzykovedenie*. 2013, no 11, pp. 3–10; Grushko G.I. Synergetics in the system of musical-pedagogical education. (Грушко Г.И. Синергетика в системе музыкально-педагогического образования). *Mir nauki*. 2017, vol. 5, no. 6, p. 6.

[22] Kuprina E.Yu. Introduction to the co-creative activities of a musician: issues of theory and practice. (Куприна Е.Ю. *Введение в сотворческую музыкально-исполнительскую деятельность: вопросы теории и практики*). Saarbrücken: LAP LAMBERT Academic Pabl., 2012. 262 p.

[23] See also: Alieva I.G., Gorbunova I.B. Problems of formation of cognitive hearing of a professional musician. (Алиева И.Г., Горбунова И.Б. Проблемы формирования когнитивного слуха профессионального музыканта). *The world of science, culture and education.* 2017, no. 3, pp. 169–171.

theoretical and practical and applied significance. The potential for modeling the process of musical creative work processes using MCT has revealed new dimensions of interaction among music, mathematics, and informatics, with active application of the apparatus of fuzzy set theory, leading to the emergence of significant scientific results in this direction, which, in turn, provide a foundation for the development of extensive scientific and practical fields, including:

– the formation of an intelligent system for cataloging and analyzing music,

– creation of an intonation catalog of music of the peoples of Russia and the world,

– the establishment of a "musical genetic bank",

– the creation of the Russian Electronic Musical Synthesizer (hereinafter — REMS) incorporating timbres of traditional musical instruments of the peoples of Russia and the world.[24]

Work in these areas is currently conducted collaboratively by researchers from the Russian Federation and the Republic of Azerbaijan, on the basis of the RML *Music Computer Technologies* of the Herzen University and the laboratory *Research of Azerbaijani Professional Music of the Oral Tradition and Their New Directions: Organology and Acoustics* of the Baku Music Academy named after Uzeyir Hajibeyli. The relevance of developments in this scientific and practical field of activity is also underscored by the urgent need to preserve traditional creativity amid globalization, and interdisciplinary dialogue creates conditions for developing a common strategy in solving scientific problems associated with research carried out in this direction.[25]

The results of research carried out in this direction were presented at the plenary sessions of the 22nd and 23d International Scientific and Technical Conferences *Development of Informatization and the State System of Scientific and Technical Information* (2023, 2024) during the speech of the authors of the article (I.B. Gorbunova) with reports *Intellectual*

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[24] See about this: Alieva I.G., Gorbunova I.B. About the project of creating an intelligent system for cataloging and analyzing the music of the peoples of the world. (Алиева И.Г., Горбунова И.Б. О проекте создания интеллектуальной системы по каталогизации и анализу музыки народов мира). *Society: Philosophy, History, Culture*. 2016, no. 9, pp. 105–108; Alieva I.G., Gorbunova I.B. On the problems of developing an intellectual cataloging system for music of the peoples of Russia and the world. A transdisciplinary approach towards study of musical phenomena: Theory of fuzzy sets. In: *Regional informatics and information security: proceedings*. St. Petersburg, 2024, pp. 316–319. (In Russ.); Alieva I.G., Gorbunova I.B. The intonational system of Azerbaijani modes: a study with the use of computer technologies. *ICONI*. 2022, no. 1, pp. 79–91. (In Russ.) https://doi.org/10.33779/2658-4824.2022.1.079-091; Gorbunova I.B., Mikhutkina N.V. A synergetic approach in electronic music creation and education. *Art Criticism*. 2024, no. 4, pp. 29–46. (In Russ.)

[25] See: Gorbunova I.B., Alieva I.G. Musical creativity of the oral tradition: Concerning the problem of conservation of intangible cultural heritage. *The world of science, culture and education*. 2017, no. 6, pp. 314–318 (In Russ.); Alieva I.G., Gorbunova I.B. Music, language, creative work: The translation of cultural traditions in the context of the development of a high-tech creative environment. In: Regional informatics (RI-2020): proceedings of the 17th St. Petersburg International conference. (Алиева И.Г., Горбунова И.Б. Музыка, язык, творчество: трансляция культурных традиций в условиях развития высокотехнологичной творческой среды. В: *Региональная информатика (РИ-2020): материалы XVII Санкт-Петербургской Международной конференции*). St. Petersburg, 2020, pp. 24–26; Alieva I.G., Gorbunova I.B. Russia-Azerbaijan: On the problem of preservation of intangible cultural heritage and music computer technologies. In: Philosophy of education and dialogue of generations: collection of scholarly papers of the 29th International conference. (Алиева И.Г., Горбунова И.Б. Россия-Азербайджан: к проблеме сохранения нематериального культурного наследия и музыкально-компьютерные технологии. В: *Философия образования и диалог поколений: сб. науч. трудов XXIX Международной конференции*). St. Petersburg, 2023, pp. 426–433.

Cataloging of the Music of the Peoples of the World: On the Formation of National Electronic Content and About a Modular Approach to Music Creative Work with Artificial Intelligence Support (Minsk, Republic of Belarus, United Institute of Informatics Problems of the National Academy of the Science of Belarus), as well as at the annual International Research and Practical Conference *Contemporary Musical Education: Creative Work, Research, Technology* (St. Petersburg, Russia; 2022, 2023, 2024), 18th and 19th St. Petersburg International conferences *Regional Informatics* (St. Petersburg, Russia; 2022, 2024), 6th and 7th International Research Conferences *Interdisciplinary Discourse East-West: 21st Century. Creative Work. Science. Technology. Education* (St. Petersburg, Russia — Baku, Republic of Azerbaijan; 2024, 2025).

The creation of REMS is based on an integrative model for the semantic space of music, developed under the scientific supervision of Mikhail Zalivadny and actively advanced through a wide range of research projects involving employees of the RML *Music Computer Technologies* of the Herzen University, which provides a robust foundation for the qualitative and quantitative assessment of musical phenomena: the creation of an intellectual system for cataloging and analyzing the music of the peoples of Russia and the world, the development of databases and the creation of new opportunities on their basis, and, accordingly, new algorithms for representing information about musical art and the formation of an appropriate artistic and expressive high-tech creative information educational environment based on the use of MCT, which is increasingly being integrated into education.

In this regard, of particular interest are large-scale methodological developments tested with the support of the *National Training Foundation* of the Ministry of Education and Science of the Russian Federation and the projects, creating within the framework of the *Informatization of the Educational System*: DER (*Digital Educational Resources*) and IEMC (Innovative Educational and Methodological Complexes), which were developed at the RML *Music Computer Technologies* of the Herzen University. The approbation system for the implementation of the project included experimental platforms established under the Ministry of Education and Science of the Russian Federation. The testing process included teacher–approbatory — winners of the competition held within the framework of the National Project *Education*. MIDI keyboards were installed in the subject classrooms of these teachers-approbators of seven pilot regions of Russia and workplaces were organized for teachers and their students (specialized MCT classes), equipped with MIDI keyboards and musical computers [28][26] networked locally.

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[26] We define a "musical computer" as a professional instrument in the field of musical creative work and music education, having specific hardware features and corresponding software. In addition to the typical components for multimedia work, a musical computer must have the following mandatory (minimum!) components: a specialized sound card, an active MIDI keyboard, a dynamic microphone, and closed-type headphones. This issue is covered in more detail in a number of works, among which we mention: Beluntsov V.O. Computer for a musician: self-study guide. (Белунцов В.О. *Компьютер для музыканта: самоучитель*). St. Petersburg: Piter Publ., 2001. 459 p.; Belov G.G., Gorbunova I.B., Gorelchenko A.V. A musical computer (A musician's new instrument). (Белов Г.Г., Горбунова И.Б., Горельченко А.В. *Музыкальный компьютер (новый инструмент музыканта)*). St. Petersburg: SMIO Press Publ., 2006. 63 p.; Belov G.G., Gorbunova I.B., Gorelchenko A.V., Chernaya M.Yu. Musical computer and synthesizer in the pedagogical process. (Белов Г.Г., Горбунова И.Б., Горельченко А.В., Чёрная М.Ю. *Музыкальный компьютер и синтезатор в педагогическом процессе*). St. Petersburg: Herzen State Pedagogical University of Russia, 2009. 138 p.

Also within the framework of the nationwide project *UMNIK-Digital Russia. St. Petersburg — 2019* the project *Creation of a Non–Visual Access Environment Based on Music Computer Technologies for Musicians with Profound Visual Impairments* was created. This project was based on the results of computer modeling of processes related to the analysis of musical theoretical research and educational practice based on modern mathematical models, which used the theory of fuzzy sets and the mechanisms of its application to approximate decision-making.

Currently, employees of the RML *Music Computer Technologies* at the Herzen University have developed and implemented master's programs in *Digital Technologies in Music and Sound Design* and *Music Computer Technologies in Education*, as well as bachelor's programs in *Information Technologies in Music* and *Sound Design* and *Music Computer Technologies*. The introduction of these programs into the educational and creative process signifies the emergence of a new transdisciplinary scientific and educational direction[27] due to the development of MCT. Furthermore, the employees of the RML *Music Computer Technologies* at the Herzen University implement a wide range of continuing professional education programs[28] for training and retraining musicians with higher and secondary professional education, related to various areas of application of MCT in the modern musical and educational process at different levels, which is due, in particular, to the search for new approaches and methods of teaching music both in the system of professional, general and inclusive musical educational systems. As Academician Mikhail Ignatiev notes, "At present, the computer has become a powerful tool in the hands of music writers, creators of new architectural projects,

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[27] Among the main educational disciplines we will name the following: *Music Computer Technologies*, *Technologies of Artistic Sound Processing*, *Musical Synthesizers*, *Computer Music Creative Work*, *Sound-Timbral Programming*, *Mathematical Methods of Research in Musicology*, *Intellectual Systems for Cataloging and Analyzing the Music of the Peoples of the World*, *Set Theory and Description of Musical Objects*, *Theory of Information and System Analysis of Music*, *Sound Design and Musical Sound Engineering*, *Computer Recording Studio and the Basics of Working in It*, *Sound Production*, *Computer Modeling of the Process of Musical Creative Work*, *Sound Design and Musical Sound Engineering*, *Sound in Screen Media*, *Musical Production*, *Information Technologies in Music*, *Digital Musical Instruments*, *Software and Hardware Complexes in Music*, *Architectonics of Musical Sound*, *Intellectual Systems for Cataloging and Analyzing the Music of the Peoples of the World*, *Musical Informatics*, *Technologies for Creating Music for Visual Media*, and many others.

[28] Among them are *advanced training programs* (there are more than 20 of them; the study period is from 1.5 to 3 months: *Music Computer Technologies*, *Technologies of Artistic Sound Processing*, *Electronic Musical Synthesizers*, *Computer Musical Creative Work*, *Musical Sound Engineering*, *Methods of Teaching Musical Disciplines Using Music Computer Technologies*, *Distance Technologies in Musical Education*, *Art of Performing Skills and Arrangements on Electronic Musical Instruments*, *Interactive Network Technologies for Teaching Music*, *Information Technologies in Music*, *Creating an Electronic Educational Environment for Distance Musical Education*, *Creation of Audiovisual Content in the System of Distance Musical Education*, *Information Technologies in Musical Education*, and others) and *professional retraining programs* (there are 7 of them; the study period is from 1.5 to 3 years: *Teaching Musical Disciplines Using Music Computer Technologies*, *Teaching an Electronic Keyboard Synthesizers*, *Information Technologies in Music and Musical Education*, *Remote Educational Technologies in Music and Musical Education*, *Technologies for Creating and Artistic Processing of Sound Information* (with the issuance of a diploma in the specialty "Sound Engineer"); developed and introduced into the educational process — *Production and Marketing in the Modern Musical Industry and Teaching Academic and Popular Vocals Using Musical Computer Technologies in the Solo Singing Class*).

and virtual reality objects, yet at the same time complex challenges arise in organizing software computing and modeling the musical perception processes." [49, p. 259] The solution to these problems is connected with structuring uncertainty, applying a fuzzy approach to studying patterns of musical text organization and perception,[29] and collaboratively modeling "generators and receivers of works of art." [Ibid., p. 260]

The developed scientific and educational directions provide an effective basis for the formation of new directions for the musical culture development, illustrating the direct connection between the achievements of the research of music and the field of computer science, which are used in their work by specialists in the field of sound design and music sound engineering, computer music creative work, digital arts, musical informatics, computer music, musical programming and sound-timbral programming, media music, media information systems, technologies for artistic sound processing, etc. (see, for example, in [50]).

Conclusion

In conclusion, we note that the active development of digital technologies in music with the involvement of a fuzzy set apparatus, the use of various methods for building AI systems has become the subject of not only scientific, but also practical interest of both individual researchers and specialized laboratories, opening up new prospects for the development of MCT itself. The number of projects in the field of musical AI — the design of various search engines, modeling of musical creativity with the involvement of MCT funds — has been steadily growing in recent years, which underscores the need to train musical and technical specialists with systemic comprehensive knowledge in a number of transdisciplinary areas of musical and technical field and MCT.

In the field of musical culture, new directions and corresponding educational disciplines have

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[29] See: Gorbunova I.B., Zalivadny M.S. About the prerequisites of soft computing in music theory. In: Contemporary musical education — 2020: Creative work, research, technology: materials of the 19th International scholarly and practical conference. (Горбунова И.Б., Заливадный М.С. О предпосылках мягких вычислений в теории музыки. В: *Современное музыкальное образование — 2020: творчество, наука, технологии: материалы XIX Междунар. науч.-практ. конф.*). St. Petersburg: Herzen State Pedagogical University of Russia. 2021, pp. 192–196; Alieva I.G. The theory of the zonal nature of musical hearing by N.A. Garbuzov and the significance of European notation for Azerbaijani modes. (Алиева И.Г. Теория зонной природы музыкального слуха Н.А. Гарбузова и значение европейской нотации для азербайджанских ладов). *Musiqi dünyası*. 2012, no. 2/51, pp. 20–25; Alieva I.G., Gorbunova I.B. Problems of formation of cognitive hearing among professional musicians. (Алиева И.Г., Горбунова И.Б. Проблемы формирования когнитивного слуха профессионального музыканта). *The world of science, culture and education.* 2017, no. 3, pp. 169–171; Alieva I.G., Gorbunova I.B. Russia-Azerbaijan: On the problem of preservation of intangible cultural heritage and music computer technologies. In: Philosophy of education and dialogue of generations: collection of scientific papers of the 29th International conference. (Алиева И.Г., Горбунова И.Б. Россия-Азербайджан: к проблеме сохранения нематериального культурного наследия и музыкально-компьютерные технологии. В: *Философия образования и диалог поколений: сб. науч. трудов XXIX Международной конференции*). St. Petersburg, 2023, pp. 426–433; Alieva I.G., Isaev Z.F. Studying the mode system of Azerbaijani music using music computer technologies. In: Gorbunova I.B., Zalivadny M.S., Tovpich I.O., Chibirev S.V. Music, mathematics, computer science: an integrative model for the semantic space of music: monograph. (Алиева И.Г., Исаев З.Ф. Изучение ладовой системы азербайджанской музыки с помощью музыкально-компьютерных технологий. В: Горбунова И.Б., Заливадный М.С., Товпич И.О., Чибирёв С.В. *Музыка, математика, информатика: комплексная модель семантического пространства музыки: монография*). 2nd Ed., add. St. Petersburg: Lan' Publ.; Planeta Muzyki Publ., 2024, pp. 257–287.

emerged, most vividly demonstrating the direct link between knowledge in the field of computer science and musicology, used by specialists engaged in developments in the field of modern MCT.

The convergence of scientific approaches from Eastern and Western scholars, along with coordinated interdisciplinary efforts among researchers in various fields (including art historians, musicologists, ethnomusicologists, cultural theorists, educators, psychologists, acousticians, physicists, mathematicians, and MCT specialists), contributes to the creation of conditions for the interpenetration of research methods from the humanities, the exact, and natural sciences and for the development of a transdisciplinary approach in science and education.

The transdisciplinary approach to the study of musical phenomena, which is largely related to the identification of a holistic musical image and the further development of an integrative model for the semantic space of music, is considered as a fundamental underlying system of views in the formation of logical principles for the creation of new widely demanded musical and educational directions.

A pivotal role in forming this transdisciplinary approach, based on the application of the mathematical theory of fuzzy sets in musicology and music education practice, is attributed by the authors to the Russian musicologist Mikhail Sergeyevich Zalivadny whose research interests encompassed such interdisciplinary areas as the application of mathematical research methods in musicology, formation of a integrative model for the semantic space of music, the use of MCT, which offers a new perspective on preserving, studying, and transmitting musical folklore, transforming folk music artifacts into a living, functioning organism through innovative sound manipulation, thereby expanding the possibilities for a composer's creative work.

Concluding the article, we emphasize that the thoughts and concerns articulated by Charles Percy Snow in his seminal lecture *The Two Cultures and the Scientific Revolution* about that "*the process of demarcation of the scientific and artistic environment*, accelerated by the 20th-century scientific revolution, took on a general cultural scale and allows us to speak about the existence of 'two cultures' — scientific and artistic, separated by a wall of alienation and misunderstanding [our italics. — *I.A.*, *I.G.*]" (Cit. ex: [51, p. 39]) now have a tendency to be overcome: the transdisciplinary approach to mastering musical and artistic culture, building a "bridge between the two cultures — natural sciences and humanities" [Ibid., p. 40], and the musical and educational processes based on contemporary MCT, determines the formation of the integrity of the process. This integrity manifests in the harmonious interaction of individual components within a whole, while preserving their specificity; at the same time the integration of these components within a holistic system provides a new interpretation and understanding of the phenomena and processes under consideration, which determine their additional or even completely new qualities.

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