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Machine Learning Technologies in Science Art of the 21st Century

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General Characteristics of the Work

Relevance. Since the early 2020s, humanity has emerged amid a new scientific and technological revolution associated with artificial intelligence technologies. Strictly speaking, this refers to deep machine learning and generative neural network algorithms, whose emergence has become the most significant phenomenon in this field. The particular interest in these technologies stems from automation and algorithmization now impacting areas such as art, design, and creative practices — domains traditionally considered humans' exclusive prerogative.

Today, machine learning technologies are beginning to be integrated as tools into various fields of art: generative art, science art, glitch art, video art, media performance, public art, activism, participatory art, as well as graphic design, cinema, commercial printing, and many others. In this context, it becomes necessary to explore the impact of these new technologies on artistic practices and to address the questions of what new forms and issues they bring to the creative process and artists' experiments. It is also vital to update contemporary media and computer art classifications, defining new boundaries within artistic practices that utilize machine learning technologies.

Documenting and studying these forms of art not only helps us understand their historical and contemporary significance and creates a foundation for exploring future technologies. A prime example is science art, which utilizes machine learning algorithms to visualize scientific data and concepts. Artists and scientists collaborate to create aesthetically pleasing works and enhance our understanding of complex scientific ideas that are difficult to grasp intuitively. For instance, algorithms can analyze large datasets, such as genomic sequences or astronomical observations, and transform them into visual forms that captivate the viewer.

However, the most intriguing aspect of this research is the field of science art, where machine learning technologies are not merely tools for automating

established artistic practices but have led to the emergence of new creative forms that would be impossible without artificial intelligence technologies. These art practices are closely intertwined with scientific research in artificial intelligence. Examples include the AARON program by artist and computer engineer Harold Cohen, who viewed art as "one of how a person acquires intelligence and beliefs" and sought to answer how the combination of primitive visual elements generates new meanings"[1]. Another example is the ABRAHAM project by American media artist Joel Kogan, which aims to create a decentralized generative art program endowed with autonomy and agency, akin to a "collective intelligence," "superorganism," or "hive," where intelligence emerges from a complex system of interactions among smaller agents[2].

Such artistic works often exist at the intersection of computer art and science art. Since the mid-2010s, a community of artists experimenting with machine learning has emerged within the framework of computer art. This community included a relatively small number of enthusiasts, including engineers and software developers. Thus, there is a clear historical continuity between these artistic practices and the traditions of computer art.

In the artworks of this direction, "algorithmic aesthetics" receives an expanded interpretation, extending beyond data manipulation or programming code[3], into a much broader area of scientific research related to cognitive processes and human perception of the world. Artists bring into the realm of algorithmic aesthetics the challenges associated with using computers as instrumental tools and the issues connected to attempts at creating genuine computer models of creativity, explored at the intersection of art and artificial intelligence technologies[4]. Thus, the theme of artificial intelligence suggests the possibility of constructing an artificial system with an agency equal to that of a human being. This, in turn, ties such

[1] Erokhin S.V. The Aesthetics of Digital Visual Art. Aletheia, 2010. pp. 221-222.

[2] Kogan G. Artist in the Cloud: Towards an Autonomous Artificial Artist. GeneKogan, 2019. URL https://genekogan.com/misc/AbrahamPoster.pdf (Accessed: 28.09.2023)

[3] Migunov A.S., Erokhin S.V. Algorithmic Aesthetics. St. Petersburg, Aletheia, 2010.

[4] Ibid.

developments to one of the unresolved issues in contemporary science—the "hard problem of consciousness."[5] Consequently, artists experimenting with machine learning have become institutionally integrated into computer and science art.

However, the study of science art using machine learning technologies has gained particular relevance today due to the emergence of significant language and multimodal models, which have established this technology's instrumental and product value, significantly expanding its application in various artistic practices and design. At the same time, machine learning technologies have demonstrated their potential as a tool for scientific research. These algorithms have shown groundbreaking results in areas of science where researchers work with large datasets, such as studying processes in the cerebral cortex, astronomy, or the synthesis of new chemical elements.

Thus, this research is essential for refining the classification of science art and computer art and continuing and clarifying the historiography of these fields within the broader context of media art. It is particularly relevant to distinguish artistic practices using machine learning technologies that emerged due to the machine learning revolution before these technologies gained instrumental value and integrated into various art and design forms. Additionally, it is essential to trace the further development of artistic experiments with science art, focusing on the creative exploration of artificial intelligence technologies and systems with non-human agency. These latter aspects represent a significant interest for artists working within the sci-art domain as they engage with and reinterpret scientific material.

[5] The "hard problem of consciousness," proposed by philosopher David Chalmers, concerns the challenge of explaining how and why physical processes in the brain give rise to subjective experience and qualia (the qualitative aspects of sensations). Unlike the "easy" problems of consciousness, which investigate the functions and mechanisms of the brain, the hard problem focuses on the internal, subjective nature of experiences. There is a gap between the objective description of brain processes and the subjective character of sensations that science has yet to bridge. Solutions to the hard problem include various philosophical approaches, such as dualism, functionalism, panpsychism, and emergentism. These approaches attempt to explain why and how physical processes lead to the emergence of conscious experience, remaining one of the most contentious and debated topics in philosophy and neuroscience.

Such practices require documentation and research to ensure consistent integration into existing classifications and the academic discourse surrounding this field. It is also important to note that these studies encompass the forms and methods of creating artworks and the cultural and philosophical reflection that contemporary art scholars have addressed. This approach allows for a comprehensive understanding, recognizing that studying art and technology in isolation can lead to the loss of significant aspects of their interaction. Specifically, machine learning raises questions for scholars about the boundaries and fundamental differences between natural and artificial intelligence. The foundation for studying these differences, mainly when such technologies are still nascent, lies within research areas such as posthumanist philosophy and object-oriented ontology. A comprehensive consideration of these factors is crucial for a deep and holistic understanding of new art forms and their place in contemporary culture.

Research Problem. Based on the study's relevance, this dissertation examines the artistic methods and practices of applying machine learning technologies that have emerged over the past decade. Traditionally, computer technologies, including machine learning algorithms, have served as tools for artists in computer art. However, currently, the most significant and striking works created using these technologies are emerging within the framework of science art , where computer technologies function as tools for scientific research and, in this capacity, become the foundation for artistic works. This aspect requires deep and comprehensive analysis, as it allows for a detailed investigation and description of the processes occurring in this area of contemporary computer art, contributing to the systematization of accumulated knowledge and artistic material.

Degree of Development of the Problem. Machine learning technologies in science art inherit a well-studied tradition within Russian art history, specifically in the field of computer art. However, within the broader scope of computer art and

the entire sphere of information technologies, it is essential to distinguish the area of engineering thought related to artificial intelligence technologies. Emerging almost simultaneously with computers, this field has radically expanded the issues surrounding the automation of human labor, now touching upon the ontological boundaries of human existence. These processes are increasingly reflected in artistic practices, making it necessary to examine them in detail.

Thus, continuing and updating the existing historiography, the full spectrum of research dedicated to intellectual technologies in computer art can be conditionally divided into two periods. The first period, Algorithmic Art (up to 2015), includes practices involving symbolic artificial intelligence. The second period encompasses Contemporary Works Utilizing Machine Learning Technologies (approximately from 2015 to the present). This classification defines the chronological boundaries of the present study.

Among the first Russian researchers to make a significant contribution to the systematization of computer art, including artistic practices using machine learning technologies (such as the science art direction under study), was Doctor of Philosophy S.V. Erokhin. He presented a detailed historiography of artistic practices that emerged with the advent of the first computers after World War II and continued through the early 21st century. Erokhin divides computer art into three periods: "early digital visual art (1960s-1970s), digital computer art of the 1980s-1990s, and digital computer art of the 21st century."[6]

An essential aspect of S.V. Erokhin's work for this study is his definition of artistic practices that use artificial intelligence technologies, including machine learning. He employs the term "artificial art," referring to the process of "creating an artwork that does not involve human participation." According to Erokhin, such artistic practices fall within the scope of fundamental and applied research in artificial consciousness. Although this term has not gained widespread acceptance in the scientific literature, it is a valuable starting point for exploring artistic

[6] Erokhin S.V. The Aesthetics of Digital Visual Art. Aletheia, 2010. pp. 33-51

practices that utilize machine learning technologies, including those within science art .

Among international researchers, art historians P. McCorduck and L. Sundararajan have focused on artificial intelligence in art and the creativity of autonomous algorithms and machines. They studied one of the most prominent art projects in this field, Harold Cohen's AARON, which existed and evolved over several decades from the 1970s until the artist died in 2016. P. McCorduck parallels science and art, emphasizing their shared conceptual foundation. She notes that "an artist aiming to express a certain idea creates an art object that is not merely a technological creation but also an embodiment of that idea, whose value is not limited to its physical manifestation; the most significant works are valued for their ideas. Ideas are universal and capable of broad application, unlike specific, unique objects." As a natural progression of thought in this direction, McCorduck also explores the "invisible world of mental processes underlying visual representation."[7]

Later, the study of art using machine learning technologies, particularly generative neural network algorithms, was explored in the works of the renowned digital technology and culture researcher Lev Manovich. Beginning with his analysis of the digitization process in general in his book *"The Language of New Media" (2001)*, Manovich developed his approaches to studying phenomena related to computerization in subsequent works such as *"Software Culture" (2010)*, *"Data Drift: Archiving Media and Data Art in the 21st Century" (2015)*, and *"Artificial Aesthetics: A Critical Guide to AI, Media and Design" (2021-2024)*.

In his latest work, *"Artificial Aesthetics: A Critical Guide to AI, Media, and Design,"* Lev Manovich explores the impact of artificial intelligence on the "global cultural ecosystem" and establishes a conceptual framework for further discussion on the issue of neural networks. The work addresses questions such as what we

[7] McCorduck P. AARONS's Code: Meta-Art. Artificial Intelligence, and the Work of Harold Cohen. New York: W. H. Freeman and Company, 1991. – p. 191-192

understand by artificial intelligence at this stage, current technology's limitations, and the specific characteristics of the aesthetic forms it generates. The research, co-authored with E. Arielli, provides a step-by-step analysis of art using machine learning technologies, tracing its development in line with the logic of technological progress. The first chapter of the book was published in December 2021, and the seventh in April 2024.

The work of Norwegian researcher J. Rettberg, titled *"Machine Vision: How Algorithms are Changing the Way We See the World,"* is of particular interest in international research. This study focuses on machine vision and provides an overview of the historical and contemporary applications of machine vision and artificial intelligence technologies. Rettberg demonstrates how various types of machine vision enable people to see in new ways through tools like home surveillance cameras, generative algorithms such as DALL-E, and satellite imagery. These technologies introduce an aesthetics of the non-human, which is gradually making its way into media art.

Both domestic and international authors have explored various aspects and directions of art using machine learning technologies. For example, E. Mendelowitz studied the impact of machine learning technologies on public art. E. Nikonole addressed the issue of online security in the Internet of Things and the growing capabilities of artificial intelligence in her project "deus X mchn" (2017), where she invaded users' personal spaces through unsecured devices connected to the Internet. The research of art historian S.S. Gribov is dedicated to the application of machine learning in dance media performance. In turn, Doctor of Cultural Studies T.E. Fadeeva examines the main trends in the development of contemporary media art, particularly under the influence of algorithms that have emerged as a result of the revolution brought about by artificial intelligence technologies.

Nevertheless, numerous studies on machine learning processes (including those by F. Gut, Z. Lipton, A.B. Arrieta, R. Guidotti, and many others) indicate

that modern neural networks, which have become the most popular approach to deep machine learning, are opaque and uninterpretable systems. These aspects imply that developers do not have a direct understanding of the mechanism behind these models, which contain billions of parameters and are often regarded as "black boxes."[8] As a result, the question of agency—specifically, the agency of machines rather than humans—becomes more relevant, emphasizing a form of agency devoid of subjectivity. In art, such explorations of areas beyond human subjectivity have been undertaken by representatives of generative art (such as P. Galanter, M. Moore, K. Sims, H. Haacke, F. Nake, and others). As P. Galanter noted, "The key element of generative art is systems to which the artist cedes partial or complete control over the creation of the work."[9]

As a result, a general direction of experimentation in art using machine learning can be identified. The technology itself borrows principles from the organization of human biological neural networks. It extends to neurocognitive research and works in the fields of philosophy, psychology, anthropology, and computer science. The core issue in previous studies revolves around the hard problem of consciousness, a central theme running through all creative practices related to artificial intelligence technologies.

Thus, the theoretical foundation of this research will rely on scholarly works that explore the mutual influence of art and science (specifically, science art or sci-art) with a focus on machine learning technologies. This approach, which combines the study of advanced computer technologies and the reproduction of current scientific and technological discourses about social processes, naturally falls within the interdisciplinary field of Science and Technology Studies (STS)—as developed by scholars such as Bruno Latour, Michel Callon, John Law, Steve Woolgar, and Abraham Moles.

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[8] Arrieta A.B., Diaz-Rodriguez N., Del Ser J. Explainable Artificial Intelligence (XAI): Concepts, taxonomies, opportunities and challenges toward responsible AI // Information Fusion, Volume 58, 2020, 82-115, https://doi.org/10.1016/j.inffus.2019.12.012.

[9] Galanter P. What is the generative art? Complexity Theory as a Context for Art Theory // P. Galanter, 2000 URL https://philipgalanter.com/downloads/ga2003_what_is_genart.pdf (дата обращения 15.04.2024)

In the works of these authors, the relationship between humans and technologies is conceptualized as a network of interactions between people, technologies, and social structures. One such approach was the analysis of laboratory practices through the study of texts, which are the products of researchers' activities and form the foundation of scientific communication. This perspective emphasizes the interconnectedness of human and technological elements within scientific and artistic processes, highlighting how these interaction networks shape knowledge production.

In science art, laboratory practice is transformed into an artistic tool, shifting from the laboratory to the gallery while maintaining the principle of communication through texts (or media texts). These texts are necessary for the viewer's perception of art objects in the exhibition space to become challenging or speculative (this issue is discussed in more detail in paragraph 2.3). This method of analyzing science art is crucial in demonstrating the connection between artworks based on machine learning technologies and cognitive research in neurophysiology or psychology, focusing on the "hard problem of consciousness." This approach helps to illustrate how these artistic practices engage with and reflect scientific inquiries into consciousness, thus bridging the gap between art and science.

Thus, works dedicated to science art as a whole gain particular significance concerning artists' engagement with the "hard problem of consciousness," as they allow for tracing key trends and contemporary issues within this artistic field. These include studies by D.H. Bulatov, O.E. Levchenko, V. Gromova, E.A. Komleva, D.V. Galkin, T.E. Fadeeva, and A.A. Pisarev, among others. Additionally, works that delve into the concepts of posthumanism—by scholars such as F. Ferrando and Eugene Thacker — are also relevant, as they offer critical insights into how these artistic practices intersect with broader philosophical discussions on the nature of humanity and technology.

Nevertheless, the democratization and accessibility of neural network algorithms have led to the emergence of individual works and entire projects that

exploit the specific features of commercial products from IT giants. These projects often use specialized generative algorithms trained on aesthetically pleasing images or visual styles popular with mass audiences, allowing for purely utilitarian tasks like image stylization for entertainment purposes. These tasks adhere to the established logic and content policies of large companies. The issue of the kitschification of art and its transformation in the digital age has been explored in the works of L. Manovich, R. Scruton, G. Lipovetsky, J. Quaranta, G. Lughi, A.A. Kurbanovsky, and others. These scholars have addressed how the commercialization and widespread availability of such technologies can impact the integrity and originality of artistic practices, raising questions about the value and authenticity of art in the digital era.

The theoretical and philosophical foundations of contemporary research on the impact of technologies on modern art can be found in the works on art theory and its interaction with technology by Walter Benjamin, Boris Groys, Rosalind Krauss, Susan Sontag, Jean Baudrillard, Jacques Lacan, Yuk Hui, N.B. Mankovskaya, V.V. Bychkov, V.P. Rudnev, A.V. Vasiliev, and I.I. Yugai. Additionally, research on modern technologies and communication media can only be completed by considering the contributions of media theory scholars such as Marshall McLuhan, V.V. Savchuk, I.V. Kiria, A.A. Novikova, and others. Thus, machine learning technologies exist as artistic tools and as part of the broader creative industries system. The creative industries exert a direct influence on the development of generative algorithms and the practices associated with them. Understanding this dynamic is crucial for comprehensively analyzing how these technologies shape contemporary art and culture.

Overall, the training and generation of images by neural network algorithms are ongoing processes whose specific nature is naturally embodied in the format of video images on a screen, with or without interactive elements. Therefore, the works of A. Djeuza, A.D. Persheeva, and A.A. Denikin, in the field of video art, become necessary for understanding these artistic practices. Their research

provides valuable insights into how video art can effectively capture and represent neural network-based art's dynamic and process-oriented nature, highlighting the interplay between technology and artistic expression in the digital age.

Additionally, several researchers analyze the mechanisms by which what are socially recognized as creative practices emerge within intelligent algorithms. Notable works include those by A. Forbes, T.E. Fadeeva, K. Yu. Bokhorov, D.V. Galkin, A. Elgammal, and M. Mazzone. These studies delve into how creativity is conceptualized and operationalized within machine learning and AI systems, exploring the boundaries between human and machine creativity and the implications for artistic practice and our understanding of creativity.

At various times, generative art has been studied by F. Galanter, who proposed using complex systems theory (complexism) for its analysis, and by E. Collabella, S. Soddu, R. Ascott, J. McCormack, T. Hobbs, B.K. Vianna, and S.S. Gribov. These scholars have explored the intricate relationships and dynamics within generative art, examining how systems-based approaches can provide a deeper understanding of this field.

Glitch art, on the other hand, has been the focus of research by M. Betancourt, I. Andrews, E.V. Zhagun-Linnik, R. Packer, Z. Blas, J. Wyman, T. Becker, and others. These researchers reject the triumphalist narrative of the so-called digital revolution. Instead of celebrating the qualities of the digital image, glitch artists emphasize the flaws and imperfections of digital processes, using them to critique and explore the limitations of digital media. Their work highlights the creative potential inherent in the "errors" and "failures" of technology, offering a counter-narrative to the seamless and flawless digital aesthetic often associated with contemporary media art.

Research object

Science art works are created using machine learning technologies.

Research subject

Artistic practices and experimental approaches at the intersection of science art and computer art, based on machine learning technologies.

Hypothesis posits that artistic works in which neural networks and machine learning algorithms form the foundation of the art object, rather than serving an auxiliary or instrumental role, are most prominently expressed within the framework of science art. In this context, they are integrated into the research discourse on the phenomenon of consciousness. Consequently, artistic experiments aim to explore issues related to the agency of machine learning algorithms, the specific nature of artificial intelligence's "understanding" of the world, and the new sensory forms that emerge from the interaction between humans and machine learning technologies.

The research aims to identify new methods and artistic practices that utilize machine learning technologies for the artistic exploration of issues within the domain of science art. In line with this aim, the research includes the following **objectives**:

1. To determine the place of science art that employs machine learning technologies within the context of contemporary computer and media art.
2. To identify the stages of development of artistic practices using machine learning since establishing these practices as a distinct field in 2015.
3. To trace the historical continuity of artistic practices incorporating machine learning technologies, linking them to established approaches in exploring artificial intelligence in art.
4. To define the logic behind the formation of artistic-expressive and poetic means in science art using machine learning.

5. To substantiate the phenomenon of interdisciplinary interaction between the sciences studying human consciousness and science art utilizing machine learning technologies.

6. To delineate the boundaries between science art and mass digital graphics using commercial algorithms and large language models.

The scientific novelty of the research arises from its focus on artistic practices based on machine learning technologies, a relatively unexplored area of contemporary visual art currently in its formation. This study conducts a historical retrospective of artistic practices using machine learning, identifying the stages of development and transformation of artificial intelligence art in recent years. It has been discovered that such generative practices, when integrated into the artistic practices of science art, form an interdisciplinary field that bridges science, art, and technology through engagement with the "hard problem of consciousness," which is fundamental to understanding the relationship between humans and the world around them. This gap and its resolution have been, and continue to be, a central issue for contemporary science art.

Theoretical Significance of the Work. This study examines science art based on machine learning technologies as a unique and independent phenomenon within the context of computer and media art practices. The research synthesizes the experiences of both domestic and international scholars, expanding them within the framework of science art that utilizes machine learning. The materials presented in this work provide a detailed overview of the practices specific to this field, document significant artists working with these technologies, and enhance existing classifications. Additionally, these findings may be valuable for further research in art studies. For example, the study describes artworks where artists use machine learning algorithms to experiment with various models within the context of the "hard problem of consciousness," creating installations that visualize human

cognitive processes and explore the emergence of consciousness on substrates other than the human body.

The work contributes to the development of computer art theory by highlighting new aspects of the interaction between humans and technology in the artistic process. Furthermore, the research continues and supplements the historiography of computer art by introducing new names and achievements in this area. An essential aspect of this study is the use of local cultural contexts, which allows for exploring how regional characteristics influence the interpretation and application of these technologies.

Practical Significance of the Work. An important practical aspect of this study is the expansion of existing conceptions of generative and science art created using machine learning technologies. Introducing new data into the academic and practical discourse contributes to further exploring these fields. The results of this dissertation are of practical interest to curators of museum and exhibition projects specializing in science, computer, and media art. The dissertation materials can be utilized in education to develop teaching materials, lectures, and seminars on curatorial practices and scientific and technological art presentations.

The research includes systematizing, revising, and expanding terminology directly related to media art based on machine learning technologies, particularly neural network algorithms. A vital component of the work is the author's use of many carefully selected and translated materials from international academic research and practice, facilitating the exchange of scientific and practical achievements and integrating Russian art studies into the global context.

Research Material. The research material consists of works by artists presented at various media art events, including the Ars Electronica media art festival, the "Art of the Future" biennale (MMAAM, 2022), and exhibitions in Moscow such as "May the Other Live in Me" and "New Elements"

(LABORATORIA Art&Science Foundation, 2021-2022), "Open Set" and "Uncanny Dreams" (Electromuseum, 2021), "Frequencies 3.0: The Magic of Supertechnologies," "Frequencies 4.0: Star Temple," and "Weather State" (Khodynka Gallery, 2022-2023), "Space of Communication: From Sign to Sensation," "Programmable Art," and "AI and? Neural Networks and the Creative Process" (Krasnokholmskaya Gallery, 2023), "The Code of Art" and "Clipboard" (GRAUND Solyanka Gallery, 2022-2023), and "New Art. Algorithms. Neural Networks. Technologies" (MARS Gallery, 2024); in Nizhny Novgorod—"Artificial" (TsECH Exhibition Space, 2024); and in Perm—"Open Body" (PERMM, 2024).

The dissertation analyzes the works of artists such as Mario Klingemann, Memo Akten, Gene Kogan, Refik Anadol, Sofia Crespo, Anna Ridler, Alexei Shulgin, Vadim Epstein, Elena Nikonole, Valeria Titova, Anna Shustikova, Yulia Vergazova, Nikita Ulyanov, Elena Demidova, Dmitry Soshnikov, Polina Chernyshova, and creative collectives like Obvious, Grey Cake, Vtol, Synticate, and graduate students from ArtTech (MISIS).

The dissertation also examines works by artists published on the Internet and social media platforms (with X, formerly Twitter, being viral) and publications on platforms like GitHub and Google Colab. Additionally, interviews, discussions, and comments within thematic communities and on artists' pages are studied as part of the research.

Methodology. The foundation of this dissertation research is an art historical approach, which enabled a detailed examination of the development of artistic practices using machine learning technologies, their expressive characteristics, and the methods and techniques employed by artists working with these technologies. The validity of the theoretical conclusions regarding the specifics of using machine learning in science and computer arts was achieved through the comprehensive application of general and specialized scientific inquiry methods.

1. The Historical-Genetic Method allowed for tracing artistic practices' development using machine learning in a historical retrospective. This method helped establish the continuity of techniques and characteristics of science art that employs machine learning algorithms within the broader context of computer and media art while also expanding and refining existing classifications of works in computer art.

2. Structural and Formal Analysis Methods provided the means to conclude the visual specificity and characteristics of artistic practices related to machine learning technologies. These methods enabled the examination of existing artworks, identifying their distinctive features, and analyzing the specifics of their content and functioning.

3. The Biographical Method played a crucial role in analyzing artistic practices by allowing them to be considered through the lens of the life events and circumstances that influenced the artists. This approach made it possible to determine the context of the emergence of machine learning algorithms as an artistic tool and to explain the preferences and motivations for using particular software tools.

Conclusion

1. Although research in machine learning and generative algorithms has been developing over the past three decades, the starting point for the related direction in computer art was the emergence of the DeepDream algorithm. The visual pattern from these experiments gave rise to unique graphic elements and established a recognizable style in artistic practices using machine learning technologies.

2. Machine learning technologies, as a tool for artistic practice, are most prominently manifested in science art. In this artistic direction, new techniques and practices of computer art related to these technologies are being discovered today,

where computer technologies, initially designed for laboratory experiments and research data analysis, become the foundation for creating artworks. In contrast, due to the increasing commercialization of generative algorithms, popular and widely accessible algorithms are trained on aesthetically appealing images or visual styles favored by the mass audience, adhering to large companies' established logic and content policies.

3. Theoretical approaches to the study of science art allow for the examination of artistic practices using machine learning technologies as an autonomous artistic system, particularly in the context of the "hard problem of consciousness." Artificial neural networks provide artists with tools to explore new forms of creative expression. These models can generate artworks by mimicking the cognitive mechanics of human creative processes and thematizing questions about mind, intelligence, and human creativity by engaging with the hard problem of consciousness.

4. Science art using machine learning technologies continues posthumanist trends that explore interactions with non-human agents and critique anthropocentrism. This aspect leads to the development of approaches where the experience of audience reception becomes more complex, and the traditional "human-to-human" communication model is expanded to include "human-machine interaction" experiences. This art appeals not only to the anthropocentric experience of the viewer, involving classical observation and internal empathy, but also attempts to transcend these boundaries, moving into the realm of communication with the non-human (the Other).

5. The reception of works of science art follows the logic of the artistic complex "art object – media text – audience," which emerges from the transfer of laboratory practices into the art gallery. This idea is a consequence of the critical role of text in contemporary scientific communication, which sociologists of science and technology identify as the crucial link between the data generated in laboratories and the circulation of scientific knowledge. This structure highlights

the importance of media texts in facilitating the understanding and interpretation of art that incorporates scientific and technological elements, making it accessible and meaningful to the audience.

Validation of Results

The author presents the main propositions of the dissertation in four publications.

These publications are featured in journals included in the List of Peer-Reviewed Scientific Publications approved by the Ministry of Education and Science of the Russian Federation and the recommended lists of the National Research University Higher School of Economics (HSE).

Milovidov S.V. Artistic features of computer artworks creating with machine learning technology. Articult. 2022, no. 4(48), pp. 3648. (in Russ.) DOI: 10.28995/22276165202243648

Milovidov S.V. From Laboratory to Gallery: Transfer of Construction Principles of Scientifi c Knowledge into Works of Science-Art, Observatory of Culture, 2023, vol. 20, no. 4, pp. 367—376. DOI: 10.25281/2072-3156-2023-20-4-367-376.

Milovidov S. Content policy and access limitations on commercial neural networks as an incentive to artivism. Artnodes. 2024. No. 33. P. 1-9.

Milovidov S. Science art and kitsch: computer art bases on the large language model. Communication. Media. Design. 2024. V. 9. № 2. pp. 45-64.

Other publications

Milovidov S. Exhibitions of Science Art in Russia: Searching for the Boundaries of the Human. In: Graduate Collection. Issue 12. Collection of Articles

Based on the Materials of the International Forum of Young Art Researchers "Scientific Spring-2022". Moscow: State Institute for Art Studies, 2023. pp. 182-188.

The results of the research have been presented at the following conferences:

- International Conference "Art and Machine Civilization," State Institute of Art Studies, 2021.
- International Conference "Theories and Practices of Art and Design: Sociocultural, Economic, and Political Contexts" (an associated event of the XXI April International Scientific Conference on Problems of Economic and Social Development), HSE University, 2021.
- International Conference "Theories and Practices of Art and Design: Sociocultural, Economic, and Political Contexts," HSE University, 2022.
- Scientific Spring 2022 VI Annual Forum of Young Researchers in Art and Culture, State Institute of Art Studies, 2022.
- International Conference "Theories and Practices of Art and Design: Sociocultural, Economic, and Political Contexts" (an associated event of the XXIV Yasin International Scientific Conference on Problems of Economic and Social Development), HSE University, 2023.
- International Conference "Theories and Practices of Art and Design," HSE University, 2024.
- Conference "Signal Systems," Gallery Krasnokholmskaya, 2024.

The structure of the dissertation is determined by the goals and objectives set forth in the research. This work consists of an introduction, two chapters, a conclusion, a bibliography containing 155 sources. The research material is presented on 150 pages.

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In the **introduction**, the topic's relevance is justified, the dissertation problem is formulated, and the object and subject, as well as the goals and objectives of the research, are defined. Additionally, the current level of research on the problem is reviewed, and the methodology for achieving scientific results is proposed. This section of the dissertation also outlines the scientific novelty and theoretical and practical significance of the work in the context of contemporary art studies. It presents the empirical materials of the research.

Chapter 1, "Historical Aspects and Axiomatic Foundations of Research on Machine Learning Technologies in Contemporary Science-Art," examines the current technologies of machine learning and approaches to defining media art, science art, and computer art. The chapter explores how artists use computer technologies and algorithms related to machine learning and artificial intelligence, presenting this analysis within a historical retrospective.

Section 1.1, "Concept of Machine Learning and Technological Tools Used by Artists," examines the primary approaches to machine learning in contemporary computer sciences to conceptualize this terminological framework within art history. The section also clarifies critical terms and concepts, including artificial intelligence, machine learning, deep learning, artificial neural networks, and significant language and multimodal models. It discusses the main aspects of using neural networks and other machine learning technologies in the context of media art.

In Section 1.2, "Machine Learning Technologies in Science Art as Part of the Broader Context of Contemporary Computer and Media Art," it is noted that machine learning technologies have become a crucial tool in media art, fitting into the broader context of modern media technologies and communication methods. Since the mid-20th century, media theory has explored how mediaization of communication affects various aspects of society, including art, and has led to

various approaches to understanding media art: from direct and media-deterministic perspectives, through technological optics that involve creative interpretations of information and communication technologies and media languages (L. Manovich[10], M. Rush[11]), to expansive interpretations of this phenomenon related to the use of new technologies and scientific approaches, which is reflected in works that combine artistic creativity with scientific and engineering methods (R. Krauss[12], K. Paul[13], T.E. Fadeeva[14], N.I. Dukhan, and A.D. Persheeva[15]). This section also defines the place of science art within computer and media art classifications. It examines the artistic practices of science art using laboratory and research tools.

Section 1.3: "Historical Retrospective of Computer Technologies and Artificial Intelligence Concepts and Their Reflection in Contemporary Computer Art" examines the history of the application of modern computer technologies in art, from early works by artists such as Paul D. Henry and M. Noll to contemporary experiments with artificial intelligence and machine learning. It traces the transformation of artistic practice, which initially required knowledge of mathematics, programming, and engineering disciplines but has become accessible to a wider audience with technological advancements.

The section discusses transformations in the artist's tools and their use, which have occurred due to the development of machine learning technologies and progress in artificial intelligence. These changes are particularly noticeable in the shift from symbolic artificial intelligence, as practiced by pioneers of computer art such as Harold Cohen with his AARON project, to modern neural network approaches. Contemporary artists actively explore these new methods, discovering

[10] Manovich L. The Language of New Media. Ad Marginem Press, 2018.

[11] Rush M. New Media in Art. Moscow: Ad Marginem, 2018.

[12] Krauss R. Under Blue Cup. MIT Press, 2011. 141 p.

[13] Paul C. Digital Art. Moscow: Ad Marginem Press, 2017.

[14] Fadeeva T.E. Media Art in the Context of the Latest Technologies. Doctoral Dissertation in Cultural Studies: 5.10.1. – National Research Mordovia State University named after N.P. Ogarev, Saransk, 2023.

[15] Dukhan I.N., Staruseva-Persheeva A.D. Optical Strategies of New Media: From Perspectivism to a Drifting Gaze // ΠΡΑΞΗΜΑ. Problems of Visual Semiotics (ΠΡΑΞΗΜΑ. Journal of Visual Semiotics). 2022. Issue 3 (33). pp. 9-38.

new forms of artistic expression and interaction for themselves and their audiences. For instance, L. Manovich and other researchers note that artificial intelligence technologies like deep learning enhance the fundamental properties of digital media—such as digital representation, modularity, automation, variability, and transcoding. These aspects underscore the work of artists within the framework of "non-classical aesthetics" (N.B. Mankovskaya, V.V. Bychkov, I.I. Yugai), which is characterized by a "diminishment or abandonment of the mimetic function of art, a rejection of anthropocentrism in art, secondary importance of aesthetics in creativity, and a lack of clear distinction between art and non-art."[16]

Chapter 2: "Problematic Field of Artistic Practice Using Machine Learning Technologies," is dedicated to exploring the thematicization of the "hard problem of consciousness" and posthumanist concepts in artistic practices that employ machine learning technologies. It analyzes various artistic approaches utilizing machine learning technologies to rethink traditional anthropocentric paradigms, offering new perspectives on the relationship between humans and technology. The chapter also examines methods of representing and perceiving consciousness in art.

Section 2.1: "Scientific Metaphor in the Works of Artists Using Machine Learning Technologies" demonstrates that the scientific metaphor in artworks created with machine learning technologies began in the mid-20th century with the advent of electronic computers and cybernetics. Norbert Wiener laid the groundwork for informatics and artificial intelligence research, aiming to automate human labor. Herbert Simon, Allen Newell, and Alan Turing proposed the "computer" metaphor for consciousness, suggesting that the brain functions like a computer by processing data and making decisions. These ideas gained widespread traction due to the proliferation and advancement of computer

[16] Mankovskaya N.B., Bychkov V.V. Contemporary Art as a Phenomenon of Technogenic Civilization. Moscow: VGIK, 2011. 208 p.; Bychkov V.V. The Art of Technogenic Civilization in the Mirror of Aesthetics / V.V. Bychkov, N.B. Mankovskaya // Questions of Philosophy. 2011. No. 4. pp. 62-72.; Yugay I.I. Media Art: Origins, Specificity, Artistic Strategies. Doctoral Dissertation in Art History: 17.00.09. St. Petersburg, 2018.

technology, facilitating the development of artificial intelligence and deep machine learning.

New artistic movements, such as bio-art and science-art, explore the human body's and technology's interaction, creating works that integrate scientific advancements into artistic expression. The section also highlights the connection between an artist's choice of expressive means and the theoretical concept of scientifically addressing the problem of consciousness.

Section 2.2: "Posthumanist Discourse in Science Art Using Machine Learning Technologies" focuses on science art through the lens of posthumanist philosophy and critique of anthropocentrism, considering artworks as parts of a "new materiality" with emergent properties. Artists exploring the difficult problem of consciousness experiment with moving away from anthropocentric views of the world, reflecting a posthumanist orientation. Consciousness, as a central phenomenon, is connected with contemporary research and digital technologies, creating a new understanding of subjective experience.

Works by researchers and artists such as Thomas Nagel and Francesca Ferrando highlight the limitations in understanding others' experiences and the role of alternative embodiments. Gilles Deleuze and Félix Guattari critique traditional structures, proposing concepts such as the "body without organs" and functional objects.

Despite their inherent agency to some extent, modern neural networks remain models that merely imitate human cognitive mechanisms. In posthumanist discourse, artificial intelligence is seen as a form of the Other, leading to a re-evaluation of human nature and consciousness and investigations into new forms of life through the integration of biological and digital realms.

Section 2.3: "Sociology of Science (STS) as a Method for Studying Artistic Works Using Machine Learning Technologies in the Context of Science Art" examines artists' works utilizing machine learning technologies and neural networks, often institutionally presented within the framework of science art

(science-art). It is crucial to consider methods of analyzing scientific practices and the functioning of academic institutions. French sociologist Bruno Latour demonstrated that scientific facts and values create knowledge by rethinking the relationship between science and society. Curatorial texts serve as scientific records in science art, transforming scientific experiences into artistic expressions.

Thus, studying such works' textual and media accompaniments is essential, as they connect science and art. Artists engage with scientific research, translating it into the language of art and creating complex systems of interrelationships and metaphors. This approach is significant because it reveals elements of science and the aestheticization of laboratory research in artistic experiments with machine learning technologies. Consequently, scientific knowledge and experimentation become integral components of artistic practice.

Chapter 3: "The Aesthetics of the Non-Human in Science Art Using Machine Learning Technologies" explores various phases in developing contemporary machine learning technologies within media art. Through specific examples, it justifies the scientific and experimental nature of these artistic practices and the formation of aesthetic forms that hyperbolize rational processes, which may reach a level of abstraction beyond human logic.

Section 3.1: "Machine Learning in Art 2016-2021. Generative Adversarial Networks (GANs)" highlights that the development of computer art received a new impetus with the advent of the DeepDream algorithm, which presented viewers with visual images generated by machines and previously non-existent in human culture. Artists began to actively incorporate neural network technologies into their work, creating unique pieces and raising questions about the boundaries of perception. Such work includes experiments by Gene Kogan and Rodrigo Pérez Estrada, which demonstrate how machines can generate and interpret images. Artists are particularly interested in the aestheticization of neural network errors, which allows them to explore the boundaries between human and non-human perception of the world. This leads to artistic practice experimenting

with complex phenomena such as the human psyche and poetry. Thus, neural networks become a tool for visualizing the "hidden world" of algorithmic aesthetics.

Section 3.2: "Commercialization of Machine Learning Tools and the Actualization of Artistic Practices in the Media Art Community" explores the development of artistic practices using machine learning technologies, particularly with the emergence of new algorithms such as large language and multimodal models. These programs require significant resources and computational power, thus operating on the infrastructure of major IT giants, which introduces limitations dictated by corporate policies. As commercial products, such algorithms (like Midjourney, DALL-E, and Kandinsky) are designed with datasets that enable the creation of aesthetically appealing images for a broad audience.

Many artists using machine learning technologies today note that, despite significant progress in image-generating algorithms, many works exhibited in museums and contemporary digital art shows are still predominantly created using older or open-source text-to-image algorithms, including those developed in 2021. The persistence of such practices can be traced to a subtle ideological conflict between artists and OpenAI in 2021. At that time, neural networks had not yet become mainstream, and deepfakes were the dominant topic, leading to extensive discussions about the implications and consequences of AI algorithms in modern society.

A series of scandals related to neural network performance raised concerns in the business world about potential reputational risks due to errors and biases in these systems. Concurrently, the discourse on freedom of speech, thought, and expression in contemporary art led to an ideological conflict as creators imposed restrictions on artistic expression tools. Previously, artists' actions were not moderated by technical means. Consequently, the community resisted this situation and, through collaboration and "collective intelligence," created their open-source

algorithms on platforms like GitHub and Google Colab, allowing individuals to conduct their own visual experiments.

Artists face an ideological dilemma of battling globalization and anti-progress in art, aiming to remain outside the system while rebelling against it. This process has led to a division in artistic practices within neural network art, as outlined by media artist and programmer Ryan Murdock, who identifies the path to text-driven visual art through the efforts of hackers in 2021 or the contemporary generation of text-to-image algorithms (post-2022).

Section 3.2: "Science-Art and Kitsch: Large Language Models in Visual Art" notes that the advancement of deep learning algorithms has led to the democratization of art and design, making them accessible to a broader audience. Major generative neural networks such as DALL-E, Stable Diffusion, and MidJourney have become popular tools for creating commercial digital images despite their tendency towards digital kitsch (R. Scruton, J. Lipovetsky, J. Quaranta, J. Lug). In this context, the appeal of science art grows for artists using machine learning technologies, as AI algorithms applied in science allow for an expansion of artistic tools while being free from commercial constraints.

However, kitschy practices involving generative algorithms turn the theme of artificial consciousness into a manipulation of the artificial unconscious. Engaging with science art raises questions about the nature of human cognitive processes.

The conclusions summarize the findings of the research. It is noted that the concept of artificial intelligence emerged almost simultaneously with the advent of early computers. Based on knowledge bases and logical deductions, the symbolic approach led to creating projects such as Harold Cohen's AARON, which aimed at the algorithmic modeling of creative processes. Artists experimenting with the creation of intelligent machines faced challenges not only in the field of algorithms but also in addressing complex issues related to the "hard problem of consciousness," reinforcing the connection of such works with science art.

Thanks to experimental algorithms such as Google's DeepDream, artistic practices utilizing machine learning technologies have become a distinct subject of art historical research. These programs quickly spread among artists, who began to master various types of neural networks. Due to their hallucinatory and distorted nature, such works might initially have resembled generative art, glitch art, or surrealism. However, behind these visual effects lie complex computational processes that open up new possibilities for visualization and the manifestation of algorithmic aesthetics.

At the same time, with the democratization and widespread adoption of generative technologies like OpenAI's DALL-E, these algorithms have begun to infiltrate other forms of art and commercial graphics. However, the control exerted by major IT giants over these technologies restricts artists' freedom, compelling them to rely on commercial tools that do not allow modifications to the algorithms and confine creative freedom within the constraints of the software developers' content policies. In response to these limitations, alternative open-source graphic generators have emerged, allowing artists to develop their own methods and styles. These new tools foster science art's growth as a technoscience form[17] and enable artists to explore computational processes within algorithms, creating unique artistic artifacts.

Machine learning algorithms radically transform the perception and reproduction of data, creating images that balance rationality and irrationality. They operate in a digital reality detached from human logic, opening up new levels of abstraction. This algorithmic aesthetics, on the one hand, evokes admiration for its novelty, while on the other hand, it raises concerns due to its blend of coherence and discreteness. Generative algorithms create images based on patterns,

[17] Technoscience is a concept that emerged in the late 1970s, referring to the interconnected domain of scientific research and modern technologies. The term emphasizes that the technogenic environment has ceased to be merely an "application" of scientific knowledge, evolving into a natural context for its development. Technoscience encompasses key areas such as nanotechnology, information technology, biomedicine, cognitive science, and other scientific and technological fields where research activities are closely intertwined with the practical application of innovations.

properties, and characteristics of billions of objects and processes learned during training, mathematically combining them in response to linguistic input, where each word corresponds to a text-image pair. The results often align with human creativity, making the non-human distance from reality noticeable only when failures occur (such as well-known glitches with fifteen fingers or strange unnatural object diffusions) or when artists intentionally expose the underlying algorithmic machinery, highlighting the non-human component of the algorithm modeling human creative acts. These aspects place the artists' creativity within the problematic field of posthumanist philosophy, which is reflected in their works.

Thus, artists using machine learning focus on conceptual challenges, exploring the boundaries of human experience and perception through their interaction with algorithms. At the same time, the widespread adoption of generative technologies such as DALL-E 2 and Midjourney blurs the lines between art and popular culture, transforming artificial intelligence into an "artificial unconscious." However, in contrast to mass-produced kitsch, science art continues to evolve as an experimental form, shaping a conceptual field that investigates the interaction between human consciousness and technology.