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Philosophical and methodological foundations of post-Turing intelligent robotics

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Author's Abstract

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General description of the work

The importance of the topic of the research.

Intelligent robotics implies a set of methods, ways of research and development of robotic systems integrating the capabilities of robotics and artificial intelligence in order to create robots, intelligent agents capable of autonomous and partly autonomous actions in different environments. The interdisciplinary nature of intelligent robotics makes it one of the most promising lines of research that has a significant influence on our whole civilization. Therefore, it is highly important to develop philosophical and methodological problems related to the development of intelligent robotics and its role in creating **Artificial General Intelligence**, which is a strategic task set today by the technologically advanced countries, including our country. Artificial General Intelligence implies a software and hardware complex capable of learning and acting better than the human expert in any area, achieving objectives in a broad range of environments with limited resources.

Since its emergence in the last century, robotics and artificial intelligence have taken different paths in the development. Robotics was used in manufacturing by adapting application tasks to the limited mechanical capabilities of the robots. Artificial intelligence, being mostly a research paradigm, aimed at researching the possibilities of simulating human mental activity and used broad software capabilities, particularly machine learning. Independent development of these separate paths was shaped by the available element base, that, in its turn, generated the possibilities for combinatorial improvements.

Robotics developed much slower due to its inherent dependence on the physical and chemical properties and engineering features of robot component parts.

Artificial intelligence with mathware and software as its main components was developing much faster than robotics due to its direct dependence on research and developments in microelectronics, that still follow Moore's law[1] (the number of transistors in a dense integrated circuit doubles about every 24 months). This enabled artificial intelligence to use exponential development of the element base of component parts such as graphic accelerators, data storage systems, various sensors and broadband communication to create software that would apply machine learning to solve a wide range of application tasks.

It resulted into artificial intelligence methods being used to solve Kuhn's robotics puzzles, thus accelerating the progress for both the paths. New programming tools and environments, such as deep neural networks, are capable of solving difficult robotics tasks. In turn, this generates new ways of human machine interaction that call for a deeper philosophical and methodological, as

[1] Leiserson C. E. et al There's plenty of room at the Top: What will drive computer performance after Moore's law? // Science 368 (6495), eaam9744.

well as epistemological consideration through the principles of post-nonclassical rationality (Stepin V.S. Lektorskiy V.A. etc.). It is the practical demand for new methodological approaches that assigns to philosophers the important role in the modern development of artificial intelligence.

The development of AI technologies and robotics has reached the point when their influence on our civilization goes beyond the economic sphere and becomes an important factor of global geopolitical and ecological agenda, while remaining one of the key problems of scientific and technological development. World economic forum [2] (WEF, 2019) acknowledges the strategic priority of these technologies and includes them into fusion technologies. The results of developing artificial intelligence and robotics may become the source of new risks and systemic issues (violation of a privacy right, transformation of the very notion of employment and so on), however they promise a healthy economic growth, mitigation of a number of negative consequences of a spiraling global civilization crisis.

Instead of stimulating cooperation, international competition for the leadership in creating Artificial General Intelligence is increasing. V.V. Putin, the President of Russia, has stressed that artificial intelligence is "indeed one of the key lines of technological development that determine and will determine the future of the whole world"[3],

USA is pursuing the policy of keeping the leadership in artificial intelligence, as "it has a critical significance for economy and national security of the United States"[4].

All of it turns artificial intelligence and robotics into geopolitical tools, making technologies the hostages to the interests of transnational corporations. A kind of corporate Manhattan project is being created[5][6].

Artificial intelligence and robotics, alongside with power industry, transportation, is the technology which, on the one hand, is a separate branch of manufacturing and, on the other, creates productive power for the remaining industries. Such technology is usually called a general-purpose

[2] Website of the World economic forum in Davos, URL: https://intelligence.weforum.org/topics/a1Gb0000000pTDREA2?tab=publications (accessed on 28.07.2020).

[3] A meeting on development of technologies in the field of artificial intelligence. URL: http://kremlin.ru/events/president/news/60630 (accessed on 28.07.2020, in Russian).

[4] Artificial Intelligence for the American People. URL: https://www.whitehouse.gov/ai/ (accessed on 28.07.2020).

[5] Levin J. C. et al Roadmap to a Roadmap: How Could We Tell When AGI is a 'Manhattan Project' Away? // ECAI 2020 URL: https://arxiv.org/abs/2008.04701 (дата обращения 20.09.2020).

[6] «Palantir exec says its work is on par with the Manhattan Project», INPUT URL: https://www.inputmag.com/tech/palantir-exec-says-its-work-is-on-par-with-the-manhattan-project (дата обращения 28.07.2020).

technology or, end-to-end technology. Permeating all areas of social life, robotics creates the effect similar to the effect that steam engine had in the time of the first industrial revolution [789].

It is noteworthy that all the necessary conditions for the Artificial General Intelligence and robotics have been met: new tools are emerging (materials, software architectures etc.), as well as new business activities making it possible to implement the intention. It was rightly emphasized by V.M. Rozin[10], who wrote that robotics has found itself in the "zone of proximal technological development" due to the above-mentioned reasons.

Robotics and artificial intelligence can also pose great danger. Machines create the conditions when it becomes impossible to distinguish real facts from lies. Artificial neural networks have become the basis for generating pseudo-realities, the so-called deep fakes, which facilitate a profound expertise crisis, the rise of relativism and skepsis not only in the common knowledge, but also in the knowledge obtained in various research centers (V.E. Lepskiy)[11]. That is why it is necessary to scrutinize all the features related to the development of artificial intelligence as a branch of science, manufacture and education from the perspective of philosophy and methodology of science. A number of aspects, such as personalization of educational paths, automatic generation of education courses and so on, call for a comprehensive and profound discussion (A.L. Semenov)[12].

Over the last decade, regardless successful developments of science and technology in the field of artificial intelligence, researchers and engineers have not come up with a clear answer as to how one should develop technologies in the coming decades. The reason is that theoretical and methodological as well as philosophical base of such planning is underdeveloped. The following K. Jaspers's thought still completely keeps its importance that "the entire future of man depends

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[7] Crafts N. Steam as a GPT: A growth accounting perspective // The Economic journal 114 (2004), 338-35 pp.

[8] O'Mahony M., Timmer M. "Output. Input. And productivity measures at the industry level: the EU klems database." The Economic Journal, 2003 119 (June), F374–F403.

[9] Graetz G., Michaels G. Robots at Work. URL: http://personal.lse.ac.uk/michaels/Graetz_Michaels_Robots.pdf (accessed on 15.08.20).

[10] Rozin V.M. Evolution of engineering and design thought. Engineering: Establishment, Development, Typology. Moscow: Lenand Publ., 2015. p.123 (in Russian)

[11] Lepskiy V.E. Asymmetric response to information wars of the XXI century // Reflexive processes and management. Information package of the XI International academic conference as of the 16-17 October 2017, Moscow / Ed. in chief V.E. Lepskiy. Moscow: Cogito-Center Publ., 2017. p. 221-224. (in Russian)

[12] Semenov A.L. Revolution of artificial intelligence and general education // A report on the 99th workshop on Philosophical and methodological and scientific and theoretical problems of AI at the meeting of Research board on methodology of artificial intelligence at a Department of social sciences of the Russian Academy of Sciences at the Institute of philosophy on the 16th of January, 2020 URL: https://drive.google.com/file/d/1aRuT4a7qGICzmsJhS1EZPPYp5hhCOEis/view (accessed on 20.08.20, in Russian).

on the tools he is going to choose to master the consequences of technological development and their influence on his life"[13]

At their time Thomas Kuhn (scientific paradigms) and Imre Lakatos (research programmes) created a foundation for planning in natural science research based on the development of physical sciences in the XIX and the first half of the XX century. However, the main discoveries in artificial intelligence and robotics fall on the second half of the XXth and the beginning of the XXIst centuries. Philosophical and methodological foundations of science that were developed based on the natural science breakthroughs of the XX century and have become the foundation for the development of cosmonautics and nuclear energy, cannot be a reliable reference point at the current stage of development of artificial intelligence and intelligent robotics.

One can see constant contradictions when forecasting the creation of Artificial General Intelligence. Computation powers that A. Turing thought were enough to create a "thinking machine" have been achieved long ago. The capacity of generating, storing and transferring information on the Internet has surpassed even the bravest dreams of half a century ago. However, all these are just individual results falling short of creating General intelligence.

This state of things turns us to look into methodology, developed by A. Turing in 1940-1950, even closer and analyze historical limitations of the methodology that must be overcome at the current, new stage of development of artificial intelligence, when we are facing the task of creating General artificial intelligence. These limitations, the drawbacks of A. Turing methodology are as follows: a. a narrow interpretation of the functionalism paradigm when a purely behavioral and operational interpretation of intelligence is given. It is related to: b. an insufficient criteria of an intelligent machine behaviour (Turing test); c. a rough separation of a human and a machine while researching their interactions (Turing wall); d. the intention to create a thinking machine, rather than a thinking robot. We can add here a number of other significant items related to the disregarded problem of consciousness, an exaggerated role of symbolic systems in intellectual activity etc. These limitations and drawbacks have to be overcome as part of the post-Turing methodology, which serves to create new theoretical frameworks, approaches and methods to develop specific cognitive architectures of General artificial intelligence (of course, without diminishing remarkable, epochal achievements of A. Turing).

The works on methodology of science have always emphasized the comprehension of a paradigm and a programme of new scientific research studies. Of these, whenever the problematics

[13] Jaspers K. Modern technology / transl. by Levina M.I. // In: New technocratic wave in the West / Gurevich S.P. (compiler). Moscow: Progress Publ., 1986. p. 119-146. (in Russian)

of artificial intelligence was discussed, convergent technologies, comprising nano, bio, information and cognitive technologies (abbreviated as NBIC), have been more than once suggested to facilitate the inter-disciplinary approach to the development of artificial intelligence and robotics.[14]. However, it hasn't justified itself (Alekseeva, Arshinov)[15], since large-scale research progreammes focused on the first part of a paradigm of convergent technologies (nano, bio) while putting off the second part (info, cognitive) for a long term.

Intelligent robotics appears simultaneously in two qualitative aspects. On the one hand, it is a field of scientific research which studies the principles and laws of interaction of physical objects endowed with intentionality by man and also capable of transferring man some information regarding the results of executing the assigned task. On the other hand, robotics includes so heterogeneous groups of technologies like domestic robots, robot cars, drones, different industrial manipulators and so on.

One can say that robotics, as a branch of technology, is a sort of bridge, a link between the rapidly increasing possibilities of artificial intelligence in the virtual world and a relatively static infrastructure created by the civilization (cities, roads, manufacture, communication systems etc.). Artificial intelligence endows any technological device with a capacity to change its behavior based on the data input from the sensors, thus turning it into a robot: the new possibilities for an integration of a human and a robot are opening up, the ones that Ju. Habermas talked about[16].

As robotics and artificial intelligence technologies improve, empirical definition of man also changes. Cyborgization, virtual intelligent assistants, devices functioning as exocortex, internal and external organs, telepresence - these are the artificial add-ons (extensions) of human abilities, without which our kind will not be able to conceive its own existence within the next couple of decades (Lektorskiy, 2019)[17]. However, these 'add-ons' pose a question of the definition of what it really means to be a human and how one can distinguish a human from a machine that is capable of performing actions that were previously deemed to be intrinsically 'human'. Can we accept the results of an exam taken by a young man, who was assisted by his personal virtual assistant? If not, then what is the principal difference between a digital assistant and a calculator?

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[14] Arshinov V.I. On the way tp anthropic dimension of NBIC-convergence // Philosophical problems of biology and medicine. Issue 4 Moscow, 2010 p.41-44. (in Russian)

[15] Alekseeva I. Yu., Arshinov V.I. Information society and NBIC-revolution Moscow: Institute of Philosophy, Russian Academy of Sciences, 2016. 196 p. (in Russian)

[16] Habermas Ju. The future of human nature. Moscow: Ves' Mir Publ., 2002. 144 p. (in Russian)

[17] Lektorskiy V.A. Are science and utopia compatible? // The mythology of the age of scientific and technological revolution. Utopias, myths, hopes and reality of the newest branches of science. From Frankenstein and elixir of immortality to biocyborgs and post-human // Ed. in chief G.A. Belkina. Moscow: URSS Publ., 2019. p. 35–49. (in Russian)

In other words, there is a reciprocal tendency, it is not only the 'corporality' of robots that changes and becomes ever more varied, including anthropomorphic, but also the corporality of man that becomes more technologized. It makes the classical rational approach, where humans are subjects and machines are objects, inapplicable. Researchers of artificial intelligence exist within the self-developing system, the high-tech industry. That is why it is necessary to apply the principles of post-nonclassical rationality as an epistemological ground for research and feasibility demonstration of: post-Turing methodology of development of artificial intelligence and intelligent robotics.

At the early stage of development of artificial intelligence and robotics (in the works by A. Turing, J. von Neumann, N. Wiener etc.), there predominated a narrow disciplinary approach that combined some relatively clear methodological and ethical aspects and practical steps aimed at developing the technology (Turing machine, von Neuman architecture). However, the modern specialization profile of artificial intelligence and its newest results reveal the gap between theoretical research in the field of philosophy and methodology of artificial intelligence, on the one hand, and practical efforts of researchers to create intelligent machines (robots), that will be no less capable than the man himself, on the other hand. The gap makes research in the field of methodological approach to the problems of artificial intelligence and robotics extremely topical and calls for development of specific interdisciplinary programmes and critical epistemological questions arising therewith. (V. Budanov)[18].

Engineering and technical problems (Kuhn puzzles) have their solutions and are being solved by multiple teams at big scientific centers and enterprises around the globe. However, the problem of long-term development of General artificial intelligence and intelligent robots has an interdisciplinary nature due to the global purpose of these technologies. The idea of relying upon the Moore's law and purely quantitative increase in computational capabilities while preserving the conceptual approach of A. Turing is a methodological dead end. New, important approaches and methodologies can not only cut the time and efforts needed to create a new generation of intelligent and useful machines, but also implement the potential of artificial intelligence and robotics to solve crucial civilizational challenges.

The degree of scientific development of the problem. Philosophical and methodological foundations for development of artificial intelligence and robotics have always attracted attention

[18] Schtukelberg K., Budanov V.G., Oleskin A.V., Kolesova L.A., Raikov A.N., Derbin E.A., Medvedev P.A., Volkov A.V., Zakharova F.Ya. Challenges of the future: artificial intelligence, technologies, ethics // Economic strategies, Vol. 21. No. 6 (164), 2019. p. 18-29 (in Russian)

of leading researchers. Their initial standpoint was suggested by A.M. Turing within the classical rationality which focused on the capabilities of thinking machines as the objects of research. In his work Computing machinery and intelligence published in 1950, the British mathematician and logician had laid down the foundations for operational, anti-essential approach to creating thinking machines, even before the term artificial intelligence appeared.

Over 70 odd years after the publication there have been proposed various approaches to identify the philosophical and methodological foundations of robotics. Since 1956, when J. MacCarthy used the term artificial intelligence for the first time, this field was related to mathematical, linguistic and algorithmic problems necessary to simulate human intelligence by means of computer.

Simultaneously to philosophical and methodological feasibility demonstration of artificial intelligence, the domain of intelligent robotics is being developed, which implies robotics capable of solving complex intelligent tasks. The term robotics appeared in 1941 thanks to A. Azimov, although the word robot appeared as far back as 1920 in the work by K. Capek[19].

Since the end of the World War Second, which gave a significant impulse to the development of computing technologies used for cryptanalysis and ballistic calculations, there has been established an inextricable connection between artificial intelligence and robotics (J. MacCarthy and J. Engelberger)[20]. The first line of research was broadly viewed by researches as a theoretical possibility to simulate human intelligence on a non-biological substrate, the second line has always set the task of authentic simulation of human actions by a robot in the physical world.

In his seminal works on artificial intelligence A. Turing highlighted the connection between cognitive functions of a brain and human motor skills. This became the foundation of another theoretical and practical discipline called cybernetics founded by N. Wiener.

The term intelligent robotics appeared in the 60-70s of the last century thanks to the work of two research teams from the USA. Stanford Research Institute created an autonomous robot Shakey, fully capable of moving in the physical space. Another line of research was creating a SHRDLY programme by T. Winograd at MIT at about the same time. The programme could understand a bounded subset of a natural language and could act in the virtual world of basic geometric objects - blocks. That programme could be called a virtual robot.

[19] In the play RUR by K. Capek robots were represented as artificially created human-like biological machines.

[20] Markoff J. Machines of Loving Grace: The Quest for Common Ground Between Humans and Robots. Harper Collins Publishers, Kindle edition, 2015. 400 p.

The principles of developing artificial intelligence at the end of the 20th century as an area of software development that can help make computers more intelligent was significantly reconsidered for various reasons, including heightened expectations of research results in the field (M. Minsky). In the 90th of the last century, the first calls to join together artificial intelligence and robotics into a single conceptual space started to be heard. (R. Brucks)[21].

Another reason for the appearance of the term intelligent robotics is a constant criticism of the line of research termed artificial intelligence as, supposedly, too remote from real achievements (R. Penrose)[22]. In the efforts to differentiate their research, many scientists tend to coin new terms such as intelligent systems, cognitive systems or cognitive robotics. However, there is no necessity in analyzing the subtleties of terminology as intelligent robotics in its essence fully covers alls the possible applications of the artificial intelligence method to robotics, being a quite adequate general term (R. Murphy)[23]. Thus, intelligent robotics is an operational line of research drawing mainly on the works by H. Morawek[24], J. Licklider[25] defining the subject area through actions of agents that should meet the functional description of three simultaneously actualized capabilities: **sensations, understandings and actions**.

Philosophical consideration of robotics and artificial intelligence questions has been undertaken by such representatives of analytical philosophy as H. Putnam, J. Fodor, T. Nagel, J. Searle, D. Dennett, D. Chalmers, N. Block etc.

It is noteworthy to point out the significant contribution into development of these questions made by the soviet philosophers in the 60s - 80s of the last century. (B.G. Biryukov, A.G. Spirkin, I.B. Novik, A.D. Ursul, L.B. Bagenov, V.S. Tyuhtin, P.V. Kopnin, L.A. Petrushenko etc.). Unlike western philosophers, they posed these questions more broadly in terms of cybernetics tasks, development of the information concept and self-organizing systems, including the problem of consciousness. Some major soviet scientists took active part in this research: A.I. Berg, A.N. Kolmogorov, N.A. Bernschtein, P. K. Anokhin, V.M. Glushkov etc., whose contribution can hardly be overestimated. All this productive and multidimensional work of soviet philosophers and scientists requires a special examination.

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[21] Brooks R. A. Intelligence Without Representation // Artificial Intelligence, 47, 1991, pp. 139–159.

[22] Penrose R. The emperor's new mind: Concerning computers, minds and the laws of physics. / Transl. from ENglish by V.O. Malishenko. Moscow: URSS: LKI Publ., 2011. 400 p. (in Russian)

[23] Murphy R. Introduction to AI Robotics. Second Edition, The MIT Press, 2019. 648 p.

[24] Moravec H. Mind Children: The Future of Robot and Human Intelligence. Harvard University Press. 1988. 224 p.

[25] Licklider J. C. R. Man-Computer Symbiosis // IRE Transactions on Human Factors in Electronics, volume HFE-1, March 1960 p. 4-11.

In the recent years, the important questions of the development of artificial intelligence have been comprehensively discussed at high-level conferences. Among them we can point out the following: contexts of the "I" computer model, introduction of conflagration and the principle of bounded rationality into the study of multiagent systems (M.A. Shestakova[26]), the problem of emotional reactions and corporality in virtual people (D. Burden, M. Savin-Baden[27]), the problem of robots' socialization, their inclusion into public space (O. Sherer, J. Parviainen[28]), the problems of different cultural approaches to creating robots , efforts to interpret the phenomenon of computers' soul (K. James[29]). Obviously, the questions of ethics and security of using robots are broadly discussed.

It is noteworthy that the researchers of robotics, for obvious reasons, focus on solving purely applied tasks, focus primarily on detailed, limited examples of robot-environment interaction, basically leaving aside those approaches that require one to solve common theoretical and philosophical-methodological questions. The development of the questions related directly to intelligent robotics is still underrepresented in our philosophical literature, although they are an important condition for its further efficient development, especially, when we talk about breakthroughs in the field.

Consequently, modern researchers of artificial intelligence aspire to a kind of ideal set by the actions of agents. Such ideal is described by B. Goertrzel: "Artificial general intelligence is an ability to study and act better than an expert in any area, reaching goals in a broad range of environments with limited resource"[30].

The important driver to create post-Turing methodology of intelligent robotics was the research by A.Yu. Alekseev[31] in the area of Turing complex test. The results of the research were broadly used in the work.

Based on significant results of research in the field conducted particularly by national philosophers (works by A.Yu. Alekseev, I.Yu. Alekseeva, A. M. Anisov, V.I. Arshinov, V.G.

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[26] Shestakova M.A. Methodological problems of multiagent systems. / Philosophy of artificial intelligence. The works from All-Russian inter-disciplinary conference devoted to the 60th anniversary of research in artificial intelligence, March 17-18, 2016, Moscow: IIntell, 2017. p. 189-202.

[27] Burden D., Savin-Baden M. Virtual Humans. Today and Tomorrow // CRC Press, 2019. 270 p.

[28] Envisioning Robots in Society – Power, Politics, and Public Space Proceedings of Robophilosophy 2018 // TRANSOR 2018 February 14–17, 2018, University of Vienna, Austria Edited by M. Coeckelbergh, J. Loh, M. Funk, J. Seibt and M. Nørskov IOS PRESS BG Amsterdam, 2018. 391 p.

[29] James K. The Battle for the Robot Soul / Philosophy Now ISSUE 139 Aug/Sept 20 - pp. 16-19

[30] Goertzel B. Artificial general intelligence: Concept, state of the art, and future prospects. Journal of Artificial General Intelligence, vol. 5, 2014. p. 1-46.

[31] Alekseev A.Yu. The philosophy of artificial intelligence: the conceptual status of Turing complex test: the PhD thesis: 09.00.08 Moscow. 2015. 482 p. (in Russian)

Budanov, V.L. Vasyukov, I.A. Gerasimova, V.A. Glazunov, D.I. Dubrovskiy, I.T. Kasavin, L.P. Knyaschenko, E.N. Knyazeva, V.A. Lekotrskiy, V.E. Lepskiy, I.K. Liseev, V.M. Rozin, V.S. Stepin, E.O. Trufanova, V.K. Finna, V.I. Shalak, E.N. Shulga etc) in the thesis there are discussed and suggested the solution of the important theoretical-methodological and philosophical questions of the current stage of development of intelligent robotics, creating specifically new cognitive architectures that meet the tasks of creating Artificial General Intelligence.

The target of research is philosophical-methodological concept and approaches to intelligent robotics reflecting the changes in the foundations of creating basic and applied technologies in the field: the emergence of large arrays of semantically mapped information for machine learning and specialized accelerators facilitating learning based on the data. The research programme that was initiated by A. Turing and was based purely on an operational approach has become significantly outdated, since simulation of intelligent human behavior is possible with artificial deep neural networks. That is why new approaches in research of artificial intelligence need to be developed.

The subject of the research are conceptual foundations (principles) of intelligent robotics in light of post-Turing methodology.

The data for the thesis research are various inter-disciplinary theoretical, empirical and philosophical works of both foreign and Russian researches, including the author's personal engineering research.

Thesis sources

In the thesis research there have been used scientific works and publications in philosophy, natural sciences and applied sciences in Russian and in English.

The goal and tasks of the thesis research.

The goal of the thesis research is to comprehensively analyze the basic technological trends, the moder state and scientific potential of intelligent robotics, as well as the ways of overcoming its theoretical and methodological difficulties by means of their philosophical and methodological consideration and development of the concept of post-Turing methodology suggested by the author.

The general goal is detailed in the following ***tasks***:

- to analyze the modern state of intelligent robotics and the priority lines of research in the field;
- classify specific Turing tests, clarify their role in development of intelligent robotics, show historical limitations of Turing methodology in light of modern tasks of intelligent robotics;

- look into basic conceptual barriers in development of artificial robotics and the premises for their overcoming; show that to that end it is necessary to use the results of philosophical and phenomenological developments of the problem of consciousness (which are ignored by the classical paradigm of artificial intelligence);
- describe the phenomenon of the Turing Wall and justify the principles of post-Turing methodology (destroying the wall), show its advantages compared to the classical Turing methodology.
- demonstrate the capabilities of using a robot E.LENA, created under the guidance of the dissertationist, as an experimental tool for the analysis of the application area of post-Turing methodology;
- map out the basic paradigmatic outcomes of post-Turing human-robot interaction.

Theoretical and methodological foundation of the research is, first of all, the concept of post non-classical epistemology elaborated in Russian philosophy in its relation to classical and post-classical epistemology (V.A. Lekotrskiy, V.S. Stepin, V.G. Budanov, V.I. Arshinov etc.) enabling one to better comprehend the peculiarities of cognitive and volitant capabilities of a subject (human), the influence it experiences from the object (a robot) and a means of observation (Turing test) in the context of interdisciplinary development of science and technologies, as well as to project them onto human-robot interaction, whose interaction is separated by a means of observation (Turing wall). The processes of development of artificial intelligence and intelligent robotics are comprehended from the perspective of post nonclassical rationality, which makes it possible to map out efficient ways for the further research into them within post-Turing methodology.

Scientific novelty of the thesis is determined by creation of a conceptual approach which theoretically justifies the transition to a new post-Turing methodology as a foundation for a breakthrough in intelligent robotics and in developing Artificial general intelligence.

The scientific novelty of the thesis research can be phrased as follows:

- there has been performed an analysis of the current state, prospects and barriers for development of intelligent robotics in the context of Turing methodology which has revealed that fundamental technological barriers can be overcome and it makes it possible to create intelligent robots of a new level, capable of facilitating the creation of Artificial general intelligence;
- local Turing tests have been analyzed and systematized, there conceptual possibilities have been identified in two dimensions: *virtual-physical* and *nonverbal-verbal*, which provides the ground for introducing the concept of tecno-umwelt, defining the world of a robot and

containing the cross-section of a world reflection as a robot (artificial intelligence) sees it, as well as the set of actions available for the given intelligent robot. Also, there have been selected and described four techno-umwelts which encompass the whole thinkable range of a robot's actions;

- there has been suggested a new approach to further scientific research in the field of intelligent robotics based on post-Turing methodology that justifies the ways of creating intelligent robots capable of self-action simultaneously in different dimensions - *virtual-physical* and *nonverbal-verbal*;
- the notion Artificial general intelligence has been specified when applied to intelligent robots acting in different techno-umwelts;
- socio-cultural and world outlook prospects of industrial and domestic human-robot communication have been considered.

Theoretical and practical significance of the research. The research that has been conducted in the thesis has allowed to theoretically justify post-Turing methodology for development of intelligent robotics and to create methodological foundation for classification of local Turing tests. The research enables a new approach to development of cognitive architectures for the technology of intelligent robotics and Artificial general intelligence based on the transitions from various domains of Turing space. Empirical results, including the published articles as well as the patent received by the author expand action capabilities of embodied intelligence and its capabilities for nonverbal communication in the physical and virtual world when interacting with a human.

Concepts to be defended:

1 There has been introduced a new way of classification of local Turing tests according to how much the tests use virtual-physical or verbal-nonverbal interaction which makes it possible to systematize the approach to their study and application for development of Artificial general intelligence and intelligent robotics. This classification allows to justify the notion of techno-umwelt and enables one to view A. Turing methodology from the perspective of post-nonclassical scientific rationality and show its historical boundedness.

2 The role of the Turing wall in Turing classical methodology has been identified as a barrier for efficient human-computer interaction. The elimination of the Turing wall enables the transition from a classical comparison of human and machine actions to their efficient collaboration in the sense of post-nonclassical paradigm of science (to solve the tasks of creating Artificial general intelligence).

3 There has been introduced a notion of post-Turing methodology, its basic concepts have been elaborated to be used in creating new cognitive architectures of Artificial general intelligence and intelligent robotics, since they provide the solution of the task of translating experience and knowledge of an intelligent robot from different techno-umwelts.

4 Some possible world outlook prospects of post-Turing human-robot communication are considered based on scenario examples in the field of education, manufacture and entertainment.

The structure and the scope of the work. The thesis consists of introduction, three chapters, conclusion and references with the total volume of 168 pages. The table of contents includes 210 source titles.

The basic content of the work.

In the Introduction the high importance of the research subject is justified, the degree of scientific development of the problem is exposed, the goal and tasks of research are identified, as well as theoretical and methodological foundations of the author's analysis, scientific novelty, basic concepts to be defended are laid down, theoretical and practical significance of the work is noted, as well as its approbation.

Chapter 1. "Methodological Analysis of Modern Research in Intelligent Robotics" consists of three paragraphs, which define intelligent robotics and provide an analytical review of the current state of its development.

Paragraph 1 "A Generalized Review of Modern Intelligent Robotics" provides a general analytical and methodological review of intelligent robotics and the peculiarities of its application for solving urgent problems of modern society and human social activity. An operationalist definition of intelligent robotics is considered, according to which any technical product by a human is an intelligent robot if it possesses three capabilities at the same time: 1) the capability to perceive the surrounding world with the help of sensory devices (video cameras, sonars, laser range-finders, radars, etc.); 2) the capability to autonomously (i.e. independently of the human operator) build models of their behavior, choosing the best ways to solve to designated problem on the basis of dynamically adaptable behavior patterns; 3) the capability to perform actions in the physical world by manipulating objects of the physical world and/or self-positioning. A number of examples of the use of robotics are analyzed, both from the standpoint of practical application, and from the standpoint of theoretical foundations of research of this line of research (R. Murphy 2019, S. Thrun 2002[32], B. Siciliano, O. Hattib[33]).

Paragraph 2 "The main trends of modern intelligent robotics in the light of methodological problems of creating Artificial General Intelligence" analyzes the trends in the development of Artificial General Intelligence and analyzes methodological problems associated with the use of robotics as a tool for research and design of new approaches in this direction. The importance of research in the field of artificial intelligence as a state task formulated in the national programs of a number of states, including the Russian Federation, is substantiated. The support of research in the field of artificial intelligence is of highest priority in Russia, it is set by the President V.V. Putin and is, basically, a megaproject (I.T. Kasavin) for Russia[34]. A working definition of intelligence is given as “the integrative ability to organize sensory data, think reasonably and

[32] Thrun S., Burgard W., Fox D. Probabilistic robotics. Cambridge, MA: MIT Press, 2005. 480 p.

[33] Siciliano B., Khatib O. Springer handbook of robotics. Springer, 2016. 2160 p.

[34] Kasavin I.T. Megaprojects and global projects: Science between utopia and technocracy // Questions of Philosophy, No 9, 2015. p. 40-56. (in Russian)

normatively regulate behavior" (A.Yu. Alekseev). An extension of this definition is the V.K. Finn model, which shows that a number of capabilities of natural intelligence can be implemented on a non-biological basis in a fully automatic mode, without human participation, while some capabilities (such as goal-setting, curiosity etc.) can only be performed in an interactive mode, with human participation.[35] Technological trends that have a fundamental impact on research in Artificial General Intelligence and Robotics are described. In particular, the emergence of cheap computer vision systems has greatly simplified the creation of new types of robots, whose behavior is based on a visual assessment of the environment and the adaptation of behavior patterns based on the input information. In addition, the existing data sets (arrays of textual, visual information) are marked up for further training by neural networks on an industrial scale. This makes available the use of multilayer artificial neural networks. Computations accelerators based on mathematical software and used for calculations in computer graphics have become widespread. It is important to emphasize that cognitive sciences have achieved significant success in studying the mechanisms of the human brain. A number of theories describing the work of human consciousness and brain have been receiving sufficient experimental validation (J. Rizzollati, A. Damasio, K. Koh, V. Ramachandran and others). In particular, the human brain carries code structures of multiple images and actions in the surrounding world. Deciphering them with neuroscientific methods opens up new possibilities for modeling complex intellectual functions in order to develop intelligent robotics and Artificial General Intelligence (D. I. Dubrovskiy)[36]. Based on a review of the use of intelligent robotics during the COVID pandemic, it has been concluded that the importance of autonomy and reliability of artificial intelligence and robots has increased (A.R. Efimov)[37].

Paragraph 3 "Theoretical and Epistimological Difficulties in the Development of Intellectual Robotics and Artificial General Intelligence" among theoretical difficulties and above all the epistemological problem of subjectivity of artificial intelligence and, therefore, the products of robotics is noted. A robot, or in general, a computing device equipped with actuators, possesses objective characteristics (a program, physics of its manipulators or a motion platform), however, its perception by a human is determined by the action capabilities of the robot itself. Hence the problem of a robot's subjectivity or, in general, of the implemented models of artificial

[35] Finn V.K. Artificial intelligence: methodology, application, philosophy. Moscow: URSS. 2018, p. 37-38 (in Russian)

[36] Dubrovskiy D.I. The problem of consciousness and brain: theoretical solution. Moscow Kanon+, 2015. 208 p. (in Russian)

[37] Efimov A.R. and others. Practical application of robots and associated technologies in the fight against the covid-19 pandemic // Robotics and technical cybernetics, Volume 8, No. 2, 2020, pp. 87-100 (in Russian)

intelligence.

The discussion of this problem began with A. Turing, who replaced the question "can a machine think" with an operational test of what is considered to be a mental act. This paradigm laid the foundation for the philosophical school of functionalism and had a fundamental methodological significance for the entire course of development of artificial intelligence and many branches of scientific knowledge. In analytical philosophy, this line was developed in the works of Putnam, Fodor, and others. However, it was subject to critical analysis in the works of J. Searle and T. Nagel, who criticized machine functionalism for ignoring epistemological issues of the value-semantic nature (emphasizing the lack of understanding by a computer of the meaning of perceived information), as well as for an extremely simplified interpretation of the concept of natural intelligence. These philosophers and their followers expressed fundamental objections to the creation of machine intelligence, which has capabilities comparable to human reasoning.

In contrast to the concepts of the representatives of analytical philosophy, which were discussed above, Soviet philosophers, back in the 60-70s of the last century, considered the problem of artificial intelligence in a much broader sense, focusing on crucial issues of cybernetics and self-organization, analysis of the nature of information, specificity and forms of information processes in their relation to physical processes and the development of the problem of consciousness, as well as prospects for the development of artificial intelligence (V.S. Tyukhtin[38], B.V. Biryukov[39], I.B. Novik[4041], L.A. Petrushenko[42], D.I. Dubrovskiy[43] and many others [44]), robotics questions were purposely discussed (E.I. Boiko[45]).

Great doubts in the possibility of creating a strong artificial intelligence were empirically validated in the 70s of the last century, when the so-called uncanny valley effect was described. According to it a robot bearing a significant resemblance to a human, while being hardly identical with him, is naturally rejected by our psyche as a subject and does not deserve the same trust that exists in human-to-human communication (Maury, McDorman, Hanson, etc.). The difficulties of

[38] Tyukhtin V.S. On the nature of the image: psychic reflection in the light of the ideas of cybernetics. Moscow: Higher School Publ., 1963. 121 p. (in Russian)

[39] Biryukov B.V. Cybernetics and Methodology of Science. Moscow: Science Publ., 1964. 416 p. (in Russian)

[40] Novik I. B. Cybernetics. Philosophical and sociological problems. Moscow, 1963. 208 p. (in Russian)

[41] Novik I.B. Philosophical issues of modeling the psyche Moscow: Science Publ., 1969. 174 p. (in Russian)

[42] Petrushenko L.A. Self-motion of matter in the light of cybernetics. A philosophical sketch of the relationship between organization and disorganization in the nature. Moscow: Science Publ., 1971. 292 p. (in Russian)

[43] Dubrovsky D.I. Mental phenomena brain: Philosophical analysis of the problem in connection with some urgent problems of neurophysiology, psychology and cybernetics. Moscow: Science Publ., 1971. (in Russian)

[44] Cybernetics. Thinking. Life / Ed. by Biryukov B.V. 1964. 512 p. (in Russian)

[45] Boyko E.I. Consciousness and robots // Questions of psychology, No. 4, 1966. pp. 169-177. (in Russian)

creating not only natural, but also artificial general intelligence (as well as the corresponding type of robots) have been oftentimes discussed in philosophical and professional literature, without coming to a generally accepted solution.

In this regard, the author examines the questions of applicability of post-nonclassical rationality for comprehending the robot-human interaction (V.S. Stepin, V.G. Budanov).

Chapter 2. "***The Role of Turing Methodology in the Development of Intelligent Robotics***" is devoted to the consideration of the functionalist principles of Turing methodology - its origin, role in the development of artificial intelligence and intelligent robotics.

Paragraph 1 "***Defining Turing Methodology in the Context of Intelligent Robotics***" examines Turing's operationalist approach to the question "Can machines think?" based on the ideas that he expressed in a fundamental article published in the journal Mind in October 1950, as well as in earlier and less famous publications. A. Turing did not think the creation of embodied physically intelligent machines was impossible, but he did not see any technical possibility for their realization.

Functional approaches, to the development of which A. Turing made a great contribution, opened up new broad perspectives in solving theoretical and methodological problems not only in artificial intelligence, but also in neurosciences, psychological and social disciplines, and many challenging interdisciplinary problems. Nevertheless, the functionalism paradigm was open to various interpretations, some of which were of behavioristic or reductionist nature, where the problem of consciousness is ignored; the phenomena of consciousness were considered excessive for solving the problems of artificial intelligence or were identified with functional processes, reduced to them, as it can be seen in some works by representatives of analytical philosophy (D. Denneet etc.). This sort of interpretation about the irrelevance of consciousness, close to behaviorist attitudes, was also peculiar to Turing. At the first stage of the development of artificial intelligence, it did not hinder research: tasks are described in terms of functional relations, on the basis of which algorithms and programs are developed, then the program is loaded into a computer, the problem is solved, and the results are used in practice. A similar methodology is still used by most experts in the field of artificial intelligence, since a consideration of the phenomena of consciousness is unnecessary for the realization of practical, one-purpose applications. However, the creation of artificial general (universal) intelligence and robotics, which is based on its use, requires different approaches and new methodological solutions.

After the appearance of the first intelligent robots with cybernetic feedback and capable of building their own dynamically adaptable patterns, Turing's operationalistic approach started to be carried over to robotics - "Can a robot perform any action no worse than a human?". The list of typical "artificial" activities formulated by Turing as far back as in the early 1950s (games,

cryptography, language learning, translations, solving mathematical tasks and verbal interaction) has expanded significantly. As a result of this approach, a large family of local Turing tests has emerged, which try to answer the particular questions of "can a machine perform a certain action?". Such local Turing tests are poorly ordered, do not have a single methodology and require comprehensive classification. This task is an important condition for development of post-Turing methodology.

Paragraph 2 "Methodological role of classification of local Turing tests for the development of intelligent robotics" the author, for the first time in the homeland literature, proposed a classification of local Turing tests in accordance with an approach based on the idea of spaces immanent for machines. The dissertationist has proposed to correlate the entire array of local Turing tests with the concept of Umwelt (J. von Uexküll, E.N. Knyazeva, V.G. Budanov)[46][47] according to a unified methodology. The concept of techno-umwelt is introduced, which defines the "world of a robot" in the Turing space, contains a cross-section of the world as it is "seen" by a robot, artificial intelligence (or machine), as well as the set of actions available to this intelligent robot (or a machine). According to the proposed approach, all local Turing tests are classified into four classes of techno-umwelt along two fundamental axes: *virtual-physical and nonverbal-verbal.* Thus, it can be shown that all local Turing tests created earlier or bound to be created in the future are classified according to four techno-umwelt, which form the Turing space of human-machine interaction: 1) virtual-verbal; 2) virtual-nonverbal; 3) physical-nonverbal; 4) physical-verbal. Each of these spaces is characterized by a cross-section of perception and a variety of available actions, which are manifested in a local Turing test taken by a robot capable of acting in a given techno-umwelt. It is shown that the world, in which a robot of a given techno-umwelt operates, is initially limited to it. The Turing methodology was based on the behaviorist approach, which implied both the exclusion of consciousness and the observer. It is not the kind of machine that gives answers (or performs actions) that is important, it is important that it gives human-like responses (actions) in a similar situation. However, this reveals a fundamental barrier that must be overcome in order to get out of the limitations of the paradigm of machine functionalism, which became the basis of Turing methodology. Overcoming the drawbacks of Turing methodology can form the basis for achieving significant progress in the field of artificial intelligence and robotics.

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[46] The term is borrowed from ethology (Uexull) Knyazeva E. N. The concept of "Umwelt" by Jacob von Uexkull and its significance for modern epistemology // Problems of Philosophy, No. 5, 2015. pp. 30-44. (in Russian)

[47] Budanov V.G., Aseeva I.A. Umwelt analysis and road maps of the Great Anthropological Transition // Materials of the International Scientific Congress "Globalistics-2017". Moscow: FGP Global Processes, Moscow State University. M.V. Lomonosov, 2017. URL: https://lomonosov-msu.ru/archive/Globalistics_2017/data/section_6_10143.htm (accessed on 20.06.20, in Russian).

Paragraph 3* "*Turing wall as a fundamental philosophical and methodological barrier to the development of intelligent robotics", a detailed analysis of the Turing methodology and the constructional design based on the test "Can a machine think?", proposed by Turing himself in 1950, is carried out. In the analysis the author reveals the significance of the Turing wall element, which had before escaped the attention of researchers. The Turing wall separating the subject of the test (a judge) and the object of the test (a human or a machine) is a fundamental epistemological barrier to the development of artificial intelligence and intelligent robotics. The reason for this is that the wall forces a robot (and, indirectly, the creators of robots or artificial intelligence) to implement only those tasks that can be solved by a robot in complete isolation from a human. However, modern research in various areas of human-machine interaction (Unhelkar, Shah etc.) [48]suggests that the maximum performance from the use of robots or artificial intelligence is achieved when they are used jointly, i.e. in human-machine collaboration. The separation of a human and a machine in the operationalist comparison is an unnecessary constraint that hinders the development of the entire field of artificial intelligence, as well as the technological progress. It is necessary to compare the effectiveness of the robot-human cooperation acting together (or, of artificial intelligence in general) in contrast to the effectiveness of human actions alone. A rigid mutual opposition and a mutual exclusion gives rise to an insoluble conflict that prevents one from solving the tasks of creating Artificial General Intelligence. But, essentially, this conflict and the Turing wall itself are related exactly to ignoring the problem of consciousness.

An analogy is traced and revealed between the post-nonclassical triad of a subject - observation tool - object and the post-Turing methodology of a man - Turing wall and Turing test - robot, where the focus of research is shifted to the subjectivity of human-robot interaction and the feedback of this interaction, bypassing the Turing wall.

Chapter 3.* "*Application prospects of post-Turing methodology in intelligent robotics" consists of three paragraphs.

Paragraph 1* "*Post-Turing Methodology as a Conceptual Tool for Breaking the Turing Wall" discusses the role and structure of the new methodology as a prerequisite for further progress in the development of Artificial General Intelligence. The concept of embodied artificial intelligence is represented in many works of modern researchers (Brooks, Herzl etc.). However, all suggestions of researchers had previously focused only on one specific techno-umwelt, which often simply reflected the specialization profile of the authors in one or another type of their

[48] Unhelkar V.V., Shah J. Enabling Effective Information Sharing in Human-Robot Teams // Conference Robotics: Science and Systems (RSS), 2018.URL: http://interactive.mit.edu/sites/default/files/documents/Unhelkar_RSS_Pioneers_Abstract_2018.pdf (accessed on 16.07.20).

activity. The new approach proposed by the dissertationist is to create such cognitive architectures and implement them in mechanisms that are initially focused on several techno-umwelts - robots or, in general, artificial intelligence can solve problems in different techno-umwelts on the basis of uniform tools, mechanisms and architectures. Designing specific systems should include the possibility of sequential operations in different “techno-umwelts”, while remaining within a single architecture and a single robot (or artificial intelligence system). This approach gives a significant increase to the complexity of the problem due to the flexibility of the systems under development. It requires a wide use of the findings of modern phenomenological studies of the dynamic structure of the phenomena of consciousness in creating relevant cognitive architectures (D.I. Dubrovskiy)[49]. To a certain extent, this approach reflects how the psyche forms in the course of biological evolution. It is theoretically acceptable that a system capable of perceiving the world and acting in all four types of "techno-umwelts" can have its own consciousness. A system operating in just one type of techno-umwelt is, basically, incapable of possessing consciousness, since it cannot abstract phenomena and independently create concepts.

At the present stage of scientific development, the use of the results of the phenomenology of consciousness and achievements in the field of neuroscientific research is a prerequisite for constructing new post-Turing cognitive architectures to create intelligent robots and Artificial General Intelligence.

Paragraph 2 "Experimental intelligent robot E.LENA" as a demonstration of applicability of post-Turing methodology" the application of post-Turing methodology is considered in creating the experimental intelligent robot-TV host "E.LENA". As shown above, Turing proposed to create intelligent machines operating in just one type of umwelt - the "***virtual-verbal***", with its operating space being limited to just reception and transmission of symbolic, verbal information. The engineering team, guided by the dissertation candidate, managed to create and patent an experimental robot that made it possible to combine two "techno-umwelts" - the "***virtual-verbal***" one inherent to Turing test, and the new "***virtual-nonverbal***" "techno-umwelt" previously used only in computer games. The robot "E.LENA" is a virtual humanoid that has a virtual humanoid body endowed with facial expressions, it can use a natural language, fully supporting the Russian language (visemes, phonemes), is autonomous (does not require any operator actions when performing basic functions), possesses its own personality (depending on the personality of a chatbot) and has a primary capability of adapting to the changes in the outside world (the robot has been implemented with the function of face recognition of its conversation partners). The architecture of such a robot is presented in scientific literature for the first time. This

[49] Dubrovsky D.I. Subjective reality // Philosophical Anthropology, vol. 4. No 2, 2018. pp. 186-217. (in Russian)

work assumed, when designing such a cognitive architecture, the use of not just a number of essential characteristics of a human subjective reality (based on modern research in the phenomenology of consciousness), but also the use of a complex set of external manifestations of a human (acting as a TV presenter) conscious activity: facial expressions, eye expressions, gestures, voice intonations etc.). It relied on the research into the problem of non-verbal communications by G.E. Kreidlin, classical ideas of M.M. Bakhtin, fundamental philosophical studies of the problem of "Indirect Speaking" by L.A. Gogotishvili, a number of works devoted to philosophical and psychological comprehension of a media discourse. The experience of creating "E.LENA" has revealed the importance of using the results of philosophical, psychological, linguistic studies of consciousness and language in order to substantiate the post-Turing methodology and efficiently advance towards General Intelligence.

Paragraph 3 "World outlook prospects of post-Turing human-robot communication" contains hypothetical considerations about the future human-robot interaction based on the assumption that robots are technologically indistinguishable from humans. Such plots have long been widely discussed in futurological and philosophical literature (V.G. Budanov)[50]. Diverse issues are usually combined here. It is one thing when it comes to the indistinguishability of human and robot behavior by a human observer in some specific cases, and another when they are indistinguishable in all cases, i.e. when a human and a robot are virtually identical. But this means that in the course of anthropotechnological evolution, a new kind of man, a posthuman has emerged. And it is about him that transhumanists write. However, their position is too controversial. We mean indistinguishability in the first case (something that can be called "technological indistinguishability"). And even on this plane, a global question is often raised about a new stage in the development of robotics, when a robot acquires an increasing number of human capabilities, can reach a level of a human and then surpass it (and a human is, meanwhile, developing in his biological form).

For a realistic assessment of the forms of human-robot interaction, to eliminate the popular in the publicistic literature stories about the inevitable destruction of people by competing machines, the concept of **Artificial General Intelligence** has been elaborated to mean the capability of a robot (or other technical system) to learn and act together with a human or autonomously in any field, but better than an expert in this field, achieving the target goals in all four techno-umwelts with limited resources consumed by a robot.

[50] V.G. Budanov A new digital and technological pattern of life - prospects and risks of transformations in anthroposphere // Philosophical Sciences, No. 6, 2016. pp. 47-55. (in Russian)

Modeling and programming such properties of robots that would meet our legal and ethical principles and completely rule out their aggression and “unfriendly intentions”, will probably call for the creation of “virtual people” - programs that will emotionally identify themselves with people, possess features of human self-awareness and the self. The questions of using such robots in the fields of education, manufacture and entertainment are considered. These are the questions of creating autonomous virtual teachers taking into account personal, including genetic, characteristics of students, or, for example, the questions of copyright for the works of art created by robots, including products based on digital twins of famous people, both living and dead. The question of drawing a line between human and technological intelligence is posed and discussed in case the level of General Intelligence is reached.

All this testifies to the growing role of philosophical and methodological approaches in solving the problems of development of intelligent robotics and artificial intelligence in general.

In conclusion, the results of the thesis research are summarized from the perspective of interconnection of the problems of consciousness, Artificial General Intelligence, intelligent robotics with the development of post-Turing methodology. It is stated that on the basis of the elaborated conceptual approach, it is possible to achieve significant results: in designing new, hybrid cognitive architectures for Artificial General Intelligence and intelligent robotics; in developing efficient operational tests to measure the progress in creating new types of robots and artificial intelligence technologies; as well as in a more thorough comprehension of the future human-robot communications and issues of an ethical approach to the creation of Artificial General Intelligence.

The reliability of the scientific concepts, conclusions and recommendations is confirmed by:

- the adequacy of the applied scientific and methodological approaches to the goals and objectives of the study;
- a scientific research based on interdisciplinary analysis and practical results;
- the consistency of conclusions with the existing relevant research in the field of artificial intelligence, robotics, post-nonclassical epistemology and synergetics;
- approbation of the research results.

Approbation of the research materials

The main content of the dissertation research is reflected in four articles published in the issues that are included in the citation indices of the Higher Attestation Commission of the Ministry of Education and Science of the Russian Federation, Scopus and Web of Science, and two patents:

- *Alekseev A.Yu.*, Efimov A.R., Finn V.K. The Future of Artificial Intelligence: Turing or Post-Turing Methodology? // Artificial societies. 2019.Vol. 14. No 4. (Electronic edition);
- *Efimov A.R*. Technological prerequisites for indistinguishability of a human and his computer simulation // Artificial societies. 2019.Vol. 14. pp. 74-80;
- *Efimov A.R.* Post-turing methodology: breaking the wall on the way to general artificial intelligence // Intellect. Innovation. Investments. 2020. No2. pp. 74-80;
- *Efimov A.* Post-Turing Methodology: Breaking the Wall on the Way to Artificial General Intelligence // Artificial General Intelligence. AGI 2020. Lecture Notes in Computer Science, vol 12177. Springer;
- *Efimov A.R.,* Gonnochenko A.S., Vladimirov M.A. A METHOD AND A SYSTEM FOR CREATING MIMICS BASED ON A TEXT // Patent for invention RU 2 723 454. 2020;
- Postnikov A.L., Gamayunov A.R., Zatyagov D.D., *Efimov A.R.* A method and a system of predictive avoidance of a collision of a manipulator with a person // Patent for invention RU 2 685 996.

Main results of the dissertation research were discussed at the meetings of the sector of interdisciplinary problems of scientific and technical development of the Institute of Philosophy of the Russian Academy of Sciences and were presented as reports at international and all-Russian conferences:

- 4th International Conference "More than Learning: How to Achieve a Change in Behavior?" (Moscow, October 25, 2019);
- All-Russian scientific conference "Supercomputer technologies in social sciences" (Moscow, September 24, 2019);
- The first meeting of the International Interdisciplinary Seminar "Artificial Intelligence: Methodology and Technology" (Moscow, September 20, 2019);
- International conference AI Journey (Moscow, November 08, 2019), attended by the President of Russia V.V. Putin;
- Internationaĭ interdisciplinarў conference "Philosophy of Artificial Intelligence" (Moscow, June 2020).

In addition, other publications and research works have been carried out on the topic of robotics and artificial intelligence:

- *Efimov A.R.* Do chatbots dream of androids? Prospects for the technological development of artificial intelligence and robotics // Philosophical Sciences. 2019.Vol. 62, No. 7, p. 73-95;

- *Efimov A.R.* and others. Practical application of robots and related technologies in the fight against the covid-19 pandemic // Robotics and technical cybernetics. 2020.Vol. 8, No 2, pp. 87-100;
- *Efimov A.R. et al*. Experimental studies of the applicability of unmanned aerial vehicles for solving urgent problems of corporate logistics // Flight. 2020. No. 7, p. 15 - 22;
- *Efimov A.R.* The relevance of using industrial exoskeletons of upper extremities to reduce the number of occupational diseases of the musculoskeletal system // Occupational medicine and industrial ecology. 2020. No. 7, p. 412-416;
- *Semochkin A. N., S. Zabihifar and A. R. Efimov* Object Grasping and Manipulating According to User-Defined Method Using Key-Points // 12th International Conference on Developments in eSystems Engineering (DeSE). 2019. Kazan, Russia, 2019, pp. 454-459;
- *Efimov A.R.* Combat robots: foreseen or unforeseen threats // Security Index. 2016. Vol. 22, No. 3-4, pp. 79-96.