Post-Turing Methodology: Breaking the Wall on the Way to Artificial General Intelligence

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Abstract. This article offers comprehensive criticism of the "Turing test" and develops quality criteria for new assessment tests of artificial general intelligence (AGI). It is shown that the prerequisites for reducing personality and human consciousness that A. Turing used reflected the level of development of technology of his period. In fact, the Turing test describes only the latter option, omitting other three. Thus, restricting thinking ability to only using symbolic systems, unknowingly, Turing constructed "the wall" that excludes all possibility of a transition from complex observable phenomena to an abstract image or concept. It is justified to approach Turing test from new requirements for assessment of artificial intelligence maturity: it must support all forms of communication with a person, it should be able to comprehend abstract images and specify concepts, and also participate in social practices.

Keywords: robotics, artificial intelligence, Turing, Turing test, philosophy of artificial intelligence, symbolic systems, verbal interaction, abstraction

1 Introduction. The background of a narrowly analytical period in assessing artificial intelligence (1950–2014).

The British mathematician Alan Turing with his works (1937–1952) laid those fundamental lines of research in the field which we now call "artificial intelligence" (AI) or "artificial general intelligence" (AGI). Relying on the new theory of computability and information, on the one hand, and on the first machines engineered for universal computing, on the other hand, Turing directly approached the difficult question, "Can machines think?" Certainly, he could not create a model that would completely describe human thinking or even the work of the brain as the basis of thinking (there was an obvious lack of neurobiological data). Therefore, he simplified the model, reducing it to machine liking to a communicating person as a subject, presented as a system of symbols or abstractions.

This simplification became the basis of A. Turing's thesis about the isomorphic features of thinking and computing: "If we consider the result of the work of calculators (that is, people employed for computing) as intellectual, then why cannot we make a similar assumption regarding machines that perform these operations faster than people?" [1].

In this work Turing was also the first to analyze the role of "embodied intelligence." He believed that a certain creature equipped with microphones, television cameras and loudspeakers can be taught to walk, balancing with his limbs and equipped with telecontrolled brains. Turing believed that if they created such a "monster" on the basis of the then available technologies, it would be "certainly enormous" and pose a serious threat to the inhabitants. Thus, recognizing the ability to imitate humans as "embodied intelligence," Turing pointed out that "the creature would still have no contact with food, sex, sport and many other things of interest to the human being" [1]. Instructed by Turing, future researchers should had been focusing on imitating human intellectual activities in these five areas:

(1) Various games, such as chess, tic-tac-toe, poker, bridge
(2) Learning languages
(3) Translations from one language to another
(4) Cryptography
(5) Mathematics

Of these five areas, Turing believed (4) to be the most useful in a practical sense for AI [1]. The identification of precisely these areas for research affected the entire subsequent development of AI till now: relatively homogeneous tasks, partially solved by computers of the 1940s, made it possible to achieve new results by simply increasing computational capabilities. A certain inertia of development shows when enormous efforts are given to solving such a narrow range of problems. But human thinking and society deal with a much wider range of "puzzles." As a result, available software tools are used in various fields of application, where they still cannot be fully applied for action in material world. This generates unfounded but very high expectations from the use of computers and, conversely, generates skepticism.

In his most frequently cited work, Turing suggested playing a "imitation game," which, in essence, was an engineering solution to the problem of answering the question "Can a machine think". Instead of looking for definitions of what is "machine intelligence" or human intelligence, Turing proposed a "blind" comparison of man's key intellectual ability: reasoning and generating illusions. The game of "imitation" has become the basis of the Turing methodology for constructing AGI. In this paper, we need only briefly to look into the scheme proposed by Turing, following the original source and using the descriptive methodology proposed in [2] by A. Alekseev.

Having set the directions in research (languages, translations, games, cryptography and mathematics) in his previous works, in 1950 [3] A. Turing strongly proposed a methodology for determining the achievement of the final result. Only in the mid-1970s this methodology came to be called the Turing test, although in essence it remained a methodology for determining the achievement of the final result (definition-of-done) in the AI research program.

Problem statement: AGI researchers and philosophers have developed various mental experiments that could form the basis of a more advanced methodology than the Turing test. Unfortunately, in the pursuit of designing a more adequate test, the researchers lost sight of the holistic methodology proposed by Turing. This paper argues that this should be corrected.

2 Critical analysis methodology of the Turing test

After introduction, it seems necessary to indicate the main methodological difficulties in modern assessment of the Turing test:
a) The test has grown so popular that it pushes many researchers toward a simplified version: "within 5 minutes of telephone talk, you must understand whether you are talking to a machine or a person";
b) any scientific research needs simple and transparent checks, yet a reliable assessment of human consciousness is still under debate. Nevertheless, all engineering products tend to use tests, and since "AI" is most often represented as software products, the test boils down to communication with the software. This has formed the inertia of perception for "intelligent machines."

If we revert to Turing's methodology proper, then it is necessary to pay attention to three aspects that are important for our subsequent considerations.

Firstly, all the five areas of research originally proposed by Turing are based solely on symbolic communication. The following decades expanded the list of areas for software development, logistics, and even for weather forecasting – but it is always work in ready-made symbolic systems. Turing considered hardware technologies extremely cumbersome and unsuitable for study of intelligence, but he recognized their importance, as shown above. Nowadays, we see a great variety of computers, but there is no direct correlation between an increase in the capacity of computing devices and improvement of their intelligence.

Secondly, Turing's methodology always presupposed a wall dividing the two key participants. All subsequent modifications of Turing's methodology that arose after 1952 implied a comparison by Judge (J) of the activities of Human (H) and Computer (C), but their activities were always divided by an impenetrable wall. Only J interacted with C or H still through "Turing's Wall" which is transparent only to symbolic communication link. But H and C did not communicate at all and did not solve problems together.

Thirdly, Turing believed that the problem consisted "mainly in programming" and did not consider the need to accelerate the speed of digital computers in order to solve the problem of "imitation game." That is, Turing viewed the task of creating AI as designing a system of abstractions that could recognize and take into account all nuances of human communication. Turing was fully aware of the problem of a multi-level symbolic game, noting that the task of a translator lies the most complicated field, noting that it "seems however to depend rather too much on sense organs and locomotion to be feasible" [1]. Unfortunately, this remark was largely overlooked by the subsequent generations of researchers, who took for granted the study of imitating the reasoning of a person or the ability to play games.

Here, we can see the formation of a kind of paradox: on the one hand, these three aspects of the methodology proposed by A. Turing constitute the cornerstone of all search for the implementation of "artificial intelligence" in 1950–2014; on the other hand, this methodology was not sufficient to solve the whole set of problems that "natural intelligence" solves, and the Turing test could not be a reliable criterion for creating "artificial intelligence." All the five Turing's research areas require solving relatively simple calculation tasks when working with large arrays of homogeneous data (dictionaries, multi-page statements, detailed maps, millions of options for arranging figures). Human intelligence is not focused on working with information organized in this way but rather on formulation of concepts, on searching for certain common features of objects (without necessarily fixation of all the others).

However, Turing's methodology has become the basis for a huge family of a various tests of AI. It is similar to the mechanistic materialism of the 18th century: initially limited, it nevertheless made it possible to solve a whole class of specific problems [2].

Object of the article: to make a step further from the Turing test as a criterion for creating a full-fledged AI. It is necessary to show the fundamental limitations of Turing's methodology and develop an approach to assessing tests created for situations that are not supposed to pass the Turing test.

Subject of the article: rejection of the paradigm of modeling consciousness that was based only on the use of symbolic systems, the contradiction of new approaches in assessing AI with the neopositivist foundations of the Turing test.

Our criterion consists in more complete assessment of the personality and agency of the individual.

3 The continuum of Turing-like tests and its limitations

Almost seventy years have passed since Turing expressed his revolutionary philosophic ideas about the possibility of creating "thinking machines" in the fundamental work in the Mind journal [3]. Several generations of mathematicians, philosophers and researchers of AI have devoted many articles to his mental experiments. As a result, a whole set of Turing-like tests have been designed. However, if you carefully consider this set of mental experiments and engineering solutions aimed at determining the definition-of-done approach to AI (summarized in Alekseev's work [2]), we can distinguish two axes that are orthogonal to each other, which we call the dimensions of the "Turing-like testing continuum." All tests are grouped around following axes.

From verbal to non-verbal.

Verbal interaction with AI involves exchange of meaningful information messages, abstractions, images in a specific linguistic context. The meaning of the messages is set precisely by their verbal semantics. These messages can refer to everyday life ("What day is it today?") or bear imaginative content ("What if the universe were closed?").

Non-verbal (one might say, non-linguistic) interaction with AI involves exchange of information messages without using language. This can include facial expressions, gestures, movements, motor skills and even emotions that are expressed in specific actions (laughter, crying, sadness, suffering).

From virtual to physical.

Virtual interaction with AI takes place exclusively via computer interfaces available to us, including traditional (and becoming outdated) hardware, such as monitor screens, keyboards, augmented / virtual reality devices, and even exciting brain-computer interfaces.

Physical interaction with AI (although the word “robot” can be used in this context, meaning a “actuated computer with AI” mentioned above) occurs in the physical world and involves its active change by AI itself. It requires specific ability to affect other physical objects. A robot operating in the kitchen can wash the dishes, an unmanned autonomous motorcar drives us from point A to point B. All these actions inevitably occur in the physical world.

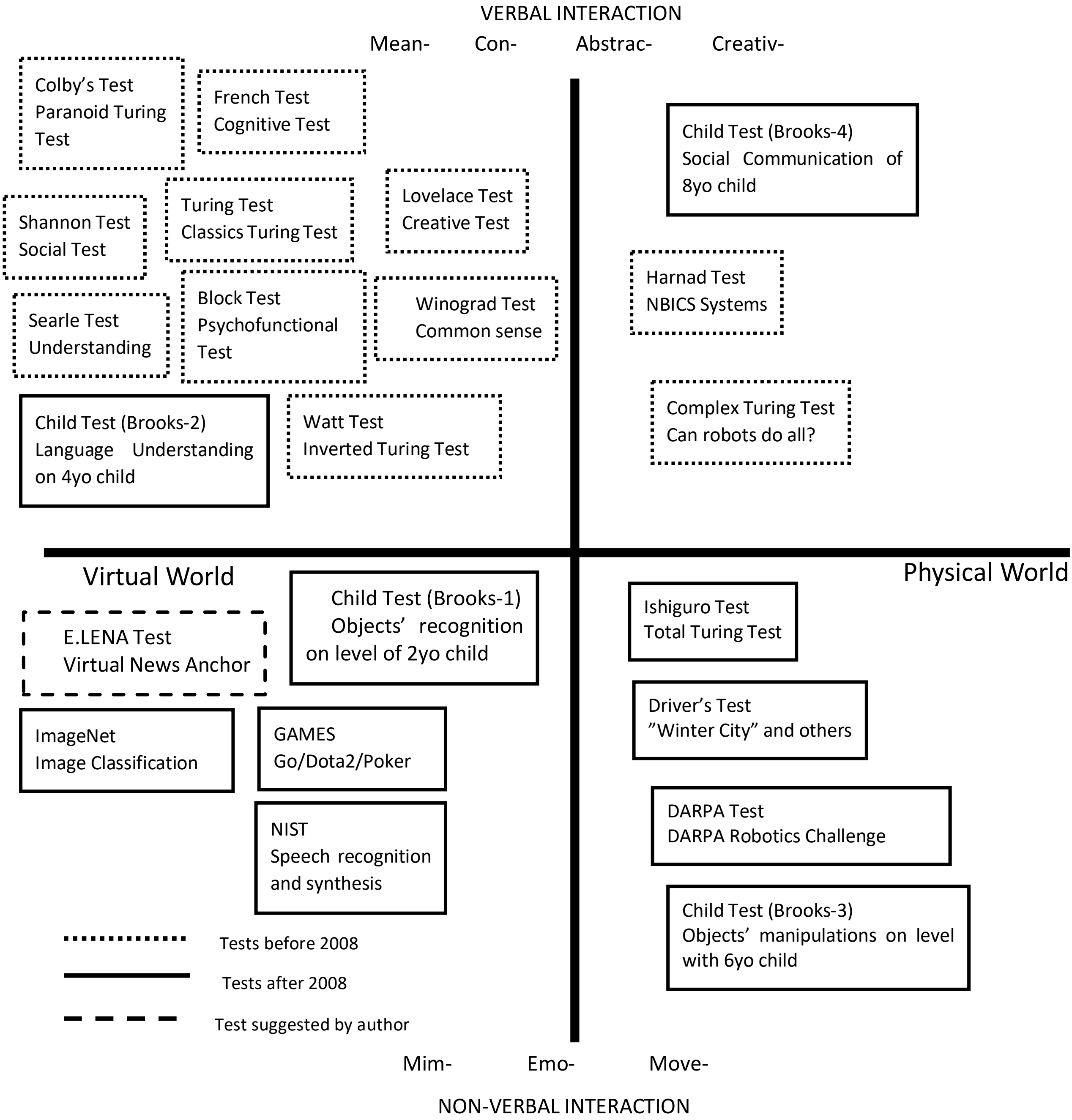

Fig. 1 Shows the continuum of Turing-like tests correlated on the virtual-physical and verbal-nonverbal axes proposed above.

Let us consider the four areas of this continuum in more detail.

Verbal interaction in the virtual world. For historical reasons, most of the tests (mental experiments) developed before 2008 relate namely to this area. In fact, the classic Turing test, Lady Lovelace's creativity test, Colby's paranoid test, Shannon's social test, Watt's test (Turing's inverted test), Searle's Chinese room experiment, and Block's psycho-functional test are focused on verbal testing of various kinds of human and AI. In this case, the environment with which a person interacts is the virtual world (screen, keyboard, mouse).

Verbal interaction in the physical world. This area was not popular among researchers, as it was rejected by Turing from the very beginning. Only S. Harnad [4] and A. Alekseev [2] proposed conducting comprehensive tests demonstrating verbal interaction of humans and AI in the physical world. Although there is a related field of research where the emotional background of the message transmitted plays a very important role, and the study of its smallest aspects is of great importance.

Non-verbal interaction in virtual world. This area of the Turing-like tests continuum remained unnoticed by researchers for a long time, although it was Turing who first drew attention to its importance for AI, when he said that intelligent machines can play chess at the human level. After all, the game (chess or any other) between AI and humans is a non-verbal manifestation of intellectual abilities in virtual space. However, chess remains a codified form of interaction. The next step in the same area of the testing continuum we are studying, actually marginal to the latter, is tests that relate to recognition of images [5] and recognition and synthesis of human speech [6]. This is already movement toward abstraction, when a concept is born out of the chaos of sounds. These tests, which played a huge role in the development of artificial intelligence technologies, are nothing more than human-machine interaction in a virtual environment. In this case, AI does not change the physical world in any way, and at the same time there is no semantic verbal interaction, even in the case of speech recognition – the machine only identifies the words correctly but does not understand their meanings. But even such interaction is estimated to be limited, as a rule, as series of variations of verbal human–machine communication.

Non-verbal interaction in the physical world. This area is the most difficult for AI to master, since it most of all depends on the level of development of robotics, sensorics and AI technologies. If the virtual world has standard environmental characteristics, then reality is inexhaustible, the role of chance is high, and abstracting is most difficult. From the very beginning, this area was ignored by researchers, including Turing, although its importance in human communication is emphasized by all communication researchers. Ishiguro [7] suggests checking the level of technological maturity of robotics and AI by contrasting an android robot and a person in simple acts of communication: the robot only speaks phrases pre-written by humans, but the robot itself is an android with maximum similarity to a person. Another example of a test in which AI and robots performed tasks that people usually did was the large-scale DARPA Robotics Challenge, which was held in 2015. At this competition, robots interacted with the physical world, eliminating the consequences of a nuclear disaster at the training ground, although there was no verbal communication with people. The latest example in this this is numerous driving contests where robots compete with humans in speed, accuracy and safety [8].

In 2018, R. Brooks [9] proposed a number of new tests for AGI. He suggested considering a child's capabilities as an indicator of technological achievement in AGI and robotics, moving away from the Turing paradigm of "conversational" AGI and people communicating through walls. Brooks proposed a competency-based:

(1) Robots should be taught to recognize any objects in the physical world at least at the level of a two-year-old child.
(2) Robots should be taught to recognize natural language at least at the level of a four-year-old child.
(3) Robots should possess manual dexterity and fine motor skills of at least a six-year-old child.
(4) Robots should have social communication skills of at least an eight-year-old child.

With these requirements in view, the Brooks' test is divided into four parts (1–4) and is located sequentially in all areas of the Turing-like test continuum in Fig. 1.

E.LENA test. In 2019, a specialized platform was developed at the Sberbank Robotics Laboratory in order to convert text into a video image of a television presenter. The platform is called E.LENA (*Electronic* Lena) [10]. The importance of assigning visual forms to AI first became popular in science fiction. Yet, researchers did not accept visualization of AI as an object of study, as appropriate technology did not exist up until now. We are first to propose a test for the perception of a digital television announcer by comparing it with a human announcer. It is completely logical if such a test is taken in the field of *non-verbal interaction* of the *virtual world*, in the continuum of Turing-like tests.

Further we need to emphasize the two observations from above. Firstly, most of the tests invented by researchers, starting with A. Turing, implied performance in one specific area, which, according to researchers, was best suited to the task of creating AGI. Secondly, the Turing's wall, separating the subject of the test (human judge) from the test object (computer, robot) only continued to solidify. Researchers could not even think of a computer/robot meeting face-to-face and interacting with each other (a typical estimate of the timing of an AI creation considers the time-out of this event, but not the specifics of programming or computer architecture [11,12]). Each of the tests of the past seventy years only strengthened the Turing wall, which separated the area of verbal, virtual communication between a machine and a person from the huge, incredibly unpredictable world outside this wall.

4 Empirical identification of inadequacy of the Turing test

Over the past ten years, two important trends have occurred that shook the Turing wall so much that it gave a strong crack and is about to collapse.

First trend become obvious in the summer of 2014, when the Royal Society in London carried out the "Turing test" *competition*. The winner was chatbot named *Eugene Goostman*, which imitated the identity of a thirteen-year-old boy from Odessa. This chatbot fooled over 30% of the judges.

This Turing-inspired test invoked much criticism. The key reproach was that despite overcoming the symbolic barrier in deceiving people, no significant breakthrough in research or in applied technologies occurred: chatbots still remained quite limited in their capabilities and declaring that they understand a person is possible only in a figurative sense. According to the cognitive scientist G. Marcus, this test did not show that AI can be considered as created, but merely reveals "the ease with which we can fool others" [13], thus reducing the Turing test to a psychological measurement of the degree of human narcissism than the development of AI. Chatbots can, at best, digress from the topic of discussion, causing the interlocutor to feel surprised and thereby giving themselves away. The philosopher A. Sloman speaks about irrelevance of the Turing test method as a behavioristic approach to assessing the intelligence of a system, as well as to assessing solvability of any true problem [14].

That is to say, chatbots outplay humans when dealing exclusively with abstractions, but the concretization of the gain and its correlation with reality is only possible with human intervention. Chess programs or chatbots have been beating humans in purely symbolic competitions for several years now. But they do not become full-fledged agents, and they cannot adapt their acquired skills to other tasks like driving. These applications cannot create new abstractions or ideal images. The test is formally passed, but the machine does not realize it – the computer program that defeated the *Go* champion cannot spent its prize money on any benefits from its own victory.

Second trend is reliance on the popular approach based on "brute force" and "greedy" (for data) neural networks as it will not help to answer the original question posed by A. Turing: "Can a machine think?" Let's make mental experiment. Imagine that we have managed to recruit volunteers (for a short time) to imitate all men and women of the Earth, dividing them into two groups – in one there will be men and women, the number of both equal to each other, and another group will be men or women who are to act as judges (gender does not matter here). If we assume that the number of adult inhabitants of the Earth is 6 billion, then in the group of men and women there will be exactly 4 billion people (equally men and women), and in the group of judges there will be 2 billion. Next, both groups begin their Turing's game of imitation, recording all the dialogues and results. Suppose that we have all the computing power for a deep learning neural network, which allows us to train a neural network to answer any conceivable question based on previous simulation games. It seems likely that if such a computer starts a game in tandem with a woman and claims to be a woman (as described above, following A. Turing), the judge will most likely be unable to distinguish the computer from a woman, and it will be equally likely to determine the AI or the person in this game. Will this mean that Turing's criteria is observed and true General AI is reached? It does not seem so, since Turing said that the computer should imitate the reasoning of a man who pretends to be a woman. In our mental experiment, the computer literally reproduces the most successful cues of women who helped them in winning the game. However, this computer is not capable of acquiring any "reasoning" ability. It only demonstrates its ability to quickly find the relevant cue based on the training set. The result of this mental experiment will be a dialogue interface capable of skillful imitation, but this computer interface is completely devoid of "intelligence."

It seems that this very consequence of the mental experiment shown here is the main reason why the approach based on the Turing method (Turing test) ceases to be relevant and should give way to another approach based on a post-Turing methodology. In such a situation, the Turing's wall separating H or C from J loses its meaning.

5 Principles proposed in post-Turing methodology for study of AI

It seems quite logical to establish a new methodology for assessing achievements in AI, taking into account both the experience of the last seventy years and the newer technological capacities. In fact, first attempts were done right after 2014 Turing test competition in London [15-21]. However, they are all lack practical implementation across all Turing continuum.

Firstly, in our concept of an intelligent computer we should reject anthropomorphism. The wall constructed by Turing bound to separate the tester and the tested (a person or a robot) essentially stimulates a person to evaluate AI in contrast to oneself, creating superfluous technological anthropomorphism. However, man learned to fly using technologies that are completely different from birds' wings. The creation of AI reasoning and communicating like a person is probably not the most effective answer to Turing's question "Can machines think?" It is counterproductive to discuss the ethical limitations of precisely humanoid robots [22]. If we evaluate the design of modern robots, then the simplest question – "How many fingers should a manipulator hand have?" – can generate multiple answers, and the two-finger solution becomes a widespread type of "hand" [23].

Secondly, we can talk about a variety of forms and methods of cognition available to computers. AI should use abstraction and concretization in a broad range. Here, the ideal becomes an independent formulation of new concepts and modeling of one's own picture of the world – of course, with restrictions regarding human safety. Now numerous attempts are made not only to improve recognition of images but also, on the basis of I. Lakatos' theory of games and concepts, to compile a conceptual apparatus for interaction of computers with mathematicians more flexible [24].

Thirdly, there should be diversity of the same forms of communication that are available to man. Machines have largely mastered computerized communication in symbolic structures, but the motor skills of robots remain imperfect. *Virtual-non-verbal*, *physical-non-verbal* and *physical-verbal interactions* are still difficult. Probably, the ideal that machines should strive for is emotionally colored communication "using the five senses," so that the robot can convey information in any set of sensations available to humans. Here, we can provide a good example of automated translation from the sign language of the deaf to the test and vice versa. So far, we can only observe it on the displays, but it should soon be accessible to the robot operators.

Fourthly, a robot should participate in human social practices as a junior partner but with an agency. R. Brooks bases his tests of AI on a comparison with the levels of a child's development – but what could be a better assessment criterion of communication skills than life in society? After all, a child's development is inseparable from socialization.

6 Conclusion

The Turing Test has virtually lost its relevance and meaning: even computer software that does not fully represent AGI can pass such tests in systems of symbolic communication. Moreover, applications can practice abstraction only in minimal forms, which limits their cognitive abilities.

Overcoming anthropomorphism and the Turing approach to assessing AGI will allow us to focus on creating systems that can demonstrate various skills in four main areas. These are: shaping the appearance of the system for performing labor operations; complete formulation of new concepts (abstracting) and their use (concretization); communication with a person involving the five senses; and, finally, personal social agency.

References

1. Turing A.: Intelligent Machinery 1948. Report for National Physical Laboratory semanticscholar.org. - 1948. Available at: https://pdfs.semanticscholar.org/b6b8/523c4e6ab63373fdf5ca584b02e404b14893.pdf.(accessed 28.08. 2019.)
2. Alekseev A. Ju. Kompleksnyj test T'juringa: filosofsko-metodologicheskie i socio-kul'turnye aspekty [Turing comprehensive test: philosophical, methodological and socio-cultural aspects] Moscow: IInteLL., 2013. 304 p. (In Russ.).
3. Turing A. Computing machinery and intelligence // Mind, 1950 г. - T. 59.
4. Harnad S. Minds, Machines and Turing: The Indistinguishability of Indistinguishables // Journal of Logic, Language and Information. vol. 9 (4). October 2000. pp. 425–445.
5. Stanford Vision Lab ImageNet // ImageNet. - Stanford Vision Lab, Stanford University, Princeton University, 17. 09. 2019. Available at: http://www.image-net.org. (accessed 28.09.2019).

6. NIST 2019 Speaker Recognition Evaluation. National Institute of Standards and Technology. 14.08.2019. Available at: https://www.nist.gov/itl/iad/mig/nist-2019-speaker-recognition-evaluation. (accessed 29.09.2019).
7. Ishiguro H. Android Science. Toward a New Cross-Interdisciplinary Framework. Robotics Research. vol. 28 Berlin, Heidelberg: Springer. 2007. pp.118-127
8. Efimov A.R. Tehnologicheskie konkursy adresovany ne startapam, a konsorciumam [Technology contests are addressed not to startups, but to consortia] Skolkovo Foundation. - Skolkovo, August 03, 2017. Available at: https://sk.ru/news/b/articles/archive/2017/08/03/albert-efimov-tehnologicheskie-konkursy-adresovany-ne-startapam-a-konsorciumam.aspx. (accessed 28.09.2019). (In Russ.).
9. Brooks R. Steps Toward Super Intelligence IV, Things to Work on Now [В Интернете] RODNEY BROOKS Robots, AI, and other stuff. - Rodney Brooks., 15 July 2018 г.. - 28 Сентябрь 2019 г.. - https://rodneybrooks.com/forai-steps-toward-super-intelligence-iv-things-to-work-on-now/.
10. Efimov A.R. [Technological background of the indistinguishability of man and his computer simulation] Tekhnologicheskie predposylki nerazlichimosti cheloveka i ego komp'yuternoj imitacii // Artificial Societies 2019. Volume 14. Issue 4 URL: https://artsoc.jes.su/S207751800007645-8-1 (дата обращения: 03.03.2020). DOI: 10.18254/S207751800007645-8
11. Müller V.C., Bostrom N. Future progress in artifi-cial intelligence: A Survey of Expert Opinion, in Vincent C. Müller (ed.), Fundamental Issues of Artificial Intelligence (Synthese Library; Berlin: Springer)
12. How Long Until Human-Level AI? Results from an Expert Assessment Seth D. Baum, Pennsylvania State University, Ben Goertzel, Novamente LLC, G. Goertzel, Rutgers University, Published in: Technological Forecasting & Social Change, 2011, vol. 78(1): pp. 185-195 This file version: 20 April 2011
13. Marcus G. What Comes After the Turing Test? // New Yorker. - Conde Nast, 9 June 2014 г.. - 28 сентябрь 2019 г. - https://www.newyorker.com/tech/annals-of-technology/what-comes-after-the-turing-test.
14. Sloman A. Judging Chatbots at Turing Test 2014 // School of Computer Science. University of Birmingham. - 25 July 2015 г.. - 28 сентябрь 2019 г.. - http://www.cs.bham.ac.uk/research/projects/cogaff/misc/turing-test-2014.pdf.
15. Marcus G., Rossi F., Veloso M. Beyond the Turing Test // AI Magazine. - Association for the Advancement of Artificial Intelligence, 2016 г.. - 28 сентябрь 2019 г.. - https://www.aaai.org/ojs/index.php/aimagazine/article/view/2650/2527.
16. Clark P., Etzioni O. My Computer Is an Honor Student — But How Intelligent Is It? Standardized Tests as a Measure of AI AI Magazine. 2016. pp. 5-12 : Т. 37(1).
17. Adams Sam S., Banavar G., Campbell M. I-athlon: Toward a Multidimensional Turing Test AI Magazine : AAAI, 2016. pp. 78-84: Т. 3.
18. Zitnick C.L. [и др.] Measuring Machine Intelligence Through Visual Question Answering AI Magazine. - [б.м.]: AAAI, 2016. - pp. 63-72: Т. 3.
19. Morgenstern L., E. Davis, C. L.Ortiz Planning, Executing, and Evaluating the Winograd Schema Challenge AI Magazine. - 2016. - 50-54 : Т. 3.
20. Kitano H. Artificial Intelligence to Win the Nobel Prize and Beyond: Creating the Engine for Scientific Discovery AI Magazine. : AAAI, 2016. pp. 39-49: Т. 3.
21. Jarrold W., Yeh P.Z. The Social-Emotional Turing Challenge AI Magazine.: AAAI, 2016. pp. 31-38.
22. Chakraborty S. Can humanoid robots be moral? Ethics in Science and Environmental Politics Vol. 18:, 2018 September pp.49– 60

23. Birglena L., Schlichtb T. A statistical review of industrial robotic grippers. Robotics and Computer-Integrated Manufacturing vol. 49. February 2018. pp. 88-97.
24. Pease A., Lawrence J., Budzynska K., Corneli J., Reed C. Lakatos-style collaborative mathematics through dialectical, structured and abstract argumentation Artificial Intelligence vol. 246. May 2017. pp.181-219.