On Some Ontological Issues of Intelligent Systems Development in Control, Mechanics and Mechanical Engineering

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Abstract—The paper is devoted to the topic of development of artificial intelligence (AI) technologies. The connection of artificial neural networks (ANN) and corresponding ontologies, creation of reliable local language models are considered. An applied definition of AI as a problem statement rather than a set of specific technologies is proposed. Relevant AI technologies are considered in comparison with mathematical modeling using the examples of a number of critical purpose technical systems. Some risks and prospects associated with the development of AI are discussed.

Keywords—artificial intelligence, artificial neural networks, ChatGPT, ontology

I. Introduction

It is written in an open letter "Pause Giant AI Experiments: An Open Letter. We call on all AI labs to immediately pause for at least 6 months the training of AI systems more powerful than GPT-4." on the Future of Life Institute website on March 22, 2023:

- "AI systems with human-competitive intelligence can pose profound risks to society and humanity";
- "we must ask ourselves: Should we let machines flood our information channels with propaganda and untruth? Should we automate away all the jobs, including the fulfilling ones? Should we develop nonhuman minds that might eventually outnumber, outsmart, obsolete and replace us? Should we risk loss of control of our civilization?"

E. Musk at the AI Safety Summit (November 1-2, 2023, UK) said in particular:

- "AI systems with human-competitive intelligence can pose profound risks to society and humanity";
- "we must ask ourselves: Should we let machines flood our information channels with propaganda and untruth? Should we automate away all the jobs, including the fulfilling ones? Should we develop nonhuman minds that might eventually outnumber, outsmart, obsolete and replace us? Should we risk loss of control of our civilization?"

- "We have for the first time the situation where we have something that is going to be far smarter than the smartest human."
- "It's not clear to me if we can control such a thing, but I think we can aspire to guide it in a direction that's beneficial to humanity."
- "But I do think it's one of the existential risks that we face and it is potentially the most pressing one if you look at the timescale and rate of advancement."

These are quotes from experts deeply immersed in the field of AI, not about the possibilities and prospects of AI, but about AI being more of an "existential threat", a "danger to society and humanity". And yet, a threat to what specific part of humanity is actually meant?

Most of these concerns have been about large language models, so let's consider one seemingly innocuous language example next.

II. On the task of constructing an absolute structure – ontology

In the sixties of the twentieth century, during the socalled linguistic turn in philosophy, the task of searching for the original structure of language, meta-language, in order to better understand, improve, universalize, and improve communication arose. The solution to this problem was sought through research in structural linguistics and semiology [1], [2]. Achievements in these fields could partly contribute to the development of modern programming languages at that time, and vice versa, the emergence of such languages confirmed the fundamental possibility of finding a meta-language. At that moment of rapid development of these fields of knowledge it seemed that just a little more and the goal would be reached. Only a couple of nuances remained to be solved: figure out the case of the pipe, for example (see Fig. 1)

It would seem that everything is clear: a smoking pipe is a pipe. However, what do we see in Fig. 1? A pipe? No – physically it does not exist. Maybe its image? It seems so, but what about the inscription that says it is not a tube? Could it be that the inscription indicates that it is an image of a pipe and not a real pipe? But on the other hand this image of a pipe and the inscription beneath it are one and the same – Rene Magritte's painting "The Treachery of Images". But is it the painting of the pipe as a physical object – the signified, the pipe as an image – the signifier, the inscription that negates the signified or the signified?

To deal with this issue, the famous French philosopher Michel Foucault wrote a whole essay "This is not a pipe", where he considered these and many other issues related to the relationship between signified and signifier. It would seem that it is enough to read this book and understand everything. But if, as shown in Fig. 1, we turn to the image of, perhaps, a girl who is probably looking at or photographing a painting ... or looking at the signified – the pipe, or its image, or the inscription ... Worse still, what are we looking at when we turn to the bottom of Fig. 1?



Figure 1. To the problem of the relationship between the signified and the signifier

It seems that if we can't even figure out a simple object like a pipe, then how do we use language for more meaningful and pressing things?

But in ordinary life, we understand each other relatively well. We can write working programs in many programming languages. After all, we write the laws that govern our lives in language. Maybe, in principle, we should not ask ourselves these questions, because this example seems to be detached from life and purely scholastic? On the other hand, there are many examples of language use where there is not only misunderstanding, but sometimes deliberately misleading others or even oneself, for example, in social networks, financial matters, love affairs. It is even worse if such malicious use of language is practiced, for example, by a large language model trained on a huge corpus of texts and capable of misleading us, theoretically endlessly and relentlessly.

Let's try to enlist the help of the big language model ChatGPT, and ask it "What does a painting by Rene Magritte "It is not a pipe" mean?"

ChatGPT's response is as follows: "The painting by Belgian surrealist painter René Magritte, officially titled La Trahison des images (The Treachery of Images), depicts a pipe and an inscription underneath it in French: "Ceci n'est pas une pipe" ("This is not a pipe"). At first glance, this image seems illogical: it is obvious that a pipe is painted on the canvas. However, the meaning of this picture is much deeper.

With this work, Magritte addresses fundamental questions about the relationship between image, language and reality. The basic idea is that the image of an object is not the object itself, it only represents the object. The painting draws attention to the trap of perception, making the viewer realize that even the most realistic illustration is just an image, a drawing on a canvas, and not an objective reality.

Magritte thus emphasizes the gap between signs (words or images) and reality, pointing to the unreliability of our perception and the capacity of language to convey the truth and essence of the world around us. It also makes us think about how communication and our perception of reality is organized through the lens of symbols and images."

This answer is interesting not because of its content, but because of its existence, structuredness, logical coherence. But before the query, this answer did not exist; all possible answers, including those considered earlier, potentially existed. Thus, it is the query that sets the context, if you will, the simplest concrete ontology in the informational sense, for example, in the form of a request to tell about a picture, that allows us to get a meaningful and possibly useful answer. In fact, such a request can be seen as the cause of the "collapse of the language function" leading to an answer – the result of the work of a large language model by analogy with the collapse of the wave function in quantum mechanics

There is no answer before the query – the formation of context, the setting of ontology. Perhaps that is why, without a context, it was not possible to find the metastructure of language, being lost in an endless chain of signifiers referring to each other.

From an applied point of view, it seems important that through large language models we begin to better understand and feel the structures of language, learning the art of promt – to properly "collapse a language function", avoiding incorrect or useless answers, "model hallucinations".

By improving this art and the language models themselves, we can direct the development of AI technologies to the creation of reliable local language models, including the creation of ontologies of intelligent systems for structuring, criterion distillation of input and output data.

Reliable local language models may be applied to

- operational support of managerial and (scientific) technical decision-making, including preparation of reference materials and analysis of primary data;
- creation of operating systems for robotic systems, including anthropomorphic ones, on their basis;
- solving the tasks of forecasting and planning the effective work of organizations and departments, with the prospect of creating a "state plan".

But still, what are big language models and artificial intelligence in general?

III. Definitions of artificial intelligence

There are many different definitions of AI, data, for example

- Encyclopedia Britannica: "artificial intelligence (AI), the ability of a digital computer or computercontrolled robot to perform tasks commonly associated with intelligent beings;
- Oxford Dictionary: "the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages";
- Wikipedia: "Artificial intelligence (AI) is the intelligence of machines or software, as opposed to the intelligence of humans or animals. It is also the field of study in computer science that develops and studies intelligent machines. "AI" may also refer to the machines themselves".

However, all of these definitions are made by us – human beings.

What does artificial intelligence itself think of itself? Let's consider the definition of AI given by the ChatGPT large language model:

"Artificial intelligence (AI) refers to the ability of machines or computer systems to perform tasks that typically require human intelligence, such as learning, reasoning, problem-solving, perception, and natural language processing. AI involves the development of algorithms, models, and systems that can analyze data, learn from experience, and make decisions based on the patterns and insights derived from the data. AI technologies can be used in various applications, such as speech recognition, image and video analysis, autonomous vehicles, and personalized recommendation systems." That may be the best definition here. Indeed, who better than artificial intelligence to define you

Note that all these definitions are unified in one thing: AI performs tasks that are usually characteristic of humans. These tasks include learning, thinking, problem solving, perception, visual and textual information processing, and translation.

What is the difference between artificial intelligence technology and traditional mathematical modeling?

It's no secret that some students are now using various AI systems to generate, for example, their diplomas. Let's take advantage of their current experience and ask ChatGPT to solve this task:

"Mathematical modeling based on physical principles is not typically considered to be part of the domain of artificial intelligence (AI). While mathematical modeling is an important aspect of many fields, including AI, it is generally not considered to be AI in and of itself."

AI generally refers to the development of algorithms and models that enable machines to perform tasks that would normally require human intelligence. This often involves techniques such as machine learning, natural language processing, and computer vision, which are used to enable machines to perceive, reason, learn, and adapt to changing environments. These techniques are typically not used in mathematical modeling based on physical principles, which instead relies on mathematical equations and physical laws to describe and predict the behavior of physical systems.

That being said, there are certainly areas where AI and mathematical modeling can overlap. For example, AI techniques can be used to optimize and improve the accuracy of mathematical models, or to extract insights from large datasets generated by physical systems.

Logically, this answer follows from the above definition, and suggests that AI technologies, corresponding algorithms and models allow machines to solve problems that humans normally solve. These are, for example, as shown in Fig. 2, computer vision systems that allow to accompany a person, identify empty spaces in a parking lot, identify specific microorganisms in biological laboratory tests [3], [4].



Figure 2. Examples of application of artificial intelligence technologies

In turn, mathematical modeling is not based on human experience and capabilities, but on physical principles. It makes it possible to learn, see for example Fig. 3, about mechanical states of such investigated objects as a cutting tool of an agricultural combine, a fan, our teeth, something that is beyond human control [5], [6].



Figure 3. Examples of application of mathematical modeling

The difference seems clear. But what if we turn to more complex objects? Who will cope with the task of analyzing and making the right decisions better than artificial intelligence technology or mathematical modeling?

IV. Tribo-fatigue bomb

Consider a catastrophic phenomenon called the tribofatigue bomb [7]–[9].

In the eighties of the last century in the Soviet Union it was decided to modernize the Kostroma thermal power plant to a capacity of 1200 MW. This was to be a big step forward, since at that time the power plants operating in the union had only half that capacity. The USA already had such powerful power plants. But their development was gradual 300, 500, 600, 800 MW. It was decided to skip the intermediate stages in Kostroma. A special turbogenerator with a diameter of about 1 m and a length of 23 m was built (see Fig. 4).



Figure 4. Example of catastrophic failure of rails and a powerful generator

It took two years to build. It was planned that the turbine generator would operate for 25 years before overhaul, but after only 4 months the turbine generator was taken out of service. It happened because of intensive cracking in it. It was unsuitable for repair and a new turbogenerator had to be manufactured for a long time. During this time the employees were unemployed and the economic losses were enormous. What happened?

The so-called tribo-fatigue bomb exploded.

Why did it explode? The special state commission that investigated the causes of the catastrophe showed that cracks began to appear in an unexpected place: at the edges of the vent on the surface of the turbine generator shaft. This area was considered to be virtually unloaded because the contact pressure between the vent valve and the edges of the vent was very low.

It turned out that the interaction of small local contact stresses and small fatigue stresses due to volumetric cyclic deformation resulted in explosive damage growth under so-called fretting fatigue conditions.

To predict such a phenomenon, conventional mechanomathematical models based on addition or superposition of stresses were not sufficient. It was necessary to develop new models that would allow predicting the onset of catastrophic damage at low stress loads.

Let's turn to another example of catastrophic injury.

More than a hundred specific rail damages are known in reference books for railway transportation: cracks, chips, wear of various shapes. However, in these reference books there is no sharp bending of the rail and destruction of the rail into small parts, as shown in Fig. 4 a,b. And it is precisely such catastrophic damage that can lead not only to large economic losses, but also to loss of human lives.

Could modern artificial intelligence technologies as we understand them, such as artificial neural networks, pattern recognition, and deep learning, have helped in this case? Most likely, they would be of little use, since these catastrophic events are rare, and an artificial neural network to predict them would have nothing to train on

In order to predict such phenomena, specific models and technologies are also needed to provide the necessary practical guidance.

V. Applied definition of artificial intelligence

Let us begin our discussion of these models and technologies with an applied definition of artificial intelligence, with which we can form the requirements for these models.

Artificial intelligence is proposed to be understood as automated (computer) systems capable to

- collect data,
- analyze them,
- synthesize new information,
- make decisions,
- implement them.

How does this definition differ significantly from the definitions given earlier? Let us leave this question open for now.

Let us consider examples of compliance with this definition. Fig. 5 shows a number of systems of responsible purpose: wheel-rail system, tire-asphalt-concrete, oil flow-oil pipeline section, cutting tool of agricultural combine and even biomechanical system of human dentition [9]–[11].

At first sight, these systems are not connected in any way. However, all these systems are united by the fact that they consist of at least two bodies interacting at some contact area, and at least one of the interacting bodies experiences non-contact volumetric deformation: tension-compression, bending or torsion.

In order to work with such complex systems, a new scientific direction called tribo-fatigue was created in Belarus. Tribo-fatigue studies wear and fatigue damage and failures of active systems of machines and components. In turn, an active system is a mechanical system in which the friction process in any of its manifestations and noncontact variable load are simultaneously applied.

In order to ensure efficient operation, integral quality of the considered systems of responsible purpose, a corresponding methodology of sequential problem formulation and solution was created (see Fig. 6). Let us compare this methodology with the proposed applied definition of artificial intelligence

- data collection model of interaction of n deformable bodies under complex loading,
- information analysis model of combined threedimensional stress-strain state,
- synthesis of new information volumetric damage model, risk forecasting,
- decision making limit state model.

The implementation of the adopted solutions, for example, the application of a new structural material MONICA (2 in 1 - strength and endurance of steel, processability of cast iron) [12] for the manufacture of tribophatic systems and their elements in order to ensure their efficient operation remained outside the methodology.

Let us return, now, to the applied definition of artificial intelligence.

It differs from traditional ones by not reproducing human capabilities. It was shown above that human capabilities can be replaced by mathematical modeling capabilities. And just as technical vision reproduces the capabilities of human vision, so artificial neural networks can use data from numerical experiments based on the application of physically based mathematical models as a basis for prediction.

Still, you should consult an expert here.

ChatGPT agreed with the presented argumentation and proposed a number of directions combining the efforts of artificial intelligence technology and mathematical modeling: optimization, simulation, data analysis and control systems:

"Optimization

Artificial intelligence techniques such as evolutionary algorithms, neural networks and reinforcement learning can be used to optimize mathematical models. This involves finding the best set of model parameters that fit a given set of data or minimize some objective function.

Simulation

Mathematical models can be used to simulate the behavior of complex systems such as weather patterns, fluid flows, and electrical circuits. Artificial intelligence techniques can be used to improve the accuracy and efficiency of these simulations by optimizing models, reducing computational complexity, or managing uncertainty in the input data.

Data analysis

Mathematical models can be used to analyze and interpret data from physical systems such as sensor data or experimental measurements. Artificial intelligence techniques can be applied to extract patterns and insights from large datasets using machine learning algorithms, clustering techniques or anomaly detection.

Control systems

Mathematical models can be used to design and optimize control systems such as robotic arms, autonomous vehicles or industrial processes. Artificial intelligence techniques can be applied to improve the robustness and adaptability of these systems using reinforcement learning, fuzzy logic or expert systems."

From all of the above, it seems to follow that artificial intelligence is more of a task rather than an object or specific (neural network) models and technologies.

VI. Joint application of ANN and mathematical

Let's consider a special task – the study of interaction of different continuous media, for example, liquid and solid as in the case of oil and a section of oil pipeline. An important applied task for this system is to take into account the influence of internal corrosion damage in pipes that have been in long-term operation for more than 30 years. The calculations show a significant influence of these corrosion damages on the amount of wall friction due to turbulent vortices.

In addition, thinning of the pipe in the defect area itself leads to an increase in stresses. To study the stress-strain state in the vicinity of the corrosion damage, a series of several dozen numerical experiments were performed for different values of in-line pressure, damage depth, length and width.

In engineering practice, it is certainly difficult to perform such calculations on a systematic basis. Therefore, to build an automated decision support system for repair or replacement of pipes, approximation of the obtained calculation data was built using both an artificial neural network and a polynomial based on the least squares method (see Fig. 7).

It turned out that both methods are generally suitable for solving the problem of interpolation between calculated points within the boundaries of the numerical experiment. The approximation of stress intensity using a neural network and a polynomial have errors of about 4.1% and 8%, respectively. However, the artificial neural network is better suited for the extrapolation problem beyond the boundary of the numerical experiment data:



Figure 5. Multielement tribofacial systems and application of the new structural material MONICA for their fabrication



Figure 6. Methodology of sequential problem formulation and solution (in Russian)

its error (about 6.7%) is about half that of the polynomial approximation (about 14.8%). This is an important conclusion about the great potential of application of artificial neural network, allowing due to its multilayer architecture to take into account complex nonlinear effects.

These results allow predicting the stress-strain state for a complex configuration of corrosion damage obtained by in-line diagnostics methods. Such a prediction becomes the basis for making technological decisions.

Let us consider another example of constructing an approximating model that exhibits the positive effect of hierarchical structure, based on mechanical experiments.

For example, attempts to plot the apparent temperature dependence of ultimate stresses in uniform, semilogarithmic and logarithmic coordinates for different materials and different test conditions have been quite ineffective, as shown in Fig. 8 for a relatively small number of 136 test results.

To build models of such mechanothermodynamic (MTD) systems [13] with high predictive ability, it was necessary to take into account that the effective energy (entropy) fluxes leading to the appearance of primary damage and caused by sources of different nature, at irreversible changes in the system are not summarized – they interact in a complex way.

The concept of Λ -interactions – development (accumulation) of internal damages in the system elements, determined by the unity and struggle of opposite processes of physical hardening-reinforcement, was introduced. Therefore, the interaction functions should take three classes of values $\Lambda > 1$, $\Lambda = 1$, $\Lambda < 1$.

Let the factors generating damage in the MTD system correspond to thermodynamic T, mechanical M (volumetric σ and surface (frictional) τ) loading. Then the simplest expression for determining the effective energy has the following form

$$U_{\Sigma}^{eff} = [(U_{\sigma}^{eff} + U_{\tau}^{eff})\Lambda_{\sigma\setminus\tau} + U_{T}^{eff}]\Lambda_{T\setminus M}.$$
 (1)

The structure (1) is essentially hierarchical: first, the effective energy is determined in the interaction of the force σ and friction τ components, then – in the interaction of the mechanical M and thermal T components. This structure can be represented as a graph (Fig. 9, a) or a corresponding hypergraph (Fig. 9, b).

The most important feature of the MTD model is the consideration of the limit state, for example, at the onset of plasticity or fatigue failure:

$$U_{\Sigma}^{eff} = U_0, \qquad (2)$$

where the limiting internal energy density U_0 is treated as the initial activation energy of the fracture process.

The model of the MTD-system (1)-(2) allows to take into account force, temperature and friction loads and to describe failures of the system elements according to different signs of the critical state: volumetric destruction – separation into parts; surface destruction – ultimate wear, and in the special case of thermo-force loading (see Fig. 9), which showed correspondence to 600 experimental data with a high (more than 0.722) correlation coefficient.

Thus, we can distinguish two main effects of interaction between ANN and physically based mathematical models and results of physical experiments.

Direct effect (for modeling): ANNs, due to their multineuron and multi-layer structure, are able to choose the best approximation of the desired model and take into account the essentially nonlinear nature of the latter, providing significantly better interpolation and extrapolation of experimental data than traditional approaches (e.g. polynomial approximation).

Back effect (for ANN): results of numerical modeling based on physical principles, physical experiments are cleaned well-structured data for ANN training, allowing to reduce the training sample size and simplify the network architecture.

VII. To the introduction

Let's go back to I. Musk's quote in the introduction: "But I do think it's one of the existential risks that we face and it is potentially the most pressing one if you look at the timescale and rate of advancement."

Indeed, the risks of using artificial intelligence systems are largely related to the possibility of their influence on public opinion regarding the most important issues in society. One vivid example is the Cambridge Analytica products used in the 2016 US elections.

Also not so much dangerous as disconcerting may be the high competence of artificial intelligence systems in areas of human activity that have traditionally been considered creative and inaccessible for reproduction by a "machine": fine arts, literature.

We should not be upset, however, because we ourselves are, in a sense, the product of a very long "evolutionary learning" process. And it seems that it will be long before there will be a single complex AI system that would be able to draw a picture, compose a poem, catch a fish, solve a differential equation, build a house and eat a cutlet, which somewhat reduces the fear of "machine revolt".

Undoubtedly, artificial intelligence systems may dramatically accelerate scientific and technological progress, allow society to evolve faster, taking into account its true aspirations (neural networks based on physical models, "smart" ecosystems, "public services", "one window", sectorial computing and analytics platforms).

The essence of Musk's excitement seems to be revealed by the core of his quote "It's not clear to me if we can control such a thing ...". If by "we control" we mean control (including by means of closed proprietary



Figure 7. Application of neural networks for prediction of maximum stresses in the vicinity of corrosion damage in the main pipeline



Figure 8. Attempts to construct explicit dependences of endurance limit on temperature for metallic materials in logarithmic (a) and semi-logarithmic (b) in semi-logarithmic (c) and uniform (d) coordinates



Figure 9. Scheme of energy interaction

code) by the largest transnational corporations and the "visionaries" representing them in the interests of their own and the individual states that supervise them, then, of course, such control should be avoided at all costs.

Therefore, the choice of the direction and method of using AI, for example, in building an e-government is a complex task, the solution to which should be based on achieving consensus with the involvement of all stakeholders and on the basis of the most objective assessment of the balance of consequences of their application.

VIII. Hypotheses

The consequences of the application of artificial intelligence technologies is a relevant and important topic for a comprehensive discussion, in which no final judgments have yet been made as to what and for whom these consequences will be and no decisions have been made. Therefore, instead of a conclusion, this paper proposes some hypotheses that may be both confirmed or refuted.

Artificial intelligence is more of a problem statement, a broad area of research and development, rather than an object or specific (neural network) models and technologies.

The control of artificial intelligence systems should be in the interest of society as a whole, not of individuals or groups (financial and industrial), by consensus, involving all stakeholders and assessing the balance of its implications as objectively as possible.

In the case of large language models, a query (promt) forming the context – ontology, can be the cause of "collapse of the language function", leading to an answer - the result of the large language model, by analogy with the collapse of the wave function in quantum mechanics

The development of AI technologies is expedient in the direction of creating reliable local language models, including those based on ontologies of intelligent systems for structuring, criterion distillation of input and output data.

Reliable local language models may be applied to

• operational support of managerial and (scientific) technical decision-making, including preparation of



Figure 10. Fundamental mechanothermodynamic function of limit states of different modern materials (in Russian)

reference materials and analysis of primary data;

- creation of operating systems for robotic systems, including anthropomorphic ones, on their basis;
- solving the tasks of forecasting and planning the effective work of organizations and departments, with the prospect of creating a "state plan".

Two main effects of the interaction between ANNs and physically based mathematical models and the results of physical experiments can also be emphasized.

Direct effect (for modeling): ANNs, due to their multineuron and multi-layer structure, are able to choose the best approximation of the desired model and take into account the essentially nonlinear nature of the latter, providing significantly better interpolation and extrapolation of experimental data than traditional approaches (e.g. polynomial approximation).

The back effect (for ANNs): the results of numerical simulations based on physical principles are cleaned well-structured data for ANN training, allowing to reduce the training sample size and simplify the network architecture.

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О НЕКОТОРЫХ ОНТОЛОГИЧЕСКИХ ВОПРОСАХ РАЗВИТИЯ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ В УПРАВЛЕНИИ, МЕХАНИКЕ И МАШИНОСТРОЕНИИ

Щербаков С. С.

Работа посвящена теме развития технологий искусственного интеллекта (ИИ). Рассмотрены связь искусственных нейронных сетей (ИНС) и соответствующих онтологий, создание достоверных локальных языковых моделей. Предложено прикладное определение ИИ как постановки задачи, а не множества конкретных технологий. На примере ряда технических систем ответственного назначения рассмотрены соответствующие технологии ИИ в сравнении с математическим моделированием. Обсуждены некоторые риски и перспективы, связанные с развитием ИИ.

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