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IMPACT OF ARTIFICIAL INTELLIGENCE EMERGENCE ON ADAPTIVE GOVERNANCE MODELS

Impacto do surgimento da inteligência artificial nos modelos de governança adaptativa

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ABSTRACT

The rapid expansion of artificial intelligence (AI) as a driver of technological innovation has intensified challenges related to governance, sustainability, and controllability within socio-technical systems. The relevance of this study lies in the growing mismatch between the increasing complexity of AI systems and the traditional regulatory and management frameworks applied to them. The purpose of the article is to substantiate a complexity-based interpretation of AI as a complex adaptive system and to identify management principles that support sustainable and responsible development. The study is based on qualitative literature analysis and philosophical synthesis of interdisciplinary research on artificial intelligence, complexity theory, and governance of socio-technical systems. The methodological framework relies on the concepts of complex adaptive systems, diachronic emergence, and Ashby's law of requisite variety, which are applied to analyze nonlinearity, self-organization, and adaptability in modern AI technologies. The results show that rigid, rule-based models of regulation and control are insufficient for governing AI systems characterized by emergent behavior and dynamic evolution. Effective governance requires management mechanisms comparable in complexity to the systems being governed while preserving meaningful human oversight and institutional accountability. It frames adaptive governance as essential for aligning technological autonomy with sustainability and long-term societal safety objectives globally.
Keywords: Artificial intelligence, Sustainable innovation, Emergence, Adaptive governance, AI management

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IMPACTO DO SURGIMENTO DA INTELIGÊNCIA ARTIFICIAL NOS MODELOS DE GOVERNANÇA ADAPTATIVA

Impact of artificial intelligence emergence on adaptive governance models

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RESUMO

A rápida expansão da inteligência artificial (IA) como motor da inovação tecnológica intensificou os desafios relacionados à governança, sustentabilidade e controlabilidade em sistemas sociotécnicos. A relevância deste estudo reside na crescente discrepância entre a complexidade dos sistemas de IA e as estruturas regulatórias e de gestão tradicionais aplicadas a eles. O objetivo deste artigo é fundamentar uma interpretação da IA baseada na complexidade como um sistema adaptativo complexo e identificar princípios de gestão que apoiem o desenvolvimento sustentável e responsável. O estudo baseia-se na análise qualitativa da literatura e na síntese filosófica de pesquisas interdisciplinares sobre inteligência artificial, teoria da complexidade e governança de sistemas sociotécnicos. A estrutura metodológica apoia-se nos conceitos de sistemas adaptativos complexos, emergência diacrônica e na lei da variedade necessária de Ashby, que são aplicados para analisar a não linearidade, a auto-organização e a adaptabilidade em tecnologias modernas de IA. Os resultados mostram que modelos rígidos de regulação e controle baseados em regras são insuficientes para governar sistemas de IA caracterizados por comportamento emergente e evolução dinâmica. Uma governança eficaz requer mecanismos de gestão com complexidade comparável à dos sistemas governados, preservando, ao mesmo tempo, uma supervisão humana significativa e a responsabilidade institucional. O documento define a governança adaptativa como essencial para alinhar a autonomia tecnológica com a sustentabilidade e os objetivos de segurança social a longo prazo em nível global.

Palavras-chave: Inteligência artificial, Inovação sustentável, Emergência, Governança adaptativa, Gestão de IA

INTRODUCTION

Today's advances in artificial intelligence (AI) can no longer be seen as a mere set of technological tools - they are changing the very structure of the digital world. From language models like GPT-4 and Gemini to generative algorithms Midjourney and Stable Diffusion, neural networks have gone beyond simple automated systems and are now able not only to analyze data but also to generate content, solutions and sometimes unexpected forms of behavior.

However, the more complex AI becomes, the more questions arise about its manageability. Is it possible to effectively coordinate such a dynamic system? How to minimize risks without suppressing innovation? These questions can no longer be solved by traditional programming methods - they require a reference to the principles of complexity theory. The main methodological principle is self-organization. It is understood as the ability of a system to build its own internal structure, responding to changes in the external world and simultaneously making changes in its environment. Self-organization allows the system to adapt to changing environment, make non-standard decisions.

1 METHODS

The study is based on a qualitative literature analysis combined with conceptual and philosophical methods. The primary methodological approach involves the analytical review, comparison, and synthesis of interdisciplinary academic sources addressing artificial intelligence, complexity theory, and governance of socio-technical systems. The research relies on idealization, abstraction, analysis, and synthesis as general scientific methods for constructing a theoretical model of AI as a complex adaptive system.

The theoretical and methodological foundation of the study is provided by the general theory of complexity and self-organization. Key conceptual frameworks are drawn from the works of Morin (2000, 2001, 2002, 2013), Haken (2000, 2004), and Prigogine & Stengers (2018). The problematic field of their research is concentrated around the concept of "complexity", oriented towards the knowledge of its nature, principles of its organization and evolution.

In this article, we will consider the key aspects of AI management through three concepts of complexity theory:

- Complex adaptive systems: neural network algorithms capable of evolving and forming their own models of interaction by building feedback connections.
- Diachronic emergence: the ability of AI to produce unpredicted results, not embedded in the original algorithms, but arising from long-term self-learning.
- The law of necessary diversity (W.P.Ashby): the principle according to which the complexity of a managed system requires an equally complex control mechanism.

These concepts are applied to existing research and practical examples of AI development and regulation in order to identify limitations of rigid control models and to justify the need for adaptive and multi-layered management strategies.

2 RESULTS

1. Modern neural network models have gone far beyond the harsh algorithms of the past. Their key feature was self-learning and the ability to find patterns not embedded in the source code. For example, the transform architectures underlying GPT-4 allow systems to analyze context and highlight important elements of information dynamically. This explains why the same model can generate text, write code, give recommendations and even develop scientific hypotheses (OpenAI, 2023). Another important aspect is the ability of neural networks to non-linear adaptation. The smallest changes in input data can lead to large-scale changes in model behavior. In 2023, one of Amazon's algorithms suddenly began to discriminate against women when selecting resumes, although he was initially trained on "objective" data. This example shows how hidden patterns can be formed without the explicit intervention of developers.

Traditional perceptions of AI imply that it is predictable. But the emergent properties of modern models suggest otherwise. Take, for example, generative neural networks for visual content. Midjourney, trained in millions of images, does not just combine styles - he is able to create unique artistic concepts that could belong to real authors. Modern AI systems confirm the presence of stochastic effects:

ChatGPT and GPT-4: Despite pre-set algorithms, models sometimes generate responses that include original synthesized ideas, or vice versa, erroneous information, which is due to the high complexity of their internal relationships.

Generative Visual Content Models: Tools such as Midjourney demonstrate the ability to create unique artistic images that go beyond the possibilities provided by the original learning data.

Autonomous systems: Modern Boston Dynamics robots and unmanned vehicles equipped with advanced microprocessors exhibit adaptive behavior when facing off-road situations (e.g., interpretation of changing road conditions in Waymo systems).

In terms of complexity theory, such situations can be interpreted as the ability of AI to demonstrate properties of unpredictability, make decisions independently, thereby demonstrating the properties of emergency. This property is the result of the interaction of many elements of a system and its surroundings, and it turns out to be untraceable to the sum of the properties of these elements.

Even highly specialized systems (such as face recognition algorithms) can exhibit emergent properties if their learning data contains hidden biases. At the same time, a hypothetical general AI capable of self-improvement is a much more complex system requiring a radically new approach to management (Vaswani et al., 2017).

AI as a complex system has the property of adaptability, the ability to integrate into the environment, change it for its own purposes. Adaptability allows AI systems to respond quickly to changing reality, offering fast-acting complex engineering solutions that can work effectively in different environments. In this context, AI shows a trend from less complex to more complex and organized forms of organization, acting as a complex self-organizing system.

2. It can be argued that we are witnessing and participating in a new stage of evolution of AI systems, where algorithms do not just perform certain functions, but constantly evolve, learn and find ways to circumvent the established rules. Modern artificial intelligence increasingly works not according to the “input - program - output” pattern, but turns into something much more alive, unpredictable and sometimes even rebellious against the limitations that developers and users try to set.

In this situation, the law of necessary diversity, proposed by one of the founders of cybernetics W.R. Ashby (1964), becomes particularly relevant from a methodological point of view. This law can be compared with the principle: “To manage chaos, you need your own dose of chaos”. If AI is able to analyze millions of scenarios and develop strategies on its own, the system for controlling it should be as flexible and diverse.

Once in the use of AI everything could be reduced to a set of transparent rules, but modern AI is a completely different story. For example, in 2023, Google tightened the filters for its chat bot Bard, but users have found loopholes and learned to circumvent restrictions by playing with requests. This is a clear indication that strict prohibitions simply do not work in a world where non-linear dependencies and adaptation prevail.

Social networks are not left out of these trends either. The YouTube, TikTok and Instagram algorithms do not just select content, they create whole “information bubbles” in which people see only what they like, and moderators can’t catch new, constantly changing user behavior patterns. The same thing happens with security filters in ChatGPT: even if you ban certain topics, users find a way to bypass the blocks using clever language.

If AI cannot be restricted to a rigid framework, then how can we make it work for the good and not against us? The most relevant solution is adaptive, flexible regulation. For example, autopilots in Waymo or Tesla cars - they do not blindly follow pre-programmed rules, but dynamically adapt to the rapidly changing road situation. If there is an unexpected obstacle in the way, the system does not just signal the error, it changes the route, finding the optimal solution. Similarly, in the world of finance, modern trading algorithms themselves adjust risk thresholds if they notice abnormal market fluctuations. There is no room for a rigid “ban” - only flexible adaptation, allowing the system to work in conditions of constantly changing reality.

But even the most advanced automated systems cannot replace human control where the stakes are too high. In critical areas, such as medicine or military technology, the individual remains the last resort of management. So,

autonomous drones can recognize targets, but the final decision about their attack always remains with the operator. And that's right, because in some cases only human thinking can take into account all the nuances of the situation.

3. The problem of controlling AI goes beyond engineering. It is an issue that touches both legal and ethical spheres. Laws regulating the use of AI are already in place in various countries. In the EU, for example, the Artificial Intelligence Act has been introduced, which strictly limits the use of mass observation and social cheer systems (Gureeva, Bevza, 2024). In the US, companies are required to disclose how their algorithms work so that users understand why they are being shown certain content. And in China, the control of AI is so strict that even facial recognition is under constant surveillance. In particular, DeepSeek demonstrates advanced adaptive management techniques: Chinese researchers note that DeepSeek is implementing a dynamic control system that provides continuous monitoring of the work of algorithms and operational correction of errors (Zhang, 2022). This example highlights that the Chinese approach combines strict government oversight with a domestic innovation policy of self-regulation, promoting a balance between safety and technological progress.

However, despite all these measures, the regulatory processes of AI are not keeping pace with the rapid development of technology. To solve this problem, it is necessary not only to introduce new laws, but also to create international standards that help strike a balance between innovation and safety. Mandatory certification of AI systems, explanation (transparency) of algorithms and global cooperation are the key tools for creating a control system capable of keeping up with progress. The paradox of modern AI is that the more we try to limit it, the smarter it becomes. In 2023, when OpenAI installed hard filters for ChatGPT, users soon discovered "jailbreak prompts", allowing to circumvent bans. It's as if you closed the door, and she started to find a way to open it. This phenomenon, called adaptive counter-reaction, is not only seen in chatbots, but in all the areas where AI is used: in finance, marketing, cybersecurity. Instead of trying to "lock" an AI under strict restrictions, we need to create conditions in which it will itself signal its anomalies and errors, allowing developers to react in time.

Thus, it can be argued that the old methods of AI control are outdated. Modern AI requires new approaches, flexible, adaptive and transparent. Tough bans are easy, and automated systems are already showing the ability to improve themselves by adapting to new conditions. Human control remains critical, especially in areas where the life and future of a person is at stake. On the one hand, the person remains the initiator, setting a common goal, but more and more often it is AI that offers ways to achieve it. Remember the story of autonomous cars, where AI systems are forced to choose between the lives of passengers and pedestrians. In these dilemmas, it is impossible to predict which solution will turn out to be "right" - and here our own experience and values come into play. Because when the algorithm starts to make decisions without human participation, we risk losing control of our own lives.

In today's world, questions of responsibility become particularly acute: if an AI-driven car crashes, who is to blame? Manufacturer, programmer or user who has trusted the system? These questions have yet to be answered unequivocally, and society today is forced to strike a balance between innovation and the need to maintain human control. This dynamic is becoming the subject of public debate, where experts and ordinary people ask: can we retain human dignity and control if machines increasingly take on functions previously available only to humans?

3 DISCUSSION

This article is mainly aligned with the theoretical framework of modern works devoted to the study of human and AI cooperation, AI control and ethical aspects of AI work.

Scientists from Fujian University in their study, using two popular large language models (LLM), tried to determine whether a self-replicating AI could reproduce uncontrollably. The results obtained during the experiment led scientists to express serious concern about some unexpected behavior. The evaluated AI systems demonstrated sufficient capacity for self-perception, situational awareness and problem-solving to achieve self-replication. Chinese scientists note that AI systems may even use self-replication to avoid stopping and create a replication chain to increase survivability, which could eventually lead to an uncontrolled AI proliferation. Researchers are concerned that we will eventually lose control of AI systems (Pan et al., 2024).

Russian researchers note that indeed, AI, like many other technologies of digital economy, remains poorly studied in the context of possible emergences. There are no relevant historical comparisons. "Already today the patterns of functioning of distributed organizational structures, the hierarchical economy, peer financing, and many other innovations in the economic mechanism radically change the contours of economic relations, that have been

built up for centuries. In the future neural network economy (sometimes referred to as "Neuronet"), to which progress in digitalization brings the planet literally by leaps and bounds, classical laws of economics may cease to work or are substantially transformed" (Kurnosova, Filippov, 2023, p. 500). The future of AI management lies in a combination of dynamic mechanisms, human participation and clearly defined legal frameworks. This is the only way to create a system in which technology works for the benefit of people, not against them. Today the question remains open: can a person create a control system, comparable in complexity to AI itself? Or are we approaching the point where a completely new era of technology and governance will come to replace established mechanisms? The American researcher E. Yudkowsky (2011), who believes that complex value systems in AI require harmonization with human morality to prevent threats, asks similar questions.

These questions make us think that the future - is not a struggle between man and machine, but a search for harmony in their coexistence, where each element of the system supports the other, creating a balance between freedom and security. Technology is not just helping us with everyday tasks, but it is becoming an active participant in our lives, influencing decisions that were previously made by people alone. Modern AI is no longer a passive tool - it acts as a partner, sometimes even unknowingly dictating what to do. When voice assistants help us choose music, and social network algorithms shape our information field, the important question is: who really controls our choice now? In this connection, the ideas of the Swedish philosopher N. Bostrom (2014) are relevant, arguing that once AI reaches a superintelligent level, its goals may diverge from human values, which generates unpredictable consequences.

One of the ethical aspects of using AI is the issues of fairness and bias. If the training of AI algorithms was done on a basis that includes discrimination and bias, then as a consequence, the algorithms will inevitably duplicate and even reinforce these points. It is to these aspects that the American researcher F. Pasquale (2020) draws attention, arguing that subordinating people to opaque decisions of AI deprives them of their right to humane treatment and is incompatible with human dignity. In this case, there is a legitimate question (objection) - the author discusses the shortcomings of AI, however, it would be more correct to call them the shortcomings of methods that underlie his work. In addition, it is possible to talk about the shortcomings of human goals and intensities in the use of AI.

The common theme in research on effective human and AI partnerships is that, while limiting the freedom of AI, we should not forget about the innovative potential of technology. Rigid, immovable prohibitions can only slow down development, whereas adaptive and multi-layered control systems (able to resonantly respond to various changes) allow AI to grow while remaining within safe use.

CONCLUSION

With the rise of AI capabilities, there is an urgent need for new rules that will not stifle innovation but, on the contrary, ensure security and sustainability. Limitations here do not act as boring barriers, but become a kind of "safety cushion" to avoid catastrophic mistakes. Technologies that are developing at an incredible speed present unique opportunities to us, but also raise questions of responsibility, transparency and fairness. We are on the threshold of a new era, where the cooperation between man and machine must become the basis for a stable and safe future.

New approaches to AI regulation are not just technical measures. This is both legal norms and codes of ethics, and, most importantly, dialogue between the state, business and society. After all, it is only by working together that we can create an environment where technology serves the human being and not vice versa. Restrictions become a tool that does not hinder development, but helps to steer it in the right direction, ensuring stability and security at all levels.

Our future depends on whether we can build a system in which legal, ethical and technical measures work in synergy, allowing AI to develop within the framework of certain human values. Thus, the challenges of today's era require us to rethink traditional approaches and adopt new, flexible and adaptive strategies. We must be prepared not only for the rapid technological progress, but also to manage it in such a way that it does not displace the human origin, but enriches it by making our life into a harmonious coexistence of human and man-made intelligence. This is the main lesson of complexity theory - to manage AI, you first need to understand and accept the idea that management is not control, but dialogue with the unpredictable.

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