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RESEARCH ARTICLE

Semantic features of complex technosocial systems: On the taxonomy of artificial intelligence technological packages

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Abstract

Objectives. The aim of this work is to enhance the scientific and methodological apparatus of artificial intelligence (AI) sciences by enriching their conceptual framework. The current conceptual framework of AI sciences does not reflect the intricate nature of this technological and socioeconomic phenomenon as possessing the diverse range of capabilities and the interconnectedness that allows for the imitation of human cognitive functions and comparable results. The author of the article structures the concept of the technological package of AI, describing its system properties, connections and functional elements based on the various types of human cognitive and operational activities.

Methods. The research is based on the concept (method) of technological packages—genetically and functionally connected sets of technologies with system properties.

Results. For the first time in Russian and international practice, the basic (general) taxonomy of the AI technological package has been specified and structured. A taxonomy of the AI metatechnological package (a package of metatechnologies) has been proposed. General taxonomy can serve as a tool for improving strategies, methodological documents and state programs to define the development of AI systems at state or industry level.

Conclusions. The suggested basic (general) taxonomy of technological package and taxonomy of metatechnologies package allows research to move away from the limited view of AI. It increases semantic and methodological clarity in relation to AI as a complex technosocial phenomenon and contributes to the harmonized integration of AI systems into the sphere of socioeconomic activities of the state. It can thus serve as a foundation for further improvement of state economic and legal regulation of AI development.

Keywords: artificial intelligence, information and communication technologies, technosocial systems, technological packages, meta-technological packages

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НАУЧНАЯ СТАТЬЯ

Семантические особенности сложных техносоциальных систем: к вопросу о таксономии технологического пакета искусственного интеллекта

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Резюме

Цель. Целью работы является совершенствование научно-методологического аппарата наук об искусственном интеллекте (ИИ) за счет обогащения их понятийного аппарата. Применяемый в настоящее время понятийный аппарат наук об ИИ не отражает сложной специфики данного технологического и социально-экономического феномена, как обладающего комплексом возможностей и соответствующих им взаимосвязей, позволяющих имитировать когнитивные функции человека и получать сопоставимые с ними результаты. С этой целью автор статьи структурирует понятие технологического пакета ИИ, описывая его системные свойства, связи и функциональные элементы сообразно видам мыслительной и деятельностной активности человека.

Методы. Исследование основано на концепции (методе) технологических пакетов – генетически и функционально связанных совокупностей технологий, обладающих системными свойствами.

Результаты. Впервые в отечественной и зарубежной практике уточнена и структурирована базовая (общая) таксономия технологического пакета ИИ, а также предложена таксономия метатехнологического пакета (пакета метатехнологий) ИИ. Общая таксономия может служить в качестве инструмента совершенствования стратегий, методологических документов и государственных программ, определяющих развитие систем ИИ на государственном или отраслевом уровне.

Выводы. Предложенные базовая (общая) таксономия технологического пакета и таксономия пакета метатехнологий позволяют отойти от редуцированного представления об ИИ, повышают семантическую и методологическую ясность в отношении ИИ как сложного техносоциального феномена и способствуют гармонизации интеграции систем ИИ в сфере социально-экономической деятельности государства, могут стать основой для дальнейшего совершенствования государственного экономического и правового регулирования развития ИИ.

Ключевые слова: искусственный интеллект, информационно-коммуникационные технологии, технологические пакеты, техносоциальные системы, метатехнологические пакеты

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GLOSSARY

Artificial Intelligence—the property of intelligent technological systems to perform creative functions that have traditionally been considered the prerogative of humans.

Taxonomy of technological package—systematized representation of key functional elements of technological package.

Technological independence—a set of measures aimed at the provision, development, and retention within the Russian Federation of human, financial, technological, and material potential aimed at the development of Russian industry, including through the predominant use of Russian industrial products, materials, raw materials, and technologies.

Technology package—a genetically and functionally related set of technologies that possess system properties. The technologies included in the package are interdependent, develop together and modify each other in the process of development.

Meta-technology package—a genetically and functionally related set of technologies that are influenced by the external environment. These technologies work together to transform the environment from its initial state to its final state.

INTRODUCTION

Artificial intelligence (AI) technologies at their current stage of development are becoming increasingly important in almost all areas of human activity. Not limited only to new products and services, AI has a transformative impact on established systems of economic, labor, social, and cultural relations [1].

Particularly in the economy, the introduction of AI systems can help to improve labor productivity, increase the efficiency of business processes and reduce costs. This, in turn, can lead to the creation of new markets and opportunities for accelerating economic growth. However, the introduction of AI can also significantly increase the risks of increased turbulence in the labor market by replacing professions that are by no means hard and unpopular, but are considered quite prestigious in society. Such an example can be seen in the capabilities of the ChatGPT-4 neural network in programming, technical writing, copywriting, and data analysis [2].

In the social sphere, the introduction of AI can lead to both the reduction of inequality, providing equal access to education, healthcare and other essential services, or, on the contrary, to an even greater exacerbation of social inequalities [1]. In modern socioeconomic conditions, AI technologies are a scarce resource due to their complexity and relatively low prevalence. However, their importance and demand are expected to increase. This circumstance can lead to a drastic escalation of social inequality, not only in terms of access to AI technologies and services, but also in terms of other essential resources, such as electricity and Internet communication, etc.

Thus, AI as a transformative technology creates technological tension: a misalignment of technological imperatives and social practices accepted in society [3]. Since these practices are deeply rooted, their forced change may result in innovative resistance in society [4]. This contradictory aspect of the adoption of new digital technologies indicates that the development of AI requires a comprehensive approach. This will involve analyzing and forecasting of potential social, economic, and cultural outcomes, risks and threats. It will also involve development of strategies and state programs to ensure the harmonious integration of AI systems into society. In this regard, it must be recognized that the current dominant view of AI in socioeconomic sciences and public administration lacks integrity at both the explanatory (concepts, principles, and semantic models) and impact (practices, methods, organizational, and activity models) levels.

The National Strategy for the Development of Artificial Intelligence until 2030 defines artificial intelligence as a set of technological solutions that enable the imitation of human cognitive functions, including self-learning and problem-solving without a predetermined algorithm. These solutions aim to achieve results that are at least comparable to those of human intellectual activity when performing specific tasks.[1] Nevertheless, in the practical sphere, AI is often understood either in a fragmentary way, i.e., as a set of unrelated ready-to-use "smart things" (tools) [5], or simplistically, as a universal and side-effect-free technological, economic, and managerial panacea [6]. Both examples of the reductionist approach to the understanding of AI contradict its nature as a complex multidimensional phenomenon that is constantly expanding its presence in more and more spheres of human activity at the individual and societal levels.

Reductionism, when applied to complex scientific and technological phenomena, greatly hinders accurate forecasting and planning for their development in order to promote economic growth and technological progress. Ultimately, it does not contribute to the harmonious adaptation of related innovations. Overcoming this circumstance requires a more effective methodological approach guided by the multidimensionality of AI. It is a complex scientific-technical, socioeconomic, and legal phenomenon that cannot be reduced to familiar examples of its applied use.

[1] Decree of the President of the Russian Federation dated October 10, 2019 No. 490 "On the development of artificial intelligence in the Russian Federation" (in Russ.). http://static.kremlin.ru/media/events/files/ru/AH4x6HgKWANwVtMOfPDhcbRpvd1HCCsv.pdf. Accessed May 23, 2023.

In this regard, this article refers to the concept (method) of technology package (TP) and applies it to AI by proposing a basic (general) taxonomy of AI TP. The methodological view of the AI TP as a package of technologies formulated in the article will allow the following actions to be performed:

- to structure the systems-relevant areas of integration of AI with humans at the individual and societal levels;
- to summarize the composition of the acts and systems of influences that AI has on these areas of systemic significance;
- to facilitate the harmonization of the concept of AI as a complex, multidimensional, and holistic phenomenon in both methodological and legal domains.

Previously, in Russian and international practice, the approach of considering AI as TP was not applied. This led to the aforementioned diminished understanding of AI, hindering the attainment of semantic clarity with respect to this phenomenon. The novelty of this article is based on the first attempt in Russian and international practice to structure the concept of AI TP. It describes the system properties, connections, and functional elements as a set of technological solutions that enable the imitation of human cognitive functions.

METHODS

In Russian scientific literature, TP is considered a genetically and functionally interconnected set of technologies and scientific and technical solutions with systemic properties [7]. The technologies included in the package are interdependent, developed together, and mutually modify each other during the development process. It is argued that TP, as a rule, fulfills one of the socially important needs [8]. In the context of AI, this requirement can be defined as the transfer of creative tasks, typically performed by humans, to intelligent systems. The aim is to lower labor expenses and enhance the effectiveness of carrying out these tasks by leveraging the capabilities of intelligent systems. This circumstance puts forward special requirements for the configuration of AI TP, emphasizing its human dimensionality (proportionality to a person). It also requires that the content and functionality of AI TP align with the values of individuals and society as both individual and collective subjects [9]. The human dimensionality in relation to AI necessitates the development of technological and humanitarian support to ensure consistent and harmonious interaction between AI and humans in all aspects of human life. Ultimately, this will lead to the convergence of human and AI capabilities within a single sociotechnological environment.

Let us try to structure the components of AI TP. As noted earlier, TP is a genetically and functionally related set of technologies with systemic properties. At the same time, TP elements should have interdependence and develop together, with the potential for mutual modification during the development process. TP has the following key structural elements: basic technology; basic ontologeme; closing technology; basic infrastructure; basic institutions (Fig. 1) [10, 11]. Let us consider them in more details.

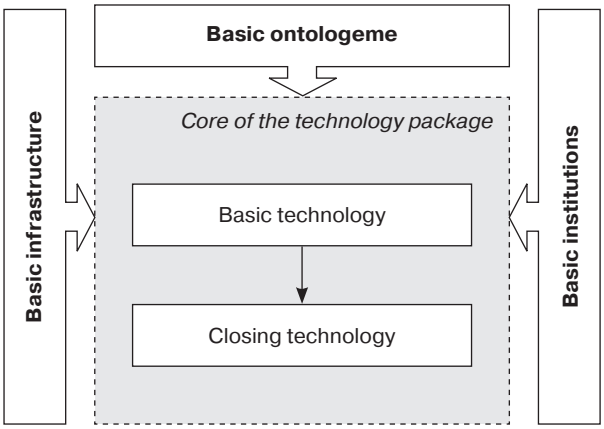

Fig. 1. TP key structural elements

Basic technology refers to the technology that enables the implementation of TP, which is the result of its development. With respect to AI, the underlying technology is machine learning, particularly deep learning [12, 13]. These technologies utilize sophisticated algorithms and neural networks to train AI systems and detect patterns in vast amounts of data. Machine learning and deep learning have now become the foundation for the advancement of various AI domains, including computer vision, natural language processing, and predictive analytics systems.

The basic ontologeme is a theoretical concept underlying TP. In other words, it is an idea that underlies the package notions. The basic ontologeme of AI is the ability to assign creative functions, which have traditionally been associated with humans, to intelligent systems. The same ontologeme determines the human dimensionality of AI.

Closing technology is a physical or humanitarian technology that combines a set of loosely related technologies into a systematically organized package. With respect to AI, a closing technology may be the development of what is known as "general artificial intelligence." This may be a thinking system capable of having multiple specific goals, switching between them, changing and updating them, including in an arbitrary order [14]. Modern AI systems can outperform humans in specific tasks, but the ability to freely switch between goals and update them is still exclusive to humans.

Table 1. Taxonomy of the AI TP key structural elements

Pos. No.	Key structural elements	Characteristics	Content
1	Basic technology	Realizes the possibility of TP implementation	Machine learning, deep learning
2	Basic ontologeme	Theoretical idea behind TP and the perceptions of it	Possibilities for delegating the creative functions traditionally inherent to human beings to intelligent systems
3	Closing technology	Completes a set of initially loosely coupled technologies into a systematically organized TP	Artificial General Intelligence: a system that is capable of having multiple specific goals, with the ability to switch between them, change and update them, and do so in an arbitrary order
4	Basic infrastructure	Critical infrastructure for TP development, the ultimate form of its implementation	Cloud computing, supercomputing, integrated data storage and analysis systems, specialized hardware
5	Basic institutions	Institutional solutions behind TP	Scientific and educational organizations, technology companies, startups, independent teams, authorities, communication platforms, regulations, standards

Basic infrastructure is a crucial infrastructure for the development of technology at a specific stage of technological and societal progress. The basic infrastructure is, in many respects, the ultimate realization of the TP. For example, in the case of nuclear energy TP, these are nuclear reactors capable of producing energy and generating new fissile materials. For AI, the underlying infrastructure includes cloud computing, supercomputers, integrated data storage and analysis systems, and specialized hardware such as graphics processing units and tensor processing units, all connected through networks and containers. These infrastructure elements provide the capability to process and analyze the enormous volumes of data needed to train AI models and offer scalability for the development and deployment of associated intelligent systems. The ultimate realization of this infrastructure can be achieved through Artificial Global Superintelligence [15]. This concept involves the creation of an integrated network of self-learning algorithms and super-powerful computing systems that span the entire world and are accessible for universal use. This hypothetical structure will be capable of processing and managing complex tasks in real time, predicting and solving global problems, and supporting the self-development and scalability of continuously improving AI systems [16].

Basic institutions are the foundational decisions that underlie TP. Basic AI institutions take into account the human dimensionality of this technology and, in many respects, mirror the structure of almost all significant social institutions. Their list includes:

- scientific research organizations (universities, laboratories, R&D centers, etc.), technology companies and startups;
- open source innovations and creative communities (open source projects and independent development teams);
- government authorities and international organizations which develop and support AI development programs and standards. This list also includes institutional mechanisms and standards for data protection, which regulate the use of AI and ensuring the safety, security and transparency of AI technologies;
- educational institutions and programs to ensure the development of skills and competencies required to work with AI technologies, and to keep knowledge up-to-date to adapt to the rapid development of this field;
- institutions and platforms that foster public discourse on ethical, legal and social issues associated with AI and ensure the participation of diverse groups in a collaborative engagement with AI.

The above listed structural elements of the AI TP are presented in Table 1.

RESULTS

The concept of AI as a TP allows us to consider this complex scientific and technological phenomenon in its entirety, including its technological, infrastructural, institutional, and social interactions. In this case, AI develops a comprehensive understanding of semantics within the methodological and regulatory framework. According to its functionality and the nature of connections within the framework of the TP concept, AI is a *technosocial system* comparable to a human being, *demonstrating tendencies towards dynamic and*

nonlinear self-expansion. The latter circumstance is due to the unique ability of AI as a technological object and non-trivial machine [17] to connect its own internal state in response to an external influence. First of all, this is expressed in the AI's ability for self-learning, such as machine learning and deep learning. It is this specificity of AI which requires further elaboration of its TP taxonomy. As noted earlier, AI is not a closed, isolated system. As a result of its self-learning nature which determines its dynamic development, AI is forced to be in a *state of reverse afferentation* [18]. It can adjust its behavior based on the information received from the surrounding technological and social environment. Receiving initial data from outside, AI, as a functional system, compares them with target settings (internal programs laid down by a human). Then, after analyzing them, it performs corrections to its activity (computational) acts. At the same time, a human being, in all of their interactions with AI and its service applications, functions as *a recipient of the outcomes generated by AI* [18]. In this capacity, *they do not act as an autonomous entity*, but rather *as a component within the functional system of AI*.

In this regard, it seems relevant to supplement the methodology of the AI TP by introducing the concept of metatechnology. Metatechnology is a technology that undergoes the effects of the external environment, transforming it from the initial state to the final state. In this case, the initial state is understood as our modern fragmented concept of AI, which consists of a collection of unrelated digital tools (things) with limited functionality. The final state is understood as AI that is equivalent to a human being, encompassing a wide range of human thought and activities. In other words, the ultimate goal of AI meta-technology is to create a cohesive system that includes various components such as systems, processes, and decision-making abilities. This system interacts with humans and has the power to significantly impact their lifestyle, thoughts, and actions. Furthermore, it has the potential to transform the way humans interact with both the social and technological environment (see Fig. 2).

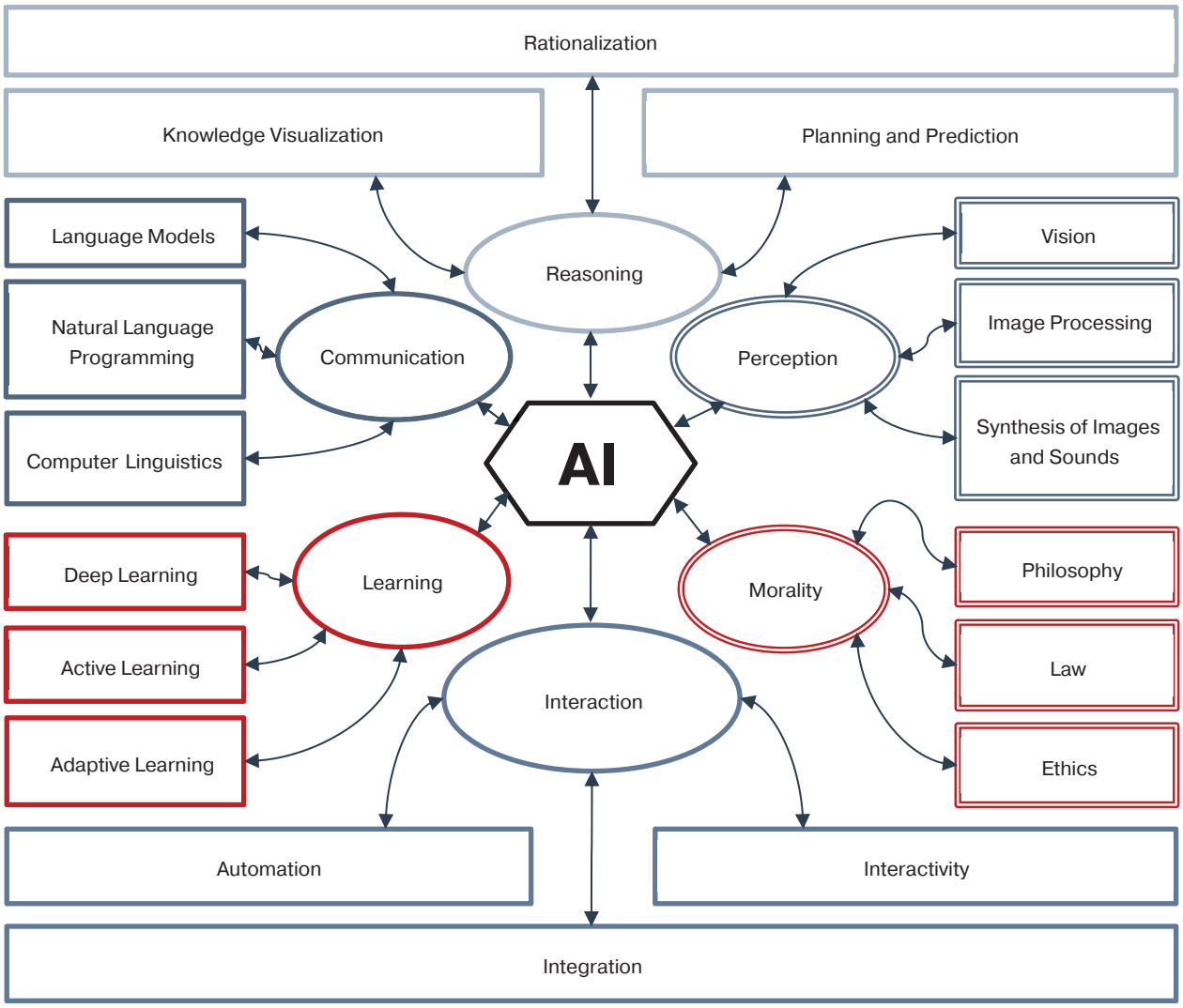

Fig. 2. AI in the space of the meta-technological connections

Table 2. Taxonomy of key structural elements of the AI meta-technology package

Functional element	Act of impact/interaction with a person	Key areas of the TP technological content
Reasoning	Knowledge visualization, automated reasoning, common sense reasoning	Case-based reasoning, inductive programming, causal inference, information theory, causal models, knowledge and reasoning representation
Planning	Planning optimization, search query processing	Bayesian optimization, hierarchical problem network, constraint satisfaction problems, metaheuristic optimization
Learning	Machine learning	Active learning, adaptive learning, generative adversarial network, generative models, deep learning
Communication	Interaction/programming in natural languages	Chatbots, natural language generation, computational linguistics, machine translation, conversational models
Perception	Computer vision	Action recognition, object recognition, face recognition
	Audio signals processing	Sound synthesis, speech recognition, sound source separation, speech synthesis
Integration and interaction	Multi-agent intelligent systems	Agent-based modeling, network intelligence, game theory, swarm intelligence, intelligent agents
	Automation and robotics	Cognitive systems, robotic systems, human-machine interaction
	Automated and automatic vehicles	Autonomous driving, unmanned systems, autonomous systems
Morality and ethics	AI ethics	Accountability, reliability, explainability
	AI philosophy	Philosophy of "weak (narrow) AI", philosophy of "strong (general) AI"

The taxonomy of the meta-technology package is designed to enable the transfer of creative functions, which have traditionally been performed by humans, to intelligent systems that operate on AI technological principles. Of course, at the current stage of systems development, it is not possible to delegate all the creative functions of a human being, whether as an individual or as a collective subject, to AI. The design of the meta-technology package deals with the fundamental functions that support the human creative process and creative communication. These functions include rationalization/planning, learning, communicative interaction, perception, activity interaction, and perception. Each of these functions can be easily associated with technological systems and AI components (Table 2).

The taxonomy of key structural elements of the AI meta-technology package incorporates:

- functional elements fully or partially associated with human creative functions: reasoning, planning, learning, communication, perception, integration and interaction, morality, and ethics;
- acts of influence/interaction of functional elements with humans: information and knowledge display, automated reasoning/rationalization, planning optimization, machine learning, natural language programming, computer vision, robotics and automation, integrated AI services, AI ethics;
- technological content allows for the performance of acts of influence or interaction between functional elements and a human being.

CONCLUSIONS

This study shows the need for AI to be moved beyond the narrow paradigm of its perception as a set of loosely coupled technological tools isolated from the multidimensional social context in which they can be applied. On the contrary, due to its ability for self-learning and its demonstration of limited tendencies towards self-development, AI should be viewed as an evolving complex technosocial phenomenon, as a technological package that includes technology, social relations, infrastructural elements, institutional support, among other factors.

This paper presents such a structured representation of AI for the first time in Russian and international practice.

At the same time, considering the intricate nature of AI as a set of technological solutions that mimic human cognitive functions and achieve comparable results to

human intellectual activity in specific tasks, this study introduces and provides theoretical support for the concept of AI meta-technology.

It is deemed to be a technology which transforms under the influence of the environment and acquires a qualitatively new state, namely, the state of AI commensurate with a human being, included in the maximum number of types of human thought. The significance of this new concept is emphasized by the specificity of AI as a rapidly evolving phenomenon. At present, there is no finalized theoretical and methodological framework capable of encompassing all the features of AI.

Within the framework of the TP concept, AI inevitably acquires economic, social, legal, and cultural significance, becoming a truly cross-cutting technology that permeates practically all spheres of human life. This fact highlights the need for new requirements in the strategies, methodological documents, and state programs that govern the development of AI systems at both the state and industry levels. In the technosocial dimension, the AI development strategy should encompass all areas where it can be implemented, using a comprehensive multifactor model to assess the potential opportunities, risks, and threats associated with the introduction of this transformative technology.

The perception of AI as a package of technologies contributes to the holistic semantic representation of this technology in the methodological and regulatory legal environment. This will facilitate harmonized AI implementation at the state and sectoral levels. It will reduce technological tension in society and, consequently, alleviate certain social contradictions caused by the implementation of new technologies.

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