Digital Scientists and Parallel Science: The Origins and Objectives of AI4S and S4AI (Postprint)

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Abstract

Focusing on recent advances in large-scale artificial intelligence (AI) model technology, this paper discusses the role of parallel intelligent technology integrating artificial and natural systems and digital human scientists, as well as their potential impact on transformations in research paradigms and social forms, from AI4S (AI for Science) to S4AI (Science for AI); it argues that such paradigm and form transformations are imperative and must be proactively addressed.

Full Text

Digital Scientists and Parallel Sciences: The Origin and Goal of AI4S and S4AI

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Abstract

Recent developments in artificial intelligence (AI) and large foundation models have sparked both astonishment and anxiety. Following AlphaGo and ChatGPT, how rapidly will new intelligent technologies iterate? When will the next "hotspot" emerge, and in what direction? Will "superintelligence" that threatens humanity truly arrive? Many such questions are not scientific in nature and cannot be answered scientifically. However, there is no doubt that AI

—this emerging intelligent science and technology—will accelerate its iterative development under the dual 加持 of continuously enhanced computing power and rapidly growing data. Human society must prepare for the societal impacts of new intelligent technologies that will far exceed those of AlphaGo and ChatGPT. As scientific and technological workers, we must also contemplate whether intelligent technologies, which originated from science, can transform current methods of learning, researching, organizing, and implementing scientific projects and engineering. If so, how quickly? Furthermore, are we about to enter, or have we already entered, an era of great transformation similar to the shift from agricultural to industrial society? In other words, has the industrial age—beginning with the power revolution and culminating in the information revolution—already ceded its central historical role to the "intelligence revolution" represented by AI, giving rise to an "Intelligent Industry Society" ? The various forms of digital technology and organization, such as metaverses, Bitcoin, NFTs (non-fungible tokens), DAOs (decentralized autonomous organizations), DeSci (decentralized science), and AI4S (AI for Science), as well as new operational service models and entrepreneurial forms, represent merely the tip of the iceberg of this "Intelligent Industry Society." However, we must recognize that technological progress alone cannot enable humanity to truly understand the essence of the "Intelligent Industry Society," let alone effectively construct this new social form. Therefore, we must transform our inherent modes of thinking and philosophical systems, re-examining fundamental concepts such as virtual versus real, number versus intelligence, matter versus spirit, and being versus becoming, along with their new interactions and relationships in this emerging social formation. From this fresh perspective, we must promote the development and integration of "New Liberal Arts," "New Sciences," and "New Engineering" to guide and serve the rising "Intelligent Industry Society." This paper explores these issues, particularly the potential transformation of science and technology they may trigger.

Keywords: artificial intelligence, intelligent science, parallel intelligence, foundation models, digital scientists, parallel sciences, DeSci

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1. Research Scope

This paper does not intend to debate whether industrial society has fully unleashed all the productive forces it can accommodate, because intelligent technology will greatly enhance and redefine the productive forces of industrial technology. Clearly, "Intelligent Industry" represents the intelligentization and morphological sublimation of industry; the two should not be opposed. We must understand that the primary task of intelligent technology (new IT) is to transform and expand existing industrial technology (old IT) and information technology (old IT), thereby transforming current social industry forms and research operation paradigms. The "de-industrialization" previously seen in some Western countries—transferring so-called "high-energy-consumption, heavy-pollution,

labor-intensive" manufacturing industries—has led to dissatisfaction with the resulting new global production and geopolitical patterns, triggering a new round of international conflicts and turmoil. This serves as a warning and lesson for every developing country.

Whether the existential conditions for "Intelligent Industry" are mature remains unclear. However, current AI technologies and applications clearly demonstrate that the social form of "Intelligent Industry" has already begun: big data has become new production material, blockchain smart contracts have formed new production relations, and AI and robots have become new productive forces. Today, phenomena ranging from AlphaGo, ChatGPT, metaverses, Bitcoin, and NFTs to DAOs, DeSci, and AI4S, along with various digital technologies and organizational forms, represent the tip of the iceberg of the "Intelligent Industry Society." Following "Industry 4.0," the EU released its "Industry 5.0" framework in 2021, aiming to use AI technology to lead Europe toward a sustainable, human-centric, and resilient industrial society [11,12]. Current consensus in international academia and industry holds that the core concepts of Industry 5.0 are "knowledge automation" and "cyber-physical-social integration" (Figure 1 [Figure 1: see original paper]), whose essence is virtual-real parallel collaboration in parallel technology and parallel industry. Its important manifestation is the emergence of "New Liberal Arts," "New Sciences," and "New Engineering."

2. Current Status and Prospects of Research Paradigm Development

2.1 Current Development Status Since early 2021, numerous universities, societies, and companies related to intelligent technology in Western developed countries—including Stanford University, NVIDIA, and Scale AI—have continuously promoted foundation models, metaverses, and collaborative robots through reports, speeches, and product releases. They claim this technological revolution will increase industrial efficiency by 1,000 times within the next decade, warning that frontier enterprises with average annual growth below 20% will fall behind or be eliminated within ten years [6]. Beyond the well-known large language and vision model technologies [7-10], NVIDIA' s industrial metaverse platform (Omniverse) is transforming manufacturing. Many previously closed industrial software companies (such as MathWorks and Autodesk) have voluntarily joined Omniverse, while international giants like Siemens, General Motors, and BMW use Omniverse for virtual-real collaborative parallel manufacturing and production. Some experts believe these technologies will transform manufacturing from mass production to green, personalized, and sustainable production, reshape the primary and secondary industries, and "harden" the tertiary industry, which is currently service-dominated. AI agents and blockchain technologies will technologize traditional "liberal arts" functions such as organization, management, coordination, and execution, turning them into "New Sciences" and "New Engineering" that will become the mainstay of future "Intelligent Industry" and redefine the "tertiary industry" [1].

The industrial world and young people have already begun transforming their

organizational and behavioral paradigms. As the scientific and technology community that hopes to lead industrial development and the new generation, we must urgently and fundamentally change professional culture and knowledge-based forms, vigorously promoting broad and profound transformations in scientific and technological paradigms.

2.2 Future Prospects The international youth generation is vigorously promoting the Web3 and DeSci movements through blockchain intelligence [5]. In fact, science has mainly existed in DeSci form since its birth; the introduction of smart contracts, NFTs, and DAOs will make DeSci penetrate every corner of society. The younger generation will become the most basic scientific and technological force and the main army of the primary productive force for industrial development in the future "Intelligent Industry Society," thus becoming the main driving force for transforming research paradigms and social forms.

3. Research Foundation Models: Parallel Technology and Digital Human Scientists

3.1 Three Types of Scientists As discussed in [2], we have entered a "Third Axial Age" of jointly developing Karl Popper's three worlds—"physical," "mental," and "artificial" —through the combined development of "old," "old," and "new" IT technologies. This era features a third wave of globalization characterized by win-win, inclusive, and "positive-sum" outcomes—a perspective far broader than that of language large models (LLMs) and vision large models (LVMs). Current large model technologies indicate that the most direct and natural way to transform industrial and research forms is to parallelize nature and artificiality, extending from natural science to artificial science and from material production to artificial manufacturing, introducing digital humans and robots to work in parallel with biological humans [13,14]. For the new research paradigm, this means "three worlds, three types of scientists" : "digital scientists," "robot scientists," and biological scientists together constitute parallel scientists, accounting for more than 80%, less than 15%, and less than 5% of research team composition, respectively (Figure 2 [Figure 2: see original paper]).

The alignment and prompting work triggered by large model technology, along with the emergence of prompt engineers, indicates that a considerable volume of future research work will be attributed to these roles. The trend shows a shift from "big problems, big models" to "small problems, big models" with vertical specialization. This trend, combined with further development around large models [15-19] and the maturation of intelligent agent technology [10,14,20], naturally defines and introduces a category of "digital scientists" for research-oriented "small problems, big models."

Simultaneously, we must introduce "robot scientists" for many research activities beyond digital forms, particularly high-risk and labor-intensive scientific experimental work. In the near future, from DeSci to autonomous scientific experiment factories and unmanned research test factories will become impor-

tant components of the "Intelligent Industry Society." The industrialization of research factories is an inevitable trend, and "robot scientists" will be their key support.

3.2 Parallel Science Scientific research has evolved from scientists' initial observations and experiments in nature to laboratory-based observation and testing, and today to computational or theoretical experiments using mathematical reasoning. The emergence of large models makes large-scale virtual parallel experiments using artificial systems a reality, whose impact will far exceed the effectiveness and benefits of traditional computer simulation experiments. It also provides new alternative pathways for many "counterfactual experiments" in social sciences, which will inevitably promote the integration of "New Liberal Arts," "New Sciences," and "New Engineering."

Thus, future research models will initiate a "three worlds, three modes" parallel research "day": "AM" (Autonomous Mode), accounting for over 80% of research work, which will be completed autonomously by "digital scientists" and "robot scientists." "PM" (Parallel Mode), accounting for less than 15%, where biological scientists must intervene and guide remotely or via the cloud to complete research projects. "EM" (Expert/Emergency Mode), accounting for less than 5%, where biological scientists must take the lead on-site with digital and robot assistants to complete corresponding research tasks.

The foundational technologies supporting this parallel research vision have already emerged: "alignment" and "prompting." However, the corresponding scientific and technological workers will not only avoid unemployment but will increase substantially in number, though they will be "delivery rider-ized." Preliminary calculations indicate this could improve research efficiency by more than 960 times [21].

4. Scientific Origin and Goals: AI4S and S4AI

The British mathematician and philosopher Whitehead once believed that modern scientific thought originated from the "artificial" arrangement of fate in ancient Greek tragedy, thus embarking on a scientific journey to explore the laws behind natural phenomena. Additionally, Simon [23], one of the founders of artificial intelligence, proposed the concept of "Sciences of the Artificial." AI, born from the philosophy of "love of wisdom," is now accelerating scientific development and changing research paradigms through AI4S [3,4]; recent applications and achievements of AI4S in materials science [24,25] have been remarkable.

As researchers, we must also examine all this from the reverse perspective of S4AI, particularly SS4AI (Social Science for AI), whose core concerns the ethics and governance of AI and broader intelligent science and technology. We must recognize that from AlphaGo to ChatGPT, current frontier AI technologies remain uninterpretable, and generalized intelligence is inherently unexplainable

scientifically. However, AI can be unexplainable yet must be governable—this is the goal of S4AI.

Blockchain, smart contracts, DAOs, and DeSci have already transformed "governance" from a liberal arts domain into a hard science and engineering category. New encryption technologies and federated methods, from NFTs, lightning networks, and federated learning to federated intelligence and federated ecosystems, have further made the governance of intelligent technology a reality, but these technologies remain insufficient. The introduction of "digital scientists" provides a new perspective for S4AI and AI governance: the education and cultivation of digital humans and digital scientists [25]. As envisioned in parallel education research, through digital schools and digital research institutes, biological and digital humans can simultaneously learn and train in various educational and research foundation models, interacting and promoting each other to make "alignment" and "governance" a long-term continuous engineering process, much like the education and research processes humans themselves undergo [26,27]. Figure 3 [Figure 3: see original paper] illustrates the "alignment" cultivation of parallel education and parallel research.

These ideas may seem somewhat ahead of their time, but given the current development trends and application momentum of large model and intelligent agent technologies, they appear to be inevitable outcomes. Therefore, we should dare to research, implement cautiously, and ensure that AI and intelligent technology benefit humanity while promoting the healthy and sustainable development of the entire ecosystem.

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Note: Figure translations are in progress. See original paper for figures.