

# New Generation Artificial Intelligence-driven Intelligent Manufacturing (NGAIIM)

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**Abstract**— In order to embrace new generation artificial intelligence to upgrade manufacturing industry, we propose the concept of new generation artificial intelligence-driven intelligent manufacturing (NGAIIM), which is a new manufacturing paradigm integrating human/machine/environment/information into product lifecycle activities. First, we introduce new generation artificial intelligence. Second, we present NGAIIM connotation, NGAIIM architecture and its technology system. Then, we examine a NGAIIM use case - CASICloud. Finally, we provide suggestions for directing the NGAIIM development.

**Keywords:** Artificial Intelligence, New Generation Artificial Intelligence, Intelligent manufacturing, Big Data

## I. INTRODUCTION

The future of industry will reward innovation, openness, sharing, green manufacturing, and the development of human talent. To promote these long-term development goals, China proposed "Made in China 2025" for building a strong nation by 2025, whose overall strategy is innovation-driven, quality-first, green development, structural optimization, and talent-based for fully leveraging emerging technologies [1]. These technologies are highlighted by the Internet of Things (IoT) [2], big data [3], cloud computing [4], 3D printing [5], Blockchain [6], and new generation artificial intelligence (NGAI) [7], etc. With the rapid development of mobile terminals, sensor networks [8], service-oriented computing [9], vehicle network [10], traditional AI is being overtaken by new generation artificial intelligence, which takes on features of big data intelligence, group intelligence, hybrid human-computer intelligence, cross-media reasoning, etc.

As one of the mandated technologies driving "Made in China 2025", NGAI promotes the transformation of production-oriented manufacturing to service-oriented manufacturing through interconnecting the physical and information worlds. NGAI is expected to support deep intelligence insights into the entire product lifecycle, from demand acquisition, design, manufacturing and operating services, maintenance and recycling. In addition, NGAI plays an important role in network collaborative manufacturing, and personalized customization, etc. For example, NGAI enables intelligent control, monitoring, and failure prediction in a product machining process.

There are few reports discussing the relationship between new generation artificial intelligence and intelligent manufacturing. We propose the concept of NGAI-driven

intelligent manufacturing (NGAIIM) for accelerating the utilization of NGAI into intelligent manufacturing. In addition, we introduce the progress of NGAIIM with the research and development of CASICloud [11].

The remainder of the paper is organized as follows. Section 2 introduces NGAI. Section 3 defines NGAIIM and identifies its features. Section 4 presents the NGAIIM system architecture. Section 5 presents technologies enabling NGAIIM. Section 6 introduces our NGAIIM practice on CAISCloud. Section 7 concludes the paper and gives suggestions directing the future NGAIIM development.

## II. NEW GENERATION ARTIFICIAL INTELLIGENCE[12]

### A. Definition

After experiencing its birth, development, and recent commercialization, artificial intelligence is booming and entering a new rapid development stage, which is called New Generation Artificial Intelligence (NGAI). In this paper, we define new generation artificial intelligence as the artificial intelligence based on the new information environment, new computing technologies, and new application development goals. The new information environment is comprised of the continually expanding Internet, increasing mobile devices, social media and networks, sensor networks, etc. New computing technologies include big data, high-performance computing, and new approaches and algorithms for machine learning, etc. New application development goals include smart cities, digital economy, intelligent manufacturing, smart healthcare, smart homes, intelligent vehicles and so on.

### B. Driving forces

With the rapid evolution of information communication technology such as mobile Internet, big data, and cloud computing, NGAI has the following driving forces:

- Rapidly expanding big data. Thanks to the proliferation of the Internet and various cyber-physical systems, the amount of data is dramatically growing, which provides the opportunity for insights through deep learning.
- Rapidly increasing data processing speed and improving computing power. The emergence of specific chips for artificial intelligence such as graphics processing units (GPUs), Neuronal Processing Units (NPU), and Field-programmable gate arrays (FPGAs) enables

machines to process big data faster.

- Deep learning breakthroughs. Deep learning has achieved state-of-the-art results across a range of difficult domains over the past years [13-15]. Deep learning algorithms have been widely used in natural language processing [16], speech processing [17], and computer vision [18, 19]. Supervised learning is evolving into semi-supervised and unsupervised learning. Machines are now beginning to distinguish objects and translate speech in real time.
- Increasing capital investment. Increased capital investing artificial intelligence helps the AI industry and start-up companies to rapidly and continuously escalate the AI business.

### C. NGAI characteristics

Driven by the above-mentioned forces, NGAI is evolving from simulating human intelligence to assisting human intelligence through the interconnecting of machines, people, and the Internet. NGAI has the following major characteristics:

**Big data-fueled artificial intelligence.** Increasingly, big data is the cornerstone for the renaissance of artificial intelligence. Unlike early reasoning-based artificial intelligence, NGAI is powered by big data for building optimal learning models through inputting big training data into the model and determining optimal parameters for the model. For example, after trained with thousands of human-played games and self-playing millions of games [20], AlphaGo defeated the top Go player in the world.

**Cross-media artificial intelligence.** NGAI is oriented to comprehensively process text, image, voice, and video information to gradually approximate human intelligence. NGAI aims to imitate human beings' perceptions such as vision, speaking, and listening and achieve the functions of recognition, reasoning, self-design, prediction, etc.

**Web-based group artificial intelligence.** Intelligence could be enhanced and enriched through grouping the participation and interaction of individuals on the Internet. NGAI is expected to create a multi-agent synergistic group intelligence through studying group intelligence theory, and organization, incentive mechanisms, etc.

**Hybrid human-machine synergized artificial intelligence.** NGAI takes account of the people in the loop of using artificial intelligence, and this takes advantage of machine intelligence in search, calculation, storage, optimization, and human intelligence in perception, reasoning, induction, and learning.

## III. NGAIIIM DEFINITION AND IDENTIFICATION

### A. NGAIIIM definition

NGAIIIM aims to realize manufacturing intelligence in product design, process, manufacturing, quality control, production management and service with the use of data modeling, processing, analysis, visualization and management.

NGAIIIM promises to achieve efficient, high quality, cost-saving, green, and flexible production, thereby increasing the market competitiveness for enterprises. NGAIIIM features autonomous and intelligent perception, interconnection, collaboration, machine learning, data analysis, decision-making, control and execution, all interacting with human, machine, environment, and the information involved in all product lifecycle activities.

### B. NGAIIIM identification

From a technical perspective, combining the Internet of Things, artificial intelligence, NGAIIIM mainly examines and visualizes big data collected from a product lifecycle, and realizes intelligent information systems in all product phases, including enterprise resource planning (ERP), manufacturing execution system (MES), Supply Chain Management (SCM), Product Lifecycle Management (PLM), Customer Relationship Management (CRM), and Process Control System, etc. Based on the ubiquitous network, with the integration of manufacturing know-how and information communication technology (ICT), NGAIIIM is expected to form a unified user-centered cloud platform that manages manufacturing resources, products, and capabilities, and enables users to efficiently access manufacturing resources on-demand and anywhere through the mobile or static terminals.

From an application perspective, NGAIIIM supports applications such as visual description, control, and decision-making based on data processing and management so as to enable intelligent design, intelligent manufacturing, networked collaborative manufacturing, intelligent service, and personalized customization, etc. NGAIIIM stores the production results in the form of standardized data, and continuously optimizes production lifecycle management and cooperation from production equipment to control level, from workshop management to enterprise operation level, all along the industrial business chain.

From a resource management perspective, NGAIIIM aims to optimize production resource and their flows involving in product lifecycle activities. Resources consist of people, technology/equipment, management, data, materials, funds (so called "six elements"). Flow consists of human, technology, management, data, logistics, and capital flow (so called "six flows").

From the manufacturing perspective, NGAIIIM creates a new intelligent manufacturing mode characterized by being user-centered, human/machine/environment/information fusion, interconnected, service-oriented, personalized customization, flexible, and socialized.

From the industry ecosystem perspective, NGAIIIM-based ecosystem is ubiquitous interconnection, data-driven, shared services, cross-border integration, and innovation.

## IV. NGAIIIM ARCHITECTURE

Fig. 1 illustrates NGAIIIM system architecture, which consists of four layers.

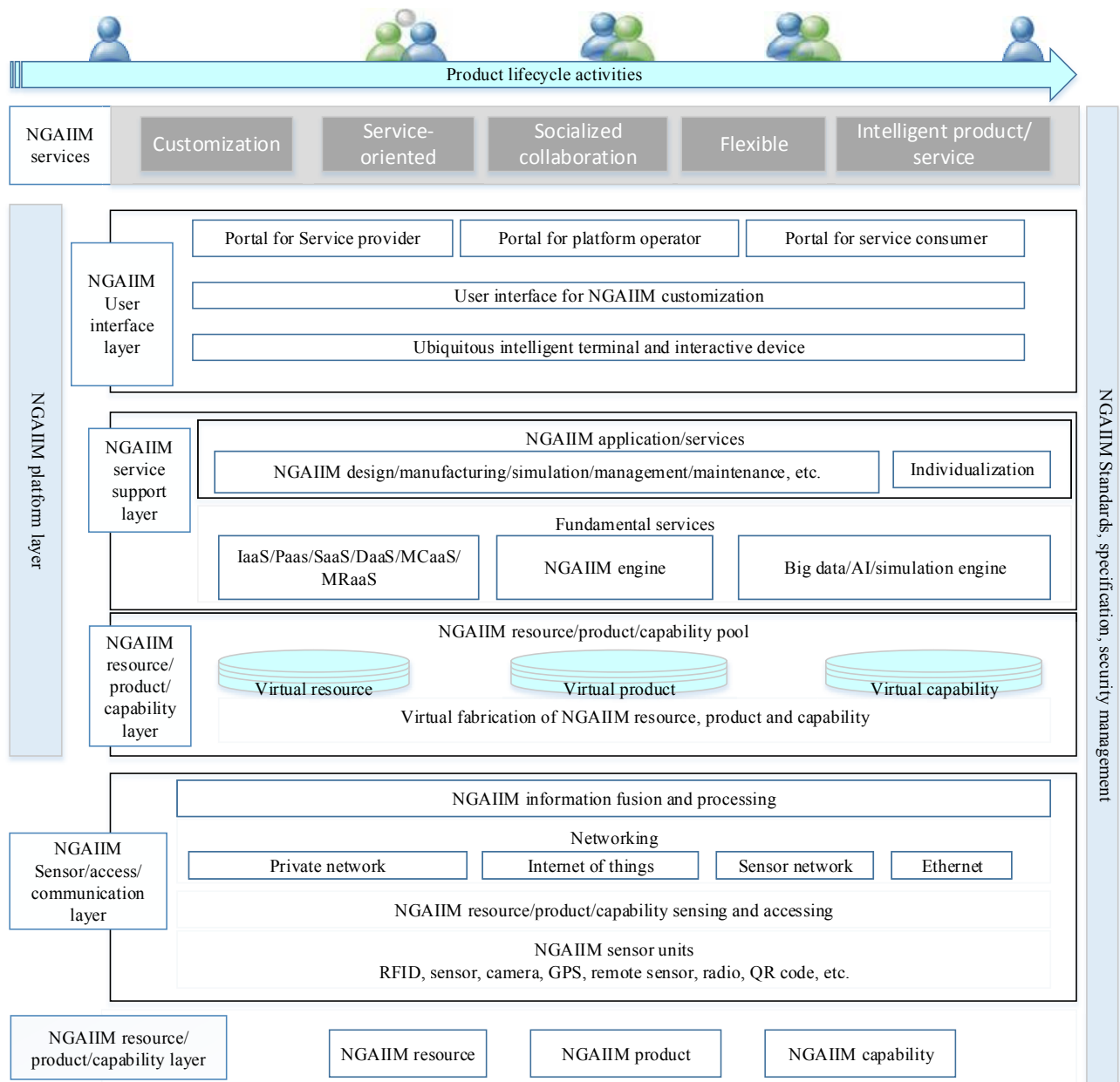


Figure. 1. NGAIIM system architecture

(1) Resources/capabilities/products layer. Includes various software/hardware resources, professional capabilities, and products.

(2) Sensing/access/communications layer. Connects various types of physical hardware/software resources/capabilities/products to networks through sensing, IoT, and terminal technology. The ubiquitous awareness and interconnection provide support for capability virtualization and service invocation. At the same time, this layer provides support for edge computing to process data locally.

(3) Platform layer. Consists of three sub-layers: virtualization, service support, and user interface. The user interface layer provides portals for the service provider, platform operator, and service consumer. The service support

layer provides fundamental services such as IaaS and simulation engine for application development. The Virtualization layer virtualizes resources/product/capability into service pool for responding to intelligent manufacturing activity requests.

(4) Service layer. Provides a new mode of intelligent manufacturing which is characterized by being highly interconnected and collaborative, service-oriented, flexible, social, intelligent, and personally customizable.

## V. NGAIIM TECHNOLOGY SYSTEM

Fig. 2 illustrates the NGAIIM technology system. It mainly consists of

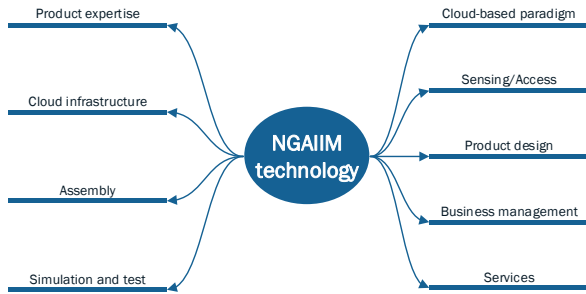


Figure 2. NGAIIIM technology system

- Cloud-based paradigm (e.g., NGAIIIM-driven business model, system integration, system architecture, standardization, system development and application, and security),
- Sensing/access technology (e.g. Internet, IoT, vehicle network, etc.),
- Product design (e.g., crowd intelligence-oriented design, cross media-design, etc.),
- Business management (e.g., big data-driven project management, enterprise management, quality management, etc.)
- Service technology (e.g., pre-sale/post-sale maintenance, value-added services, etc.)
- Product expertise (e.g., service-oriented)
- Cloud infrastructure (e.g., virtualization, simulation engine, pervasive human computer interface, etc.)
- Assembly (e.g., industrial robotics, 3D printing, etc.)

- Simulation and testing (e.g. big data-driven modeling and simulation, cloud-based simulation, etc.).

## VI. NGAIIIM USE CASE - CASICLOUD

Based on our R&D on the Chinese aerospace industry and the pioneering experience in the industrial Internet, we applied NGAIIIM into the development of the first China's industrial Internet platform: CASICloud [21]. This platform efficiently integrates and shares high, medium, and low-end industrial resources at home and abroad. CASICloud provides core technologies of resource virtualization, capability-based service, and product-based service for intelligent manufacturing.

China's manufacturing currently coexists at different levels of development: Industry 1.0, Industry 2.0, and Industry 3.0 enterprises. CASICloud can be used by all industry levels to provide enterprises, governments, and entrepreneurs with a comprehensive "Internet + Intelligent Manufacturing" solution covering the entire industry chain and production life. NGAIIIM is expected to leverage Chinese industry 1.0/2.0/3.0/4.0. This section focuses on the architecture of CASICloud, its artificial intelligence system, and the user cases.

### A. CASICloud system architecture

Fig. 3 illustrates CASICloud architecture, which consists of Device, IoT, Access, INDICS platform, Service and application layers. The INDICS platform provides small to medium enterprises (SME) with successful access to intelligent factories, the industrial cloud, industrial big data, and intelligent services.

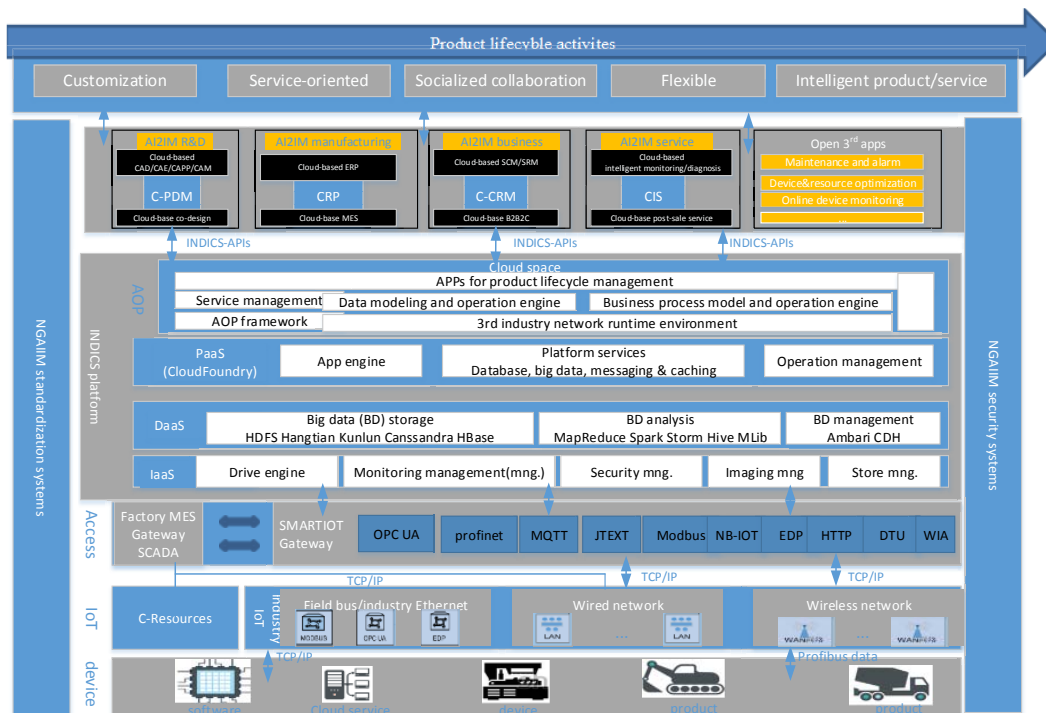


Figure 3. CASICloud architecture

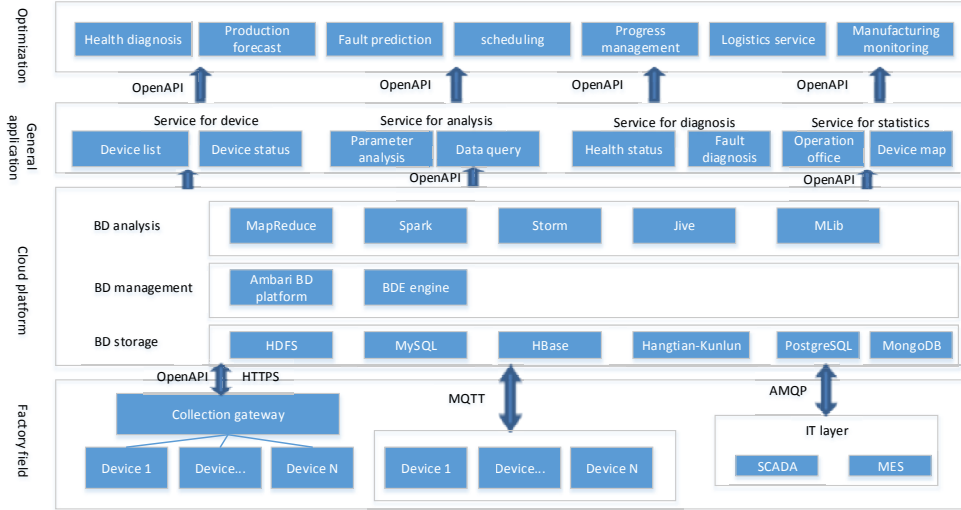


Figure 4. CASICloud big data/AI system

### B. user cases

#### 1) CASICloud big data/AI system

Figure 4 presents CASICloud big data/AI system, an industrial big data/artificial intelligence subsystem, which consists of optimization, general application, cloud-based big data platform and factory field layers.

#### 2) Key technology for CASICloud big data

The key technology covers big data integration, cleaning, storage and management, analysis and mining, visualization, standards and quality, and big data security [24].

In the big data integration and cleaning, we used Extract-Transform-Load (ETL) to clean and convert the redundant and dirty data created by operating equipment so as to achieve effective access to equipment data. We monitored data quality for massive enterprise's data storage and management based on time series and columnar database, distributed historical data storage, and document database.

We implemented off-line analysis and mining for overall equipment effectiveness (OEE) based on Hadoop. We implemented real-time fault diagnosis based on Storm. We realized the visualization of enterprise data based on Business Intelligence (BI). We studied data encryption, backup, and access authority to maximize data security.

With the above big data intelligence technology, CASICloud is able to upgrade and enhance the competitiveness of enterprises through informatization, industrial IoT device interconnection, cross-border data exchange, business optimization, etc.

#### 3) Applications

Currently, the industrial big data subsystem of the CASICloud has achieved impressive results in R&D, production, operation and maintenance. For example, during aerospace cable design, we saved the development time using the cable design tool E3 based on the historical big data and integrated flight performance data.

Another example is Hangtian-based production scheduling, which collects and monitors multiple CNC machining centers

through cloud-based Manufacturing Execution System (MES), and schedules and optimizes production resources across different locations for large-scale cooperation of aerospace products.

## VII. CONCLUSION AND FUTURE

Big data and artificial intelligence are key technologies for intelligent manufacturing. Deep learning plays an indispensable role in intelligent design, intelligent production, networked manufacturing, intelligent services, and personalized customization. In this paper, we introduce the new generation artificial intelligence that brings the concept of NGAIIIM; we examine NGAIIIM from the perspectives of technology, application, resource management and industry ecosystem; we present the NGAIIIM architecture and outline its technology system; in addition, we present a user case of NGAIIIM-driven CASICloud.

NGAI in intelligent manufacturing is still in its infancy. We take the lead in studying NGAIIIM to integrate NGAI into R&D on manufacturing intelligence. At present, NGAIIIM faces many issues, such as the standardization of manufacturing product big data, IoT equipment control technology, seamless information integration, and big data security. In the future, we will further research and develop NGAIIIM by applying the latest technologies such as cloud computing, the Internet of Things, artificial intelligence, and 5G to the following three principles:

(1) NGAIIIM is a new intelligent manufacturing mode, which fully leverages the upgraded technology of Internet, big data, artificial intelligence. NGAIIIM presents a new technology that accelerates the development of intelligent manufacturing.

(2) NGAIIIM is under development. Its development needs the coordination and collaboration of NGAIIIM technology, NGAIIIM application, and NGAIIIM industry. Its development path should persist in the innovation-driven integration of industrialization and informatization.

(3) NGAIIIM development and implementation also require cooperation and exchanges between at home and abroad. At the same time, NGAIIIM should pay attention to the differences of various industries and enterprises.

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