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Industrial Software Integration and Identification Resolution Path

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Abstract: Industrial software integration is the foundation that supports the production and digital transformation of industrial enterprises. It is also the core for realizing product lifecycle management. The identification resolution path is key to realize the interoperability of all industrial elements and is thus conducive to the deep integration of industrial software. In view of the data and business islands faced by industrial software integration in China, we analyze the demand for industrial software integration from the perspectives of product design and production, quality information traceability, and production–finance integration. Subsequently, we examine the development history of industrial software integration in China and abroad and summarize the challenges from the perspective of data interoperability and full-set software procurement. Additionally, we propose the development idea of combining industrial software integration with identification resolution, focusing on the physical gateway, interface platform, and cloud component technology. The idea includes the technical architecture, identification resolution technology path, data management mode, and core functions. Finally, we suggest promoting the coupling of the identification resolution system with industrial software from the aspects of development of the industry drive, corporate culture, and talent support.
Keywords: industrial software; identification resolution; information islands; digital transformation

1 Introduction

In recent years, novel production and organizational methods and business models have continued to develop with the vigorous advance of information technologies such as cloud computing, big data, artificial intelligence (AI), edge computing, fifth-generation mobile communication (5G), and blockchain. The world is in a transition period of accelerated transformation from an industrial to a digital economy. The development of industrial integration with the core digital economy has become a trend [1]. Industrial informatization is a typical representation of the integration of the digital economy and industry, and it relies on the development and innovation of industrial software [2]. As a key element in realizing intelligent manufacturing in the era of Industry 4.0, industrial software is the core and soul of the digitalization, intelligent transformation, and upgrade of industrial enterprises [3], and it ushers in unprecedented development opportunities. Industrial software has become an indispensable industrial soft equipment. In industrial enterprises, industrial software is the entry and breakthrough point for the “integration of industrialization and industrialization” to enhance the value of industrial products, reduce enterprise costs, and improve the core competitiveness. It also promotes the adjustment and upgrading of a country’s industrial structure and maintains a stable economic development.

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Industrial software refers to the software applied in industrial design, production, management, and other links, and it can be categorized into system software, application software, and middleware. Its development is divided into three stages: the developing stage of the software itself, the collaborative application stage with the collusion and optimization of business processes, and the industrial cloud stage by integrating multiple types of software functions and providing the overall solution of “software + service.” Currently, the integration of industrial software is a mainstream trend. The functions of industrial software, heterogeneous data interoperability, enterprise collaborative optimization, and industrial chain resource allocation are realized through the integration of independent industrial software in a horizontal or vertical manner. Industrial software is widely used in all aspects of industrial production, along with the entire lifecycle of products, from research, development, production, and sales to after-sales services. The global industrial software market is steadily developing, with an output value of approximately 410 billion USD in 2019. The huge scale of China’s industrial system and the transformation of manufacturing power have led to the demand for industrial software and the expansion of the application scope and depth [4]. For example, from 2016 to 2019, the compound annual growth rate of Chinese industrial software product revenue was 16%, exceeding the global average. In 2019, the industrial software product revenue reached 172 billion CNY.

In the context of new infrastructure and dual circulation, industrial digitization will boost the rapid development of industrial software integration [5]. Fast integration with other new infrastructures forms a complete industrial Internet chain, which compensates the shortcomings of industrial enterprises and accelerates their digital and intelligent transformation [6]. With the rapid promotion of industrial Internet platforms, the integration of industrial Internet identification and industrial software has become an important driving force for the innovation and development of the industry, giving intelligent manufacturing richer connotative features and application scenarios. Facing the significant trends and urgent challenges in the development of the industrial Internet, this study investigates the path of industrial software integration and identification analysis, analyzes the application requirements, sorts out the development status, looks for problems, proposes new technology ideas, and demonstrates a new technology architecture to provide a basic reference for industrial software development.

2 Integration requirements of industrial software

Industrial software provides special links for industrial processes and needs to cover various applications in the entire product lifecycle through data integration. Industrial software has three aspects: product, production, and business. Each industrial software product may only be applicable to a single business link (Fig. 1). Industrial software is mainly categorized into design and development industrial software, such as computer-aided design (CAD), computer-aided engineering (CAE), computer-aided manufacturing (CAM), and computer-aided process (CAPP); information management industrial software, such as product lifecycle management (PLM), enterprise resource planning (ERP), and production execution systems (MES); and industrial control software, such as supervisory control and data acquisition system (SCADA) and programmable logic control unit (PLC). During the entire lifecycle of industrial products, the cooperation of multiple types of industrial software is required; therefore, data interoperability across software is extremely important.

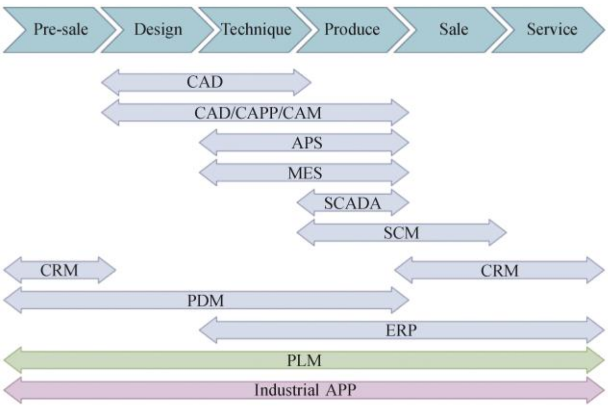

Fig. 1. Business scenario of industrial software.

Note: APS stands for advanced production planning and scheduling system. SCM stands for supply chain management system. CRM refers to a customer relationship management system. PDM stands for product data management system. APP represents the application program.

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2.1 Macroscopic demand

The phenomenon of information islands in industrial software seriously hinders the digital transformation of enterprises [7]. A product may involve a variety of cross-functional, cross-disciplinary, and cross-branded industrial software throughout its entire lifecycle. The corresponding underlying logic, data format, and application scenarios are significantly different. In a complete industrial process of data transmission, instructions, and signals, production control and information management are blocked layer by layer, which makes it difficult to effectively undertake the production chain [8]. (1) R&D and design industrial software focuses on basic disciplines, covering the R&D and design stages of products with obvious tool attributes [9]. (2) Production control software focuses on product production processes with obvious engineering attributes. (3) Industrial information management software focuses on the business management and business model of an enterprise with obvious management attributes. These types of industrial software products are provided by different manufacturers, serve different businesses, and involve various disciplines. Lack of integration between software results in multiple information islands in each business link of the enterprise, which affects the product design cycle, quality traceability, and financial efficiency of the supply chain [10].

At present, industrial software manufacturers and enterprises in China and abroad are actively concerned about the integration of industrial software and pursue the seamless bidirectional transfer of data from various industrial software products in the design and production process. Developed countries have taken the lead in establishing a relatively complete and distinctive industrial system that relies on the progress of information technology to implement the integrated construction of industrial software. In contrast, there is a gap in China that may restrict the development of its manufacturing sector. With the steady improvement of Chinese intelligent manufacturing capabilities, the integration of industrial software is urgently needed to strengthen the industrial system. Therefore, the integration of industrial software can not only ensure the development of intelligent and high-end manufacturing and accelerate the widespread application of the industrial Internet but also increase the industry penetration rate of industrial software, which generates economies of scale and synergies.

2.2 Technical requirements

Industrial chain collaboration is the development trend of the industry and is also an ultimate goal of the enterprise digital transformation. Currently, the requirements for industrial software to realize industrial chain collaboration are strict. Only the specified software can be used or high docking costs are required (in most cases, only the specified functions can be implemented). However, the yield is extremely low. The collaborative manufacturing of the industrial Internet puts forward technical requirements for industrial software integration in the following aspects:

2.2.1 Reducing the iteration time for product design and production

It is difficult to obtain product information between heterogeneous PDMs. The progress is difficult to control, and evaluation methods for collaborative design in different places. The development data of different enterprises and products are typically stored in their own PDM databases. It is also difficult to query and share the PDM design data across enterprises. In the process of product data exchange, there is no unified object metadata model standard (e.g., product class, name, identification code, version, product object data, and documents). The heterogeneous characteristics of product data make them unique and consistent; thus, real-time performance is difficult to guarantee. There is a lack of unified management capability for the collaborative product design process among heterogeneous PDMs. It is difficult for the main manufacturers to follow the design and development progress of purchased parts and outsourced tooling from suppliers and to transmit changes in design requirements and progress requirements in real time. For suppliers of purchased parts, it is impossible to evaluate whether the outsourced parts meet the overall design requirements in time. For the collaborative development of products, non-development work links, such as information transfer between enterprises, require an excessive amount of time, which affects the product design cycle. There is an urgent need for reliable and efficient multi-person collaborative evaluation methods in different places to conduct a collaborative evaluation of products. The integrated technology of identification analysis and industrial software can effectively open up the silos of project management information, enable efficient project management and control, realize rapid response process optimization of production execution, and strengthen the process flexibility.

2.2.2 Lowering the difficulty in tracing quality information and improving credit

The data in the quality information traceability process are not sufficiently open and are isolated from each other, which leads to a crisis of trust among enterprises. This solution lacks open-source tools, resulting in high technical requirements and difficulty in opening. The limited coverage of a single industrial software, the difficulty of quality traceability, and the lack of open identification data further restrict the development of product traceability systems. Production, circulation, supervision, and other industrial product processes are managed by different departments. The corresponding platforms are independent of each other (not directly connected). It is difficult to distinguish the authenticity of the traceability information. The new trusted traceability technology is immature, which weakens the reliability and application value of traceability data. The traceability data come only from a single enterprise or a few related enterprises. This cannot ensure the accuracy of product information, which limits the scope of traceability. There is asymmetry between enterprises and customers in the quality and credit information of industrial products, which may lead to speculation by sellers and consumer dishonesty. The traceability of identification data can break through the information exchange barriers between consumers and manufacturers and improve the transparency of after-sales product information.

2.2.3 Breaking down the information barriers in business and financial integration of enterprises

The product supply chain is affected by data barriers in the entire lifecycle, resulting in the long-term contradiction of strong demand and weak credit in supply chain finance. It is difficult for core enterprises to penetrate the entire industry chain, leading to insufficient credit transmission to suppliers above the second level. Small and micro enterprises have financing difficulties and prominent problems with the self-certification of credit. Banks recognize core enterprises’ ability to control goods and adjust sales. Therefore, when the production data of upstream and downstream enterprises cannot be reliably obtained, banks are only willing to provide advance payments or capital injections to the upstream suppliers (the core enterprises have direct accounts payable obligations). Thus, the financing requirements of the second and third tier suppliers cannot be met. The total business volume of the supply chain finance is limited. The integration of identification analysis and industrial software can promote global exchange of supply chain information that supports dual circulation and establish a real-time dynamic, comprehensive, and accurate corporate reputation evaluation system to support supply chain finance.

3 Current development of industrial software integration

3.1 Dominance of leading enterprises in industry development

Based on these characteristics, leading international enterprises have rapidly expanded their capabilities through mergers and acquisitions, forming an industrial software ecology oriented to the platform and cloud. Data integration across industrial software has been carried out using an industrial software cloud platform. The relevant products of Dassault Systems Group and Siemens Co., Ltd. represent the development trend of international industrial software integration [11,12].

In 2019, Dassault systems changed the name of SolidWorks software to 3DExperience Works, indicating that the importance of a single software tool brand tends to weaken, and the platform has become the main direction of industrial software development. Based on the 3DExperience platform, it constructs and implements 3D design, engineering, 3D CAD, modeling, simulation, data management and process management, which provide a unified digital environment for small- and medium-sized enterprise users.

Siemens Co., Ltd. actively creates digital capability and has adhered to the digital twin strategy for a long time. It obtains the required industrial software primarily through acquisition. An industrial Internet of Things (IoT) operating system named Mindsphere was launched in 2016 which provides platform services based on Amazon’s infrastructure as a service (IaaS). On one hand, it connects all types of equipment, providing a unified interface and interconnection between different equipment. On the other hand, it provides environments for the development and operation of various application software, supporting industrial enterprise customers for the collection and analysis of all the data of the production process on the same platform, which can optimize operational efficiency [13,14].

3.2 Decentralized technical solutions widely adopted in China

Most domestic industrial software enterprises have adopted various data-integration technical schemes to integrate heterogeneous systems according to the specific scenarios of the target company [15]. (1) Web page capture technology mainly aims at old legacy systems and systems with complex business logic, as well as the

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isolation of internal and external systems of enterprises and the difficulties in the coordinated development of third-party service-oriented interfaces to carry out data integration processing and system integration [16,17]. (2) Database log transformation technology specifically configures the database and monitors the database log and its transformations. Then, the data transformations are propagated using the message middleware. It is generally used to integrate the internal systems of enterprises. Independence on the interface of third-party systems ensures that it satisfies certain real-time data requirements [18]. (3) Data exchange and integration between services realizes the simultaneous change and fallback of data between different systems in the same transaction, and only simultaneous success and failure are allowed [19,20]. (4) The application program interface (API) called by the third party usually writes a structured query language (SQL) and automatically converts the SQL statement into an open API (for the third-party system) based on the development of different architectures and technologies for the internal heterogeneous system of the enterprise [21,22]. (5) Kafka connector integration, as an extensible streaming data transmission tool, provides a relatively mature and stable basic framework and tool for intelligent data-management platforms. It can not only extract data from the database to Kafka as the source end but also push data from a Kafka topic to the database as the receiver end [23].

Most users in domestic enterprises carry out low-cost transformation scenarios, which are complex and inefficient to form large-scale effects. It is usually difficult for the above scheme to comprehensively solve the needs of enterprises in data integration and heterogeneous systems. Therefore, it is necessary to adopt a variety of schemes synthetically, which not only causes difficulties in maintaining and upgrading the system but also affects the cooperation efficiency, security, and stability of the system [24].

4 Difficulty in industrial software integration

4.1 Low efficiency to break through data islands

A large number of domestic industrial software enterprises have pursued single-point technological breakthroughs for a long time. Single-point technology is a data island that results in lengthy processes and data distortion. Barriers to data interconnection also become thicker. The traditional way to open up a data island is to retrieve data from the database of the software system through data capture and database interfaces to realize data integration indirectly across the software system. However, the following problems still exist.

First, software imports occupy a dominant part in the market, which is inevitable. In China, the industrial software market, especially core software, is occupied by international brands. For example, over 95% of CAD software consists of imported products. Domestic industrial software faces basic problems such as weak ecology, insufficient basic capabilities such as modeling and virtual simulation, lack of domestic standards, and a low application degree of comprehensive integration, which has always restricted the development level of domestic industrial software integration.

Second, industrial software is expensive to develop. Software data are important strategic resources for industrial software suppliers. Original software manufacturers hold the authority of the database and data dictionary and have a powerful voice in the process of requesting integration. Consequently, they are unwilling to make concessions on matters involving their own interests and tend to raise the interface cost to compensate for their possible losses. As an industrial product, industrial software requires a long cycle to accumulate and develop. The data application modes of different software products are different. It is also a long-term and high-cost technical task to carry out data screening, reuse, and analysis of the original database.

Third, it is difficult to connect and coordinate different software systems, which is the main challenge in domestic industrial software integration. The software systems belongs to different systems and suppliers. It is difficult to determine the coordination and cooperation of various software manufacturers. One module requires the joint participation and coordination of multiple parties. Domestic manufacturing enterprises are accustomed to using imported industrial software with mature functions, and thus are vulnerable to the changes in the international economic and trade situation. The cooperation and coordination processes may also face additional resistance. In addition, certain problems have caused practical difficulties in program compatibility and data interconnection, such as the lack of domestic industrial software specifications, the low degree of induction and integration, and the difficulty of international industrial software enterprises to unify at the normative level.

4.2 Unsustainability for purchasing complete sets of foreign industrial software

Purchasing imported products to realize industrial software integration is facing practical problems regardless of the perfect ecology, mature technology, and complete functions of the industrial software of leading international enterprises.

First, high-end manufacturing industrial software carries the risk of being constrained by foreign technologies. Although purchasing imported industrial software can solve the problem of industrial software data islands to the greatest extent, many industrial enterprises can easily become bound to the ecosystem of imported products. R&D and design industrial software products are necessary core tools for high-quality development of the manufacturing industry. However, the lack of independent product applications and iterative processes will inevitably hinder the independent research and development of key industrial software for high-end manufacturing, which may lead to the gradual backwardness of technology and even its disappearance. This will be detrimental to the transformation and sustainable development of China's manufacturing industry.

Second, industrial enterprises face information security risks. Important equipment industries depend extensively on imported industrial software. The trend is to increase the proportion of applications to improve the industrial technology level. However, it is difficult to completely eliminate the information security risks of imported software, and serious consequences may result from information leakage and attacks.

Third, industrial software incurs high operational costs. Imported industrial software is expensive, and the utilization threshold is high. If small- and medium-sized domestic enterprises fully adopt it, they will inevitably face cost pressure. The industrial software purchase in some enterprises are not sufficiently professional. Moreover, blind purchases even lead to the coexistence of different manufacturers and multiple brands of industrial software. Repeated purchases consume resources and increase costs.

4.3 Potential technical solutions

With the improvement in the comprehensive strength of China's industrial software enterprises, the capacity of some domestic industrial software has significantly improved, which provides a certain foundation for replacing the imported software to provide key services for industrial enterprises. However, a small amount of imported software cannot be replaced by domestic software because of the barriers of the underlying technology and usage inertia. The irreplaceable nature of specific software will lead to potential problems in industrial data exchange and software docking, which will directly affect the localization and integration of industrial software systems. It can be considered that the localization of industrial software is mainly subject to the industrial software ecology of international leading enterprises.

To break away from the ecosystem of imported industrial software and overcome the irreplaceability of specific software, the industrial Internet identification resolution technology is an important development direction. Some domestic industrial software will replace imported products and break the monopoly of the imported industrial software ecosystem, while temporarily retaining irreplaceable foreign industrial software. Then the functions of heterogeneous data transformation and information exchange will be realized based on physical gateway, API interface, and cloud components. First, starting with an identification resolution system, a unified data standards system can be established, thus promoting the construction of brand ecology, business ecology, and functional ecology of the domestic industrial software. This will quickly form a unified and cooperative development situation for the domestic industrial software. Further, the data of industrial enterprises can be registered in the identification resolution system through the identification resolution middleware. Therefore, other enterprises in the industrial chain can find the location of relevant data through analytical addressing, which can be converted into a unified data model through identification resolution middleware to realize the point-to-point transmission of key data among enterprises. The application of industrial Internet identification resolution technology can realize the data integration of domestic and imported industrial software, obtain the data of all links of the supply chain, and promote the efficient coordination of global production planning.

5 A novel strategy of industrial software integration: identification resolution of industrial Internet

Industrial software can enhance the value of industrial products, reduce enterprise costs, and improve the core competitiveness, which is an important entry point for the industrialization and industrialization of industrial enterprises. Therefore, it is important to promote industrial software integration. As the ID card of the digital world, the identification resolution system is the key to driving the innovation of the industrial Internet. The combination of identification resolution with physical gateways, interface platforms, and cloud integration technology can reduce the integration cost of industrial software, improve its service capacity, and enable the interconnection of

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the entire industrial chain (Fig. 2).

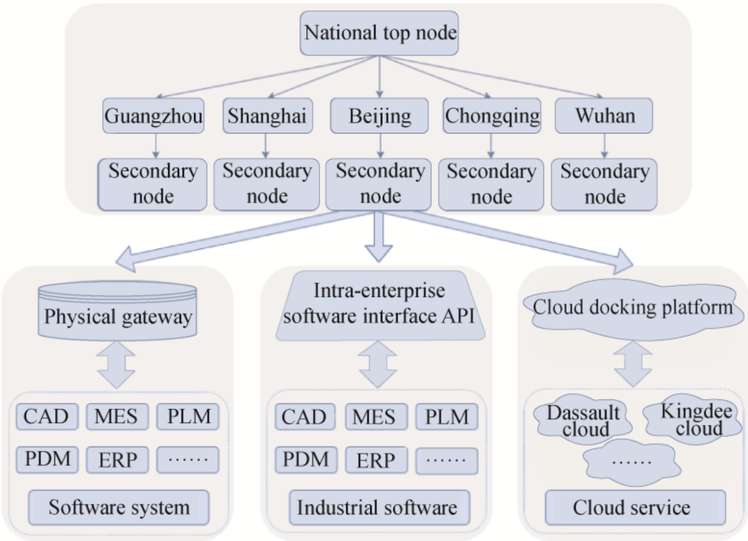

Fig. 2. Industrial software integration strategy based on industrial Internet identification resolution.

Note: Kingdee cloud is provided by Kingdee International Software Group Co., Ltd.

According to research on industrial software integration, the identification resolution of the industrial Internet requires that people, objects, and materials have unique and unambiguous names (i.e., identification, which is composed of letters and numbers). Hierarchical identification is generally adopted. Taking the gateway as an example, the naming rules are defined as naming authority, object, hardware, network equipment, physical layer, and Internet interconnection protocol (IP) address. A chord ring establishment should consider the IP, resource, and other identifiers of each node as the key. The unique code (ID) of the current storage node is value1 and the IP location of the actual information storage is used as value2 to form a key–value pair (key, value1, value2). In the storage stage, hash mapping disperses key–value pairs on the chord ring. The placement positions of the three replicas are calculated considering load balancing. In the search phase, the hash (key) is calculated according to the key of the target resource, the search method of which is the chord algorithm.

Identification resolution technology can solve the problems of single-domain name resolution (DNS) services and weak resource description ability. It can also expand the subject identification of goods, sensors, and services, which overcomes the shortcomings of single-point overload and service congestion based on IP addressing. This technology can meet the resolution requirements of ultra-low delay of massive data in the industrial Internet of Things (IIoTs). The identification resolution achievements include, but are not limited to, IP addresses, which can meet the diversified and differentiated requirements of the industrial Internet.

5.1 Physical gateway

As the core component of the identification resolution for the industrial Internet, the physical gateway connects the industrial software within the enterprise to the information flow of the industrial Internet. The edge physical gateway has the characteristics of software definability, highly integrated interface, and network boundary data isolation and exchange. It can provide a strong edge-computing capability to adapt to industrial operating conditions. Integrated interfaces for industrial data acquisition such as RS485, MBUS, Hart, and LoRa can match the integration of industrial software in complex environments. The physical gateway has complete expansion and development capabilities. It supports secondary development, user-defined data formats, transmission directions, and interface functions. It provides services similar to private cloud services and builds an internal industrial Internet identification system through three modes: IaaS, Platform as a Service, and Software as a Service.

A high-performance network processing platform system is a typical application of physical gateways in the field of the industrial Internet. Platform products include industrial Internet gateways, IIoT gateways, application delivery load-balancing equipment, network deep packet inspection equipment, converged application shunting equipment, general routing encapsulation gateways, virtual tunnel endpoint gateways, virtual routers, virtual firewalls, visual information display systems, P1, P2, P3, P4, and other network application products.

We exemplify the heterogeneous data IoT module of industrial equipment in which the core supporting capabilities of a physical gateway are reflected in three aspects. First, an enterprise's internal industrial software system is built by gathering, transforming, integrating, and caching information in a noninvasive manner and forming a unified entrance for real-time queries of business product data. Second, we can obtain industrial software information noninvasively and avoid data collection at database and application interface levels. The required data content is obtained directly from the user page. Configuration and marking tools are used to assist with accurate data collection. Third, industrial equipment information can be obtained in an integrated manner. Through an acquisition interface compatible with conventional industrial data, industrial equipment information can be collected directly, and the equipment access capacity can be broad (the scale is of thousands of equipment units). In addition, the identity resolution area server provides the link connection function of fixed and non-fixed IP in the form of middleware, which provides an intelligent distributed identity system solution for small- and medium-sized enterprises.

Industrial software integration and identification resolution are combined to support the deployment of industrial Internet gateways and the industrial IoT application module on the platform architecture. It can also support the transmission control protocol, user datagram protocol, message queue telemetry transmission protocol, restricted application protocol, ModBus communication protocol, program bus network, hypertext transmission protocol (HTTP), HTTP secure version, Kafka, and other common protocols, and some enterprise private protocols. Therefore, external wireless communication modules such as LoRa, mobile hotspot (Wi-Fi), fourth generation mobile communication, and 5G reflect the technical advantages of high performance, high reliability, flexible deployment, low cost, and simple maintenance.

5.2 Interface platform

An interface is a protocol to define a program which describes a set of related behaviors belonging to any class or structure. It provides applications and developers with the ability to access a set of routines based on software or hardware (without accessing the source code or understanding the internal working mechanism). In the hierarchical architecture of an industrial Internet identification resolution system, the interface platform mainly serves two types of objects. The first is to reduce the technical threshold for identification access to enterprise applications and integrate the identification system of various industrial enterprise information systems under the condition of low code for the identification resolution system. The second is to provide various application scenario interfaces based on identification to understand the purpose of identification and to provide technical support for the application of industrial enterprise information systems.

An interface platform usually adopts a micro-service architecture. A micro-service is an independent entity that can be deployed and upgraded independently. Micro-service instances can be replaced without affecting other micro-services. The identification resolution interface platform can be divided into identification services, master data management, metadata management, big data services, business scenario services, application software interface services, and other modules (Fig. 3).

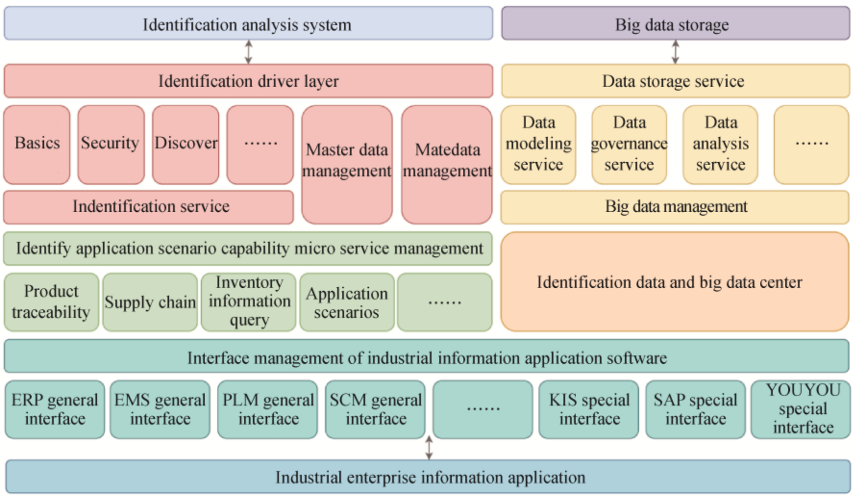

Fig. 3. Technical architecture of the identification resolution interface platform.

Note: KIS is a product by Kingdee International Software Group Co., Ltd.; SAP is an enterprise management resolution of SAP SE; YOUYOU is a software product of YONYOU Network Technology Co., Ltd.

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The identification service module provides identification-related capability services, such as parsing, registration, management, security, discovery, and other identification functions, as well as the management ability of master data and metadata involved in identification. Big data services mainly provide storage, governance, resolution, modeling, and other capabilities of non-identified data. The identification application scenario combines identification and business, enriches the platform capabilities, serves the data relationship application of the industrial chain, and supplies a chain between application software, enterprises, and industries. Identification and big data middle offices provide data middle office capability for application software. Industrial information application software interfaces are divided into general classes separated from the business level and special classes separated from the manufacturer level, which provide industrial enterprises with the access identification system of the original application. For example, K/3Cloud connects the identification resolution system with the internal ERP system of industrial enterprises to synchronize the information and services between the identification system and industrial software. Through the information exchange between the identification resolution system and the K/3Cloud system, the functions of viewing, saving, submitting, approving, anti-approving, and deleting logistics order information are realized. The interface platform is a lightweight, maintainable, and scalable web service developed using RESTful architecture. The delivery material information, delivery time, delivery planner, receipt information, and other information in the logistics order are connected to the identification service, which connects the logistics code and internal code of industrial enterprises. It accelerates the circulation of logistics information and improves the accuracy of logistics services.

5.3 Cloud component technology

The integration of industrial software and identification resolution components involves the interconnection of all aspects in the entire process of industrial production and production factors. Cloud-component technology is a relatively competitive solution. For example, an industrial Internet cloud platform based on micro services can integrate industrial software through identification resolution. The cloud-based identification resolution and industrial software integration service component integrate the Internet micro service architecture, cloud capabilities, and middleware. This enables technical encapsulation of the integration of heterogeneous industrial software, shielding the difference in the operating environment. Standard and convenient service interfaces are provided to industrial enterprise users, which improve the efficiency and quality of integration and reduce the difficulty of development, operation, and maintenance (Fig. 4).

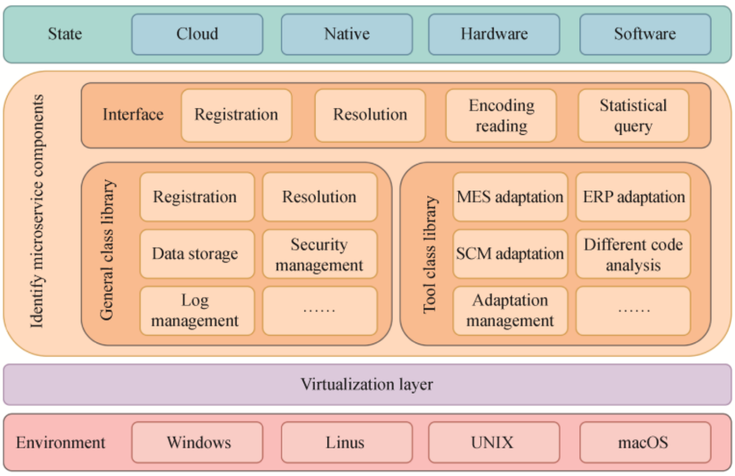

Fig. 4. Cloud identity micro–service reference architecture.

An industrial software cloud platform comprises multiple independent dimensional services. Each micro service has its own business logic and database, which is convenient for technological upgrades and flexible applications. By integrating the identification data from edge devices, the cloud identification micro service realizes content analysis, filtering, extraction, and reintegration of device messages. The device messages are then forwarded to back-end services. The storage components, function computing, big data analysis suite, and industrial software applications are seamlessly connected at the back end of the cloud platform, breaking the data isolation between devices and industrial software. The cloud identity micro service uniformly analyzes massive industrial identities and risk management and process management are implemented using XML/JSON and other formats above the message queue service or RESTful web services. The cloud identity micro service transfers statistical data or necessary information to other information technology or operating technology systems, such as PLM, ERP, MES, SCM, and warehouse management systems.

6 Development suggestions for industrial software integration and identification resolution

6.1 Deepening enterprise application and industry drive

Identification resolution promotes the integration of industrial software, industrial technological innovation, and demand change. The industrial Internet identification resolution technology should be fully integrated with the Internet, cloud computing, big data, AI, intelligent sensing, and other technologies at multiple levels to promote innovative technological changes, such as intelligent product traceability, supply chain coordination, and product lifecycle management. This technology helps to explore the identification resolution and industrial software, further deepens the comprehensive integration with production data, and forms a closed loop of business data such as information flow, logistics, and capital flow centered on the supply chain. Moreover, in view of the trend of increasingly personalized and diversified customer needs, industrial software integration should actively explore new modes of accurate market prediction and marketing. Finally, industrial software integration should realize interactive integration between a large number of users and enterprises with the help of identification to enable mass personalized customization and precise decision-making.

The integration of industrial software should be devoted to optimizing the resource allocation of enterprises and enabling high-quality growth in industrial efficiency. Industrial software should be opened through identification resolution to realize high-speed circulation of production factors worldwide. Several methods can be applied according to the driving factors, such as the change in industry growth rate, change in customer demand, technological innovation, marketing innovation, and the increasing globalization of the industry. We should take enterprise demand as the starting point, adhere to it, deepen the understanding of the needs of industrial enterprises in all links of the product lifecycle, and mine scenarios around user needs. We should also provide distinctive middleware products and services, in combination with the characteristics of different fields in the industry, to promote jointly the reform and development of the industry.

6.2 Creating industrial ecology and changing enterprise thought

The integration of the identification resolution technology with industrial software can get through the information islands within the enterprises. Simultaneously, numerous application scenarios will create more opportunities for enterprises and create a new driving force. On one hand, it builds a solution supplier directory, cultivates a number of middleware suppliers, and constantly strengthens the demand feedback channels between middleware providers and industrial enterprises. By establishing an effective communication mechanism, middleware providers can quickly obtain the demand and use feedback. They can quickly perform middleware product iterations. However, the formulation of these standards should be strengthened. The formulation of basic standards provides a clear understanding of the definition, characteristics, service mode, deployment mode of identification resolution, and industrial software docking middleware. It guides industrial enterprises in selecting and evaluating middleware services and lays a foundation for the popularization and application of middleware in enterprises.

Simultaneously, the development of industrial software integration and identification resolution should accelerate the transformation of enterprise ideas, promote the establishment of collaborative manufacturing and quality credit systems, and strengthen collaborative publicity. Enterprises should be fully prepared, firmly grasp the opportunities, accelerate the internal digital transformation and intelligent upgrading, and strengthen their talent training and infrastructure support. Enterprises should cooperate with partners in various vertical industries through a unified, standard, and open architectural system and interface. Enterprises should also combine the advantages of their respective subdivided fields and integrate professional digital solutions for the entire product lifecycle to work together and build an ecosystem with data as the core and industrial software interconnection.

6.3 Building the training mechanism to strengthen talent support

The construction of industrial Internet identification resolutions has entered a critical period of industrialization with the commissioning of multiple national major projects. The development of industrial Internet identification

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resolution involves many aspects, including system construction, technical research, application promotion, and ecological construction. It should accelerate the development of talent in the field of industrial Internet identification resolution and integration. Simultaneously, talent training should be ensured to support the development of identification applications, technical standards, and industrial ecology. The training mechanism should aim at the forefront of industrial Internet development and ensure that talent training can continuously promote the engineering development of industrial Internet.

Talent training for industrial software integration aims to achieve multi-disciplinary, long-span, and deep-seated penetration to a greater extent. Training should focus on compound talents with strong innovation and operational abilities. It needs not only academic talents with outstanding innovation ability, but also applied talents with strong practical ability. The preservation of talent can promote the integration of industrial software and identification resolution applications, further deepening the application of industrial Internet and identification resolution.

References

[1] Xinhua Net. Xi Jinping hosted the 14th meeting of Central Committee for Deepening Overall Reform [EB/OL]. (2020-06-30) [2021-02-24]. http://www.xinhuanet.com/politics/leaders/2020-06/30/c_1126179095.htm. Chinese.

[2] Ministry of Industry and Information Technology of the People’s Republic of China. Policy interpretation on Notice of the General Office of the Ministry of Industry and Information Technology on accelerating the development of the industrial Internet [EB/OL]. (2020-03-21) [2021-01-05]. http://www.gov.cn/zhengce/2020-03/21/content_5493935.htm. Chinese.

[3] Edge Computing Consortium, Alliance of Industrial Internet. Collaborative edge computing and cloud computing white paper (2018) [R]. Beijing: Edge Computing Consortium, Alliance of Industrial Internet, 2018. Chinese.

[4] Jiang X H, Zhang G N. Industrial software industry status quo, development trend and basic analysis [J]. World Telecommunications, 2016 (2): 13–18. Chinese.

[5] Zhou Y, Zang J Y, Miao Z Z, et al. Upgrading pathways of intelligent manufacturing in China: Transitioning across technological paradigms [J]. Engineering, 2019, 5(4): 691–701.

[6] The State Council of the People’s Republic of China. Made in China 2025 [EB/OL]. (2015-05-08) [2019-10-08]. http://www.gov.cn/zhengce/content/2015-05/19/content_9784.htm. Chinese.

[7] Yi S P, Liu M, Wen P H. Overview of cloud manufacturing service based on lifecycle theory [J]. Computer Integrated Manufacturing System, 2016, 22(4): 871–883. Chinese.

[8] Hinterreiter D, Prähofer H, Linsbauer L, et al. Feature-oriented evolution of automation software systems in industrial software ecosystems [C]. Funchal: 2018 IEEE 23rd International Conference on Emerging Technologies and Factory Automation (ETFA), 2018.

[9] Tong W W, Jia N, Gao C, et al. Research on license resource sharing platform based on R & D and design software [J]. Computer & Network, 2018, 44(10): 65–68. Chinese.

[10] Zhou J, Li P G, Zhou Y H, et al. Toward new-generation intelligent manufacturing [J]. Engineering, 2018, 4(1): 11–20.

[11] Alliance of Industrial Internet. Industrial Internet builds the cornerstone of the fourth industrial revolution: Tracking research on the development of international industrial Internet [J]. China Telecommunication Trade, 2019 (3): 19–23. Chinese.

[12] Zhou J. Development status of Chinese industrial software enterprises and breakthrough of bottleneck gradient [J]. China Industry and Information Technology, 2020 (3): 56 –61. Chinese.

[13] Ministry of Industry and Information Technology of the People’s Republic of China. Notice on issuing the Industrial Internet innovation and development action plan (2021—2023) [EB/ OL]. (2020-12-22) [2021-01-15]. http://www.gov.cn/zhengce/zhengceku/2021-01/13/content_5579519.htm. Chinese.

[14] Wang C, Song L, Li S K. The industrial Internet platform: Trend and challenges [J]. Strategic Study of CAE, 2018, 20(2): 15–19. Chinese.

[15] Ren Y Z, Xie R C, Zeng S Q, et al. Survey of identity resolution system in industrial Internet of things [J]. Journal of Communications, 2019, 40(11): 138–155. Chinese.

[16] Aujla G S, Singh A, Kumar N. Adaptflow: Adaptive flow forwarding scheme for software-defined industrial networks [J]. IEEE Internet of Things Journal, 2019, 7(7): 5843–5851.

[17] Wei Y, Blake M B. Service-oriented computing and cloud computing: Challenges and opportunities [J]. IEEE Internet Computing, 2010, 14(6): 72–75.

[18] Tao F, Zuo Y, Xu L D, et al. IoT-based intelligent perception and access of manufacturing resource toward cloud manufacturing [J]. IEEE Transactions on Industrial Informatics, 2014, 10(2): 1547–1557.

[19] Villamizar M, Garces O, Castro H, et al. Evaluating the monolithic and the microservice architecture pattern to deploy web applications in the cloud [C]. Bogota: 2015 10th Computing Colombian Conference (10CCC), 2015.

[20] Liu Y X, Wang J, Li J Q, et al. Zero-bias deep learning for accurate identification of Internet of things (IoT) devices [J]. IEEE Internet of Things Journal, 2020, 11(4): 2627–2634.

[21] Kang Y P, Hauswald J, Gao C, et al. Neurosurgeon: Collaborative intelligence between the cloud and mobile edge [J]. ACM SIGARCH Computer Architecture News, 2017, 45(1): 615–629.

[22] Gu H F, Zhang J N, Liu T, et al. DIAVA: A traffic-based framework for detection of SQL injection attacks and vulnerability analysis of leaked data [J]. IEEE Transactions on Reliability, 2020, 69(1): 188–202.

[23] Sgambelluri A, Pacini A, Paolucci F, et al. Reliable and scalable Kafka-based framework for optical network telemetry [J]. Journal of Optical Communications and Networking, 2021, 13(10): 42–52.

[24] Guo Z H. Analysis of current situation and trend on industrial Internet technology [J]. Process Automation Instrumentation, 2020, 41(5): 1–4. Chinese.