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https://doi.org/10.1162/dint_a_00231

Smart management information systems (SMIS): Concept, evolution, research hotspots and applications

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Abstract: Management information system (MIS), a human-computer system that deeply integrates next-generation information technology and management services, has become the nerve center of society and organizations. With the development of next-generation information technology, MIS has gradually entered the smart period. However, research on smart management information systems (SMIS) is still limited, lacking systematic summarization of its conceptual definition, evolution, research hotspots, and typical applications. Therefore, this paper defines the conceptual characteristics of SMIS, provides an overview of the evolution of SMIS, examines research focus areas using bibliometric methods, and elaborates on typical application practices of SMIS in fields such as health care, elderly care, manufacturing, and transportation. Furthermore, we discuss the future development directions of SMIS in four key areas: smart interaction, smart decision-making, efficient resource allocation, and flexible system architecture. These discussions provide guidance and a foundation for the theoretical development and practical application of SMIS.

Keywords: smart management information system, next-generation information technology, human-computer integration, collaborative decision making, personalized knowledge services

1 Introduction

In 1967, Professor Gordon B. Davis of the University of Minnesota established the discipline of Management Information Systems (hereafter referred to as MIS). In 1985, he and Professor Margrethe H. Olsen defined MIS as an integrated human-computer system that provides information to support organizations' operations, management, and decision-making [1]. During the era of economic development dominated by the information industry, the widespread adoption of next-generation information technology has accelerated the growth of the digital economy and

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This work was supported by the National Natural Science Foundation of China (grant number: 72131006, 72071063, 72271082); Anhui Provincial Key R&D Programme (grant number: 2020i01020003).

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https://doi.org/10.1162/dint_a_00231

brought significant changes to both the organization and society. Consequently, organizations operate in complex and uncertain environments. As a fundamental tool for modern organizational operations, MIS deeply integrates next-generation information technology and management services. Driven by social needs, economic development, and next-generation information technology, MIS has entered a new development period. To cope with the complex and evolving external environment and meet the dynamic needs of users, MIS has gradually shifted towards smart solutions that support organizations in adapting to external changes, integrating internal and external resources, and providing users with personalized solutions.

In this paper, we define MIS in the smart period as Smart Management Information Systems (hereafter referred to as SMIS). SMIS is a human-computer integration system that can dynamically perceive environmental information, deeply analyze the potential needs of users, and provide personalized and scenario-based management services. Based on network communication technology and next-generation information technology, the system continuously acquires massive amounts of heterogeneous data from multiple sources through ongoing interactions with users and the environment. It dynamically identifies users' behavioral characteristics and personalized needs, extracting knowledge from the accumulated data. Through learning processes, the system strengthens its self-monitoring, self-diagnosis, self-correction, and self-organization capabilities. It autonomously identifies the operational status of the organization, responds to and adapts to the dynamic external environment, and facilitates real-time sharing and coordination of internal resources. Additionally, the system can independently or collaboratively assist the organization in complex activities such as prediction, control, and decision-making, enhancing management services and fostering user value creation within a distributed human-machine collaborative symbiosis system. The system exhibits high agility, flexibility, openness, adaptability, self-organization, non-linearity, emergence, and robust interactivity.

Currently, research on SMIS primarily focuses on integrating next-generation information technology with the management domain. Some studies explore the smart features of MIS and investigate technological approaches to enhance its smart functions [2-4]. Furthermore, Jussupow et al. [5] and Cheng et al. [6] examine how SMIS improves management processes and decisions across various domains, such as business, healthcare, and public administration. Moreover, some researchers focus on the enhancement of the smart functions of organizational production and service systems by emerging technologies such as big data and the Internet of Things (IoT), which are used to solve the problems of dynamic perception, smart decision-making, and system agility [7-9]. These researches establish a vital theoretical foundation for the development of SMIS, fostering its smart, integration, and personalization. However, the current research on SMIS is still in the initial stage, lacking a comprehensive overview of the evolution and typical applications of

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SMIS. Moreover, the research hotspots and future development directions of SMIS are not yet clear.

The remainder of the paper is organized as follows: Section 2 summarizes the evolution of SMIS and analyzes the characteristics of each period. Section 3 utilizes bibliometric methods to summarize and analyze the research hotspots of SMIS in recent years. Section 4 presents notable industry examples to illustrate the application prospects of SMIS. The future research directions for SMIS are summarized in Section 5. Finally, this paper is concluded in Section 6.

2 Evolution of SMIS

MIS has undergone significant development since its origins in scientific computing and transaction processing in the 1970s [10]. With the widespread application of information technology, MIS has become an indispensable tool in people's work and life, playing a significant role as a nerve center in society and organizations. Under the interaction of computer-related technologies and the development need of enterprises, MIS progresses from the initial period of simple applications to the current period of deep integration. MIS transitions from centralized application systems that perform independent and basic tasks to intelligent and comprehensive service providers, gradually entering the smart period with the advent of next-generation information technology. Figure 1 illustrates the evolution of SMIS.

Service model	Simple transaction processing services	System-oriented services	Multi-system integration service	Integrated system integration services
Features	Electronic data processing	Systematization of business processing	Intelligent information management	Intelligent human-computer interaction
System architecture	Single machine centralized	Local distributed	Wide-area open	Internet of everything
Application scope	Job-level applications	Departmental applications	Inter-enterprise applications	Inter-industry applications
Application level	Rarely applied	Proactive application	Widely used	Deeply applied
Representativ e systems	Data processing system, transaction processing system	Material requirements planning, decision support system	Enterprise resource planning, supply chain management	Internet hospital, intelligent transportation system
	1950s~1970s	**1970s~1990s**	**1990s~2010s**	**2010s~now**
	Start-up period	**Development period**	**Popularization period**	**Integration period**

Figure 1. The evolution of SMIS

2.1 Start-up period: 1950s~1970s

The start-up period of MIS can be traced back to the 1950s to the 1970s. In 1954, IBM released the first computer capable of floating-point calculations, which prompted many

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companies to automate employee payroll calculations and process simple data in batches [11]. During this period, MIS was based on high-level programming languages and document management technologies to process departmental data within organizations. This led to the achievement of electronic data processing and the emergence of information systems that could handle repetitive transactions in administration. These systems allow for the management of centralized documents, significantly enhancing the efficiency and accuracy of transaction processing. Furthermore, as the data required for calculations could also be utilized to generate reports for managers, computer-based management information systems become an unintended consequence of the automation of computing operations.

2.2 Development period: 1970s~1990s

During the 1970s to 1990s, MIS experienced significant development driven by database technology, data communication, and computer networks. This period marks the expansion of MIS from single applications designed for specific positions to interdepartmental applications within enterprises. In 1971, Gorry and Scott-Morton [12] proposed an MIS framework (refer to Figure 2) to identify the types of information required for management at all levels. In this period, MIS forms a distributed, component-based, and service-oriented system technology architecture, and provides managers with integrated services for operations and supervision, decision support services, and other related systems, facilitating the transformation from operational control to management control. As a result, the comprehensiveness, systematicity, and timeliness of management information processing improved. Moreover, MIS that emerged during this period include Material Requirements Planning (MRP), Decision Support Systems (DSS), and Customer Relationship Management (CRM).

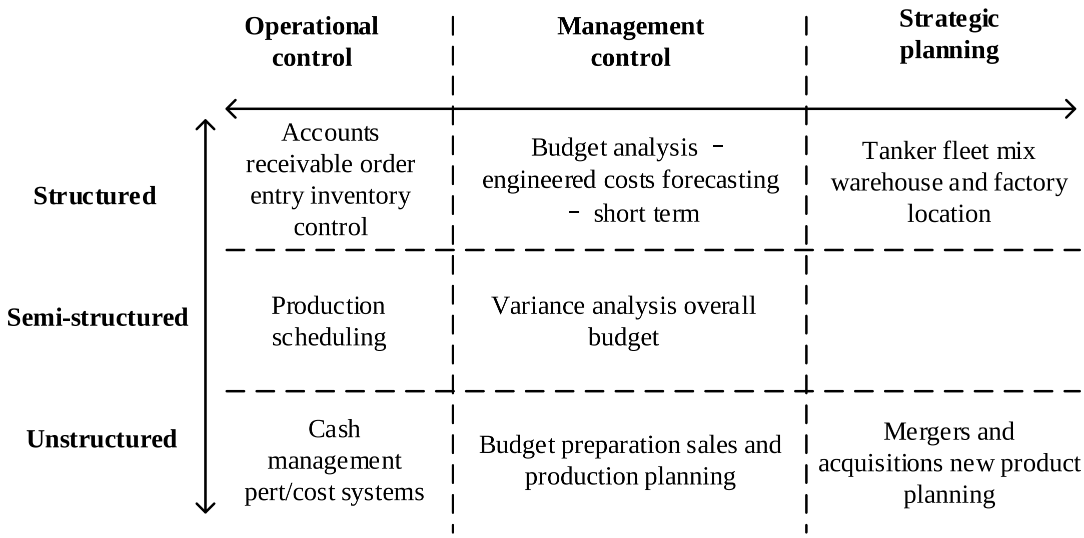

Figure 2. The framework of MIS proposed by Gorry and Scott-Morton

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2.3 Popularization period: 1990s~2010s

At the end of the 20th century, the development of technologies such as the Internet and cloud computing led to the emergence of new applications like e-commerce and social media. This development expands the application scope of MIS beyond the boundaries of enterprises, propelling MIS into a period of globalization and popularization. During this period, the decision support systems evolved to encompass support for group decision-making and embedded artificial intelligence technologies. MIS transitions towards intelligent information systems with enhanced capabilities for knowledge innovation and solving unstructured affairs. These systems achieve integrated information management, a multidimensional service model, and intelligent computer-aided management with human-computer coordination. Gradually, MIS acquires the characteristics of intelligence and self-organization, and provides organizations with integrated services for strategic management and other collaborative system integration [13]. Figure 3 illustrates an open architecture of cloud-based MIS [14].

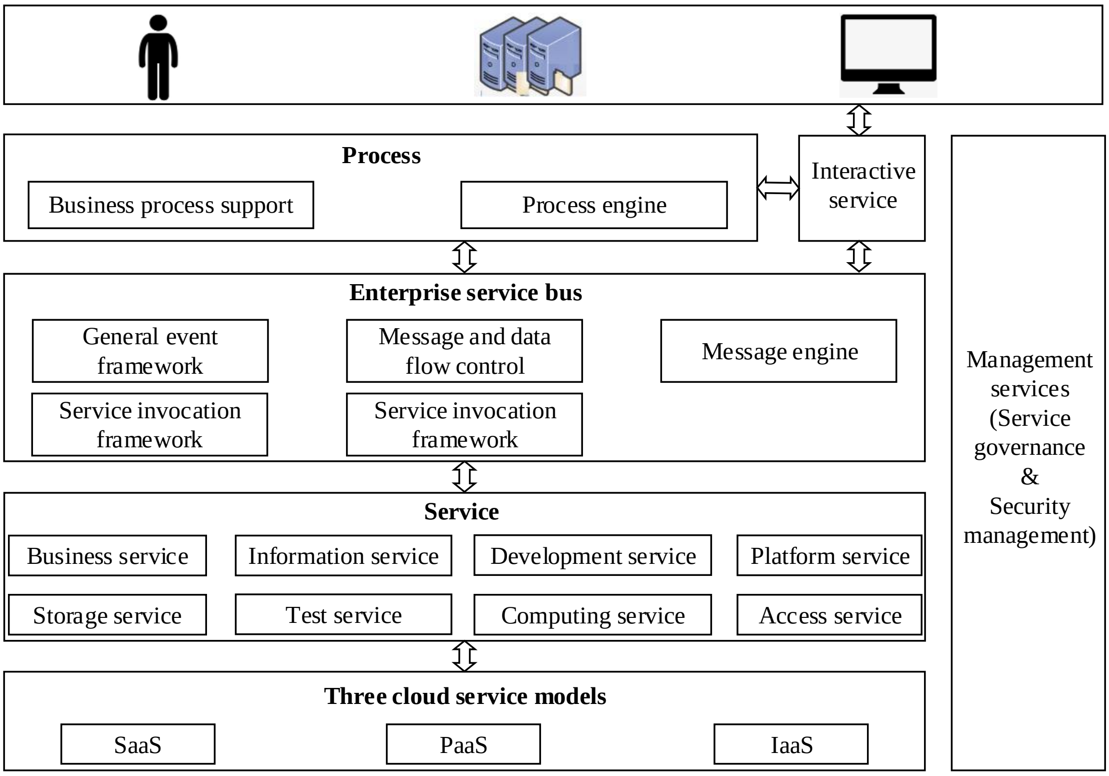

Figure 3. An open architecture of cloud-based MIS

2.4 Integration period: 2010s~present

In 2008, IBM proposed the concept of the "Smart Planet," advocating for the development of wisdom across all industries to enhance the overall knowledge of human society globally [15]. As a crucial tool for the functioning of contemporary society, the explosive growth of data, the complexity of the external environment, and the diverse and personalized user needs necessitate

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the evolution of MIS towards the smart period. The next-generation information technology, including mobile Internet, big data, artificial intelligence, and IoT, has enabled advanced smart sensing, interaction, control, collaboration, and decision-making. This technological development significantly enhances organizations' abilities to acquire, process, and apply data resources, providing the technical foundation for the smart development of MIS. SMIS, which is developed on the basis of the intelligent management information system combined with next-generation information technology, can continuously interact with the environment and users and obtain real-time environmental status information and dynamic user needs. It adapts to environmental changes and facilitates cross-domain, cross-organizational, and cross-departmental multi-channel resource sharing and collaborative allocation based on user needs, and makes independent or assisted managerial decisions, which significantly improves organizational management efficiency and decision-making agility. Hence, we propose a distributed SMIS architecture based on the cloud-edge-terminal, as shown in Figure 4.

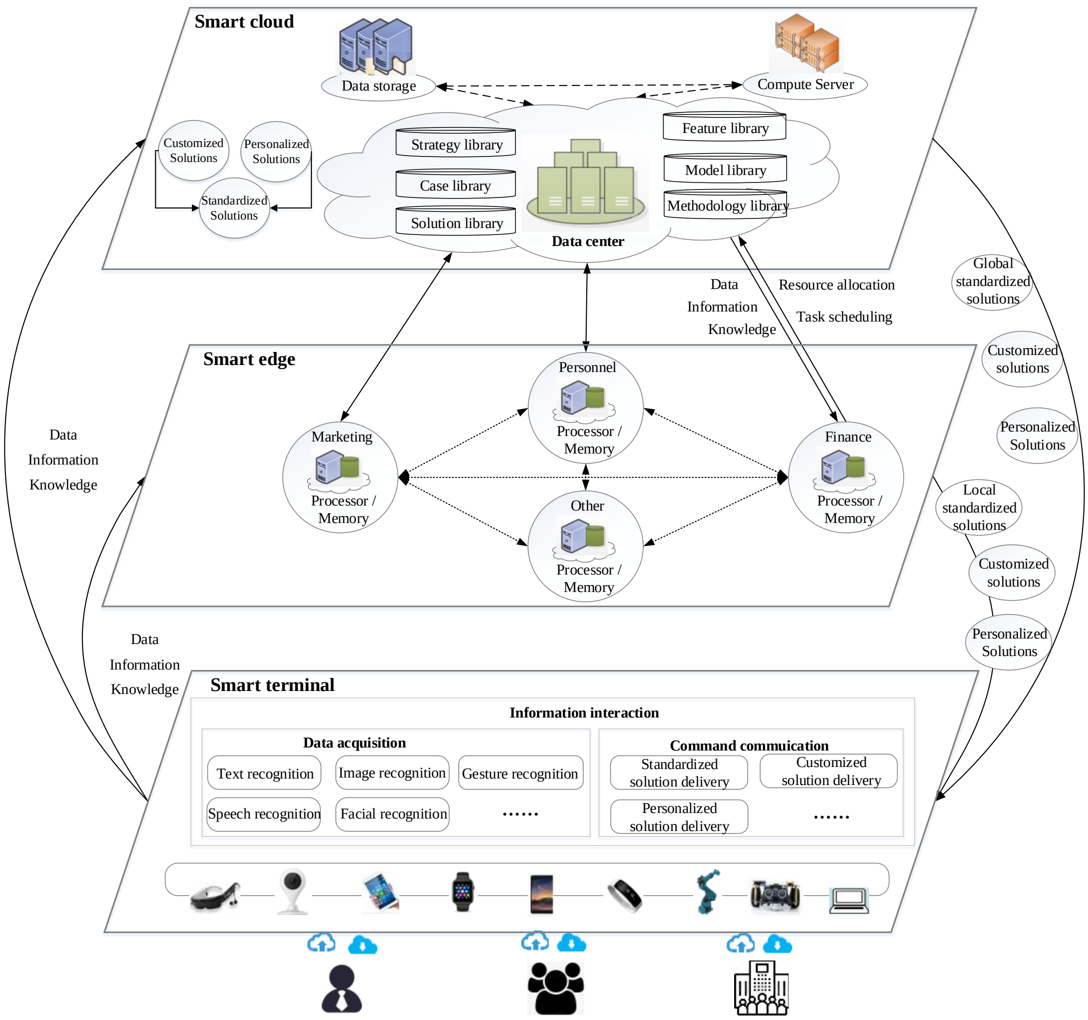

Figure 4. The architecture of SMIS

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3 Research hotspots of SMIS

With the continuous development and application of SMIS, a series of studies on SMIS have been conducted in the academic community. In this paper, we employ bibliometric analysis to analyze the relevant literature on SMIS in recent years. Moreover, we utilize Citespace software to visualize the results and provide valuable insights into the current trends and directions of SMIS research.

3.1 Data source

This paper is based on the Web of Science repository, specifically the Web of Science Core Collection. The citation indexes selected for this study are the Science Citation Index Expanded and the Social Sciences Citation Index. The publication date range for the literature search is set from January 1, 2010, to May 1, 2023. The following search formula was used: (TS= ("Management Information System*") OR (TS= ("Information System*") AND TS=("Smart")) OR (TS= ("Information System*") AND TS=("Intelligent")) OR (TS= ("Information System*") AND TS= ("Big Data")) OR (TS= ("Information System*") AND TS= ("Internet of Things")) OR (TS= ("Information System*") AND TS= ("Cloud Computing")) AND DT=(Article) AND LA=(English). We manually exclude the literature records with non-relevant and duplicate topics, and finally collect 4261 relevant literature records.

3.2 Research hotspots

In this paper, we extract keywords from related literature and use Citespace 6.1 R6 software to reveal the research hotspots of SMIS. The following parameter settings are used in Citespace: Years Per Slice = 1, Node Types = Keyword. Moreover, we choose the critical pathfinder algorithm to simplify the network and highlight key nodes, and merge similar words such as Internet of Things (IoT) and Geographic Information Systems (GIS). Table 1 presents the compilation of the top 20 keywords based on their co-occurrence frequency in related literature. Additionally, Figure 5 illustrates the co-occurrence network of keywords in related literature from 2010 to 2023. These visual representations provide a clear understanding of the research trends and interrelationships among keywords in SMIS.

Table 1. Frequency Ranking Statistics of Top 20 Keywords for the research of SMIS

Key words	Co-occurrence	Link strength	Year of first appearance
big data	266	0.20	2014
internet of things	223	0.22	2011
information systems	221	0.29	2010
cloud computing	219	0.21	2010
geographic information system	139	0.13	2012
smart city	103	0.06	2016
machine learning	92	0.05	2014
artificial intelligence	84	0.07	2011
data mining	65	0.06	2012
industry 4.0	61	0.03	2017
intelligent transportation systems	57	0.08	2010
big data analytics	51	0.06	2016
management information systems	47	0.02	2010
health information system	43	0.02	2013
deep learning	43	0.04	2017
data analytics	42	0.03	2015
information technology	35	0.03	2013
smart card	34	0.03	2013
remote sensing	28	0.02	2010
driver information systems	27	0.03	2015

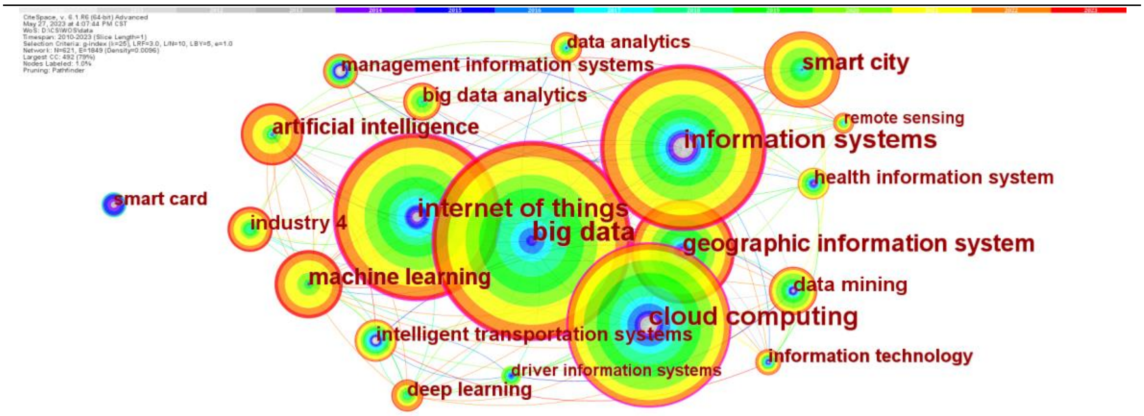

Figure 5. The keyword co-occurrence mapping of SMIS

Table 1 reveals that the keywords with a high frequency are big data, IoT, information systems, and cloud computing. These keywords are interconnected and belong to next-generation information technology. Big data, IoT, and cloud computing are significant research drivers in SMIS. Information systems serve as the main research focus in the field. This aligns with the

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objective of this paper, which aims to explore the development of SMIS in the context of next-generation information technology. Furthermore, another category of keywords with high co-occurrence frequency includes machine learning, artificial intelligence, data mining, and deep learning. These keywords represent the technical and methodological aspects of research in SMIS. Figure 5 illustrates that most keywords are interconnected, indicating that published papers in SMIS often cover multiple topics. Combining with Table 1, we can find that the research content of most of these papers is related to SMIS, mainly using different techniques and methods or applied in different research areas. Additionally, keywords with high co-occurrence frequency, such as geographic information systems, intelligent transportation systems, health information systems, Industry 4.0, and driver information systems, represent the application research fields of SMIS.

In addition, we employ a literature review approach to synthesize the literature related to SMIS over the last three years (2021-2023). The results are shown in Table 2.

From Table 2, we can find that research on SMIS in the last three years has predominantly utilized next-generation information technology, such as big data, IoT, blockchain, and cloud computing. The application areas of SMIS have been explored in various fields, including smart city, smart healthcare, smart manufacturing, smart transportation, and smart information systems. Drawing on the results obtained from the bibliometric analysis, we elaborate on the research hotspots for SMIS in the domains of smart medical management, smart manufacturing management, and smart transportation management.

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Table 2. The focus of research related to SMIS from 2021 to 2023

References	Focus areas	Focus of attention	Key technologies
Chatterjee et al. [16]	Smart city	Data protection model	IoT, big data
Anthony Jnr [17]	Smart city	Digital transformation	-
Zekić-Sušac et al. [18]	Smart city	Intelligent system	Machine learning
Hanen and Thierry [19]	Smart medical	Medical information systems	AI, knowledge management, big data, data mining
Soni and Singh [20]	Smart medical	Privacy-preserving authentication, telecare medicine information systems	Sensors, wearable components
Dwivedi et al. [21]	Smart medical	Smart healthcare system	Internet of Medical Things (IoMT)
Zhang and Ming [22]	Smart manufacturing	Smart manufacturing information systems	IT
Zuo [23]	Smart manufacturing	smart manufacturing system	Blockchain
Beverungen et al. [24]	Smart manufacturing	Smart platforms	IT
Abdel-Basset et al. [25]	Smart transportation	Smart transportation systems	IoT, Internet of Vehicle (IoV), blockchain
Ali et al. [26]	Smart transportation		Big data analysis, cloud computing
Wu et al. [27]	Smart transportation	Intelligent network slicing management	Industrial IoT (IIoT)
Sinulingga et al. [28]	Smart information systems	Supervision management information system	Data analysis
Berdik et al. [29]	Smart information systems	Information systems protection	Blockchain
Alzoubi et al. [30]	Smart information systems	Intelligent information systems	BLE Beacon
Gaurav et al. [31]	Smart information systems	Business information systems	IoT, machine learning
Lv and Li [32]	Smart information systems	Intelligent management system	IoT, big data

The first research hotspot is smart healthcare and elderly care management. Researchers have developed IoT-based enterprise health information systems [33]. Research in medical informatics focuses on data mining and machine learning in the technical dimension, and elderly care in the health service dimension [34]. In the context of smart healthcare, Gu et al. [35] proposed a healthcare reasoning knowledge generation method with an evaluation mechanism that facilitates the generation of knowledge-based solutions for new decision problems. This method describes a healthcare decision case as a set of (x, y) vectors, where $x = (x_1, x_2, \ldots, x_n)$ represents a vector of feature attributes, $y \in Y$, and Y represents a discrete variable corresponding to a class. The class values (conclusion or scenario class knowledge) of historical

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cases in the case knowledge base are known. Given a new problem, the problem can be transformed into an unsolved target case with unknown class values. The variable-weighted heterogeneous value difference distance algorithm enables the generation of inferential knowledge to provide decision-makers with knowledge references.

Specifically, $\mathrm{WHVDM}(t,r)= \left(\sum_{i=1}^{n} w_i d_i^2\,(t,r)\right)^{1/2}$, where

$$d_i^2(t,r) = \begin{cases} vdm_i(t,r), if\ x_i\ is\ discrete \\ diff^2(x_{t,i}, x_{r,i}), if\ x_i\ is\ continuous' \end{cases} \tag{1}$$

where $vdm_i(t,r)$ is the value difference matrix (VDM), its value is calculated according to Equation (2):

$$vdm_i(t,r) = \sum_{a\in Y}(pr(y = a|x_i = x_{t,i}) - pr(y = a|x_i = x_{r,i}))^2, \tag{2}$$

where y represents the conclusion class variable, and Y represents the domain of variable y. The term $diff^2(x_{t,i}, x_{r,i})$ corresponds to a component of the traditional Euclidean distance and represents the squared distance between the target case t and the historical case r on continuous attributes, as shown in Equation (3):

$$diff^2(x_{t,i}, x_{r,i}) = (x_{t,r} - x_{r,i})^2. \tag{3}$$

This algorithm is applied to distance measures in cases involving discrete and continuous variables, thereby emphasizing the relative importance of case attributes. Moreover, in a study on content analysis and health support using artificial intelligence algorithms for online health communities, Gu et al. [36] develop an intelligent method for identifying psychological cognitive changes based on natural language processing (NLP) techniques. This method aids in determining whether patients have experienced any psychological cognitive changes. Figure 6 illustrates the architecture of the model.

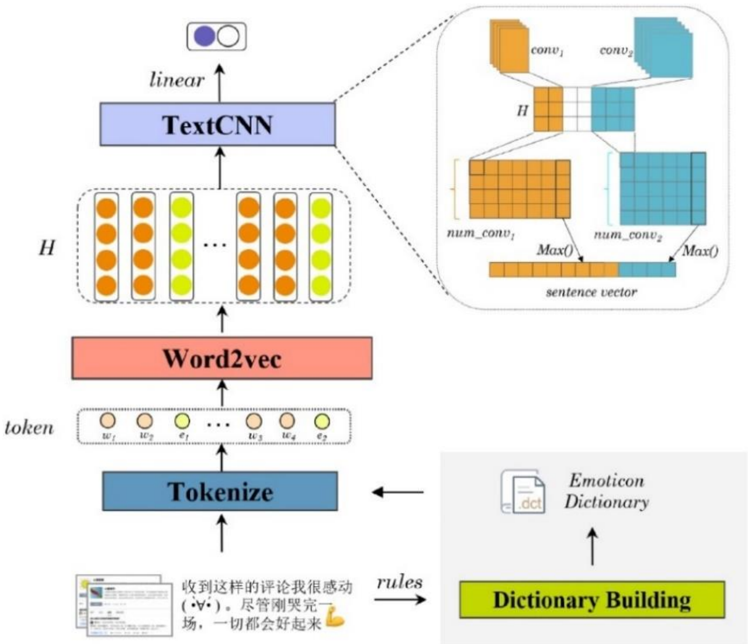

Figure 6. A model based on NLP for identifying mental cognitive changes

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In terms of smart healthcare information systems for elderly groups, the concept of a smart elderly service supply chain has been proposed in academia [37, 38]. With the development of technologies such as the IoT, cloud computing, and big data, a smart elderly service system has been established [39]. This system aims to provide daily services and health support for the elderly. However, before providing services to the elderly, it is crucial to uncover their implicit service needs from their actual behavioral data. To gather behavioral data from the elderly, various sensing devices are utilized. One widely used sensing device for real-time healthcare applications in daily life is the Wireless Body Sensor Network (WBSN) [40, 41]. Hussain et al. [42] propose a human sensor network that detects abnormal vital physiological parameters. The decision-making process is carried out by the sensor nodes. Events (E) are defined based on threshold values for these parameters. For instance, a healthcare system (S) can be defined with three parameters, E_1, E_2, andE_3, as follows:

$$S = (E_1, E_2, E_3). \tag{4}$$

If the parameter values are interdependent, and we denote the thresholds for E_1, E_2, and E_3 as E_{1th}, E_{2th}, and E_{3th}, respectively, we can define the data collection function as

$$f(S_g) = \begin{cases} f(E_1) & if\ E_1 < E_{1th} \\ f(E_1, E_2) & if\ E_1 \geq E_{1th}\ and\ E_2 < E_{2th}. \\ f(E_1, E_2, E_3) & if\ otherwise \end{cases} \tag{5}$$

This event-driven data collection approach minimizes the utilization of communication resources and significantly reduces overhead. Furthermore, Su and Chiang [43] introduce the development and general architecture of the Intelligent Aging-in-place Home Care Web Services Platform (IAServ). This platform operates in a cloud computing environment and offers personalized healthcare services to support a cost-effective and highly satisfying approach to elderly care. The architecture of IAServ is depicted in Figure 7.

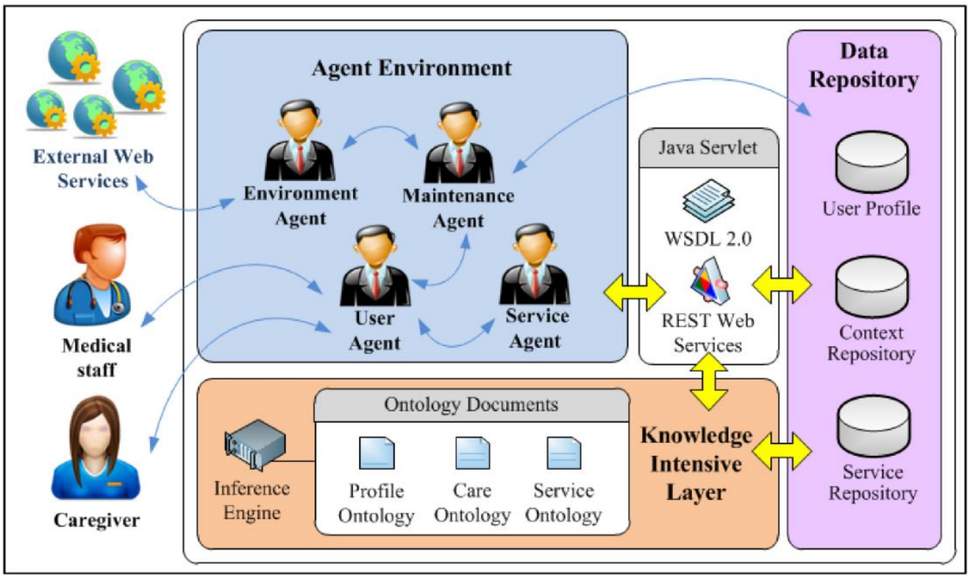

Figure 7. The architecture of IAServ

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The second research hotspot is smart manufacturing management. Predictive manufacturing systems [44], event-driven manufacturing information systems [45], and data-driven intelligent manufacturing systems have gained prominence [46]. Additionally, researchers introduce a novel manufacturing paradigm known as cloud manufacturing. This paradigm combines emerging technologies such as cloud computing, IoT, service-oriented technologies, and high-performance computing [47]. Figure 8 depicts the architecture of a cloud manufacturing service system based on cloud computing and IoT technologies [48].

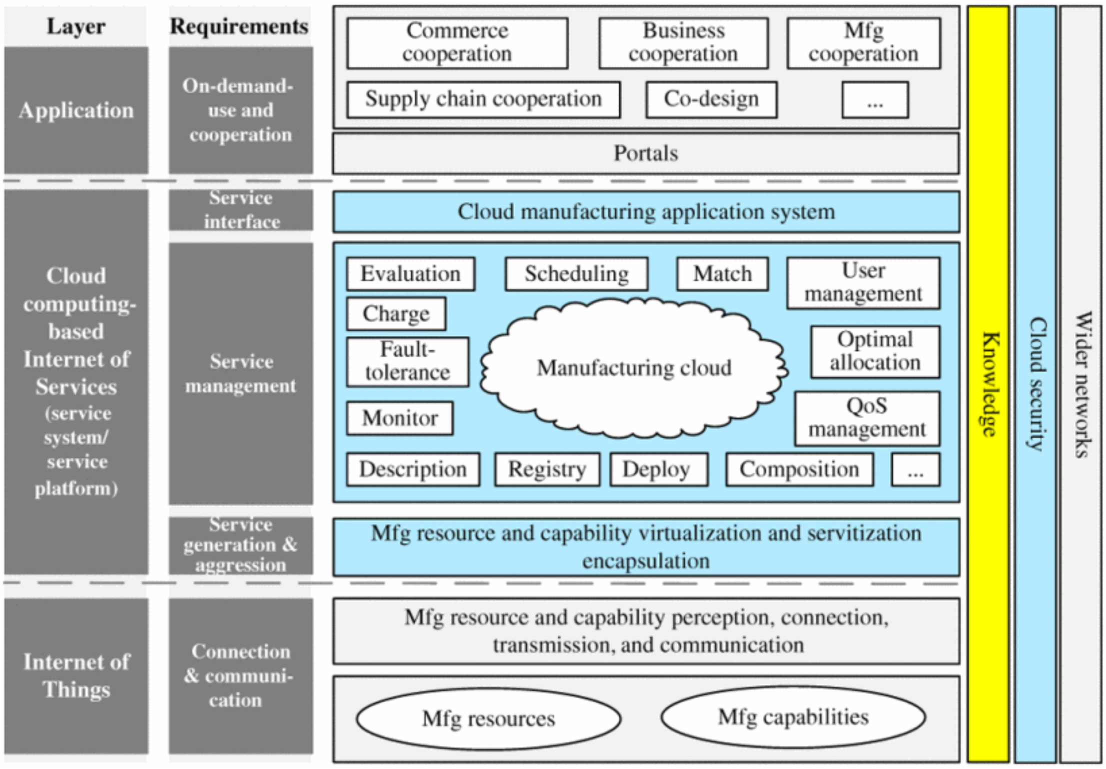

Figure 8. A cloud manufacturing service system architecture

Cloud computing, a robust system with extensive computational capabilities, can store and aggregate relevant resources. It can be dynamically configured to provide personalized services to users [49]. The technical foundation of cloud computing lies in loose coupling, where the infrastructure is logically or physically separated through technologies like virtualization. Cloud computing operates on a client-server model, where the client or cloud user is loosely connected to the server or cloud provider with minimal data or control dependencies. However, data dependencies are crucial in high-performance computing and can be formalized in the following format[50]:

Users are categorized into user sets $Uset_1$, $Uset_2$, …, $Uset_m$ $(m \geq 1)$, while providers are categorized into provider sets $Pset_1$, $Pset_2$, …, $Pset_n$ $(n \geq 1)$. The user set $Uset_i$ and provider set $Pset_j$ are loosely coupled, represented as $Set(Uset_i, Pset_j)$. The three attributes are defined as follows:

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Independent user set:

$$Uset_i \cap Uset_j = \varphi(0 \le i,j \le m, i \ne j). \quad (6)$$

Independent provider set:

$$Pset_i \cap Pset_j = \varphi(0 \le i,j \le m, i \ne j). \quad (7)$$

Independent loosely coupled (cloud subscriber connected to cloud provider) set:

$$Set(Uset_{i1}, Pset_{j1}) \cap Set(Uset_{i2}, Pset_{j2}) = \varphi. \quad (8)$$

IoT plays a critical role in bridging the physical environment of manufacturing with the computing platforms and decision algorithms in cyberspace. Edge computing, a complement to cloud computing, focuses on big data analysis in IoT. It effectively addresses issues such as high latency and performance bottlenecks in cloud computing by offloading computation and storage tasks from remote cloud servers to local edge servers [51]. The selection algorithm for edge computing servers can be outlined as follows [52]:

$$T_{task}(x, esc) = T_{trans}(x, es) + T_{que}(x, es) + T_{process}(x, es) + T_{re}(x, es), \quad (9)$$

where T_{trans} represents the time taken to send task x to the edge server (ES), T_{que} represents the time spent in the queue, $T_{process}$ represents the processing time, and T_{re} represents the time taken to receive the task.

The third research hotspot is smart transportation management. Researchers make significant advancements by developing intelligent transportation systems that leverage IoT and big data approaches to address challenges such as parking and route planning [53, 54]. These systems transform the existing transportation infrastructure into smart transportation systems with Vehicle-to-Everything (V2X) [55]. V2X enables vehicles to connect with various entities. In this context, V stands for the vehicle, and X encompasses objects that interact with the vehicle to exchange information. The current X primarily includes vehicles, pedestrians, roadside infrastructure, and networks. The information exchange modes of V2X interactions include Vehicle-to-Vehicle (V2V) communication between vehicles; Vehicle-to-Infrastructure (V2I) communication between vehicles and roadside infrastructure; Vehicle-to-Pedestrian (V2P) communication between vehicles and pedestrians; Vehicle-to-Network (V2N) communication between vehicles and the network. Figure 9 illustrates the concept of a smart transportation system [56].

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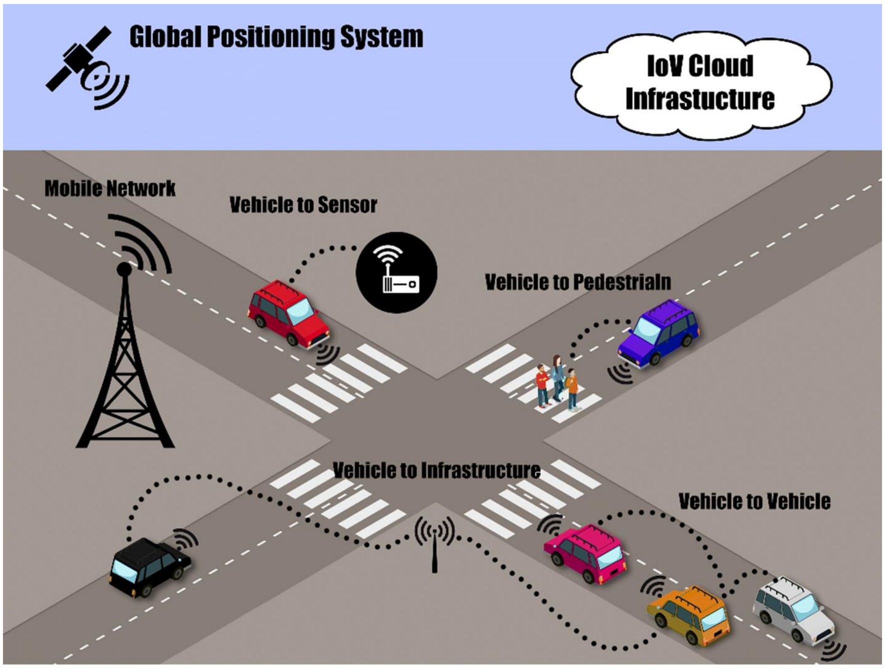

Figure 9. The conceptual diagram of a smart transportation system

V2V enables vehicle-to-vehicle communication and data sharing through the device-to-device (D2D) protocol in Cellular-Vehicle-to-Everything (C-V2X), leveraging cellular networks. This communication facilitates effective path planning and helps reduce fuel consumption. Xiao et al. [57] propose an optimization algorithm to address energy efficiency issues related to multiplexing cellular user resources in D2D-based C-V2X. The algorithm aims to optimize the following problem:

$$\max E_e = \max \frac{\sum_{m=1}^{M} B \log_2(1+SINR_m)}{\sum_{m=1}^{M}\left(\frac{2}{M}p_m^0+\eta\rho_{k,m}p_m^d-E_m\right)}, \quad (10)$$

$$s.t. \quad SINR_m \geq \gamma_m \ \forall m \quad (10a)$$

$$SINR_k \geq \gamma_k \ \forall k \quad (10b)$$

$$0 \leq p_m^d \leq p_{total} \ \forall m, \quad (10c)$$

where $SINR_k$ represents the signal-to-noise ratio for the k cellular user (C-UE) at the base station (BS), $SINR_m$ represents the signal-to-noise ratio for the k C-UE user at the BS, and $\frac{2}{M}p_m^0 + \eta\rho_{k,m}p_m^d - E_m$ represents the power loss of the m pair of vehicular users (V-UE). Equation (10a) and (10b) impose constraints on the $SINR$ for V-UE and C-UE users, respectively, while Equation (10c) restricts the maximum power for V-UE users. The variable p_{total} represents the maximum transmit power allowed for the m pair of V-UE users.

According to the analysis of the core technologies employed in popular research fields of SMIS, we can find that an increasing number of technologies and methods have been introduced to facilitate the continuous development of SMIS. Moreover, the application areas of SMIS have expanded significantly, resulting in the emergence of various SMIS, such as smart healthcare

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information systems, smart elderly information systems, smart manufacturing management systems, and smart transportation management systems. These systems exhibit human-like features, including self-organization, self-adaptation, and self-evolution, enabling them to provide users with smart analysis, management, and decision-making services across diverse scenarios.

4 Typical Applications of SMIS

Based on the analysis of research hotspots in the academic community and the review of the current application of SMIS, we focus on four prominent practical applications: smart healthcare management system, smart elderly care management system, smart manufacturing management system, and smart transportation management system.

4.1 Smart healthcare management system

Smart healthcare has experienced rapid development since IBM introduced the concept in 2009. Healthcare information systems play a crucial role in hospital management and patient care, serving as integrated systems that support the comprehensive information needs of various stakeholders, including hospitals, patients, clinical services, ancillary services, and financial management [58]. The smart healthcare information system, integrating technologies like 5G, blockchain, IoT, and artificial intelligence, addresses the limitations of decentralized traditional healthcare systems, fragmented medical information, and resource disparities. It offers various scenario-based applications and personalized services, including one-stop consultation, electronic health record management, telemedicine, and intelligent prediction and analysis. These services facilitate enhanced interconnectivity, real-time information sharing, and business collaboration among patients, healthcare professionals, healthcare institutions, and healthcare devices.

Harman, a wholly-owned subsidiary of Samsung Electronics Co., Ltd., unveiled the Harman Intelligent Healthcare Platform, a new comprehensive digital health platform designed to help healthcare and life sciences enterprises in their journey towards personalized customer-centric services. Harman Intelligent Healthcare Platform leverages artificial intelligence and machine learning modules to improve customer experience and engagement through predictive analytics and actionable insights on data harnessed from disparate sources. The key modules of the Harman Intelligent Healthcare Platform are depicted in Figure 10 [59].

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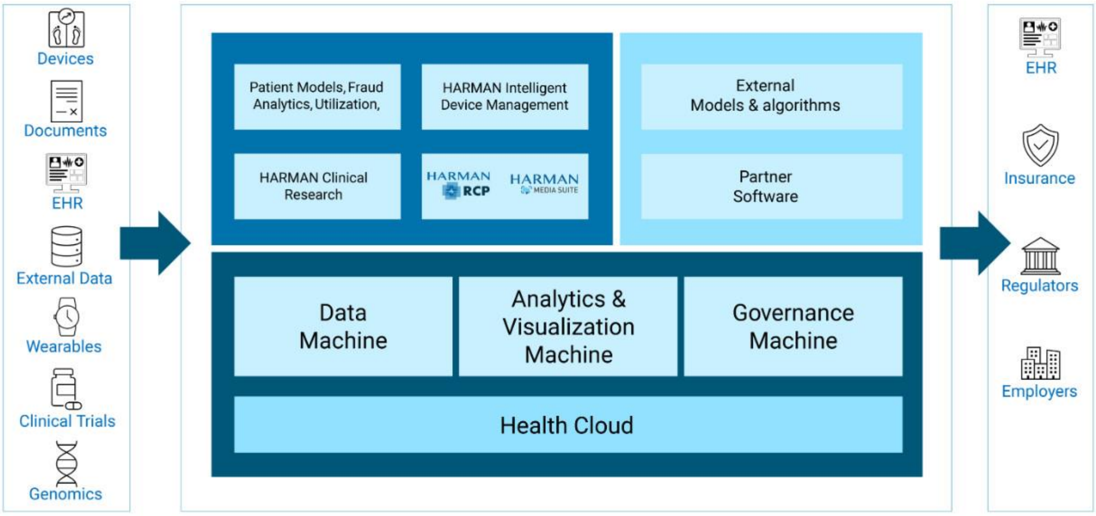

Figure 10. The key modules of the Harman Intelligent Healthcare Platform

4.2 Smart elderly care management system

The concept of smart elderly care was formally introduced by the Life Trust of the United Kingdom in 2012. It means that people can build an IoT system and information platform for family, community, and institutional elderly care through various modern scientific and technological means, such as the Internet and cloud computing [60]. Smart elderly care, guided by the needs of the elderly and facilitated by the smart elderly care platform, utilizes intelligent products to connect both the supply and demand sides [61, 62]. It brings together the elderly, community, medical personnel, medical institutions, government, and service organizations to provide convenient, efficient, IoT-enabled, connected, and smart elderly care services.

Hengfeng Information is an exceptional information technology service provider specializing in smart city solutions in China. Leveraging technologies such as the Internet, mobile Internet, IoT, and cloud computing, the company has developed an innovative “Internet + community home care services” platform. This platform has successfully established a comprehensive home care model. This model combines a “care center + service site + call center + shopping mall for the elderly + alliance merchants” approach [63]. The platform of Internet + community home care services developed by Hengfeng Information is shown in Figure 11.

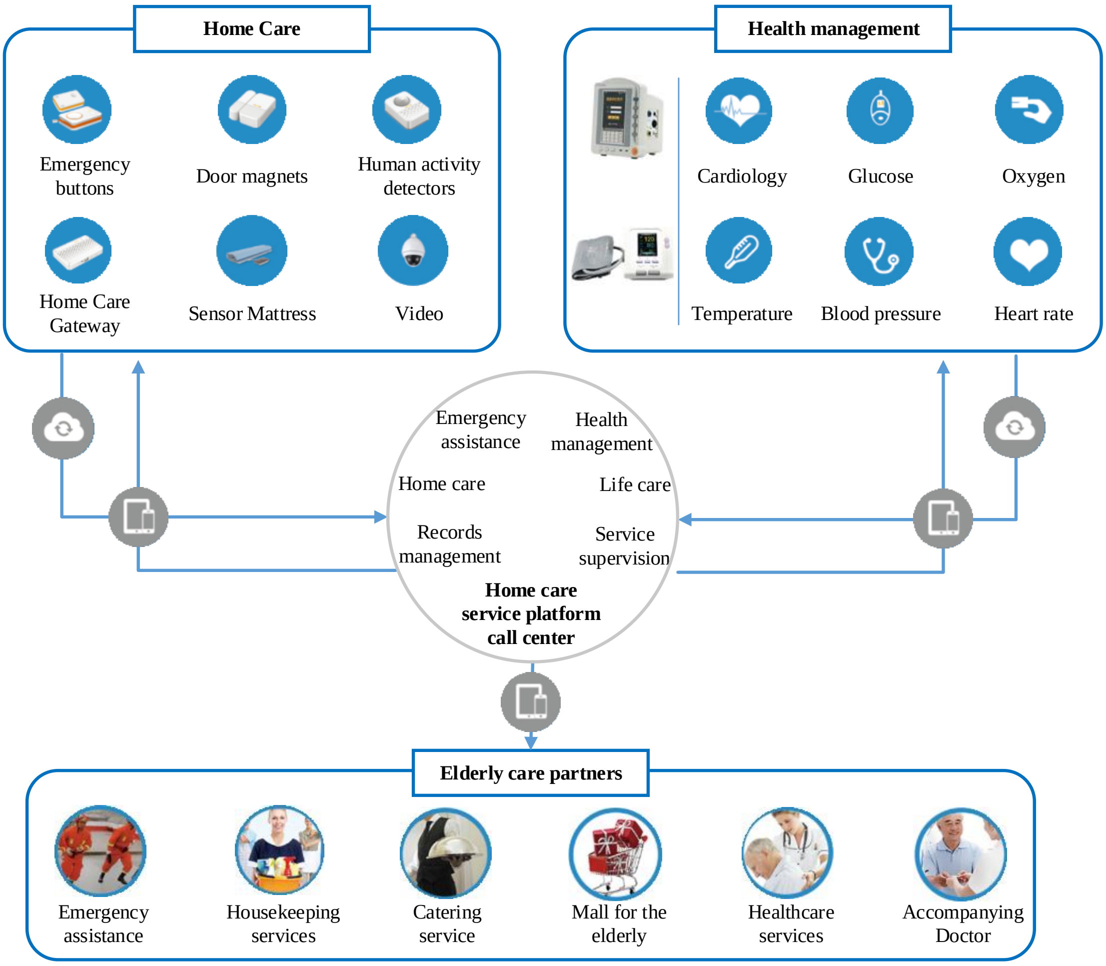

Figure 11. The platform of Internet + community home care services

4.3 Smart manufacturing management system

With the introduction of Germany's Industry 4.0, enterprises have embraced the establishment of industrial Internet enterprise-level manufacturing platforms to facilitate their operations' digital, networked, and intelligent transformation. This transformation is supported by intelligent manufacturing management information systems, ultimately enabling the realization of green and intelligent manufacturing practices. Smart manufacturing, further advancement of intelligent manufacturing, signifies the integrated application of next-generation information technology in the manufacturing industry. Through the utilization of technologies such as the IoT, active perception, and scene intelligence, smart manufacturing explores user needs, enables large-scale personalized customization, facilitates accurate supply chain management, and implements whole lifecycle management, thereby promoting a more intelligent approach to manufacturing management.

Haier, a prominent Chinese home appliance industry player, has established an integrated, digital, and intelligent service platform known as the Cloud of Smart Manufacture Operation Platform (COSMOPlat) [64]. COSMOPlat serves as a catalyst for the comprehensive upgrade of

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Chinese manufacturing by accelerating its transition towards a more advanced and efficient model. The architecture of COSMOPlat is depicted in Figure 12.

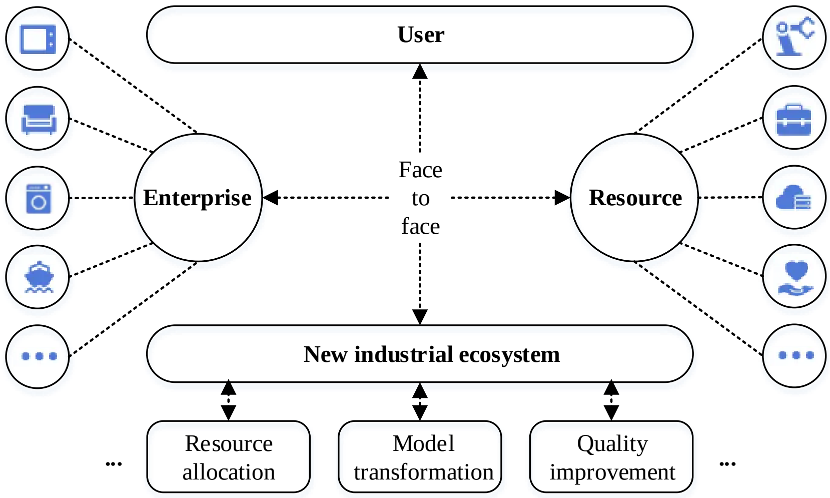

Figure 12. The architecture of COSMOPlat

4.4 Smart transportation management system

Smart transportation originated from the smart earth proposed by IBM in 2008 and the smart city proposed in 2010. It is developed by integrating intelligent transportation systems with emerging technologies such as the IoT, cloud computing, and the mobile Internet. The smart transportation system addresses the need for real-time traffic monitoring, public vehicle management, travel information services, and vehicle-assisted control. It enables collaborative interactions among humans, vehicles, and roads, significantly enhancing transportation efficiency, improving the transportation environment, and playing a crucial role in optimizing traffic operations and providing intelligent public travel services.

Baidu, a leading autonomous high-tech enterprise in China, has developed the "Baidu ACE (Autonomous Driving, Connected Road, Efficient Mobility)" vehicle-road mobility engine. This innovative solution utilizes artificial intelligence, big data, autonomous driving technologies, vehicle-road collaboration, high-precision maps, and other information technologies to advance road infrastructure and promote smart infrastructure, smart transportation equipment, and convenient travel services [65]. The architecture of the Baidu ACE traffic engine is depicted in Figure 13.

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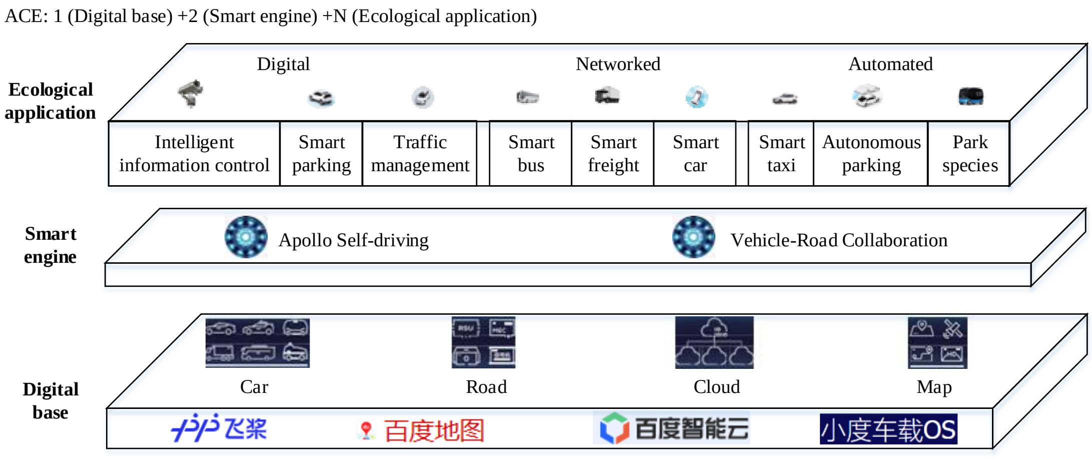

Figure 13. The architecture of the Baidu ACE

Based on the aforementioned practical application cases, SMIS has yielded significant accomplishments in smart healthcare, smart elderly care, smart manufacturing, and smart transportation. Moreover, applications are growing in areas such as smart communities [66] and smart tourism [67]. These successful application practices demonstrate the substantial potential for the development and wide-ranging application prospects of SMIS.

5 Development directions of SMIS

SMIS actively senses and adapts to changes in the external environment using multiple sensors, engaging in real-time interactions with users to collect multimodal data. It extracts knowledge and user preferences from vast data, providing customized smart solutions tailored to their specific requirements. To facilitate smart decision-making services, SMIS optimizes and allocates processes and resources across domains, organizations, and departments. This requires the development of an open and flexible architecture capable of integrating diverse systems on a larger scale. In light of these considerations, this paper identifies four key areas for the future development directions of SMIS: smart interaction, smart decision-making, efficient resource allocation, and flexible system architecture. These aspects are interconnected and supported by a flexible architecture, as illustrated in Figure 14.

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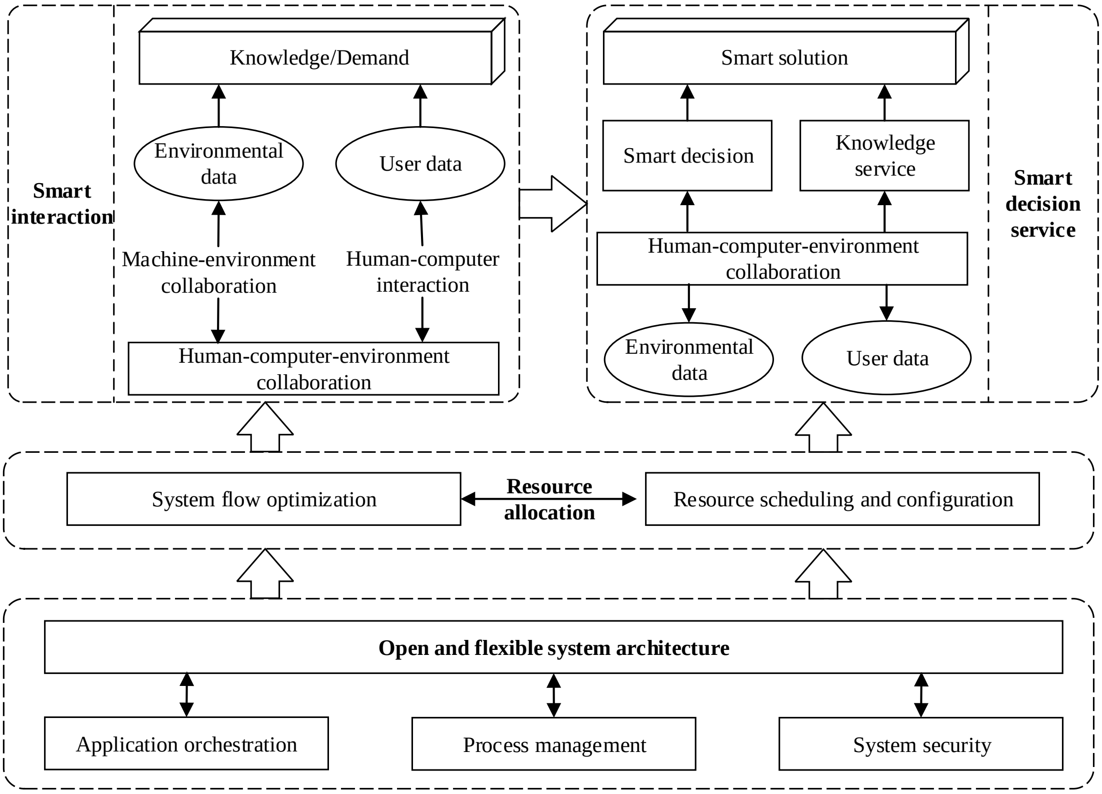

Figure 14. The research framework for the development directions of SMIS

5.1 Dynamic perception and human-computer interaction mechanisms in complex and open environments

In the era of economic globalization, organizations face a rapidly changing market environment, requiring real-time interaction with the environment to gather information on its current state. Similarly, organizations need to engage with users directly to understand their needs and incorporate them into SMIS operations to enable effective human-machine collaboration. To achieve dynamic perception, SMIS should consider various sources such as user feedback, environmental conditions, and targeted data in order to gain comprehensive insights into stakeholder interactions in multimodal scenarios. This exploration of data characteristics and understanding of state change patterns enable the development of dynamic perception mechanisms for multiple scenarios.

Advancements in information technology have enabled the virtual synergy of human behavior and the fusion of nature and human society, ushering in a new era of data [68]. Consequently, when interacting with users and the environment, SMIS needs to acquire and analyze massive amounts of heterogeneous big data from various sources within and outside the system. This involves identifying implicit user needs, adapting to changes in the external environment, promptly responding to user needs, and providing comprehensive service support. Such actions facilitate the synergistic symbiosis of the human-machine.

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For instance, in smart healthcare, SMIS can integrate and analyze big data features and knowledge requirements within complex medical scenarios such as diagnosis, treatment, prediction, warning, and rehabilitation. By employing knowledge semantic dynamic modeling methods based on heterogeneous health big data from multiple sources and interpretable machine learning, along with large-scale user collaborative modeling methods for cross-organizational multi-level task requirements, SMIS can achieve highly reliable and interpretable collaborative knowledge reasoning. This approach supports decision-making efficiency and service quality by leveraging healthcare expert experiences and incorporating patient feedback interventions.

5.2 Smart collaborative decision-making and personalized knowledge service model for users' implicit needs

SMIS leverages emerging technologies such as big data, artificial intelligence, and deep learning to enable smart decision-making and scenario-based services. It provides smart decision-making support to users by employing multi-agent learning mechanisms in complex and dynamic environments. Current advancements in this area include multi-agent reinforcement learning based on populations [69], information systems supporting organizational creativity [70], and medical-assisted decision support systems [71]. Future research can explore smart group modeling and adaptive decision models to enhance the capabilities of SMIS.

Addressing users' implicit needs, SMIS should develop personalized knowledge service models to recommend knowledge service solutions using digital twin technology. This approach enhances the system's knowledge service capabilities and improves user satisfaction. For instance, during major public health emergencies, cross-organizational health data resources from hospitals, public health institutions, and communities can be utilized. A collaborative knowledge inference method based on a multi-case base can generate medical knowledge maps rapidly and dynamically construct cross-organizational case bases. This enables disease risk identification and collaborative decision-making among multiple medical and defense bodies by leveraging joint data and knowledge. Moreover, it facilitates the integration, smart analysis, and active service of medical and health data, and public health monitoring data. This technical support is valuable for dynamic disease monitoring and intelligent collaborative decision-making in the context of medical and defense collaboration.

Additionally, in medical prevention and coordination, the personalized knowledge needs of various stakeholders, such as disease control personnel, doctors, and patients at different levels, can be analyzed in dynamic medical prevention and coordination task scenarios. Furthermore, mechanisms for matching the needs with service resources can be explored. This can involve the development of knowledge recommendation methods based on machine reasoning and natural

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language understanding, as well as multi-grain knowledge matching and retrieval methods. The goal is to provide personalized, dynamic, and smart knowledge services to individuals involved in disease prevention and control.

5.3 Cross-organizational scenario-based approach to system process optimization and resource allocation

SMIS plays a crucial role in providing smart decision-making and scenario-based services. To achieve smart decision-making goals and deliver scenario-based services effectively, SMIS needs to optimize process modeling and allocate resources efficiently. This requires the establishment of a flexible system process model and the exploration of methods for customizing and reusing personalized process modules. Furthermore, there is a need to address the demand for flexible and personalized modeling of cross-organizational business processes.

Regarding resource allocation, it is essential to study cross-domain, cross-organizational, and cross-departmental resource scheduling models and methods that incorporate smart and intelligence. This research can significantly enhance the efficiency and effectiveness of resource allocation. Given the diverse characteristics of resources in the human-computer system, such as varying sizes, distributions, and dynamics, applying self-organization theory can provide insights into the multi-level resource interaction mechanism across the value chain. Moreover, it can facilitate the development of dynamic self-organization methods for resources to pursue multiple objectives and tasks.

By analyzing resource management scenarios and resource optimization goals in complex and dynamic environments, it becomes possible to explore self-adaptive mechanisms for resource allocation, scheduling, and organization. Additionally, research on resource scheduling methods, based on deep reinforcement learning, can address the dynamic needs of multiple subjects and various grain sizes. This not only enables effective interaction and collaboration among multiple subjects within the system process model but also caters to users' personalized and dynamic needs at different levels.

5.4 Open and flexible management information system architecture and governance system

To ensure rapid processing and response to internal and external needs, the architecture of MIS needs to evolve from a traditional centralized structure to a distributed and flexible one. This involves building the system as a distributed and adaptive scheduling multi-subject architecture with reconfigurable real-time tasks. Flexible access system architectures capable of supporting diverse requirements and facilitating agile service creation have already been developed [72]. Additionally, middleware platforms based on OpenStack have been employed to facilitate and orchestrate the offloading process [73].

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Regarding system architecture, SMIS can adopt an object-oriented approach to plan system functions and achieve flexibility within management information systems. This can be accomplished through the personalized configuration of functional modules and the utilization of multi-agent configuration methods. Hence, SMIS can effectively monitor and manage system functions, processes, and operational status, while also enhancing the system to adapt to environmental changes and individual user needs. Furthermore, the open and flexible architecture of SMIS places greater emphasis on the system's governance. In terms of SMIS governance, blockchain technology can be explored to establish mechanisms for data quality control, system security protection, and user privacy protection. These mechanisms ensure the continuous and stable operation of the system.

6 Conclusion

As an important tool for assisting organizations in management and decision-making, SMIS plays a crucial role in society and organizations. This paper begins by presenting the evolution of SMIS based on previous research and defines the different periods of SMIS, highlighting how management information systems have evolved into the smart period. Next, by analyzing literature related to SMIS over the past decade, the paper summarizes the research hotspots in SMIS and identifies the healthcare, elderly care, manufacturing, and transportation fields as prominent areas where SMIS is widely and maturely applied. Furthermore, the paper examines typical application cases of SMIS, showcasing the significant development potential of SMIS. Lastly, the paper outlines the future development directions of SMIS, focusing on four key aspects: smart human-computer interaction, smart decision-making services, efficient resource allocation, and flexible system architecture.

SMIS is capable of addressing complex and ambiguous user needs in real-time, providing users with smart analysis, management, and decision-making services. In future research, it is important to explore diverse human-machine partnerships to enhance the human-like capabilities of SMIS. By leveraging these partnerships, SMIS can deliver more smart and personalized services tailored to the unique requirements of different positions and users in various roles. Additionally, there should be a focus on cross-platform integration of SMIS to enable seamless resource integration and collaboration across domains, organizations, and departments. This cross-platform integration will facilitate the efficient utilization of resources and promote cooperation among different entities. To further advance SMIS, it is crucial to conduct in-depth case studies and experimental research. These studies will provide valuable insights into the practical implementation and impact of SMIS in real-world scenarios.

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