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Research on community elderly care service system based on digital twin

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Abstract: *With the ongoing development of demand for elderly care and advancements in information technology, smart elderly care emerges as a crucial solution to address the challenges posed by an aging population. The integration of digital twin technology into smart elderly care can facilitate overcoming the technical bottlenecks associated with implementing elderly care services. This paper explores the synergy between digital twins and community-based elderly care service systems, examining the functional mechanisms of digital twins across various practical entities within these systems. A comprehensive system architecture is proposed structured around five levels: sensing layer, communication layer, data processing layer, application layer, and display layer. This framework aims to address critical pain points and difficulties inherent in traditional community elderly care service systems—such as limited resource allocation, inefficient demand matching, lack of precision in service delivery, and delayed monitoring—and offers innovative pathways for enhancing intelligent elderly care services through the utilization of digital twins.*

Keywords: *Digital Twin; Community Aged Care; Smart Elderly Care; Elderly Care Service System*

1. Introduction

For an extended period, China's population structure has experienced complex and profound transformations driven by various factors, including regional economic disparities, shifts in fertility concepts, social development changes, and adjustments to population policies. Currently, China's social stability is challenged by significant issues related to its population structure: a low fertility rate coupled with high aging rates and the imbalance resulting from negative population growth. By the end of 2023, there were approximately 216.76 million individuals aged 65 or older, representing 15.4 percent of the total population according to official statistics. The dependency ratio for those aged 65 and above increased from 13.1 percent in 2013 to 22.5 percent in 2023[1]. Over the past decade, this rising number has intensified the burden on the workforce responsible for supporting the elderly.

Given that China remains in the primary stage of socialism, its capacity to provide adequate pension resources as well as a robust pension security system and service framework for its substantial elderly population remains insufficient. This considerable gap within the elderly care service market is fostering new opportunities for growth of pension service institutions and the silver economy industry; concurrently, demand among older adults is shifting from mere survival needs towards developmental aspirations.

In order to enhance the elderly care service system and address the diverse, multifaceted, and multi-tiered needs of older adults, the integration of digital technology with elderly services is crucial for tackling the challenges associated with an aging population. By leveraging big data, cloud computing, the Internet of Things (IoT), artificial intelligence (AI), and other advanced technologies, smart elderly care can effectively align with the varied requirements of seniors. This approach enables the provision of personalized and efficient eldercare services while significantly addressing the limitations inherent in traditional caregiving models.

2. The Background of smart elderly care development in China

The concept of smart elderly care encompasses three key dimensions: wisdom in assisting the elderly, wisdom in filial piety, and wisdom in utilizing the capabilities of the elderly. This approach emphasizes leveraging information technology and other modern technologies to support, honor, and engage with older adults. It also involves that the development of the elderly human resources through certain systems

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or platforms enables a better realization of the goals of "the elderly making contributions" and "the elderly being utilized effectively"[2].

With the ongoing increase in demand for elder care services alongside advancements in information technology, the smart elderly care services industry is currently experiencing significant growth. Specifically, there has been a rapid evolution and proliferation of smart health care products; this sector has begun to establish a substantial market presence as smart applications gradually penetrate basic pension services. Furthermore, policy guidance plays a crucial role. In 2021, both the Ministry of Industry and Information Technology and the National Health Commission released the "Action Plan for the Development of Smart Healthcare and Aged Care Industry (2021-2025)," which outlined six major development priorities along with capacity enhancement initiatives and promoted three types of special projects within smart pensions. Supported by these policies, economically developed regions facing high levels of aging have taken pioneering steps toward innovative practices in smart elderly care. Notable examples include Tianjin's Intelligent Service Platform, community-based smart healthcare initiatives, Wuxing District's Smart Elderly Care Service Center in Huzhou City, and Hangzhou Shangcheng District's digital twin eldercare home.

China faces severe and complex challenges related to aging; notably, structural imbalances in resource supply represent the most significant constraint on current social pension system. Deep-rooted issues such as inadequate elder care facilities and insufficient effective service provision further exacerbate these challenges. Despite having emerged only slightly over a decade ago amidst numerous obstacles—achieving initial successes at this stage—the smart elderly care industry continues to face a range of complex and evolving challenges.

Currently, smart elderly care is confronted with several key issues that hinder innovation in its model. These include limited policy support at district and county levels, outdated technological platforms, a narrow range of elderly care services offered, inconsistent service quality, and a shortage of skilled personnel. Addressing these challenges necessitates urgent reforms and innovations within the sector [3].

3. The application of digital twin technology in elderly care field at home and abroad

Digital twin technology serves as a means to create a virtual representation of a physical entity in a digital format, enabling the simulation, verification, prediction, and control of the entire life cycle process of that entity through data transmission and algorithmic modeling [4]. The primary structure of applications driven by digital twins typically encompasses five key elements: the physical entity, the virtual model, the service system, twin data, and their interconnections. Integrated with emerging information technologies, it can fulfill the requirements of virtual-real convergence, real-time interaction, evolution and iteration while providing comprehensive support across various fields through full-factor, full-process, and full-business data [5].

Currently, research on digital twins is still in its nascent stages in China. Relevant technologies and concepts have reached relative maturity within industrial design and intelligent manufacturing sectors but are gradually being extended to encompass top-level design frameworks for smart cities. Significant advancements have been observed in areas such as smart transportation, smart logistics, smart communities, smart facilities, and smart healthcare. Furthermore, the academic community is actively exploring feasibility studies focused on vertical applications within specialized domains centered around specific subject entities.

By integrating virtuality with reality—characterized by inclusivity and precision—the concept of digital twins holds multi-dimensional significance with high practical value for both production processes and daily life in contemporary society amidst rapid Internet development.

As for the application of digital twins in smart elderly care, China is currently prioritizing innovative medical and health services as well as health management solutions tailored for the elderly population. In terms of patient information digitization, Zhang Jie et al. [6] developed a real-time health risk monitoring and alarm system specifically designed for older adults using digital twin technology. This system integrates vision sensors, artificial intelligence chips, deep learning algorithms, and 3D modeling to provide immediate responses to various risks faced by the elderly—particularly those with dementia—including incidents such as disorientation, falls, and medical emergencies. A pilot operation was conducted at Tianbao Nursing Home in Hongkou District, Shanghai. Li Jiacai et al. [7] focused on the establishment and monitoring of a digital twin care system for elderly patients with cognitive disorders, which assists caregivers in promptly identifying abnormalities in the elderly and facilitating timely

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intervention treatments.

Regarding innovations in community elderly care service systems, Cheng Haolun [8] proposed a "patient -- digital twin -- comprehensive medical and health service" docking model based on the service demand orientation of community health management. This approach utilizes digital twins to innovate the community geriatric disease health management service mode, encompassing system construction, implementation pathways, and platform design.

In terms of enhancing elderly care infrastructure, Jia Guofeng [9] explored methods for implementing a digital intelligent twin fire cloud platform within elderly care institutions. By accurately deploying functions such as early warning systems, command protocols, and rescue operations, this platform enables real-time situational awareness during emergencies while allowing for swift coordination and dispatching of all rescue resources to improve fire emergency response efficiency in these facilities. Huang Lidi and Zhao Chaorui et al. [10] introduced a joint simulation evacuation method utilizing a digital twin model specifically designed for elderly apartments; this method is aimed at assessing fire safety and optimizing design strategies for such residences while proposing transformation measures based on simulation results related to evacuation optimization in elder housing scenarios.

Through the analysis of domestic research, it is evident that within the framework of intelligent elderly care driven by digital twins, the current theoretical application primarily focuses on innovative implementation pathways for health and medical services tailored to elderly patients. This approach effectively highlights the capabilities of digital twins in accurately restoring and mapping physical entities. However, the potential applications of digital twin technology extend beyond this scope.

As previously mentioned, there are significant challenges currently facing elderly care: the spatial distribution of service resources is uneven; the old-age security system remains imperfect; there is a low level of digitalization in elderly facilities; and the content offered in elderly services is limited. A comprehensive consensus has emerged regarding leveraging information technology to address these issues in eldercare. Introducing the concept of digital twins at the community level can achieve breakthroughs in overcoming technical bottlenecks within existing elderly care service systems. It can also foster innovative integration pathways for community-based eldercare resources, promote optimal allocation of these resources, create personalized service offerings that cater to deeper needs, and accelerate advancements in happy aging, healthy aging, and smart aging initiatives.

4. The conduction path of the digital twin system targeting the pain points of community elderly care

Community-based elderly care refers to a model in which the family serves as the core and the community acts as the support. Government and market introduce multiple entities to provide professional elderly care services, including daily care, medical assistance, home help, and spiritual comfort. However, during the transmission and implementation of community elderly care service resources, issues such as uneven distribution and imbalances between supply and demand frequently arise. These discrepancies are attributed to variations in policy transmission across provinces, cities, districts, and neighborhoods; differences in operational mechanisms; diverse resource characteristics; varying progress in environmental construction; and distinct needs among the elderly population.

To address the critical issue of uneven supply of elderly care service resources, it is essential to apply digital twin technology to establish a resource integration system that encompasses a broader scope, achieves higher precision, enables more accurate deployment, and facilitates more agile feedback mechanisms.

First and foremost, the digital system must gather essential information regarding the scale, location, and capacity of urban public service facilities, community infrastructure, and third-party cooperation institutions. It is imperative to implement comprehensive monitoring of accessible resource throughout the entire process. The frequency, duration, and preferences associated with the use of spaces, facilities, and services within the system will be meticulously recorded to serve as a foundation for decision-making consultations as well as operation and maintenance management. Through automated comparison and evaluation mechanisms, detailed feedback will be provided concerning specific deficiencies in resource of communities that lack adequate elderly care service functions. Additionally, alternative facilities characterized by low utilization rates but located nearby—along with high service integrity—will be highlighted within neighborhoods. This approach aims to facilitate cross-matching between supply and demand at both community and street levels while diminishing the territorial management model

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traditionally emphasized in social governance.

The real-time data updates also streamline what has historically been a lengthy process involving consultation, inquiry, waiting periods, and booking applications for elderly individuals. For daily needs related to care services as well as leisure activities such as entertainment or sports, users need only select their desired type of service; real-time availability across various facility tiers will be clearly presented. Elderly users can either opt for an optimal arrival plan recommended by the system or re-evaluate available service types based on geographical considerations. This operational framework aligns more closely with the decision-making habits of older adults as well as their mindsets of reducing the burdens on their children, while empowering them to exercise autonomy effectively. Consequently, it maximizes the advantages offered by intelligent decision-making systems. For limited resources that require a high degree of specialization, such as healthcare, it is essential to enhance the supply from multiple entities, facilitate the collaboration between medical resources within the community and those in surrounding areas, and establish a platform for integrating medical and nursing services in the community. On one hand, this approach can alleviate the operational pressures on government-led elderly care service institutions. On the other hand, it can improve the single service form, achieving that proficiency in healthcare services including care services, rehabilitation and health care, family doctors, health consultations, and psychological consolation can meet diverse needs across various levels. Furthermore, this strategy facilitates the provision of tailored solutions for elderly individuals with differing economic circumstances and physical conditions.

In addition to addressing some of the supply-demand imbalances through resource activation at physical sites, limitations imposed by spatial constraints can be mitigated through digital twin virtual spaces [11]. Activities that are feasible online can be integrated into these digital twin environments corresponding to offline service scenarios. For instance, online psychological services, hobby training sessions, safety education lectures for seniors, and educational courses can all be accessed without requiring individuals to leave their homes. This setup allows for real-time monitoring and communication while fostering mutual assistance among participants. On the one hand, it offers a channel for elderly individuals with limited mobility to enjoy services, and also enhances social participation and mental well-being among older adults. On the other hand, it expands the service audience, conserves space and service costs.

The human resources involved in community elderly care primarily consist of in-service staff from institutions, social workers, volunteers, and charitable organizations. For an extended period, it has been challenging to assemble a substantial pool of human resources for elderly care services in regions with limited developmental capacity. This challenge is compounded by issues such as the insufficient professional qualifications of service teams, minimal practical operational experience, and discontinuity in service provision. On the basis of maintaining regular community services on a daily basis, while also taking into account the emergency demands of the elderly, such as medical assistance, doorstep errands, and housekeeping services, etc., it necessitates adequate support from human resources. Problems arising from inadequate personnel—including ineffective service implementation and delayed responses to demands—must be addressed urgently.

The digital twin technology holds promise for achieving rapid responses to temporary needs [11]. The specific operation involves importing digital models of community spatial layouts along with information about various participants. Once a service demand is registered, the system automatically identifies the nearest available service provider online or customizes the best-suited provider based on relevant attribute labels corresponding to specific service needs. This process allows for immediate task distribution while eliminating delays associated with logging into platforms for consultation and acceptance of requests.

For younger seniors who are open to re-employment opportunities, the digital system simultaneously assigns them roles as both service providers and recipients. These re-employed seniors benefit from independent choices regarding work types and schedules while bypassing traditional processes such as publicity campaigns or registration procedures through designated channels. This effectively enhances flexibility in employment options for older adults while fostering their sense of achievement and overall well-being.

Therefore, the digital twin demonstrates its practical significance in enhancing the efficiency of supply and demand alignment, optimizing the allocation of service personnel, and facilitating re-employment opportunities for the elderly.

In the transition from family care to community care, not all elderly individuals and their families are willing to embrace community care services. This reluctance primarily stems from a distrust of service

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providers and concerns regarding the quality and safety of elderly care services [12]. The elderly often face various health issues, making it challenging for service providers to fully comprehend each individual's physical health status. Moreover, mental health is frequently overlooked due to its subtle nature; thus, community elderly care services are generally perceived as less meticulous compared to familial caregiving.

To address the challenges encountered by the elderly when accessing community care services, digital twin technology can be employed. This technology enables dynamic monitoring of health indicators, body posture, and activity positions through sensor devices while seniors engage in these services. It automatically uploads data to create personal digital health information files and corresponding digital twin models. By integrating algorithmic analysis, this system can assess the health status and behavioral dynamics of older adults in real time, facilitating risk alerts and early warning functions.

The digital twin effectively replicates an elder's activity status without utilizing image data. This approach not only safeguards the privacy of seniors but also allows family members, caregivers, and healthcare professionals to continuously monitor health data—thereby mitigating risks of health. Additionally, it aids in gathering evidence during disputes by clarifying rights and responsibilities, and consolidating the elderly security framework. Moreover, maintaining a personal digital health information archive streamlines access for service personnel who need quick reference points for developing targeted medical and healthcare plans tailored to individual needs.

Inspired by the above, the entities and their operational relationships are summarized in Figure 1.

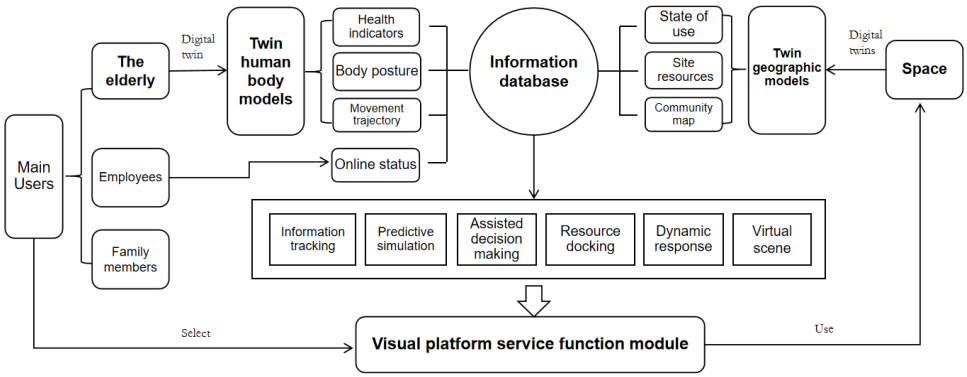

Figure 1: Operation mechanism of community elderly care digital twin system

Starting from the aforementioned concepts, this paper aims to establish an architectural framework for a community elderly care service system based on digital twins. As shown in Figure 2, the architecture is structured in layers, progressing from the bottom layer to the top layer: sensing layer, communication layer, data processing layer, application layer, and display layer. Various information technologies are integrated to facilitate inter-layer connectivity.

The sensing layer comprises diverse sensors and sensor networks that convert collected physical signals into digital signals suitable for processing and transmission. The acquisition of objective data includes human body data, environmental thermal data, scene data, and statistical information; these rely on sensors to record real-time changes. In contrast, subjective data refers to artificially modifiable information such as feedback from individual consciousness and periodic data collection that serves as a constant reference over time.

The communication layer is tasked with transmitting the collected data from device terminals to the data processing platform primarily through wireless means. In this study, the community elderly care service system employs WIFI, Bluetooth, ZigBee, and cellular technologies to construct a transmission framework tailored for various scenarios concerning communication distance, transmission speed, and real-time performance.

The data processing layer is responsible for managing and utilizing data information. A cloud database is employed for storage and retrieval purposes, while Building Information Modeling (BIM), Geographic Information Systems (GIS), and Artificial Intelligence (AI) are utilized to construct digital models of buildings, sites, and human bodies, respectively. Additionally, a rendering engine is used for

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scene rendering. By integrating deep learning, big data algorithms, data fusion techniques, and data security protection, the system aims to develop core functions such as scientific prediction, intelligent decision-making, optimization and matching processes, as well as intelligent management and simulation capabilities.

The application layer translates these core functions into practical applications that can be tailored to various user needs. This layer can be further categorized into distinct visual operation platforms and functional module interfaces based on user requirements. For instance: it includes monitoring transmission systems, alarm response mechanisms, service selection options, and task initiation functionalities designed specifically for elderly users; information retrieval, file editing, medical services, and warning reception functions for healthcare workers; life service, task reception, and reward mechanism functions for social workers and volunteers; as well as information presentation, event promotion, and intelligent management functions for facilities and institutions.

Finally, the display layer presents the system's applications to users through visual display equipment to complete the use and operations. This comprises a range of electronic devices such as Augmented Reality (AR) displays, Digital Light Processing (DLP) projectors, LED large screen displays and computers tablets smartphones among other technological mediums.

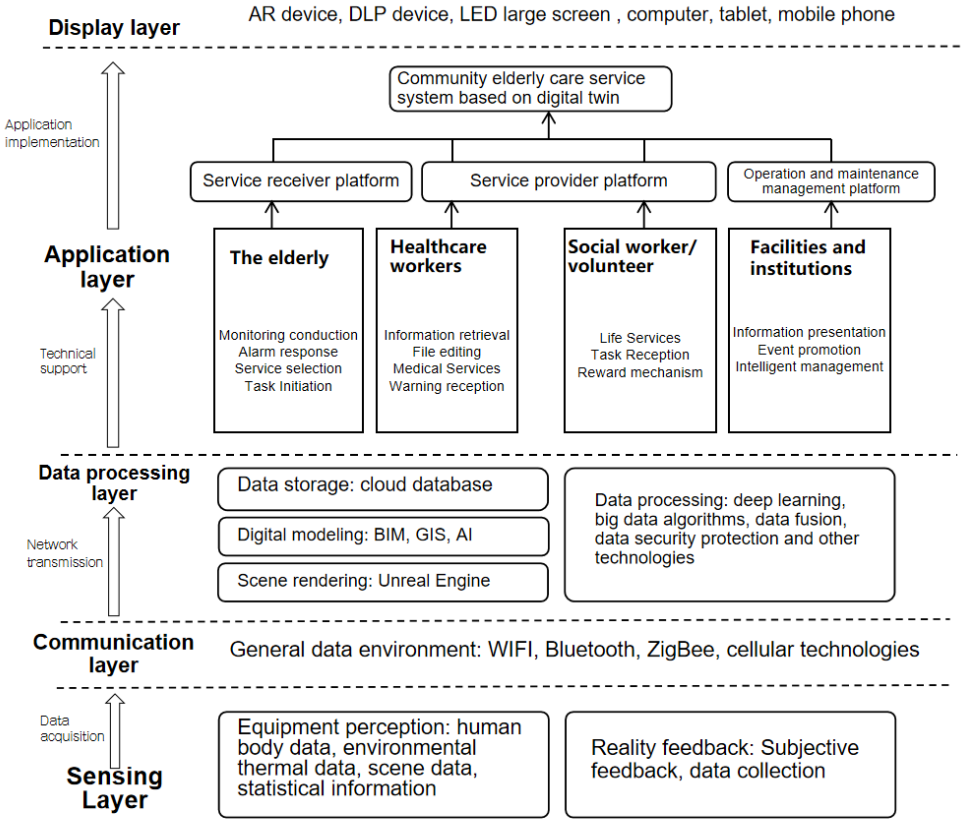

Figure 2: Architecture of community elderly care digital twin system

5. Conclusion

The community elderly care service system based on digital twin, as an innovative approach to the concept of smart elderly care, aims to tackle various challenges such as resource disconnection, supply and demand misalignment, service deficiencies, and extensive management in the context of rapid aging. Proceeding from overcoming the practical dilemmas of community elderly care, this paper, relying on digital twin and related information technologies, focuses on the demands of the elderly for optimizing resource allocation, expanding virtual space, precisely matching services, responding to demands efficiently, monitoring health in real time, and assisting in intelligent decision-making. Furthermore, this study endeavors to establish a mechanism and system architecture for a community elderly care digital

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twin system. The goal is to provide new insights into the transmission pathways for enabling intelligentization of community elderly care services through digital twin. Looking ahead, it is anticipated that the construction of smart elderly care will incorporate more digital segments that deeply promote the smooth practice of elder care services and fulfill the diversified demands of participating subjects. The establishment of an elder-friendly society remains a key emphasis in future development.

References

[1] The Ministry of Civil Affairs, the People's Republic of China, the National Office on Aging. The 2023 National Bulletin on the Development of undertakings for the Elderly. 2024-10-11.
[2] Zuo Meiyun. The meaning and mode of intelligent pension [J]. Social Work in China, 2018, (32): 26-27.
[3] Zhang Haomiao, Tan Hong. Innovative practice and optimization of smart community health and elderly care service—Based on the local experience of Chengdu city [J / OL]. Journal of Chengdu University (Social Science Edition), 1-16 [2024-11-12].
[4] Li Yun. Research on standardization and application exploration of digital twinning technology in smart city [J]. Information Technology and Standardization, 2021, (10): 13-19.
[5] Tao Fei, Liu Weiran, Zhang Meng, et al. Digital twin five-dimensional model and the top ten field applications [J]. Computer Integrated Manufacturing System, 2019,25 (01): 1-18.
[6] Zhang Jie, Qian Hong, Zhou Hongyuan. Exploring the application of digital twinning technology in the field of safety and health monitoring for the elderly in the community [J]. Chinese Journal of Medical Devices, 2019,43 (06): 410-413 + 421.
[7] Li Jiacai, Zhang Hao, Shen Yang, et al. Exploration of the application of the care system for cognitive disorder elderly based on digital twinning [J]. Digital Medicine in China, 2023, 18 (12): 64-67 + 79.
[8] Cheng Haolun. Research on the Design of Health Management Services Based on Digital Twins—A Case Study of Community Geriatric Health Management Services [D]. Beijing Institute of Printing Technology, 2022.
[9] Jia Guofeng. Research on the design of intelligent fire fighting cloud platform for pension institutions based on digital twin technology [J]. Scientific and technological Innovation and Productivity, 2024,45 (01): 135-137 + 141.
[10] Huang Liti, Zhao Chaorui, Sun Zhimin. Joint simulation method of digital twin model of elderly apartment building [J]. Henan Science, 2023,41 (03): 414-422.
[11] Guo Bin, Chen Gong, Zou Yunjin. Digital Twins drive the wisdom of community governance: reality pattern and path exploration [J]. Science and Technology Management Research, 2024,44 (08): 137-145.
[12] Huo Wenjing. Research on the practice path of social work participation in the resource integration of community elderly care services [D]. Northwest A & F University, 2023.