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INNOVATIVE RESEARCH ON THE HEALTH MONITORING SYSTEM BASED ON CHINA'S AGING POPULATION

An aging population is an inevitable consequence of improved living standards and longer life expectancy. According to the seventh national census of China, in 2020, the total number of elderly people aged 60 and above in mainland China was 264 million, accounting for 18.7 % of the total population. The deepening of the aging society has also led to the coexistence of the demand for elderly care at home and financial pressure in many families. Therefore, the smart health industry needs to combine innovation in many ways. This article will verify the "government-enterprise-family" tripartite sharing mechanism through the design of a non-contact health monitoring system combined with a cost-benefit analysis, thereby providing an economic management paradigm for the Internet of Things health monitoring system.

Keywords: Aging in China; Internet of Things; health monitoring system; interdisciplinary; economic management.

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ИННОВАЦИОННОЕ ИССЛЕДОВАНИЕ СИСТЕМЫ МОНИТОРИНГА ЗДОРОВЬЯ В УСЛОВИЯХ ПОВЫШЕННОГО УРОВНЯ СТАРЕНИЯ НАСЕЛЕНИЯ КИТАЯ

Старение населения является неизбежным результатом повышения уровня жизни людей и увеличения продолжительности жизни. Согласно данным Седьмой национальной переписи населения Китая, в 2020 году численность пожилого населения в возрасте 60 лет и старше в материковом Китае достигла 264 миллионов человек, что составило 18,7 % от общего населения. Углубление старения общества привело к одновременному росту спроса на домашний уход за пожилыми в семьях и увеличению финансового давления. Поэтому в сфере интеллектуального здравоохранения необходимо инновационное объединение многоаспектных подходов. В данной статье посредством проектирования бесконтактной системы мониторинга здоровья и анализа рентабельности будет обоснован механизм трёхстороннего распределения затрат между «государством – предприятиями – семьями», что позволит предложить экономическую управленческую модель для систем мониторинга здоровья на основе интернета вещей.

Ключевые слова: пожилость населения Китая; интернет вещей; система мониторинга здоровья; междисциплинарность; экономическое управление.

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Introduction

Population ageing has become a common phenomenon worldwide. As China's social ageing deepens, the health management of the elderly has also become a focus of social concern. However, the traditional medical service model is difficult to meet the growing home health needs of the elderly. Research and analysis of the Internet of Things health monitoring system and economic management innovation under this new situation is of great practical value and significance for promoting the development of elderly care services.

According to data released in the 2023 National Aging Development Bulletin, by the end of 2023, there will be 296.97 million people aged 60 and above in China, accounting for 21.1 % of the total population; and 216.76 million people aged 65 and above, accounting for 15.4 % of the total population. Meanwhile, according to data from the National Bureau of Statistics for 2023, the number of empty-nesters has reached 130 million. This shows that the issue of ageing at home is becoming increasingly urgent, and the financial expenditure on elderly care has reached 6.2 % of GDP. The Action Plan for the Development of the Smart Health and Elderly Care Industry also clearly proposes to strengthen interdisciplinary and cross-domain cooperation to enhance the intelligence level of health and elderly care products and services. The plan also shows the importance China attaches to the development of the smart health and elderly care industry.

The safety of elderly people living alone or without family is never guaranteed. Related studies show that the development of home-based elderly care services in China is relatively slow at present, and there are problems such as inefficiency in the elderly care services provided by the community. Moreover, the children of the elderly are often not around, making it difficult to provide adequate support and assistance to the elderly and to meet their diverse needs. The imported sensor technology for health monitoring systems is too expensive for ordinary families to afford. Therefore, exploring the Internet of Things elderly care monitoring system under the current situation is a necessary topic. Through in-depth research, we hope to explore and propose more innovative technical optimization and economic management solutions to achieve the goal of "inclusive smart elderly care".

1. Technical system design

The Internet of Things-driven health monitoring system for the elderly at home needs to take into account technology, cost and user-friendliness. This section will be based on the localized needs of China, namely social structure, policy environment, technological foundation, economic conditions and cultural habits, etc., and will be designed on the basic system architecture of smart home care safety monitoring at the application layer, network layer and perception layer (application layer, middleware layer and sensors layer [1]).

1.1. Application layer

1.1.1. Functional sections

Family-end WeChat mini-program: According to Tencent's official data analysis, the number of active elderly WeChat users was 1.31 million in June 2014, increased to 7.68 million in September 2016, and reached 50 million in September 2017, so that more than 30 % of new WeChat users come from the elderly group. As a social platform with a penetration rate of over 95 % in China, WeChat is an ideal entry point to connect the elderly with their children.

Core functional areas (as shown in *Figure 1*).

Function	Design details	Localization adaptation
Real-time Status Monitoring	Breathing/Heart Rate Curve, Environmental Safety Index (Temperature and Humidity, Gas)	Data refreshes every 10 seconds to avoid frequent notifications disturbing the elderly
Anomaly Event Early Warning	Popup Alert + SMS Notification (Supports Voice Broadcasting)	Dialect voice packs (such as Cantonese, Sichuanese, etc.)
Health Report	Weekly/Monthly Health Trend Analysis (Sleep Quality, Activity Volume)	Integrate with the TCM Constitution Identification Model to provide health advice.
Family Interaction	Voice Message, Medication Reminder Settings, Emergency Contact One-Click Call	Automatically generate an "Electronic Filial Piety Report" on festivals and holidays.

Fig. 1. Core functional areas.

1.1.2. Age-friendly interaction design

Visual optimisation: font size is enlarged (minimum 24pt) and high-contrast colouring (yellow background with black text) is used, with vibration feedback for key buttons. Research shows that this dynamic feedback optimisation will reduce the error rate by 62 %.

Voice control: Using the iFLYTEK speech engine,the system has its ownership of independent IPR in both speech synthesis and speech recognition technologies [2] and the system's speech recognition accuracy has been improved to over 97 %, supporting voice input in 21 dialects, which is both accurate and convenient.

1.2. Network layer

1.2.1. Urban-rural differentiated deployment

1) Urban technology portfolio: high speed, low latency.

2) Rural technology portfolio: wide coverage, low consumption.

1.2.2. Privacy-compliant design

1) Data localization.

Raw data should be stored in a data center certified at the third level of the protection classification system to ensure data security.

2) User authorization management.

Set relevant terms and obtain user authorization through a WeChat mini program to facilitate relevant operations.

1.3. Perception layer

Perception tools.

- Wireless radar: millimeter wave radar;
- Thermal carpet: infrared thermal imaging array;
- Gas alarm: piezoelectric thin film sensor;
- Reasons: Reduce the use of cameras, reduce the elderly's aversion, domestic parts are cheaper, and the use of solar energy in rural areas is environmentally friendly and economical.

Data processing.

The introduction of multimodal theory [3] into the service system enables high-precision, low-cost health data collection and promotes the universalization of smart elderly care.

2. Cost management

2.1. System design and benefit analysis diagram

Hierarchy	Technical components	Detailed description	Economic Management Correlation Points	Detailed description	Cost-benefit analysis
Application Layer	WeChat Mini Program	Mobile application with low development cost, convenient for the elderly and their families to view health data	Collaborative Management	Government-enterprise data sharing mechanism, promoting data interconnectivity	Government subsidy 40% (320 yuan/set)
	Government Data Interface	Accessing government health data interfaces to provide more comprehensive health services			Household contribution 30% (240 yuan) Corporate discount 30%
Network Layer	Alibaba Cloud IoT Platform	Providing an IoT platform service with a pay as you go model	Light Asset Operation	Avoiding hardware reinvestment, reducing corporate operational risks	
Perception Layer	Domestic Millimeter Wave Radar	Domestic millimeter-wave radar with 50% cost reduction, used for monitoring the activities of the elderly	Supply Chain Domestic Substitution Strategy	Adopting Hunxi HiSilicon chip procurement, reducing external dependence	Cost per set of equipment (after localization) 800 yuan
	Lolla Environmental Sensor	Used for monitoring home environment data (such as temperature, humidity, etc.)			Lifespan 5 years
					Annual operation and maintenance cost 120 yuan

*Fig. 2.*Technical system design.

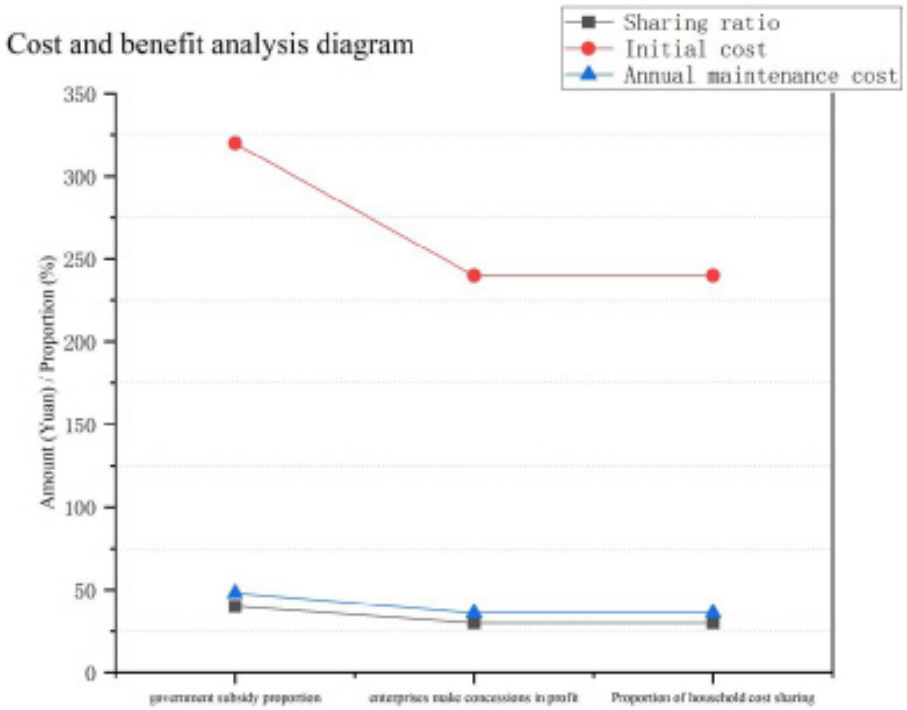

Fig. 3. Cost and benefit analysis diagram.

2.2. Cost management plan

When designing a health monitoring system for the elderly at home, we need to integrate technological innovation and cost control, so as to ensure the practicality and affordability of the system and facilitate cost management.

At the application layer, our system uses WeChat mini programs , which are relatively easy and inexpensive to develop [4], so that the general public can also use this channel to check the health data of the elderly and their families anytime, anywhere. By accessing the government health data interface, the system can provide more comprehensive health services, such as health consultations and emergency assistance. In terms of financial management, the system adopts a tripartite sharing mechanism of "government-enterprise-family", with the government subsidizing 40 % (320 yuan/set), the family bearing 30 % (240 yuan), and the enterprise making a 30 % profit.This model not only helps to alleviate the family's financial pressure, but also promotes the sustainable development of the enterprise. Through the combination of these two forms, a win-win situation can be achieved.

In terms of the network layer, the system uses the Alibaba Cloud IoT platform, which can remotely monitor the status and real-time data of IoT devices, effectively monitoring data in real time. The automated centralized management of the cloud platform monitoring system can bring together various traditional monitoring platforms from different companies for management and operation [5]. This function reduces overall operating costs and hardware idle rates , and also avoids the operational risks associated with heavy hardware investment.

In terms of the perception layer, our system uses a domestically produced millimeter-wave radar that reduces costs by 50 %. The co-founder of a domestic technology company also proposed that "the localization of millimeter-wave radar products is the general trend". This radar can accurately monitor the activity status of the elderly, effectively improving the

safety of elderly care at home. In addition, the system is equipped with LoRa environmental sensors with a low cost and a high sensitivity that can monitor key data such as temperature and humidity in the home environment in real time and make intelligent adjustments [6], with the aim of providing the elderly with a comfortable living environment. In terms of the supply chain, the aim is to reduce costs and overseas supply by purchasing Huawei HiSilicon chips, which helps to enhance the system's autonomy and controllability. Thanks to these localization efforts, the cost of a single set of equipment has been successfully controlled at 800 yuan, and the equipment has a long life cycle of 5 years. The annual maintenance cost is only 120 yuan, significantly reducing the economic burden on users.

3. Economic management model: tripartite collaboration and risk control

3.1. Framework and rendering

Category	Subcategory	Describe	Concrete content	Case/Data
"Government-Enterprise-Family" Cost Sharing Model	Government Role	Policy Subsidies	Procurement bidding, providing market opportunities for corporate products	
		Data Openness	Emergency system integration, enhancing emergency response efficiency	
	Corporate Role	Technology Iteration	Continuously optimizing products, reducing false alarm rates	False alarm rate optimization, for example, the Suzhou pilot has reduced from 12% to 7.5%
		Service Subscription	Providing continuous service, charging annual fees	Annual fee of 200 yuan/household
	Family Role	Hardware Acquisition	One-time payment for hardware costs	
		Value-Added Services	Subscribing to premium services such as health reports	
Risk Management Framework (ISO 31000)	Risk Type	Technical Risk	Response strategy: Redundant design (dual sensor verification)	Suzhou pilot false alarm rate has reduced from 12% to 7.5%
		Market Risk	Response strategy: Differential pricing (first-tier cities vs. rural areas)	Rural government fully subsidizes, urban families share 50% of the cost
		Compliance Risk	Response strategy: Compliance with both GDPR and China's Personal Information Protection Law	Data anonymization processing to ensure privacy security; local server storage to reduce data leak risk

Fig. 4. Tripartite collaboration model and risk control framework.

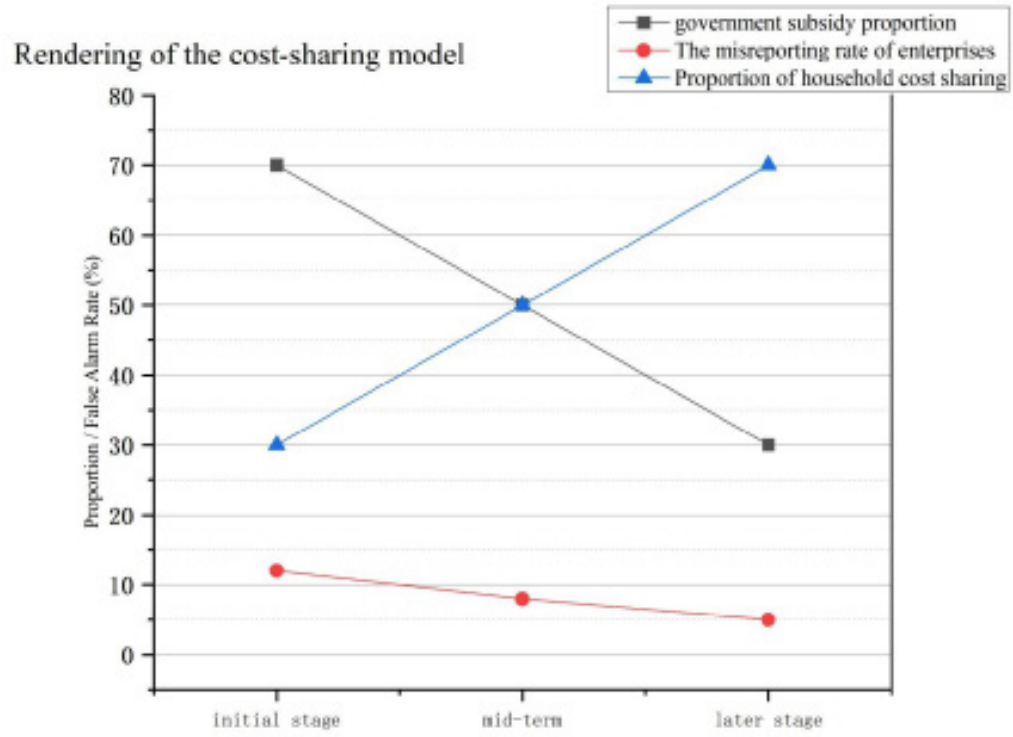

Fig. 5. Rendering of the cost-sharing model.

3.2. Model analysis

This paper proposes a cost-sharing model for tripartite collaboration between the government, enterprises and households, with the aim of maximizing the economic feasibility and social benefits of the system through multi-party cooperation.

The government plays a crucial role in this model. Through procurement bidding, the government not only provides a broad market opportunity for the products of enterprises, but also ensures the quality and cost-effectiveness of the system. The opening up of government data interfaces, especially the connection with the emergency rescue system, significantly improves emergency response efficiency and provides more timely and effective safety protection for the elderly.

Enterprises are responsible for technological updates and service completion, and need to continuously optimize products and reduce the false alarm rate to improve user experience and trust. In the Suzhou pilot project, the false alarm rate was successfully reduced from 12 % to 7.5 % by adopting a redundant design with dual sensor verification. This result not only verified the correctness of the technical route, but also laid a solid foundation for subsequent market promotion. The company also provides ongoing services such as service subscriptions, including system maintenance, health report generation, etc., with the aim of providing comprehensive health management support for family users.

The role of the family as the end user is indispensable. The family needs to bear the one-time hardware purchase cost and subscribe to value-added services to obtain more comprehensive health management services. Although the initial investment is high, considering the long-term benefits of the system and the government's subsidy policy, this cost is manageable for most families.

In terms of risk management, this paper adopts the ISO 31000 framework for systematic management. Market risks are addressed through differentiated pricing. The rural market is fully subsidized by the government due to relatively poor economic conditions, while in first-tier cities, where residents have higher incomes, households share 50 % of the cost, which not only ensures the company’s profit margin, but also promotes the popularization of the system. In terms of compliance risks, the relevant provisions of the GDPR and the Personal Information Protection Law of the People’s Republic of China are strictly followed. Measures such as data anonymization and local server storage are taken to ensure user privacy and data security.

4. Discussion: Model promotion and industry-university-research collaboration

4.1. Framework and renderings

Category	Please provide a detailed description.	Relevant examples or data
Challenge	Low network coverage rate in rural markets (requires 5G infrastructure support)	According to data from China's Ministry of Industry and Information Technology, by the end of 2022, the 4G network coverage rate in rural areas of China reached 97%, but the 5G network coverage rate was only about 20%, much lower than in urban areas. For example, in a remote village in Guizhou Province, due to the complex terrain, the construction of 5G base stations is difficult, resulting in the local aging population being unable to enjoy high-quality Internet of Things health monitoring services.
	The Dilemma of Balancing User Privacy and Data Security	In 2021, a well-known health monitoring equipment company experienced a data breach due to inadequate data protection measures, resulting in the exposure of health data of millions of users. This incident highlighted a significant challenge in Internet of Things health monitoring systems: how to ensure user privacy and data security. The company subsequently invested heavily in strengthening data encryption and access control, but user trust was still somewhat affected.
Industry Academia-Research Path	Educational Empowerment: Universities Offering Micro Majors in "Smart Health Economic Management"	Peking University launched the "Smart Health Economics Management" micro major in 2023, which aims to cultivate interdisciplinary talents with knowledge in health management, economic analysis, and information technology. The curriculum includes practical courses such as Agile Development and Cost Accounting to better serve the innovation and promotion of the Internet of Things health monitoring systems.
	Technology Export: Promoting to the Eastern European Market via the "Belt and Road Initiative" (Adapting to the Aging Needs of Belarus)	Huawei has collaborated with a medical institution in Belarus to customize an Internet of Things health monitoring system for the health needs of the aging population in Belarus. The system leverages Huawei's technological advantages in 5G and cloud computing, providing services such as remote medical consultation and health data monitoring for the elderly in Belarus. Since the implementation of the project in 2022, it has covered multiple cities in Belarus and has been widely praised by the local government and the public.
	Ecological Construction: Joint Laboratories Built by Governments, Universities, and Enterprises (e.g., Cooperation with Hikvision)	In 2023, the Zhejiang Provincial Government, Zhejiang University, and Hikvision jointly established the "Smart Health Internet of Things Joint Laboratory". The laboratory focuses on the research and development and application of Internet of Things health monitoring technology, promoting the transformation of innovative achievements through a model of government guidance, university scientific research support, and enterprise market operations. For example, the intelligent wearable devices developed by the laboratory have been applied in multiple domestic elderly care institutions, effectively improving the health management level of the elderly.

Fig. 6. Challenges and industry-university-research pathways.

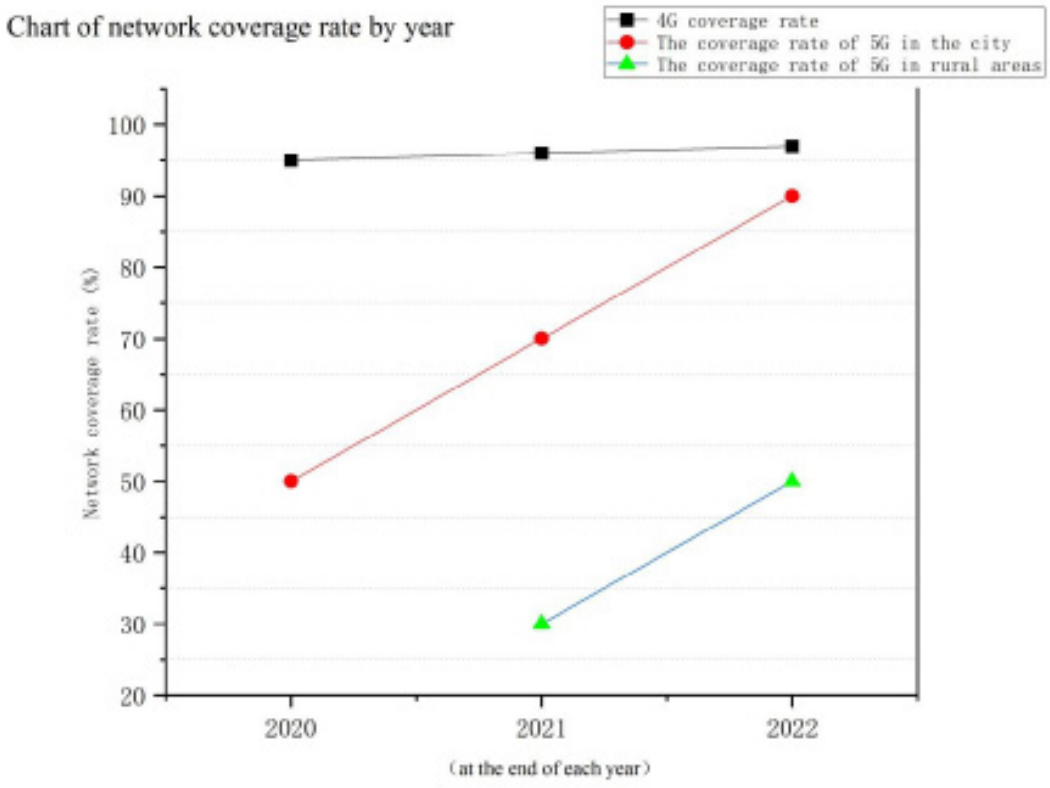

Fig. 7. Chart of network coverage rate by year.

4.2. Discussion on collaborative development between industry, university and research

The low network coverage in rural markets is an urgent problem that needs to be solved. According to data from the Ministry of Industry and Information Technology of the People's Republic of China, by the end of 2022, although the coverage of 4G networks in rural areas of China will reach 97 %, the coverage of 5G networks will only be about 50 %, which is much lower than that in urban areas. This means that many elderly people cannot enjoy high-quality IoT health monitoring services. Therefore, strengthening the construction of 5G infrastructure in rural areas and improving network coverage can be said to be the key to promoting the IoT health monitoring system. At this time, relevant communication companies need to put people first, adapt to local conditions, actively seek potential markets, and give priority to consumer demand when pricing their services .

In the promotion of the IoT health monitoring system, balancing user privacy and data security is also an important challenge. In recent years, frequent data breaches have posed a serious threat to user privacy and security. When designing the system, full consideration must be given to user privacy and data security issues, and advanced data encryption and access control technologies must be adopted to ensure the security and privacy of user data.

In order to promote the innovative development of the IoT health monitoring system, this paper actively explores new paths for collaborative development among industry, academia, and research. In terms of education empowerment, Peking University and other universities have established a minor in "smart health economic management," which aims to cultivate interdisciplinary talent with knowledge in multiple fields. These talents will play an important role in the innovation and promotion of related smart industries. In terms of technology export, companies such as Huawei have cooperated with Eastern European countries to customize relevant IoT health monitoring systems to meet the health needs of the aging population there. This cooperation model not only promotes the international dissemination of technology, but also provides more convenient and efficient health services for local elderly people. In terms of ecological construction, governments, universities and enterprises have jointly established joint laboratories. The "Smart Health IoT Joint Laboratory" established by the Zhejiang Provincial Government, Zhejiang University and Hikvision is one example. These laboratories promote the research and development and application of IoT health monitoring technology through the integration of resources and collaborative innovation, providing a continuous flow of fresh blood for the development of the smart elderly care industry.

5. Summary and outlook

This paper discusses the simple design and economic management costs of an IoT health monitoring system based on the realistic background of China's aging society. By designing a non-contact health monitoring system combined with a "government-enterprise-family" tripartite sharing mechanism, the aim is to provide the elderly with more convenient, economical and efficient health management services. It is believed that with the continuous innovation of IoT technology and the continuous expansion of application scenarios, the smart elderly care industry can usher in a broader development prospect.

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