Construction of a Three-Level Emergency Response Information Coordination System for Smart Home-Based Elderly Care Services: Post-Print

Authors: Ma Jie, Li Lu, Geng Hanbing, Hu Mo

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[Purpose/Significance] Aiming at the problems existing in China's home-based elderly care emergency services, this study constructs a three-tier emergency response information collaboration system for smart home-based elderly care services, aiming to improve emergency rescue efficiency through efficient multi-agent emergency information collaboration. [Methods/Process] Using social research methods, we analyze the current problems in China's home-based elderly care emergency services, construct an information collaboration system based on elderly information, with call centers as information distribution hubs, and family members of the elderly, emergency service volunteers, hospitals and other medical rescue institutions as three-tier elements, and demonstrate its feasibility. [Results/Conclusions] We analyze the inter-agent information collaboration relationships, construct a system model, and propose safeguard strategies for the implementation of the system model.

Full Text

Construction of a Three-Level Emergency Response Information Collaboration System for Smart Home-Based Elderly Care Services

Ma Jie[1,2], **Li Lu**[1], **Geng Hanbing**[1], **Hu Mo**[1]
[1]School of Management, Jilin University, Changchun 130022
[2]Research Center for Information Resources, Jilin University, Changchun 130022

Abstract

[**Purpose/Significance**] Aiming at the problems existing in China's home-based elderly emergency services, this study constructs a three-level emergency response information collaboration system for smart home-based elderly care services to improve emergency rescue efficiency through efficient multi-agent emergency information collaboration. [**Method/Process**] Using social research methods, this paper analyzes the current problems in China's home-based elderly emergency services, constructs an information collaboration system based on elderly information, with a call center as the information distribution hub, and with family members, emergency service volunteers, and hospitals/rescue institutions as the three-level elements, and demonstrates its feasibility. [**Result/Conclusion**] The paper analyzes the information collaboration relationships among agents, constructs a system model, and proposes guarantee strategies for system implementation.

Keywords: smart elderly care; home-based elderly care; emergency service; information collaboration; emergency service volunteer
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Introduction

With China's economic development and urbanization reform, smart cities have gradually emerged as a "powerful weapon" to solve "urban diseases" [1], and smart elderly care, as an important component of smart city construction, has attracted significant attention from both government and the public. The primary goal of smart elderly care is to meet the daily living, healthcare, and safety needs of the elderly [2], among which life safety should be the top priority. In recent years, incidents of empty-nest elderly dying at home and being discovered days later have occurred frequently across China: according to Qilu Evening News, at least eight elderly people living alone died in Jinan within just two months [3]; Anhui Net reported that two empty-nest elderly were found dead days after passing away in Wuhu within three days [4]. Many common and sudden illnesses among the elderly would not be life-threatening if treated promptly, yet these recurring incidents indicate significant problems in China's emergency elderly care services regarding timely information transmission and collaborative response.

It is projected that by 2020, China's population aged 60 and above will reach 234 million, accounting for 16.0% of the total population [5], with the number of elderly living alone and empty-nest elderly increasing to approximately 118 million [6]. As population aging intensifies and the "4-2-1 family" structure persists, the elderly face high rates of illness and sudden diseases, creating growing demand for emergency rescue services and urgent need to improve emergency elderly care service levels. Currently, scholars across various fields in China are actively exploring new approaches to smart home-based elderly care, and the

government has introduced numerous policies to support the development and application of elderly care service platforms to provide emergency and daily living services for the elderly. However, these incidents demonstrate that China's current emergency elderly care service system still has obvious deficiencies, with significant gaps in service levels and emergency efficiency compared to developed countries, and lacks research on the timeliness and efficiency of emergency services. Based on the existing elderly care service system and premised on information accessibility and collaborative interaction, this paper constructs a three-level emergency response information collaboration system for smart elderly care to improve emergency rescue efficiency for the elderly and better protect their life safety.

2. Definition of Core Concepts

The core of the three-level emergency response information collaboration system for smart home-based elderly care services is the efficient information collaboration among three-level agents. To construct the system more precisely, we first analyze and define its core concepts.

2.1 Smart Home-Based Elderly Care

The concept of smart elderly care was first proposed by the UK Life Trust Foundation. It generally refers to the use of information technologies such as the Internet of Things, big data, and cloud computing to develop IoT system platforms that provide safety assurance, home care, and medical services for the elderly, offering efficient and intelligent elderly care services [7] and realizing an online-offline integrated medical-care combined elderly care model [8]. Smart home-based elderly care means providing smart elderly care services to home-dwelling seniors, using modern information technology to establish an elderly care service model based on home, supported by community, supplemented by institutions, and combining medical care with elderly care [6].

2.2 Emergency Response

Emergency response refers to the reactions made by organizations, systems, or individuals during sudden emergency events, typically including preparations for various unexpected incidents and the rapid measures and actions taken after incidents occur [9], aiming to minimize the scope, quantity, and impact of incidents and prevent escalation and deterioration [10].

2.3 Information Collaboration

Literally, "collaboration" means many people working together to achieve a common goal. Information collaboration refers to an information activity in which two or more participants, through information exchange within a certain period, meet their own information needs and achieve common objectives [11].

2.4 Emergency Response Information Collaboration System

An information collaboration system can be understood as an orderly whole in which multiple agents, supported by certain information technologies and within defined organizational boundaries, jointly comply with collaborative norms and management rules for information exchange and sharing to achieve common goals. An emergency response information collaboration system is an information collaboration system aimed at high-efficiency emergency response and collaborative handling of sudden incidents.

3. Current Research Status and Problem Analysis of Smart Home-Based Elderly Emergency Services in China

3.1 Theoretical Research Status and Problems

In recent years, research on smart home-based elderly care services in China has gradually increased. The government and academia have been actively exploring new ways to improve elderly emergency service levels. In July 2015, the State Council issued the "Guiding Opinions on Actively Promoting 'Internet Plus' Actions," explicitly proposing to "promote the development of the smart health and elderly care industry" and encouraging the application of emergency call monitoring equipment to improve elderly care service levels [12]; in February 2017, the "Notice on Issuing the 13th Five-Year Plan for National Aging Cause Development and Elderly Care System Construction" was released, pointing out the need to promote the integration of medical care and elderly care, consolidate the foundation of home-community elderly care services, focus on disabled, solitary, and empty-nest elderly, integrate and establish home-community elderly care service information platforms, call service systems, and emergency rescue service mechanisms, and implement the "Internet Plus" elderly care project [6].

Alongside these policy releases, elderly emergency services have also attracted widespread attention from scholars in different disciplines both domestically and internationally: (1) In technology research, P. Udupa et al. proposed the need to develop a wireless sensor-based monitoring and control system applicable to wearable devices for the elderly through a review of existing sensor technologies [13]; Ou Yu proposed a new home-based elderly care service model that integrates communication and alarm technologies, computer network technology, and software technology to comprehensively serve the elderly [14]; Zhu Xiaofeng explored the construction of a smart elderly care service platform using Android technology based on analysis of elderly needs, establishing electronic health records for the elderly to facilitate timely understanding of their health status by both seniors and their families [15]. (2) In platform construction, K. Kurnianingsih et al. proposed a personalized adaptive system with three subsystems—model predictive positioning, emergency alarm, and adaptive regulation—to improve platform performance [16]; Li Caining et al. proposed a "five smart" multi-angle smart elderly care model and constructed a smart elderly care service technology platform including an emergency rescue

system [17]; Xu Jiyong et al. developed and tested a cloud platform-based smart health elderly care service system including smart terminals and service platforms, verifying its feasibility [18]. (3) In emergency services, K. L. Courtney et al.'s research shows that more elderly people are choosing CCRCs (Continuing Care Retirement Communities) that use smart home-based information technology to improve residents' quality of life and safety [19]; Japan and Finland have implemented small-scale multi-functional robot-assisted elderly care that accompanies the elderly and constantly monitors their physical condition [20]; Zhang Peng pointed out that China's pre-hospital emergency rescue service system in the home-based elderly care environment lacks a unified management system, professional and sustainable rescue teams, and connection mechanisms between pre-hospital and in-hospital emergency rescue [21]; Qi Tengfei et al. noted that China's overall pre-hospital emergency level is lagging, with ambulances taking 15 minutes to reach patients' locations, seriously behind developed countries in terms of residents' right to life protection [22]. (4) In information collaboration, the United States has long explored regional health information sharing dominated by community health information networks, achieving information sharing among institutions [23]; C. Yates et al. proposed that rational use of the synergy between health information use and personal health status can address the situation where chronic diseases have become the main cause of death among the elderly [24].

From the theoretical research perspective, domestic and foreign scholars have conducted in-depth research on smart elderly care technology. In terms of emergency services and information collaboration, foreign approaches and models are relatively flexible and diverse, while research in these two areas is relatively scarce in China, with significant research gaps remaining in how to meet service timeliness requirements.

3.2 Practical Status and Problems

3.2.1 Application Status of Smart Home-Based Elderly Care Service Platforms

(1) Application scope of platforms: Under relevant policy guidance and strong government support, numerous enterprises have begun developing applications for smart home-based elderly care service platforms. Based on telephone interviews with communities and online research conducted in this study, platforms such as Ankangtong, Yijiantong, and "12349" are widely used by communities and elderly care institutions, with "12349" being the most extensively adopted.

(2) Service content of platforms: Research on numerous elderly care platforms reveals that they primarily provide two types of services for the elderly: emergency rescue services and daily living services, including specific items such as emergency rescue, daily care, housekeeping services, leisure and entertainment, legal consultation, and spiritual comfort [25].

(3) Emergency rescue functions of platforms: Taking "12349" as an example, the platform's emergency rescue approach involves distributing mobile terminals to elderly in need within communities, using base stations and satellites for dual positioning to quickly lock onto the exact location of the person seeking help. When elderly encounter emergencies, they press the help button, and information is automatically transmitted through the 24-hour "12349" rescue command center to quickly connect with family members, communities, and 120 emergency services, enabling multi-party call emergency rescue [26]. Specifically, the main functions include: (1) helping to call 120, 110, and 119; (2) contacting emergency contacts; and (3) providing emergency guidance for elderly self-rescue.

3.2.2 Current Status of Community Home-Based Elderly Emergency Services To comprehensively understand the current status and existing problems of community emergency services for home-based elderly care in China, we conducted telephone interviews and online surveys of 24 communities in 12 cities. Based on the "New First-tier City Summit and 2018 China City Business Charm Ranking" list [27], we selected 12 cities from first-tier to fifth-tier categories. Since first-tier cities have significantly larger areas and populations, we randomly selected 4 communities in first-tier cities and 2 communities in other tier cities, conducting face-to-face or telephone interviews with community leaders. Interview questions focused on: (1) How does the community handle sudden elderly conditions (such as heart attack, stroke, sudden fall)? (2) How can elderly notify the community during emergencies? (3) Does the community have emergency handling platforms or elderly care service platforms? The survey results are shown in Table 1 .

3.2.3 Problems in China's Smart Home-Based Elderly Emergency Services Based on the above practical investigation, the following problems exist in China's home-based elderly emergency services:

(1) **Single emergency response mode and insufficient utilization of optimal rescue time.** The emergency rescue service functions of elderly care platforms show that when elderly send distress signals, platforms only contact hospitals or emergency contacts through call centers, failing to utilize the waiting time before ambulances arrive. For some acute conditions, this likely misses the critical rescue window. Medicine recognizes concepts such as the "golden 4 minutes" after cardiac arrest [28] and "platinum 10 minutes" after trauma [29], highlighting the importance of emergency rescue during sudden crises. Foreign emergency response platforms average 7 minutes and have emergency stations with ambulances on standby in their respective areas [30]; whereas China's average emergency response time is about 16 minutes, often delayed significantly due to traffic congestion and other reasons [31].

(2) **Community service personnel quantity and qualifications can-**

not meet home-based elderly emergency service requirements. Based on experiences from developed countries and regions, community elderly care services require professional staff, but currently, many communities in China cannot meet elderly needs. Even in first-tier cities with excellent elderly care platforms and volunteer service organizations, there remains a shortage of service personnel and inability to guarantee medical rescue qualifications, lacking certification models. For example, Workers' Daily reported that Wuhan's "Yijiantong" service was interrupted due to insufficient community service personnel [32].

(3) **Insufficient emergency service levels in fourth and fifth-tier cities.** Interview results show significant differences in elderly emergency service levels between cities with different economic development levels. First-tier cities such as Shanghai, Wuhan, and Beijing have installed "Ankangtong," "Yijiantong," and other elderly care service platforms with emergency response functions through government procurement. Through cooperation with these platforms, local elderly care services have become intelligent and information-based, increasing safety for the elderly. However, interviews revealed that communities in fourth and fifth-tier cities generally lack platform support, requiring elderly to contact communities by phone themselves, and have no nighttime emergency services. If elderly suddenly fall ill with no one around and cannot make phone calls, their lives face severe threats. Fourth and fifth-tier cities account for about 65% of China's cities, making it urgent to improve emergency service levels in these areas.

4. Basic Framework and Implementation Conditions of the Three-Level Emergency Response Information Collaboration System

4.1 Basic Framework

4.1.1 Design Approach Based on the above problem analysis, the core issues in current elderly care emergency response are insufficient utilization of optimal rescue time and insufficient community service personnel. This study focuses on improving information collaboration efficiency in the elderly care system and volunteer program planning to design the framework.

Inspired by the "Didi Dache" (ride-hailing) app, we propose cultivating a "Didi Emergency Service Volunteer" system to solve the problems of insufficient volunteer numbers and inability to fully utilize the golden rescue time. "Didi Dache" achieves timely calling, timely response, and collaborative dispatching. "Didi Volunteers" can timely receive calls, respond, and rush to the scene to provide basic emergency treatment, obeying unified dispatch from the call center. "Didi Volunteers" should possess the psychological, physical, and social capabilities to handle emergency situations and have certain medical first-aid knowledge to provide reliable emergency services for the elderly before rescue teams arrive,

minimizing threats to elderly lives. Since volunteers have no legal responsibility or obligation relationship with the elderly, they are positioned as second-level elements.

This framework builds upon the rescue process of existing emergency call modules in elderly care platforms, uses multi-channel information collaboration as its core concept, constructs a three-level emergency response information collaboration hierarchy, designs information collaboration relationships, and provides technical guarantees at the system and technology levels to shorten emergency response times. In terms of volunteer program planning, drawing on the ideas and principles of "Didi Dache," we propose cultivating community emergency volunteer groups, providing them with graded medical training, and securing them through incentive and reciprocal systems. This approach aims to shorten emergency response times by increasing the number and response efficiency of rescue personnel, with feasibility demonstrated through extensive social research.

4.1.2 System Components Based on elderly demographic and health information, with the call center as the information hub, and with three-level elements interacting and collaborating, the system operates through information exchange and coordination among the three-level elements.

The three-level elements are divided according to their close relationship with the elderly and the nature of emergency tasks:

(1) **First-level element: Family members.** Relatives bear responsibility and obligation for the elderly's safety and are the closest individuals or groups to them. When emergencies occur, family members are the first to be contacted for handling and decision-making. Family members should be children or relatives with support obligations and should possess the psychological, physical, and social capabilities to handle emergency situations.

(2) **Second-level element: Emergency service volunteers.** Sufficient numbers of qualified emergency service volunteers are essential for fully utilizing optimal rescue time. China urgently needs volunteer groups who can implement basic first-aid measures before ambulances arrive. Currently, China has such groups—pre-hospital emergency volunteers—but faces problems: (1) insufficient quantity and distribution density of emergency volunteers [33], unable to guarantee timeliness of home-based emergency care; (2) no volunteer groups specifically organized for elderly emergency services. The elderly, as a vulnerable group, cannot handle dangers such as fire, gas leaks, or sudden diseases by themselves in a timely manner, urgently needing volunteer groups specialized in home-based elderly emergency services.

(3) **Third-level element: Hospitals, fire departments, police stations, and other rescue institutions.** Based on the nature of the elderly's

emergency, hospitals, fire departments, and police stations are determined as 联动 institutions and serve as third-level elements in the emergency system. These elements implement specific handling procedures. When the call center receives an alarm from the elderly, it promptly notifies nearby rescue institutions based on the situation, which must prepare emergency resources and dispatch medical vehicles, police, or fire trucks to ensure the fastest possible arrival at the elderly person's home.

(4) **Smart home-based elderly care emergency response platform: Call center, smart bracelet dispatch module, and emergency volunteer dispatch module.** The operation of the three-level emergency response information collaboration system requires an emergency response service platform. The call center, smart bracelet module, and emergency volunteer dispatch module are characteristic features of this platform. The smart bracelet collects elderly health information and remotely inputs it into the service platform, sending emergency information in real time. The call center, after receiving emergency calls, sends emergency information to the three-level elements according to the collaboration hierarchy and tracks and coordinates information exchange among the three-level elements throughout the process. The volunteer dispatch module schedules the nearest volunteer based on the location of the elderly needing emergency care.

4.1.3 Basic Framework Based on the above design approach and component description, we propose the basic framework of the three-level emergency response information collaboration system for smart home-based elderly care services, as shown in Figure 1 [Figure 1: see original paper]. The information agents in this framework include the elderly, family members, emergency service volunteers, and hospitals/institutions. Each agent uses the call center as a hub to achieve information sharing and collaborative work. The basic information collaboration 思路 is as follows:

(1) When the elderly have emergencies, they send distress signals to the call center via smart bracelets. The call center extracts the elderly's natural and medical information, communicates with the elderly online, and simultaneously notifies family members.

(2) A conditional mechanism is set at the boundary where the call center transmits information to family members and volunteers, with two scenarios: (1) After receiving the elderly's call, the call center, while notifying family members, activates the volunteer dispatch module to call volunteers to participate in rescue; (2) After receiving the call, the call center notifies family members, who decide whether to call volunteers, and the call center decides whether to activate the volunteer dispatch module according to the family's wishes; if family members do not respond, the call center immediately activates the volunteer dispatch module. These two scenarios are preset by users in the system. Through the volunteer dis-

patch module, the call center can notify nearby volunteers based on the elderly's location. Volunteers can "accept orders," and the dispatch center "assigns orders" based on the location and qualifications of the accepting volunteers, ensuring suitable volunteers can arrive promptly to participate in rescue.

(3) While the call center notifies family members or volunteers, it also notifies nearby hospitals and rescue institutions based on the elderly's condition, ensuring professional emergency personnel receive information and rush to the scene at the first moment.

4.2 Implementation Conditions

4.2.1 Prerequisites For the three-level emergency response information collaboration system for smart home-based elderly care to operate, besides technical support, it requires acceptance and active cooperation from the three-level elements and the elderly themselves. The system's operation must meet the following conditions: (1) elderly acceptance; (2) family acceptance; (3) sufficient volunteers; (4) technical support; (5) community support. This study uses social survey methods to examine whether these conditions are met.

4.2.2 Survey Design and Data Collection (1) Survey purpose and dimensions. To comprehensively understand user groups' acceptance of the emergency service system, we used questionnaires from three dimensions: the elderly themselves, family members, and volunteers to investigate acceptance of the three-level elderly emergency service system and the feasibility of "Didi Volunteers."

(2) Questionnaire design and data collection. Two questionnaires were designed. Questionnaire 1 surveyed elderly willingness to use the emergency service system, distributed to people over 60, including questions about: (1) elderly living conditions and health status; (2) whether elderly accept the emergency service system. Questionnaire 2 surveyed the 20-60 age group about their concern for parents' conditions and willingness to participate in elderly care volunteer services. This age group is precisely the demographic whose parents are mostly still alive and who have the capability to serve as emergency service volunteers—they are both first-level elements and potential second-level elements. Questionnaire 2 included two parts: one investigating whether this age group accepts the emergency service system as family members of the elderly; the other investigating their willingness to become emergency service volunteers. The design of these two questionnaires can examine whether conditions , , and are met.

Questionnaire 1 covered 16 cities in 10 provinces nationwide, with geographical distribution shown in Figure 2 [Figure 2: see original paper]. A total of 145 paper questionnaires were distributed, with 145 returned, achieving 100% validity. Questionnaire 2 covered 94 cities in 26 provinces nationwide, with geographi-

cal distribution shown in Figure 3 [Figure 3: see original paper]. The survey was conducted via Wenjuanxing, with 695 questionnaires returned. After eliminating invalid questionnaires, 600 valid questionnaires were obtained, with an 86.3% validity rate.

4.2.3 Survey Results Analysis (1) Elderly generally accept the emergency service system. The elderly are the service objects of the entire emergency service system. Whether they are willing to wear smart bracelets and use the system is a prerequisite for implementation. Regarding willingness to wear smart bracelets and send distress signals during emergencies, the survey results are shown in Table 2 , with 75.2% of elderly willing to wear smart bracelets. Among the 36 elderly unwilling to wear bracelets, most are self-sufficient and live with their children. The data shows that most elderly support wearing smart bracelets and are willing to accept the emergency service system.

(2) Family members generally accept the emergency service system. The 600 valid questionnaires from Questionnaire 2 show that 52.7% of respondents do not live in the same city as their parents. Among the 284 respondents living in the same city as their parents, only 158 live with them, meaning only 26.3% of respondents live with their parents, indicating most elderly live alone and the emergency response system has strong social demand.

The system's operation requires certain financial investment, with families needing to install smart access control systems and smart bracelets. Their specific functions are shown in Table 3 . Considering most elderly's income situations, this survey targeted first-level elements—family members—asking whether they are willing to equip elderly with necessary smart facilities and whether they agree to volunteers and rescue institutions entering elderly homes when they are absent. The survey results are shown in Table 4 : 88.8% of respondents agree to apply for their parents to join community emergency service systems; 82.8% agree to purchase smart access control systems; 89.8% agree to purchase smart bracelets; 90.7% agree to allow emergency service volunteers to enter elderly homes through smart access control systems during emergencies.

(3) Surveyed individuals aged 20-60 are generally willing to become emergency service volunteers. Having sufficient volunteer quantity and qualifications is an important condition for system implementation and key to the success of the "Didi Volunteer" design. The survey asked the 20-60 age group whether they are willing to become emergency service volunteers and learn emergency handling measures, with results shown in Table 5 : 84.8% are willing to become emergency service volunteers; 72% are willing to enter their information into a secure volunteer platform; 81.8% are willing to spend time learning emergency handling measures; 83.5% are willing to collaborate with hospitals and other institutions to provide rescue services. The survey results indicate that most young and middle-aged Chinese have social responsibility, and emergency service volunteers for home-based elderly care have broad acceptance and a large population base.

4.2.4 Survey Conclusions From the above data analysis and online survey results: (1) The vast majority of elderly in China accept using the emergency service system. (2) The vast majority of family members accept using the emergency service system. Many elderly are empty-nest seniors whose children cannot always fully care for them, requiring the emergency service system to ensure their safety, which is also what the elderly need. (3) The vast majority of family members are willing to become emergency service volunteers and join the emergency service system to help more elderly. (4) China already has many mature elderly care service platforms, and the level of network technology, communication technology, and information collaboration technology is sufficient to meet the technical requirements of this system. (5) As China increasingly emphasizes elderly care issues, communities across the country are paying more attention to improving elderly care service levels and increasingly using elderly care service systems, so community support is also not a problem.

In summary, all five implementation conditions for the home-based elderly emergency service system can be met.

5. Construction of the Three-Level Emergency Response Information Collaboration System

5.1 Basic Information Management

This system stores information through five databases: elderly information cloud database (including basic and medical information), smart bracelet cloud database, emergency service volunteer basic information cloud database, hospital/rescue institution basic information cloud database, and geographic spatial location information cloud database.

(1) The elderly information cloud database stores natural and medical information of the elderly, including: (1) name, gender, age, ID number, blood type, allergies, home address, health status; (2) family members' names, gender, contact information, residence; (3) medical history and records generated from community hospital or hospital examinations and treatments, including medical visit records, physical examination records, and medication records, which are uploaded and updated to the cloud by hospitals in a timely manner.

(2) The smart bracelet cloud database stores real-time dynamic vital signs collected by smart bracelets, including real-time heart rate, blood pressure, location, and other information generated over time.

(3) The emergency service volunteer basic information cloud database stores volunteers' names, gender, age, ID number, home address, occupation, and certified emergency and medical knowledge level.

(4) The hospital/rescue institution basic information cloud database stores medical records of elderly patients and contact information and emer-

gency contacts for hospitals, fire departments, and police stations that can provide emergency rescue.

(5) The geographic spatial location information cloud database stores the geographic locations of each hospital, fire department, or police station, can input local maps to highlight these locations, and displays real-time locations of the elderly, family members, volunteers, and rescue vehicles.

5.2 Collaboration Agents

"Collaboration" is cooperation among multiple agents, and the information collaboration process is one of information transmission, exchange, sharing, and utilization by information agents [11]. The collaboration agents in this information collaboration system include: family members, emergency service volunteers, and rescue institutions such as hospitals, fire departments, or police stations. These "three levels" achieve the goal of efficient emergency rescue through sharing and utilizing elderly information, using the call center as the information exchange hub to transmit and exchange information among themselves.

5.3 Inter-Agent Local Collaboration Relationships

5.3.1 Collaboration Between Family Members and Emergency Service Volunteers When the elderly send alarm information to the call center, the call center extracts family member information to contact them. If family members cannot be contacted or need volunteers, the call center publishes the elderly's geographic location, basic information, medical information, and family contact information to the "Didi Volunteer" platform. Volunteers can decide whether to accept orders based on the location of the elderly seeking help and their own location. If multiple volunteers accept, the platform automatically assigns orders based on location and qualifications. After volunteers are confirmed, the call center sends the volunteers' basic information and real-time location to the elderly and their families. Volunteers maintain contact with family members, who use the smart access control system's remote control to open doors for volunteers, enabling timely entry into the elderly's home. The information collaboration relationship is shown in Figure 4 [Figure 4: see original paper].

5.3.2 Collaboration Between Family Members and Hospital/Rescue Institutions After the call center receives the elderly's distress call, it contacts rescue institutions while contacting family members. Based on the situation and the elderly's basic and medical information, it notifies hospitals, fire departments, or police stations. After rescue institutions respond and decide to dispatch, the call center sends the contact information of the dispatched vehicles to family members and simultaneously sends family contact information to the dispatched vehicles. Rescue personnel can communicate with the elderly

and their families in real-time voice to guide self-rescue and family-assisted rescue. The collaboration relationship is shown in Figure 5 [Figure 5: see original paper].

5.3.3 Information Collaboration Between Emergency Service Volunteers and Hospital/Rescue Institutions After volunteers accept orders, the "Didi Volunteer" platform sends volunteer contact information to the call center, which forwards it to dispatched rescue vehicles while sending vehicle information to the accepting volunteers. When necessary, rescue personnel can communicate with volunteers in real-time voice to guide them on how to rescue the elderly. The collaboration relationship is shown in Figure 6 [Figure 6: see original paper].

5.3.4 Overall Inter-Agent Collaboration Relationship The elderly send distress signals to the call center, which notifies the three-level elements—family members, emergency service volunteers, and hospital/rescue institutions—to provide emergency rescue. Meanwhile, these three-level elements collaborate with each other, transmitting and exchanging information to jointly and efficiently provide emergency services for the elderly. The overall collaboration relationship is shown in Figure 7 [Figure 7: see original paper].

5.4 Information Collaboration Technologies

The technical support for the three-level emergency response information collaboration system for smart home-based elderly care mainly includes framework technology, collaboration technology, encryption technology, authentication technology, positioning technology, communication technology, network technology, and other information technologies.

(1) **Framework technology:** The system construction needs to be based on SOA (Service-Oriented Architecture) framework technology. SOA is a service-oriented architecture comprising a complete set of new distributed software system construction methods and environments, including operating environments, programming models, architectural styles, and related methodologies, covering the entire service lifecycle [34].

(2) **Collaboration technology:** Connections between platforms within the system and between information personnel require collaboration technology to enable seamless "communication" between information and information.

(3) **Encryption technology:** Related to security, to protect user privacy, the system needs to incorporate mature security mechanisms to ensure information security.

(4) **Authentication technology:** Users entering the platform need identity verification through ID or facial/fingerprint recognition technology to better protect user privacy [35].

(5) **Positioning technology:** GPS positioning technology is used throughout the system, utilizing GeoHash positioning principles to locate the elderly, screen nearby volunteers, track volunteer real-time locations, and locate ambulances.

(6) **Communication technology:** Communication technology refers to using various communication facilities to transmit and exchange information. Today, electronic communication technology and mobile communication technology are highly developed. This system uses communication technology for elderly distress signal transmission and call center notification to three-level elements.

(7) **Network technology:** Internet technology is now widely used, and the entire system's information transmission requires mobile communication networks and wireless network connections, making network technology indispensable.

5.5 Three-Level Emergency Response Information Collaboration System Model

Based on the basic framework of the three-level emergency response information collaboration system for smart home-based elderly care, and analysis of information collaboration agents, relationships, and technologies, we propose the system model (see Figure 8 [Figure 8: see original paper]). The system consists of five layers: information layer, transmission layer, collaboration layer, application layer, and supervision layer. (1) The information layer mainly comprises the elderly basic information cloud database, smart bracelet cloud database, emergency service volunteer basic information cloud database, hospital/rescue institution basic information cloud database, and geographic spatial location information cloud database. This layer needs security mechanisms to ensure database reliability and low invasiveness. (2) The transmission layer accurately, reliably, securely, and quickly transmits data collected by various sensing devices through wireless networks and mobile communication networks to big databases or other platforms [15]. (3) The collaboration layer is the most important layer and the core of this system. After the elderly send distress information to the call center, family members, emergency service volunteers, and hospitals/fire departments/police stations share elderly information. The three parties connect and cooperate with each other through information transmission to accurately ensure elderly safety. (4) The application layer, or platform/application layer, is the medium connecting people and information. It mainly includes smart bracelet/one-touch platforms, emergency volunteer service platforms, and regional map platforms. These platforms adopt B/S architecture [15], using smartphones as terminals for convenience and cost savings. (5) The supervision layer involves government, enterprises, and communities supervising the entire transmission process. Communities are mainly responsible for information management, supervising information transmission between the call center and various platforms. The call center acts as the central nervous system of

this system, issuing commands to various platforms while timely receiving and transmitting information. Communities should establish specialized groups to manage the call center to ensure effective operation when elderly have emergencies. Enterprises are responsible for technology platform development and operation, ensuring information security, system maintenance, and upgrades to guarantee normal operation of the call center and various platforms. Government is responsible for system implementation and support, providing overall management of volunteers, communities, hospitals, and rescue institutions from incentive and constraint policies, qualification certification, and other aspects.

6. Implementation Guarantee Strategies for the Three-Level Emergency Response Information Collaboration System

6.1 Information Security Guarantee

Implementing the three-level emergency response information collaboration system for smart home-based elderly care must first ensure network security, protecting the privacy of the elderly and all collaboration agents. Technically, besides antivirus protection, the system should adopt encryption technology to prevent database data theft and improve data security. In system management, confidentiality agreements should be signed with all three-level elements to prevent leakage of personal privacy.

6.2 Volunteer Capability and Qualification Guarantee

To fully utilize the golden rescue time, volunteers need certain medical first-aid knowledge. Before joining the emergency service volunteer platform, volunteers need training in pre-hospital first-aid knowledge and other emergency knowledge (such as fire and gas leak handling). According to this study's social survey, over 80% of 20-60-year-old respondents are willing to join volunteer teams and receive first-aid training. Training can be organized by government and communities, with multi-party fundraising to hire professional trainers and certify volunteer medical levels. Certification can reference existing pre-hospital first-aid training and medical nursing training standards. When registering on the platform, volunteers should provide their certified medical first-aid level. Volunteers can continuously improve their medical first-aid level through ongoing training, which also enhances their own quality of life and capabilities.

6.3 Legal Guarantee

In recent years, some "bad" cases in society have made people worry about getting into trouble when encountering emergency rescue situations. Although volunteers have certain medical first-aid knowledge, non-professional medical personnel engaging in emergency medical activities may lead to various disputes [36], and volunteers worry about assuming unnecessary responsibilities, which

is also an important factor limiting volunteer numbers. To reduce "bad" cases and protect the rights of "good people," China's "General Principles of the Civil Law" implemented on October 1, 2017, stipulates in Article 184: "If damage is caused to the rescued person due to voluntary rescue actions, the rescuer does not bear civil liability." Volunteers who rescue without seeking any benefit are engaging in voluntary behavior. This law can eliminate volunteers' concerns about liability. However, if volunteers accept orders but fail to arrive at the elderly's location in time, delaying treatment, they need to bear relevant responsibilities. Before system establishment and operation, comprehensive rights and responsibility systems among multi-collaboration agents need to be formulated, requiring signatures from participating elderly and three-level elements. This content involves legal, ethical, and moral aspects requiring specialized research for demonstration and verification.

6.4 Government Reward System Guarantee

Volunteers' rescue behavior belongs to the category of righteous and helpful actions, which the government should support through reward systems. For example, providing free first-aid medical knowledge training for volunteers; issuing honorary certificates to outstanding volunteers; giving priority consideration in various excellent selection activities at the community, volunteer unit, and citizen levels. Through these systems, more people will dare and be willing to join volunteer ranks to protect more elderly lives.

Conclusion

In today's era of continuous information technology development, exploring new smart home-based elderly care service models is an important approach to solving elderly care problems. Through extensive social surveys and literature analysis, based on goal orientation and efficient information collaboration, this paper proposes a three-level emergency response information collaboration system for smart home-based elderly care services. With the participation of "Didi Volunteers" as the key node, it focuses on solving the problems of optimal rescue time utilization and insufficient elderly care service personnel, emphasizing multi-agent collaboration and effective information synergy, leveraging respective advantages of agents, providing new ideas for effective handling of emergency incidents in home-based elderly care, offering new approaches to improve home-based elderly emergency service levels, and safeguarding the life safety of the elderly in their later years.

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Author Contributions:
Ma Jie: Topic selection, research framework design, paper revision and finalization;
Li Lu: Data investigation and compilation, paper writing and revision;
Geng Hanbing: Data collection;
Hu Mo: Paper revision.

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Note: Figure translations are in progress. See original paper for figures.