Research on the Design of Smart Home Care Wearable Devices for the Elderly Based on TRIZ Theory

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Abstract. With China's rapidly aging population, smart home-based elderly care has become a vital strategy for addressing age-related challenges. As core terminals in these systems, wearable devices play a key role in health monitoring and emergency response. However, current products—ranging from health monitoring to safety protection, life support, and functional assistance—suffer from issues such as rigid form, discomfort, inconvenient use, and outdated design, significantly reducing their acceptance and usability among older adults. This study addresses the common issues of function overload and inadequate age-friendly design in existing devices by introducing TRIZ theory to guide the innovative form design of wearable devices for smart home-based elderly care. By identifying design contradictions through user demand analysis and applying TRIZ tools, this research proposes innovation strategies such as segmentation, composite materials, modular integration, and localized optimization to improve both device performance and user experience. The findings demonstrate that TRIZ provides a systematic framework for innovation in elderly care wearables, offering valuable theoretical and practical guidance for enhancing age-friendliness and usability.

Keywords: TRIZ Theory; Smart Home Care for the Elderly; Wearable Devices; Design Research

1 Introduction

The continued global aging of the population is making the "silver economy" an increasingly important driver of socio-economic transformation. It is projected that by 2035, over 30% of the population will be aged 60 or above, and the arrival of a deeply aged society is generating enormous demand for elderly care services and age-friendly products [1]-[2]. Against the backdrop of deep aging, smart wearable devices serve as the core carriers for smart home-based elderly care. Current research on smart elderly care wearables mainly focuses on functional integration and hardware development (e.g., improved sensors, longer battery life) [3, 6–7], or targets isolated aspects of user experience like simplified interfaces. However, these efforts often overlook the complex, conflicting needs of elderly users—such as balancing rich functionality with ease of use,

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durability with lightness, and continuous monitoring with low power consumption—resulting in limited usability and acceptance in real-world contexts [3].

This study offers several key innovations. It is the first to systematically apply TRIZ theory to the form and age-friendly design of smart elderly wearables, providing a structured approach to identifying and resolving design contradictions. It focuses on the core conflicts between user needs—such as usability, comfort, and safety—and technical performance metrics like accuracy, battery life, and signal strength, moving beyond the conventional approach of function stacking. Additionally, it demonstrates the practical use of TRIZ tools, particularly the contradiction matrix, by applying them to real-world design challenges such as casing structure, power interference, and interface complexity, thereby enhancing the theory's practical value and relevance to design.

2 Overview of TRIZ Theory

TRIZ (Theory of Inventive Problem Solving) is the acronym derived from the Russian phrase meaning "theory of inventive problem solving." It was developed by the Soviet inventor Genrich S. Altshuller and reveals the underlying laws and principles of invention, forming a systematic innovation theory [4]. Unlike traditional innovation methods, TRIZ is based on the analysis of a vast number of patents and engineering problems, offering a standardized set of problem-solving tools that provide systematic, cross-disciplinary solutions to complex technical challenges. In recent years, TRIZ has been widely applied in product design and functional innovation, offering a feasible and efficient methodology for addressing complex, dynamic, and conflicting problems [5].

The basic problem-solving process in TRIZ starts from a practical problem (see Fig. 1), identifies the essential contradictions through functional analysis and causal chain analysis, and abstracts the issue into a general TRIZ problem. TRIZ tools are then employed to generate ideal solution approaches, which are subsequently transformed into specific design solutions to resolve the original problem.

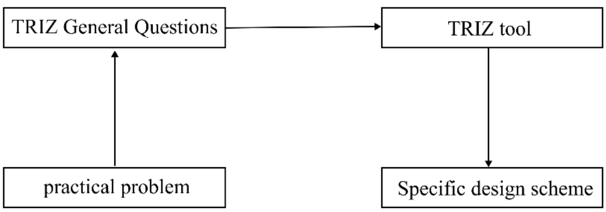

Fig. 1. Basic ideas of TRIZ theory to solve problems

In the design of smart elderly care wearable devices, TRIZ's core tool—the contradiction matrix—demonstrates strong practicality and guiding value. Its application involves three steps: first, translating the characteristics to be optimized and their negative effects into the 39 standard engineering parameters defined by TRIZ; second, using the matrix to identify the intersection between the improving and worsening parameters to obtain the corresponding inventive principle numbers; and finally, interpreting the recommended principles within the specific design context to generate innovative solutions. This method concretizes abstract design contradictions and leverages cross-domain principles to inspire creativity, effectively overcoming the limitations of traditional design where conflicting factors are difficult to reconcile.

3 Analysis of the Current Status of Smart Home-Based Elderly Care Wearable Devices

The accelerated aging of the global population has driven the development of smart health and elderly care. China faces a particularly severe demographic challenge in this regard. To address this, the *Action Plan for the Development of Smart Health and Elderly Care Industry (2021–2025)* explicitly mandates deepening the integration of information technology with elderly care services[2]. As the core component of home-based elderly care systems, smart wearable devices have made notable progress in areas such as health monitoring (e.g. fall detection alarms), safety protection, and remote communication [6]-[7].

Currently, these devices can generally be classified into four functional categories: health monitoring devices, such as smart clothing and wristbands, which primarily focus on physical activity and health tracking, with mature ECG and fall detection technologies already applied at scale; safety protection devices, such as smartwatches and emergency buttons, which have relatively well-developed basic functions like SOS alerts but lack multi-source risk coordination and age-friendly interactive design; life support devices, such as voice assistants, which are increasingly equipped with functions like medication reminders but face persistent issues of poor inter-device connectivity and interaction barriers; and functional compensation devices, such as hearing aids and exoskeletons, which emphasize physiological assistance and rehabilitation, holding high research value but suffering from slow commercialization and limited adoption.

Analysis of current smart elderly care wearables and user feedback reveals that the core issues extend beyond limited form factors or outdated designs, rooted instead in fundamental conflicts between technological solutions and the actual needs of elderly users. Health monitoring devices aiming for higher accuracy often suffer from high power consumption and short battery life, leading to frequent charging and reduced user compliance; their high-precision sensors require close skin contact but may cause discomfort due to rigid materials or complicated wearing methods, especially for users with fragile skin. Safety devices like emergency buttons, while essential, are frequently difficult to locate or operate quickly during emergencies. GPS-based tracking struggles with unstable signals and high power usage indoors or in rural areas, failing to provide reliable all-day positioning. Daily support devices such as voice assistants face challenges in dialect recognition, noise interference, and speech adaptation, resulting in frequent interaction failures and increased user frustration. Moreover, complex inter-device connectivity and app-based configurations often exceed the cognitive capacity of many elderly users. Functional compensation devices, including hearing aids, may cause discomfort or unwanted noise, while exoskeletons tend to be bulky, heavy, and cumbersome to wear, limiting their practicality for everyday use.

According to the TRIZ laws of technological system evolution and the S-curve theory [8], the overall development of smart home-based elderly care wearable devices is currently in a phase of rapid growth. Compared to the maturity stage, current research and development efforts are primarily focused on functional integration and age-friendly improvements, without yet achieving cross-system breakthrough upgrades. Therefore, there is an urgent need for systematic innovation approaches to improve the overall ideality and user value of these products.

4 Analysis of the Current Status of Smart Home-Based Elderly Care Wearable Devices

The design of smart home-based elderly care wearable devices requires comprehensive consideration of multiple factors, including technical performance and user needs. By analyzing existing devices and mature market products, seven key system components can be identified as the core of such devices, as detailed in Table 1. Based on the functional analysis of these components, the process proceeds through component identification followed by analysis of the interactions between components. Specifically, after identifying the components, it is necessary to analyze their interrelationships and construct an interaction matrix, as shown in Table 2, where "+" indicates the presence of interaction between components, and "-" indicates no interaction [9].

Table 1. List of System Components

Technical System	Primary Functions	System Components	Supra-System Components
Smart Home-Based Elderly Care Wearable Devices	Health Monitoring and Risk Intervention	Vital Sign Sensors Location Module Communication Module Alarm Button Housing Power Module Feedback Module	Human Home Environment

From this system analysis, three main types of design contradictions can be extracted: physical contradictions, technical contradictions, and energy-efficiency contradictions. These contradictions are reflected in the design of various functional modules. A thorough analysis of these contradictions is crucial. Enhancing casing protection with metal or high-strength plastics improves durability but creates electromagnetic shielding that weakens signals like WiFi, Bluetooth, and GPS, while tight manufacturing tolerances limit antenna design flexibility. Power reliability conflicts with sensor accuracy, as heat and electromagnetic noise from the power module cause sensor drift and reduce signal quality. Extending battery life typically requires larger batteries, increasing device size and weight, which compromises wearability—despite emerging battery technologies, widespread adoption remains limited. Adding more functions introduces extra sensors and interfaces, increasing complexity and cognitive load, making devices harder for elderly users to operate and ultimately reducing usability and acceptance.

In addressing such systemic conflicts within the limited product space, traditional incremental optimization methods face inherent limitations. Therefore, there is a need to leverage the systematic problem modeling and innovative solution tools provided by TRIZ theory to overcome design bottlenecks.

Table 2. Interaction Matrix Analysis of Components

component	sensor	location module	communication	alarm button	housing	power module	feedback module	human	environment
sensor		+	+	-	+	+	+	+	-
location module	+		+	-	+	+	-	+	-
communication	+	+		+	+	+	+	+	-
alarm button	-	-	+		+	+	+	+	-
housing	+	+	+	+		+	+	+	+
power module	+	+	+	+	+		+	+	-
feedback module	+	-	+	+	+	+		+	-
human	+	+	+	+	+	+	+		+
environment	-	-	-	-	+	-	-	+	

5 Solution Derivation Based on TRIZ Theory

Table 3. Contradiction Analysis Reference Table

NO.	Contradiction Description	Corresponding TRIZ Engineering Parameters	Type of Contradiction	Relevant TRIZ Inventive Principles
1	Housing protection vs. Signal strength	24.Loss of information 29. Accuracy of Manufacturing	Technical Contradiction	NO.1(Segmentation) NO.40(Composite Materials)
2	Power module vs. Sensor measurement accuracy	27.Reliability 28. Measurement Accuracy	Technical Contradiction	NO.2(Taking Out) NO.24(Intermediary)
3	Battery life vs. Device weight	1.Weight of moving object 35.Adaptability	Physical Contradiction	NO.5(Merging) NO.35(Parameter Change)
4	Device Functionality vs. Operational Complexity	35. Adaptability 37. Complexity of Control	Technical Contradiction	NO.3(Local Quality) NO.6(Multifunctionality) NO.33(Homogeneity)

In the design of smart home-based elderly care wearable devices, various contradictions often arise that affect both performance and user experience. To effectively address these challenges, key contradictions are systematically translated into TRIZ problem models using the Altshuller Contradiction Matrix, providing a theoretical foundation for subsequent solution derivation. The specific details are presented in Table 3.

By translating the key contradictions in wearable device design into TRIZ problem models, systematic analysis and solution derivation can be conducted using TRIZ theory. The contradiction between housing protection and communication signal strength, where enhanced protective performance weakens signal transmission, involves engineering parameters such as manufacturing precision and information loss; this technical contradiction can be addressed through the separation principle by partitioning the housing or applying composite materials.

The contradiction between power module reliability and sensor accuracy—where heat and interference from the power module affect sensor performance—can be addressed by spatially separating components or adding insulating elements. The conflict between battery life and device weight, a typical physical contradiction, may be optimized by integrating the battery with other modules or using advanced materials to enhance energy density without increasing weight.

Finally, the contradiction between device functionality and operational complexity, where added functions increase user difficulty, is a technical contradiction involving adaptability and control complexity. This can be addressed by enhancing the local quality of frequently used functions, integrating multifunctional operations, and adopting interaction patterns familiar to elderly users, thereby simplifying operation.

6 Conclusion

The core value of design lies in addressing real user needs through systematic innovation. As China's aging population grows, smart home-based elderly care wearables have become crucial for ensuring health and safety, making design innovation essential to improving care quality. This study identifies key issues such as feature overload and inadequate age-friendly design, constructs a technical system model and interaction matrix to locate core contradictions, and applies TRIZ theory—especially the contradiction matrix—to propose solutions like zoned composite casings, thermally isolated power modules, and integrated multifunctional interfaces. These strategies balance technical performance with user-centered design, effectively resolving key conflicts between elderly users' needs and device capabilities, and offer a reusable framework for developing age-friendly products in aging societies.

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