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A study on requirement optimization of intelligent health care information system for rural elderly based on improved FKM-TOPSIS method

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Abstract. Against the backdrop of China's young and middle-aged population moving to the cities to work, older adults in rural areas of China are facing even more severe old-age and healthcare dilemmas. Under such circumstances, how to improve the functions of age-appropriate smart wearable products to meet the needs of older adults in rural areas for old age and health care has become a focal issue in Chinese society. In this paper, we change the traditional Fuzzy Kano Model (FKM) research method, quantify the research results, and use the superiority and inferiority coefficient formula to scientifically classify user needs after conducting research on different functions of smart wearable devices and obtaining different user needs: M denotes must-be demand; O denotes performance demand; A denotes attractive demand; and I denote indifferent demand. A theoretical multidimensional analysis of the generated data was performed to determine the requirements priority of the rural elderly. Then, using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach, compute the relative closeness of user satisfaction, i.e., the priority of functional needs. Finally, testing the product prototypes of "PC-based and mobile-based" information systems of smart wearable devices and identifying the most critical demand concentrated on emergency assistance for rural older adults. Such as 120 Call, Call Emergency Contacts, Positioning System, Blood Pressure Testing, Heartbeat Pulse Monitoring, etc. These functions can effectively reduce the health risks of older adults in critical emergencies, confirm the scientific character of user demand prioritization, establish the viability of the study, and provide new ideas for intelligent product-related research to continue.

Keywords: Smart wearable products, rural elderly, user needs, functional attributes, Kano model, TOPSIS method, product prototypes

1. Introduction

With the advent of aging in China, older people's physical and psychological healthcare problems are becoming increasingly severe, particularly in rural regions, where healthcare conflicts are more evident owing to the limits of rural areas. It is worth noting that data from the Seventh Population Census shows

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that China has a migratory population of 376 million, with more than 80% of the mobile population coming from rural areas, leaving about 40 million older people behind in rural areas, accounting for 37% of the rural elderly population. However, as many young rural people migrate to cities for work, working and caring for older adults who cannot care for themselves cannot be combined, leading to little workspace for many children caring for their parents [1]. Rural elderly left behind without family care often go to the village health center to deal with their illnesses simply or suffer from them, leading to irreversible consequences over time [2]. Although governments at all levels have implemented large-scale poverty alleviation measures for rural areas, such as the construction of nursing homes, because it is a poverty alleviation project, many townships share a single home for older people. Hence, the facilities and staffing are relatively simple and can only provide the most basic living, not even medical facilities. Thus the medical and pension issues of older people left behind in rural regions remain unsolved [3]. The older people left behind in rural areas need more acceptance of innovative products due to their literacy, age, and lack of smart devices, particularly in intelligent payment and smart medical care, which is a fatal blow to the rural older people. In this situation, developing intelligent monitoring wearable devices and information systems for the old rural left behind can effectively allow children away from home to stay informed about their parent's health and lifestyle.

We must thoroughly understand the present demands of older rural residents before designing the information system and APP for smart wearable devices. User demands determine the path of product innovation and design, and meeting those needs entails raising user satisfaction. Propose the combined FKM-TOPSIS approach in this research. The product questionnaire is quantified and improved by the FKM approach, and the attribute categorization of user needs is more accurate than the outcomes of the conventional Kano model analysis. However, because this model's questionnaire asks for positive and negative aspects, different people may have different perspectives. As a result, various uncertainties, such as the variety of evaluation indicators, the subjectivity of indicator weights, and the ambiguity of evaluation information, impact the evaluation results. And TOPSIS, on the other hand, is a multi-objective and multi-attribute efficient evaluation method in operations research that primarily evaluates the importance of product quality elements and makes full use of the user demand evaluation information obtained in the FKM model to rank the proximity of several evaluation schemes to the idealized object. Explore each demand for smart wearable devices as a solution in this study. SI and DSI are utilized as evaluation indices for each solution to assess the relative benefits and drawbacks of the available solutions. Combining the two models generates fresh possibilities for study into intelligent product design.

Additionally, we design the dynamic product interaction prototypes on the PC and mobile-based of the information system of smart wearable devices to confirm the objectivity of the user requirement satisfaction weighting using test data.

2. Literature review

Identifying consumer demands is the beginning point for the idea development phase of the new product development process. It directly influences consumer happiness and product quality [4].

On the one hand, given the many needs of rural elderly for intelligent products, research in the field of smart wearable products has shifted to focusing on the needs of a set of intelligent products, decreasing the cost of the elderly in rural regions, and popularizing intelligent wearable technology products [5]. Based on differences in exploratory perspectives, research on intelligent wearable technologies to help rural elderly's lives at home and abroad is mainly distributed in three aspects: (1) The research carriers for intelligent wearable devices are primarily specific people or groups, such as the usage of wearable items for diabetes patients for blood glucose measurement, insulin infusion, and other autonomous treatment [6]. Such as Smart devices are implanted in a disabled person's body to provide intelligent support and let them interact more effectively with their surroundings [7]. Smart wearable devices were employed in studies to remotely monitor the monitoring data of elderly individuals with atrial fibrillation [8]. However, a single smart wearable device is a significant challenge for rural older adults due to the economic pressure, laborious operation process, and the fact that a single device can only solve a single problem. So improving the quality of life first requires solving medical and health problems affecting all body parts. (2) Investigate the acceptability of intelligent wearable devices by older persons, for example, by developing a theoretical model to examine the factors that impact more senior adoption of innovative technology devices. According to Stephen M. Golant, intelligent wearable technologies have low knowledge of privacy protection for older adults [9]. Some academics have utilized two algorithms to increase privacy protection for smart device app users and increase older people's adoption of intelligent devices. Both are research on the subjectivity of older persons' reception of intellectual products [10,11]. With the emergence of rural issues such as fewer children, aging, remote rural locations, relatively poor infrastructure, and an insurmountable "digital divide" for older adults, the emergence of intelligent wearable products has alleviated the physical and psychological problems of the older adults, for example, smart devices and cloud diagnosis can help treat rural older adult's diseases [12]. It belongs to the objective reality constraints that must accept intelligence to ensure the quality of life of rural older adults. (3) According to an analysis of older adults demands in rural areas, whether in China or other nations, considering such needs progressively seriously. In Tianjin, China, Lin Hongyan et al. examined a sample of elderly rural people. They discovered that depression was a severe issue among rural older persons, accompanied by poor sleep and other mental problems requiring immediate attention [13]. The chief physician of a test conducted by a joint geriatric rehabilitation department of a tertiary care hospital showed that the mental state of the older adults who regularly participated in socialization and outside communication was significantly better than those who did not [14]. Kshatri et al. used regression models to analyze rural elderly people with multiple chronic diseases in India and found that their frailty and dependence became more intense with age [15]. Kuo et al. discovered that the rural elderly had a greater risk of death from heart disease when comparing urban and rural Taiwan areas to investigate variations in variables impacting mortality [16]. Referring to the research literature above, it is known that physical and mental health issues continue to be the top priorities for rural older adults.

Moreover, in rural areas, the proportion of older adults who are defrauded is very high compared to those in urban areas, as Deliema et al. (2020), whose proportion of rural older adults who are tricked has gradually increased in recent years and depression has become an essential factor affecting the probability of being defrauded [17]. Empirical evidence by Wei et al. (2021) also found that individual financial literacy significantly reduces their likelihood of being tricked, and compared to the urban older adults, the rural low literacy level of older adults resulted in them being the most affected by fraud [18]. Manea et al. concluded that a significant risk factor for chronic diseases is a lack of exercise and using simple wearable devices to record data on changes in the body [19]. The results showed that moderate leisure activities could reduce the risk of chronic diseases. Combining these current conditions suggests that with the advent of aging, older adults' daily life, recreation, and spiritual needs seriously affect their physical and mental health [20] and some literature shows that compared to urban areas, rural elderly are more willing to age at home [21]. All these phenomena provide a broad commercial market for technological products such as intelligent assistive devices and smart homes [22].

On the other hand, the Kano model is a standard method to identify customer requirements, and the use of the Kano model helps designers identify customers' different functional needs and enables them to control quality and satisfaction more accurately in the product design and development process [23]. Many scholars have been expanding the integration method of the Kano model with other methods. For one thing, the traditional Kano model research methods are improved, such as the FKM (Fuzzy Kano Model) model, which quantifies and improves the five satisfaction levels of the questionnaire's demand attribute classification the Kano model to ensure a more accurate attribute classification of user demand [24]. This method applies to all products that need to explore user needs and satisfaction types. For another, the Kano model is widely combined with various ways represented by TOPSIS to form a closed loop of mapping from customer requirements classification and definition to product architecture, which provides technical support and methodological guidelines for design. For example, To efficiently solve the evaluation problem, Shan Du developed the Kano-DEMATEL-TOPSIS method and applied it to logistics service supply chain (LSSC) management [25]. Chen et al. proposed a hybrid analytical method integrating the fuzzy Delphi method (FDM), Kano two-dimensional quality model, and theory of innovative problem solving (TRIZ) was proposed [26].

Previous studies on the needs of rural older adults have failed to integrate the two issues of "intelligent products" and "life needs of the rural elderly". The information systems of intelligent wearable devices developed based on the psycho-physiological needs of rural older adults cannot only alleviate the health problems of the rural older adults but also play a comforting spiritual role for the older adults with its on-demand functions, and the rural older adults have a tremendous demand for chronic disease management, so the use of smart wearable products for primary monitoring and health care can prevent malignant changes of chronic diseases. Smart wearable devices in their intelligent mode, with less operation, less interaction, automatic all-around monitoring, and simple digital literacy for rural elderly, can be used [27–29]. Based on the above considerations, this paper uses the FKM-TOPSIS method to conduct a study on the actual needs of smart wearable monitoring devices for rural older adults, to effectively enhance their participation in intellectual development and enjoy the dividends of Internet development.

3. Integration analysis of the demand for innovative wearable products for rural older adults

Although the development of smart wearable devices is intended to solve the problem of older people in rural areas, the majority of users of its information system are village officials, village doctors, children of older people, and other participants in the direct care of older people, and their needs for the functions of the smart wearable products are highly consistent with those of older people. In this study, we investigate village authorities, village physicians, senior people, and their children as a group and analyze their common needs for smart wearable devices.

Jiangsu Province served as the overall sample and using a three-stage sampling approach to sample the population to determine the user demand for information systems for smart wearable devices for older individuals living in rural areas. The PPS unequal probability sampling technique was used in the first stage to sample eight Jiangsu Province prefecture-level cities based on the fraction of each town in Jiangsu Province; the random sampling method was used in the second stage. 36 villages were chosen randomly from a list of all the villages in the eight prefecture-level cities to represent the sample. Still, they had to satisfy two requirements simultaneously: they had to have a nursing home and a village medical and health facility. In the third stage, the research team contacted the village committee to obtain a list of committee members, village doctors, and older adults residing in nursing homes. Based on this list, they selected the village committee members, village doctors, children of older adults, and older adults who choose randomly as the final sample. A total of 110 samples—including 20 village committee members, who made up about 18% of the total sample, ten village doctors, who made up about 9% of the total sample, 43 older adult children, who made up about 39% of the total sample, and 35 older adults, who made up about 34% of the total sample—were ultimately collected for this study. We conducted an interview study on the daily needs of rural older adults, and these interviewees were potential users of intelligent wearable products. The researcher randomly interviewed the children of older people and others after arriving in the rural areas, and interviews with village doctors and village council members were pre-arranged. The research proceeded quite well since these problems are more prevalent and perceived easily daily.

The interviews with the village doctors focused on the health of older adults in rural areas, including the number of older adults with underlying diseases (hypertension, hyperlipidemia, hyperglycemia, etc.), the level of older adults' knowledge of their illnesses, the complementary treatments that were available for the older adults with underlying conditions, and first aid for the older adults. It took around half a day to complete.

The interviews with village committee officials covered topics such as the number of older adults in the village, their physical and psychological conditions, how many people have experienced fraud in the past and how resolved it, what measures the village committee has taken to deal with older adults in an aging society, how the spiritual life of older adults in rural areas, and so on. It lasted approximately half a day.

The interviews with the children of older adults focused on what concerns the children have about the older adults' problems, whether they plan to be involved in older adults in the future, which older adults' assistance products they want to popularize, what kind of elderly care model the children of older adults believe their parents prefer, what special needs they have for the future of specialized elderly care, and so on. It took around 2–3 h.

The randomly selected older adults are primarily from rural areas, and the research takes about 4-5 hours. It asks questions like what kind of elderly care mode they prefer, what aspects of life they believe are more difficult right now, what types of help the older adults most need right now, what kind of expectations they have for their old age, etc.

To verify the study's adequacy and objectivity [30]. We interviewed experts specializing in the information system for smart wearable items and other relevant practitioners using the Delphi expert survey method. These professionals comprised front-line intelligent product salespeople, product managers from firms that manufacture intelligent products, academics with backgrounds in information systems from universities, as well as physicians and nurses. After several rounds of gathering expert opinions on the issues raised and following repeated solicitation, generalization, modification, evaluation, and classification, resulting in a platform architecture system, the research process needs to be informed of each requirement's feasibility and technical difficulty in addition to determining the reasonableness of the system's user requirements. And evaluated and categorized each functional attribute and resulting in a platform architecture system that includes five categories of Medical Services (MS), Communication Functions (TC), Anti-fraud System (FS), Leisure and Entertainment (ET), and Sports and Health (SH), with a total of twenty-five functional requirements, a complete understanding of the full picture of the information system of smart wearable products. As shown in Table 1.

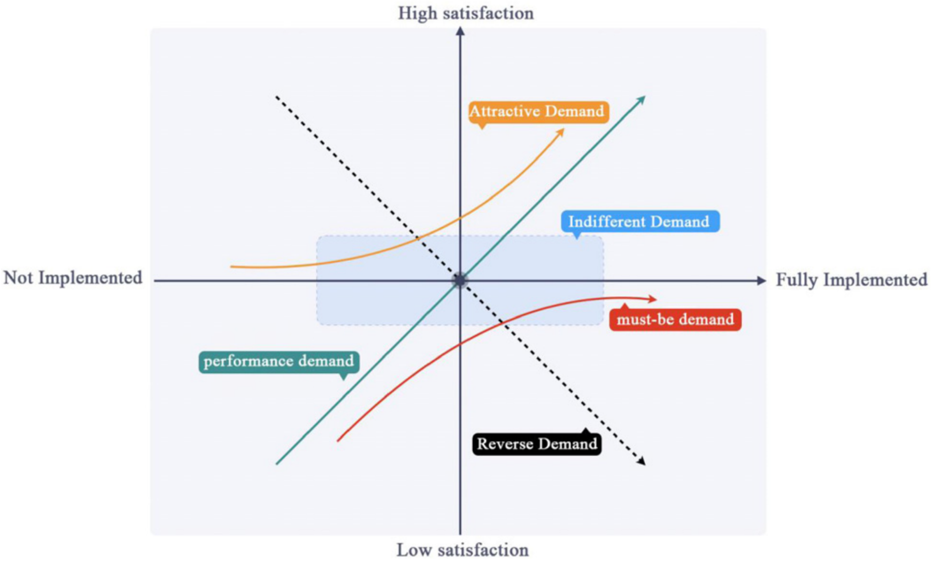

Fig. 1. Kano model user requirements classification chart.

4. User research and data collection

Due to their lack of knowledge and restricted vision, it is difficult to fully and adequately identify the demands of the rural old, and older adults have a wide variety of needs. This article employs a questionnaire and in-depth user interviews to acquire original consumer demand information. The fuzzy clustering approach is then used to classify the original user demand information to get new user demand information, thereby reducing the effects of user demand information clutter on user demand analysis.

4.1. Survey questionnaire setting

Noriaki Kano, a Tokyo Institute of Technology professor, established the Kano model as a method for categorizing user demands based on user satisfaction [31,32]. The Kano model allows for qualitative and quantitative study of user requirements, exploring the breadth and depth of user demands, comprehension of the user needs hierarchy, and identification of critical factors to increase satisfaction. The Kano model organizes user requirements into five categories based on the non-linear connection between product characteristics and user satisfaction. M means Must-be Demand: customer satisfaction does not rise when providing this demand but considerably reduces when it is not; O means Performance Demand: user satisfaction will increase when providing these demands, whereas it will fall when it is not; A means Attractive Demand: it falls under an unanticipated user demand; if not provided, user satisfaction won't be affected, yet, if it is provided, user satisfaction will be significantly higher; I means Indifferent Demand: user satisfaction will not vary whether this demand is met or not, and users do not care; and R means Reverse Demand: users do not have this demand, and if provided it, user satisfaction will decrease. As shown in Fig. 1.

The original Kano model questionnaire used five degrees of possibility to answer questions such as "Like", "Deserved", "Indifferent", "Tolerated", and "Disliked". Some rural older adults' subjective consciousness does not accurately represent their will while making decisions, resulting in ambiguity in

Table 1
Functional requirements of intelligent wearable products for rural older adults left behind

Service dimension	Code	Functional requirements	Service demand connotation
Medical services (MS)	MS1	Call family doctor	Rural seniors can call their family doctor for consultation if they are unwell and not in a life-threatening situation while at home.
	MS2	Review reminder	When treatment is completed, the elderly will usually request a follow-up visit, which can be set through the APP and reminded when it is time.
	MS3	Blood glucose testing	Non-invasive blood glucose measurement technology is applied to the bracelet, which automatically calls 120 when the blood glucose is too high or too low, and life is in danger.
	MS4	Sleep monitoring	The users can use this function to detect the sleep quality of the elderly in real time for the family's reference users.
	MS5	120 call	The APP can detect blood pressure in real-time and automatically call 120 when blood pressure is too high or too low and life-threatening.
	MS6	Heartbeat pulse monitoring	Binding APP, you can view real-time heartbeat records, issue HRV reports, and automatically call 120 when the heartbeat is too fast or plunges into a life-threatening situation.
	MS7	Medication reminder	Rural older adults alone at home need to take medicine to avoid forgetting to take medication or forgetting the name of the medicine dosage, etc., can be set up in the APP to complete when the time is to remind.
	MS8	Blood pressure testing	If no one is around or you are alone and feel extremely unwell and need to be admitted to the hospital, you can call 120 any time.
	MS9	Two QR codes and one nucleic acid result	The health code icon allows you to view your trip code and health code at any time, including the movement track, etc., and view your nucleic acid results.
Communication function (TC)	TC1	Video voice call	Through bluetooth, you can take incoming calls from your cell phone or make video and voice calls.
	TC2	Positioning system	When the elderly are out, they can be located in real-time to determine whether they are safe.
	TC3	Monitoring system	Check the status of the elderly in real-time and remind them of precautions, etc.
Anti-fraud system (FS)	TM1	Anti-fraud system	This function can provide intelligent identification of suspected fraudulent phone calls, SMS, APP risk, and warning and prompt of risky behavior.
	TM2	Payment function	Payments are made by verifying the other party's identity, predicting the risk of high costs, and uploading the payment information to the App for family members to know.
	TM3	Large spending limit	You can set a limit for each purchase and provide fraud prevention warnings for large purchases.
Leisure and entertainment (ET)	ET1	News radio broadcast	It can help rural older adults to understand the current news.

Table 1 (Continued)

Service dimension	Code	Functional requirements	Service demand connotation
	ET2	Call emergency contacts	Emergency contacts can be called in case of an emergency or the intelligent band is lost.
	ET3	Opera music playback	Voice searchable for all opera and music works on the internet.
	ET4	Dating system	Add friends face to face through the smart bracelet and chat and communicate with friends listening through the smart bracelet.
	ET5	Robot chat system	Voice search or Q&A is available, and the robot can tell jokes, sing, tell stories, and more.
Sports and health (SH)	SH1	Real-time pedometer	The number of steps and trajectory of the day can be calculated in real-time and uploaded to the system.
	SH2	Exercise reminder	The elderly are sedentary and can be instantly reminded of the dangers of being sedentary.
	SH3	Energy consumption	Exercise according to the older person's blood sugar to burn excess energy and ensure good health.
	SH4	Action track	Family members can check the activity tracking of the older adults at home through the APP to prevent them from getting lost.
	SH5	Weather forecast	It can broadcast the weather conditions and remind the rural elderly of the precautions to take when they go out.

demand survey data from some consumers. Thus it is suggested to utilize fuzzy interval values to describe the users' sentiments instead, which is more accurate for ambiguous situations. Therefore, the FKM model questionnaire quantifies and improves the five possibility degrees of user needs [33,34], and the total score of the five levels of options is set to 1 and represented by a number between 0 and 1, making the attribute classification of user demands more precise. Table 2 depicts the initial Kano questionnaire, and Table 3 illustrates the improved FKM questionnaire.

4.2. Examples of user requirement attributes classification

In this paper, we conducted data research on rural older people and their children, village doctors, village committee officials, and a random group of people who need the product. And to score the functional requirements of the smart wearable products in Table 1 by the improved KFM questionnaire based on the fuzzy Kano model questionnaire. A total of 150 questionnaires were distributed, of which 138 were valid to ensure the validity of the research data.

Taking the "Call Family Doctor (MS1)" of the intelligent monitoring wearable product for the rural older adults left behind as an example, using the research data of the FKM questionnaire to classify the user demand attributes. The responses of the respondents in the fuzzy Kano model questionnaire in Table 1 on whether the "Call Family Doctor (MS1)" is provided or not are quantified digitally, as shown in Table 3. Then the matrix of providing this function, i.e., $Y = [0.7\ \ 0.2\ \ 0.1\ \ 0\ \ 0]$, not providing this

Table 2
Example of KANO model questionnaire

Design elements	Number	Elemental analysis	User requirements	Like	Deserved	Indifferent	Tolerated	Disliked
Medical services (MS)	MS1	Call family doctor	Provide	☑	☐	☐	☐	☐
			Not provide	☐	☐	☐	☐	☐
	MS2	Review reminder	Provide	☐	☐	☐	☐	☐
			Not provide	☐	☐	☐	☐	☐
	MS…	……	…	…	…	…	…	…
	MS9	Two QR codes and one nucleic acid result	Provide	☐	☐	☐	☐	☐
			Not provide	☐	☐	☐	☐	☐

Table 3
Example of FKM questionnaire

Design elements	Number	Elemental analysis	User requirements	Like	Deserved	Indifferent	Tolerated	Disliked
Medical services (MS)	MS1	Call family doctor	Provide	0.7	0.2	0.1	0	0
			Not provide	0	0	0.1	0.3	0.6
	MS2	Review reminder	Provide	0.6	0.3	0.1	0	0
			Not provide	0	0.1	0.1	0.2	0.6
	MS…	……	…	…	…	…	…	…
	MS9	Two QR codes and one nucleic acid result	Provide	0.3	0.5	0.1	0.1	0
			Not provide	0	0.2	0.1	0.4	0.3

function matrix, i.e., $N = [0\ \ 0\ \ 0.1\ \ 0.3\ \ 0.6]$, which generates the following interaction matrix.

$$S = Y^T N = \begin{bmatrix} 0 & 0 & 0.07 & 0.21 & 0.42 \\ 0 & 0 & 0.02 & 0.06 & 0.12 \\ 0 & 0 & 0.01 & 0.03 & 0.06 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

As shown in Table 4, the values in matrix S correspond to the user requirement attributes in the Kano model attribute classification table.

Table 4
Comparison table of KANO model attributes classification

Product/service request		Negative issues				
Positive issues	Scale	Like	Deserved	Indifferent	Tolerated	Disliked
	Like	Q	A	A	A	O
	Deserved	R	I	I	I	M
	Indifferent	R	I	I	I	M
	Tolerated	R	I	I	I	M
	Disliked	R	R	R	R	Q

Table 5
Summary of research data on functional attributes of the "Call Family Doctor"

Researchers	M	O	A	I	R
Person no. 1	0	1	0	0	0
Person no. 2	1	1	0	0	0
Person no. 3	1	0	0	0	0
Person no. 4	0	1	1	0	0
…	…	…	…	…	…
Person no. 138	1	0	1	0	0
Data aggregate	67	38	25	12	0

Calculate the affiliation vector L for the "Call Family Doctor (MS1)" attribute category.

$$T = \left\{ \frac{0.18}{M}, \frac{0.42}{O}, \frac{0.28}{A}, \frac{0.12}{I}, \frac{0}{R} \right\}.$$

The data of the affiliation vector obtained from the "Call Family Doctor (MS1)" is processed utilizing a threshold value α to improve the data of reliability. At first, the value of α is 0.4. when the attribute value of this function is greater than or equal to 0.4. the element represents by 1, otherwise by 0, Then $L = (0\ \ 1\ \ 0\ \ 0\ \ 0)$. The total value of each attribute (M, O, A, I) of the "Call Family Doctor (MS1)" was obtained by summing up the attribute values of this function after processing by all investigators, and the attribute with the highest value was used as the attribute type of this function. When the values are equal, the function attributes can be classified in the order of priority M, O, A, and I. As shown in Table 5, the "Call Family Doctor (MS1)" of the smart wearable product for rural older people left behind belongs to the must-be demand (M).

4.3. *Functional attribute categorization and satisfaction coefficient*

The demand attribute categorization and satisfaction and dissatisfaction coefficients for all functions of the smart wearable products for the rural older adults were calculated using Eqs (1) and (2) based on the results of the FKM questionnaire, as shown in Table 6. The following equation *SI* represents the user satisfaction coefficient when the product provides a particular demand; *DSI* represents the user dissatisfaction coefficient when the product does not offer a specific need, and i means the i-th demand [35]. It is assumed that providing and not providing this function are equally significant. i.e., the *SI* and *DSI* formulas are as follows.

$$SI_i = \frac{A_i + O_i}{A_i + O_i + M_i + I_i} \tag{1}$$

$$DSI_i = \frac{M_i + O_i}{A_i + O_i + M_i + I_i}. \tag{2}$$

5. Functional satisfaction analysis based on the TOPSIS method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is a multi-generic decision-making system that uses a multi-generic ranking mechanism to approximate idealized solutions [36]. The researchers used the TOPSIS method to fully utilize the information obtained in the FKM model for evaluating the user requirements of the information system of intelligent wearable devices for rural older adults and ranking several evaluation solutions based on their proximity to the idealized objects. Each demand in this work serves as an evaluation solution, and SI and DSI are evaluation indices for each scheme. As a consequence, comparing the relative benefits and drawbacks of existing programs and the assessment findings can more precisely depict the gap between the evaluation objects. Following that, the programs are ranked based on the size of the cumulative evaluation value. And in this paper, the weights of the two indices are set to be equal or 0.5 for each. The following are the steps in the TOPSIS approach for making decisions on functional satisfaction.

Step 1, construct the evaluation matrix of users' satisfaction with each function.

$$Z_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}_{n\times m} .$$

In the above matrix, n is the number of functions of intelligent wearable products, $n = 25$; m is the number of evaluation indicators, $m = 2$.

In step 2, the functional satisfaction evaluation matrix is weighted and normalized to form a weighted normalized decision matrix, i.e.

$$Z_{ij} = \omega_j X_{ij} \bigg/ \sqrt{\sum_{i=1}^{n} X_{ij}{}^2} . \tag{3}$$

In Eq. (3), ω_j is the weight of the evaluation index, each is 0.5.

Step 3, calculate the weighted normalized evaluation matrix's positive and negative ideal solutions.

$$Z_j{}^+ = \max(z_{ij})_{i=1}^n \tag{4}$$

$$Z_j{}^- = \min(z_{ij})_{i=1}^n . \tag{5}$$

Step 4, calculates the Euclid distance of positive and negative ideal solutions.

$$D_i^+ = \sqrt{\sum_{i=1}^{n}(z_{ij} - z_j^+)^2}, \quad j = 1, 2 \tag{6}$$

Table 6
Categorization of functional demand attributes of intelligent wearable products and their satisfaction coefficients

Code	Functional requirements	M	O	A	I	Results	SI	DSI
MS1	Call family doctor	67	38	25	12	M	0.444	−0.739
MS2	Review reminder	66	45	26	6	M	0.497	−0.776
MS3	Blood glucose testing	32	55	19	15	O	0.612	−0.719
MS4	Sleep monitoring	66	35	31	12	M	0.458	−0.701
MS5	120 call	24	49	32	6	O	0.730	−0.658
MS6	Heartbeat pulse monitoring	67	55	34	16	O	0.685	−0.615
MS7	Medication reminder	29	41	56	3	A	0.752	−0.543
MS8	Blood pressure testing	21	59	31	18	O	0.698	−0.620
MS9	Two QR codes and one nucleic acid result	47	32	19	9	M	0.477	−0.738
TC1	Video voice call	67	47	29	17	M	0.475	−0.713
TC2	Positioning system	20	48	28	11	O	0.710	−0.636
TC3	Monitoring system	59	34	22	11	M	0.444	−0.738
TM1	Anti-fraud system	69	41	29	14	M	0.458	−0.719
TM2	Payment function	55	32	24	5	M	0.483	−0.750
TM3	Large spending limit	21	35	49	8	A	0.743	−0.496
ET1	News radio broadcast	23	29	15	32	I	0.444	−0.525
ET2	Call emergency contacts	22	49	32	6	O	0.743	−0.651
ET3	Opera music playback	58	29	31	17	M	0.444	−0.644
ET4	Dating system	26	37	48	6	A	0.726	−0.538
ET5	Robot chat system	15	21	35	39	I	0.509	−0.327
SH1	Real-time pedometer	32	34	48	9	A	0.667	−0.537
SH2	Exercise reminder	67	38	25	12	M	0.444	−0.739
SH3	Energy consumption	18	27	39	12	A	0.688	−0.469
SH4	Action track	61	44	28	13	M	0.493	0.719
SH5	Weather forecast	12	28	33	47	I	0.508	0.333

$$D_i^- = \sqrt{\sum_{i=1}^{n}(z_{ij} - z_j^-)^2}, \quad j = 1, 2. \tag{7}$$

Step 5, calculates the relative closeness of each function.

$$L_i = \frac{D_i^-}{D_i^- + D_i^+} \quad 0 \le L_i \le 1, i = 1, 2, \ldots, 25. \tag{8}$$

According to Eqs (3)–(5), the normalized user demand satisfaction matrix and its positive and negative ideal solutions are obtained, and the results are shown in Table 7.

The Euclid distance and the relative closeness Vi values of positive and negative ideal solutions for each user demand satisfied were calculated using Eqs (6)–(8). Based on the normalized user satisfaction decision matrix and positive and negative ideal solutions, the results are shown in Table 8.

Based on the relative proximity of user satisfaction as calculated by the TOPSIS method. each function demand is prioritized in the following order: MS5 >ET2 >TC2 >MS3 >MS8 >MS6 >MS1 >MS2 >MS7 >ET4 >TM2 >SH4 >MS9 >TM3 >TC1 >SH2 >TC3 >TM1 >SH1 >MS4 >SH3 >ET3 >ET1 >SH5 >ET5.

Table 7
Weighted normalization matrix of user demand satisfaction and its positive and negative ideal solutions

Code	Functional requirements	Normalized satisfaction matrix	
		SI	DSI
MS1	Call family doctor	0.087835	0.126841
MS2	Review reminder	0.087221	0.123832
MS3	Blood glucose testing	0.107435	0.114705
MS4	Sleep monitoring	0.080516	0.111894
MS5	120 call	0.128192	0.104917
MS6	Heartbeat pulse monitoring	0.120267	0.098173
MS7	Medication reminder	0.132093	0.086568
MS8	Blood pressure testing	0.122561	0.098934
MS9	Two QR codes and one nucleic acid result	0.083731	0.117785
TC1	Video voice call	0.083444	0.113666
TC2	Positioning system	0.124775	0.101385
TC3	Monitoring system	0.078076	0.11775
TM1	Anti-fraud system	0.080372	0.114696
TM2	Payment function	0.084807	0.119649
TM3	Large spending limit	0.130587	0.07906
ET1	News radio broadcast	0.078076	0.083794
ET2	Call emergency contacts	0.130544	0.103915
ET3	Opera music playback	0.078076	0.102809
ET4	Dating system	0.127624	0.085902
ET5	Robot chat system	0.089432	0.05221
SH1	Real-time pedometer	0.117114	0.085602
SH2	Exercise reminder	0.077938	0.117964
SH3	Energy consumption	0.120774	0.07478
SH4	Action track	0.086632	0.114732
SH5	Weather forecast	0.089299	0.053177
Positive ideal solution		0.132093	0.126841
Negative ideal solution		0.077938	0.05221

6. PC and mobile-based product prototype testing for smart wearable device information system

With the aid of the prototyping software "AXURE", we quickly created a dynamic product interaction prototype for the PC and mobile-based of the smart wearable device information system to verify the scientific nature of the satisfaction weighting of user requirements [37,38]. As shown in Figs 2, 3, the product prototype resembles a finished item. It dynamically links the entire system's interaction, usage process, and specific contents to create a complete set of production process systems.

The system's interface prototypes may interact dynamically according to the operation flow, giving users a realistic operating experience without requiring numerous scripting. For example, the main functional data display interface on the computer-based and the heart rate data page on the mobile-based—heart rate detail page—triggered the 120 emergency calls page after a sudden abnormality in the data. As shown in Figs 2, 3, and other processes, these prototypes provide a clear, logical relationship for the system development, ensuring the product's usability. After generating the system prototype, we shared the prototype through the AXURE software to retrieve the link and QR code, which was sent to those who had previously participated in the research, including village officials, village doctors, children of

Table 8
Relative proximity of user needs

Code	Functional requirements	D^+	D^-	V_i	Weighting
MS1	Call family doctor	0.044258	0.075284	0.629769	7
MS2	Review reminder	0.044973	0.072221	0.616251	8
MS3	Blood glucose testing	0.027483	0.069106	0.715461	4
MS4	Sleep monitoring	0.053700	0.059739	0.526619	20
MS5	120 call	0.022268	0.072825	0.765829	1
MS6	Heartbeat pulse monitoring	0.031011	0.062484	0.668314	6
MS7	Medication reminder	0.040273	0.064134	0.614269	9
MS8	Blood pressure testing	0.029490	0.064609	0.686609	5
MS9	Two QR codes and one nucleic acid result	0.049203	0.065830	0.572270	13
TC1	Video voice call	0.050402	0.061702	0.550399	15
TC2	Positioning system	0.026487	0.067910	0.719408	3
TC3	Monitoring system	0.054777	0.065539	0.544724	17
TM1	Anti-fraud system	0.053128	0.062533	0.540658	18
TM2	Payment function	0.047831	0.067787	0.586304	11
TM3	Large spending limit	0.047805	0.059100	0.552829	14
ET1	News radio broadcast	0.069072	0.031584	0.313785	23
ET2	Call emergency contacts	0.022978	0.073761	0.762476	2
ET3	Opera music playback	0.059122	0.050599	0.461161	22
ET4	Dating system	0.041182	0.060031	0.593115	10
ET5	Robot chat system	0.085963	0.011494	0.117938	25
SH1	Real-time pedometer	0.043875	0.051476	0.539857	19
SH2	Exercise reminder	0.054878	0.065753	0.545077	16
SH3	Energy consumption	0.053277	0.048418	0.476109	21
SH4	Action track	0.047046	0.063123	0.572963	12
SH5	Weather forecast	0.085192	0.011402	0.118040	24

older people, and older adults with smartphones, who clicked on the link or scanned the QR code on their cell phones to access the system. Researchers gave testers test accounts, performed simulations using the test data to provide users real-world access to the product, and clicked the “Like” button for each favorite demand. Following the completion of the test, monitor the number of “Like” for each user’s demand by the prototype’s back-end and rate the satisfaction level of all user requests. The more increased the “Like” number, the higher the user’s contentment with the demand.

Combined with Fig. 4, by the amount of user “Like” for each demand, we can see that the most important functions with the demand are concentrated in emergency assistance for rural older adults. Such as 120 call (MS5), Call Emergency Contacts (ET2), Positioning System (TC2), Blood Pressure Testing (MS8), Heartbeat Pulse Monitoring (MS6), etc. These functions can effectively reduce the health risks of older adults in critical emergencies, and improving these functions is therefore significant. As a result, improving the usability and quality of the aforementioned top-ranked functionalities is a significant issue for smart wearable product developers. On the contrary, non-emergency life care tasks, such as Weather Forecast (SH5), News Radio Broadcast (ET1), Opera Music Playback (ET3), Energy Consumption (SH3), Sleep Monitoring (MS4), Real-time Pedometer (SH1) and so on, are substantially less relevant to users’ demands. Although these duties contribute to the health monitoring of older people, they are not extraordinarily vital and are essentially auxiliary support functions. Even the absence of these

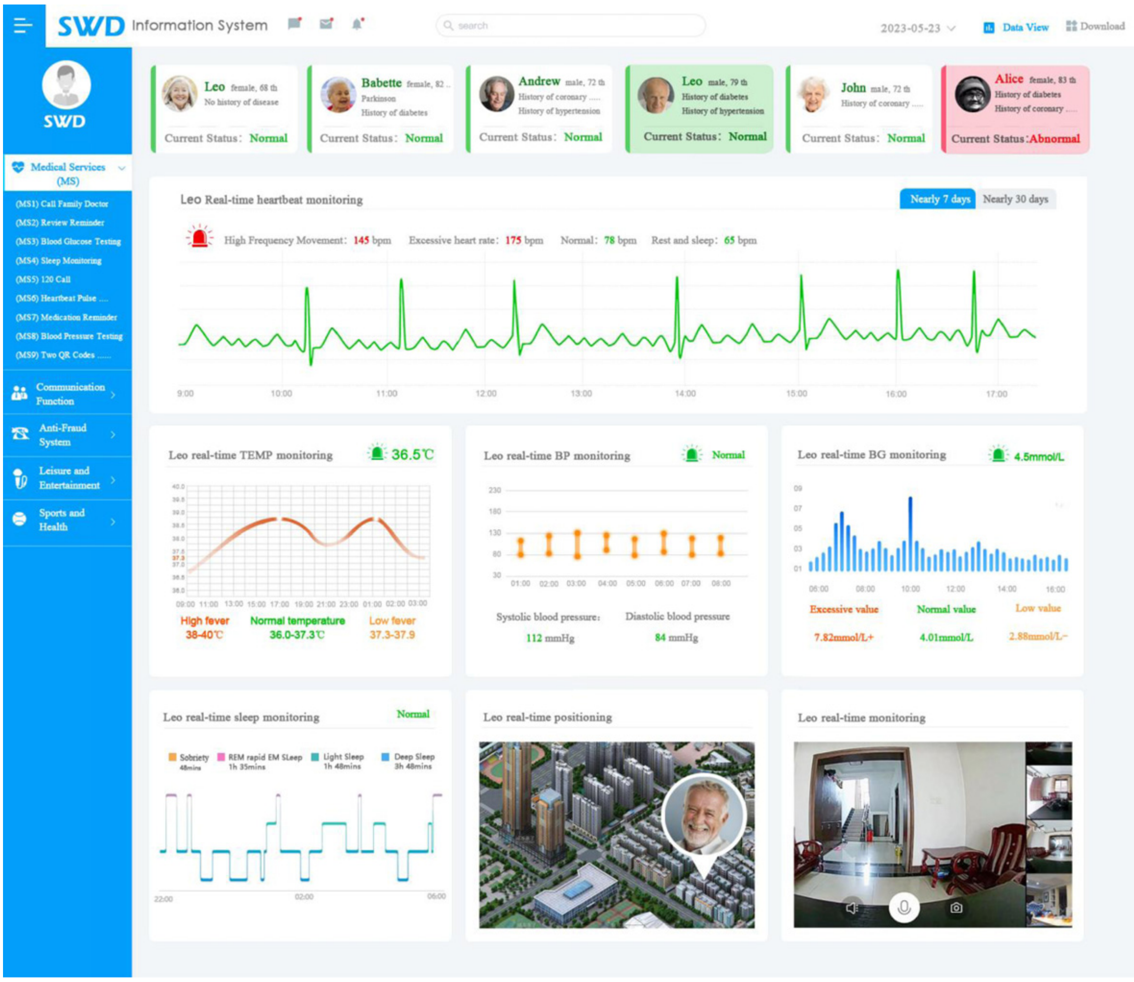

Fig. 2. Screenshot of the PC-based display interface of the information system prototype of intelligent wearable devices for rural older adults.

functions does not cause severe discomfort to older adults in some circumstances. Therefore, improving these functions does not significantly impact the enhancement of user satisfaction with smart wearable devices in general.

7. Conclusion

This paper constructed a service system for elderly-friendly smart wearable products by dividing the functional types into five major categories, comprising twenty-five functional requirements. On this basis, the Kano model analyzes the demand levels of this product's functional services to theoretically dig deeper into the demand centers of rural elderly groups. To use the TOPSIS method to calculate the relative closeness of user satisfaction and the priority weighting of functional demands to uncover the core demands and hidden needs of older people in rural areas for age-friendly smart wearable products

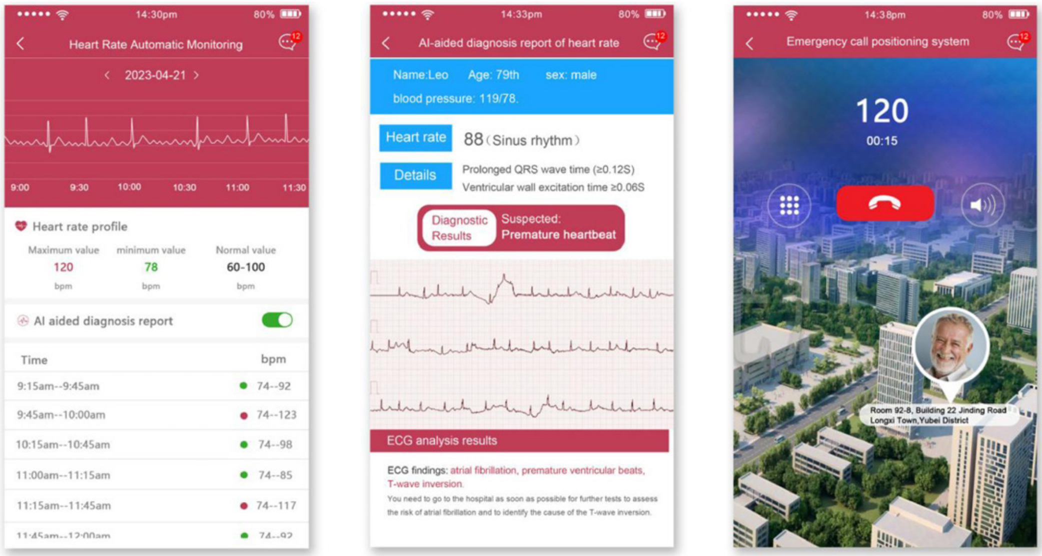

Fig. 3. Partial screenshot of the mobile-based interface of the information system prototype for smart wearable products for older adults.

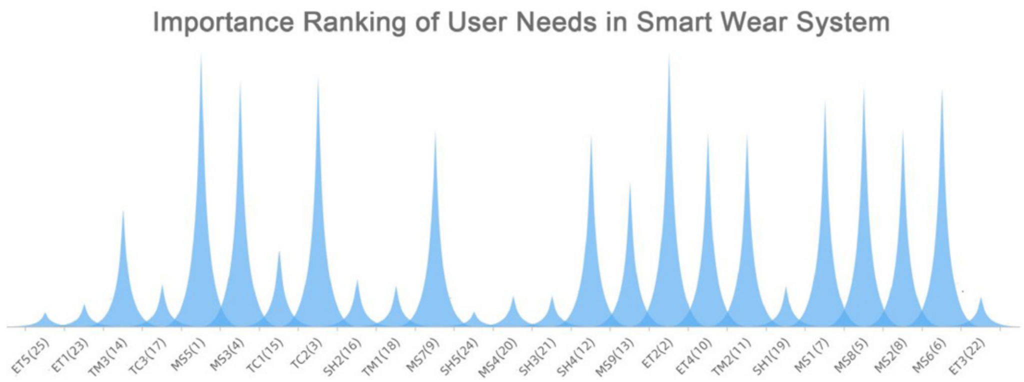

Fig. 4. Screenshot of user demand "Like" data of the information system's prototype for smart wearable products for rural elderly.

to promote the more profound development of these products. This study can give critical information for planning, developing, or optimizing the demand services of age-appropriate smart wearable products by addressing the diverse needs of the aged population for intelligent wearable devices. The paper's disadvantage is that: while the research group is primarily rural older adults, the specific situations of rural older adults are not subdivided, such as rural elderly left behind, elderly depending on their children, entirely self-care elderly, crippled elderly, etc. The demands of older people are different in different contexts. Therefore, to deepen the refinement of the user group in this work and the follow-up study, we may build a research questionnaire based on the focus on the needs of different groups.

Furthermore, while this paper addresses the classification of functional categories, it does not pay specific attention to disparities in demand for age-appropriate smart wearable products by gender. As a result, the follow-up study should further refine the distinct demand groups of the rural older people, achieve product function differentiation and customization, and always pay attention to the breakthrough of new age-appropriate technology and the dynamic changes in the new demand of the rural older people.

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