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Nurture: A System for Monitor the Movement of the Elderly and Detect Falls

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Abstract. Research has found that by the end of 2022, China will have the world's largest population of people over 65 years of age, and has entered a deeply aging society. The lifestyle of elderly users has changed, and their demand for products has shifted from simple practical needs to complex emotional needs. Issues such as how to deal with accidental falls and how to deal with emergencies when the elderly are alone at home have attracted extensive attention from researchers. This paper introduces Nurture, a fall detection system for the elderly based on RF sensorless detection technology. through the point cloud imaging technology, after detecting the fall of the elderly, the real-time monitoring sends out an alarm and contacts the emergency contact person or relevant service personnel. During daily use, it analyzes the user's activity track such as bedtime and the number of times he/she gets up during the night, and provides appropriate care knowledge on the APP. The self-contained voice call system is more helpful for real-time communication between empty-nesters and caregivers. We have collected the common problems faced in the design of the detection system, such as the accuracy of detection, timeliness of reminders, and practicality of information pushing, in order to develop a product that is convenient for the elderly to use.

Keywords. The depth of the aging society, Fall detection system, Elderly people living alone.

1. Introduction

In this study, our aim was to understand the work of various researchers in the field. For instance, Apple has been actively engaged in developing health detection products. Notably, in 2014, Huang developed a ZigBee-based system that can remotely detect falls, locate the person's location and subsequently notify concerned personnel for immediate assistance, upon confirmation. The Apple Watch features a fall detection function designed specifically for elderly users. Using multiple sensor modules, it collects information about the user's movements and analyses acceleration and movement trajectory to determine whether a fall has occurred. When a fall is detected, the device continues to vibrate to detect unconsciousness, and if there is no response within a certain period of time, it will automatically dial emergency contact

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information. Technical term abbreviations are explained upon first use. The text is grammatically correct, free from stylistic errors and adheres to a formal tone. In addition to Philips' alarm device, which requires the user to be conscious after a fall, this study categorizes fall alarms as automatic or autonomous, and incorporates voice recognition and data analysis to provide the user with relevant care information through an app. Researchers' experiences inform this work.

To develop Nurture, an iterative and innovative design process was employed, consisting of three steps:[1] The first step involved reviewing a large amount of relevant data in consultation with experts to identify the challenges this design would present, with a particular focus on accurately detecting activity in older adults and ensuring timely alerts. The second step is outlined below.[2] After conducting step 1, we established the design concept and product prototype to enhance the product's aesthetic appeal in terms of form and installation convenience.[3] Subsequently, we executed preliminary research and conducted visits to gather primary data and insights. It was demonstrated that both empty nesters and their careers were willing to incorporate Nurture into their daily routines. But there are also challenges: Regarding application functionality: The Nurture system's software should offer a range of functions, including social media interaction, entertainment media, geo-location services and health tracking. The challenge is to design an easy-to-understand and user-friendly application interface. Reliability and Accuracy: The Nurture system needs to detect falls of the elderly through RF imaging radar technology and obtain information about the location and movement of objects in the environment, how to ensure the accuracy and reliability of the system is a challenge. User acceptance: The success of the Nurture system also needs to take into account user acceptance, such as the attitude of the elderly towards using the technology, their experience of using the system, and their feedback on the system, all of which will affect the actual application of the system. Therefore, in order to successfully promote and apply the Nurture system, these challenges need to be overcome and the design and functionality of the system need to be continuously improved and optimized.

In this paper, solutions to the above problems are given: A sensor-based unimageable monitoring product and an application are designed to protect the user's privacy. A voice recognition system is added to allow the elderly to independently choose whether they need immediate assistance after a fall. The product samples and encodes the voice, and uses a network transmission medium to send the audio data to a remote location for a real-time conversation with the caregiver. Nurture detects the user's movement trajectory and body morphology through point-cloud imaging technology, records the bedtime, sleep duration, and nighttime rise time, and analyses the quality of the user's sleep, so as to provide users with appropriate care learning materials through big data analysis and the formation of proprietary data. Provide corresponding nursing learning materials to be viewed on the app.

2. Related work

2.1. Alarm devices

Prior work has confirmed that elderly behavioral recognition fall detection tools can be effective in improving the effectiveness of empty nesters in dealing with emergencies they face and avoiding serious consequences as much as possible. Due to this

importance, a number of elderly fall alert device approaches have been proposed. For example, user-autonomously activated alarm devices. Philips personal emergency alarm system of watch type button, is a portable watch system. However, the limitations are large and many elderly people are incapacitated after a fall, which prevents them from autonomously activating the alarm device. visual monitoring devices. Addie university human visual monitoring equipment, this kind of equipment is generally in the elderly often activities of indoor places to install the camera to monitor the behavior of the elderly, and geographical and personnel limitations, need to pay attention to the state of the elderly in real time. Wearable elderly fall automatic detection and alarm equipment. Inspired by this, this paper explores the rationality as well as the effectiveness of the alarm device to ensure that the elderly population is provided with a more appropriate means of assistance.

2.2. Detection system

After reviewing, analyzing, and summarizing the researches of domestic and foreign researchers on motion recognition for the elderly, it can be found that the current detection system devices have become more and more mature. For example, a video-based fall monitoring system spreads table images of human activities by fixing and installing video sensors in the area of human activities, and analyzes the captured images to determine whether a fall has occurred. However, the privacy of the user is a major security risk. Ambient fall monitoring system, which detects falls by placing non-video wireless sensors such as by sound, infrared, pressure, Doppler radar, etc. in the active area, mainly captures information such as human movement as well as posture. This is because the human body always has to be within the detection range of the sensor, thus greatly limiting the range of human activity. Wearable fall detection systems, which utilize clothing, cell phones, watches, etc. as carriers, implant sensor-based detection hardware into them to measure the limb movement or related physiological parameters of the human body. Based on the previous work, this paper further explores the detection system technology to provide a detection system that protects the user's privacy and has more accurate detectability.

2.3. Applications

Currently, most of the research efforts are directed at how to deal with older adults in the moment of a fall, while neglecting the subsequent preventive efforts of care. For example, the Apple Watch's fall monitoring function is limited to contacting emergency services. Fallcall Lite: an iOS app designed for older adults that detects falls and automatically sends out an emergency help alert. On top of the existing functions, this design adds various kinds of related care knowledge information to the app, which serves as prevention as well as summarizing the learning afterwards.

3. Design process

3.1. Design discussions with experts

In this work, preliminary research was conducted with three experts with relevant research experience and education in the area of mental health and sensor use in several studies of older adults. Each design discussion session lasted about 60 minutes and consisted of the following steps: presentation of their initial ideas, sharing of experiences by the experts, discussion with the experts, and comments on the work. They all agreed on the starting point of the design "to take into account the psychological factors of empty nesters and post-accident learning and prevention." The following suggestions were made: P1 suggested that when using the app to learn about caregiving, the information should be tailored to the different age groups of the elderly; P2 and P1 suggested that multiple trials should be conducted to improve the accuracy of the detection; P3 suggested that the alarm device is a critical step and needs to be designed with a strong focus.

3.2. Design Objectives

Based on the design discussion meetings with experts and related preliminary work, the following key objectives were synthesized: Reduce to a great extent the injuries of the elderly after a fall, and therefore put more effort into the design of the information push. Improve voice call settings so that empty nesters feel less lonely. Autonomous selection of alarm settings to reduce the sense of uselessness of the elderly, fear of becoming worthless and a burden. Therefore, they can choose whether to activate the alarm device within a certain period of time according to their own conditions.

4. Description of the system

Based on design exploration with experts, a prototype Nurture was developed, consisting of hardware and software. The hardware uses radio frequency imaging radar technology to detect if an elderly person has fallen, and radio waves to obtain information about the position and movement of objects in the environment. A two-way audio communication feature was added, based on the capture, transmission and reproduction of sound signals, enabling two-way communication between the sender and the receiver. Equipped with speech recognition technology and natural language processing, the sound is converted into digital audio signals, which are then converted into text enabling the system to read the user's commands. In software, the monitoring data provided by the hardware, real-time collection of activity data in the room, analysis of the user's action trajectory to determine the general physical condition, such as: bedtime, sleep duration, statistics on the number of trips to the bathroom of high frequency or time changes indicate possible problems. And according to the user's age group, physical condition timely pushes the appropriate teaching materials, and real-time feedback. Both software and hardware are connected via Wi-Fi.

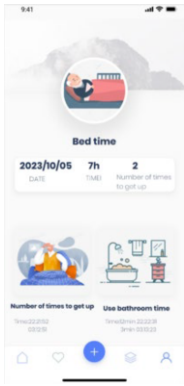


Figure 1. Record the trajectory of the action.

4.1. Applications

Nurture is a round shaped device that mounts on the wall, connects to WiFi for use, and works with an app.The elderly user logs into the app, enters personal information: age, gender, height, weight, past medical history, current address, contact information, and binds three emergency contacts(Figure2).When detecting the elderly fall, you can choose whether you need help according to your own feelings, which can be operated through the APP or voice intercom. If there is no any autonomous operation for one minute, the emergency contact will be contacted according to the emergency contact's entry, from the first to the third in order until someone responds, and if there is no operation of the emergency contact within two minutes, it will automatically dial the phone number of help and contact the relevant rescuers Afterwards, the app is used to input the cause of this fall, physical sensations, and examination results, and Nurture analyzes and summarizes the collected data, and relies on big data technology to make personalized pushes, including prevention guides, emergency measures, and other information.

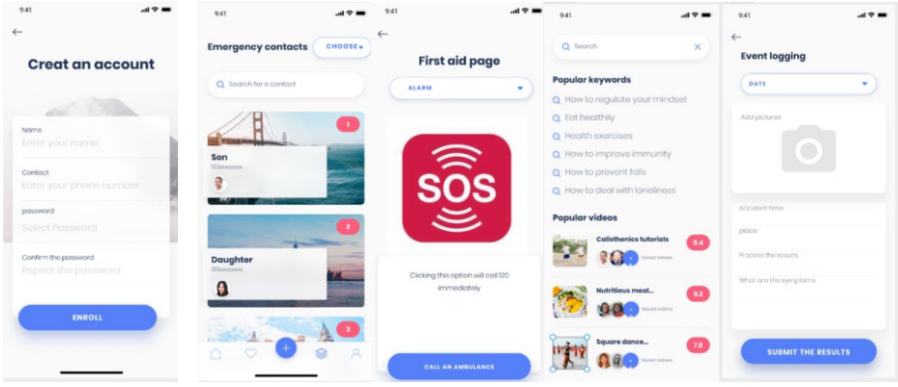


Figure 2. Application page

4.2. Product Information

As a product inspection system, Nurture uses RF Imaging Radar, a radar system that uses radio frequency signals for imaging and, unlike traditional radar, focuses on creating a high-resolution image of an object rather than just detecting its presence and distance. Images of the target object are created by sending RF signals and receiving signals reflected back, which are processed to obtain the location, shape, size and other characteristics of the target. RF imaging radars have higher resolution and can more accurately capture the details of a target object while providing real-time imaging.

A technique for acquiring, processing and rendering the surface of a three-dimensional object through point cloud imaging. It creates a 3D point cloud model by measuring the coordinates of a series of points on the surface of an object. These points provide an accurate representation of the shape of the object in 3D space. The steps are as follows: Data Acquisition: By using LIDAR, structured light, stereo vision, or other sensors, point cloud data is collected from the surface of the target object. LIDAR is commonly used for long-range or high-precision data acquisition, while structured light and stereo vision are commonly used for close-range applications.

Point cloud generation: A point cloud representing the surface of the object is generated from the collected data. Each point has 3D coordinate information and possibly color information.

Point Cloud Processing: Processing the point cloud, including removing noise, aligning point cloud data from different viewpoints, merging multiple scans, and so on. This step aims to obtain a more accurate and complete 3D model.

Surface Reconstruction: Converting the point cloud data into a continuous surface model. This can be achieved by different algorithms such as triangular mesh generation or voxel meshing.

Therefore Nurture is not a camera, does not become an image, and does not violate privacy rights. It also has a 120° field of view angle, maximum coverage of 16 m^2, and one machine for a single room. It is a non-contact non-sensory detection, no need to wear any equipment. Compact size, supports wall and ceiling mounting, 7x24 hours continuous monitoring. Uses 2.4GHz WiFi connection.

Products using RF imaging radars are relatively unaffected by water vapour and light as they operate in the Radio Frequency (RF) bands, typically in the millimeter or centimeter wave range. These frequency bands have better penetration capabilities relative to visible and infrared light, and are therefore less sensitive to the scattering effect

As the alarm device of the product, the action of the elderly person detected by the detection system, whether it is a quick fall, a slow fall, a fall from the bed, or a fall in different postures, such as on the side, on the stomach, on the back, etc., will form a corresponding electrical signal, which will be transmitted to the control unit of the alarm system, and then the signal will be processed and analyzed, and an alarm sound will be emitted and an emergency notice will be sent out. The process of the alarm system is as follows: operate independently within one minute, choose to need assistance or not; if no operation immediately contacts the emergency contact, if there

is no response on the APP within two minutes, the alarm system will be automatically activated to contact the relevant rescuers to take action.

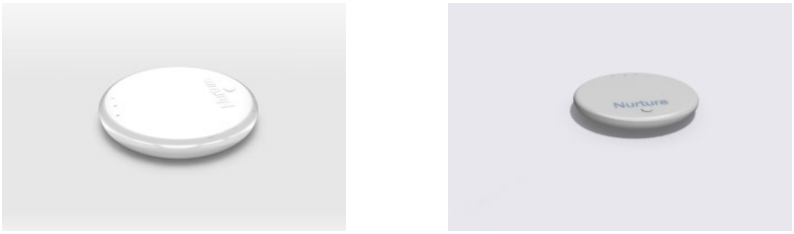


Figure 3. Product appearance.

Figure 4. Monitoring modalities.

5. Interaction and Principle

Based on the design probes, the interaction modes of voice interaction and graphical user interface are selected to be used on the product.

5.1 Voice Interaction

Nurture uses a voice interaction mode in which the user communicates with and controls applications and devices by voice.

Speech recognition technology is used to convert the user's verbal commands into text or device-understandable commands, and speech synthesis technology is used to convert the computer's or device's response into a voice response. Usage scenarios are as follows: when an elderly person falls, if it is just an unintentional stumble that does not require assistance, and when it is not possible to use the APP to operate it, then it is possible to send out voice commands that do not require an alarm to convey to Nurture. At leisure, two-way communication is also available, with real-time calls between the three bound emergency contacts and the elderly user, which can keep a real-time eye on the health and safety of the elderly, give the empty-nesters certain psychological support and relieve loneliness, and at the same time, can keep abreast of the needs and

problems of the elderly and intervene in a timely manner, which can prevent the problem from worsening and provide the necessary support and help.

5.2 Graphical User Interface (GUI) Interaction Mode

The GUI is cross-platform, allowing the development of cross-platform graphical applications, so Nurture comes with an app. The GUI is intuitive and the user can easily understand the use of the app.The application has features such as: social media interaction, allowing the creation of profiles, posting of statuses, interaction with family and friends. Entertainment and media features, including e-book reading and video playback. Geo-location features that provide location-related services using GPS or WiFi data. Health tracking features. Messaging and communication features, including text messaging, voice messaging, image and video messaging, and instant messaging applications.

6. Initial user studies

In order to identify how older users interact with Nurture and their perceptions of Nurture, a user study was conducted in this work. Four older users A (age 55,gender:male), B (age 62,gender:female), C (age 71, gender: male) and D (age 51,gender:female) were recruited from the local community. All used Nurture for one week and made satisfaction scores.

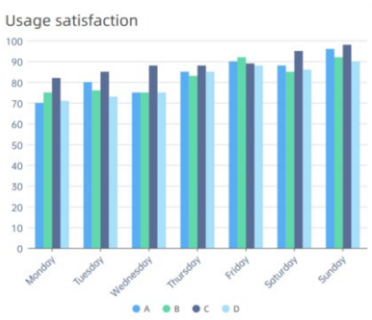
6.1. Procedure

The experiment was carried out in a nursing home. First, participants were recruited to record their age, gender and physical condition, and four participants were recruited and instructed on how to use the product and the application. The participants then used the product for one week. During this week the participants were observed and asked about their views on Nurture and a semi-structured interview (SI) was conducted. The following themes were focused on:[1] How they felt about using Nurture, including whether they were used to it and whether the product was easy to use. [2] Participants' usage habits and preferences, and the influence of the relevant environment on their experience of using Nurture. [3] To gather opinions and feedback on Nurture, including strengths and weaknesses and suggestions for improvement.[4] Expectations for Nurture, including participants' needs for product features, design and experience.

6.2. Results

When asked how participants felt about using Nurture, A said, "Once I tripped and fell on the ground and couldn't get up, Nurture sent out an alarm, and my son rushed home to deal with it after receiving it, avoiding serious consequences." B said, "I usually encounter problems in the nursing home can only call for help through the bell at the bedside, and I can't press the button when I go to the bathroom for inconvenience, but after using Nurture, I can detect inconvenience in the bathroom, balcony, and other spaces, which is so convenient says: "The accompanying software for Nurture has been very useful, detecting that I was getting up too often and pushing a lot of information to

me on the subject, and my daughter gave me a check-up after seeing my weekly health report." D added: "It allows us to share what we are doing and learn about our health with our partners in real time so that we know how the other person is doing even if we are far apart." In conclusion, all participants were willing to use Nurture, and the results of this study suggest that Nurture is a safety precaution for seniors living alone. （Figure5-8）.



Figur5. Satisfaction surveys.

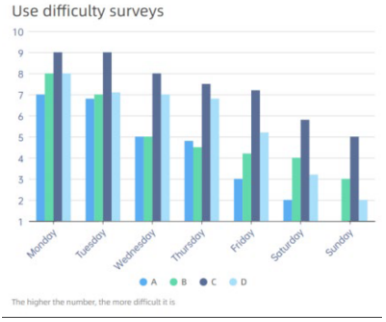


Figure6. Use difficulty surveys.

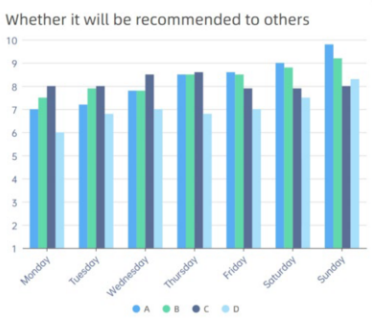


Figure7. Whether this product will be recommended.

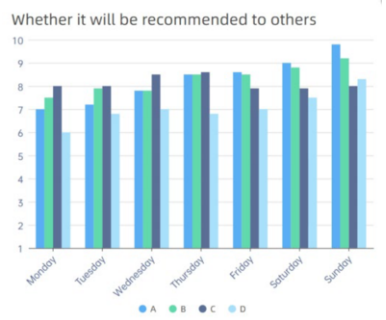


Figure8. Caregivers use satisfaction surveys.

7. Limitations and future work

Certain limitations were found in this design. Firstly, the coverage area of the detection system is not wide enough, and multiple Nurture installations are required for larger indoor spaces; secondly, the usage is limited to specific applications, such as elderly monitoring, fall detection, etc., and not applicable to other medical detection needs. Finally, it is not a clinical diagnostic tool and cannot replace the diagnosis of doctors, but is mainly used for monitoring and providing alarms.

In the future, I will further improve the system functionality and expand the monitoring area and access to Nurture. Covering a wider range of millimeter-wave frequencies using a 4D radio frequency imaging chip (RoC) wherever possible. At the same time, the interface of the application will be more simplified as much as possible, taking into account the elderly and people with special needs. Finally, attempts will also be made to recruit more users.

8. Conclusion

In this paper, Nurture, a product that monitors the behavioral trajectory of elderly people and detects falls, and the accompanying app were introduced. Many empty nesters suffer from mental emptiness, emotional loneliness, and poor environmental safety due to lack of companionship. Nurture can help empty nesters to get timely assistance in case of emergencies, as well as the caregiver can receive the specific physical condition of the person being cared for in time and take appropriate measures. Nurture can provide both mental and behavioral help and care. In addition, we hope that Nurture can play a more positive role.

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