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A Data Driven Assistive Monitoring Framework of Elderly Care Based on Australian Nursing Home Foundation

Aoyang Zhang

Smartcare Australia Pty Ltd, N.S.W. 2000, Australia;

Australian Nursing Home Foundation, N.S.W. 2134, Australia.

info@thewain.com.au

Abstract

Facing the gradual ageing society, elderly people living independently are in need of serious attention. In order to assist them to live in a safer environment, more and more innovation framework in the medical domains have attracted industry and academia across the globe. One of the most cutting edge application in wisdom pension and care is the combination of wearable devices and one health data analysis, which offers efficient and reliabile real-time health monitoring facilities. Thus, in this paper we highlight the advantage of this technology that exist for assistive monitoring, initiative caring and human anomalous behavior detection. We observe that, the caregivers can monitor the physiological signals and abnormal events in a long time and find out potential risk of seniors. This proposed model also can be used as a mean to engage both of the caregivers and older adults to the community, making them become more active, improve their mental well-being and subsequently reduce the cost of health services to the society.

Keywords

Wearable Device, Initiative Caring, Assistive Monitoring, Anomalous Behavior Detection.

1. Introduction

Advances in the medical field are improving the quality and increasing the longevity of life. As a result, the percentage of elderly people in the overall population is increasing significantly. It is predicted that the number of elderly population (age > 65) will be greater than the number of younger population (age < 5) by 2020 and will double by 2050 [1]. In 2017, there were 3.8 million Australians aged 65 and over (comprising 15% of the total population) —increasing from 319,000 (5%) in 1927 and 1.3 million (9%) in 1977. The number and proportion of older Australians is expected to continue to grow. By 2057, it is projected there will be 8.8 million older people in Australia (22% of the population); by 2097, 12.8 million people (25%) will be aged 65 and over [2].

People face many challenges as they age such as cognitive impairment, memory loss, chronic illness, vision and hearing constraints and many other diseases. The 2020 Dementia Australia Prevalence Data reveals that there is currently an estimated 459,000 people living with all forms of dementia. Without a major medical breakthrough this figure is projected to increase to 1,076,000 people by 2058 [3]. Similarly, chronic diseases are very common in Australia. Around 50% of the elderly Australian population are suffering from at least one chronic disease and 25% of the population are suffering from two or more [4]. Thus, the increasing number of elderly people is having a significant impact on health-care systems.

Another important issue with an aging population is the place of living. Elderly people have options such as nursing homes or aged-care institutes, but most of the aging population prefer to live in their own home as they find it comfortable and emotionally attached. However, the independent living of

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elderly people needs serious attention, as in some cases the elderly people are also found dead in their homes [5]. In addition, the shortage of health-care workers further complicates independent living for elderly people. A large number of health-care workers are required to meet the need. Therefore, it is important to bring Innovative technological solutions to meet the challenges of the elderly people to support their independent living.

2. Related Work

2.1 Monitoring System

Initiative health care for elderly people has become an active research field. Some of the major works in the fields are behaviour monitoring [6], [7], fall detection [8], [9], anomalous behaviour detection [10] [11], medication reminders [12] [13], daily tasks of home care [13], [14], cognitive decline monitoring [15], vital signs monitoring [16]. Recently, researches on elderly monitoring have gained a lot of interest. From 2015, there were 1574 articles published in this field, and the number showed an increasing trend. It is foreseeable that smart health care promotes the development of medical care and integration. It is very important and necessary to carry out aged care and services through information technology.

Both of the home-based assisted living and aged-care center, abnormal behavior can refer to deterioration of health or any unsafe situation of the person which would indicate a fall or medical event. Thus, remote monitoring of behaviour and detection can significantly improve the quality and efficiency of aged caring.

2.2 Wearable Product Development

In recent years, the attention to wearable products has been paid increasingly. By reviewing relevant literature and research which analysis lots of wearable products in the market, most versatile feature of wearable products is the ability to be worn, combined with cutting-edge technologies including smart devices such as multimedia, wireless communications, flexible screens, GPS positioning systems, micro-sensing, virtual reality and biometrics. These techniques can be used to collect body-related information anytime and anywhere, achieving the purpose of analysis and feedback. In addition, it has the characteristics of wear ability, strong adaptability and small volume [17].

Wearable devices have been widely used for its functions such as extracting data, transmitting data and processing data. There are many literatures and researches on wearable devices user interaction [18], [19]. Nowadays, the application of wearable devices are mainly applied on health monitoring. Not only for young people, but also community elderly care can open up a new area for wearable products in contrast.

Most of the existing studies for assisted-living are either based on wearable devices [20], [21]. Wearable sensor-based techniques use sensors such as gyroscopes, accelerometers and RFID tags (Radio Frequency Identification) to monitor human activities and detect any anomaly. These sensors are generally placed directly or indirectly on the person and the signals are generated when activities are performed by the user. Although wearable devices are considered effective to meet the challenges of supporting independent living, they have several limitations with respect to practical uses. The use of wearable devices has many challenges such as wearing comfort, privacy concerns and complexity in operation [22].

The recent advances in the field of microelectronics has enabled sensors with unprecedented characteristics. They are now smaller in size, low in cost and have touch screen that add advantage in ubiquitous sensing. Intelligent integration monitoring based solutions are capable to create safer environments, alarm any emergency situations and call emergency services if required.

Healthcare wearable devices range from the popular fitness trackers (e.g., ANHF SmartWatch, AppleWatch, MI Band) to more complicated healthcare wearable devices like smart clothes. Fitness trackers such as Garmin can record the users' exercise tracing, users' steps count and heartbeat. Other wearable devices such as smart clothes can detect users attitude moving, sleeping efficiency and other

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physiological parameters [23]. These devices allow users to continuously monitor body mass index or related parameters and manage their health on a personal basis, or grant specialist access to their information, then give personalized medical advice. However, most wearable devices passively receive data now, users must use the corresponding software or APP to view the collected data report. To those dementia users who cannot use the app conveniently, once the emergency happens, their caregiver cannot grasp the situation immediately. In order to satisfy the appeal, the health care system in this study not only develops passive care system to notify the caregiver, but also add care notification system as proactively system to help the other users to manage their health status.

In this study, we use wearable devices (smart watch) to record users' physiological signs and attitude. The physicians can set a threshold for each user. Once the data values are not in the standard interval, the care notification will inform the caregiver and the users' family which will trace the situation in the setting time. For the users who have chronic but still can self-care, the system will keep in touch with the users by questionnaires and health knowledge regularly.

3. Monitoring Framework

This section discusses the functionalities and considerations regarding the design of monitoring platform. The framework will contain the four main components:

3.1 Wearable Devices.

As elderly people often experience issues with aging related functional impairment such as hearing or vision impairment. Therefore, it is necessary to develop the proper features and critical UI aspects that have an impact on the user experience. To facilitate interaction on the wearable devices, we will incorporate a range of features such as:

I) Communication-data based features. To ensure the safety of elderly in an emergency. Wearer can call three emergency contacts when the button on the pendant is pressed for three seconds. Consecutively (one by one) calls each contact until someone answers. Wearer or responder can cancel the call sequence at any time. In addition, to expand the users' social contact, voice and video calls allow elderly to add their families to the social network and contact them at any time. They can send and receive private messages with each other as well.

II) Location-data based features. Both of the Elderly themselves and their families can view real time location using GPS, in this way, all help calls and notifications contain an exact address on Google Maps. For elderly who are at risk of wandering, the fencing and tracking option allow caregivers to monitor if the wearer strays outside or gets lost.

III) Physiology-data based features. This feature allows elderly to know their physical condition or everyday status such as heart rate, blood pressure, and sleep quality, etc. It helps users observe overall health, which plays a personal medical assistant during the daily life. Meanwhile, the health information can be shared with your families or friends, which attracts more participants in socializing in old age.

3.2 Integrated Monitoring Terminal.

I) Easy to use. According to the original design goals, our target user population is a community pension group, so the community is essential as an important component. Many elderly people or staff in the community are not familiar with technology; therefore, our monitoring framework integrates front-end and back-end together relying on the cloud server, then provide an all-in-one simple terminal – an online website, which can be accessed anywhere and anytime if there is an internet connection, without installing and configuring the application. It can also be viewed and accessed on different devices across many operating systems such as Linux, Windows and MacOS, etc.

II) OA (Office Automation) nursing home. OA is a new type of office which combines the modern office and computer network. The system streamlines the OA page by reducing some unwanted features to reduce the flow of data transmission. The system also has a high-level security to provide

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a reliable guarantee for the safety of the user [24]. By forming the important link between the elderly and nursing home, it has the advantage of rapid response. When the elderly is in a situation or request, they can respond quickly. The functional framework of the community is not only a monitoring display, but also divided into three parts: the elderly member management system, the chat & mail system and the staff member management system. The community needs to be able to manage the elderly in the community, including recording relevant health data and related operations. At the same time, the chat & mail system ensures that member information is received in time and community activity information is sent. The staff management system ensures that the community is able to obtain schedule, task, compliance and performance of each staff.

III) Intelligent aged care. Speeding up the construction of health database and cloud platform for the elderly by means of information technology such as internet, Internet of things, artificial intelligence and big data, developing ealthy old-age data management, intelligent analysis, centralized storage, open sharing, interconnection and integration, and standardized invocation systems, and establishing and improving the connotation construction of intelligent healthy old-age service, so as to provide more convenient, accurate and efficient healthy old-age care services [25].

3.3 Caregiver Operation Application.

I) Relying on mobile terminal. Caregivers could arrange the work with priority, as well as organized. With the real-time and dynamic data uploading, both of the elderly health information and care services feedback can be collected and viewed on the APP, which enhance the information level of the services, and establish a unified "community network". Thus, unified grasp the needs of the elderly at home, accurate service delivery.

II) Care notification system. the platform will detect if an elderly requires assistance, on the one hand, the APP will notify the caregivers when detect abnormal physiological measurement automatically. On the other hand, the elderly can input their vital signs such as pressure, heartbeat or even blood sugar, uric acid by themselves. The notification system can immediately transmit data to the staff through the defined API format. The staff will then decide whether to broadcast alert notification to emergency center. Thus, enables faster service delivery.

III) Online training system. To increase talent introduction and professional team building, the application can provide lots of training material for administrators, medical staff, registered nurse and even professional members of psychologists, from the aspects of adaptation counseling and psychological counseling, we can really understand the elderly, meet their needs and realize intelligent old-age care.

IV) Delivering service: Caregiver who would like to help can send a response and deliver the service. The APP provides a communication channel for users to be approved by the professional organization with qualification. After they have been approved, they can meet offline to deliver the service. The service provider can be either a group or a user from different generations. In fact, anyone who would like to deliver the service can express their interest.

3.4 Elderly Social and Care terminal.

I) Social Media. Research found that for adults over the age of 50, staying in touch with family is the number one reason they use social networking sites [26]. A research study that developed a research model to examine the motivation of older people in adopting social media used three main needs of older adults: health needs, social needs, and dignity needs [27] linked to Maslow's model of the hierarchy of needs. In this case, on the elderly terminal, the application provides instant messaging (IM) function, encouraging the elderly to take participate in the activities so as to make them feel more involved in social community.

II) Requesting service. The elderly who need assistance can create a service request using terminal. The service requests will transmit to either a nursing service department or an independent service provider. After that, they could leave their feedback, usually with a particular score, which is to help

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caregivers find 'the best ways are to ensure customer satisfaction'. Furthermore, collecting the useful and legible data and plan further steps for continuous improvement.

III) Online event calendar and register: This function allows users to create a group of users with similar interest or needs. When they are familiar with each other, they can organize a physical meeting or event to discuss more on their interest. This function will also allow people to host and manage their social competition. By bringing people together, we aim to create an environment where they can get to know new people and interact with them and help reduce social isolation and loneliness.

4. Implementation

4.1 Web Client:

Web client refers to the browser on the user's side that they use to access the platform, the front-end is optimized using Vue.Js - an incrementally adoptable ecosystem that scales between a library and a full-featured framework. Bootstrap also has been imported to ensure the UI components are rendered correctly on different screen size. Therefore, it enhances the accessibility of the platform on mobile devices. Along with Bootstrap, CSS3 and HTML5 will also be sed to provide a modern look to the platform.

4.2 Mobile App:

Mobile App is being developed with native programming language: Java (Android), Objective-C (IOS). This interface allows users to view the information related to their physiological data, social activities and care service network module. It also allows users to view each other profile, send a private message to each other, view and post status update, create interest group, etc. Apart from that, it also uses Google Map API and Google Geocoding Service API to retrieve the location of elderly who need help.

4.3 Cloud Deployment:

The software handles all the operation based on cloud server. It will utilize the rolling deployment technology designing a scalable, efficient, and cost-effective deployment solution throughout the complete application lifecycle. Resource provisioning, configuration management, application deployment, software updates, monitoring, access control, and other concerns are all important factors to consider when designing a deployment solution.

4.4 Database:

Our platform uses SQL as it offers a wide range of security and recovery features. These features are critical to a database in the production environment.

5. Innovation

5.1 Proactive Service

Proactive service adopts wearable devices and care notification system mainly used on the residents who have chronic but can still take care of themselves. By wearing smart watch or update the physiological data, the health care system can record their raw data and transfer the analysis data into health report. Each resident can be set with a standard value according to their own health situation. With the defined API format, the health care system can transmit the abnormal system into care notification system at once. The care notification system will regularly send health knowledge and precautions questionnaires by a person to help the residents to manage their health. However, there are hundreds of attributes received by wearable IoT devices. In this care, data reduction and extraction approach such as principal component analysis (PCA) will play an important role in proactive service.

For instance, if the assistive monitoring framework try to implement a fall detection alert, the acceleration and gravity should be two factors in traditional algorithm. However, the data captured from the IoT devices are very abundant dynamic data, which allows the cloud computing to simulate actual situation rapidly and accurately. Thus, principal component analysis (PCA) fundamentally

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forces on the feature extraction and compression vector dimension, which is just suitable in this application, which can speed up the efficiency and increase the accuracy simultaneously. For N simples set $X = (x^i, \dots, x^N)$ with each simple $x^i \in \mathbb{R}$, the eigenvectors of the scatter matrix of X are found:

$$\Sigma = \frac{1}{N}\sum_{i=1}^{N}\left(x^{(i)} - \bar{x}\right)\left(x^{(i)} - \bar{x}\right)^T \tag{1}$$

where $\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x^{(i)}$ is the sample mean vector. The eigenvectors in columns could form the matrix $U = (u^{(1)}, u^{(2)}, \dots, u^{(p)})$. The reconstructed data is $\hat{x}^{(i)} = u^1 x_{rot1}^i$, where $X_{rot} = U^T \tilde{X}$.

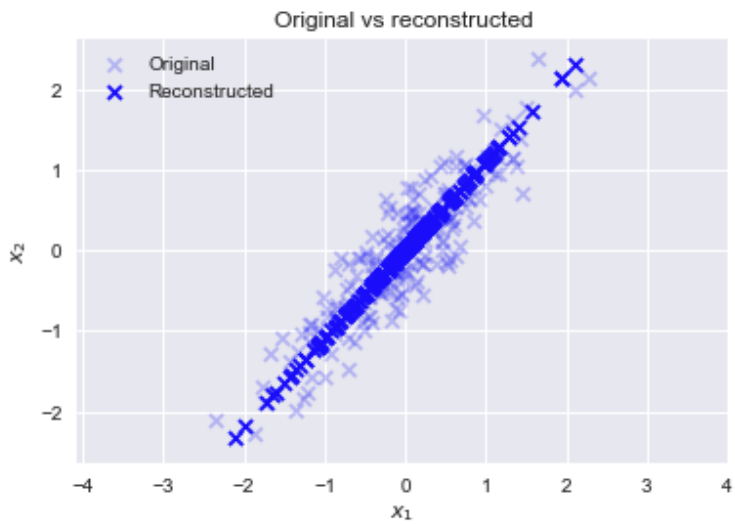

Figure 1. Original and Reconstructed Visualization

As a result, mathematically, the high dimensional data can be projected onto lower dimension such that the variance of the projected data is maximized. Nursing home or induvial caregivers can not only detect the emergency but also reduce fake alert in certain circumstances.

5.2 Emotional Well Being

Emotional well being is a critical part an old person to help them age gracefully and remain independent as well as integrated with society [28]. Similar to the Net Promoter ScoreSM (NPS®), which is a simple but powerful tool to measure client satisfaction, the elderly who has frequently given positive emotion expression feedback is more likely to have a lower risk of depression and frustration, vice versa.

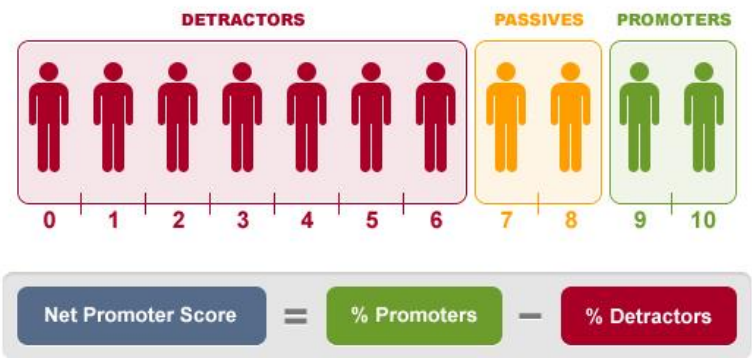

Figure 2. Calculating the Net Promoter Score

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In this case, we adopt Emotion Expression Score (EES) to collect the mood state. The EES is calculated as the difference between the NPS. The EES is expressed as a pictographic option of satisfied level. For instance, if the elderly gave a feedback with satisfied, the EES will be +1. A positive EES (>0) is generally considered as good.

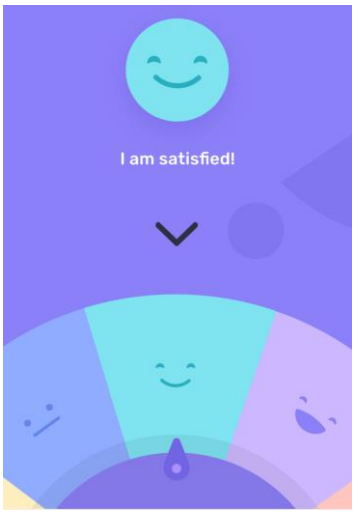

Figure 3. Collecting the Emotion Expression Score

Moreover, based on the EES, caregivers can improve their service in targeted area with regression model. As we all know, regression is one of the most widely used statistical techniques. By setting up the model, we can learn the relationships between several dependent or independent variables. In its classical form, multiple regression assumes that the relationship between the variables is linear,

$$y_a = \beta_0 x_{1a} + \beta_1 x_{2a} + \cdots + \beta_k x_{ka} + \varepsilon_a \tag{2}$$

where $x_{1a}, x_{2a}, \ldots, x_{ka}$ are samples, y_a is the customer satisfaction at time a. $\beta_0, \beta_1, \ldots, \beta_k$ are regression coefficients, ε is the standard distribution error term.

Authors' first embryonic idea for the application in our product is to modelling customer satisfaction with corresponding factors. We can easily calculate the expression if we digitize the feedback, then, using Python or other statistical software such as R or SAS to represent the visualization result such as heat map as follows. The influential factors can be clearly displayed. Through the regression heat map, it can tell which factor has a strong connection with elderly satisfaction, whereas, which factors is not remarkable.

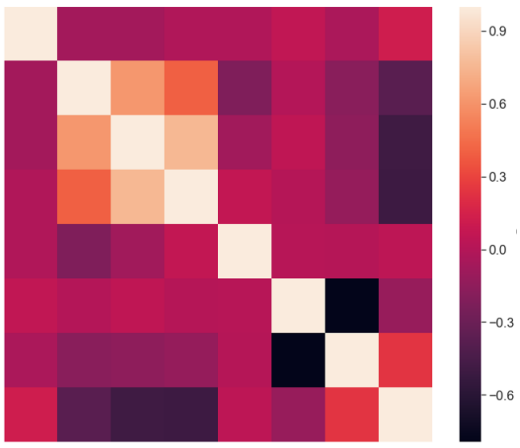

Figure 4. Heatmap of the Covariance Matrix

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6. Discussion and Further Work

Wearable products, as a product of emerging technologies, integrate many advanced technologies, such as sensors, wireless communications and so on [29]. In this paper, we introduce a platform allows wearable devices and integrated monitoring framework collaboratively operate with each other. Furthermore, by taking the design practice of ANHF smart watch and community social media as an example, we discuss how to eliminate the risk of social isolation and allow caregivers to be more productive.

Alternatively, the elderly who received services can also leave a feedback or feelings on the platform. This way, the platform is bridging the gaps (e.g. awkwardness, shyness, etc.) to help caregivers improve their service.

However, there are a few challenges in future development. Firstly, older people tend to suffer from visual impairments, which can make it hard for them to read small characters and different background colors can also prevent them from viewing the contents on a web page. Secondly personal privacy must be concerned. Moreover, another aspect to consider is the limitation in technical experience of elderly people. Some of them may not be familiar with the new concepts and therefore, the platform shall offer a set of clear instructions for the available features.

7. Conclusion

In this paper, we first gave a brief overview tendency of aging population, and then reviewed the development of wearable devices and monitoring platform. Faced with many elderly problems and challenges, we propose an integrated data driven service framework for data transmission between the IoT devices or elderly input and destination nodes in nursing home or caregivers. Moreover, in this study, we combined three terminals: monitoring terminal, caregiver operation terminal and elderly social and care terminal, as a comprehensive solution that does reduce not only its impact on the government but also harvests its contribution to the society.

In the future study, we plan to explore speech recognition, A.I. Driven conversational survey and other critical aspects that contribute to the development of elderly care. The ultimate aim is to develop an assistive platform that attracts and facilitate elderly people's engagement and addresses both their social and service needs.

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