

Smart Home: Improving Quality Living of Elderly

SIRF
2020

Tackling Double Ageing by Double Smart
以雙智慧應對雙老化

SOCIAL INNOVATION REGIONAL FORUM

社會創新區域論壇
2020

Thematic sessions 專題研討



What are the best smart living technologies to be placed at home for the elderly?



Daniel Chun
Vice President (Elect) – Smart City Consortium

MACS, MBCS, M.Res MBA M.Sc B.Sc
daniel.chun@smartcity.org.hk
daniel@airxed.com



*Public advocacy, Education, Civic engagement
Technology leadership & entrepreneurship*

*Sustainable Use of Air Conditioning using IoT
technologies for Energy Saving and Smart Living*





Feature Paper Tackling Double-ageing with Double-smart

K.K. Ling and Karen Lee

K.K. Ling is the former President of HKIP (2007-2009) and former Director of Planning (2012-2016). He is now the Director of Policy Club Design Institute for Social Innovation and Professor of Practice (Planning) of The Hong Kong Polytechnic University...

Karen Lee is the Project Manager II (Special) of the Policy Club Design Institute for Social Innovation of The Hong Kong Polytechnic University. She is a chartered town planner and project manager specialising in urban integration and city management strategies.

Keywords: population ageing, building stock, ageing technology, smart city, smart ageing, double-ageing, double-smart, smart city governance, smart neighbourhood, smart community, planning standard, guideline, HKPSG, age-friendly city, ageing-in-place, urban integration, city management, urban design.

Introduction

Population ageing and building stock ageing are usually tackled as two separate subjects and each has already received much attention. However, the Hong Kong community at large is less aware that the combined impact of population ageing and building ageing, i.e., "double ageing", is a much more complex issue to address...

A strategic policy framework to tackle the complex issue of double-ageing is still lacking. The first objective of this paper is to elaborate on the problems and evaluate existing efforts in tackling the challenge. As problem identifiers and solution advocates for the city, town planners ought to articulate the socio-economic challenges of double-ageing in the strategic policy agenda and play a facilitating role in coordinating interdisciplinary efforts to tackle the issue.

Double-ageing: the unique challenge for Hong Kong

Population ageing

Double-ageing is an issue forewarned in the latest version of strategic plan of Hong Kong, "HK2030+: Towards a Planning Vision and Strategy Transcending 2030" (HK2030+). As a population with the highest life expectancy in the world, Hong Kong's population is ageing amongst the fastest of all economies (Elderly Commission, 2017). The increase in life expectancy means that bulge of the largest age cohort at present, 50-54 year olds, is projected to move upwards to 80-84 by 2044 (see Figure 1).

According to 2015-2064 population projections, Hong Kong's elderly population (65+) will increase from 15.3% of the total population (1.12 million people) in 2015 to 30.6% (2.51 million) in 2043 and 35.9% (2.58 million) in 2064 respectively, putting massive pressure on the already gridlocked medical, social welfare and elderly support services system. If we take 85+ as the benchmark that a certain degree of caring services is almost unavoidable, the cohort would increase almost five-fold from 3.2% in 2014 to 10.1% in 2064. Society at present tend to focus resources on addressing the needs of the elderly

Feature Paper To What Extent Can Smart City Technologies Solve Problems with Our Aging Population?

Daniel Chun Chairman of Research and Blueprint Committee, Smart City Consortium

Over the past few years, smart city technologies have been widely discussed. In 2016 and 2019, Daniel has also co-edited an ICT book, Up An Age, which has evaluated the feasibility of enhancing urban engagement through the use of QR/Media mobile technologies. He also currently serves as Council Member and Chairman of the Research & Blueprint Committee of the Smart City Consortium.

The roadmap of smart city projects in Hong Kong

According to the United Nations (2019), it is projected one in every three people in cities with at least half million future years, is likely to be over 65. In order to be sustainable, cities need to increase the quality of life of its inhabitants. New ways of life of innovative technologies as policy frameworks are needed (Al, 2012; Cozzani, 2016). In this urban development, technology administrators, urban professionals and legislators to come forward and developing infrastructure, develop change, writing legislation to technologists and methods to forward.

In Hong Kong, there are also a smart city - review (Yip, 2015) and regional role (Kw, 2015). The Central Policy Unit government had announced collaborate with research institute private organization to study of implementing smart city. The same year, the HKSAAL

Technology Service (ITS) was formed, and the ITS project to formulate a digital framework and to develop a citywide blueprint that helps to raise the industry standard for developing

connected city, sustainable city and green city (Pau and Fung, 2011; Chandra et al., 2012; Hulteen, 2016; Long, 2016; Lee and Pajanan, 2017; Li, 2017; and Latham, 2018). In considering the matter, there are also many different topic upon writing smart cities is a very multidisciplinary topic. While there could be many subject matters worth discussing about policy and technologies, for the rest of this article, the focus is placed on the issues relating to ageing population and public health care.

Ageing population in industrialised economies

The topic of ageing population is not new. In fact, as early as 2001, the Task Force on Population Policy of the HKSAR Government had reported that Hong Kong will soon see the large-scale public services and also increasing share on the younger generation due to a decrease in birth rates and an increase in life expectancy. The change in the population distribution will be significantly altered as depicted by the graphical representations on the right in Figure 1 and Figure 2 which was based on data collected by the Task Force on Population Policy and traced by the Faculty of Medicine of the Chinese University of Hong Kong. By observing the two graphs, it is not difficult to understand that the city will increasingly have more citizens aged 85 and above. The capacity, adequacy, reliability and level of services from all our national services will have to be increased as a direct result of the demographic demographic.

Hong Kong is not alone facing this issue of ageing population. According to the World Health Organization (WHO), between 2015 and 2030, the proportion of the world's population over 65 years will nearly double from 10% to 20%. In addition, the term "aging society" has been popularised since 1991 and according to Denney-Susan (1991), this phenomenon is observed to be most pronounced in Germany amongst industrialised economies and OECD countries like Canada, France, Italy, Germany, Japan, UK, and US had shown similar patterns (see Table 1).

By the same token, it is also quite logical to make a fair judgement that even though not as aging, Hong Kong will see a more elderly population.

require some form of medical or health-related caregiving. The demand for public health care services from the Hospital Authority (HA) will also be increased as a result. Fiscal support for such will also have to be increased. It is already been widely discussed recently at the HKSAR Legislative Council and at various committees that hospital support staff and trained medical practitioners are overworked (SCMR, 2019) and this may compromise the quality of services being delivered.

What could the smart city technology roadmap help in public healthcare?



Courtesy of Leggo and credit: Filabay

notion of humanoid robot patrolling delivering butler like services sounds attractive for our home and the eldering at home, this highly publicized at the application layer is by no means an economically viable alternative. In fact, it is economically viable alternative as an affordable and universally available technology at the time of writing this paper, it is undeniably true that such technologies are advancing so fast that it will be in place in the future if and when is false, cybersecurity, privacy issues, 5G, operating lifetime, and always-on communications are all resolved. The narratives of machine intelligence, figure and deep learning have come since many of us left campus, and use mainframe computers and dumb terminals which the most trivial computer routine and decision making was done as an expert system (Horvitz, Henrion, 1988). Talking screens and robots could become the future of in the future.

So, if humanoid robots are not entirely ready to replace the tender loving care offered by healthcare workers (Loxton and Liu, 2018) as yet, does it necessarily mean that the ontology (nature) and epistemology (practice) of healthcare could not be re-engineered and reoriented with appropriate technology enhancement to provide predictive and preventive healthcare. In light of this argument, we are in the opinion that healthcare workers and their professional practice could be greatly enhanced with the application of appropriate sensors and big data analytic network, a fiscal policy and a holistic strategy that supports the concept of smart living and healthy environment.

"Aging with dignity is mere fantasy of most senior citizens."

In 2015, Hong Kong had 1.12 million people aged over 65, 15% of which were over 85. The trend of the aging population is getting steeper as baby boomers reach their retirement age. By 2040, one in every three people in Hong Kong will be over 65 (Leggo, 2015). Currently, there is a queue of 32,000 elderly citizens waiting for nursing homes. And equally alarming is that there are over 18,000 new cases of elderly citizens diagnosed with dementia each year. Our current senior care and healthcare systems have been placed under an unprecedented amount of pressure. Meanwhile, aging with dignity is mere fantasy of most senior citizens. In order to facilitate healthy aging in Hong Kong, there are opportunities now to create and foster a Proactive, Predictive and Preventive living environment supported by a holistic smart health system that links up families, neighbors, caregivers and doctors together, to keep our elderly citizen safe, healthy and happy at home. By adopting these three pillars, this could improve our elderly citizen's wellbeing while distributing resources equitably to those in need.

The following three pillars are part of our recommendations which were also presented in the Smart City Consortium's Interim Advisory Report for Hong Kong's Smart City Blueprint (SCC, 2016):

i) Proactive Smart Health Monitoring - An indoor and outdoor smart Internet of Things



Figure 1: Population Distribution in 2007

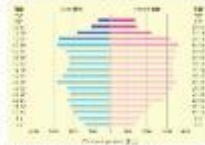


Figure 2: Population Distribution in 2027

Table 1: Old age dependency ratio for some OECD countries. Columns: Country, 1970, 2010. Rows: Canada, France, Italy, Japan, UK, US. Average of them 1970, 2010.

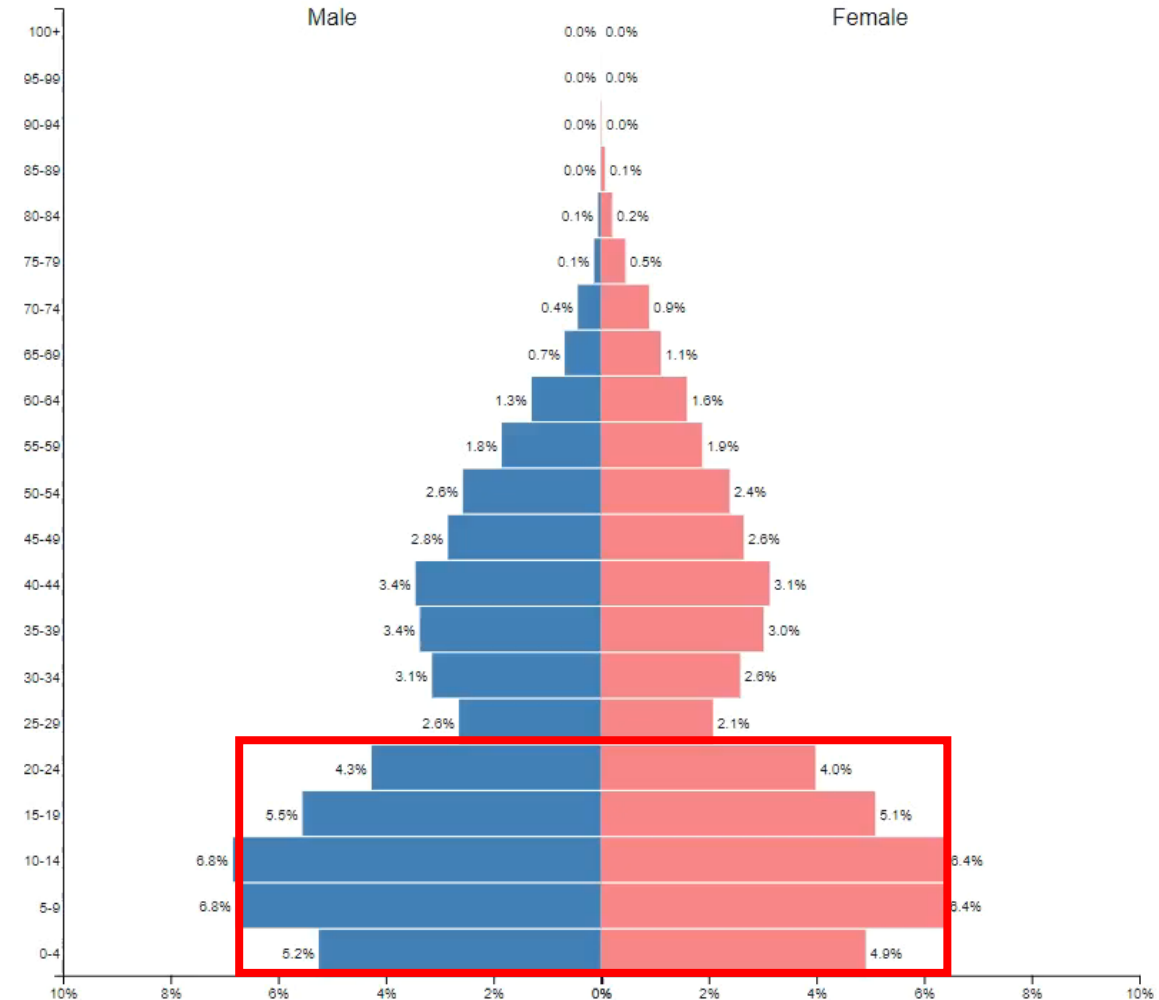
Source: OECD (2008) old-age dependency ratio (15-64 years) (1970-2010). Member of Organisation for Economic Co-operation and Development (2016)





<https://smartcity.org.hk/en/info-research.php>

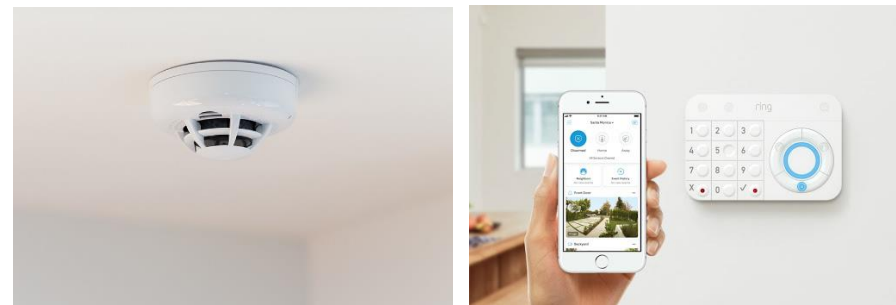
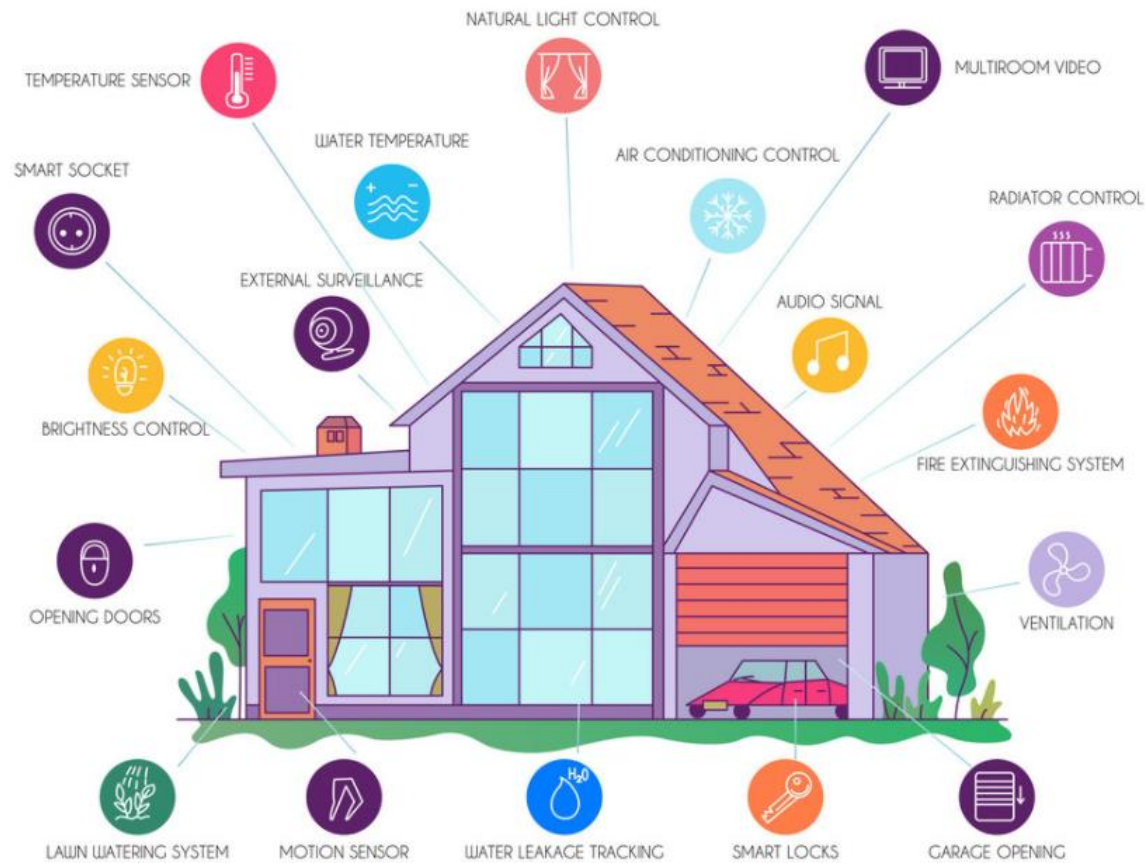
**Blueprint Advisory Report(s)
 2016, 2017, 2020**



<https://www.populationpyramid.net/china-hong-kong-sar/2045/>

Value propositions & promises of Smart Home Technologies

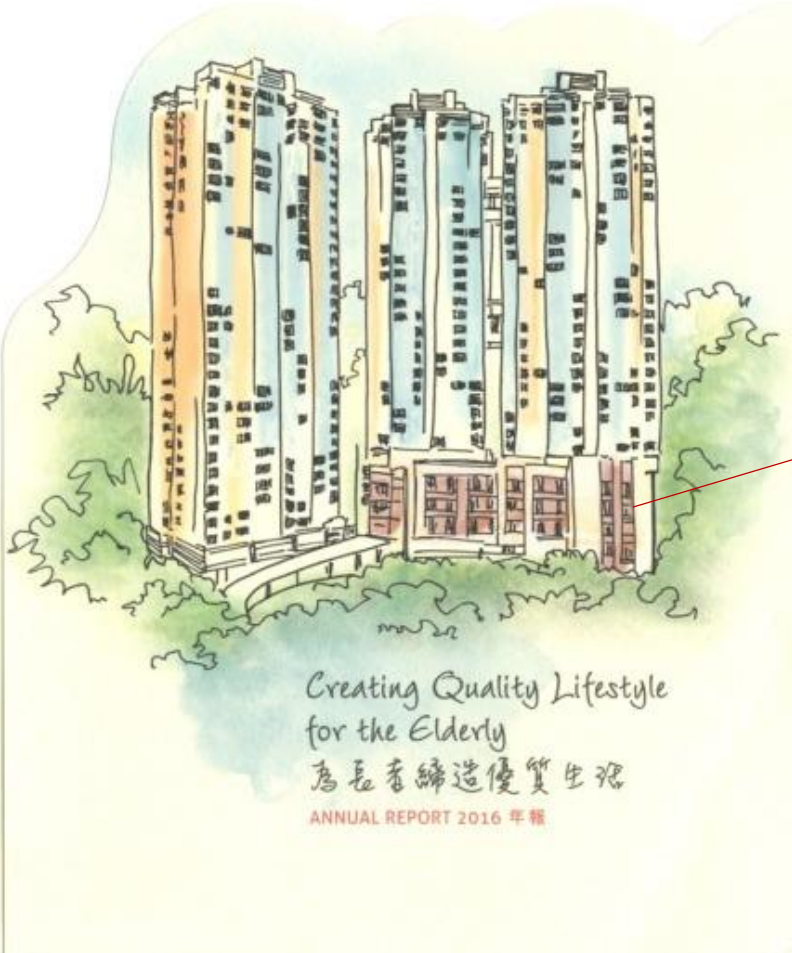
SMART HOME TECHNOLOGY



Safety and Prevention (SP)



Hong Kong Housing Society has deployed the use of some sensors for detection



SCA Training Seminar
Sep 29, 2020

Source: Hong Kong Housing Society website

47% of the fall is indoor and 66% is within home environment

- For the over-65 population, falling can be a serious health risk. One in four older adults falls each year; but less than half tell their doctor. Falling once doubles your chances of falling again.
- In Hong Kong, each year 25% of community dwelling elders suffer from fall. 75% of them get injury include head injury and fracture. Elders who fell in the past six months had shown to have increased risk of fall in near future.
- Elderly Commission Dept of Health in Hong Kong also has similar warnings for elderly fall-related hazards.



Chu, L. W., Chiu, A. Y., & Chi, I. (2008). Falls and subsequent health service utilization in community-dwelling Chinese older adults. Archives of gerontology and geriatrics, 46(2), 125-135.

Chu, L. W., Chiu, A. Y., & Chi, I. (2007) Falls and fall-related injuries in community-dwelling elderly persons in Hong Kong: a study on risk factors, functional decline, and health services utilisation after falls Hong Kong Med Journal 2007; 13(Suppl 1):S8-12



ORIGINAL RESEARCH

Falls Among the Community-living Elderly People in Hong Kong: A Retrospective Study

Kenneth N.K. Fong^{a,*}, Andrew M.H. Siu^a, Kenneth A Samantha W.S. Cheung^b, Chetwyn C.H. Chan^a

^a Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Hong Kong
^b Elderly Resource Centre, Hong Kong Housing Society, Hong Kong

Received 12 February 2011; received in revised form 8 April 2011; accepted 27 April 2011

KEYWORDS

Accidental falls;
Community-living elderly;
Retrospective study

Abstract

Purpose: To examine the base rate of falls for a group of Hong Kong. **Methods:** This was a retrospective cross-sectional study above living in various geographical regions of Hong Kong a community centre over a period of 4 months. Participants were sampled and stratified by age range according to the district were asked to report on their fall history for a period of 12 months. **Results:** Of all the participants, 111 reported having fall fall rate was 29%, and the 1-year prevalence of falls was 47%. Of all the falls, 47.7% occurred indoors whereas 52.3% occurred outdoors. Of all the falls, 66% occurred within the home and 34% occurred outside the home (within the estate). **Conclusion:** We determined the base rate of falls for a group of Hong Kong. Retrospective methods, which ask elderly their falls, may be used to identify risks preceding falls. Copyright © 2011, Elsevier (Singapore) Pte. Ltd. All rights reserved.

* Reprint requests and correspondence to: Dr. Kenneth N.K. Fong, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Hong Kong.
E-mail address: rsnkfong@polyu.edu.hk (K.N.K. Fong).

Table 1 (continued)

Characteristics	All participants (N = 554)
Part-time domestic helper	8 (1.4)
Family members	47 (8.5)
Others	3 (0.5)
Dependency for heavy household duties	
Take care of own self	228 (41.1)
By couple	53 (9.5)
Full-time domestic helper	36 (6.5)
Part-time domestic helper	63 (11.4)
Family members	135 (24.4)
Others	39 (7.0)
Mobility aid	
None	406 (73.2)
Walking stick/umbrella	135 (26.0)
Quadripod	1 (0.2)
Walking frame	3 (0.5)
Mobility status	
Assistance indoor	3 (0.6)
Supervision indoor	2 (0.4)
Supervision outdoor	8 (1.4)
Independent outdoor	541 (97.5)
TUGT	14.5 ± 4.5
FRF (cm)	24.5 ± 6.2
BMI	24.3 ± 3.6
AMT	8.7 ± 1.6
Visual acuity (Left)	5.5 ± 1.8
Visual acuity (right)	5.7 ± 1.6
Presence of chronic diseases	
Yes	446 (80.4)
No	108 (19.5)
Comorbidities	
Stroke	29 (5.2)
Dementia	1 (0.2)
Osteoporosis	27 (4.9)
Arthritis	76 (13.7)
Parkinson's disease	1 (0.2)
High blood pressure	278 (50.1)
Low blood pressure	9 (1.6)
Diabetes mellitus	101 (18.2)
Eye disease	93 (16.8)
Chronic chest disease	12 (2.2)
Cardiac disease	60 (10.8)
Depression	9 (1.6)
Cancer	9 (1.6)
Previous upper limb fracture	8 (1.4)
Previous lower limb fracture	11 (2.0)
Low back pain	8 (1.4)
Number of drugs taken	
Nil	153 (27.6)
1–3 kinds	371 (66.8)
>4 kinds	30 (5.4)
Receiving social services	
Day activity centre	2 (0.4)
Elderly centre	462 (83.2)
Enhanced home care service	36 (6.5)
Receiving medical service	427 (76.9)
Receiving active rehabilitation service	10 (1.8)

Table 1 (continued)

Characteristics	All participants (N = 554)
Incidence of falls within 1 y	
Yes	111 (20.0)
No	443 (80.0)

Note. AMT = Abbreviated Mental Test; BMI = body mass index; FRF = Forward Reaching Test; TUGT = Timed Up & Go test. Values are shown as number (%); means are presented as the mean ± standard deviation.

living environments was similar to that of the study population with 39.5% lived in public housing estates and 35.8% in private housing (including 12.3% in housing of housing ownership scheme). Of all the falls, 47.7% occurred at home or within buildings/housing estates and 52.3% outdoors; most (79.9%) occurred during daytime. Most indoor falls happened in dining areas (17%) and at lifts and lobbies (9%). Of all the fallers, 36.9% perceived environmental factors as the cause of the fall, 39.6% perceived personal or behavioural factors as the major cause, and 12.6% perceived their falls resulting from both environmental and personal reasons.

Table 3 shows the results of a comparison of demographic and functional parameters in fallers and nonfallers. Significant differences were found between both groups in terms of gender ($p = .008$), drug intake ($p = .019$), use of walking aids ($p = .001$), histories of chronic diseases ($p = .021$), previous upper limb fracture, ($p = .003$), and performance on the TUGT ($p = .001$). It was interesting to find out that the number of near-miss experienced by fallers and nonfallers in the past 12 months was similar and there were no significant differences between them ($p = .902$).

Table 4 lists the results of logistic forward regression analysis of demographic and functional parameters for one or more falls ($N = 554$). This logistic regression analysis showed that female gender (odds ratio [OR] = 2.54), TUGT (OR = 1.07), self-reported history of upper limb fracture in the preceding 12 months (OR = 9.36), taking four or more drugs (OR = 3.17), receiving rehabilitation services (OR = 3.68), and living as a couple (OR = 2.06) were significant predictors for whether the participant had at least one fall in the previous 12 months.

Table 5 summarizes the results of logistic regression analysis of demographic and functional parameters for two or more falls. History of stroke (OR = 3.73), depression (OR = 8.53), previous upper limb fracture (OR = 6.68), and those receiving rehabilitation services (OR = 5.01) were significant predictors of two or more falls.

Discussion

The estimates for fall rate and prevalence in our study are similar to the results of a previous falls survey in Hong Kong using prospective methods (Chu et al., 2007). We found that the retrospective method—asking elderly people living in a community to recall their falls during the preceding

Table 2 Characteristics of Fallers.

Characteristics	Fallers (N = 111)
Living environment	111 (100.0)
Public housing estate	46 (41.4)
Housing ownership scheme	18 (16.2)
Private housing	20 (18.0)
Rented room	0 (0)
Senior citizen hostel	8 (14.4)
Squatter hut/Temporary house	16 (14.4)
Others	3 (2.7)
No. of falls within 1 y	111 (100.0)
1	76 (13.7)
2	24 (4.3)
3	8 (1.4)
4	1 (0.2)
>5	2 (0.4)
Site of falls	111 (100.0)
Indoor	53 (47.7)
Outdoor	58 (52.3)
Environments of indoor falls	53 (47.7)
Dining area	19 (17.0)
Bedroom	3 (2.7)
Kitchen	7 (6.3)
Bathroom/toilet	6 (5.4)
Main flat entrance	2 (1.8)
Public area (within apartment)	4 (3.6)
Public area (within housing estate)	10 (9.0)
Others	2 (1.8)
Activity participation during indoor falls	53 (47.7)
Toileting	1 (0.9)
Dressing	0 (0)
Bathing	2 (1.8)
Changing position/transfer	8 (7.2)
Food preparation	4 (3.6)
Household tasks (other than food preparation)	4 (3.6)
Going in/out	5 (4.5)
Sleep	3 (2.7)
Cannot identify	13 (11.7)
Cannot recall	4 (3.6)
Time of falls	111 (100.0)
Daytime (6:01 AM to 6:00 PM)	88 (79.9)
Evening (6:01–12:00 PM)	20 (18.0)
Midnight (12:01–6:00 AM)	3 (2.7)
Medical consultation after falls	111 (100.0)
Yes	10 (9.0)
No	101 (91)
Self-perceived reasons of falls	111 (100.0)
Environmental factor	41 (36.9)
Personal/behavioural factor	44 (39.6)
Both environmental & behavioral factors	14 (12.6)
Unlucky or no specific reason	12 (10.8)

Values are shown as number (%).



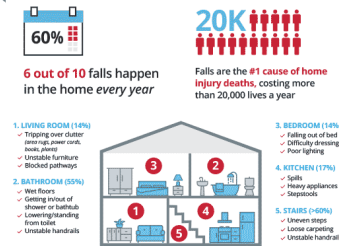
Sample Size
n=111

47% indoor

66% within home

34% outside home
(within the estate)

FALLING IN THE HOME



Fong, K. N., Siu, A. M., Yeung, K. A., Cheung, S. W., & Chan, C. C. (2011). Falls among the community-living elderly people in Hong Kong: a retrospective study. *Hong Kong Journal of Occupational Therapy*, 21(1), 33-40.

Assisted Living technologies

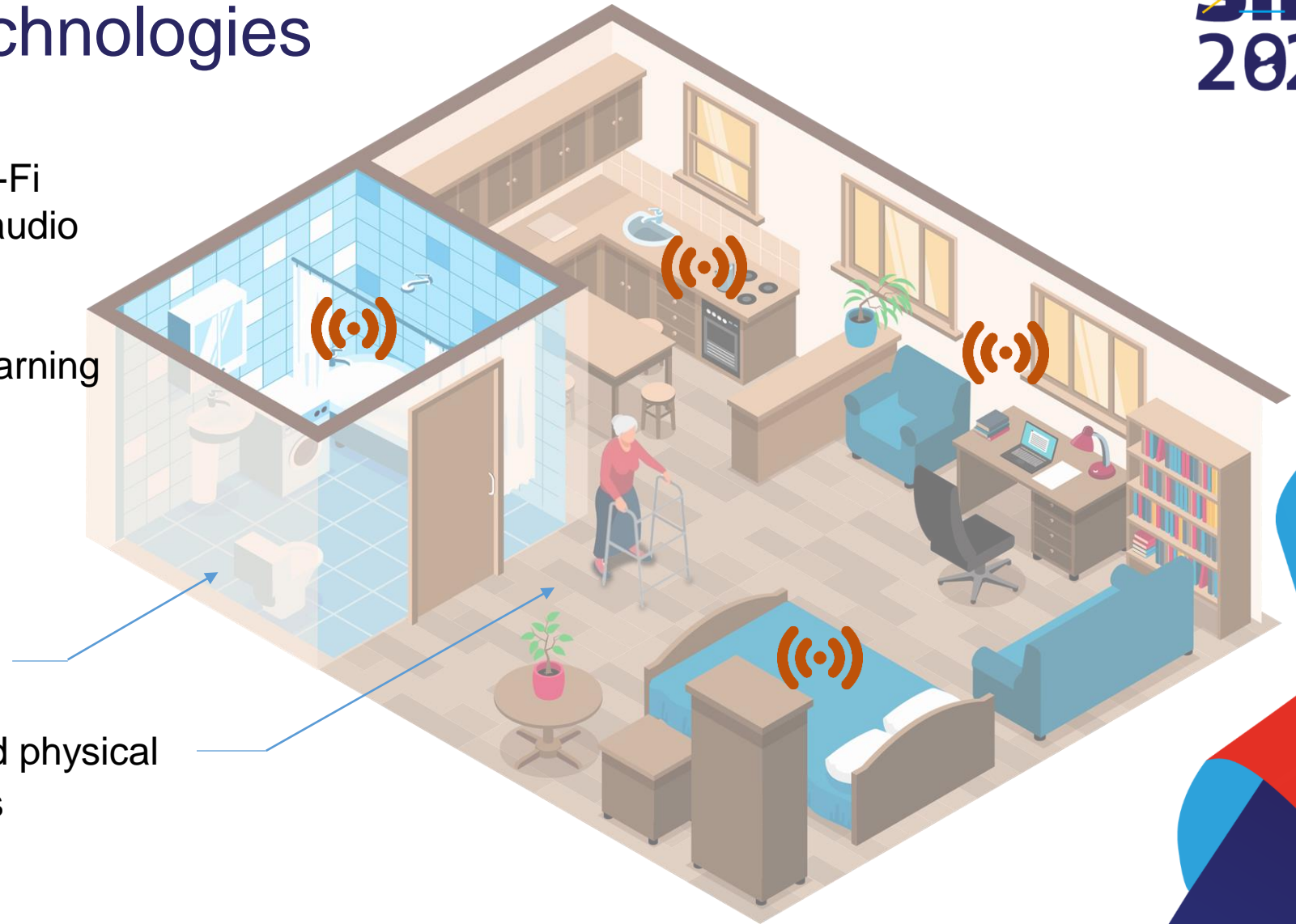
Unobtrusive radar sensors, a Wi-Fi network, a gateway and simple audio and/or video communication.

Uses data modeling, machine learning and A.I to predict anomalies

Emergency alert for care staff

Complete respect of privacy

Understanding the behaviour and physical activities of the elderly occupants



Radar Sensors An alternative to cameras and other wearable sensors



5072 IEEE SENSORS JOURNAL, VOL. 20, NO. 9, MAY 1, 2020 IEEE Sensors Council

Deep Learning Radar Design for Breathing and Fall Detection

Abhijit Bhattacharya, Student Member, IEEE, and Rodney Vaughan, Life Fellow, IEEE

Abstract—The automated detection of people having a fall is particularly important for the elderly in indoor care situations. Privacy concerns, and regulations that prohibit cameras in indoor environments, mean that optical sensing must give way, at least in some situations, to less explicit sensing such as radar. Currently, fall detection using radar Doppler signatures has limitations. We demonstrate a radar-based technique that detects breathing and other movements seamlessly, and can detect a fall after it has happened, i.e. even when the person is static. Using a low-cost, ceiling-mounted radar at low microwave frequencies (sub-6 GHz), our results show it is possible to remotely localize a person within a few cm. The sensor system includes a small neural network model that can distinguish a person from other moving objects in an indoor environment. This can reduce false alarms of the fall detection and hence improve system reliability in real-world deployment. In our experiments, the neural network differentiates a person from a pet (an example of complex moving entity) with an accuracy exceeding 95%. This sensor system demonstration paves a way forward for general indoor fall detection, extending to the well-being of our elderly through real-time, ongoing monitoring of their breathing and other activities of daily living.

Index Terms—Radar sensor, breathing, fall detection, patient monitoring, deep convolutional neural network, IoT.

I. INTRODUCTION

RADAR sensors are appearing in everyday life alongside conventional commodity sensors such as cameras, and infrared and ultrasonic technology. Radar technology is environmentally robust, for example working in unilluminated settings, and integrated circuit advances have enabled small, affordable, short-range radars. They operating at frequencies from few GHz to hundreds of GHz (mmwaves) for very short-range sensing. This has made radar a choice for many new applications such as collision avoidance in cars, adaptive control of autonomous vehicles and drones [1], [2]; structural monitoring; airport security [3], [4]; gesture recognition [5], [6]; and so on. Patient monitoring in another area of interest in recent years [7]–[9]. For such human monitoring, conventional wearable sensors (10) are often cumbersome, and people prone to forget to wear them. Cameras [11] are seen as infringing on privacy, particularly in bedrooms and bathrooms. Radar offers remote monitoring, without requiring the user to carry any electronic device, and it also protects privacy better than a camera. Researchers have looked into the potential of remote monitoring of vital signs (breathing and heartbeat) using radar [12], [13], and studied elderly fall detection from Doppler signatures to distinguish fall from daily activities [14], [15]. Fall detection from Doppler signatures has been limited success for two main reasons. Firstly, due to the complex and varied nature of falls, it has proved difficult to differentiate from some other normal activities when observing from different angles [16]. Secondly, it is hard to collect real-world fall data, which forces researchers to use data gathered from young volunteers, and thus limits the system performance in real-world implementation.

This work contributes three new aspects to the study of radar-based fall detection. (i) Fall detection and vital-sign monitoring have largely been treated in the literature as two separate problems. Here we locate the person through movement as well as breathing, and decide on fall event from the person's proximity to the floor. The radar is ceiling-mounted. We present a technique for detecting breathing that can be integrated with the detection of other movements for localization, including when the person is inert (such as fallen on the floor). (ii) A study of human radar cross section (RCS) is presented along with new results on the statistics of human RCS including the case of circular polarization. (iii) A neural network classifier is used to train on radar Doppler signatures to differentiate people from other moving entities present in an indoor environment. Using the receiver operating characteristic (ROC) metric, we show that applying the classifier along with range tracking has the potential to reduce false alarms and improve system reliability.

Manuscript received November 30, 2019; accepted December 30, 2019. Date of publication January 17, 2020; date of current version April 13, 2020. The associate editor coordinating the review of this article and approving it for publication was Dr. Ying Zhang. (Corresponding author: Abhijit Bhattacharya.)

Abhijit Bhattacharya is with Serwa Wireless Inc., BCV 3V3A, Canada (e-mail: abhijit@serwa.com).

Rodney Vaughan is with the Engineering Science Department, Simon Fraser University, Burnaby, BC V5A 1S6, Canada (e-mail: rodney_vaughan@sfu.ca).

Digital Object Identifier 10.1109/JSEN.2020.2967100

1558-1748 © 2020 IEEE. Personal use is permitted, but republication/redistribution requires IEEE permission. See https://www.ieee.org/publications_standards/publications/rights/index.html for more information.

Authorized licensed use limited to: The University of British Columbia Library. Downloaded on October 22, 2020 at 05:14:33 UTC from IEEE Xplore. Restrictions apply.

5073 IEEE SENSORS JOURNAL, VOL. 20, NO. 9, MAY 1, 2020 IEEE Sensors Council

Deep Learning Radar Design for Breathing and Fall Detection

Abhijit Bhattacharya and Rodney Vaughan

FIG. 1. Generalized working principle of the fall detection system.

the revised systems, combinations of LSTM and CNN are used for fall detection to overcome the general vision related problems such as image noise, occlusion, incorrect segmentation, perspective, etc. While CNN and LSTM architectures are mostly used for supervised learning, auto-encoders are used for learning efficient data coding in an unsupervised manner [108], [110]. Generally, some techniques are applied on the transformed dataset to distinguish between the events. Thus, the reviewed systems were categorized based on the principal method used to infer the events. The categorization focuses on how the different principal methods (CNN, LSTM, and Auto-encoder) handle the event data captured by the sensors.

In this review, we have categorized the reviewed systems on the nature of handling the event data by the deep learning methods. Thus, the reviewed systems can be categorized into the following three major categories:

- Convolutional Neural Networks (CNN)
- Long Short-Term Memory (LSTM) with Recurrent Neural Network (RNN) and Recurrent Convolutional Network (RCN)
- Auto-encoder

Figure 2 is a general representation of the categorization. The figure also represents the specific architectures that are generally used under every subsection. The use of the different architectures is mostly dependent on the sensor data or the technique used to represent fall and ADL events [48], [49].

The rest of the paper is arranged as follows: Section 2 discusses the literature on the methods and systems developed for fall detection. Discussion and future directions demonstrated in section 3 including the summary and performance analysis. Finally, we conclude this review in section 4.

VOLUME 9, 2020

5075 IEEE SENSORS JOURNAL, VOL. 20, NO. 9, MAY 1, 2020 IEEE Sensors Council

Deep Learning Radar Design for Breathing and Fall Detection

Abhijit Bhattacharya and Rodney Vaughan

FIG. 2. Deep learning methods used for fall detection.

In the recent decade, several deep learning systems have been developed for recognizing fall in real-world situations. In this review, we focus on vital and most recent researches and for fall detection with the description of:

- Introducing the system
- Working principle of the system
- Datasets used for training and experiments
- Critical and performance analysis

A. CONVOLUTIONAL NEURAL NETWORK FALL DETECTION SYSTEMS

Most of the reviewed systems in this field for developing the automatic fall detection takes an image as input, then processes it into the feature space. The processed image under certain given CNN technique passes each input image (labeled alphabetically) for all directions in ϕ and θ . This study was taken up to assess the variability of human RCS with height (190 cm for the tall man to 120 cm for the child), body shape (slim or fat) and posture (sitting, standing, extending arms etc.). Interestingly we see that for about 90% of the angles, the RCS stays within about 0.5 square meters, with the exception of the *fallman*. For the *fallman* extending his arms we notice increased response to the ϕ polarization. Fig. 3 also indicates the likely need for higher transmit power for detecting breathing which of course is restricted to small movements of the torso.

Fig. 4(a) shows the distribution of co-polar RCS for the model in Fig. 2. It can be seen that an exponential power distribution represents this RCS well for about 90% of the angles.

This means that most of the backscatter can be explained by Swerling case 1, which assumes a target with a “few” independent scatterers of comparable returns, i.e. of similar size (NB, the exponential distribution for power corresponds to the Rayleigh distribution for magnitude [34]), so Swerling’s “few” corresponds to “many.” Moreover, the remaining 10% to 15% of the backscatter that is primarily from the front and back of the body close to the azimuth plane (with a standard deviation of about 15° in elevation) conforms well with Swerling case 3 which assumes one dominant scatterer which is physically larger than the others together with few weaker ones (NB, the Rice distribution for magnitude). Therefore, based on the application, one should be able to choose the right model for human RCS distribution. For example, when verifying radar’s range performance (in subsection D) we chose the model in Fig. 4(a) (Swerling case 3). But considering the application to fall detection where the antenna is mounted on the ceiling of a room, distribution in Fig. 4(a) (i.e., Swerling case 1) is more appropriate.

The monostatic RCS described above is the far-field case where the target is in the far-field of the radar and vice versa, so it assumes that the target is illuminated with a uniform plane wave. But in our application the antenna is mounted on the ceiling not far from the human body, so the target may be in the near-field of the radar, and illuminated with a spherical wavefront that has also amplitude taper from the representing beam shapes. The potential impact of the near-field case is investigated in Fig. 5 which shows RCS distribution in the near-field. From a simulation using WPL-D of a numerical model of the linearly polarized antenna used in our radar.

FIG. 3. GDF of RCS for a family of human body models with the equivalent dielectric.

FIG. 4. PDF of co-polar RCS for full-scale human body model with equivalent dielectric. (a) Overall distribution, (b) distribution near stomach.

FIG. 5. Distribution of co-polar RCS for full-scale human body model with equivalent dielectric. (a) Overall distribution, (b) distribution near stomach.

5079 IEEE SENSORS JOURNAL, VOL. 20, NO. 13, JULY 1, 2020 IEEE Sensors Council

Sensor Technologies for Fall Detection Systems: A Review

Anuradha Singh, Saeed Ur Rehman, Senior Member, IEEE, Sira Yongchareon, Senior Member, IEEE, and Peter Han Joo Chong, Member, IEEE

Abstract—The risk of falls in older adults restrict their social life and independent living. The assisted living devices help older adults to live independently in their home, giving a psychological boost, and releasing the burden on the caregiver and the healthcare providers. A robust and accurate fall detection system is essential to provide immediate help and to reduce the severe post-fall consequences, and the associated medical care cost significantly. This review aims to provide a comprehensive technical insight into the existing fall detection systems, to classify various approaches and the challenges encountered during implementation. The fall detection are broadly classified into three categories, namely wearable, ambient-based, and hybrid sensing detectors, which are further explored by the sensor technology. This review provides a comprehensive overview of each competing sensor technology ranging from an accelerometer, pressure sensor, and radar to camera-based and their infusion into a complete fall detection system. It outlines the strength and limitations of different sensor fall detection systems in terms of feature extraction, classification, performance, and experimental dataset. The user adaptability, installation complexity, and power requirement of the systems are the main areas, which are not addressed adequately in the literature. In the end, the review provides a basic framework in deciding the technology for a specific scenario or location according to the prerequisites for the deployment.

Index Terms—Assisted living, elderly assisted living, fall detection, smart homes, sensor technology, wearable sensor.

I. INTRODUCTION

THE world health organization reported that approximately 25–35% of the people of age over 65 years had suffered fall every year, and it increases to 32–42% for older adults over 70 years of age [1]. It is projected that the worldwide population of old age people over 65 would increase by 21.64% by 2050 [2]. The effect and risk of falls increased exponentially with age due to weak leg strength, side effects of prolonged medication, vision problems, and strength reduction

In other tissues. Fall-related injuries result in pain, disability, and sometimes leading to premature death [3]. The average medical cost for injuries related to falling varies widely across countries. For instance, the average yearly health system cost per fall for the people aged 65 and above in Finland US\$ 3,611, Australia US\$ 1,049, Ireland US\$ 6,666, and in the USA was US\$ 17,483 for the survey year of 2002 (as reported in 2007) [4]. Specifically, the total population of New Zealand is predicted to increase by 25% over the next 30 years, and 150% for people aged 75 and above. The average health system cost per annum is expected to rise to NZ\$ 10 billion from existing NZ\$ 7,000 million within the next 30 years [5]. More than 25% of this is expended on the people above 70 years of age. Injuries due to fall being one of the most significant causes of this medical care expense. From 2011 to 2016 the fall-related injuries increased from 170,000 to 216,000 approximately by 27%.

The fear of falling itself leads to a restrictive way of living for the old age people, e.g., restricted social life, reduced daily activities, and depression [6]. The alarmingly increasing rate of fall-related injuries necessitates the need for assistive care devices to detect and raise alarms in emergencies [7].

Manuscript received December 3, 2019; revised January 26, 2020; accepted February 13, 2020. Date of publication February 28, 2020; date of current version June 4, 2020. The associate editor coordinating the review of this article and approving it for publication was Dr. Marco J. Da Silva. (Corresponding author: Anuradha Singh.)

Anuradha Singh and Peter Han Joo Chong are with the Department of Electrical and Electronic Engineering, Auckland University of Technology, Auckland 1142, New Zealand (e-mail: engaru@aut.ac.nz).

Saeed Ur Rehman is with the College of Science and Engineering, Flinders University, Adelaide, SA 5042, Australia.

Sira Yongchareon is with the Department of IT and Software Engineering, Auckland University of Technology, Auckland 1142, New Zealand.

Digital Object Identifier 10.1109/JSEN.2020.2976554

1558-1748 © 2020 IEEE. Personal use is permitted, but republication/redistribution requires IEEE permission. See https://www.ieee.org/publications_standards/publications/rights/index.html for more information.

Bhattacharya, A., & Vaughan, R. (2020). Deep Learning Radar Design for Breathing and Fall Detection. *IEEE Sensors Journal*, 20(9), 5072-5085.

Islam, M. M., Tayan, O., Islam, M. R., Islam, M. S., Nooruddin, S., Kabir, M. N., & Islam, M. R. (2020). Deep Learning Based Systems Developed for Fall Detection: A Review. *IEEE Access*, 8, 166117-16637.


Singh, A., Rehman, S. U., Yongchareon, S., & Chong, P. H. J. (2020). Sensor Technologies for Fall Detection Systems: A Review. *IEEE Sensors Journal*, 20(13), 6889-6919.

Radar Sensors

is about collecting behaviour data for modelling, predictive analysis

Article

A Radar-Based Smart Sensor for Unobtrusive Elderly Monitoring in Ambient Assisted Living Applications

Giovanni Diraco * , Alessandro Leone and Pietro Siciliano

National Research Council of Italy, Institute for Microelectronics and Microsystems, 73100 Lecce, Italy; alessandro.leone@le.imm.cnr.it (A.L.); pietro.siciliano@le.imm.cnr.it (P.S.)

* Correspondence: giovanni.diraco@le.imm.cnr.it; Tel: +39-832-422-540

Received: 17 October 2017; Accepted: 21 November 2017; Published: 24 November 2017

Abstract: Continuous in-home monitoring of older adults living alone aims to improve their quality of life and independence, by detecting early signs of illness and functional decline or emergency conditions. To meet requirements for technology acceptance by seniors (unobtrusiveness, non-intrusiveness, and privacy-preservation), this study presents and discusses a new smart radar system for the detection of abnormalities during daily activities, based on ultra-wideband radar providing rich, not privacy-sensitive, information useful for sensing both cardiorespiratory and body movements, regardless of ambient lighting conditions and physical obstructions (through-wall sensing). The radar sensing is a very promising technology, enabling the measurement of vital signs and body movements at a distance, and thus meeting both requirements of unobtrusiveness and accuracy. In particular, impulse-radio ultra-wideband radar has attracted considerable attention in recent years thanks to many properties that make it useful for assisted living purposes. The proposed sensing system, evaluated in meaningful assisted living scenarios by involving 30 participants, exhibited the ability to detect vital signs, to discriminate among dangerous situations and activities of daily living, and to accommodate individual physical characteristics and habits. The reported results show that vital signs can be detected also while carrying out daily activities or after a fall event (post-fall phase), with accuracy varying according to the level of movements, reaching up to 95% and 91% in detecting respiration and heart rates, respectively. Similarly, good results were achieved in fall detection by using the micro-motion signature and unsupervised learning, with sensitivity and specificity greater than 97% and 90%, respectively.

Keywords: fall detection; vital signs monitoring; heart rate; respiration rate; ultra-wideband radar; micro-Doppler; supervised; unsupervised

1. Introduction

The population aged 65 and over, which is the fastest growing sector in developed countries [1], suffers from the highest morbidity and mortality rates due to age-related disorders (e.g., illness and functional decline) [2] and injury-related conditions (e.g., trauma and fractures) [3,4]. In this context, it is paramount to monitor older adults in their own homes, but it becomes challenging when family members or caregivers cannot be always available. Consequently, during the last years, the demand for unobtrusive sensing of human activities and behaviors as well as physiological parameters has increased notably in the ambient assisted living (AAL) domain. Indeed, automated sensor systems can help by continuously monitoring elderly for detection of dangerous situations and even for early prediction of health disorders, in order to provide timely medical assistance and alerts to caregivers.

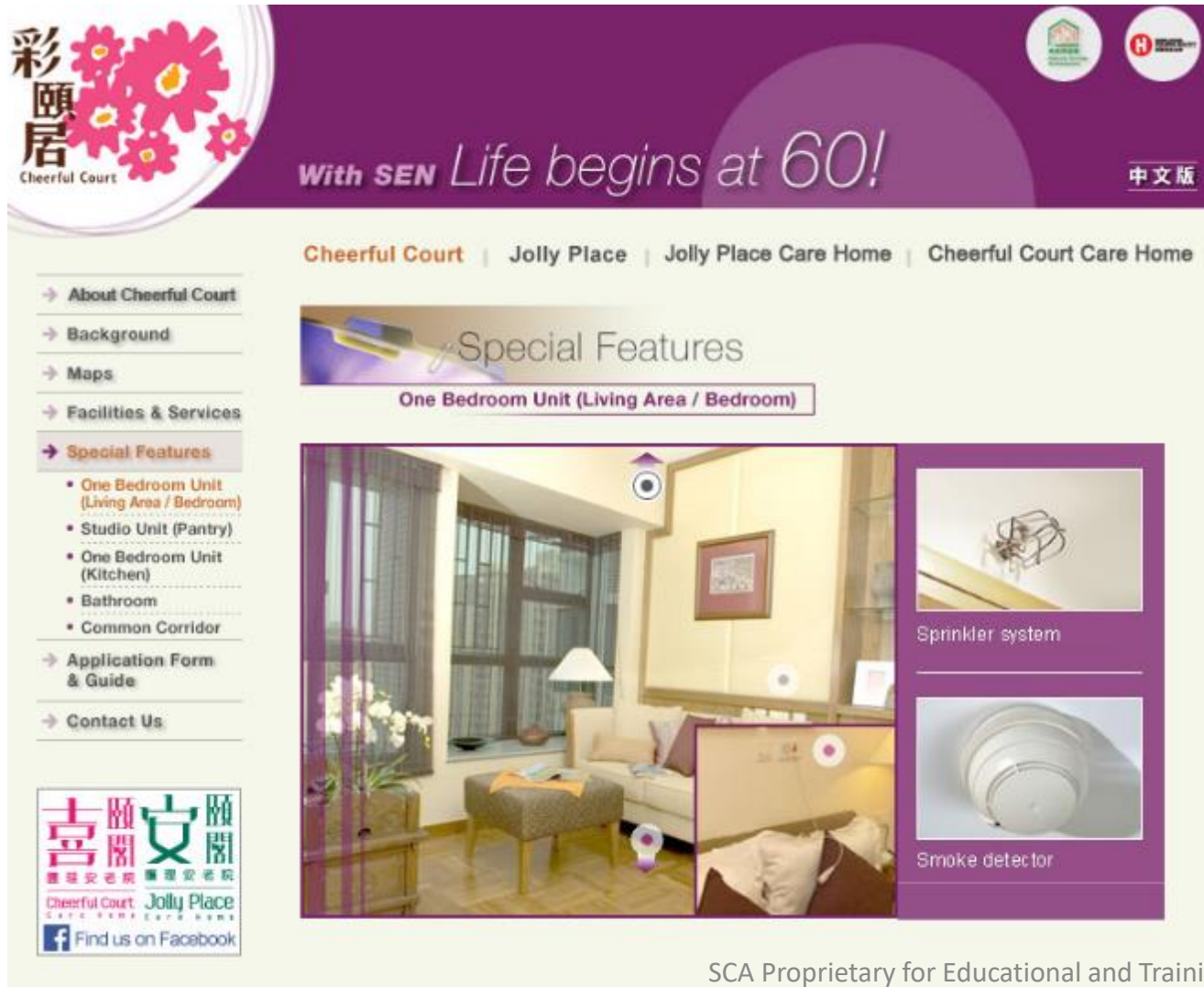
Most of the current elderly monitoring systems are aimed to monitor activities [5] and vital signs [6] of elderly in their daily life for the automated detection of abnormal events, among which falls are without doubt one of the major healthcare concerns [7]. In fact, as some studies pointed out [8–10],

“Continuous in-home monitoring of older adults living alone aims to improve their quality of life and independence, by detecting early signs of illness and functional decline or emergency conditions.”

“The reported results show that vital signs can be detected also while carrying out daily activities or after a fall event with accuracy varying according to the level of movements, reaching up to 95% and 91% in detecting respiration and heart rates, respectively. Similarly, good results were achieved in fall detection by using the micro-motion signature and unsupervised learning, with sensitivity and specificity greater than 97% and 90%, respectively.”

Diraco, G., Leone, A., & Siciliano, P. (2017). A radar-based smart sensor for unobtrusive elderly monitoring in ambient assisted living applications. Biosensors, 7(4), 55.

Smart Home - Use of sensors for safety



彩願居
Cheerful Court

With SEN Life begins at 60!

中文版

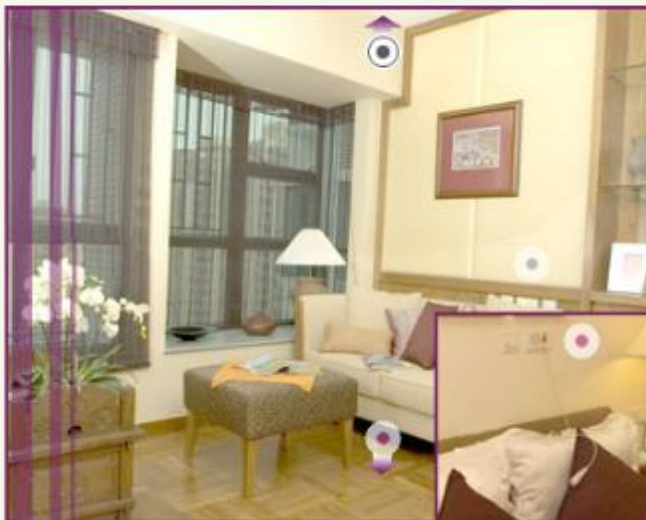

Cheerful Court | Jolly Place | Jolly Place Care Home | Cheerful Court Care Home

→ About Cheerful Court
→ Background
→ Maps
→ Facilities & Services
→ **Special Features**


- One Bedroom Unit (Living Area / Bedroom)
- Studio Unit (Pantry)
- One Bedroom Unit (Kitchen)
- Bathroom
- Common Corridor

→ Application Form & Guide
→ Contact Us

Special Features
One Bedroom Unit (Living Area / Bedroom)

Sprinkler system



Smoke detector

喜願安 喜願安
護理安老院 護理安老院
Cheerful Court Jolly Place
CARE HOME CARE HOME
Find us on Facebook

Cheerful Court | Jolly Place | Jolly Place Care Home | Cheerful Court Care Home

Facilities & Services
Occupational Therapy



Occupational therapy is a kind of rehabilitation therapy for people with temporary, permanent or developmental disabilities. Through tailor-made activities and therapeutic processes, occupational therapists enhance both physical and psychological functions, prevent illness, facilitate independent living, improve quality of life of the disabled and people with special needs, and promote their reintegration into home, work and society.

Scope of Service:

- Provides activities of daily living skills assessment and training;
- Provides swallowing assessment and treatments such as oral-motor therapy and exercises, Vitalstim® Therapy;
- Provides cognitive assessment and treatments including cognitive training, multi-sensory therapy, reminiscence therapy and reality orientation;
- Provides treatments for client after stroke and traumatic brain injury to improve their mobility and independence;
- Provides pressure mapping and seating assessment, and recommendation in the use of assistive device;
- Provides home environment assessment and recommendation;
- Provides carer training courses.




Perfect use cases scenario to use the technologies to collect data about the elderly's daily activities



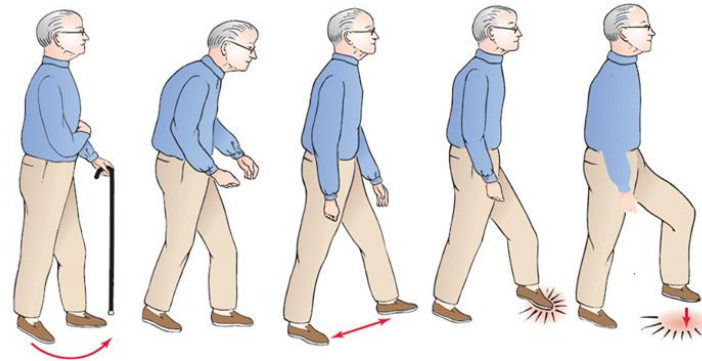
**HONG KONG
HOUSING SOCIETY**
香港房屋協會

- Home care support system
- Anti-wandering systems with RFiD
- Health Monitoring System – data are collected daily
- Entrance Door / Non-motion response detection system
- Emergency Call system

3 major reasons why these data should be captured by unintrusive radar sensor technologies



Capture data such as unreported falls and near-falls



Capture data to determine upright gait stability

<https://braceworks.ca/2019/07/24/health-tech/gait-and-balance-dysfunction-in-older-adults-challenges-and-interventions/>



Capture data to analyse sleep patterns, activity levels, frequency, mobility



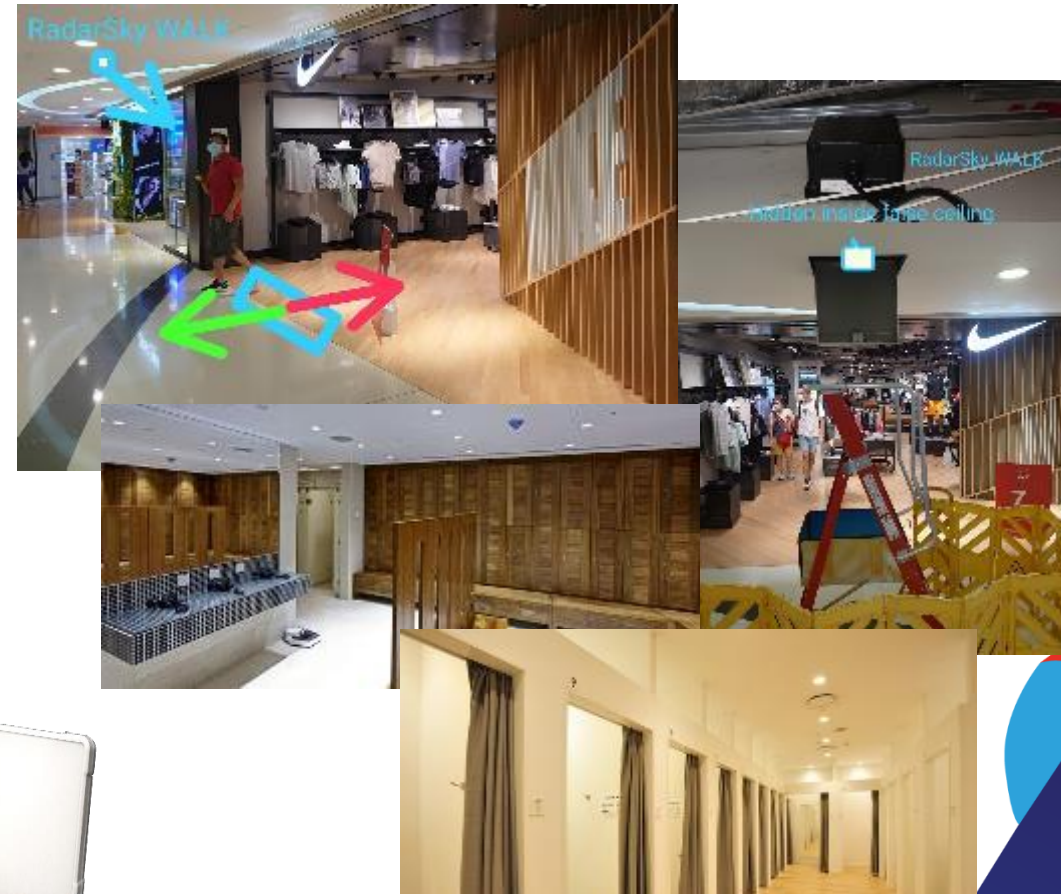
0:00 / 1:39



- MIoT Ltd - a start-up from HKSTP had shipped various IoT radar solutions in Hong Kong and Shanghai

Benefits

- Avoid breaching data privacy, radar solutions is used for accurately counting foot traffic in retail malls, shops and communal spaces (e.g Fitting rooms, gym, washrooms)
- mmWave radar with Cellular NB-IoT network is completely safe for human. Easy for fitting and installation, Data visualized in Dashboard for management, other sensors like Indoor Air Quality sensors and HVAC control system can be developed based on traffic modelling and sensors
- Lower Maintenance cost



Comfort Convenience and Control, Safety & Prevention (3CsSP)

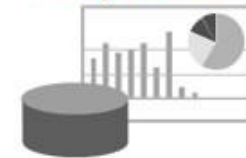
Panasonic



- Cloud-service air conditioning
- In-home monitoring and comfort services



FUJITSU



- Non-contact life-sign sensors
- Activity rhythm analysis

Attentive monitoring of seniors' activities



Monitoring via appliances embedded in living space

Occupant

Provides safety, peace of mind, and comfort



Family



Providing an integrated system that makes it easy to understand activity rhythms

Caregiver

Reduces workload of making rounds



Detecting abnormal patterns in response to each person's activity rhythms

Operator

Improves customer and employee satisfaction and work efficiency



From Smart Home, Smart Building, Smart Neighbourhood

Conceptual Framework for Implementing “Double-smart” Approach

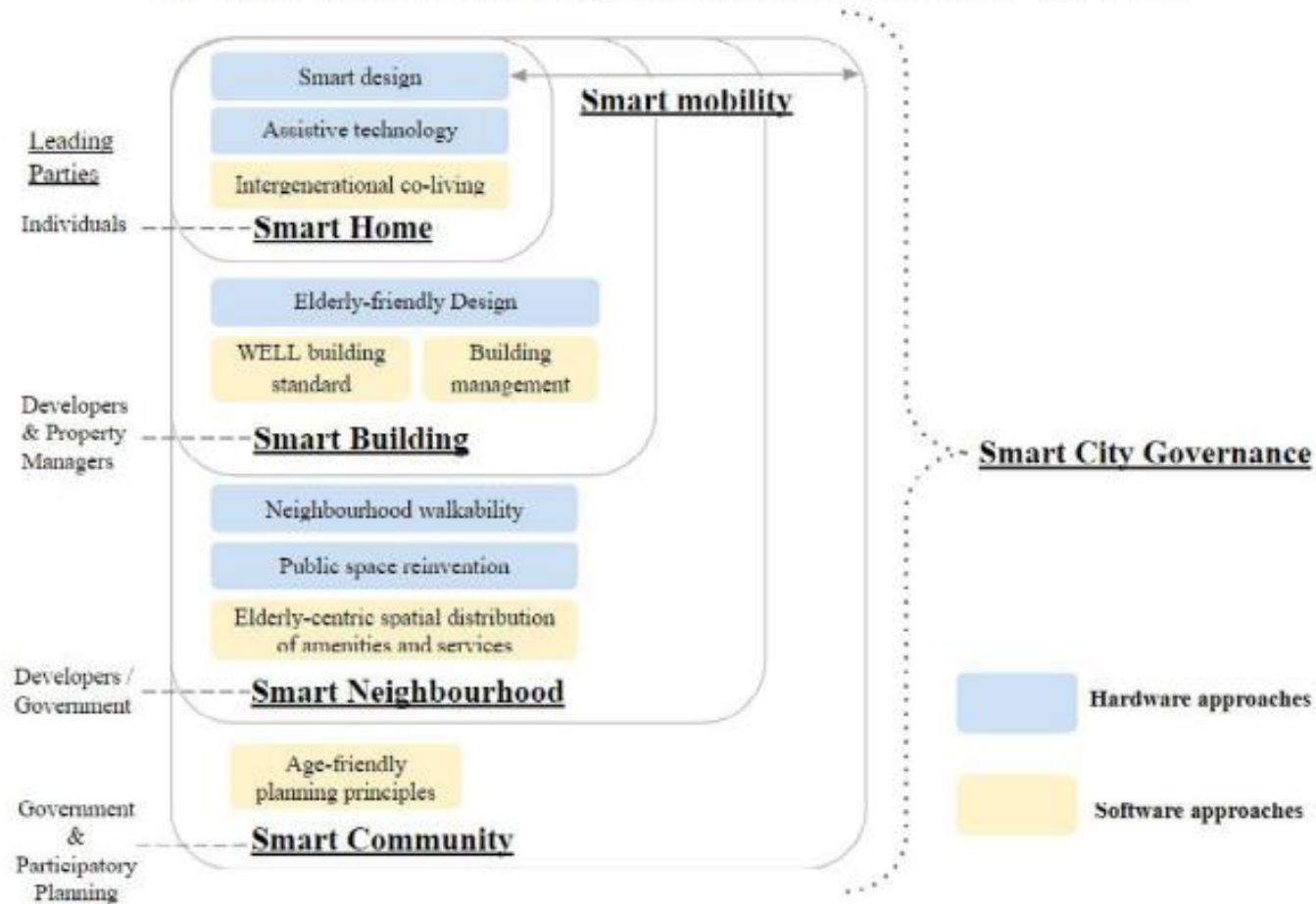


Figure 2 Key concepts in re-defining smart city from the elderly-centric perspective

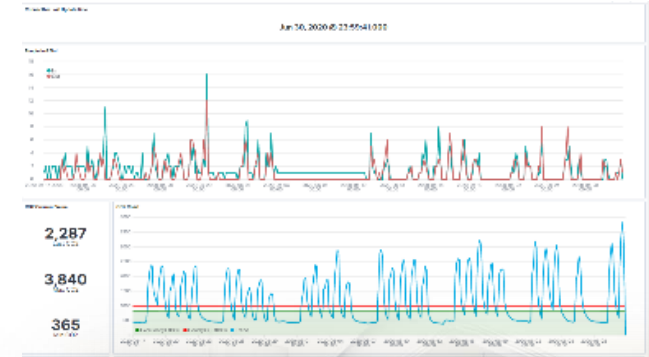
Data



My vision for the smart home technologies for elderly care



Vayyar Home



Track elderly activities
Fall Detection
Sleep quality analysis
Gait stability analysis
Indoor Air Quality control
Indoor Air Climate Control

People Tracking in communal area
Presence detection
Activities analysis
Indoor Air Quality control
Indoor Air Climate Control





HC3A250 Bluetooth version

Real-time monitoring check your heart at any time

- Monitoring heart health
- Ultra lightweight Small
- More performance stable
- Easy to use simple
- Industry Leading

Monitor the automatic notification contact

Specialist certified physician online Q & A

Double-click the APP button to notify the contact

15 minutes free monitoring report service

Double-click the action button to notify the contact

Certified physician for one-on-one telephone consultation

Video Interview by Daniel Chun with York Hwe of BISA
<https://www.facebook.com/watch/?v=358422021867617>



HOME-BASED HEALTH MONITORING

Self-administered diagnostic monitoring and remote health tracking

➔ **Self-Administered Test**

Home-based monitoring:
clinic visit/ medical staff NOT required

➔ **No Wait Time**

Additional remote monitoring modality to streamline long queues in CT/ USI/ MRI



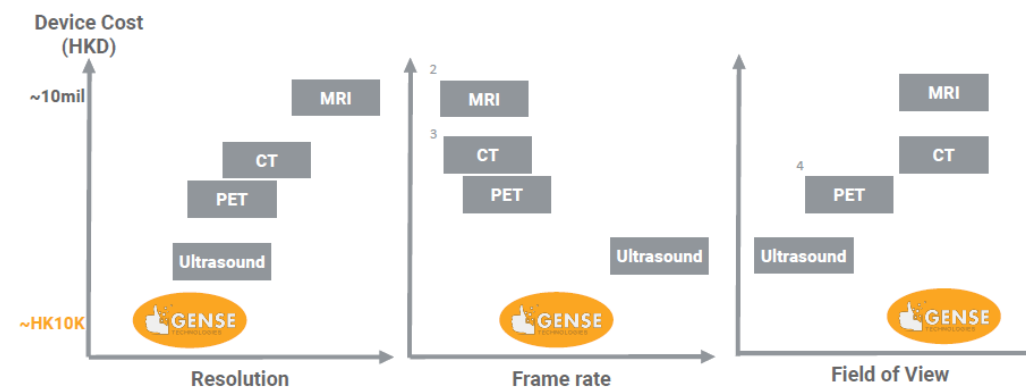
Weekly/ Daily Self-Test

5-mins passive test on chest/ abdomen/ limbs for health scanning



Flag Health Concerns

Flag up health concerns in lungs/ liver/ tendon



MRI = Magnetic resonance imaging PET = Positron Emission Tomography CT = Computer Tomography

²MRI Provides high resolution at 8 fps for regional mapping with the low dose of recommended amount of contrast agent.

³CT in lungs has low frame rate because of low dose radiation with contrast agent.

⁴PET in lungs typically small FOV since low dose of tracer; specifically to screen lung nodules.

Is there any other alternative ?

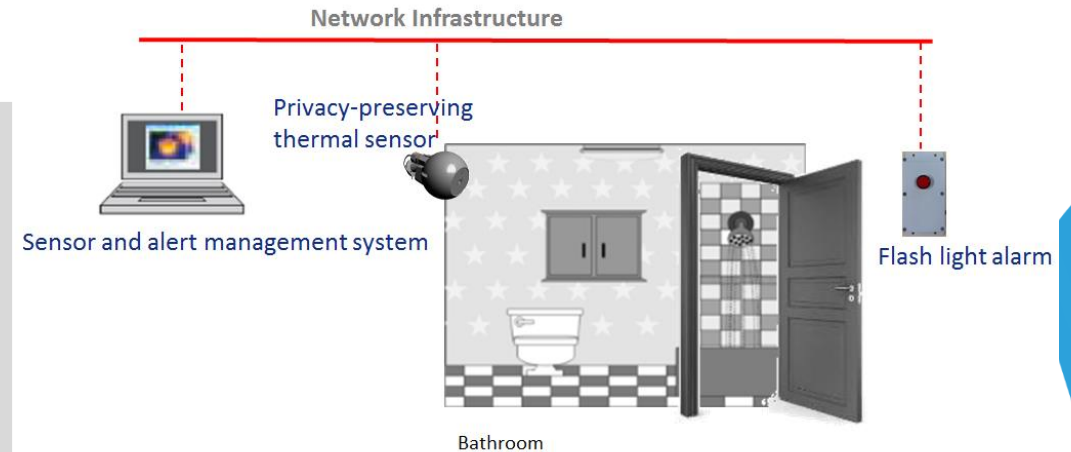
Infrared Thermal Sensing Safety Alert System for Elderly

長者紅外線熱能感應安全監護系統



Logistics and Supply Chain MultiTech R&D Centre
 物流及供應鏈多元技術研發中心

The Infrared Thermal Sensing Safety Alert System for the Elderly is a privacy preserving system which monitors an individual's safety in a private space by analysing the real-time thermal data of the private space to detect the human movement. When the body movement of the individual is not detected for a period of time, an alarm will alert the caretakers that the individual is in danger. It consists of several movement sensitivity levels and can be installed easily inside a toilet or a bathroom.



In 2019, the system won a Gold Medal at the 47th International Exhibition of Inventions Geneva. It also received a Silver Medal at the 1st Asia Exhibition of Inventions Hong Kong which was held in 2018. There were wide media coverages about the system.

Radar for Every Home

Microwave Journal
Frequency Matters.

www.microwavejournal.com/blogs/17-gary-lerude-mwj-technical-editor/post/31250-a-radar-in-every-home-maybe-two-or-three

A Radar in Every Home — Maybe Two or Three

October 24, 2018

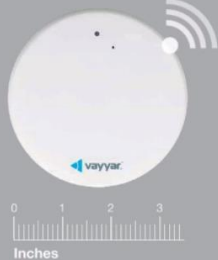
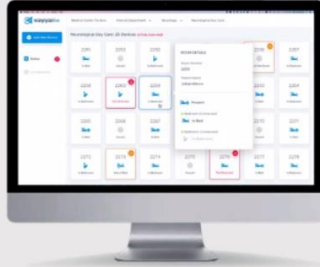
New commercial applications for radar was the theme of the opening keynote presentation of the 2018 EDI CON USA conference, held in Santa Clara on 17-18 October. **Ovi Jacob** of **Vayyar Imaging** energetically described novel and intriguing applications enabled by Vayyar's ultra-wideband (UWB) radar IC.



Mammography Sans X-Ray

Vayyar Imaging was formed in 2008 with the vision to create a means for detecting breast tumors without using ionizing radiation (i.e., X-rays). Believing radar is a viable alternative, Vayyar developed an UWB radar IC (the VYYR2401-A3) with an upper frequency range of 20 GHz that integrates some

Vayyar HOME

11 Vayyar Imaging Confidential 18/12/19

Vayyar HOME turns any home into a smart home, protecting you inside out.

Inside, Vayyar Home monitors and analyzes your health including:

- ▶ Activity analysis
- ▶ Sleep patterns
- ▶ Breathing

Out, we keep you safe:

- ▶ Detecting falls
- ▶ Intruders
- ▶ Automation



<https://www.microwavejournal.com/articles/print/31250-a-radar-in-every-home-maybe-two-or-three>

With MIoT and Vayyar



GIES 樂齡科技博覽暨高峰會
Gerontech and Innovation Expo cum Summit

關於我們 一般資訊 網上高峰會 博覽 參展單位資訊 傳媒中心

AAA Languages

19-22.11.2020
香港會議展覽中心
展覽廳1A-C
博覽無需登記免費入場

香港會議展覽中心 展覽廳 1A-C

網上高峰會: 2020年11月18-20日 (星期三-五)
博覽: 2020年11月19-22日 (星期四-日)

登記
網上高峰會

Reading Resources and references



Smart City 3.0 E-Book



<https://smartcity.org.hk/en/info-smartcity.php>

Smart Vision Magazine



<https://smartcity.org.hk/en/info-vision.php>

Blueprint Advisory Report(s) 2016, 2017, 2020



<https://smartcity.org.hk/en/info-research.php>

Abstract

One of the most important element for assisted living for elderly care should be in home monitoring

Smart Home technologies typically offers these promises Comfort, Convenience, Control, Safety and Prevention (CCCSP). The 3Cs brings a lot of time-saving, automation and value in smart living and possibly increase the value of your property. Whereas, Safety and Prevention (SP) helps provide a well-balanced preventive care environment for the household occupants. And to do this, either you can rely on human or machine to do the same job. This presentation will focus on technology that focus in monitoring in home. Then the next question we asked ourselves is what are the problems that are burning and need to be solved with new latest smart home and IoT technologies. We want to focus on the problem in elderly occupants falling in any residence – inside home or elderly centre. We all know that any type of falling will be detrimental and will cause head injury and fracture, but this problem magnifies more for anyone older than 65. According to the Elderly Commission in Hong Kong, each year 25% of community dwelling elders suffer from fall. 75% of them get injury include head injury and fracture. Elders who fell in the past six months had shown to have increased risk of fall in near future. With various solutions available in the market, what are the most useful and commercially sound implementation of using these assisted living technologies. Are these technologies applicable in the Hong Kong market. This session attempts to provide insights to elderly home care centres, property developers and property managers how best to adopt latest technologies in home care for the elderly without infringing privacy issues

Reference:

Elderly Commission (2020) Retrieved from https://www.elderly.gov.hk/english/books/files/fall_prevention/Fall_Prevention_booklet.pdf

HKIP Journal (2019) – Page 28-32 To what Extent does smart city technologies solves problems with our aging population
Retrieved from

<https://static1.squarespace.com/static/591e6a001b631bff6312f919/t/5d89affc87e82e702f513c8f/1569304663088/f+HKIP+Journal+33.pdf>

The author / presenter is Daniel Chun who is currently CEO at a smart living – home automation technology company with over 30 years experience in the technology sector from telecom infrastructure, network services to consumer electronics; the author is also serving as the Vice President at Smart City Consortium

Twitter @djychun
Wechat @dctw200

