Cities for All Ages: Singapore Use Case

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Abstract. *Healthcare & well-being needs a revolution - and it is needed now*. In the coming years, the relationship between people and digitized systems is going to change due in large part to the adoption of ambient technologies in daily life and to the considerable development in AI (Artificial Intelligence). This includes emerging 5G technologies, small medical devices, non-invasive new sensing technologies, collaborative robots (e.g. Amazon Echo, Google home, etc.), Internet-of-Things (IoT) applications, and secured data exchange mechanisms (e.g. Blockchain). Over the next 20 years there will be demographic shift from predominantly younger populations to older ones. Current models of care and pathways need to be transformed to become more citizen focused as well as to support greater community resilience and sustainability. This will require different approaches to innovation in information technologies to improve quality of life for people as they age, to reduce onset of frailty as well as to better support those with long term conditions employing self-management and prevention strategies. This paper describes on-going project between NUS, IMT, HDB (Housing Development Board), and AXA Insurance, and aiming at preserving patient health and avoid deterioration of their quality of life (and also of their families) by fully utilizing disruptive information & communication technologies. Additionally, the goal is to help improve the quality of life of citizens while reducing the health-care expenditure.

Keywords: Smart living · Human-environment interaction · IoT · AI · Ageing & wellbeing people

1 Introduction

1.1 Public Health vs. Wellbeing

The WHO Regional Office for Europe now embraces Wellbeing as a vital public health metric. The 2015 WHO European Health Report stated[1]: "Health 2020 implementation is gaining momentum, but broader monitoring is needed to capture its true impact,

[1] https://www.cdc.gov/hrqol/wellbeing.htm.

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including concepts such as community resilience, empowerment and sense of belonging"

Why is wellbeing useful for public health?

1. Wellbeing integrates mental health (mind) and physical health (body) resulting in more holistic approaches to disease prevention and health promotion.
2. Wellbeing is a valid population outcome measure beyond morbidity, mortality, and economic status that tells us how people perceive their life is going from their own perspective.
3. Wellbeing can provide a common metric that can help policy makers shape and compare the effects of different policies (e.g., loss of green space might impact well-being more so than commercial development of an area).
4. Measuring, tracking and promoting wellbeing can be useful for multiple stake-holders involved in disease prevention and health promotion

Cities and governments are increasingly placing emphasis on Wellbeing in public policy and urban planning. This is consistent with the paradigm shift that has taken place in public health – from a focus on morbidity and mortality to a focus on health and wellbeing.

1.2 Behavior Change

Aging natural process is associated with significant behavior change and continuous decline in physical and cognitive abilities. To be more specific, we consider the distinct phases of aging from active aging to dependent aging through frailty targeting three age groups as following (see Fig. 1): **Active ageing**: 55+ considered as future aging. **Pre-frail and frail**: 60+ considered also as active people, but facing chronic diseases (e.g., diabetes type 2, respiratory disease, etc.). **Dependent**: 65+ might face cognitive and physical decline.

Fig. 1. Aging trajectories of health and functions

Detecting behavioral change, and predicting corresponding risk, in early evolution stages is a keystone to better adapt intervention on elderly people and improve their quality of life. Nevertheless, existing psychogeriatric methods diagnose a limited number of possible changes at assessment time and in assessment place [7].

2 Non-invasive Based Technologies

Our ambition is to focus on Non-invasive based technologies to monitor and assess aging people over extended periods in their living environment [1] and detect insights of long-term changes in their behavior based on key geriatric factors [2]. This involves, as illustrated in figure below (see Fig. 2), **Sleep quality monitoring** through bed-based sensors, (for example, micro bend optical fiber sleep mat), and/or wearable devices, such as Fitbit; **Fall detection and prevention** using the inertial measurement unit of a smartphone attached to the subject's body with the signals wirelessly transmitted to a cloud-based server or non-invasive new sensing technologies (ex. using ambient WIFI signals, smart meters); **Mobility monitoring** using wearable activity trackers (smart watches) and urban low energy communication (e.g. Beacons, Sigfox, LORA).

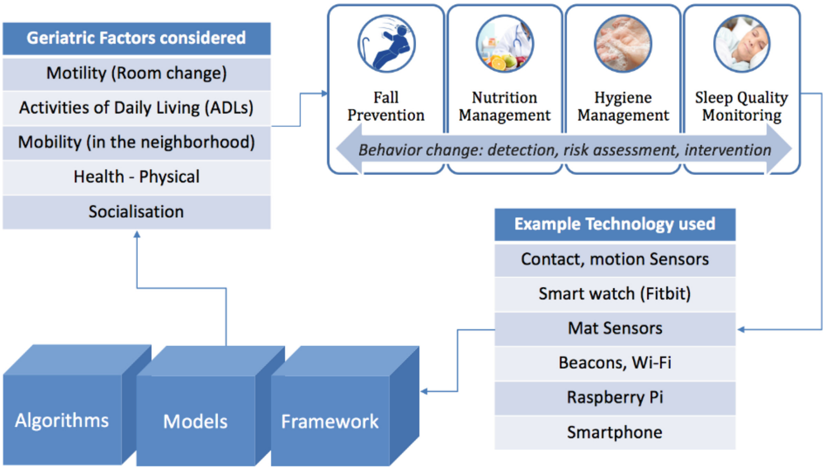

Fig. 2. Use cases for monitoring and assessment of human behavior based on key geriatric factors.

Generic human activity recognition system for smart living - One of the main problems of current activity recognition systems is that the models learned for a given environment and user cannot be used in another context. Given the great heterogeneity of data acquisition systems for smart cities and the number of potential users, that lack of generality can be disastrous. To make activity recognition systems available for smart cities, this project will conduct research on generic recognition systems. Our approach is to capture the inherent semantics of sensor activations. For example, when a binary sensor that monitors the state of a given door gets activated, we will register a "door open" action. Developed framework and associated integrated sensors, where deployed in real life condition in close collaboration with Housing Development Board (HDB) and Senior Activity Centre in the area of Tech Ghee (Ang Mo Kio) in Singapore.

3 Singapore Test Bed and Preliminary Results

3.1 Sensing and Data Collection Indoor

In order to enlarge the audience of the project to the research community and industry players, numerous events and briefing sessions were organized to share about the project at its local scale and internationally. Several types of sensors where deployed in 20 homes of people living in the area of Teck Ghee Neighbourhood with the support of Senior Activity Centre, Town Council and HDB (see Fig. 3):

- **Motion sensor**: it detects indoor movements and it will be in the main room, bedroom, kitchen, and bathroom.
- **Contact sensor**: it will be placed on the fridge to infer kitchen activity such as preparing meals and it will be placed on the main door to monitor the user interaction with the outdoor environment.
- **Optical fiber mat sensor**: it detects bed occupancy, heart rate, breathing rate, body movements, bed-exit moments, sleep quality. The sensor is to be placed underneath the user's bed mattress targeting the upper part of the body.
- **Fitbit and similar**: it is a wearable type of devices which can provide information about user's movement activities, heart rate, sleep and sleep quality.
- **Smartphone**: embedded sensors such as magnetometers, accelerometers, and gyroscopes can predict user's movement pattern, i.e., sitting, walking, cycling, riding. etc.

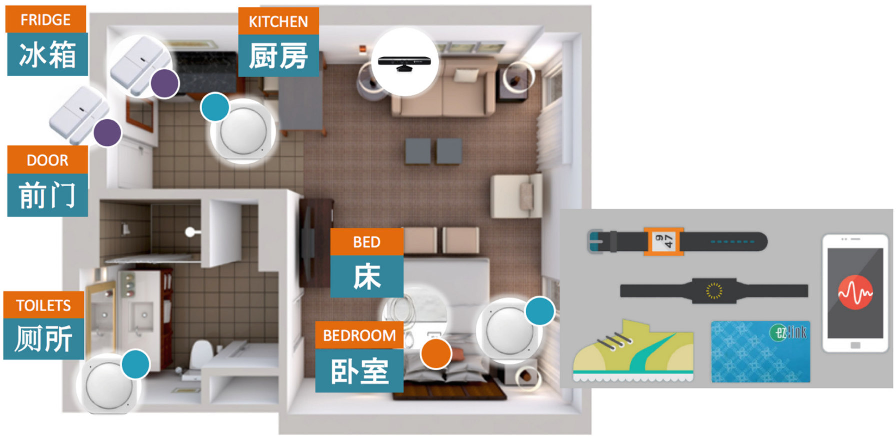

Fig. 3. Distribution of the unobtrusive sensors in a typical user's home

3.2 Sensing and Data Collection Outdoor (Neighborhood)

Beside de deployment indoor in the home of frails people, we managed to deploy about 15 Beacons (Bluetooth Low Energy), in the same area, in several places of interest (Food Court, bus station, physical activities areas, Senior Activity Centre, Town Council premises, etc.) to monitor outdoor location activities (Fig. 4). Additionally some participants where provided with a Fitbit to monitor physical activities.

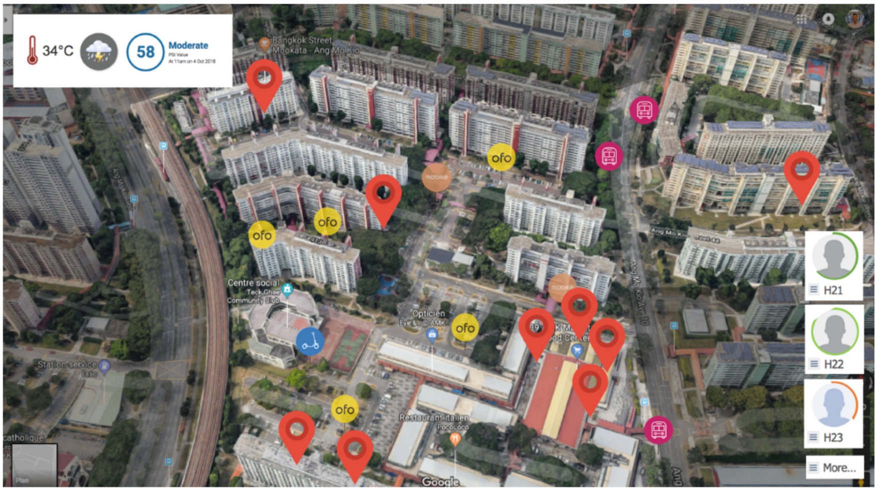

Fig. 4. Deploying a local neighborhood - community partners

Indoor and outdoor data, including open data (Air Quality, weather conditions) where analyzed and integrated in a dashboard for experts and end-users.

3.3 Dashboard and Mobile App Intervention

Several personalized dashboards, for data analytics and community monitoring, and Apps, for individual data collection and intervention, were designed to target several key players: end-users, family members, formal and informal caregivers, organizers, professionals, technical experts, and so on could monitor, be reminded/notified, to activate corresponding action (Human and/or system intervention). For example, Figs. 5 and 6 gives an example of a user-friendly interface displaying some activities of daily living (sleep time, kitchen activity, and toileting time) and some personalized tips, and urban data (air quality, weather, bikes location etc.).

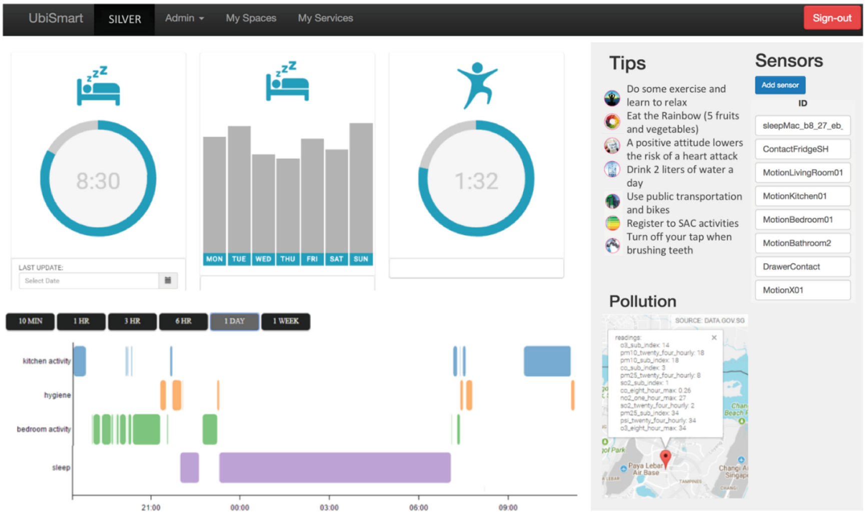

Fig. 5. Distribution end-users and caregivers' dashboard

The dashboard is facilitating the observation of different geriatric factors groups over time. Caregivers can select one category and display more details, for example in term of Instrumental Activities of Daily Living (Cooking, hygiene, …) and Motility (ability to move across rooms, rooms number of visits and time spend…). The different curves bring to sub-sections of the geriatric groups. Data can be seen with the granularity of the low elementary actions and measures (set of sensor events transferred to the data repository and displayed in this dashboard).

3.4 Preliminary Results

More than 70 participants were actively involved: 21 elderly people equipped (sensors deployed in their own homes), 5 caregivers equipped (using the App and Dashboard), 12 experts (involved in the design and in the validation phase), and more than 35 interviewed (understanding the users requirements).

Historical data can be correlated using the Senior Activity Center's presence sheet, activity logs, visit observations and updates about the participants to the caregivers (ex: hospitalization, family visit, holiday trip) (see Fig. 6). This data can be annotated by the local caregivers in order to keep track to the evolution of the monitored factors. When a peak is observed, the data is crossed checked with other sub-category data and external datasets (including third parties' knowledge).

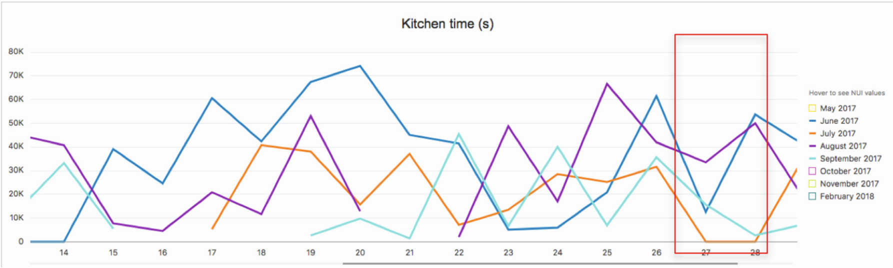

Fig. 6. Data annotation related to change of behavior (for example no activity in July 2017 due to holiday)

4 Related Work

In the medical field, behavior change refers to abandoning health-compromising behaviors (e.g., drink, smoke and over-eat), and maintaining health-improving behaviors (e.g., physical exercise, weight control, preventive nutrition and dental hygiene). Geriatricians use psycho-geriatric scales and questionnaires to analyze elderly people behavior and detect possible health changes. They study question replies and task executions, such as “How many falls did you have in the last 6 months?” [3], “Have you dropped many of your activities and interests?” [4] and “Do you perform your activities of daily living independently (A), not spontaneously or not totally or not correctly or not frequently (B), only with help (C)?” [5]. These scales compute psycho-geriatric scores evaluating physical, emotional, nutritional, social and cognitive abilities. However, Psycho-geriatric scales are insufficient to follow-up health status on a daily basis [6] as subjective information and missing details might influence assessment results [7]. Therefore, Thus, geriatricians need technological services to acquire new objective observations that complete their medical observations [8]. Monitoring technologies can help follow-up elderly people at home and in the city, in order to early detect possible health changes [9].

5 Conclusion

Singapore pilot site team is deploying its technological platform for Ambient Assisted Living. This platform enables to gather the raw signals from deployed sensors and to interpret the data (reasoning engine, rule-based algorithms). This technology infers several measures on Activities of Daily Living and other parameters such as mobility. From this platform, the team co-designed a set of tools to be used by the “caregivers” with the help and guidance of several partners: academic partners working on ageing, community organizations and user caregivers themselves (from partner Senior Activity Centers).

The team have performed interview sessions with elderly participants and with caregivers in order to assess the system overall acceptance and quality of the intervention. Preliminary results are encouraging as most of caregivers saw the impact of such a solution in their daily routine activities. Even if most of the end-users adopted the system, they still didn't perceive an impact on their daily activities. Large scale deployment strategy needs to be performed to provide appropriate impact analysis of people lifestyle.

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