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SINGTRACEX: NAVIGATION SYSTEM TO ADDRESS WANDERING BEHAVIOR FOR ELDERS AND THEIR CAREGIVERS

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Abstract. The issue of an ever-increasing ageing population has been the increasing burden on caregivers to care for the elderly population. Caring for elders, especially those diagnosed with dementia, can be challenging. People living with dementia (PWD) require extra care and attention from the caregivers due to the associated behaviours that come with dementia. Wandering is a frequent behaviour exhibited by PWD, which can bring about negative outcomes on the PWD as well as increasing the stress of the caregivers. Though many technological solutions exist, they are not widely deployed. This paper introduces a technological framework, bridging the localisation technologies to the needs of elders and caregivers. The aim is to minimise or eliminate the negative outcomes of dementia wandering and to reduce the burden and stress on the caregivers, thus improving overall well-being. In this paper, we study the application, SingTRACeX, features by considering user needs from the field study with 2 focus group discussions (FGD), comprising of 14 professional caregivers and coordinators. The proposed system features Real-time Location Tracking and Indoor Localisation. The location is determined by GPS location from the Sensor module when outdoors, and estimation using data from the WiFi module, and Bluetooth module when indoors. The indoor navigation provided by the Indoor Localisation module uses an A-star search algorithm. This paper could serve as a foundation that can be built upon over time as the needs of elders and caregivers may change over time, as well as the evolution of technology that may bring about new methods to address needs.

Keywords: Localisation, navigation, ageing population, dementia, Flutter, mobile application, e-health

1 INTRODUCTION

The World Health Organisation has reported the rise of ageing population, people over 60s, nearly doubled from 2015 to 2050 [1]. The demographic shift create a number of research interest to tackle the health and societal challenges. In particular, Singapore, an urbanised city-state, is facing the issue of an aging population, with the old-age dependency ratio predicted to increase from 13 elders per 100 working adults in 2010 to about 91 elders per 100 working adults in 2080 [11]. This poses an ever-increasing need for caregivers to care for the elderly population.

Dementia is a condition that affected one in ten elders, and the number is projected to increase over the years. People with dementia (PWD) are less capable of taking care of themselves, and require extra care due to the associated disorders that can come with it. In addition, there is presently no cure for dementia [3]. Wandering is one of the many behavioural disorders that occur frequently in PWD. One in five PWD was reported to exhibit wandering behaviours and prevalence estimates were reported to be as high as 63 %. Wandering can bring about negative outcomes on PWD, including accidents, going missing, malnutrition, social isolation, and injury among others. In addition to negatively affecting the well-being of the PWDs, it increases the stress of the caregivers caring for them as well [10].

Technological solutions, such as mobile applications, for assisting caregivers or to address dementia wandering are numerous. These solutions are found to be either using GPS for localisation limiting in an indoor environment, or addressing only few specific needs of wandering activity. Global Positioning System (GPS) has been integrated in smartphone where satellites technologies, radio wave, is used to determine the user location outdoors. For the indoor environment where GPS is obstructed by the roof and multi-storey buildings, other resources are being used such as WiFi routers, Bluetooth beacons, etc. to station or relay at targeted spaces. In particular, [8] proposed a practical closed-loop WiFi-based indoor navigation system focusing on the construction of the indoor map, collection of data and testing of service. Anyplace indoor navigation services introduced a state-of-the-art modular and scalable navigation architecture using WiFi, on-board smartphone sensors and outdoor positioning system such as Google Map [16].

While the general-purpose indoor navigation model showed great potential and readiness in the deployment, it relied heavily on the WiFi's received signal strength. Bluetooth beacons can be installed within buildings to act as location ground truths indoors to complement WiFi and sensor-based position estimate. Furthermore, designing the context-aware navigation systems requires unique features that is extracted from the the needs and feedback from users [6]. There are several solutions aimed at dementia wandering and recovery. AngelSense for Elderly introduced a GPS tracking device to track the live locations of PWDs [5]. The device is also capable of detecting pre-lost patterns and allows PWDs to call their caregivers for help. Similarly, BoundaryCare is an application solution providing tracking and pre-lost detection functionalities through a combination of GPS and cellular tower locations and geofencing technologies [7]. However, these solutions are not as effective indoors as they largely depend on GPS to determine the locations of PWDs. Additionally, the solutions are costly and may not be affordable to those who need it.

Therefore, this paper aims to introduce a technological solution in the form of an application system that addresses the needs of elders, especially PWD, and their caregivers in the urbanised city, such as Singapore, as the following:

- Propose multi-source position estimate and navigation system architecture to develop on cross-platform framework such as Flutter [2].
- Support real-time location tracking and indoor navigation.
- Feature conceptualised and designed to address the needs of elders and caregivers, mainly pre-lost detection and prevention as well as locate and navigate wandered seniors.

2 REQUIREMENTS FOR THE APPLICATION SYSTEM

Answering to the wandering activities, real-time feedback of the current location and direction, refer to as "positioning and navigation system", directly address the challenge. Furthermore, it is equally crucial to build the solution on the device that are widely accepted by the users. In fact, it is estimated that more than 5 billion people own the devices [13]. The adoption of the mobile technology has rapidly risen among the seniors to more than double as compared to 2013 [4].

Hence, in this paper, we proposed the application system architecture that leverages on the resources equipped in smartphone and widely available technologies such as GPS, WiFi and Bluetooth.

The requirements for the application system are gathered primarily from two sources: a generic conceptual map and technological framework for managing dementia wandering [12] and our focus group discussion with caregivers from community care centres in Singapore. Precisely, the user needs and requirements were consolidated from 2 mixed FGDs, comprising of 14 professional caregivers/coordinators.

As a result, the list of requirements for the application system is identified in Table 1.

3 SYSTEM ARCHITECTURE

Figure 1 illustrates the system architecture of the application, comprising a mobile application, Flask server on Python, and an external Firebase Cloud Platform

Type	Description
Adopted from initial requirements and related studies	Provide accurate location of PWD via GPS and Indoor Localisation techniques
	Identify basic wandering behaviours: pacing, lapping
	Identify eloping behaviours using geofence technologies
	Alerting caregivers if a PWD is lost
	Informative assistant on wandering behaviours and how to intervene
	System must be reliable to achieve the project objectives
	System must be portable to target as many devices as possible
Adopted from FGD	Real-time location tracking of PWD
	PWD check-in into care centres
	Manually marking PWD as lost or found
	Directing caregivers to locations of PWD (navigation)
	Profile the location and wandering history of PWD
	Identify pre-wandering patterns based on profiling data
	Detect anxiety using available body sensors
	Scheduling system: reminders for caregivers and PWDs

Table 1. List of proposed requirements

(FCP) back-end. The mobile application comprises features designed for the caregivers and elders, developed using the Flutter framework to target both iOS and Android platforms. The Flask server contains computational-heavy back-end logic, including indoor location estimation of a user and detecting pre-lost patterns using data collected from the application. The FCP is utilised primarily for its real-time capable database and cloud messaging between various users' devices.

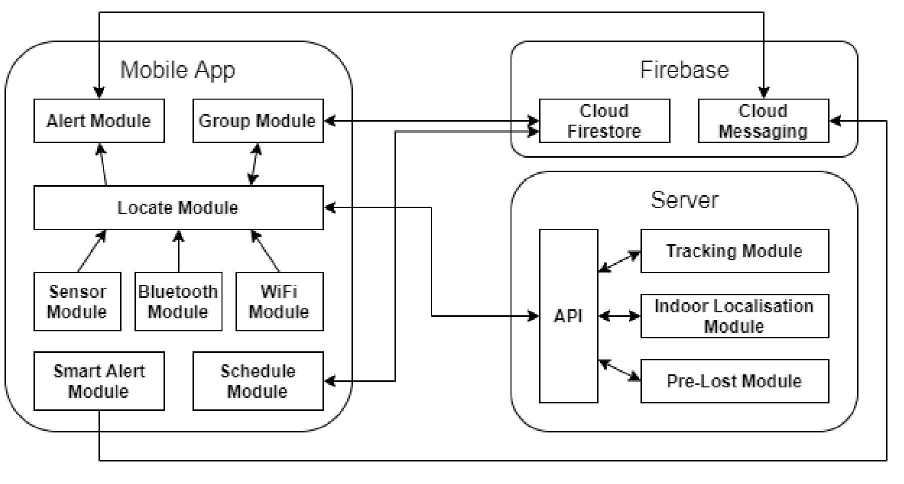

Figure 1. SingTRACeX system architecture

3.1 Real-Time Location Tracking

The location of a user is determined through two methods:

- GPS location from the Sensor module when outdoors;
- Estimation using data from the WiFi module, and Bluetooth module when indoors.

The WiFi and Bluetooth modules continuously scan, respectively, for received signals from WiFi access points and Bluetooth Low Energy (BLE) beacons. The WiFi data and BLE beacons are collected and set up when the system is initially deployed at an indoor location, which can be used to perform WiFi fingerprinting and beacon pass-by detection. For the Wifi fingerprinting, the signal strength of the WiFi access points formed a Fingerprint databased and used by the prediction model to estimate the current location. For the beacon pass-by detection, as the name implies, when the user device passby a beacon, the receiver will capture the beacon identity and the location is determined. Both WiFi fingerprinting and prediction via Bluetooth beacons are methodologies of indoor localisation [17] [18], which is necessary to obtain an accurate indoor location of a user due to the inaccuracies of GPS indoors. The model for WiFi fingerprinting is obtained from a previous work conducted in the School of Computer Science and Engineering, NTU [15].

As shown in Figure 1, the data from the WiFi and Bluetooth modules, along with the GPS location obtained from the Sensor module, is passed to the Locate module, and subsequently to the Indoor Localisation (IL) module on the server, periodically. The server returns three results to the Locate module:

- Estimated location using WiFi prediction model;
- BLE location upon detecting BLE becaons;
- Estimated location using GPS.

The user is determined to be indoors if either of the first two results holds, and the location is estimated using the WiFi estimated location and/or BLE beacon location. If both locations are available, a multilateration algorithm is used to estimate the location. Otherwise, the user is determined to be outdoors and the estimated location is the GPS location.

A caregiver may track the location of elders in the same group as him/her, as determined through the Group module. A stream channel is opened via the Tracking module on the server between the caregiver's device and the elder's device. It allows the elder's device to continuously stream its location to the caregiver.

3.2 Navigation and Indoor Way-Finding

The Indoor Localisation module can additionally provide indoor navigation for a caregiver that is tracking an elder. During the initial deployment of the system, a floor plan of the indoor location is drawn up in addition to the collection of

WiFi data and setting up of BLE beacons. Way points are uniformly distributed across the accessible path ways based on the floor plan, and A-star search [9] is performed to obtain a fastest path from the caregiver's location to the elder's location, which is then returned to the Locate module for display. This process is illustrated in Figure 2 where the dots represents the way point distribution on accessible path ways.

If the caregiver is outdoors, he/she will be directed to continue the navigation in the Apple Map or Google Map application that is pre-installed on iOS and Android devices, respectively.

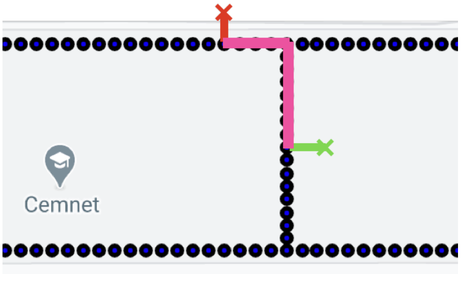

Figure 2. Path finding using A-star search through the way points (green and red marks denote starting and ending points, respectively)

3.3 Firebase Cloud Platform

The Firebase Cloud Platform (FCP) is utilised primarily for several of its services that the application system requires. Table 2 illustrates the services utilised along with their respective considerations: Overall, Firebase reduces development time by eliminating the need to develop additional subsystems and functionalities. Cost-wise, both authentication and cloud messaging functionalities are provided for free, while the cloud database has a very generous free-tier usage daily. Additionally, Firebase guarantees a 99.99 % up-time and provides automatic load balancing for optimised performance [19].

3.4 Flask Server on Python

The server component is a Flask microserver developed and running on Python. The server contains computational-heavy back-end logic, including:

- Indoor location estimation of a user.
- Computing navigation routes.
- Detection of pre-lost patterns using data collected from the application.

Service	**Considerations**
Authentication	Reliable and secure authentication system as compared to a self-designed authentication system through Flask
	Easily integrated with Google Accounts and Apple ID authentication.
	Users of Android phones and iPhones should have an existing Google Account or Apple ID
Firestore Cloud Database	Built-in security with Firebase Authentication.
	Detailed data access logs.
	Automated backups.
	Scalable for large applications.
	Real-time capable to support the real-time features of the application system.
Cloud Messaging	Push-notification services.
	Eliminates the need to self-design an alert system.

Table 2. FCP services utilised and their respective considerations

The back-end logic is accessible from the mobile application via REST API requests to the server, depicting in Figure 3. An encrypted user ID of 16 alpha-numeric characters is appended as a request parameter to authenticate with the server. The ID is unique for each authenticated user, stored in the cloud database, retrieved and cached by the application during the startup process until the application is killed. This is implemented to prevent unauthorised users from guessing the request parameters and making illegal requests, which can hog up server resources, or incur additional costs due to the usage of services with quota provided by Google.

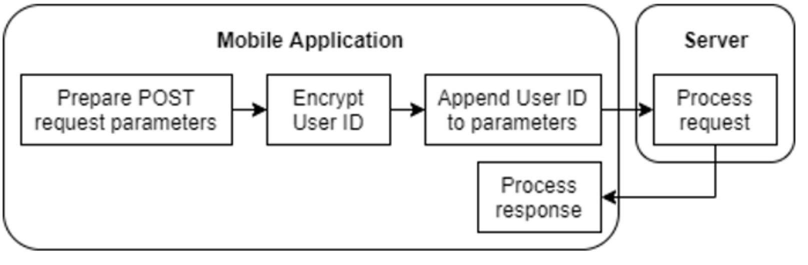

Figure 3. Communication between the server and mobile application via REST APIs

4 EXPERIMENTAL FEATURE DESIGN AND IMPLEMENTATION

An overview of the features that are available to caregivers and elders is illustrated in Figure 4, designed to meet the requirements gathered from the field study as mentioned in Section 2. The design concept for caregivers and elders differ where

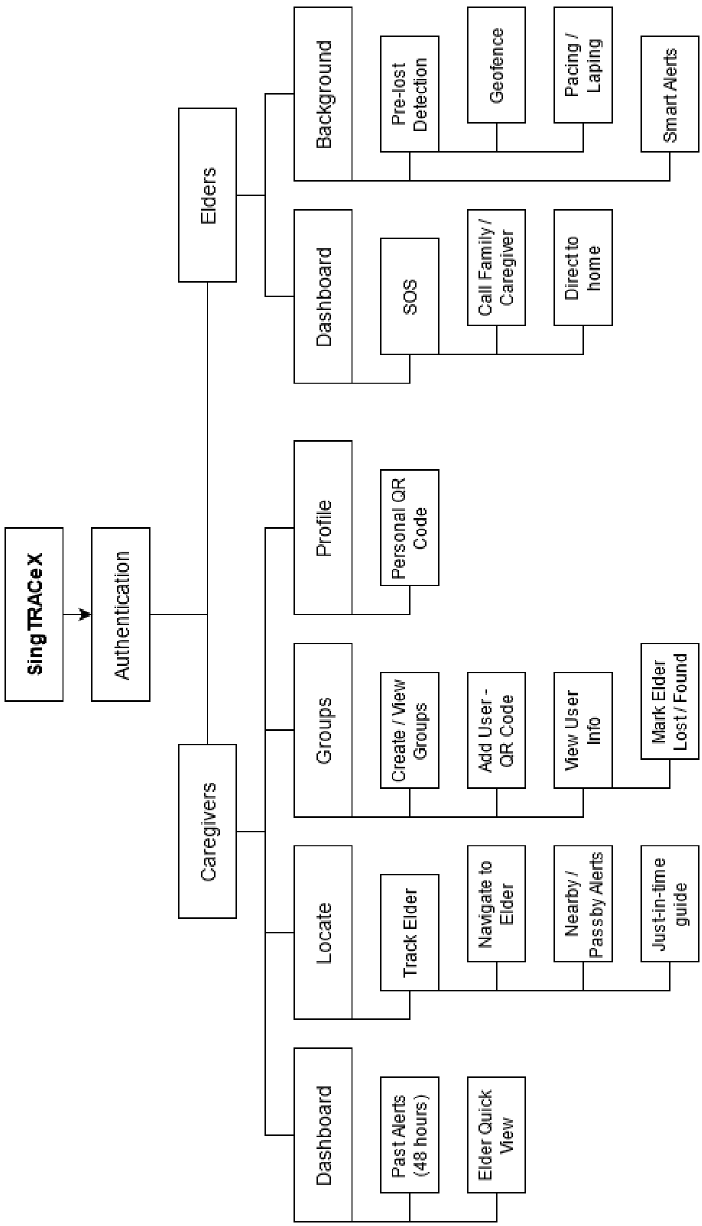

Figure 4. SingTRACeX features overview

the feature for elders are kept simple with SOS panic button and background update in order to perform pre-lost detection and prevention as well as locate and navigate. The caregiver is provided by the tool to quickly access to the elderly under their care under dashboard and locate them with ease.

This section discusses the design and implementation of the key features, excluding those already mentioned in the previous section. The features could be grouped into

1. user role management,
2. pre-lost detection and prevention,
3. real-time lost and found navigation, and
4. SOS button for elderly.

4.1 User Roles and Groups

Users are classified into one of two roles: caregiver and elder. The role assignment is arranged such that there could be more than one caregiver caring for an elder and a caregiver could be caring for more than one elder (Figure 5).

A user role is assigned when they first sign-in with the application via a Google account. Caregivers may only gain visibility to an elder's information, including tracking of their location, if both the caregiver and elder belong in the same group. Groups could be created by any caregiver, and they may add another user into the groups by scanning the personalised QR code found in that user's profile, as illustrated in Figure 6. The QR codes contain only internal IDs and are encrypted using simple ciphertext. This prevents leakage of private data and bad faith actors from identifying users through the internal ID.

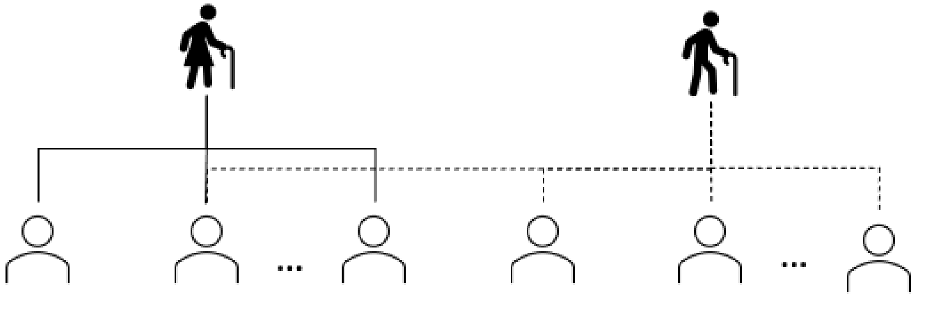

Figure 5. User roles assignment

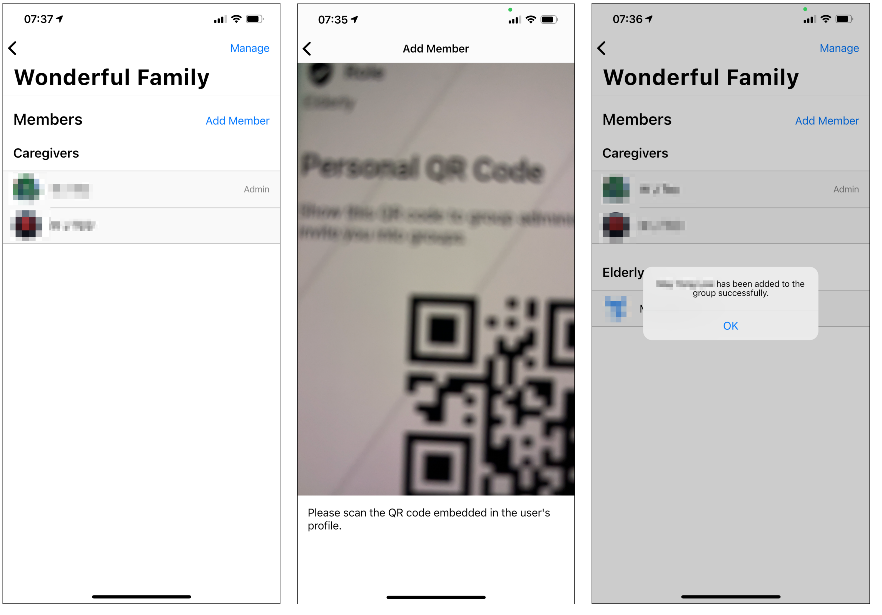

Figure 6. A caregiver adding another member via QR code

4.2 Pre-Lost Detection and Prevention

4.2.1 Smart Alerts

The Smart Alert System alerts caregivers automatically when certain conditions are triggered on an elder's device. The conditions are as follows:

- Elder's Application is terminated.
- Elder signs out of their account on the application:
  - While precautions have been implemented on the Elder's application to prevent accidental sign-outs, it is still entirely possible for Elders to sign out of their accounts.
- Elder device battery dropping below a threshold (configurable):
  - Individual alerts at 30 %, 20 %, and 10 %.
- Elder failed to check-in at care centre after a certain time:
  - During the registration process, caregivers indicate the days and time the Elder is supposed to be at a care centre (example: every weekday, 08:00–18:00).
  - If the Elder fails to check-in after the configured timing, an alert will be broadcasted.

- Elder failed to return home after a certain time:
  - After the Elder has been checked-out by a caregiver, the system calculates the estimated time required to travel home via Google APIs.
  - If the Elder has failed to reach home after that period of time plus a grace period, an alert will be broadcasted.

4.2.2 Lost and Found Alert System

Elders who are enrolled in care centres are checked in by the caregivers when they arrive. A geofencing algorithm runs in the background on the elders' devices to detect if an elder has wandered out of the care centre while checked in. A summary of the algorithm is as follows:

- Check if an elder's GPS location is outside the geofence with no indoor location predictions while checked in.
- If the GPS location is outside the geofence for more than 30 seconds, the elder is flagged as missing.
- The missing flag could be deactivated, i.e. flagged as found once again, upon confirmation by caregiver that the elder is safe.

Additionally, caregivers may also manually flag an elder as "missing" if the need arises. When an elder is flagged as missing, an alert will be broadcasted to all caregivers in the same group as the elder. Caregivers are then required to manually flag the elder as "found" to return his/her status to normal. An example of the manual flagging process is illustrated in Figure 7.

4.2.3 Pacing and Lapping Detection

A basic form of wandering behaviour detection is implemented via the detection of walking patterns, specifically pacing and lapping patterns. The detection algorithms are adopted from those proposed by Vuong et al. in 2011 [14]. Overviews of the pacing and lapping detection algorithms are illustrated in Figure 8 and Figure 9, respectively. Pacing detection is triggered if there are at least four locations in the visited list, which is the minimum number of locations required to detect minimally the pattern of A–B–A–B. Lapping detection is triggered if there are at least six locations in the visited list, which is the minimum number of locations required to detect minimally the pattern of A–B–C–A–B–C–A.

In the implementation, every time a Bluetooth beacon pass-by occurs, the beacon in question is saved to build the list of visited locations. The list is then passed into the back-end service to check for pacing and lapping patterns, as stipulated in Figure 8 and Figure 9. Both algorithms also run recursively, removing the first location from a copy of the visited list until the end of list, to detect possible patterns of pacing or lapping in subsequent locations from the first. Similarly, if an elder is suspected to be wandering based on the algorithm results, a push notification will

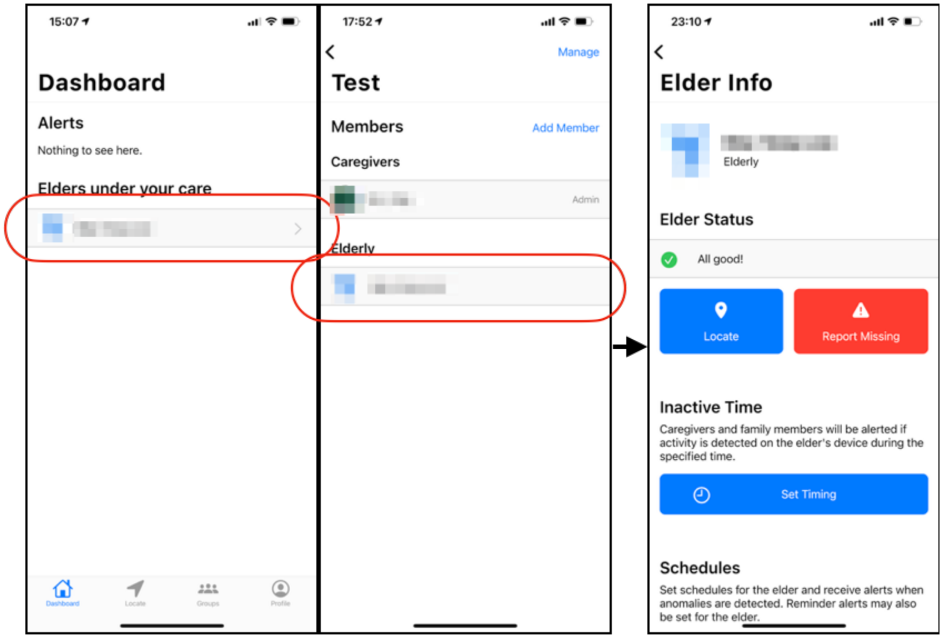

Figure 7. Manually flagging an elder as missing

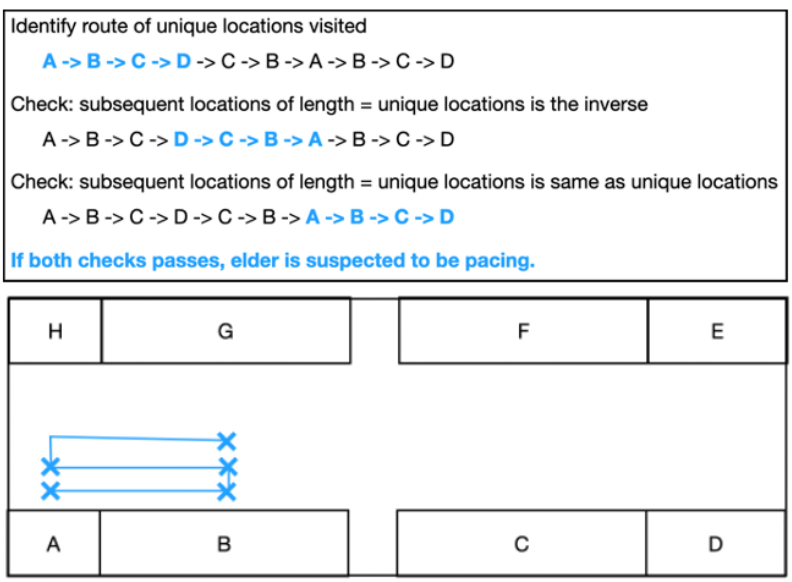

Figure 8. Overview of the pacing detection algorithm

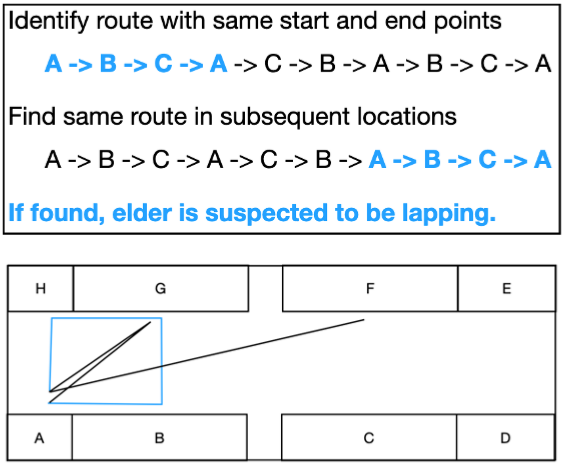

Figure 9. Overview of the lapping detection algorithm

be broadcasted to all caregivers in the same group as the elder, and the information view of the elder will also be updated accordingly.

4.3 Real-Time Locate and Navigation

This feature uses the real-time tracking and navigation features proposed in Section 3 and Figure 10 to locate and navigate to the senior who is exhibiting the wandering behaviours. To assist the navigation process in the crowded places and amidst of hurry, in-built smartphone Bluetooth is being used.

4.3.1 Nearby and Pass-by Alerts

When a caregiver is trying to locate an elder, notification alerts and in-app banners are generated and displayed when the following conditions are met:

- The caregiver's location is within 100 m of the elder's location.
- Bluetooth pass-by occurs between the caregiver's and elder's devices.

The alerts and banners are meant to alert the caregiver to be on a look out for the tracked elder, an example of which is illustrated in Figure 11.

4.4 Elder SOS Button

The SOS feature, comprising a gigantic SOS button, provides two actions that the elders can make use of, which is also illustrated in Figure 12.

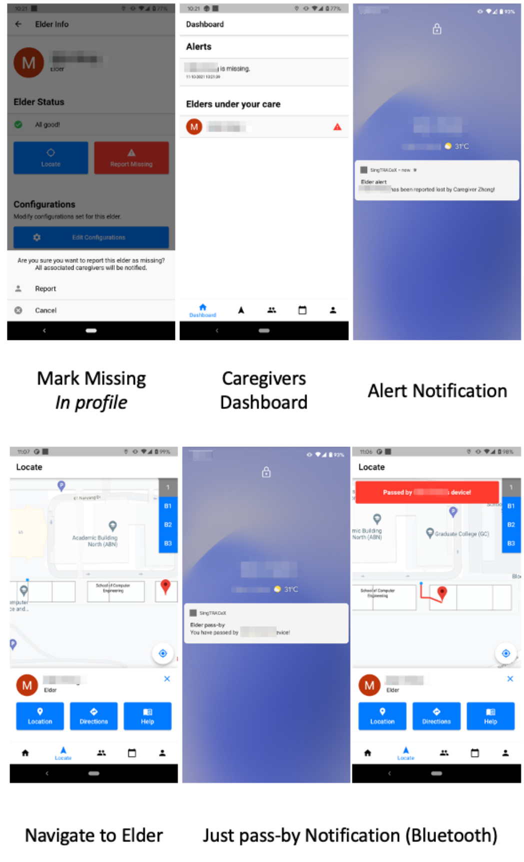

Figure 10. Real-time locate and navigate workflow (after reported missing)

- Direct call to caregiver;
- Directions to care centre or home.

This feature serves as an emergency patch through to caregivers and the SOS button is designed to be easily distinguished on the elder's screen, as illustrated in Figure 12. Caregivers may additionally configure for a call to be placed directly without further interaction from the elder when the SOS button is pressed.

5 CONCLUSION

This paper introduces a technological solution in the form of an application system that addresses the needs of elder and their caregivers in an urbanised city-state, such as Singapore. The proposed system architecture supports real-time location

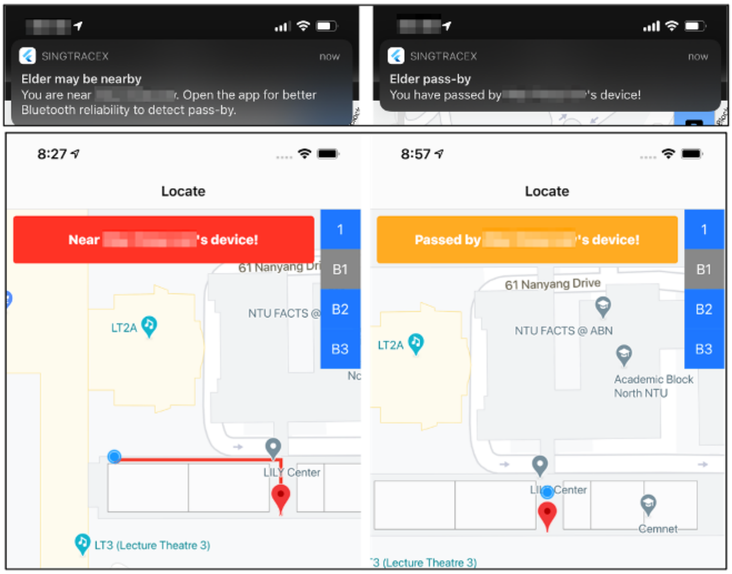

Figure 11. Example of notifications sent during the tracking process

tracking and indoor navigation using the combination multi-sources such as WiFi, Bluetooth, GPS and in-built smartphone sensors. The requirements of the application system is gathered primarily through referencing past works and a focus group discussion with caregivers of community care centres. The case study was conducted in Singapore. In order to address the challenge of wandering activities, we highlight feature designs to bridge the gap between the up-to-date technological framework and the users' needs. They are user role management, pre-lost detection, prevention, real-time lost and found navigation, and SOS button for elderly. We hope that the solution serves as a foundation that can be built upon over time as the needs of elders and caregivers may change, as well as the evolution of technology that may bring about new methods to address said needs.

In the future work, we aim to combine with the crowd-sourced location information from nearby mobile devices and explore 5G mechanism to improve the real-time tracking and navigation. In addition, the proposed features are planned to be tested in the feasibility and usability studies by the professional caregivers. Another direction is to develop a token for the elder instead of using the smartphone.

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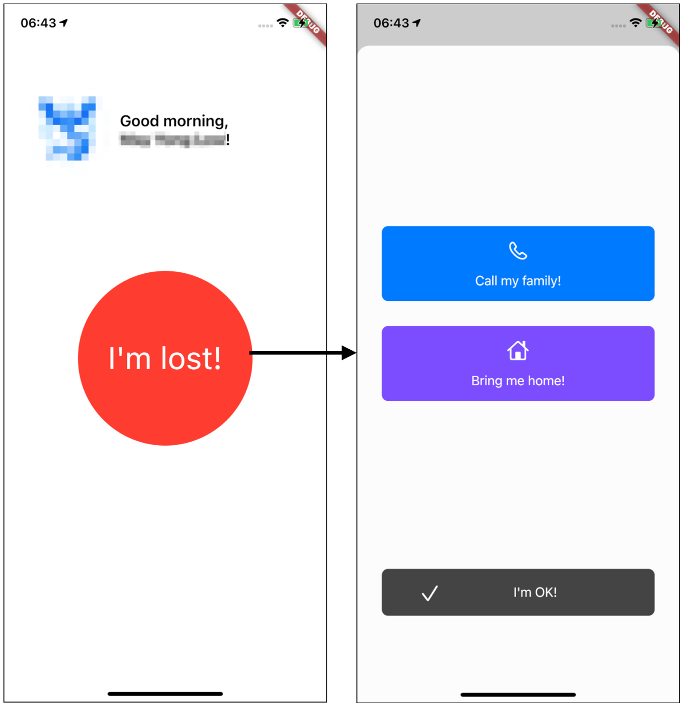

Figure 12. Main user interface of the application for elders

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REFERENCES

[1] Ageing and Health. 2018, Available at: `https://www.who.int/news-room/fact-sheets/detail/ageing-and-health`.

[2] Flutter Software Development Kit. 2019, `https://flutter.dev`.

[3] Alzheimer's Disease Association: Dementia in Singapore. `https://alz.org.sg/dementia/singapore`.

[4] Anderson, M.—Perrin, A.: Technology Use Among Seniors. 2019, `https://www.pewresearch.org/internet/2017/05/17/technology-use-among-seniors/`.

[5] AngelSense: GPS Tracker for Elderly with Dementia and Alzheimer's. `https://www.angelsense.com/gps-tracker-for-elderly`.

[6] Barberis, C.—Bottino, A.—Malnati, G.—Montuschi, P.: Experiencing Indoor Navigation on Mobile Devices. IT Professional, Vol. 16, 2014, No. 1, pp. 50–57, doi: 10.1109/MITP.2013.54.

[7] BoundaryCare: How It Works. https://www.boundarycare.com/how-it-works.

[8] Han, D.—Jung, S.—Lee, M.—Yoon, G.: Building a Practical Wi-Fi-Based Indoor Navigation System. IEEE Pervasive Computing, Vol. 13, 2014, No. 2, pp. 72–79, doi: 10.1109/MPRV.2014.24.

[9] Hart, P. E.—Nilsson, N. J.—Raphael, B.: A Formal Basis for the Heuristic Determination of Minimum Cost Paths. IEEE Transactions on Systems Science and Cybernetics, Vol. 4, 1968, No. 2, pp. 100–107, doi: 10.1109/TSSC.1968.300136.

[10] HealthHub: Dementia Care and Activities of Daily Living (ADL). https://www.healthhub.sg/a-z/diseases-and-conditions/518/managing-activities-of-daily-livings-CGH.

[11] Ministry of Social and Family Development: Singapore's Demographic: Resident Population Above 65. 2019, https://www.msf.gov.sg/research-and-data/Research-and-Statistics/Pages/Singapore-Demographic-Resident-Population-Above-65.aspx.

[12] Vuong, N. K.—Chan, S.—Lau, C. T.: Conceptual Map and Technological Framework to Manage Dementia Wandering. 2014 IEEE International Symposium on Bioelectronics and Bioinformatics (IEEE ISBB 2014), 2014, pp. 1–4, doi: 10.1109/ISBB.2014.6820889.

[13] Silver, L.: Smartphone Ownership Is Growing Rapidly Around the World, but Not Always Equally. 2019, https://www.pewresearch.org/global/2019/02/05/smartphone-ownership-is-growing-rapidly-around-the-world-but-not-always-equally/.

[14] Vuong, N. K.—Chan, S.—Lau, C. T.—Lau, K. M.: Feasibility Study of a Real-Time Wandering Detection Algorithm for Dementia Patients. Proceedings of the First ACM MobiHoc Workshop on Pervasive Wireless Healthcare (MobileHealth '11), ACM, 2011, Art. No. 11, doi: 10.1145/2007036.2007050.

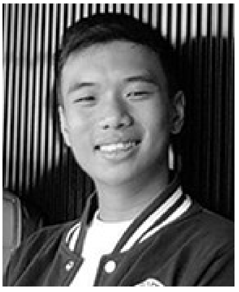
[15] Yean, S.—Lee, B. S.—Oh, H.L.: Feature Engineering for Grid-Based Multi-Floor Indoor Localisation Using Machine Learning. 2020 International Conference on Intelligent Data Science Technologies and Applications (IDSTA), IEEE, 2020, pp. 142–148, doi: 10.1109/IDSTA50958.2020.9263706.

[16] Zeinalipour-Yazti, D.—Laoudias, C.: The Anatomy of the Anyplace Indoor Navigation Service. SIGSPATIAL Special, Vol. 9, 2017, No. 2, pp. 3–10, doi: 10.1145/3151123.3151125.

[17] Zou, H.—Huang, B.—Lu, X.—Jiang, H.—Xie, L.: A Robust Indoor Positioning System Based on the Procrustes Analysis and Weighted Extreme Learning Machine. IEEE Transactions on Wireless Communications, Vol. 15, 2016, No. 2, pp. 1252–1266, doi: 10.1109/TWC.2015.2487963.

[18] Zou, H.—Jiang, H.—Luo, Y.—Zhu, J.—Lu, X.—Xie, L.: BlueDetect: An iBeacon-Enabled Scheme for Accurate and Energy-Efficient Indoor-Outdoor Detection and Seamless Location-Based Service. Sensors, Vol. 16, 2016, No. 2, Art. No. 268, doi: 10.3390/s16020268.

[19] Firebase: A Cloud Firestore Pricing Example. https://firebase.google.com/docs/firestore/billing-example#free-stuff.



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