Low-Energy Bluetooth Beacons for Lifespace Assessment of People with Neurological Conditions

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***Abstract*— Lifespace is the geographic space in which a person lives and conducts their activities. It is recognised that having dementia is likely to constrict a person's lifespace and reduce their community participation. This work presents the application of using smart-phones and low-energy bluetooth beacons to passively measure the lifespace of participants with dementia or mild cognitive impairment (MCI) from an existing longitudinal study.**

Keywords—Low-energy bluetooth, remote monitoring, dementia.

I. INTRODUCTION

People with progressive neurological conditions such as Parkinson's disease and some types of dementia can experience a loss of function in multiple domains including, speech and communication, independent functioning and movement quality often coupled with reduction in their activity and community participation. Due to the complexity, ongoing progress and fluctuations in symptoms, it is widely accepted that the full extent of many neurological conditions cannot be fully assessed during standard clinical consultations. Clinicians have limited time and can only assess the current status at the time, and rely on patient self-report to assess overall patterns of symptoms and well-being. Given the presence of memory impairment as part of many neurological conditions, requesting detailed self-reporting of symptomatology and independence may be unrealistic and burdensome.

Remote monitoring using smart-phones is becoming increasing prevalent due to their ubiquitous presence; the ease of custom designed software applications and the plethora of on board sensors such as GPS and accelerometer. Although numerous studies have considered this, there is still a growing need for accessing in-home lifespace and mobility patterns where GPS signal fails to measure.

This work presents the summary of an approach capturing in-home lifespace using low-energy Bluetooth beacons to passively monitor and log the locations and patterns of participants' activities inside their own home. Details of the technology solution are provided, along with preliminary data from studies being conducted in Sydney and Brisbane, Australia and involving participants with Parkinson's disease, mild cognitive impairment or probable dementia.

We demonstrated that in-home lifespace as measured using low energy bluetooth beacons paired with a custom smartphone app can give insights into home activities without requiring self-report. In conjunction with a broader remote monitoring system can provide valuable insights into the health, function and quality of life for people with neurological conditions, which has clinical implications for the comprehensive, community based measurement and management.

II. LIFESPACE

Lifespace is a measure of the geographic space in which someone lives and conducts their regular activities [1]. Arising from gerontological studies, lifespace was originally conceptualised as concentric circles, centred around a person's bedroom and extending into zones including other areas of their house, outside areas, and then beyond this, into the community [2]. Within population-based studies, it is a powerful predictor of future morbidity and mortality [2] onset of dementia and cognitive impairment [3] and the need for residential care [4] in older populations. Having a more constricted lifespace is also predictive of more rapid deterioration for people with have dementia [5]. Lifespace can indicate the community participation of people and indicate the effectiveness of treatments [6].

Though traditionally measured using self-reported records of people's travels within the different zones over the previous weeks or months, it is becoming more common for devices collecting GPS to be used [7]. Passively collecting GPS data can indicate the lifespace metrics, including furthest distance travelled, number of trips outside the home and percentage of time spent at home [8]. This does not rely on recall or serve as a substantial burden for participants.

While GPS data can provide insights into the community-based lifespace of people, it does not provide sufficient accuracy and detail to indicate home-based lifespace (i.e. the three inner zones of lifespace). Gaining sufficient detail about this aspect of lifespace is essential for generating lifespace scores that compare with traditional methods, and also provide important insights for participants who spent a substantial proportion of their time at home. Exploring the locations and patterns of activity at home will provide important insights into understanding the needs and experiences of this group.

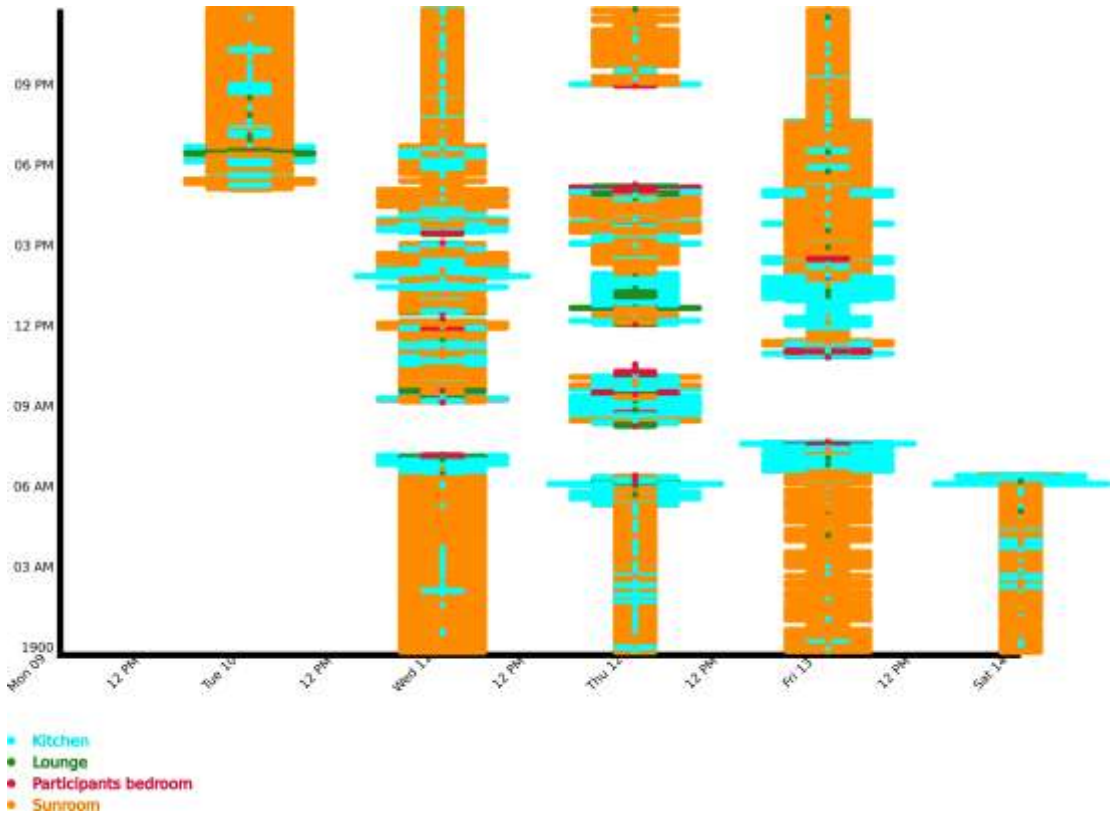

Figure 1 Collected Bluetooth beacon data over a continuous 5-day period from a participant with mild cognitive impairment. Time blocks with no discovered beacon indicate the participant is not at home or the smart-phone is switched off.

III. Low-Energy Bluetooth Beacons

In this work custom designed, low-energy Bluetooth beacon devices were placed in the participant's house. Low-energy Bluetooth technology was chosen for this study as it fulfils the criteria of running on minimalist power and being compatible to the Android operating system. The RedBear Bluetooth 4.0 Low Energy Module (model: RBT01), Bluetooth SIG certified with on-board chip antenna is used in the beacons [9]. This module utilises the Texas Instruments CC2540 2.4 GHz Bluetooth System-on-Chip. Custom firmware was developed that periodically broadcasts an advertisement packet for 5 seconds and sleeps for 60 seconds. Whilst in sleep mode the CC2540 requires only 0.4 μA. The standard Bluetooth advertisement packet consists of 32 bytes however in this instance it was kept small to conserve battery power and thus only the media access control (MAC) address, battery voltage and required configuration parameters was broadcasted. The transmit power was kept constant at 0 dBm. Each deployed beacon has a corresponding MAC address that was used to identify the device. Figure 1 gives a photo the RedBear module which has dimensions of (L) 39mm x (W)18.5mm x (H) 3.8mm. This module was further in-cased in a plastic shell for more f weather proofing. The beacons were powered from a 9V battery however the module maybe powered between 3.4V to 11V.

A corresponding Android application was developed for a smart-phone that creates a log entry for when an advertisement packet is received from a known beacon device. The beacon device ID is logged (MAC address) as while as the relative signal strength indicator (RSSI), and the date and time the device was discovered. Devices that were unknown to the application were ignored. In order to conserve the battery on the smart-phone the application listens for beacons for 1 second and then pauses for 10 seconds. The application also logged GPS data for when the participant leaves home. This data will not be reported here.

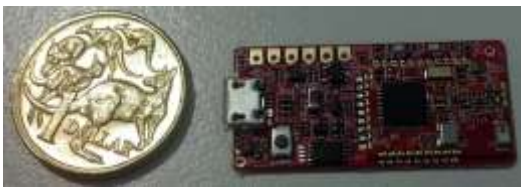

Figure 2 Photo of the The RedBear Bluetooth 4.0 Low Energy Module (model: RBT01)

IV. PRELIMINARY DATA

Figure 1 gives Bluetooth beacon data that was collected continuously for 5 days from a person with a consensus diagnosis of mild cognitive impairment. The beacons were placed in the kitchen, lounge, bedroom and sunroom as determined by the attending research assistant. The x-axis represents a particular day whilst the y-axis represents the specific time. As the beacons broadcast periodically every 1 minute, the resolution of the y-axis is segmented into 1 minute blocks. If a beacon is identified in that time block a rectangular object is placed. The normalised width of this object is dependent on the RSSI value according to:

$$W = \begin{cases} 1, \text{RSSI} \le -50 \\ 0.75, \ -50 < \text{RSSI} \ge -60 \\ 0.5, \ -60 < \text{RSSI} \ge -70 \\ 0.25, \ -70 < \text{RSSI} \ge -80 \\ 0, \ \text{RSSI} < -80 \end{cases} \quad (1)$$

This allows the visualisation of multiple beacons in the same time block i.e. the higher the RSSI of the discovered beacon the wider the rectangular object in the time slot. Figure 1 shows multiple beacons were discovered in the same time slot quite frequently. It is likely the participant is closest to the beacon with the highest RSSI this might not necessarily be the case due to complex propagation channels the broadcast signal may take. Figure 1 show some time blocks have no discovered beacons which could indicate the participant is not at home or the smart-phone is switched off. In this instance a cross checking of the captured GPS data shows these empty slows correspond to when the participant has left their home dwelling.

At present time the beacons are being used in studies involving healthy adults as well as adults with Parkinson's disease, mild cognitive impairment and dementia. Challenges and findings from its use with these groups can be reported. The development of metrics with clinical relevance is also being explored.

V. CONCLUSIONS

There are potentially multiple ways to represent the in home lifespace data collected including heatmaps and metrics to enable comparison between participants and over time. The ability to passively collect in-home lifespace data without creating an undue burden for the participant or using expensive and specialist equipment, is an important step for monitoring and measuring the community lives of people with a neurologial impairment.

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References

[1] P. S. Baker, E. V. Bodner, and R. M. Allman, "Measuring life-space mobility in community- dwelling older adults," *Journal of the American Geriatrics Society,* vol. 51, pp. 1610-1614, 2003.

[2] C. Peel, P. S. Baker, D. L. Roth, C. J. Brown, E. V. Bodner, and R. M. Allman, "Assessing mobility in older adults: the UAB Study of Aging Life-Space Assessment," *Physical Therapy,* vol. 85, pp. 1008-1019, 2005.

[3] P. A. Boyle, A. S. Buchman, L. L. Barnes, B. D. James, and D. A. Bennett, "Association between life space and risk of mortality in advanced age," *Journal of the American Geriatrics Society,* vol. 58, pp. 1925-1930, 2010.

[4] B. D. James, P. A. Boyle, A. S. Buchman, L. L. Barnes, and D. A. Bennett, "Life space and risk of Alzheimer disease, mild cognitive impairment, and cognitive decline in old age," *The American Journal of Geriatric*

[5] K. D. Sheppard, P. Sawyer, C. S. Ritchie, R. M. Allman, and C. J. Brown, "Life-space mobility predicts nursing home admission over 6 years," *Journal of aging and health,* vol. 25, pp. 907-920, 2013

[6] K. D. Sheppard, P. Sawyer, C. S. Ritchie, R. M. Allman, and C. J. Brown, "Life-space mobility predicts nursing home admission over 6 years," *Journal of aging and health,* vol. 25, pp. 907-920, 2013

[7] J. Liddle, D. Ireland, S. J. McBride, S. G. Brauer, L. M. Hall, H. Ding, *et al.*, "Measuring the lifespace of people with Parkinson's disease using smartphones: proof of principle," *JMIR mHealth and uHealth,* vol. 2, 2014

[8] A. K. Schenk, B. C. Witbrodt, C. A. Hoarty, R. H. Carlson, Jr., E. H. Goulding, J. F. Potter, *et al.*, "Cellular telephones measure activity and lifespace in community-dwelling adults: proof of principle," *J Am Geriatr Soc,* vol. 59, pp. 345-52, Feb 2011.

[9] BLE Mini, [online] 2015, http://www.redbearlab.com/blemini (Accessed 17th Julty 2015)