iWander: An Android Application for Dementia Patients

Frank Sposaro
Department of Computer Science
Florida State University
Tallahassee, Florida 32306
sposaro@cs.fsu.edu

Justin Danielson
Department of Computer Science
Florida State University
Tallahassee, Florida 32306
danielso@cs.fsu.edu

Gary Tyson
Department of Computer Science
Florida State University
Tallahassee, Florida 32306
tyson@cs.fsu.edu

***Abstract*—Non-pharmacological management of dementia puts a burden on those who are taking care of a patient that suffer from this chronic condition. Caregivers frequently need to assist their patients with activities of daily living. However, they are also encouraged to promote functional independence. With the use of a discrete monitoring device, functional independence is increased among dementia patients while decreasing the stress put on caregivers. This paper describes a tool which improves the quality of treatment for dementia patients using mobile applications. Our application, *iWander*, runs on several Android based devices with GPS and communication capabilities. This allows for caregivers to cost effectively monitor their patients remotely. The data cnnollected from the device is evaluated using Bayesian network techniques which estimate the probability of wandering behavior. Upon evaluation several courses of action can be taken based on the situation's severity, dynamic settings and probability. These actions include issuing audible prompts to the patient, offering directions to navigate them home, sending notifications to the caregiver containing the location of the patient, establishing a line of communication between the patient-caregiver and performing a party call between the caregiver-patient and patient's local 911. As patients use this monitoring system more, it will better learn and identify normal behavioral patterns which increases the accuracy of the Bayesian network for all patients. Normal behavior classifications are also used to alert the caregiver or help patients navigate home if they begin to wander while driving allowing for functional independence.**

I. Introduction

Dementia is the loss of cognitive functioning. This effects the person's daily life and activities such as the ability to think, remember and reason. Alzheimer's disease, the most common form of dementia, is progressive and slowly destroys the brain limiting functionality, decreasing quality of life and eventually leading to death. [1]

With advances in medicine and technology the number of older adults and life expectancy is increasing. The amount of people across the world with Alzheimer's disease is predicted to almost double every twenty years [2]. Currently, an estimated 5.3 million Americans have Alzheimer's disease. This is one out of eight people over the age of sixty five. In the year 2050, the number of Americans over eighty five will quadruple, leading to 959 thousand new cases of Alzheimer's in that year alone [3].

Cost of caring for dementia patient is steep. While the cost increases with more severe stages of dementia the average lifetime cost of care for a single person is greater than $174,000. Total direct and indirect costs in the US is over $100 billion annually. Businesses are spending $24.6 billion in health care while Medicare expenditures are an estimated $160 billion. Seven out of ten people with the disease live at home where 75% of costs are absorbed by the family [4].

In addition to incurring a large financial burden, the family also assumes responsibility as the primary caregiver, often an emotionally and stressful task. Caregiving may also have a negative impact on health, employment, income and financial security. About one third of family caregivers showed signs of depression, while half reported effects caused by caring to be their major health problem. Although the majority of caregivers live close to their patient, about 15% are considered long-distance caregivers, living over an hour away [3]. This makes constant monitoring of patients extremely difficult these remote caregivers.

Current systems require the user to carry dedicated units which may be a GPS or push button alerts. They are monitored by a third party service whom charges a monthly fee. The GPS units are only used to locate the user or confine them to a specific radius, they do not issue dynamic alert automatically. Push button system are also limiting because they must be manually pressed by the user.

The presented system, *iWander*, is designed to partially alleviate stress, financial burden, and offer easier remote monitoring to caregivers by using the user's social network as a monitoring service. It is an application which runs on any Android enabled device that possesses the correct hardware. Most Android devices are commercial products, which amortized against total sales will keep the cost per unit down. The application runs in the background and collects data from the device's sensors such as GPS, time of day, weather condition, stage of dementia, and user feedback. This data is then evaluated using Bayesian network techniques to determine the probability the person is wandering. Depending on the probability, *iWander* automatically takes actions that help navigate the patient to a safe location, notify caregivers, provide the current location of the patient and call 911.

II. Methods and Design

A. Software

This application is designed on the Android software stack produced by Google. Android is an open source framework designed for mobile devices. It packages an operating system, middleware, and key programs [5]. The Android SDK provides libraries needed to interface with the hardware at a high level and make/deploy Android applications [6]. Application are written in Java and use SQL databases to store persistent data. We choose this platform as opposed to others because of the ability to easily thread background running processes, the polished Google Maps and Navigation API, and compatibility with other Android devices.

Unlike dedicated systems this software is intended to integrate with the device's existing applications; *iWander* must share resources with other applications. To make for a pleasant integration, it runs as inconspicuously as possible while using limited resources. We launch a background service that requests the GPS location and other data. Only when the probability of wandering is high will the activity wake up and interrupt the patient. Based on the probability evaluation and patient's response the app can take different actions. Which allows *iWander* to run harmoniously on the system while minimizing memory consumption and providing ease of use to the patient.

B. Wander Detection

Wandering occurs because many dementia suffers have hypertension and feel a compelling urge to walk. Unfortunately, roughly 40% of them get lost when they do wander [7]. In order to identify a patient that is in danger of wandering the application creates safe zones, which are considered to be indoor or home locations where the patient is safe from the potential harms of wandering. These zones are identified by monitoring the GPS locations for areas where the phone is charged for extended periods of time. The safe zone's radius is relatively small and is only intended to enclose the patient's dwelling. However, the exact size can be adjusted for extenuating circumstances. If the patient is inside a safe zone the app remains transparent.

Once the patient is outside of the safe zones the probability of wandering is determined using Bayesian network techniques. A Bayesian network is a model for determining the probability that an event occurs given other variables of interest. As the variables change, inference can be applied to determine the likelihood of a specific event occurring [8]. The collection of relevant information allows predictions to be made with a larger degree of certainty. Overtime, more and more information is collected, and the occurrence of false positives is reduced [9].

The variables for the Bayesian network are chosen carefully because they directly effect the probability estimation. Researchers have shown the correlation between wandering and age, severity of dementia, and time of day [10]. *iWander* also adds time of day, current weather conditions, and time outside into this equation. Analyzing these variables against a collection of exsisting data can help classify behavior as normal or abnormal.

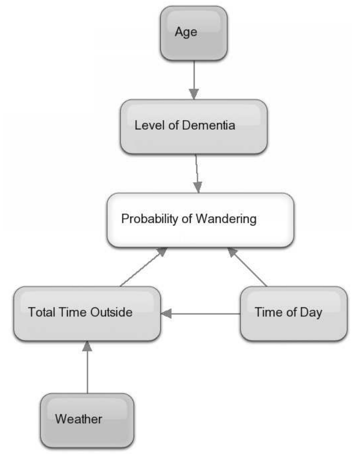

Fig. 1. Bayesian Network Variable Relations Affecting Wandering Probability

There are several methods for classifying such cases. Currently we are choosing to use a two step approach described in [11], however our system is versatile enough to change methods during testing. First, the data is passed through a one-class support vector machine (SVM) [12], [13]. This filters out obvious, normal activity. It is important to pick proper sensitivity parameters to achieve a good trade off between false positive and false negative rates. To track successes and failures a simple prompt is issued ,after an alert, requesting feedback about correctness. The system can use this feedback along with usage statistics to dynamically adjust sensitivity. After the SVM, data is then passed to a nonlinear regression function which will finally classify behavior as normal or abnormal.

The network shown in figure 1 displays the relations between the variables and how they affect the probability of wandering. Time of day greatly impacts wandering because about half of dementia patients experience night time walking of which a significant number result in the patient getting lost [14]. Therefore patients are more likely to wander at night. Dementia patients are outside less during night hours so length of time outdoors and weather also affect the probability of wandering. Lastly, dementia worsens with age [1]. Older adults have more severe dementia and suffers from the latter stages of dementia are more susceptible to wandering.

Implementation of the Bayesian network is done in three phases. First is the pre-installation phase. This is the period of time where the network is static and the base case solely affects the probability of wandering. The relationships and statistics between the variables are the only inputs. Second is the configuration phase. Setting up the device for that specific patient is necessary as some information such as age and level of dementia is given as user input. The remaining information like safe zones, GPS, time of day and weather can be implicitly gathered by the device and geared of the individual patient. The last phase is the extended learning. Once the devices are deployed they continually learn from the gathered data. This data not is only tailored for the individual patient, but also has an affect on the baseline model. Thus the more the network is used the higher the accuracy is for all patients, an inherent property of Bayesian networks [15].

C. Alert Actions

If the probability suggests the patient is likely wandering, action is taken. First, a notification prompts them to provide feedback if they are okay. It has been shown that interrupts may help bring them out of a demented state [16]. The single option, "Yes, I am Okay," is given. With positive feedback the alert process will pause, this also reduces false positives. If the patient does not respond, it is inferred that he or she is not okay and may be lost. The GPS coordinates are used, with Google Maps and Navigation tools, to give them directions to the safe zone. If no progress is made after a set period of time an alert is sent to the caregivers. Wanderers may not be properly prepared for harsh weather conditions such as extreme hot and cold temperatures and thus faster action must be taken [17]. The device can easily retrieve current weather conditions from reliable, dedicated services via the Internet. This course of action is also taken if the time spent out of the safe zone is to great.

The purpose of the alert is to notify the caregiver of wandering behavior, establish bidirectional communication with the patient and relay information. When an alert is issued the device calls a single Google Voice number. Google Voice will then ring several different caregiver numbers simultaneously. When any of those caregivers answer they will be connected and the patient's device will automatically be placed on speakerphone [18]. Enabling bidirectional communication between the patient and caregiver further reduces the number of false positives. Using Google Map APIs, longitude and latitude can be converted into a street address and relayed to the caregiver in several ways including SMS messages, email, or web interface updates. By communicating with the patient and evaluating location information the caregiver can plan an appropriate course of action. In urgent cases, the caregiver can give a command to instruct the patient's device to 3-way a call to 911. By calling 911 from the patient's device, it can be certain that the patient's local 911 station will be called. This process allows caregivers to reduce the number non emergency calls to 911 and provide long distance, remote monitoring to the dementia patients.

D. Automotive Travel

If the patient is traveling in an automobile it is highly probable they will travel outside of their safe zone. To limit the number of false positives the speed in which the patient is traveling is checked. This is done through the Haversine formula [19], which divides successive GPS coordinates by the time interval between them. Once the patient is determined to be in an automobile the Bayesian network is not used. Instead, *iWander* gathers specific information on that individual person.

Many older people with dementia are not supposed to be driving, however they often do [20]. Driving is a sensitive issue that should be discussed between the patient and their primary caregivers [21]. *iWander* could send an alert every time the patient is driving however patients may reject the system if there are conflicts regarding driving privileges or they may simply be a passenger. Instead, *iWander* tries to prevent the patient from getting lost and offers location information to the caregivers which may promote functional independence.

If the patient is determined to be an automobile two things are noted, time of day and common routes. By learning basic travel patterns alerts are only issued in abnormal situations such as traveling along an unfamiliar route at uncommon times. Issuing an onscreen notification which forces them to press a button may be distracting. Instead the app audibly prompts them offering directions if needed. Using Google Voice recognition and Google Navigation it searches for and gives them turn by turn directions to their destination.

III. Challenges

A. Hardware

Designing on the Android platform provides several hardware related benefits. New hardware with additional sensors, increased performance, and better battery life are constantly being released. The system works under the assumption that the patient carries the device on them. While the likelihood of remembering to carry a cell phone is higher due to common society standards, this may not be the case with all dementia patients. Often times phones are too bulky or forgotten [22].

A viable solution is to use an Android enabled watch. It possesses all the capabilities of an Android smartphone, but condensed into a watch version. Once attached, the patient is more likely to have it on them as many older adults are already accustomed to wearing watches for fall emergencies. An Android watch can automatically detect falls as well as wandering and can replace current push button watch alarms [23]. Due to the small screen size *iWander* would have to adjust screen displays to the user. Since the system is designed to reduce interactions with the user this change would be minimal.

B. Patient Interaction

To overcome potential learning curves *iWander* operates discreetly and require minimal patient interaction. The majority of interaction is done through simple prompts, voice commands, and text to speech. Older adults often have difficulty with their haptic perception. To avoid the need for the software keyboard on the device, input is provided through the use of easy to press buttons and auditory input when applicable. By request of the patient the text on the screen can be read aloud through built in text to speech libraries. Lastly, all color schemes have high contrast ratios to promote ease of readability [24].

C. Implementation

Accuracy of GPS is a major concern. However, previous dementia wandering systems using cellphone technology have proven the GPS accuracy to be reliable enough for similar systems [22]. The only remaining problem is a loss of connection. In the event of satellite connection is lost, the device can implement coarse-grain GPS which uses nearby antenna stations to triangulate the location of the device. This provides a less accurate alternative to the fine-grain, satellite GPS, while the connection is being reestablished [25]. If the fine-grain and coarse-grain GPS both fail, the device will broadcast the last known location when necessary. Last known location within minutes is usually acceptable for locating wandering persons because their position does not rapidly change [26].

Although battery technology is rapidly improving, the frequent use of GPS shortens the battery life. To prevent rapid battery loss the GPS is polled. For these purposes receiving new coordinates once every 5-10 minutes is sufficient [26]. When wandering is detected, the GPS locations can be obtained more frequently to monitor the patient closely. Another method to avoid low battery life is to remind the patient to charge if possible instead of waiting until the battery is critical to issue a reminder. If the patient is in a safe zone the battery can be charged and the user is prompted.

IV. Conclusion

We have presented the *iWander* application which is used to assist dementia patients and their caregivers. By running on commercial Android devices and using the patients social network as a monitoring service the operating cost is reduced. Data is passed into a Bayesian network and correlated to classify behavior as normal or abnormal. Based on the estimated probability of wandering automatic actions are taken to help guide the user home and alert caregivers.

A. Evaluation Framework

We are currently working with Westminster Oaks, an assisted living facility, in Tallahassee Florida to deploy devices running *iWander*. Focus groups are planned to discuss special interface and procedural needs. The alert protocol will be modified slightly since the on-staff nurses are the primary caregivers and dialing 911 is not needed. Our goal is to mine enough data to create an efficient baseline model to detect wandering probability with good accuracy. Once openly released to everyone, the baseline model will be modified based on learning to increase accuracy.

B. Future Works

Many patients with dementia may also be depressed. We will monitor patient behavior such as movements (using bluetooth technology [27]), communication patterns and level of activity. Once a normal pattern is established we can use our modified Bayesian network to detect non-normal activity. The device can also issue a version of the standard depression index test to mine feedback from the user.

References

[1] Alzheimer's Disease Education and Referral Center. Alzheimer's disease fact sheet. *NIH Publication No. 08-6423*, February 2010.

[2] Times Online. Number of dementia sufferers will double every 20 years. October 2009.

[3] Alzheimer's Association. Alzheimer's disease facts and figures. *Alzheimer's and Dementia*, 6, March 2010.

[4] Christine Kennard. Statistics about the financial costs of alzheimer's disease. *About.com Health's Disease and Condition*, September 2006.

[5] Google Inc. Android. www.android.com.

[6] Google Inc. Android developers. developer.android.com.

[7] Allegra Stratton. Charity backs tagging for dementia sufferers. December 2007.

[8] David Heckerman. A tutorial on learning with bayesian networks. Microsoft Research, March 1995.

[9] Los Alamos Center for Bayesian Methods in Environment, Safety, and Health. What is bayesian inference? September 1998.

[10] Diane A. Klein, Martin Steinberg, Elizabeth Galik, Cynthia Steele, Jeannine-Marie Sheppard, Andrew Warren, Adam Rosenblatt, and Constantine G. Lyketsos. Wandering behaviour in community-residing persons with dementia. *International Journal of Geriatric Psychiatry*, pages 272–279, April 1999.

[11] Jie Yin, Qiang Yang, and Jeffrey Junfeng Pan. Sensor-based abnormal human-activity detection. *IEEE TRANSACTIONS ON KNOWLEDGE AND DATA ENGINEERING*, March 2007.

[12] B. Scholkopf, J. Platt, J. Shawe-Taylor, and A. Smola. Estimating the support of a high-dimensional distribution. *Neural Computation*, 13(7):1443–1471, July 2001.

[13] D.M.J. Tax and R.P.W. Duin. Support vector domain description. *Pattern Recognition Letters*, 20(1113):11911199, 1999.

[14] Tracy Lee and Alex Mihailidis. An intelligent emergency response system: preliminary development and testing of automated fall detection. *Journal of Telemedicine and Telecare*, 11(4):194–198, 2005.

[15] S. Russell and P. Norvig. *Artificial Intelligence: A Modern Approach*. Prentice Hall, 1995.

[16] Katherine Heard and T. Steuart Watson. Reducing wandering by persons with dementia using differential reinforcement. *Journal of Applied Behavior Analysis*, 32(3):381–384, 1999.

[17] Myra A. Aud. Dangerous wandering: Elopments of older adults with dementia from long-term care facilities. *American Journal of Alzheimer's Disease and Other Dementias*, 19(6):361–368, 2004.

[18] Frank Sposaro and Gary Tyson. Geriatric medical application suite on a sweet phone. First AMA IEEE Medical Technology Conference on Individualized Healthcare, March 2010.

[19] C.C. Robusto. The cosine-haversine formula. *The American Mathematical Monthly*, 64(1):38–40, January 1957.

[20] G.K. Fox, F. Withaar, and G.M. Bashford. Dementia and driving: a survey clinical practice in aged care assessment teams. *Australian Journal on Ageing*, 15(3), 1996.

[21] Gary J. Kennedy MD. Advanced age, dementia, and driving: Guidance for the patient, family and physician. *Primary Psychiatry*, 16(9):19–23, September 2009.

[22] Oxford University Press on behalf of the British Geriatrics Society. Electronic tracking of patients with dementia and wandering using mobile phone technology. *Age and Ageing*, 34:497–518, 2005.

[23] Frank Sposaro and Gary Tyson. ifall: An android application for fall monitoring and response. *31st Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 1:6119–22, 2009.

[24] Arthur D. Fisk, Wendy A. Rogers, Neil Charness, Sara J. Czaja, and Joseph Sharit. Chapter 5: Design of input and output devices. *Designing for Older Adults: Principles and Creative Human Factors Approaches*, pages 65–72.

[25] Noam Shoval, Gail K. Auslander, Tim Freytag, Ruth Landau, Frank Oswald, Ulrich Seidl, Hans-Werner Wahl, Shirli Werner, and Jeremia Heinik. The use of advanced tracking technologies for the analysis of mobility in alzheimer's disease and related cognitive diseases. *BCM Geriatrics*, 8(7), March 2008.

[26] Koichi Shimizu, Kuniaki Kawamura, and Katsuyuki Yamamoto. Location system for dementia wandering. *Proceedings of the 22nd Annual EMBS International Conference*, pages 1556–1559, July 2000.

[27] Ben Fagin, Frank Sposaro, and Gary Tyson. Indoor tracking of geriatric patients using bluetooth. First AMA IEEE Medical Technology Conference on Individualized Healthcare, March 2010.