Proceedings of the 29th Annual International
Conference of the IEEE EMBS
Cité Internationale, Lyon, France
August 23-26, 2007.

Early Detection of Health Changes In Older Adults

Harry W. Tyrer[1] PhD, Member IEEE, Myra A. Aud, PhD, RN, Gregory Alexander, PhD, RN, Marjorie Skubic PhD, Member IEEE, Marilyn Rantz PhD

Abstract— **We have placed a network of sensors in a residential home for the elderly who are aging in place. Restlessness data is displayed as graph of event counts detected by sensors over some time interval, typically a day. This data is related to the actual activities as recorded by the resident. We show two cases of elderly individuals. In both cases the individuals underwent surgery. The restlessness indicators showed changes in patterns that were related to those events. Analyzing the data even at this level we gain increased confidence that technology will be a welcome addition as the population ages and require increasing care.**

I. Introduction

We believe that technology has much to offer the elderly to lead full productive and independent lives. The goal for seniors is to provide a stable home environment that fosters independence [1-4]. There are a variety of sensors that provide motion, location and activity information; sensors are available to monitor physiologic and medical conditions; and a variety of communication devices and protocols are available to interconnect these sensor systems to computers. Finally there are a variety of statistical and computational intelligence paradigms that will help make sense of the data. Indeed there is much technology can do for the elderly. Ubiquitous monitoring in space and time can provide urgent or emergency help rapidly. Longitudinal assessment of the data can provide a means to detect early failings for an appropriate intervention. Access through web sites or other communication can extend the caregivers to include loved ones not immediately local or accessible. And of course there is the increased peace of mind in the elderly and loved ones that simple events will not cascade and catastrophically spiral out of control.

The rationale for providing technology to monitor the elderly is to improve the quality of life. Life follows a relatively constant quality of life until event occurs that reduce functionality or cognitive capability, as shown in figure 1.

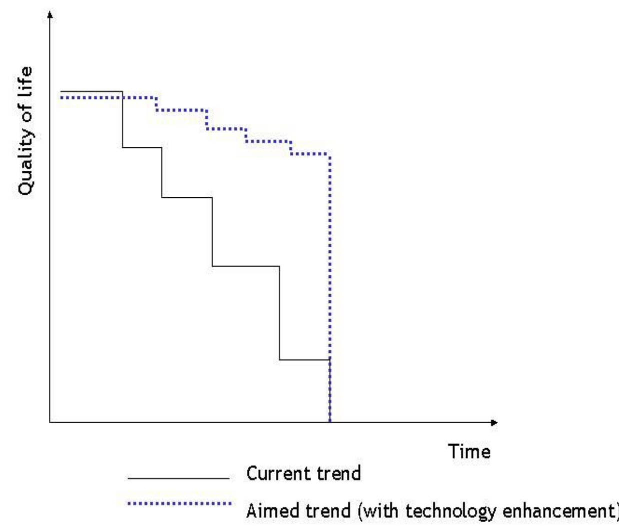

Figure 1 Trajectory of functional decline and goal for the use of technology. The quality of life remains relatively constant until some reduction in cognition or functional capability occurs in the individual. In the elderly life continues at that reduced quality of life, until a spiral of events occurs that reduces further the quality of life. Quality of life is not measurable, but we can measure surrogates such as functional activity and cognitive activity.

This figure arose from discussion with expertise in geriatric care in our technology group. It has the same general overall upper diagonal parallelogram shape as the mortality chart showing population age vs. percent survivors or in curves estimating cell survival. In the elderly a set of events may occur that leads to the downward spiral: taking medicine causes a fall that breaks a bone that causes depression and social withdrawal, the person stops eating and further events occur. So the goal is to extend life at a given quality of life, and to reduce the drop in quality of life, either by technology or by individual intervention. The effect, and our goal as shown in the figure is to raise the quality of life over all and may even extend life. It has been

[1] Manuscript received June 25, 2007, The authors are grateful for the support from NSF ITR grant IIS-0428420 and the U.S. Administration on Aging, under grant 90AM3013.
Harry W. Tyrer is professor in Electrical and Computer Engineering at the University of Missouri – Columbia He is the corresponding author Please use email tyrerh@missouri.edu, Day phone is 573 882 – 6489, shipping address is 305 Engineering Building West, University of Missouri – Columbia; Columbia, Missouri 65211
Myra A. Aud is Associate Professor, Sinclair School of Nursing, University of Missouri-Columbia
Gregory Alexander is Assistant Professor, Sinclair School of Nursing, University of Missouri-Columbia
RN; Marjorie Skubic is Associate Professor in Electrical and Computer Engineering at the University of Missouri – Columbia
Marilyn Rantz is Professor, Sinclair School of Nursing, University of Missouri-Columbia
Portions of this paper were presented at the Midwest Nursing Research Conference in March 2007

shown that elderly can indeed grow muscle and that they can recover from unfortunate events; the effect is to raise the extended fixed value of quality of life. So the chart shows a pessimistic outcome. Clearly the most pessimistic out come is that the presumed fixed quality of life deteriorates, that outcome cannot be excluded. There are two important measures that relate to quality of life: functional status and cognitive status. Functional status can be measured using a variety of instruments that record Active of Daily Living (ADLs), cognitive status can be measured using similar instruments. Care givers practicing geriatric care use questionnaire instruments based on the concepts to measure these activities.

TigerPlace is an innovative retirement community that is designed to promote aging-in-place. Early detection of health status changes leads to early intervention and presumably better health. So, unobtrusive sensor systems were deployed in apartments of resident-volunteers to establish baseline patterns in activities, and to recognize variations from baseline patterns that may reflect to health status changes [5-9].

Substantial effort is placed on recruiting residents to participate in the project. Residents are informed of the technology, all devices with their benefits and drawbacks are described. In the end the resident may choose to participate with no consequences if they do not. The participants do so for many reasons, including a belief that the technology will help them and an interest in the supporting new science.

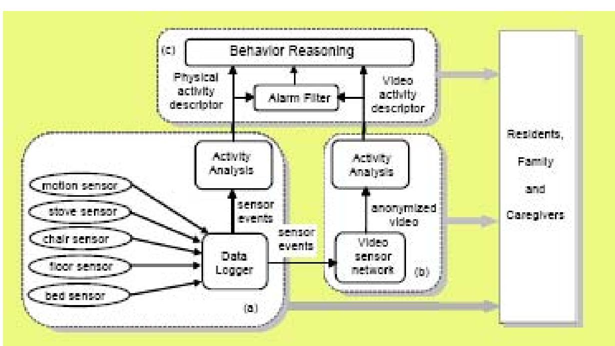

Figure 2 Block diagram of sensor system with video component (b), computational intelligence component (c), and communication for residents, family, and caregivers. Component (a) is the sensor system connected to the server. We show the sensors for motion, stove, chair, floor and bed.

II. TWO CASE STUDIES

For the two case studies described here, figure 2 part (a) shows the technology installed in the residences. Sensors placed through out the apartment send to the data logger, which then transfers the data to a server where activity analysis takes place. Further activity, not considered here includes anonymous video, behavior reasoning and data sharing.

The data analyzed was the restlessness displayed by the resident. This is in essence a time vs. event-frequency detected by the system [10, 11].

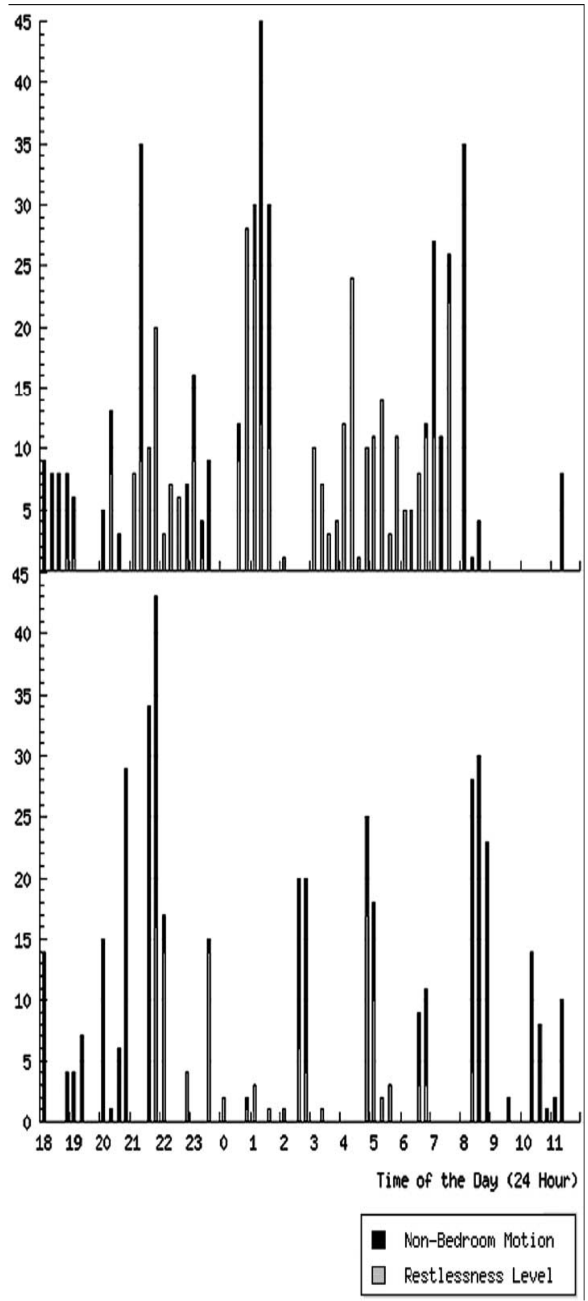

Figure 3 Restlessness data on individual residents. The data shows the counts of bedroom and non-bedroom motion events from 6:00 pm to 11:00 am the next day. The upper chart shows substantial restlessness around 1 am compared to the lower chart. Similarly from 3 am to 9am. The quiet period from 9 to 11 am may mean that the individual slept at that time, or more likely was not in the room.

We want to assess the correspondence between data collected by the unobtrusive sensor systems in the apartments of two residents and the reality of their activities when data is reviewed in the context of known health-related events. The method was to perform small group interviews with each resident-volunteer, a family member, and appropriate research team member. With the volunteer we performed a retrospective review of graphically displayed activity and bed restlessness sensor data. In summary, Sensor data accurately capture resident activities, and sensor data provides indications of health status changes.

A. Resident #1

This is an 82-year-old man, living alone in one-bedroom apartment. He was initially independent in all measures of activity of daily living. His major health event during 16 months of sensor system deployment was elective knee replacement surgery.

The sensors captured a consistent pattern of activities preoperatively, his recovery from knee replacement surgery, and additional family presence in the apartment within the first 2 days after hospital discharge. Furthermore he showed unbroken sleep on first night back from hospital related to fatigue (according to the resident), and broken sleep on subsequent night related to restlessness attributed to discomfort and/or fatigue from physical therapy. The physical therapy consisted of bed exercises and helped restore a pattern of personal care i.e., morning routine, shower, bedtime routine

B. Resident #2 is an

This is an 80 year old man living alone in one-bedroom apartment initially independent in ADLs showed deteriorating health during 14 months of sensor system deployment including several hospitalizations for cardiovascular events and one hospitalization for CVA.

The sensors captured a pattern of frequent trips to bathroom during the night. A change of pattern noted as a reduction in the frequency of trips to bathroom at night with use of Flomax (Trade Mark), immediately prior to CVA. The resident displayed three nights of increased restlessness. After discharge from hospital post CVA, he stayed in bed longer in the morning, and spent more time in bed during the day. The sensors also detected installation of shower chair by two workers and other activities by personal care aides.

III. Discussion

A previous description of our system emphasized part (a) of figure 2, which is the sensor network section of our system. Current work continues in developing an anonymous video system and to provide additional sensing elements [9, 12]. Additionally work models the data using Hidden Markov models, and fuzzy logic to provide descriptors of events or sequence of events [13. 14].

The data presented here gives much encouragement that the sensor system detects events that can be related to the reality of resident's activity. While this data may seem obtrusive there is substantial effort expended in making sure that the residents are not identified, even to the point of making the data anonymous in the private meetings of our group. Anonymity is a concern of the residents; identified data is discussed only with the resident, with their permission family members, and known only to the individual responsible for such discussions. We have Institutional Review Board approval for our study and each accepted volunteer signs a consent form [15].

The restlessness indicator is a very useful tool, particularly used with the bed sensor. It shows if the individual is resting well or has discomfort. An important and possibly easy intervention is to remove the cause of the discomfort. It is a passive indicator and requires some comparison with previous behavior.

IV. Conclusion

We have installed and are operating sensor nets in apartments of willing volunteers in TigerPlace, an aging in place residential setting for elderly. We have analyzed restlessness data from two residents and have related that data to important event in their lives. We have related the restlessness data to events that the residents confirm as correct.

In the future we expect to analyze additional sensor data and to model that data to obtain additional information.

References

[1] (Frank 2001). How long can I stay?: The dilemma of aging in place in assisted living. In B. Schwarz (Ed.), Assisted living: Sobering realities. New York: Haworth Press.

[2] Manion 1995) & Rantz, M.J. 1995. Relocation stress syndrome: A comprehensive plan for long term care admissions. Geriatric Nursing, 16(3), 108-112.

[3] (Rantz 1998) Mehr, D., Popejoy, L., Zwygart-Stauffacher, M., Hicks, L., Grando, V., Conn, V., Porter, R., Scott, J., & Maas, M. (1998). Nursing home care quality: A multidimensional theoretical model. Journal of Nursing Care Quality, 12(3), 30-46. *

[4] (Rantz 1999) Zwygart-Stauffacher, M., Popejoy, L., Grando, V., Mehr, D., Hicks, L., Conn, V., Wipke-Tevis, D., Porter, R., Bostick, J. & Maas, M. 1999. Nursing home care quality: A multidimensional theoretical model integrating the views of consumers and providers. Journal of Nursing Care Quality, 14(1), 16-37*

[5] (Marek 2000) Rantz, M.J. 2000. Aging in Place: A New Model for Long Term Care. Nursing Administration Quarterly, 24(3), 1-11.

[6] Marek, (2004), Rantz, M.J., & Porter, R. 2004. Senior Care: Making a difference in long-term care of older adults. Journal of Nursing Education, 43(2): 81-83.

[7] (Rantz 2000) Marek, K.D., & Zwygart-Stauffacher, M. 2000. The future of long-term care for the chroniacally ill. Nursing Administration Quarterly, 25(1), 51-58.

[8] (Rantz 2003). Aging in place. Nurseweek Midwest/Heartland Edition, 4(2), 7.

[9] (Rantz 2004b) Rantz, M.J., Marek, K.D., Aud, M. A., Tyrer, H. W., Skubic, M., Demiris, G., & Jussam, A.A. (in press). Technology and nursing collaboration to help older adults age in place. Nursing Outlook. In press.

[10] M Alwan, J Leachtenauer, S Dalal, et al. Validation of Rule-Based Inference of Selected Independent ADLs. Accepted for publication in the *Journal of Telemedicine and E-Health*, Oct. 2005, Vol. 11, No. 5: 594-599.

[11] S Dalal, M Alwan, R Seirafi, S Kell, D Brown. A Rule-Based Approach to Analyzing Elders' Activity Data: Detection of Health and

Emergency Conditions, *Proceedings of the AAAI's Fall Symposium on AI & Eldercare: Caring Machines*, Washington, DC, November 2005.

[12] Tyrer, H., Alwan, M., Demiris, G., He, Z., Keller, J., Skubic, M., Rantz, M., "Technology for Successful Aging", *Proceedings, IEEE 2006 International Conference of the Engineering in Medicine and Biology Society*, New York, NY, August 30-September 3, 2006, pp. 3290-3293.

[13] Anderson, D., Keller, J., Skubic, M., Chen, X., He, Z., "Recognizing Falls From Silhouettes", *Proceedings, IEEE 2006 International Conference of the Engineering in Medicine and Biology Society*, New York, NY, August 30-September 3, 2006, pp. 6388-6391.

[14] Wang, S., Keller, J., Burks, K., Skubic, M., and Tyrer, H., "Assessing Physical Performance of Elders Using Fuzzy Logic", *Proceedings, 15th IEEE International Conference on Fuzzy Systems*, Vancouver, Canada, July, 2006, pp. 2998-3003.

[15] Demiris G, Skubic M, Rantz MJ, Courtney KL, Aud MA, Tyrer HW, He Z, Lee J. "Facilitating interdisciplinary design specification of "smart homes" for aging in place," *Proceedings, International Congress of the European Federation of Medical Informatics*, Maastricht, Netherlands, August 2006, IOS Press, p. 45 – 50