Linking Resident Behavior to Health Conditions in an Eldercare Monitoring System

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Introduction

Early detection of health changes among older adults is the key to maintaining health, independence, and function. Non-wearable sensors such as depth cameras, motion sensors (passive infrared, PIR) and bed sensors (based on ballistocardiography) are able to detect changes in gait activity and sleep, and have emerged as a possible solution for early detection of health changes. Since 2005, our interdisciplinary research team has investigated, developed and tested a state of the art sensor monitoring system for older adults at TigerPlace, a unique eldercare facility in Columbia, MO[1].

Analyzing and acting upon sensor data remains a challenge for clinicians due to data variety (many sensor types) and velocity (continuous monitoring). To view the context of the health alerts sent by the monitoring system, clinicians currently use a secure interface to review multiple data displays that may take 7 minutes per alert. To save clinicians' time and make alerts easier to interpret, we are investigating a new knowledge-generation methodology based on linguistic summaries as a tool to provide more meaningful and easier to interpret alerts to clinicians.

While certain nonspecific behaviors were shown to be linked to diseases in the elderly[2] and non-wearable sensors can capture those behaviors[3], more specific information is needed for our monitoring system. As an initial step in creating linguistic summary alerts, our team conducted a survey of clinicians to determine which signs and behaviors captured by the monitoring system they find most relevant in evaluating and treating health conditions among older adults. The results of this survey will guide the development of linguistic summary methods.

Methods

Our survey instrument consisted of a 7-item questionnaire in which clinicians were asked to rate how useful they would find a set of sensor measurements when evaluating or treating health conditions among the elderly. Respondents used a 1-4 scale to assess the usefulness of each behavior and sign: 1= *Not Useful*; 2 = *Somewhat Useful*; 3 = *Useful*; 4 = *Very Useful*. Resident behavior measurements were computed by our monitoring system based on the non-wearable sensors shown in Table 1. For example, the number of bathroom visits was computed based on the data provided by the bathroom motion sensor, and the walking speed and stride length were computed based on depth sensor (Kinect) data (see http://eldertech.missouri.edu/papers for more details).

Table 1. Resident behavior captured by given sensors in our monitoring system

Resident Behavior	Sensor
Apartment activity (overall motion)	Motion sensors
Number of bathroom visits	Motion sensors
Amount of time spent in bed	Bed sensor
Rate of respiration while in bed	Bed sensor
Restlessness while in bed	Bed sensor
Pulse rate while in bed	Bed sensor
Walking speed and stride length	Depth sensor

We assessed 12 health conditions in this survey: depression, dementia, mental status change, chronic obstructive pulmonary disease (COPD) exacerbation, chronic health failure (CHF) exacerbation, atrial fibrillation, transient ischemic attack (TIA)/stroke, fall risk, hypo/hyperglycemia, urinary tract infection (UTI), pneumonia and pain.

The sample for this preliminary survey consisted of 11 physicians, 5 registered nurses and 6 licensed practical nurses. These clinicians, all users or familiar with our monitoring system, were recruited from TigerPlace, from our assisted living research sites, and via existing contacts in the MU Health System through referral. Clinicians took part in the survey in-person and or via an online Qualtrics (http://www.qualtrics.com) instrument. All materials and protocols were approved by the University of Missouri IRB.

Results

Three resident behaviors (signs) in order of their importance for assessing 12 health conditions are shown in table 2.

Table 2. Three resident behaviors in order of their importance for assessing 12 health conditions among the elderly

Condition	Behavior (sign) 1	Behavior (sign) 2	Behavior (sign) 3
Atrial Fibrillation	Pulse: 91%	Respiration: 50%	Restlessness: 36%
CHF Exacerbation	Pulse: 82%	Respiration: 82%	Restlessness: 55%
COPD Exacerbation	Respiration: 96%	Pulse: 68%	Restlessness: 50%
Dementia	Restlessness: 68%	Overall Motion: 59%	Time in Bed: 59%
Depression	Time in Bed: 91%	Overall Motion: 82%	Restlessness: 59%
Fall Risk	Stride length: 100%	Bathroom Motion: 82%	Overall Motion: 68%
Hypo/Hyperglycemia	Bathroom Motion: 32%	Restlessness: 28%	Overall Motion: 24%
Mental Status Change	Time in Bed: 82%	Restlessness: 77%	Overall Motion: 68%
Pain	Stride length: 82%	Respiration: 73%	Pulse: 73%
Pneumonia	Respiration: 86%	Pulse: 59%	Overall Motion: 41%
TIA/Stroke	Stride length: 55%	Pulse: 46%	Respiration: 27%
Urinary Tract Infection	Bathroom visits: 96%	Restlessness: 46%	Overall Motion: 46%

From the above table we see that for 9 out of the 12 conditions, more than 80% of the clinicians seem confident (scores 3 and 4) that our system could provide useful information. For three conditions listed above (TIA, hypo/hyperglycemia and dementia) our monitoring system doesn't seem able to provide useful information.

Conclusions

Based on data in table 2, for residents with a history of one of the above conditions (extracted from our nursing EMR), we will provide linguistic summaries that provide context for the health alerts of the form: "Observed an increase in bathroom visits and an increase in bed restlessness. Possible UTI." Note that the data in table 2 can be used as a fuzzy rule decision support system for producing alerts, with rules of the form: "IF *the number of bathroom visits* is high AND *night restlessness* is high and *apartment motion* is low THEN the possibility of UTI is high." Our team is currently exploring the timeframe and directionality of our set of health behaviors through further clinician surveys in order to refine a system of thresholds for deploying alerts.

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References

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