

Squaring the Life Curve with Proactive Healthcare Technology

Marjorie Skubic, PhD

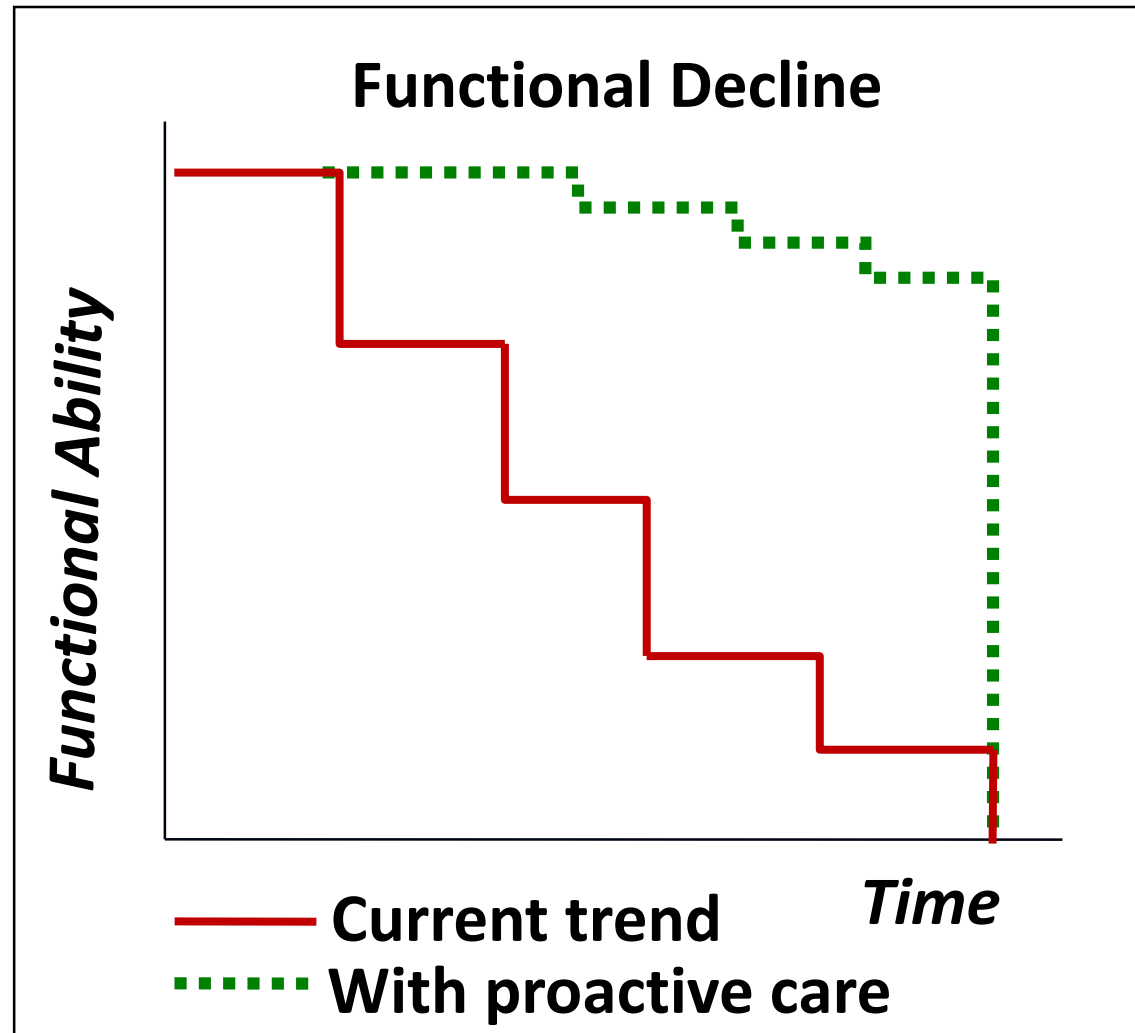
Professor, Electrical Engineering & Computer Science

Director, Center for Eldercare & Rehab Technology

www.eldertech.missouri.edu

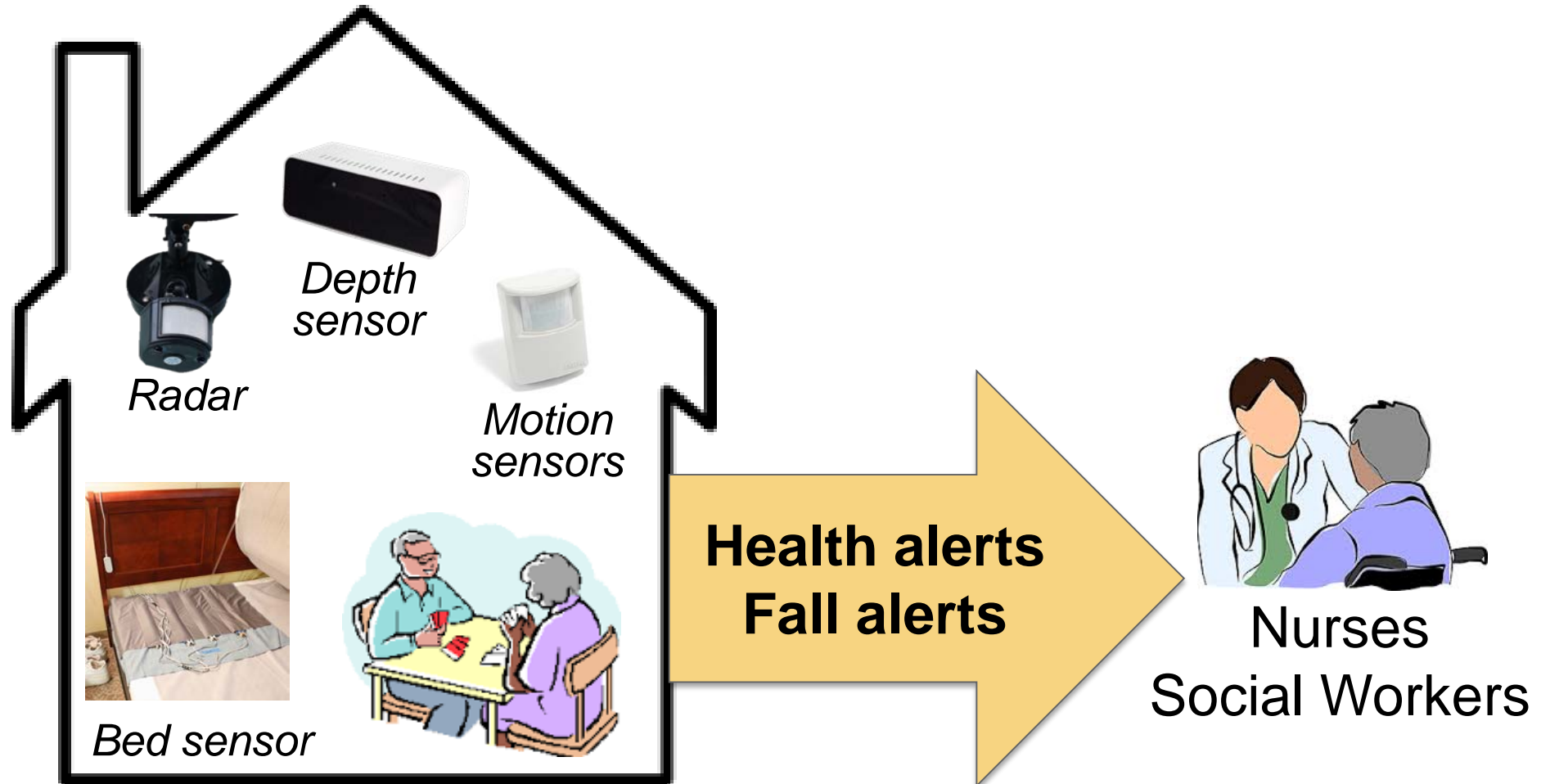


Squaring the Life Curve



Rantz et al, *Nursing Outlook*, 2005

Detecting Health Changes with In-Home Sensors



TigerPlace

54 apartments

Designed for Aging in Place

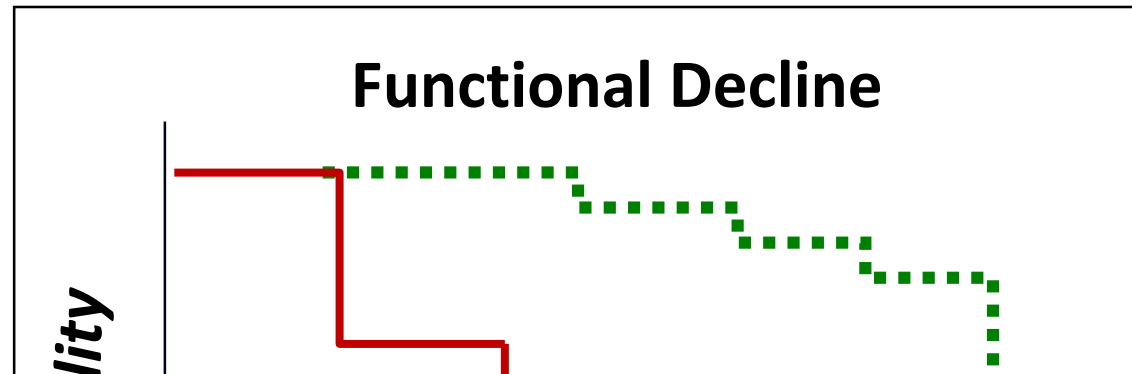
...built by Americare

...clinical care by U of Missouri Nursing School



- 65 residents, aged from about 70 to 100
- Almost all have a chronic illness, e.g., arthritis, heart disease, diabetes, stroke risk
- Some early stage Alzheimers
- 35% use a walker; some wheelchairs

Squaring the Life Curve



- TigerPlace residents without in-home sensors stay 2.6 years: **0.8 years longer** than seniors in comparable U.S. housing
- TigerPlace residents with in-home sensors stay 4.3 years: **1.7 years longer** than those without sensors at TigerPlace

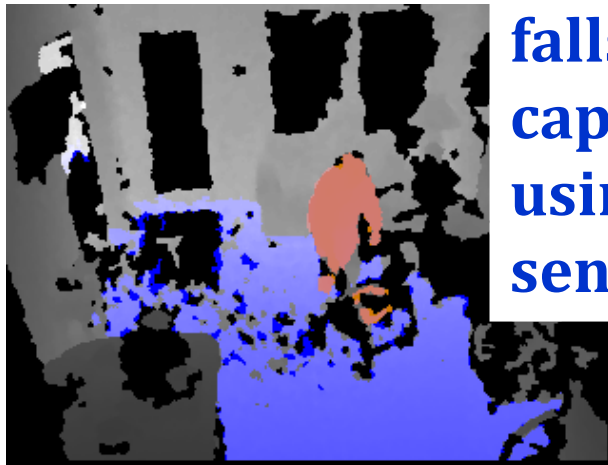
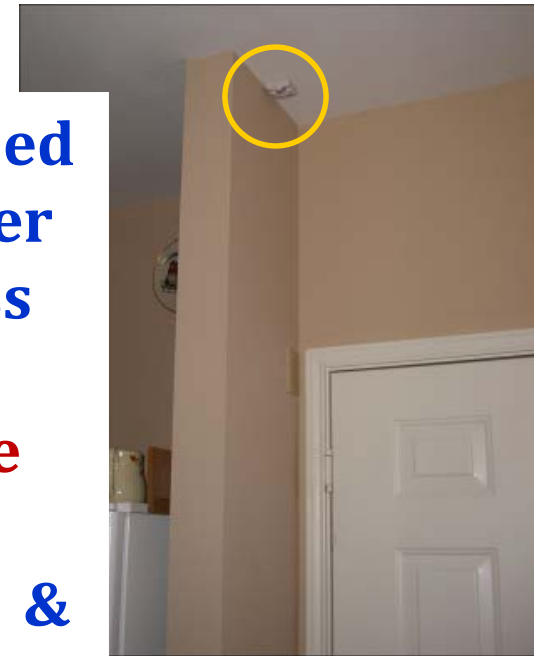
Sensors



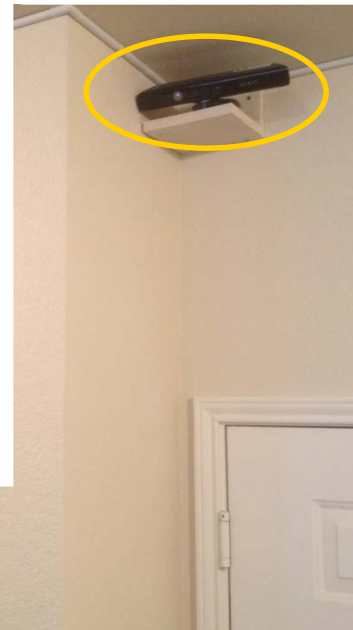
Passive
Infrared
motion
sensors



Hydraulic bed
sensor under
the mattress
captures
quantitative
pulse,
respiration &
restlessness

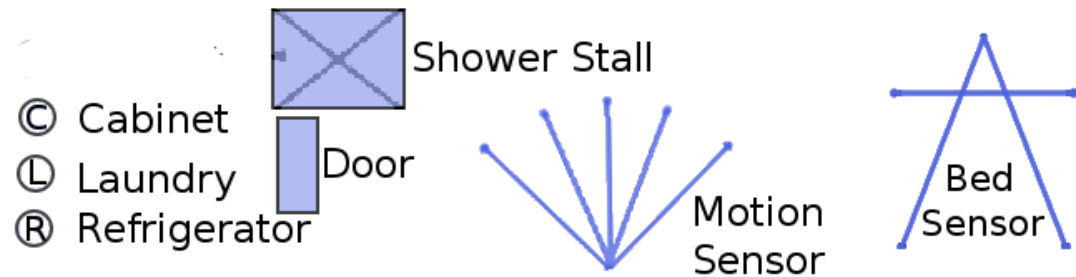
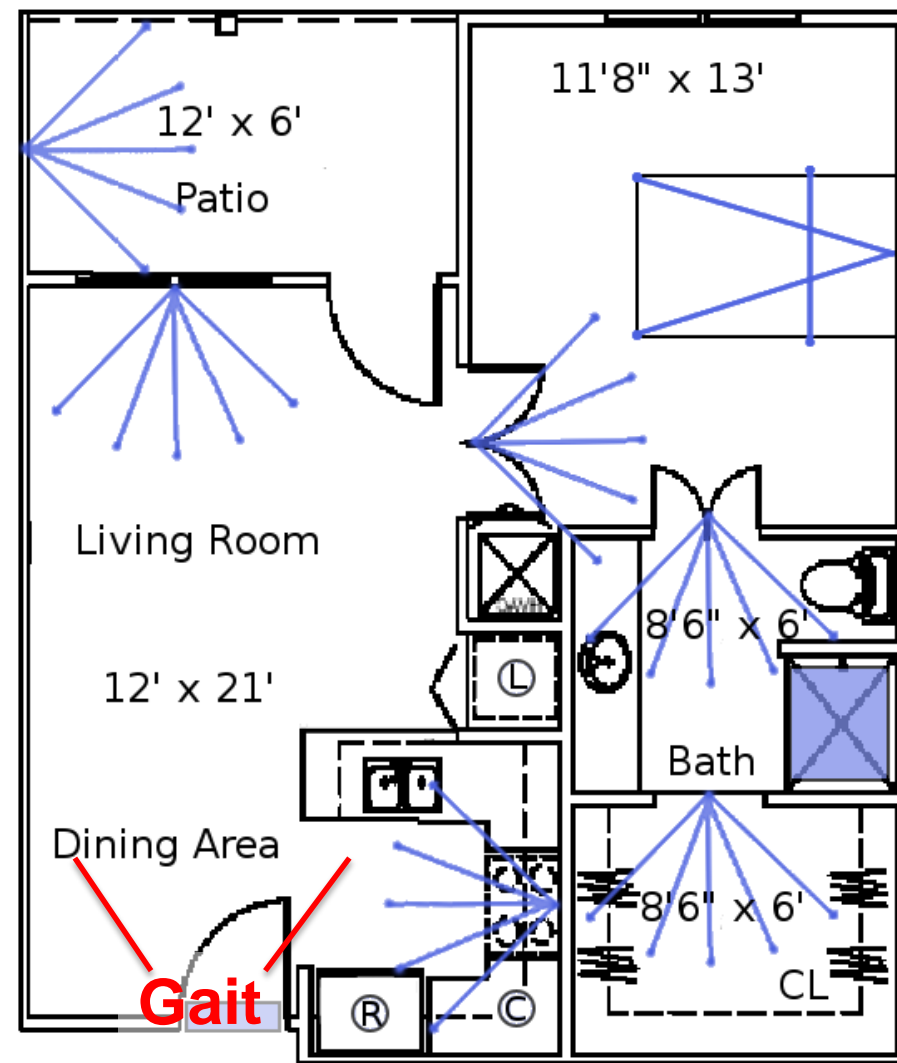


Gait
parameters &
falls are
captured
using depth
sensors



A Typical One-Bedroom Apartment

- 4-6 motion sensors
- 1-2 bed sensors
- 1-2 depth sensors for gait and fall detection



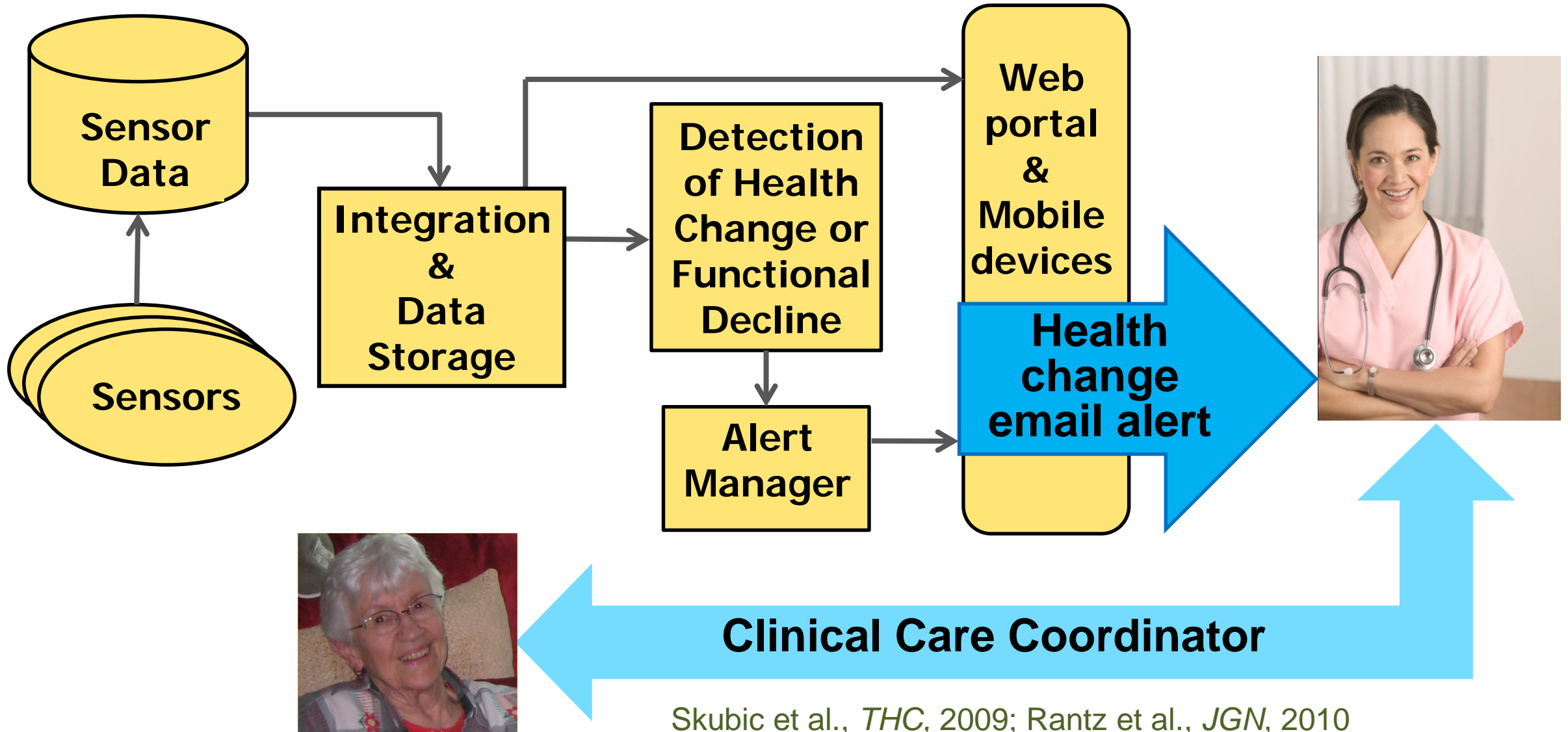
Keeping Eva out of the hospital

Recognizing early heart failure problems with a bed sensor



Sensor Network for Health Alerts

clinical decision support system



Health Alerts from Email – early work

Night Health Alerts:69

cirl.missouri.edu@gmail.com

Sent: Tue 3/5/2013 10:01 AM

To: [redacted]

Night Time (10PM - 6 AM) Alert Summary for 69 on March 4, 2013.

Time Frame in Days: 14

**** ABNORMAL BEHAVIORS ****

[INCREASE in Bathroom](#) (4.16 Deviation)

[Submit Feedback](#)

[Add Progress Note](#)

[Add Visit Note](#)

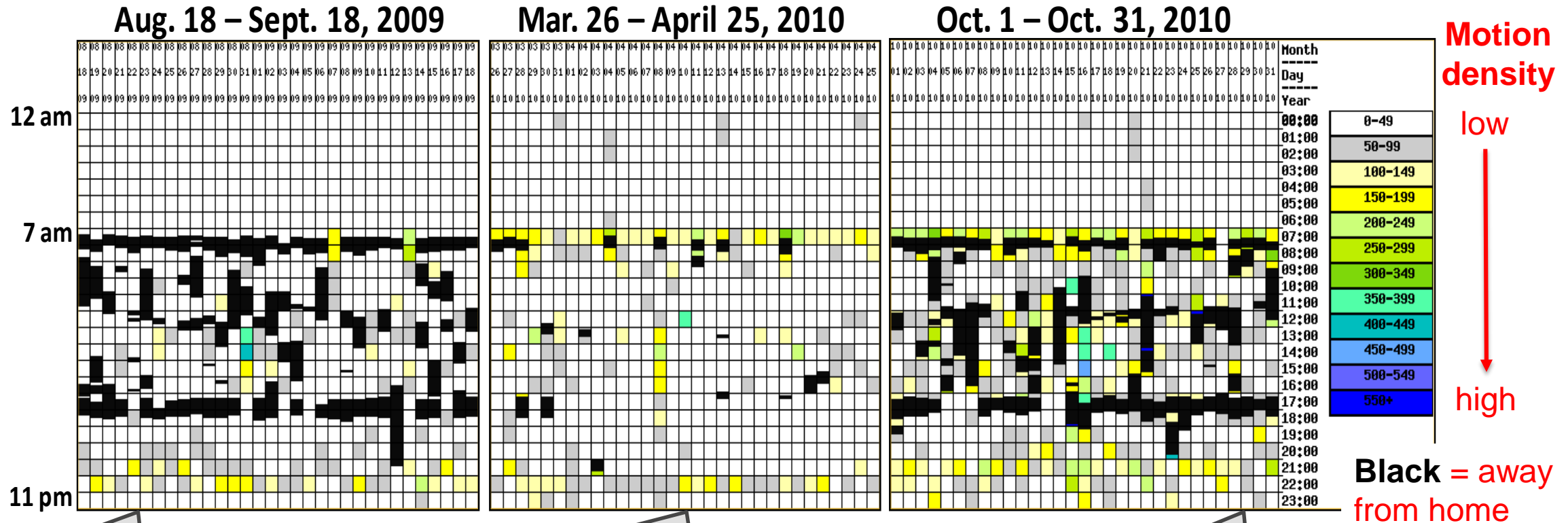
-- CERTAlertManager 1.0

Link to the interactive sensor interface

Feedback from clinicians is used to build a database of good vs. poor alerts for future refinement

Links to the EHR

Diagnosis & History of Depression



Depression managed & followed by a geriatric psychiatrist

After personal losses resident reported low energy, had trouble eating, and stopped going to the dining room

After intervention, resident's activity pattern increased

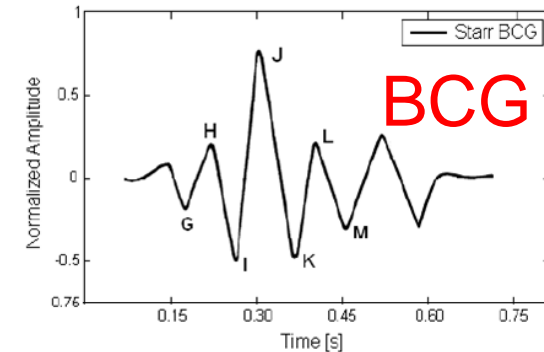
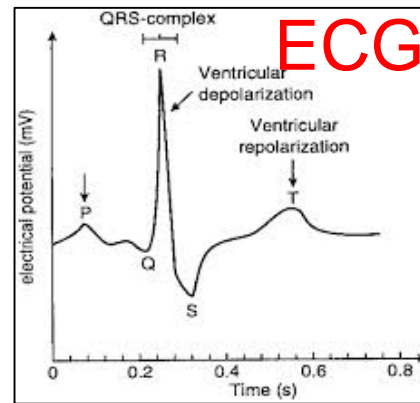
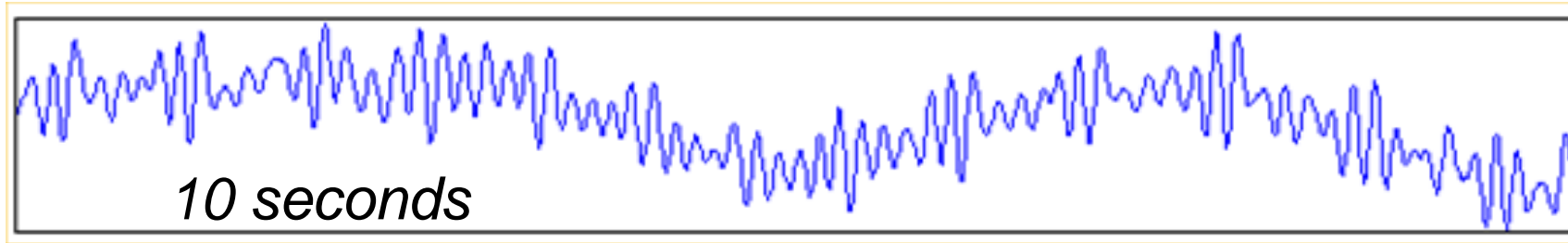
Health Changes Detected Early

- urinary tract infections
- pneumonia & other upper respiratory infections
- increasing congestive heart failure
- pain post hospitalization
- delirium
- low blood sugar

Used a model of early illness recognition to generalize across different health problems

MU Hydraulic Bed Sensor

Captures the ballistocardiogram & respiration

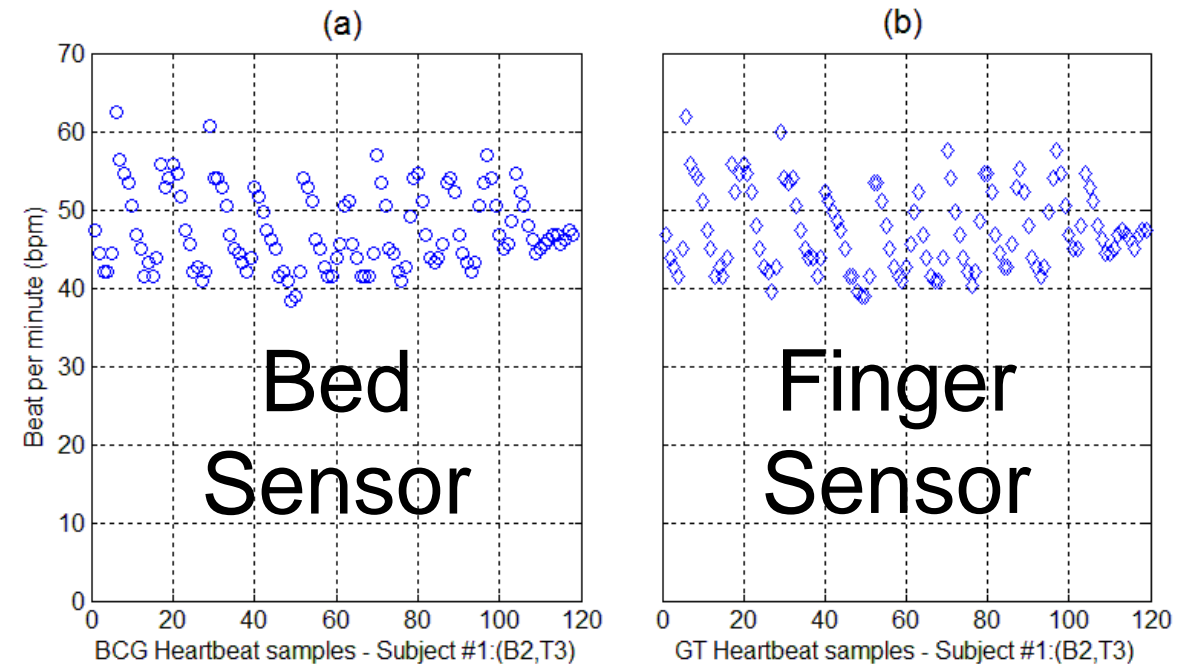
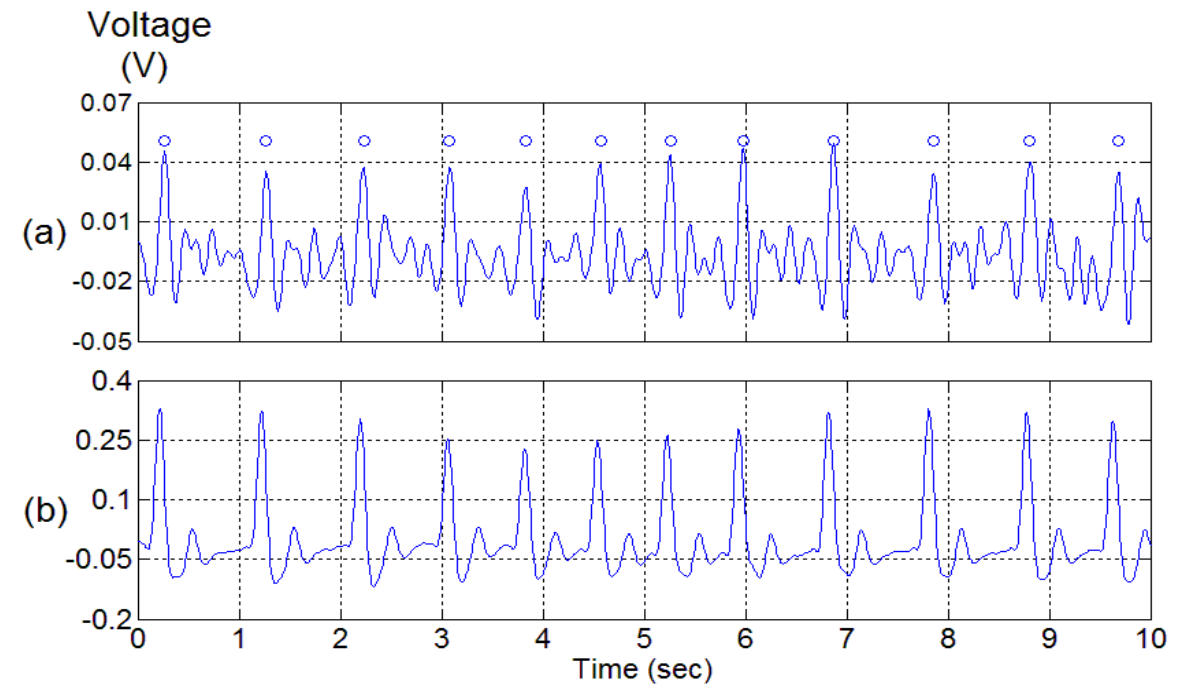


Heise et al., 2011, 2013

Heartbeats from bed sensor

Finger sensor

Beat to beat interval



Capturing Gait in the Home Using Depth Data

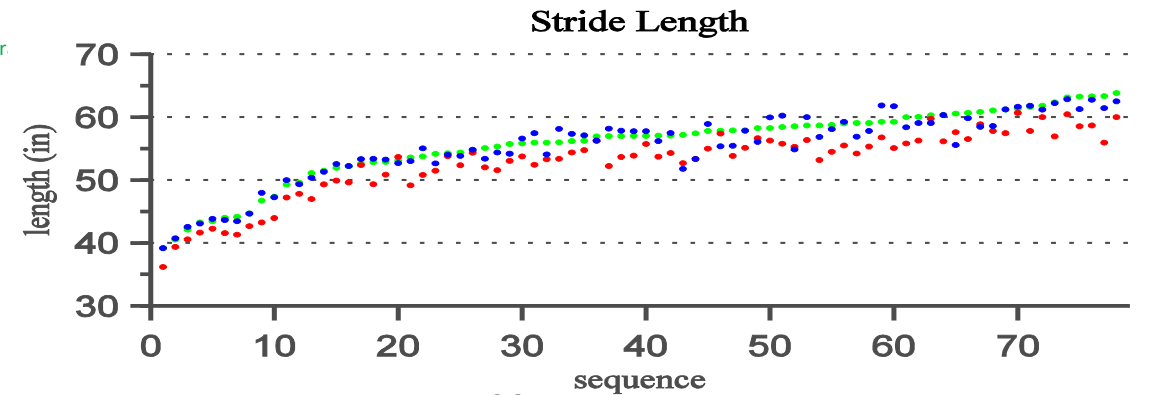
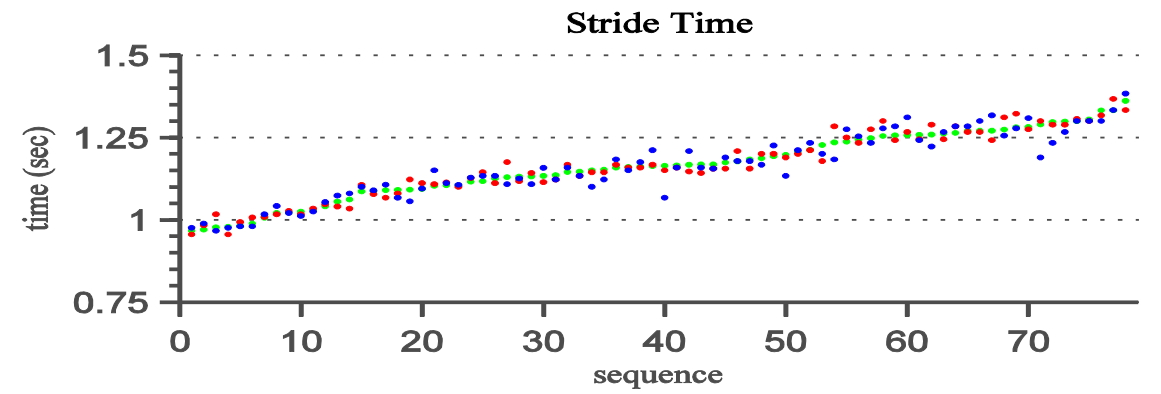
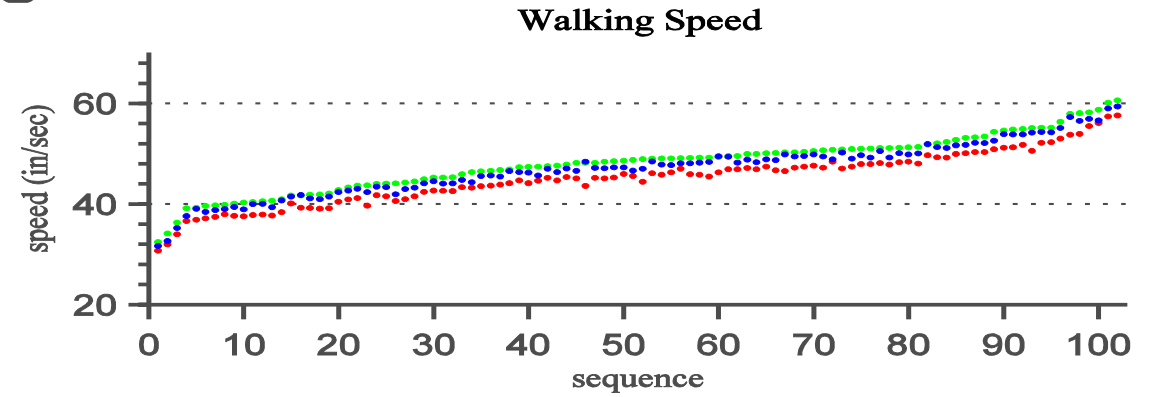
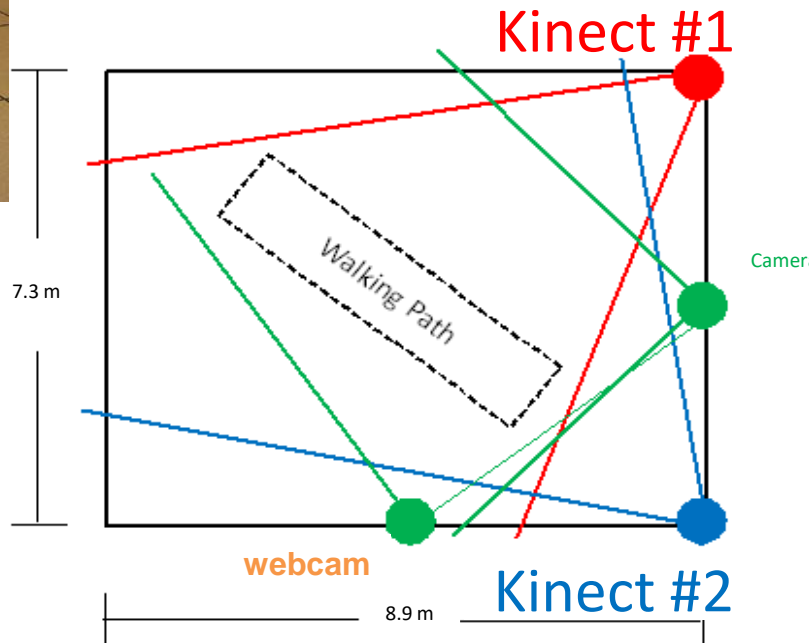


Stone & Skubic, *JAISE*, 2011, *TBE*, 2013

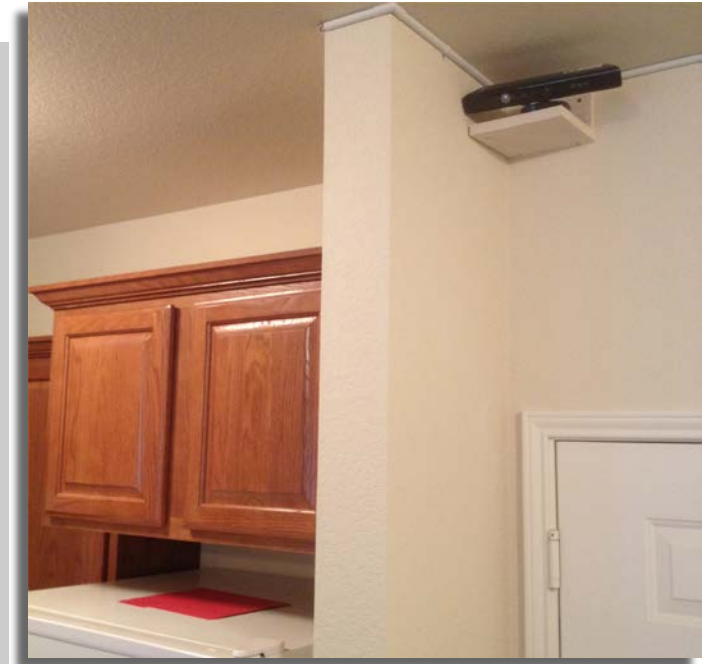
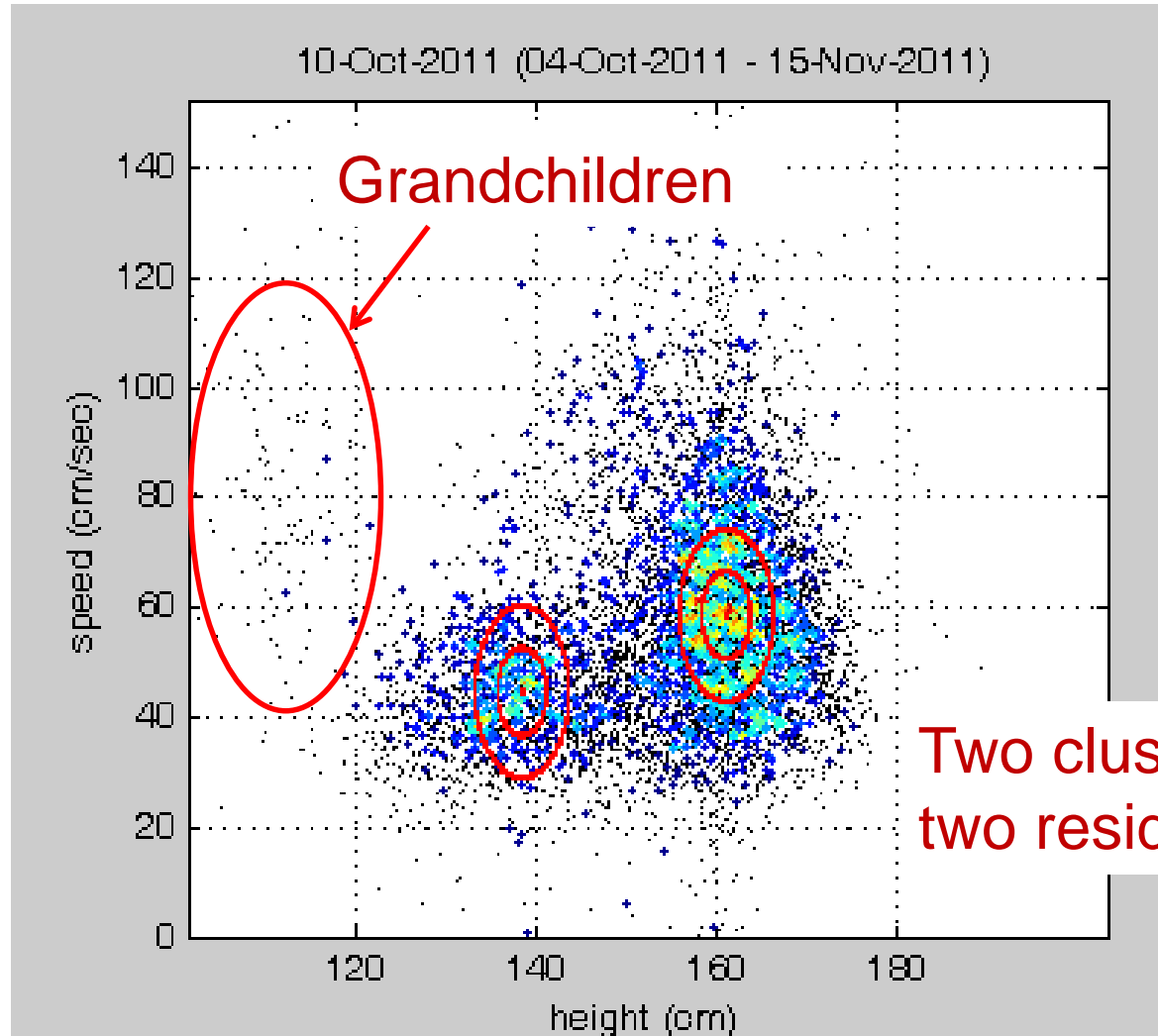


In-Home Gait: <https://www.youtube.com/watch?v=MF6yZyLuull>

Validation in the Lab

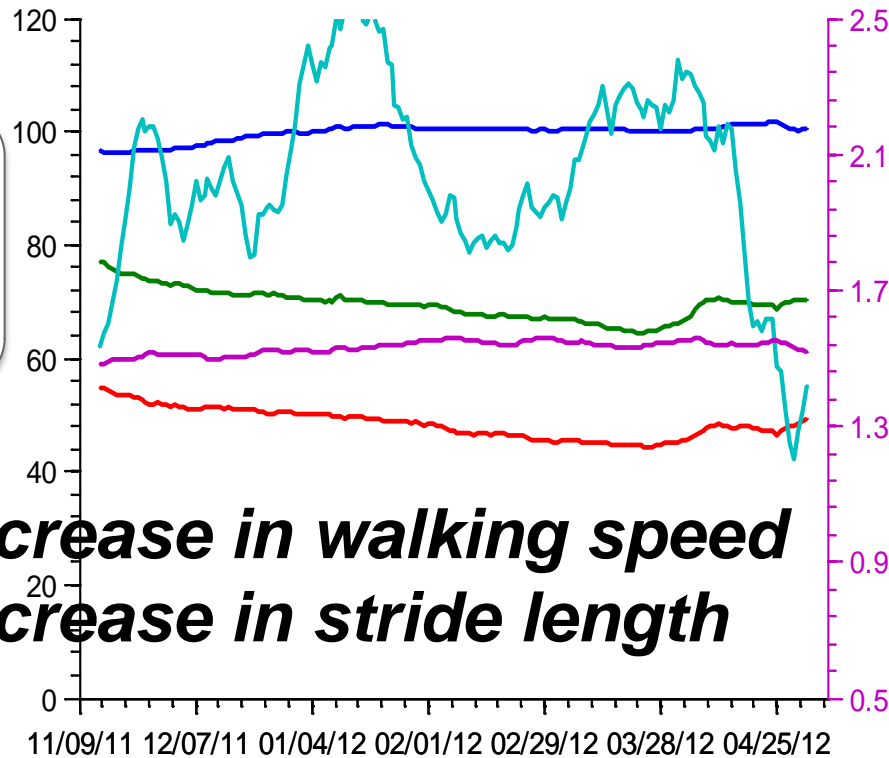
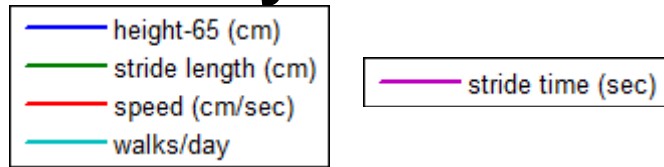


Capturing Gait in the Home



Case Study: Capturing Gait Changes

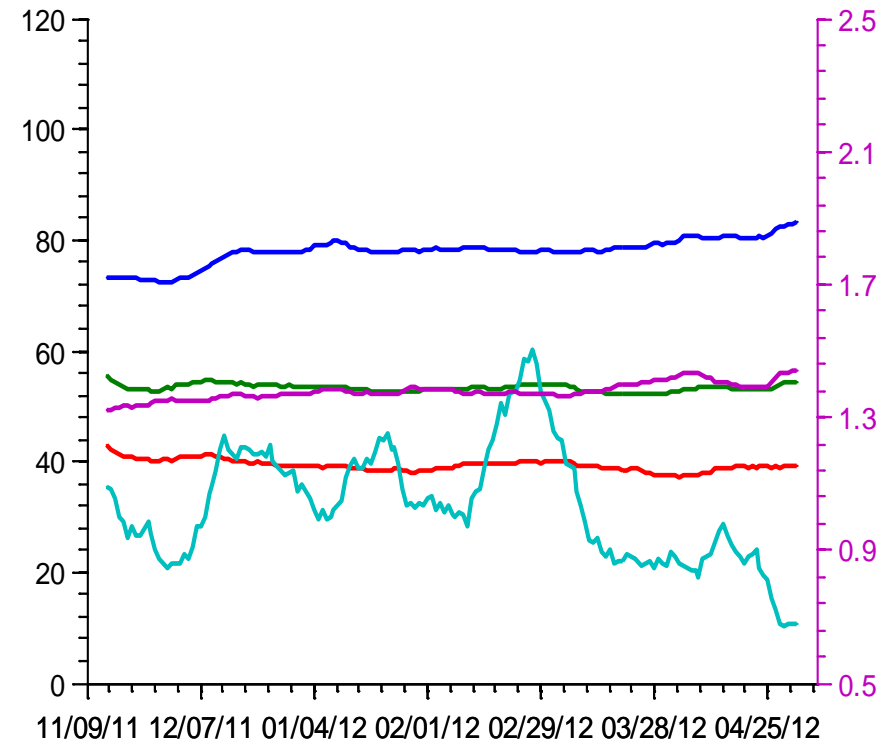
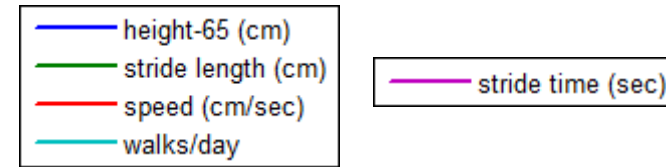
“Healthy” Husband



Cognitive Decline

Decrease in walking speed
Decrease in stride length

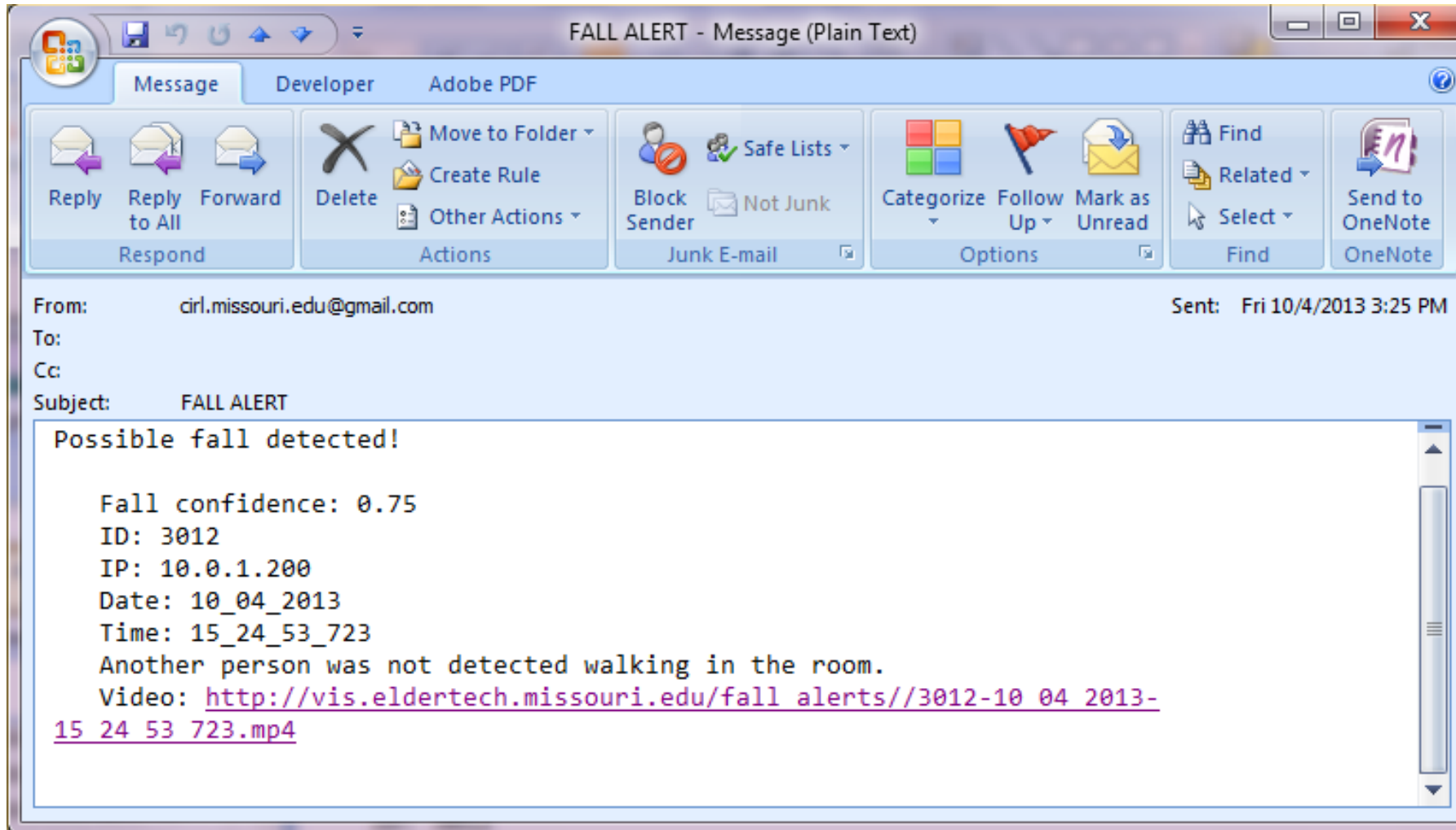
Wife with Parkinson's



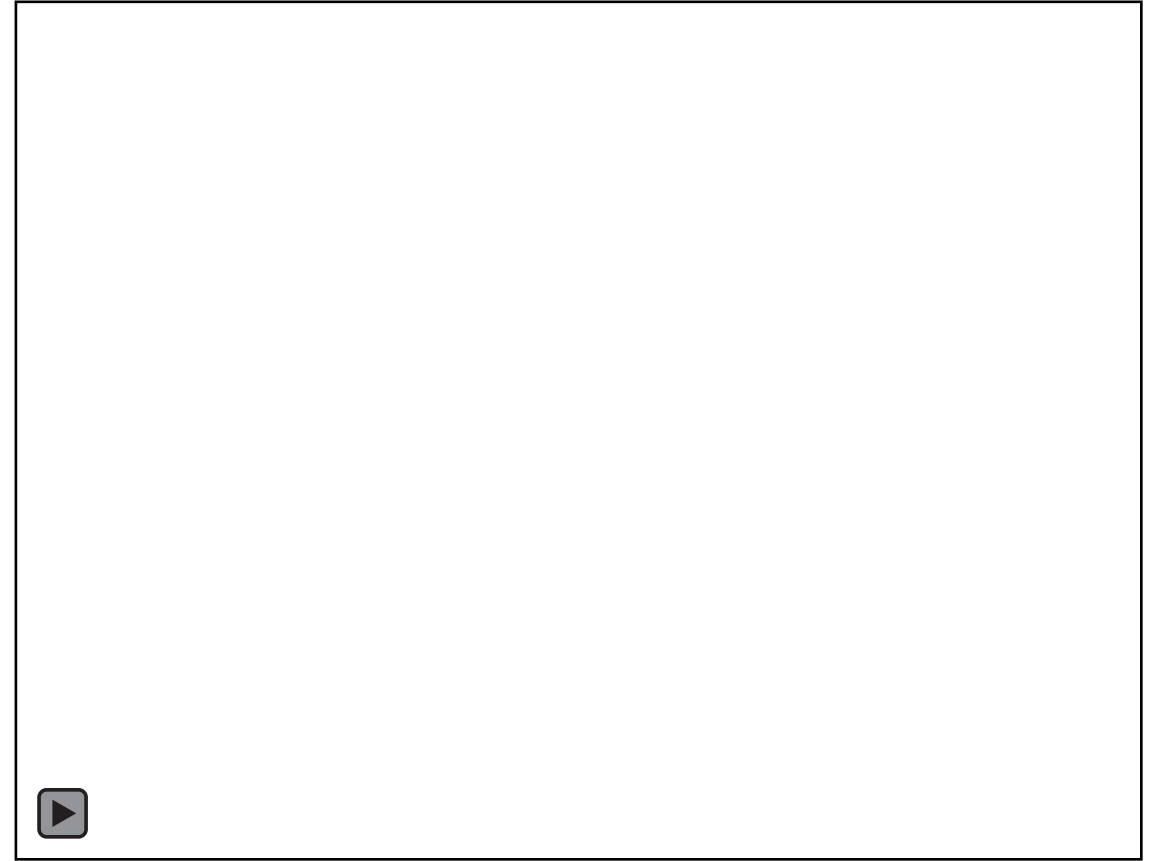
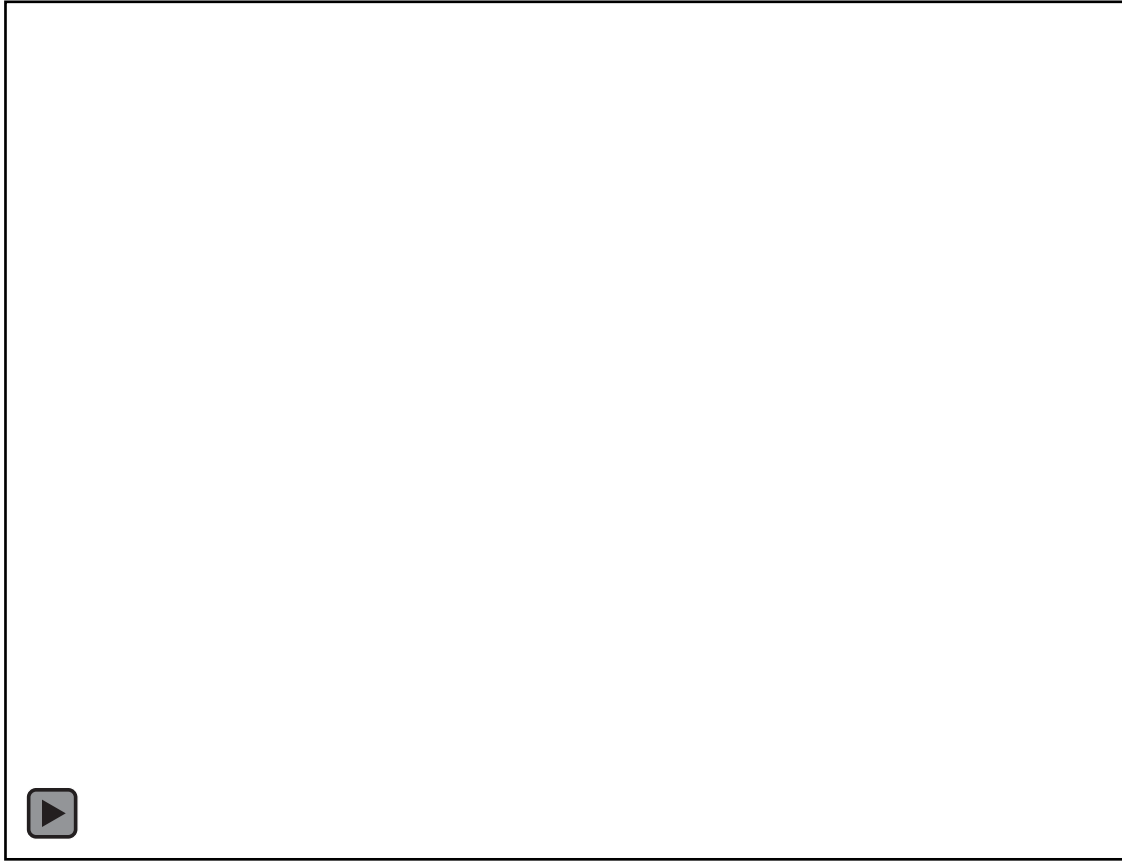
In-Home Gait Changes Predict Falls

- Decrease in walking speed of 5.1 cm/sec over 7 days
→ 86% probability of falling within the next 3 weeks
- Decrease in stride length of 7.6 cm over 7 days
→ 51% probability of falling within the next 3 weeks

Fall Alerts using Depth Data



Capturing Falls in the Home with Depth Sensors



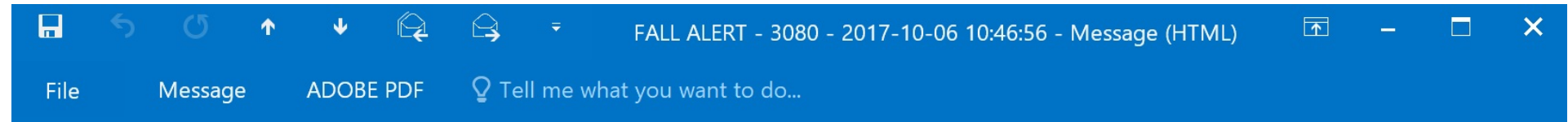
Stone & Skubic, 2014, 2015

In-Home Falls: <https://www.youtube.com/watch?v=TFB7YOUmHho>

False Alarms in the Home



Fall Alerts Today



 MU Elec & Comp Engr General Communication | Fri 10:47 AM
FALL ALERT -
i You forwarded this message on 10/6/2017 1:58 PM.

Possible Fall Detected!

Site: ElderTech Visualization Interface
Fall Confidence: 94%
Resident Id:
Apartment:
Date/Time: 2017-10-06 10:46:56 AM

The system did not detect another person in the room

[View Alert Video](#)

[View Rewind Player](#)

(Please note that the video will not be available in the Rewind Player until the data has had a chance to transfer from the sensors to the server. This could take a couple hours or more.)

If you have any questions, please contact the ElderTech Administrator at eldertech@missouri.edu.

This email was automatically generated.

Generating Linguistic Summaries of Sensor Data

Previous

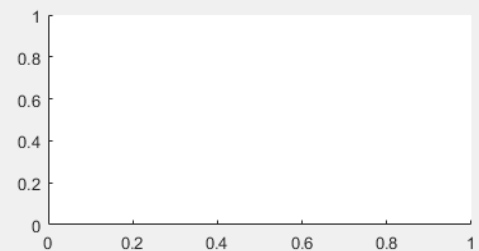
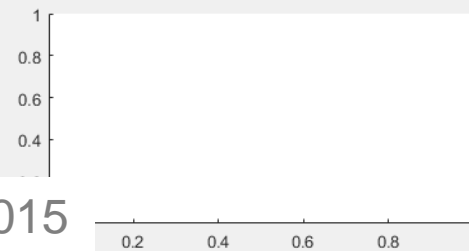
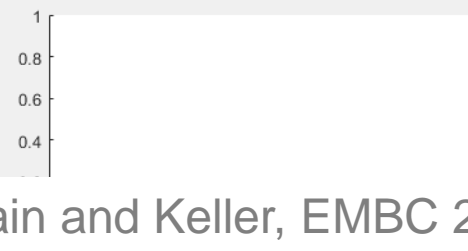
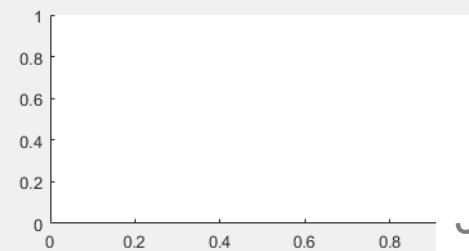
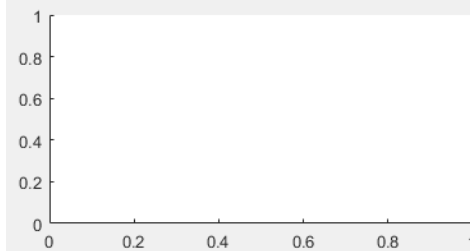
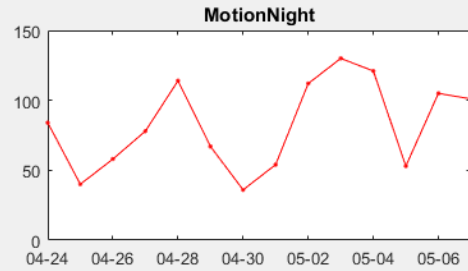
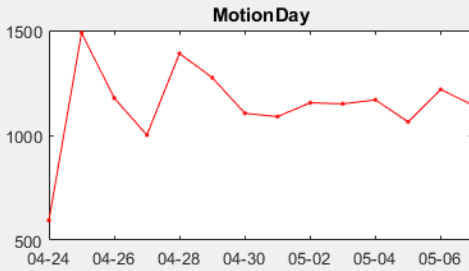
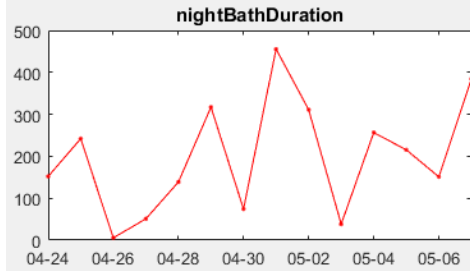
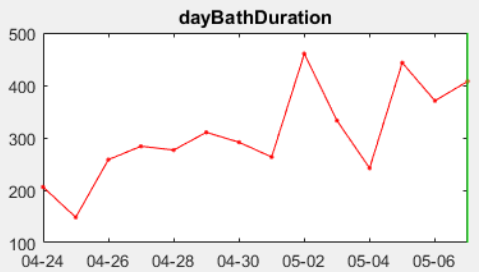
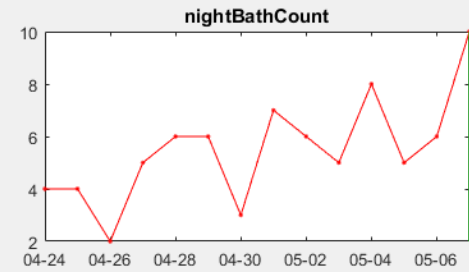
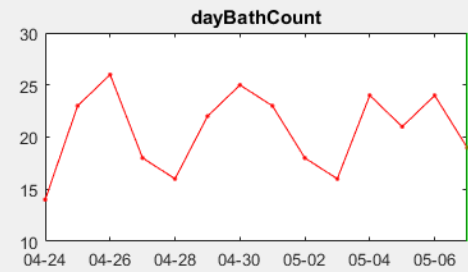
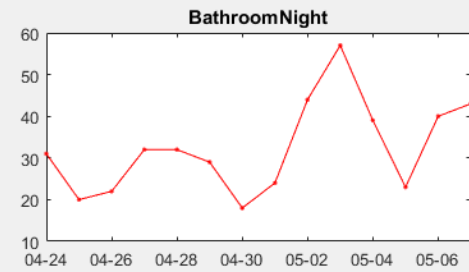
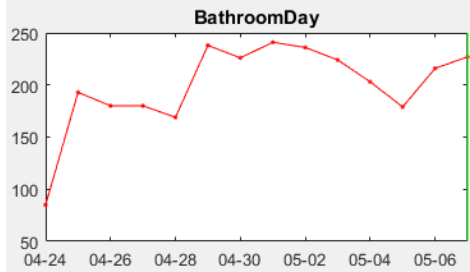
Next

9
3062
07-May-2015
TP

Possible UTI

AUTO-GENERATED SUMMARY:

In the past two weeks, there were many days with high Bathroom & Overall Activity. Also, Restlessness have been increasing for the past 5 days.



Health Alerts Evolution

Alert Summary

**Simple
alert**

Resident id 3076 has had 6 health alerts since Saturday, September 23, 2017. Please visit the visualization interface via the link below to view the details of the alerts.

[View Data on Interface](#)

Alert Summary

**New
linguistic
style**

Day & Night time Time in Bed have been increasing for the past 5 days.
Many instances yesterday had low pulse rate.
Many instances yesterday had low respiration rate.

[View Data on Interface](#)

Mom and Dad at Home, 2006

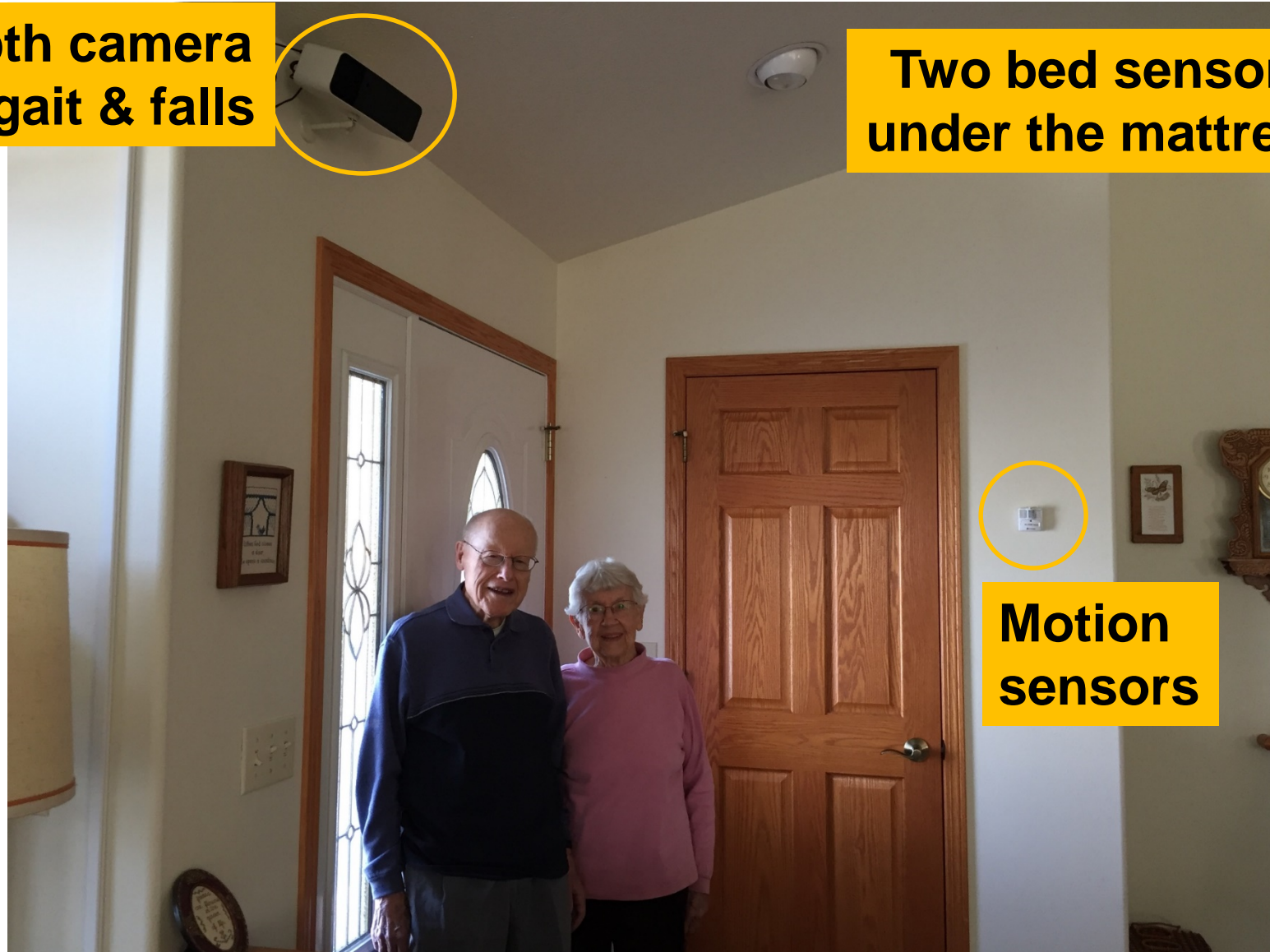


Still at Home, January, 2017

**Depth camera
for gait & falls**



**Two bed sensors
under the mattress**



**Motion
sensors**

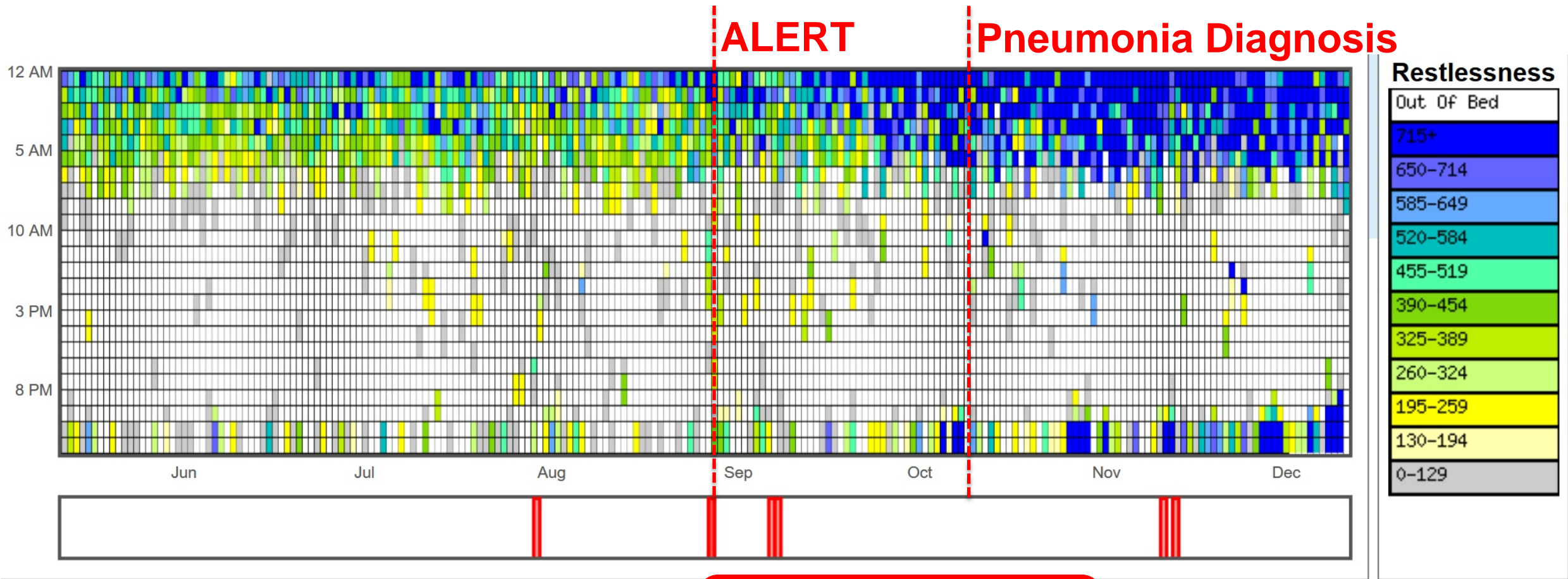
August, 2017



January, 2018



Changes in Bed Restlessness Density



1.00 Alert
Date: 8/27/2017
Restlessness Pct Time In Bed Increase

Changes in Gait

Gait Parameters

Estimated TUG (Fall Risk)

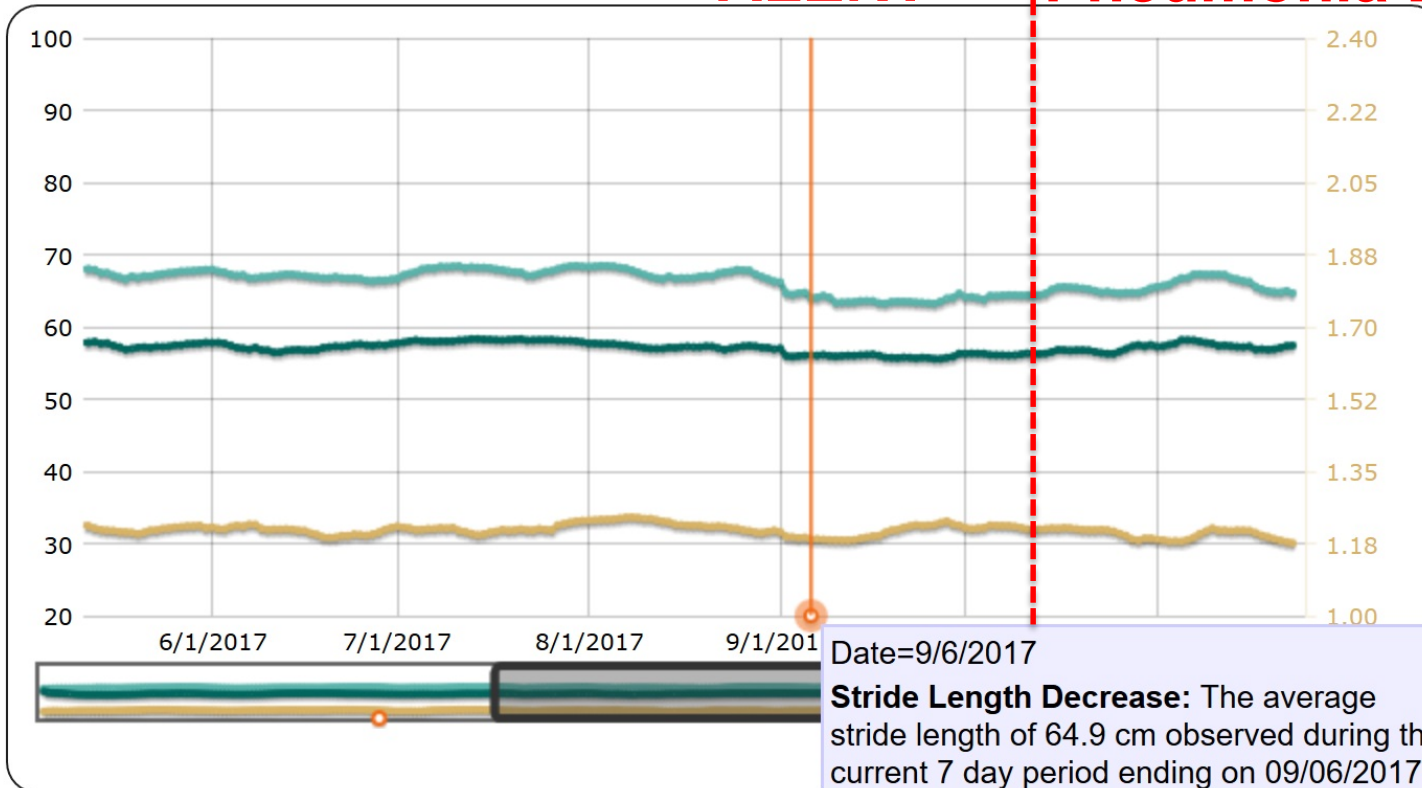
Walk Data Scatter Plots and Model(s)

Model Initialization

Model Window Size: 30 days

Data Window Size: 14 days

ALERT Pneumonia Diagnosis



- Stride Length (cm)
(Higher is better)
- Average Speed (cm/sec)
(Higher is better)
- Stride Time (sec)
(Lower is better)
- Gait Alerts
- 95% Intervals

Date=9/6/2017

Stride Length Decrease: The average stride length of 64.9 cm observed during the current 7 day period ending on 09/06/2017 is 3.1 cm (4.6%) lower than the average stride length of 68.0 cm observed during the 7 day baseline period which ended on 04/15/2017.

Dad at TigerPlace March, 2018

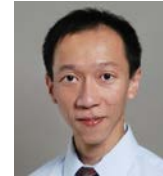


Many thanks to our faculty and student collaborators, the study participants & the funding agencies.

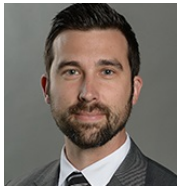
See also
www.eldertech.missouri.edu



Many Collaborators ...+ students & seniors



Social
Work



Nursing



Engineering &
Computer
Science



Physical
Therapy



Occupational
Therapy

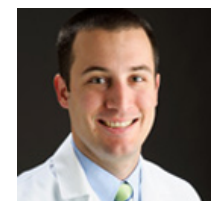
Education



Foresite
Healthcare



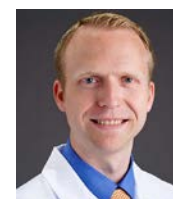
Architectural
Studies



Music



HMI



Medicine



Center for Eldercare and Rehabilitation Technology

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www.eldertech.missouri.edu

www.ForesiteHealthcare.com