RecognitionTechnology to Support Aging in Place

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Research Team

- **MU Engineering**
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- **MU Nursing**
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  - Students: Jie Yu, Jean Krampe
- **MU Health Informatics / Physical Therapy / Social Work**
  - Faculty: Mihail Popescu, Carmen Abbott, Deb Oliver, Colleen Galambos
  - Students: Saurav Garg , Rohan Ohol, Jarod Giger
- **MU Family Medicine**
  - Faculty: Richelle Koopman
- **University of Washington**
  - Faculty: George Demiris

Outline

- Motivation
- Integrated Sensor Network
- TigerPlace Case Studies
- Video Sensor Network
  - Protecting privacy
  - Detecting falls
  - Extracting gait parameters
- Conclusions

The Challenge

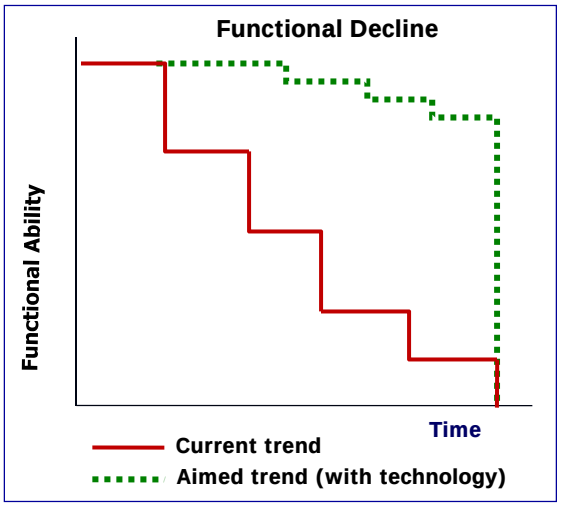
Give us technology for TigerPlace that will help elder residents stay as active and functionally independent as possible.

TigerPlace: Designed for Aging in Place




Opened in June, 2004; 54 apartments

Trajectory of Functional Decline

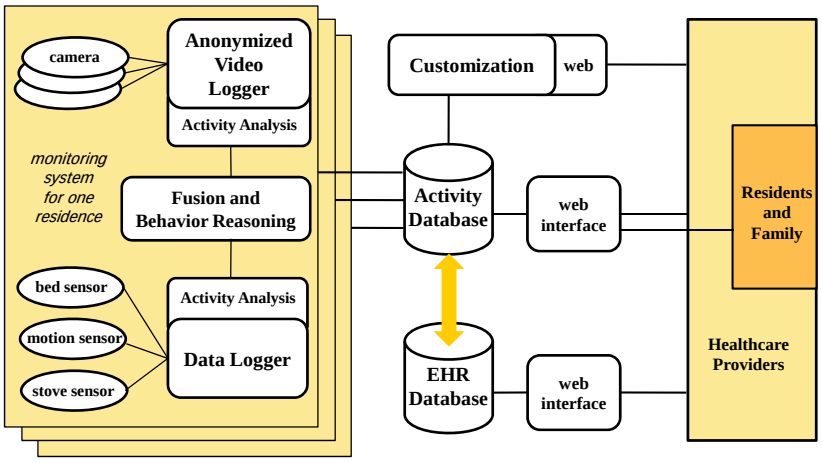


- Detect falls
- Assess gait & activity level
- Assess normal patterns
- Recognize pattern changes
- Detect acute illness onset or changes

Rantz, Marek, Aud, Tyrer, Skubic, Demiris & Hussam, *Nursing Outlook*, 2005

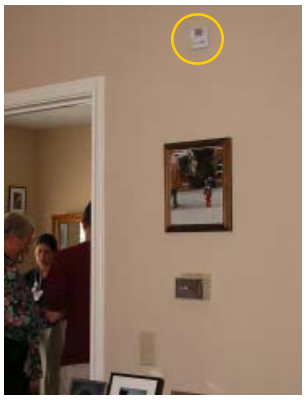
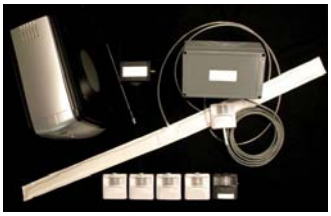
Our Goal:
Keep them functionally active!

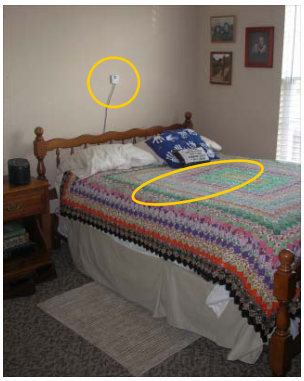
Integrated Sensor Network



Skubic, Alexander, Popescu, Rantz, Keller, *Technology & Health Care*, 2009.

Basic Sensors



Video Processing

Young Elliott Anderson

Priceless

Low cost cameras (on Tripods for the picture)

$100 each

"Little Elliott": Low cost CPU with GPU for processing power

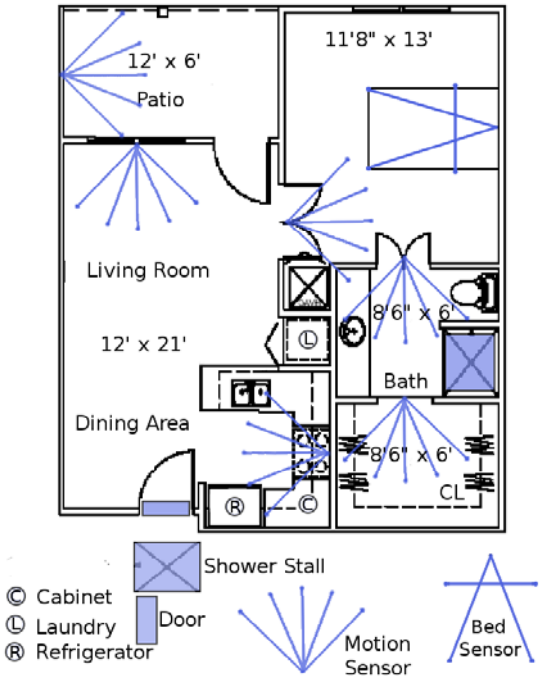
$500

A typical sensor network

11 motion sensors
1 Bed sensor unit
1 Stove temp unit
1 PC appliance

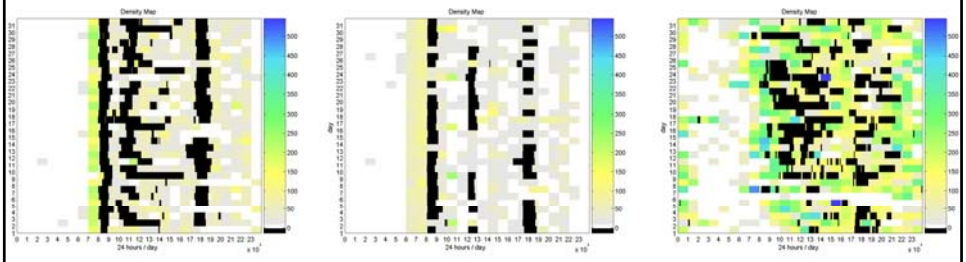
30 sensor networks installed since Oct., 2005

Average time: 2 years



Motion Sensor Density Map

A different way to look at motion sensor data:
A visualization and a similarity measure captures changes in lifestyle

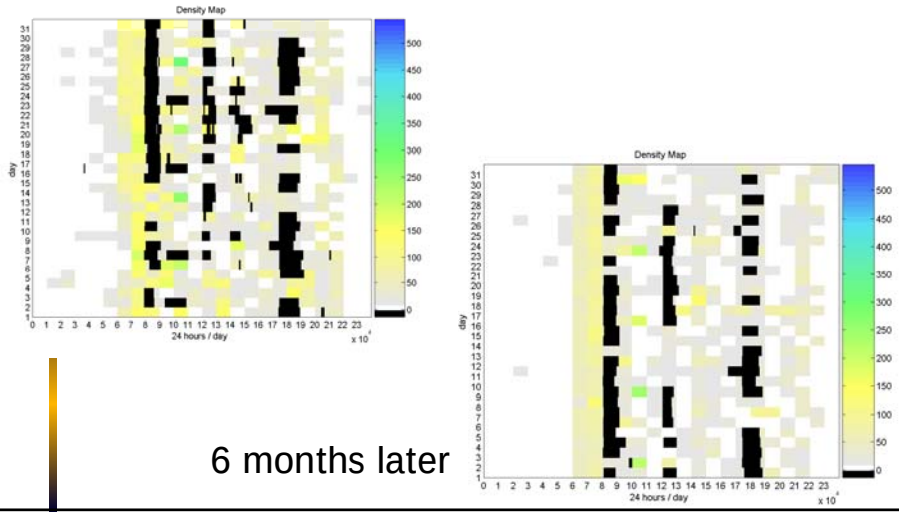


Active | Sedentary | Cognitive Impairment

S Wang & Skubic, IE 2008
S Wang, Skubic & Zhu, EMBC 2009

18

Motion Sensor Density Map—same resident



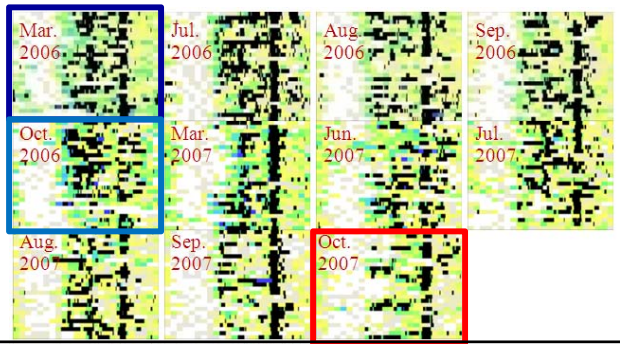
6 months later

Dis-similarity Measure Based on the Co-occurrence Matrix

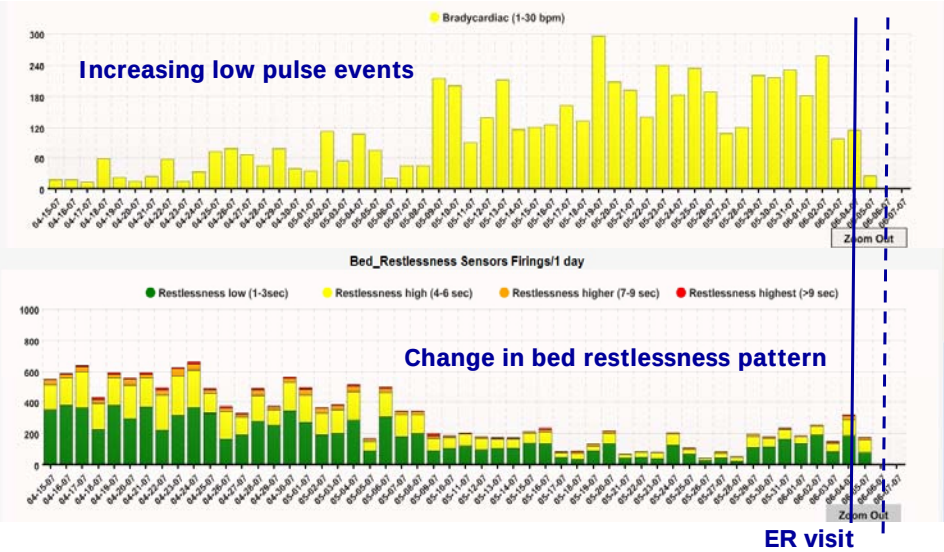
- Capture the change using *texture information* in the motion density map
- We propose a dis-similarity measure based on the *co-occurrence matrix*
- Calculate Activity CM from the motion sensor density and TAFH directly

Case Study

Dis-similarity changes of a resident



Bed Sensor Data Changes

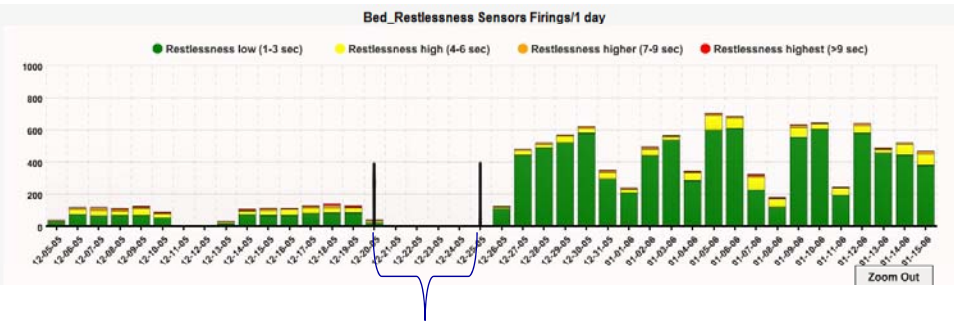


ER visit

Hospitalization

Rantz, Skubic, Miller, and Krampe, ICOST 2008

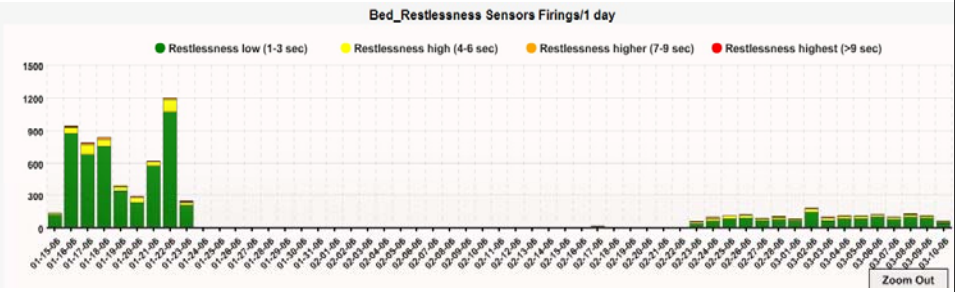
Increase in Bed Restlessness Following Surgery



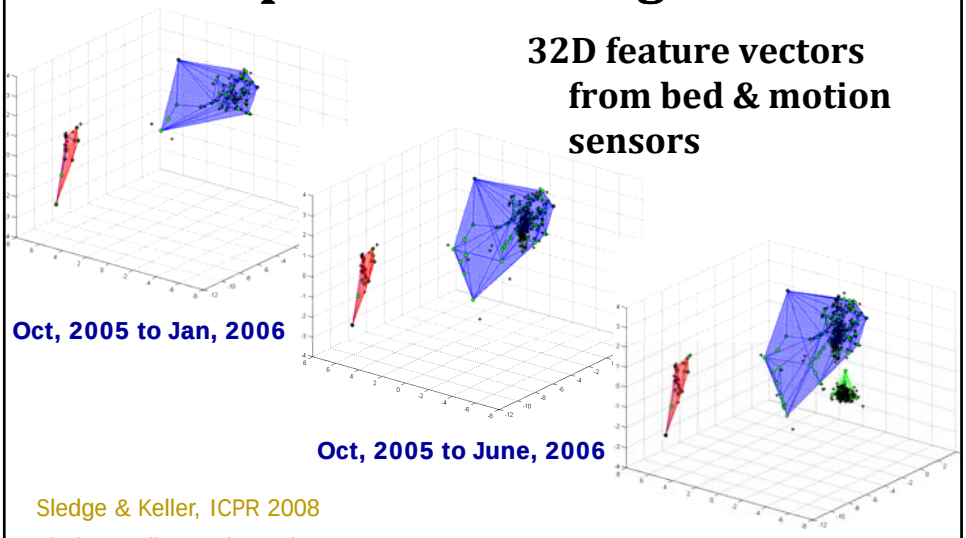
Heart attack and bypass surgery

Rantz, Skubic, Miller, and Krampe, ICOST 2008

Return to Normal Bed Restlessness Following Cardiac Rehabilitation



Growing Neural Gas for Temporal Clustering



32D feature vectors from bed & motion sensors

Oct, 2005 to Jan, 2006

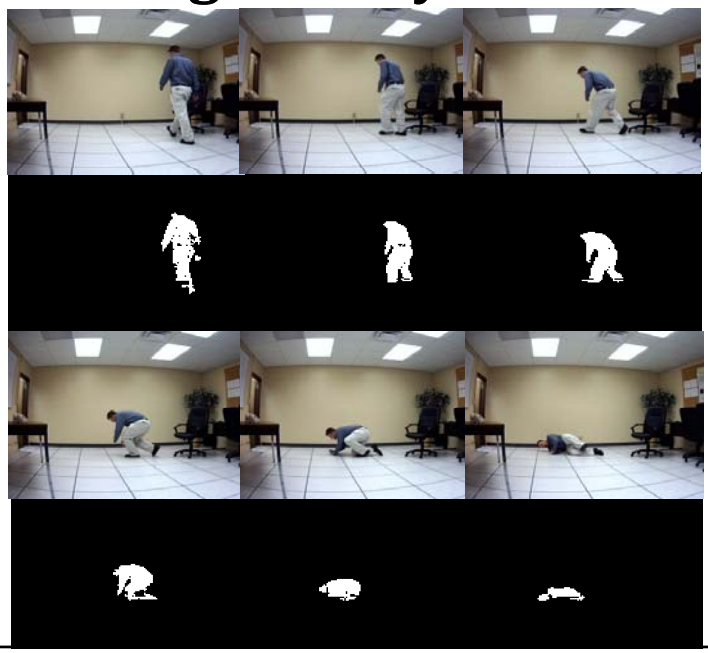
Oct, 2005 to June, 2006

Oct, 2005 to Nov, 2006

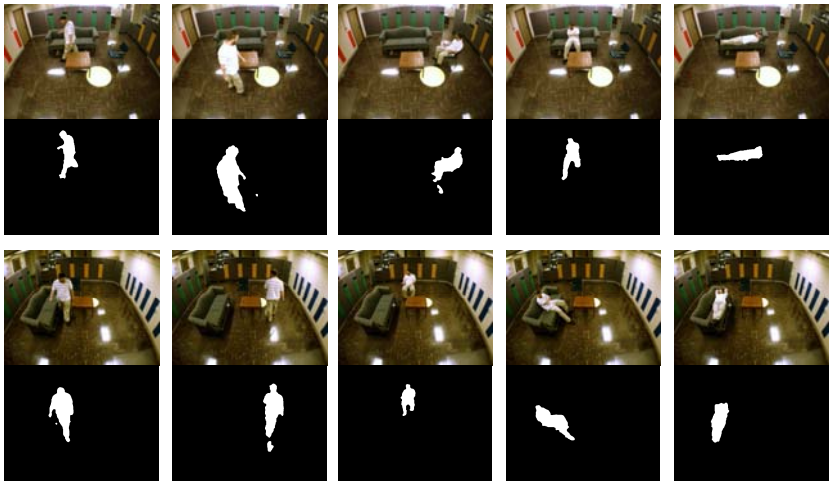
Sledge & Keller, ICPR 2008

Sledge, Keller & Alexander, EMBC 2008

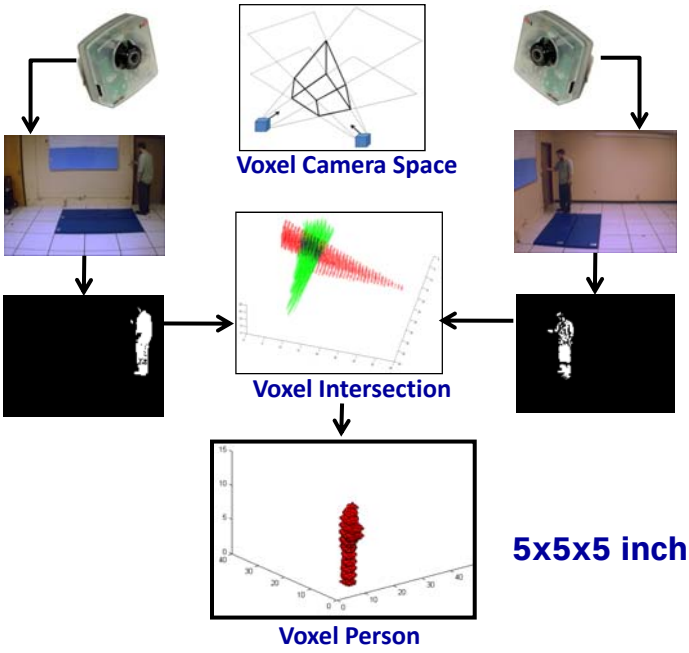
Preserving Privacy with Video

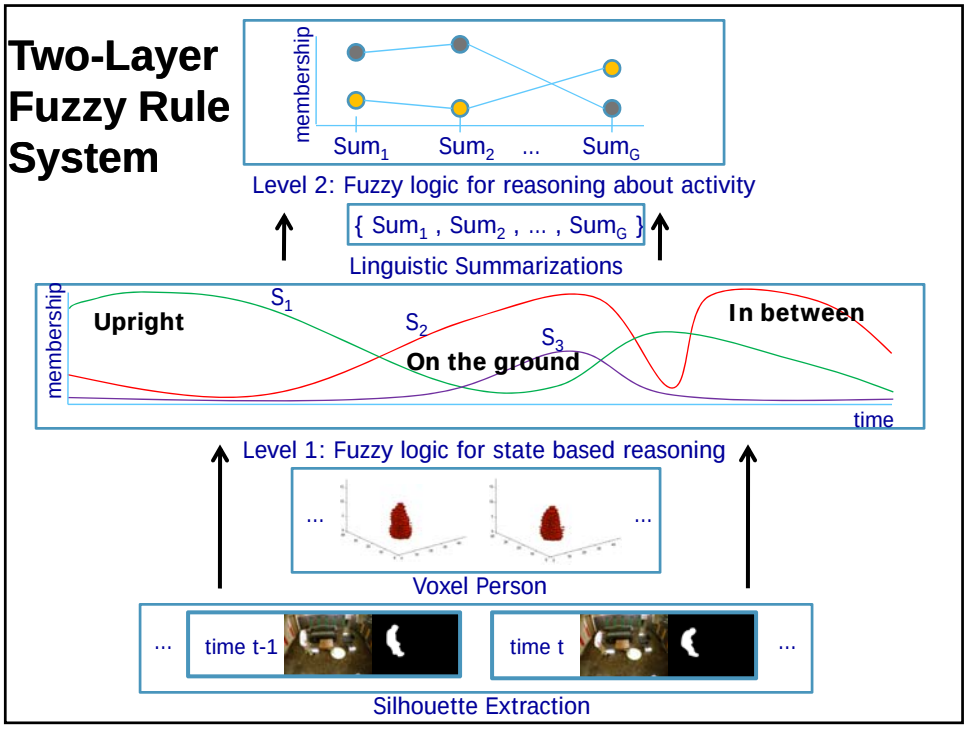


Multiple Cameras and Silhouettes



Creation of 3D Voxel Person





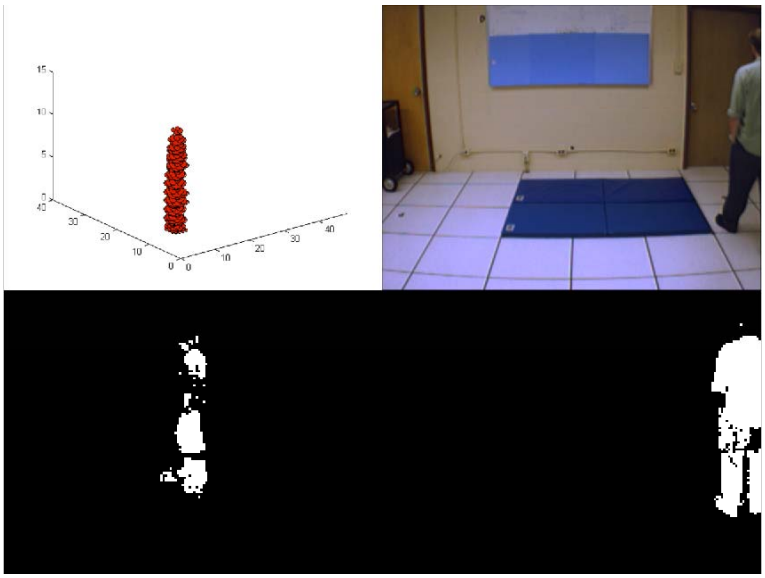
Fall Detection

- Second layer uses domain knowledge about elderly falls
- Input → linguistic summaries
- Output → confidence of a fall

Anderson, Luke, Keller, Skubic, Rantz & Aud, *Computer Vision and Image Understanding*, 2008

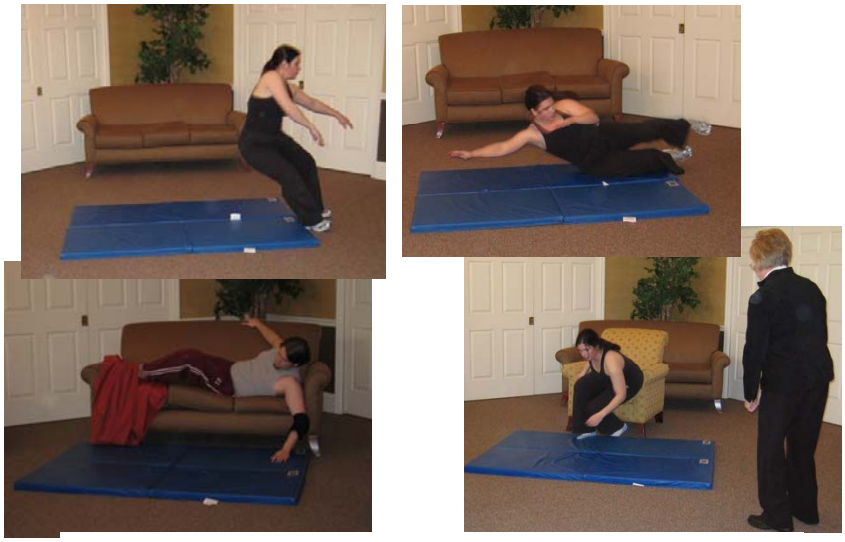
Anderson, Luke, Keller, Skubic, Rantz & Aud, *IEEE Trans. Fuzzy Systems*, 2009

Voxel Person for Fall Detection



Acquiring Realistic Data Using Stunt Actors

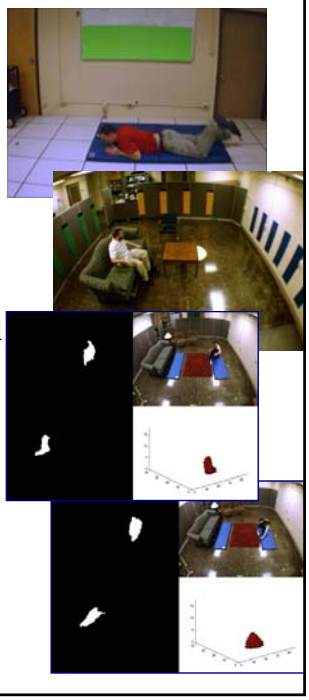
But first, we had to train them!



Rantz, Aud, Alexander, Wakefield, Skubic, Luke, Anderson & Keller, *Journal of Nursing Care Quality*, 2008.

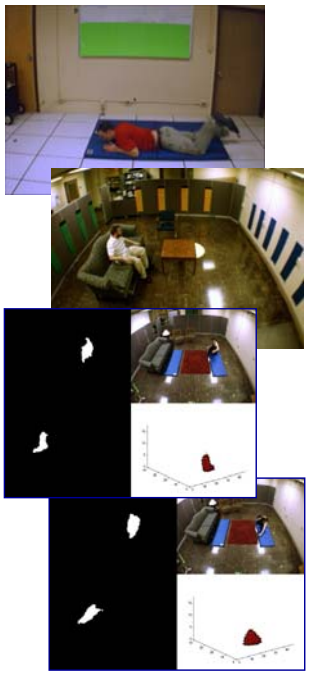
Data Sets

- **Students** (20 falls, 27 non-falls, 8 others)
  - Forward, backward, and to each side
  - Some lasted only a couple of seconds, after which the person got back up, some where the person stayed down on the ground but attempted to get back up, and some where the person simulated a severe injury and laid on the ground motionless
- **Stunt actor** (11 falls, 112 non-falls, 73 others)
  - Fall protocol designed by nurses
    - Balance loss
    - Momentary loss of consciousness

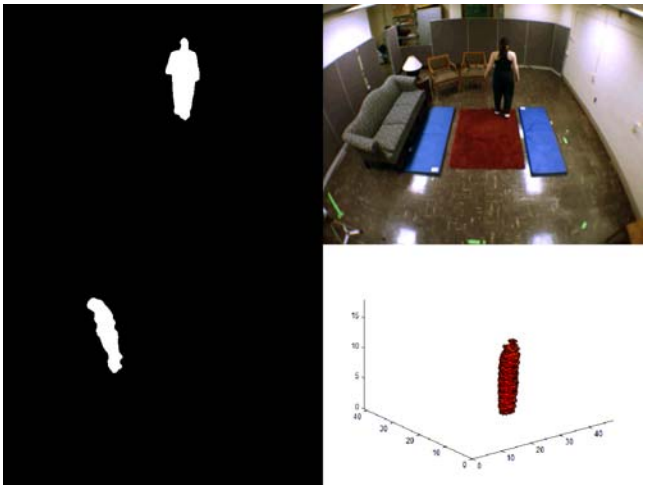


Activities Performed

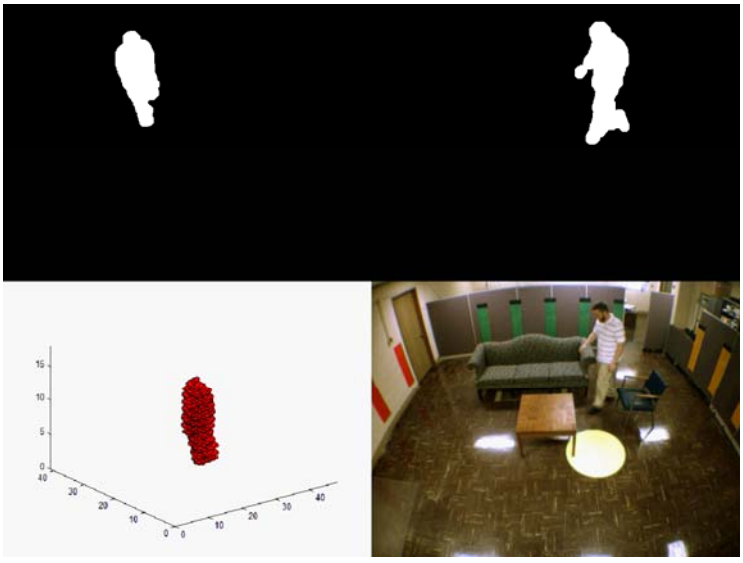
- Falling
- Standing
- Walking
- Sitting and lying on the couch
- Sitting on a chair
- Stretching
- Kneeling down to tie ones shoes
- Tripping and getting back up
- Going to the ground in a safe fashion
- Exercising while upright and on the ground
- Lying down on the ground



Silhouettes and Voxel Person for Stunt Actor Fall



Non-falls / Other Activities



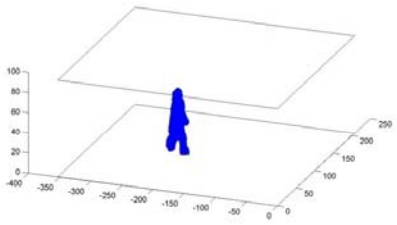
Anderson, Luke, Keller & Skubic, WCCI 2008.

Confusion Matrix for Falls

		Ground Truth	
		fall	non-fall
Systems: Fuzzy Rules	fall	31/31	1/220
Systems: HMMs	fall	29/31	54/220
Systems: Fuzzy Rules	non-fall	0/31	219/220
Systems: HMMs	non-fall	2/31	166/220

Fuzzy Rules: Recognized ALL falls with 1 false alarm on a floor exercise

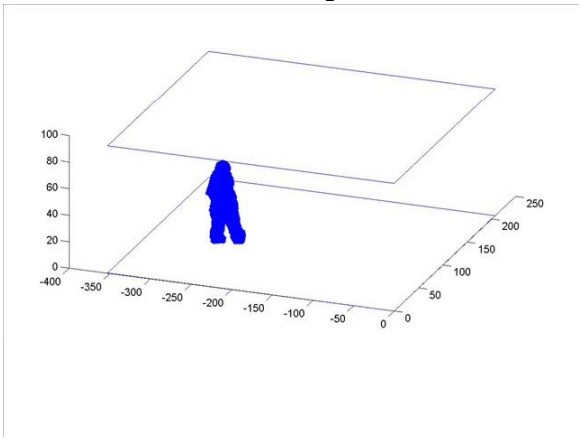
Using Voxel Person for Gait Analysis



1x1x1 inch voxel person

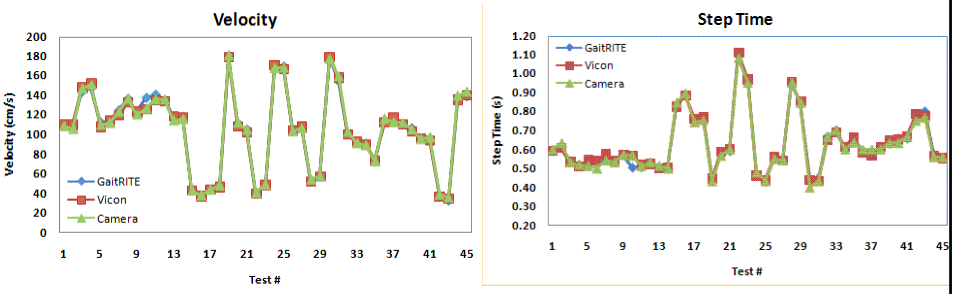
Compare extracted gait to GAITRite and Vicon motion capture for validation

Velocity from Voxel Person vs. Vicon Velocity



- Webcams: 105 cm/s Vicon: 103 cm/s
- Difference: < 2%

Validation with GAITRite and Vicon



Our $100 webcams compare favorably to the $150K Vicon system and the $30K GAITRite.

F. Wang, Stone, Dai, Skubic, and Keller, EMBC 2009.
F. Wang, Stone, Dai, Banerjee, Giger, Krampe, Rantz, and Skubic, EMBC 2009

Voxel Person Footsteps

Camera #1

Camera #2

Footsteps from the GAITRite mat

Footsteps from Voxel Person

Stone, Anderson, Skubic, and Keller, Gerontechnology 2010.

Footsteps from the GAITRite mat

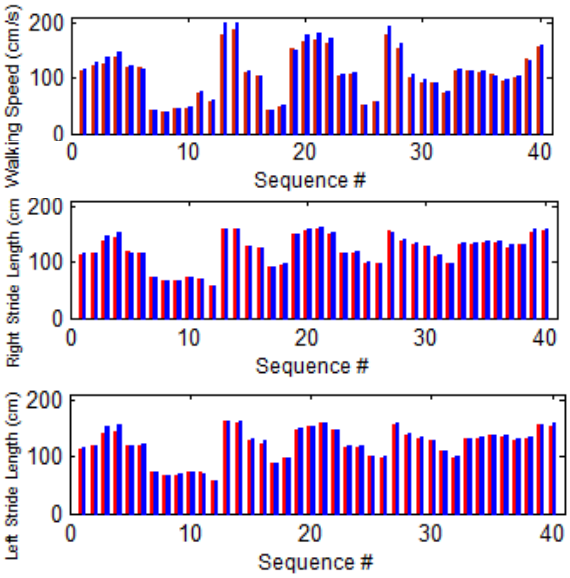
Footsteps from Voxel Person

GAITRite and Voxel Person Comparison

	Velocity (cm/s)	Stride Length (cm)		Step Length (cm)	
		Left	Right	Left	Right
GAITRite	66.6	90.8	91.1	44.6	46.2
Voxel Person	68.4	91.6	93.1	45.9	45.7

4

Validation with GAITRite



Walking speed

Right foot stride length

Left foot stride length

Stone, Anderson, Skubic, and Keller, EMBC 2010.

Conclusions about Residents

- Elders take ownership of the sensor data
- Elders want control over who has access to <u>their</u> data
- Acceptance is related to need and perceived benefits.
- Privacy can be sacrificed for needs/benefits
- Elders tend to underestimate their own needs
- Elders care about the look of the technology
- Elders are willing to accept technology if it
  - Meets a need
  - Has an appropriate interface (address sensory limitations)
- Elders do not consider silhouette imagery to be a privacy invasion

Demiris, Parker Oliver, Dickey, Skubic, Rantz, *Technology and Health Care,* 2008

Demiris, Parker Oliver, Giger, Skubic & Rantz, *Technology and Health Care*, 2009

Research Funding

- NSF
  - ITR grant IIS-0428420 (Skubic, PI)
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  - CPS grant CNS-0931607 (Skubic, PI)
- NIH
  - 5R21AG026412-02 (He, PI)
  - 1R21NR011197-01 (Rantz, PI)
- Administration on Aging (90AM3013) (Rantz, PI)
- RAND/Hartford Foundation (9920070003) (Rantz, PI)
- Alzheimer's Association (Smart Carpet) (Tyrer, PI)
- Agency for Healthcare Research and Quality (Rantz, PI)

See also **http://eldertech.missouri.edu**

Our Mission: Keeping older adults functionally active (and productive!)