Human Performance Evaluation

Minh Nguyen, Liyue Fan, Luciano Nocera, Cyrus Shahabi

minhnngu@usc.edu

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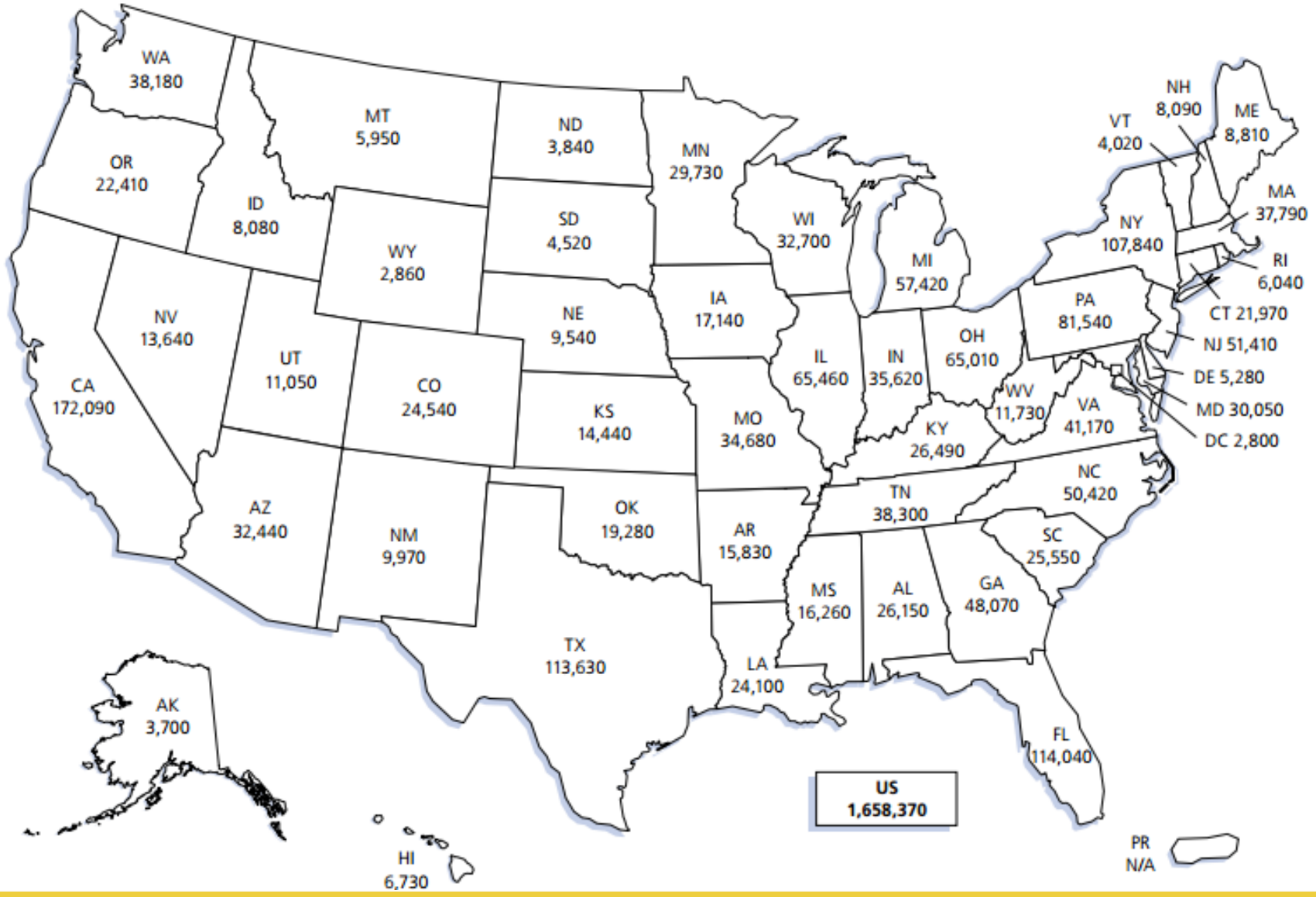
Integrated Media Systems Center

University of Southern California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NJ 51,410
DE 5,280
MD 30,050
DC 2,800
AK
3,700
HI
6,730
US
1,658,370
PR
N/A

Motivating Application

8.2 million

People die each year from cancer, an estimated 13% of all deaths worldwide

Motivating Application

70%

The increase in new cases of cancer expected over the next 2 decades

Motivating Application

>100

Cancer types exist, each requiring diagnosis and treatment

Motivating Application

- Lung Cancer - Elderly People
- Chemotherapy
- **2 Problems:**
  - Based on 4 or 6 week intervals
  - Automatic classifier
  - Scoring – Type of Activities

Evaluation

- At office
  - Kinect sensor
- At patients' home
  - Wearable devices
  - Minh Nguyen, Liyue Fan, and Cyrus Shahabi, Activity Recognition Using Wrist-Worn Sensors for Human Performance Evaluation , The Sixth Workshop on Biological Data Mining and its Applications in Healthcare in conjunction with the 14th IEEE International Conference on Data Mining (ICDM 2015), Atlantic City, New Jersey, USA, November 14-17, 2015.

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Activity Recognition Using Wrist-Worn Sensors for Human Performance Evaluation

Minh Nguyen, Liyue Fan, and Cyrus Shahabi

{minhnngu, liyuefan, shahabi}@usc.edu

Nov. 14, 2015, Atlantic City, NJ, USA

Motivation

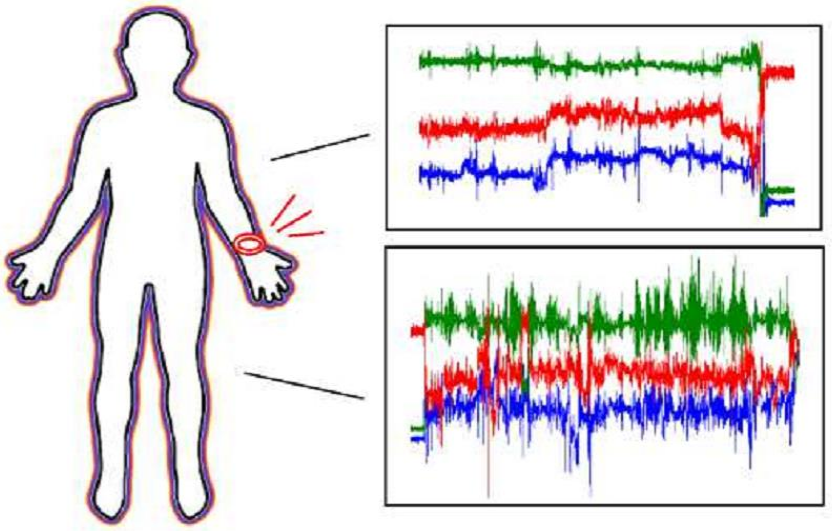
GRADE	ECOG PERFORMANCE STATUS (*)
0	Fully active, able to carry on all pre-disease performance without restriction
1	Restricted in physically strenuous activity but ambulatory and able to carry out work of a light or sedentary nature, e.g., light house work, office work
2	Ambulatory and capable of all self-care but **unable to carry out any work activities; up and about more than 50% of waking hours**
3	Capable of only limited self-care; **confined to bed or chair more than 50% of waking hours**
4	Completely disabled; cannot carry on any self-care; totally confined to bed or chair
5	Dead

Opportunity – Wearable Devices

- Continuous Monitoring
- Activity Types

Our Goal

- Unobtrusive, Easy-To-Use
  - One Wrist-Worn Sensor
  - Only Acceleration Data
- Accuracy
  - Various Single Classifiers
  - Ensemble of Classifiers
- Type of Activities



Outline

1. Related Work
2. System Components
   a) Data Collection & Preprocessing
   b) Feature Extraction
   c) Classification
3. Experiment – Result
4. Summary – Future Work

Related Work

	Sensors/Classification	Result
Bao, et al., 2004	Multiple sensors Decision table C4.5, k-NN, Naïve Bayes	20 activities 80 – 95%
Parkka, et al. 2006	Multiple sensors Automatically Generated Decision Tree, ANN	Lying, Sitting, Standing, Walking, Nordic Walking, Running, Rowing, Cycling 82% - 86%
Brezmes, et al., 2009	Mobile phone sensor K-NN	Walking, Standing up, Sitting down, Climbing stairs 70 - 90%
Bayat, et al. 2014	Mobile phone sensor Multilayer Perceptron	Dancing, Running, Fast-walking, Slow-walking, Stairing up-down 82% - 89.72%

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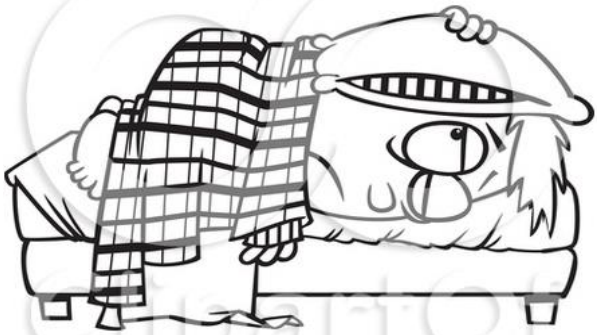
System Components

Data Collection

Sitting

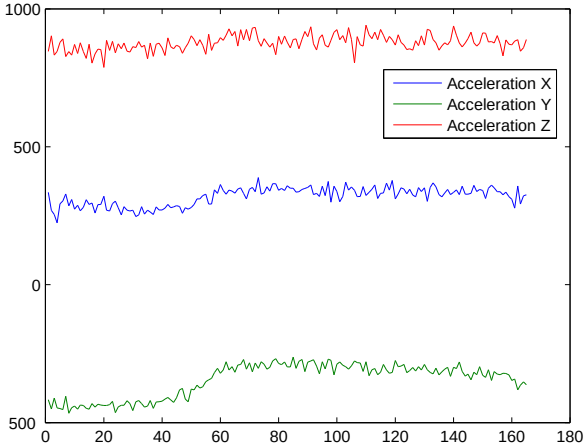
Walking



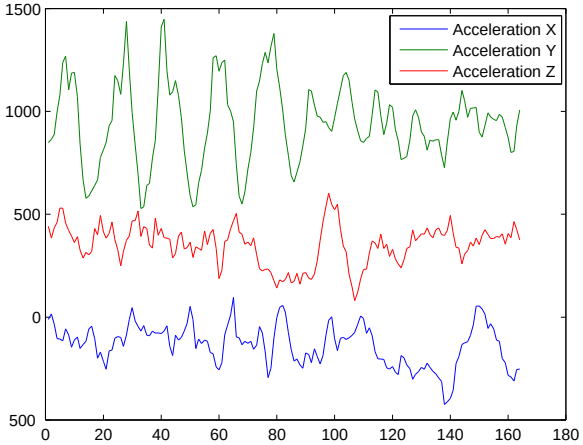
Lying

Standing

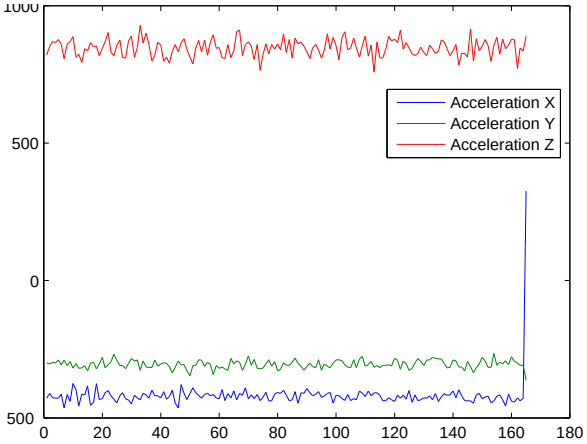
Data Collection



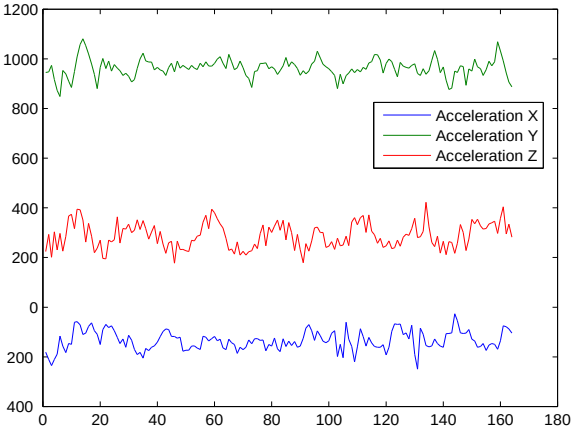
Sitting



Walking



Lying



Standing

Tri-axial Acceleration Raw Data

Data Preprocessing

Timestamp	X	Y	Z
0	-362	842	401
33	-409	744	593
.....			
3900	183	-772	-624
3933	233	-685	-644
.....			
6067	360	-735	-609

Segmentation:
One window with 128 records corresponding to 4.2s

Window Sliding:
50% Overlapping

Feature Extraction

$$X = \{x_1, x_2, \ldots, x_{n-1}, x_n\}$$

Extracted for each axis

- Mean $\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$
- Energy $\text{Energy}(X) = \frac{\sum_{i=1}^{n} F_i^2}{n}$
- Frequency-Domain Entropy $H = -\sum_{i=1}^{n} p_i \ln p_i$

X-Y, Y-Z, X-Z

- Correlation between 2 axes $\rho(X,Y) = \frac{covariance(X,Y)}{\sigma_X \sigma_Y}$

Classification

- *Single Classifiers*
  - Naïve Bayes
  - SVM
  - Decision Tree
  - Multilayer Perceptron
  - k-Nearest Neighbors
  - Random Forest
- *Ensemble of Classifiers (voting)*
  - Average of Probabilities
  - Majority Voting

Popular classifiers/ensembles in activity recognition literature, but not have been tested on wrist-worn acceleration.

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Experiment Methodology

- Dataset of Activity Recognition Challenge
- Acceleration data - 3 subjects - Morning Activities
- Walking, Standing, Sitting and Lying

- Only consider wrist sensors
- The sampling frequency is 30Hz
- Over 300,000 records or 2300 windows (window length is 128) for each wrist of a subject.

Experiment – Individual Classifier

Classifier	Left Wrist				Right Wrist			
	S1	S2	S3	Average	S1	S2	S3	Average
Naive Bayes	63.48%	71.09%	76.60%	70.39%	80.46%	67.43%	57.18%	68.36%
SVM (one-vs-one)	75.68%	75.48%	79.13%	76.76%	83.19%	74.89%	81.76%	79.95%
Decision Tree	77.84%	79.06%	81.31%	79.40%	88.30%	79.58%	83.43%	83.77%
Multilayer Perceptron	81.38%	82.52%	83.42%	82.44%	87.65%	80.63%	83.97%	84.08%
k-NN	82.94%	82.71%	84.58%	83.41%	89.31%	81.74%	83.57%	84.87%
Random Forest	84.26%	84.99%	85.95%	85.07%	91.92%	84.70%	86.77%	87.80%

Best Average Range: 85.07% - 87.80%

Best Accuracy: Random Forest - Right Wrist - 91.92%

Experiment – Individual Classifier

Ground Truth	a	b	c	d	Classified As
Left Wrist	**652**	70	43	1	a = Standing
	96	**192**	12	0	b = Walking
	13	0	**510**	0	c = Sitting
	22	5	0	**49**	d = Lying
Right Wrist	**733**	33	7	0	a = Standing
	73	**226**	3	0	b = Walking
	7	0	**521**	3	c = Sitting
	0	0	10	**68**	d = Lying

Confusion Matrix of Random Forest

- Misclassification between Standing and Walking (both wrists)
- Misclassification between Standing and Sitting (left wrist)
- Right-handed object (dominant hand)

Experiment – Multiple Classifiers

Combination of Classifiers	Avg. of Poss.	Major. Voting
k-NN, Decision Tree, SVM	89.96%	89.79%
Random Forest, Decision Tree, SVM	89.13%	90.56%
k-NN, Multilayer Perceptron, Decision Tree	90.32%	89.55%
Random Forest, kNN, Multilayer Perceptron, SVM	90.86%	89.79%
Random Forest, k-NN, NB	90.20%	90.38%
Random Forest, k-NN, Decision Tree	90.62%	91.27%
Random Forest, kNN, Multilayer Perceptron, Decision Tree	90.97%	90.56%
Random Forest, k-NN, SVM	91.63%	90.38%
Random Forest, k-NN, Multilayer Perceptron	91.15%	91.03%
Random Forest, k-NN	91.98%	90.20%

Best Accuracy: Random Forest + K-NN
Average of Probabilities: 91.98%

Experiment – Multiple Classifiers

Ground Truth	a	b	c	d	Classified As
Left Wrist	**651**	69	45	1	a = Standing
	89	**196**	12	3	b = Walking
	14	0	**509**	0	c = Sitting
	18	5	0	**53**	d = Lying
Right Wrist	**731**	34	7	1	a = Standing
	65	**236**	1	0	b = Walking
	8	0	**517**	6	c = Sitting
	0	0	13	**65**	d = Lying

Confusion Matrix of Random Forest + k-NN

- Misclassification between Standing and Walking (right wrist) is reduced
- More misclassification between Sitting and Lying (right wrist)

Standing <-> Walking

K-NN

Sitting <-> Lying

Random Forest

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Summary

- One Wrist-worn Sensor
- Accuracy by individual classifiers range from 68.36% to 87.80%
- Random Forest achieves the highest accuracy: 91.92%
- The combination of Random Forest + k-NN: 91.98%
- Most confusions happen in Walking vs. Standing

Future Work

- Misclassification Walking and Standing
  - Considering other features
- Try Other Ensemble Methods
  - Considering the strength of individual classifiers
- Complex Activities
  - Considering daily activities to include housing cleaning, cooking, working at the computer, etc.

Q&A

Minh Nguyen
University of Southern California
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minhnngu@usc.edu