Human Activity Recognition Using Tag-Based Radio-Frequency Localization

Aras Yurtman, Billur Barshan
yurtman@ee.bilkent.edu.tr, billur@ee.bilkent.edu.tr
Electrical and Electronics Engineering
Bilkent University

Activity Recognition

Classifying what a person is doing:
(1) walking, (2) falling, (3) lying down, (4) lying, (5) sitting down, (6) sitting, (7) standing up from lying, (8) on all fours, (9) sitting on the ground, (10) standing up from sitting, (11) standing up from sitting on the ground

Radio-Frequency Identification (RFID)

- identification of RFID tags via RFID antennas mounted in the environment
- each tag has unique ID
- up to 200 m range

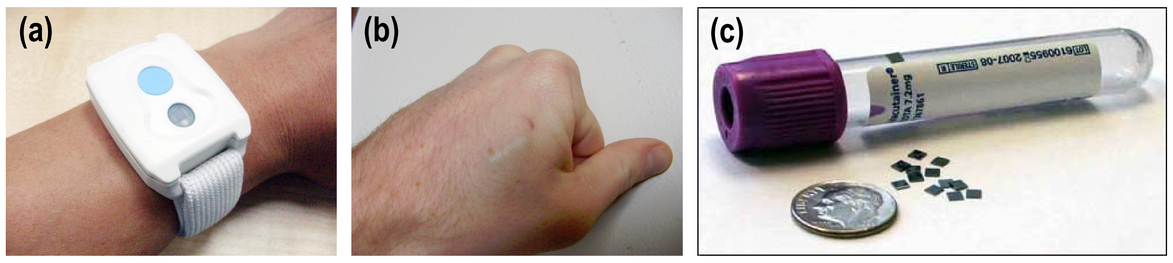

Figure 1. (a) an active RFID tag worn as a bracelet, (b) a passive RFID tag buried under the skin, (c) tiny RFID tags of size 2 × 2 mm.

Radio-Frequency Localization

- 2-D or 3-D position estimation of RFID tags in addition to identification
- cheap, extremely small tags mounted on human body
- passive tags without batteries or active tags with very long battery life

- UBISENSE PLATFORM:
  - 3-D position estimation at 10 Hz for each tag
  - up to tens of meters range
  - 15 cm accuracy (across 95% of readings)

  - DISADVANTAGES:
    - position of each tag is estimated at different time instants
    - relatively high measurement noise
    - position cannot be estimated occasionally

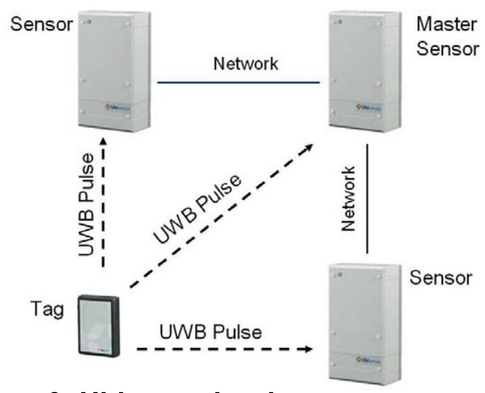

Figure 2. Ubisense hardware components.

Experiments

- 4 RFID tags mounted on left and right ankle, chest and belt
- 5 subjects, each performed 5 experiments of duration 3 min
- the same activity sequence in each experiment:
  walking—sitting down—sitting—standing up from sitting—walking—falling—lying—standing up from lying—…

Dataset

- position of each tag is estimated at different time instants
- 10% of samples are missing—the sampling rate is about 9 Hz for each tag

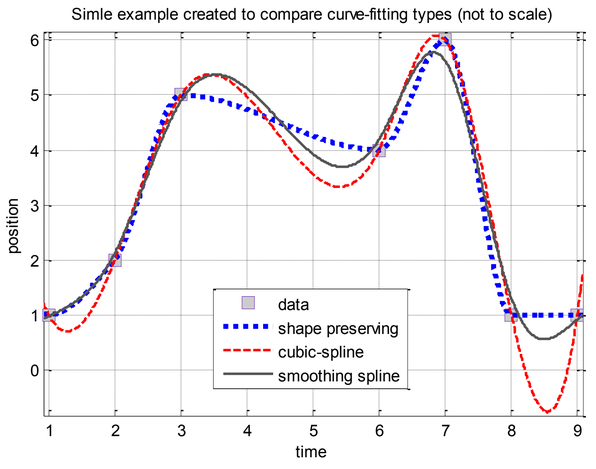

Figure 3. The three curve-fitting methods applied to simple synthetic data.

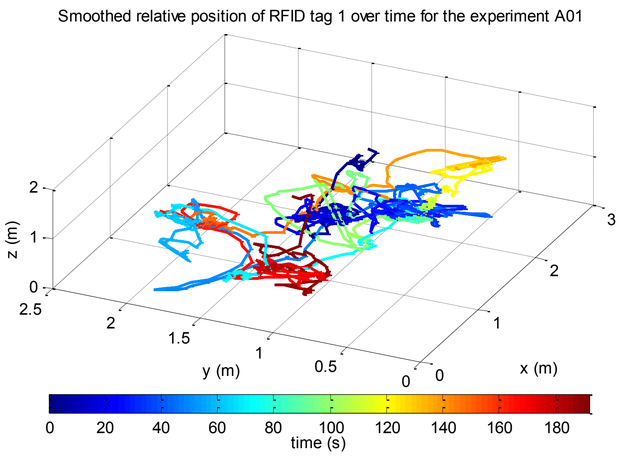

Figure 4. The position of the tag on the left ankle in experiment 1 of subject 1.

Pre-processing of Data

- CURVE-FITTING: a curve is fitted to 3 axes of each tag's position using
  1. shape-preserving interpolation
  2. cubic-spline interpolation
  3. smoothing spline
- RE-SAMPLING: fitted curves are re-sampled synchronously at a fixed sampling rate
- SEGMENTATION: a new segment is started when maximum segment size is reached or a new activity starts
- FEATURE EXTRACTION:
  - features for each axis are the minimum, maximum, mean, variance, skewness, kurtosis values; autocorrelation sequence, 10 peak FFT coefficients and corresponding frequencies
  - about 200 features for each segment
- FEATURE REDUCTION: *n*-D PCA, *n*-D LDA, without feature reduction

Classification

- 10 CLASSIFIERS:
  1. Gaussian classifier with the same arbitrary cov. matrix for each class
  2. Gaussian classifier with different arbitrary cov. matrices for each class
  3. Gaussian classifier with different diagonal cov. matrices for each class
  4. mixture of Gaussians classifier (with two mixtures)
  5. naïve Bayes classifier
  6. *k*-nearest neighbor (*k*-NN) classifier
  7. dissimilarity-based classifier
  8. minimum least-square linear classifier
  9. nearest mean classifier
  10. scaled nearest mean classifier

Table 1. Minimum error percentages of each classifier.

Classifier	Error Percentage ± Standard Deviation*			
	11 classes		*5 classes (1, 4, 6, 8, 9)*	
	5-fold	*subject-based L1O*	*5-fold*	*Subject-based L1O*
1	20.89 ± 0.02	23.52 ± 0.00	6.06 ± 0.01	7.63 ± 0.00
2	20.76 ± 0.04	23.69 ± 0.00	5.48 ± 0.02	7.73 ± 0.00
3	21.65 ± 0.05	24.11 ± 0.00	6.02 ± 0.02	7.92 ± 0.00
4	20.75 ± 0.07	23.70 ± 0.00	5.19 ± 0.03	7.63 ± 0.00
5	22.84 ± 0.16	24.46 ± 0.00	7.24 ± 0.16	9.49 ± 0.00
6	8.67 ± 0.10	21.30 ± 0.00	1.12 ± 0.04	6.52 ± 0.00
7	19.41 ± 0.16	22.10 ± 0.04	4.66 ± 0.16	7.33 ± 0.03
8	25.26 ± 0.52	26.83 ± 0.00	7.37 ± 0.17	9.30 ± 0.00
9	23.60 ± 0.06	27.02 ± 0.00	6.07 ± 0.02	8.21 ± 0.00
10	20.94 ± 0.04	23.59 ± 0.00	6.04 ± 0.03	7.58 ± 0.00

** In each case, the sampling rate, segment duration, curve-fitting method, feature reduction method and dimension resulting in the highest accuracy is chosen.*

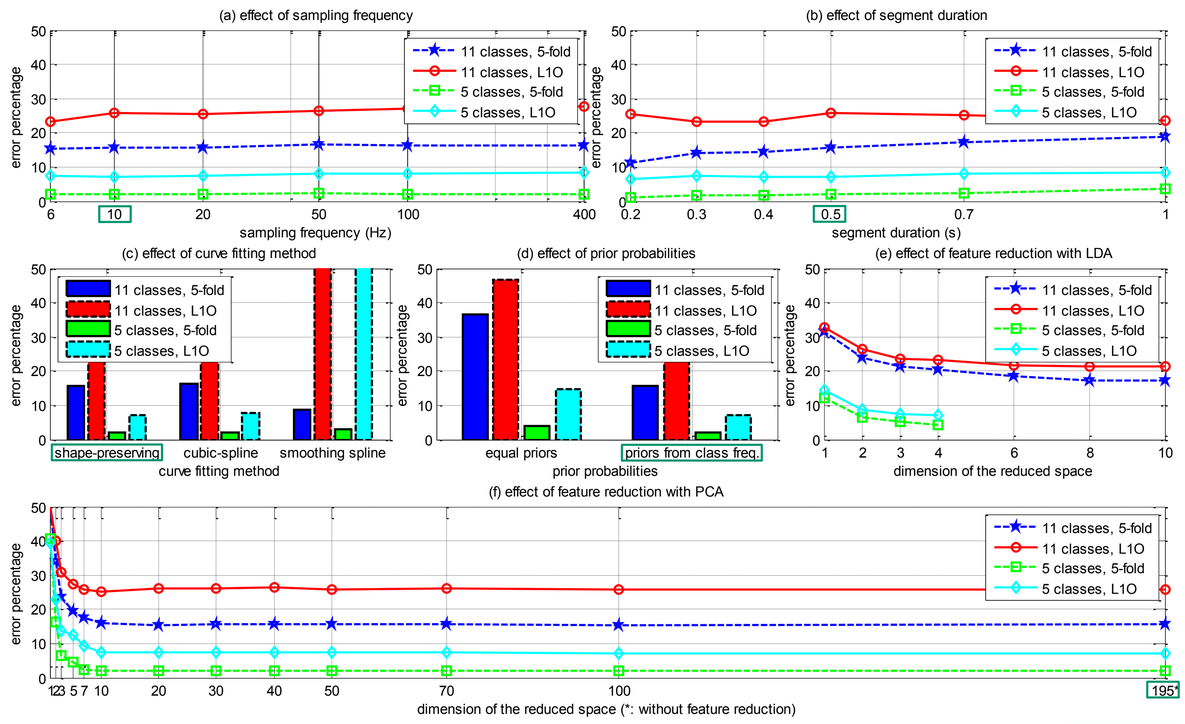

Figure 5. Comparison of parameters for k-NN classifier.

Conclusion

- *k*-NN is the best classifier for 11- and 5-class datasets
- In LDA, data of different subjects are brought together, whereas in PCA they are separated from each other

Acknowledgements

This work is supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK) under grant number EEEAG-109E059 that participates in MOVE (COST Action IC0903).

References

1. K. Altun, B. Barshan, O. Tunçel, "Comparative study on classifying human activities with miniature inertial and magnetic sensors," Pattern Recognition, 43(10):3605-3620, October 2010.
2. "Localization data for person activity data set," UC Irvine Machine learning Repository. Available from: http://archive.ics.uci.edu/ml/datasets/Localization+Data+for+Person+Activity.
3. M. Luštrek, B. Kaluža, and E. Dovgan, "Behavior Analysis Based on Coordinates of Body Tags," Ambient Intelligence, 5859:14–23, 2009.

BOĞAZİÇİ UNIVERSITY
FACULTY OF ENGINEERING
100 years

MASFOR 2012