Understanding Movement Variability of Simplistic Gestures Using an Inertial Sensor

Miguel Xochicale[1], Chris Baber[1] and Mourad Oussalah[2]; [map479@bham.ac.uk]
[1] School of Electronic, Electrical and Systems Engineering, University of Birmingham, UK
[2] Center for Ubiquitous Computing, University of Oulu, Finland

Introduction

Variability is an inherent characteristic of human movement [1]. Generally, humans perform the same action slightly differently trial by trial which is a common challenge in Human Activity Recogtion (HAR) [2]. The time-delay embedding theorem and Principal Component Analysis (PCA) have proven to be reliable methods for feature extraction in HAR [3, 4]. It is therefore hypothesised that these methods might be useful to learn the variability of human activities. Therefore, the following research questions will be addressed:

- Can we use the movement variability not only to identify an activity but also to use it as a index of user's performance over the course of training, practice or rehabilitation?
- How can the time-delay embedding and PCA methods quantify the variability of human activities?

Human Activity Recognition Chain

Bulling *et al.* [2], for instance, reviewed the state-of-the-art of Human Activity Recognition to identify activities or gestures from body-worn intertial sensors.

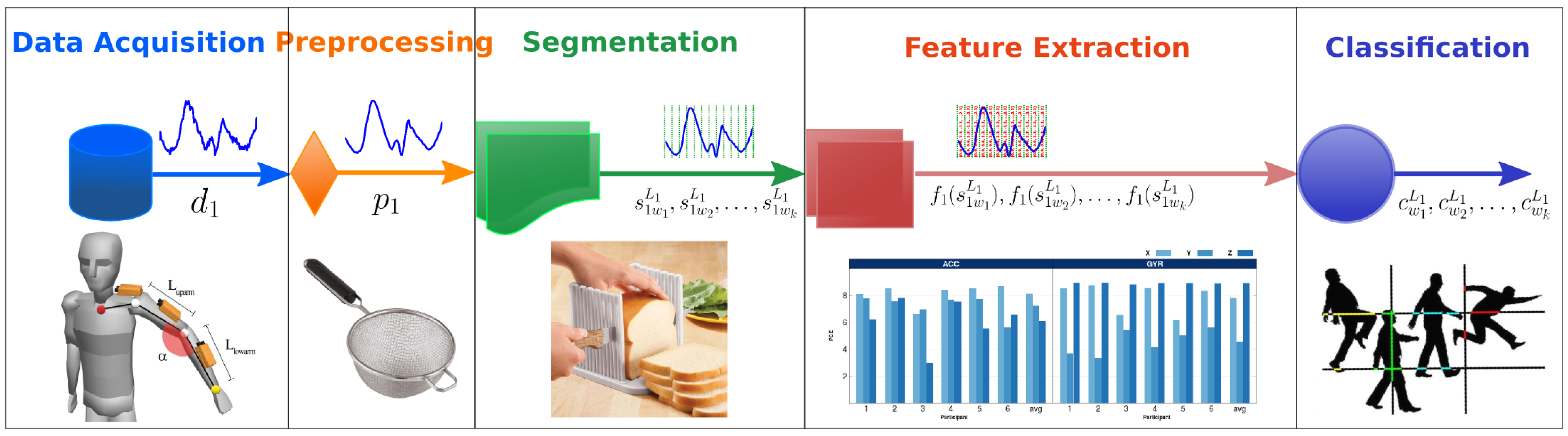
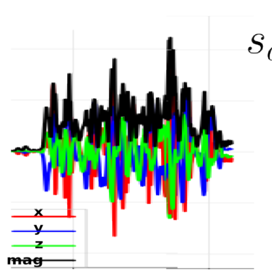


Diagram is replicated from the work of Banõs *et al.* [5].

Materials and Methods

Raw time-series data is collected from a triaxial accelerometer (a_x, a_y, a_z). Then, a N samples length time-series, e.g. a_x, is used to obtain the time-delay embedded matrix, $E\{a_x\}$, with $m = 20$ and $\tau = 6$ [3, 4]. Finally, PCA is applied to $E\{a_x\}$ to compute the percentage of cumulative energy (PCE) [6].

Raw Data: $s_a(n)$

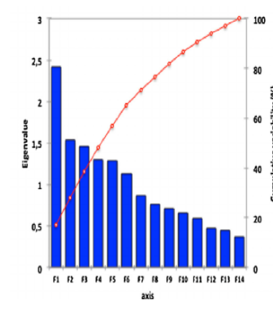


$s_a(n) = \{s_a(1), \ldots, s_a(L)\}$
s = sensor (acc,mag,gyr)
a = axis (x,y,z)
n = index
L = window length

Takens's Theorem: $E_m^\tau\{s_a(n)\}$

$E_m^\tau\{s_a(n)\} = \{s_a(n), \ldots, s_a(n-(m-1)\tau)\}$
E_m^τ = Embedded Matrix
τ = Time-delay
m = Dimension

Principal Component Analysis



$\mathrm{PCA}[E_m^\tau\{s_a(n)\}] = (\lambda_i, v_i)$
λ_i = Eigenvalues
v_i = Eigenvectors

The method is then applied to six simple movements which were performed by five participants wearing a low-cost and commertial intertial sensor on their right wrist; each movement was continuously repeated for 10 seconds.

Conclusion and Outlook

Although the time-delay embedding technique is subject to different values of embedded parameters (m and τ) according to the length and complexity of the time-series, the technique is useful to present the inherent features of variability between five participants for six different gestures.

In the future, we will collect data from a wider range of individuals (gender and age) and from additional sensors. Also, different classification techniques will be explored.

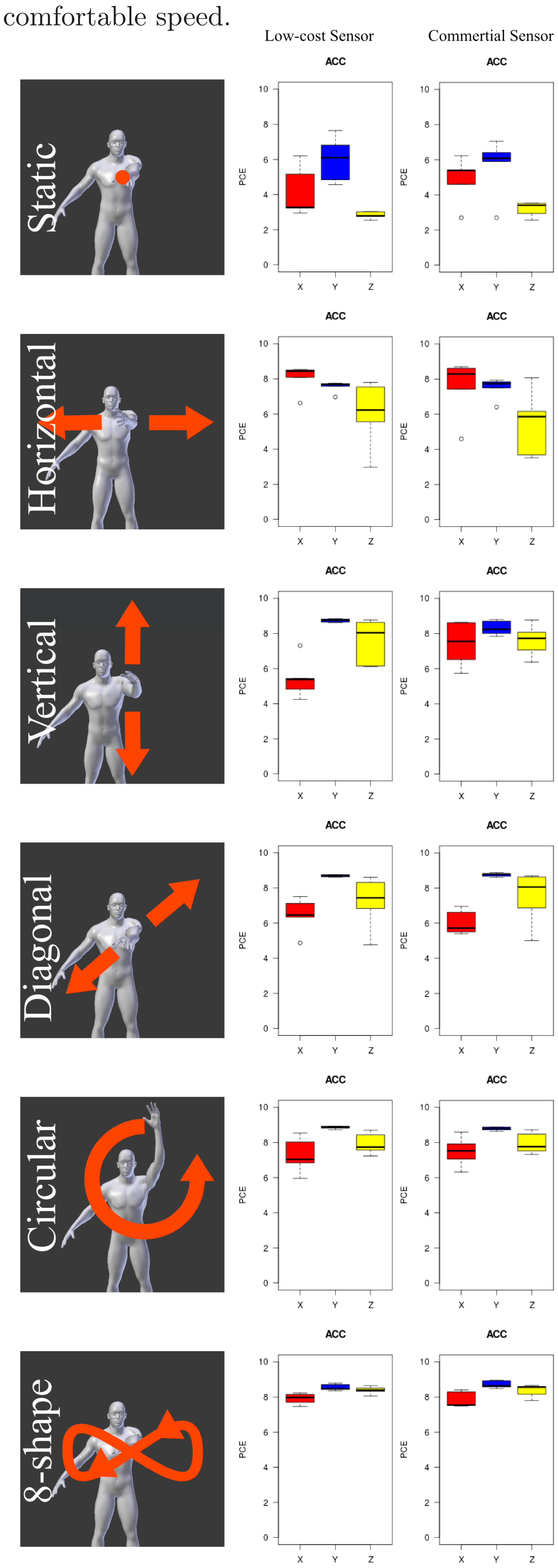
References

[1] Karl M. Newell and Daniel M. Corcos. 1993. Variability and motor control. Human Kinetics Publishers.
[2] Andreas Bulling, Ulf Blanke and Bernt Schiele. 2014. A tutorial on human activity recognition using body-worn inertial sensors In *ACM Computing Surveys (CSUR)*, vol. 6, 1-33.
[3] Jordan Frank, Shie Mannor and Doina Precup. 2010. Activity and Gait Recognition with Time-Delay Embeddings. In *Proceedings of the 24-th AAAI Conference on Artificial Intelligence*, 1581-1586.
[4] Albert Samà, Francisco J. Ruiz, Núria Agell, Carlos Pérez-López, Andreu Català and Joan Cabestany. 2013. Gait identification by means of box approximation geometry of reconstructed attractors in latent space. In *Neurocomputing*, vol. 121, 79-88.
[5] Oresti Banos, Juan-Manuel Galvez, Miguel Damas, Hector Pomares and , Ignacio Rojas. 2014. Window size impact in human activity recognition. In *Sensors (Basel, Switzerland)*, 14, 6474-99
[6] Nils Y Hammerla, Thomas Plötz, Peter Andras and Patrick Olivier. 2011. Assessing Motor Performance with pca. In *International Workshop on Frontiers in Activity Recognition using Pervasive Sensing*, 18-23.

Results

The values of the percentage of cumulative energy (PCE) from five participants are presented using boxplots for both low-cost and commertial triaxial accelerometer (ACC) sensors. It is evident that both sensors present similar results for each movement. It is highlighted that the circular movement shows the least variation of ACC per component compare to the other movements.

However, we assume that the evident variability of the movements is due to the flexibility in the experiment where participants were only asked to perform the movements at a comfortable speed.



Acknowledgements

Miguel Xochicale gratefully acknowledges the studentship from the National Council for Science and Technology (CONACyT) Mexico for pursuing his doctoral studies at The University of Birmingham, UK.