# Towards the Quantification of Human-Robot Imitation Using Wearable Inertial Sensors

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# Outline

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# Dancing Waltz with Markovito @ the Mexican Tournament of Robotics 2013

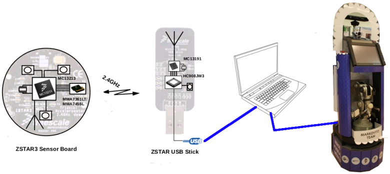



Figure 1: Human-Robot Interface

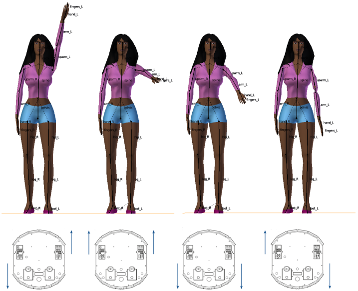


Figure 2: Human Body Gestures

# Outline

# Movement Variability is not NOISE

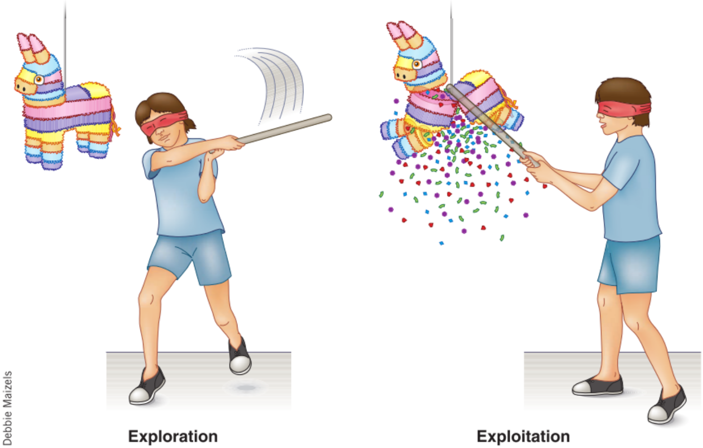



Figure 3: Find the piñata [Herzfeld and Shadmehr, 2014] .

# Movement Variability

Movement Variability is an inherent feature that occurs not only within individual but also between individual systems of movement **[Newell and Corcos, 1993]** .

# How to measure Movement Variability?

According to **[Preatoni et al., 2013]**, some nonlinear dynamics tools (dynamic invariants) can be used to explore the nature of movement variability and their relationship with skills development:

- **Reconstructed State Space (RSS)**;
- Lyapunov Exponent.

# Outline

# Reconstructe State Space (RSS)

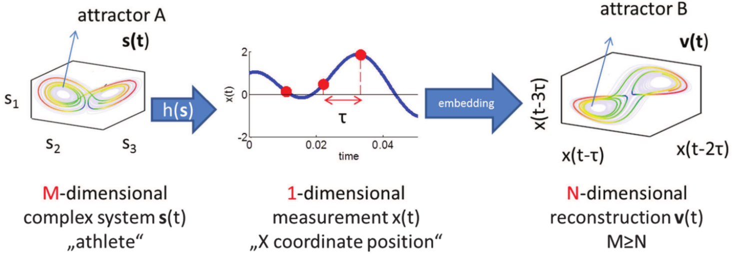



Figure 4: Reconstruction of a multidimensional attractor **[Quintana-Duque, 2012]** .

# RSS in HAR

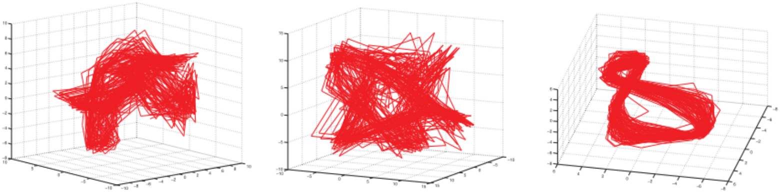


Figure 5: 3D Reconstructed State Spaces ($m = 3$, $\tau = 4$) for walking (left), running (middle), and cycling (right).
**[Frank et al., 2010, Frank et al., 2012]** .

# RSS in HAR

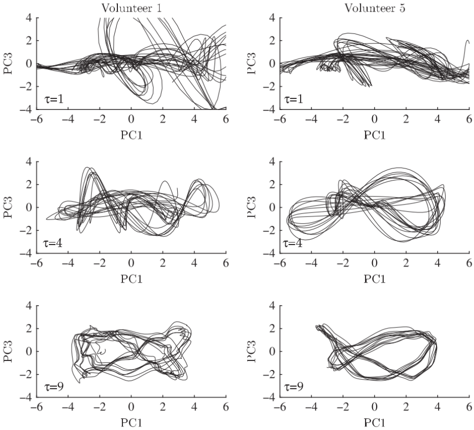



Figure 6: 2D Reconstructed State Spaces for gait patterns of two persons ($m = 20$ for $\tau = 1$, $\tau = 4$ and $\tau = 9$, respectively).
**[Samà et al., 2013]** .

# How to build the Reconstructed State Space

For a given discrete time-series $x(n) = [x(1), x(2), \dots, x(N)]$, a reconstructed state space can be created by

$$\overline{x}(n) = [x(n), x(n-\tau), x(n-2\tau), \dots, x(n-(m-1)\tau)]$$

which creates a concatenated column-wise matrix of time-delay versions of the original signal:

$$\mathbf{X} = \begin{pmatrix} x(1) & x(1-\tau) & x(1-2\tau) & \dots & x(1-(m-1)\tau) \\ x(2) & x(2-\tau) & x(2-2\tau) & \dots & x(2-(m-1)\tau) \\ \vdots & & & \ddots & \vdots \\ x(N) & x(N-\tau) & x(N-2\tau) & \dots & x(N-(m-1)\tau) \end{pmatrix}$$

where $m$ is the **embedding dimension** and $\tau$ is the **embedding delay** **[Takens, 1981]** .

# Takens' Theorem

The Takens' Theorem states that for a large enough $m$ is possible to unfold the attractor and $\tau > 0$ is chosen to maximize the information content of $x(n)$.

False Nearest Neighborhood and Mutual Information algorithms are used to compute the optimal value of $m$ and $\tau$. However, as pointed out by **[Samà et al., 2013]** the optimal values don't neccesarily represent the best rate of recognition.

# RSS using PCA

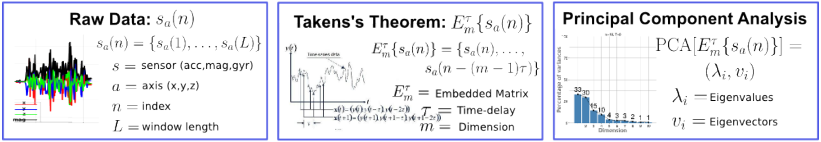
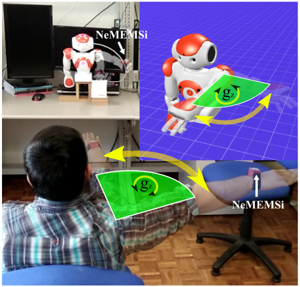


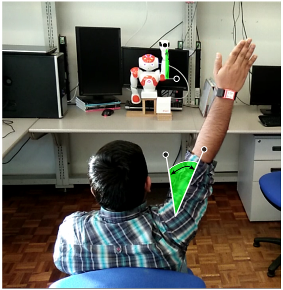

Figure 7: Framework to build the RSS

# Outline

# Experiment Design

HORIZONTAL VERTICAL



* HNormal
* HFaster

* VNormal
* VFaster

Figure 8: Front-to-Front Human-Humanoid Imitation Using Wearable Inertial Sensors

# Outline

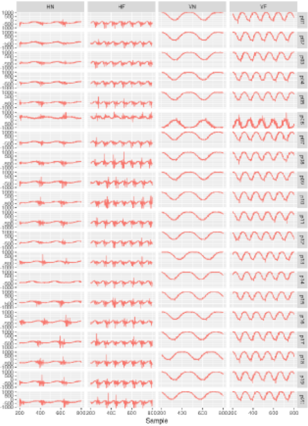
# Participants

Twenty right-handed healthy participants (two females and ten males) with a mean age of 19.5$\pm$0.79 (abbreviated as p01 to p12) were invited to participate in this experiment.

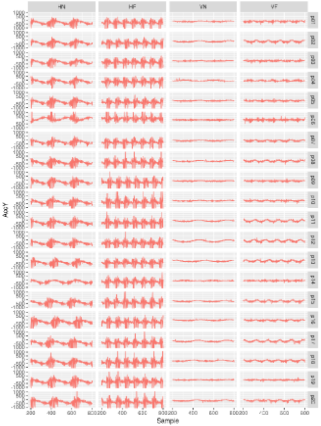
# Outline

# Raw Data from NAO

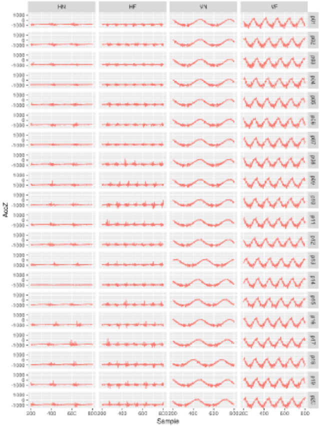
## AccX



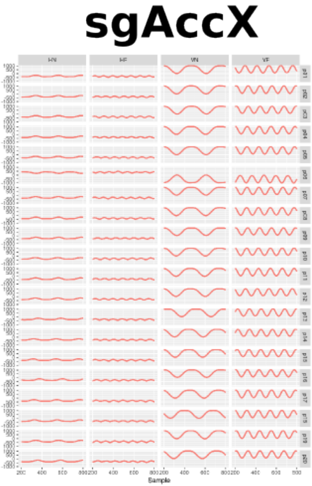

## AccY

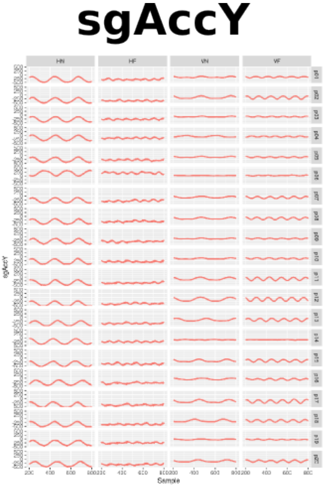


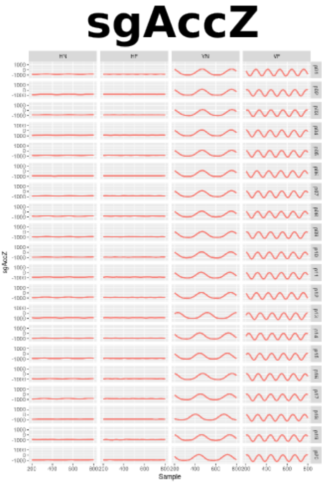

## AccZ



# Smoothed Data from NAO

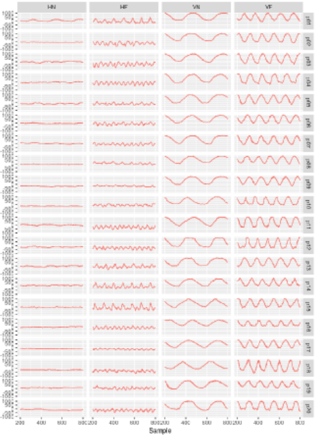


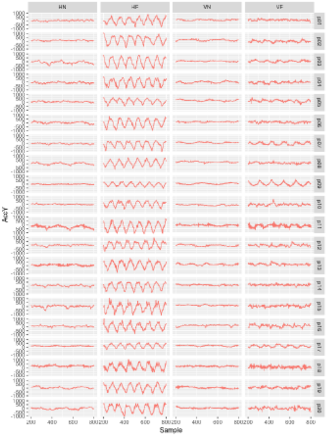



# Raw Data from Participants

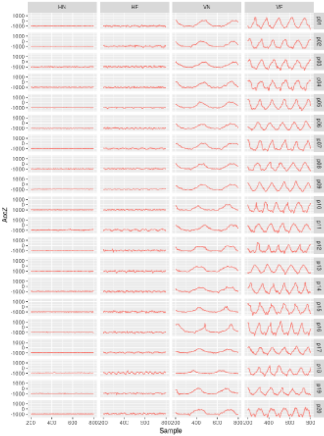
## AccX



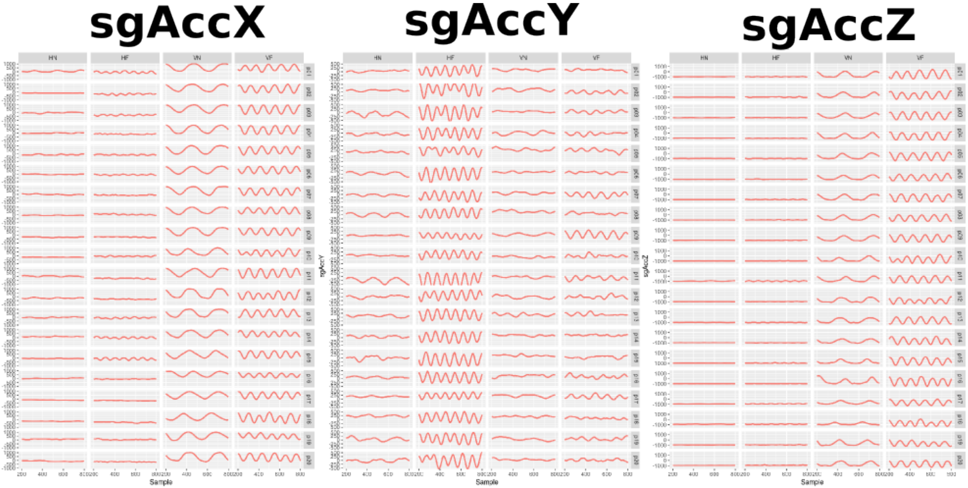

## AccY




## AccZ



# Smoothed Data from Participants

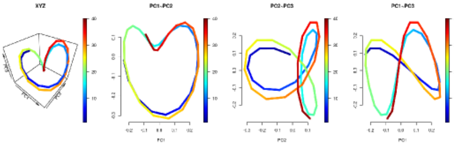


# Outline

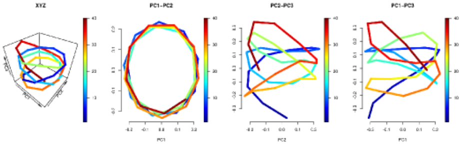
# RSS for NAO TRIAL 01 (sgAccX)

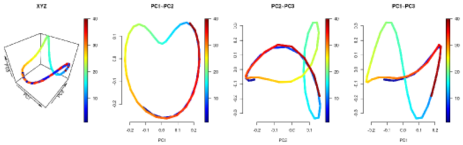
RSS with $m = 40$, $\tau = 10$

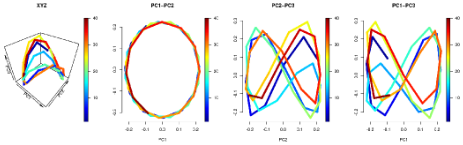
**HN**




**HF**



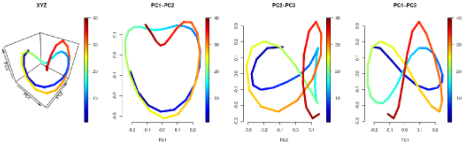

**VN**

**VF**

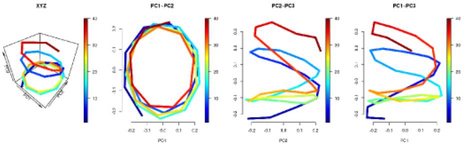
# RSS for NAO TRIAL 10 (sgAccX)

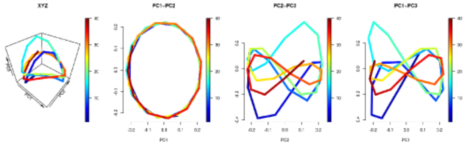
RSS with $m = 40$, $\tau = 10$

**HN**

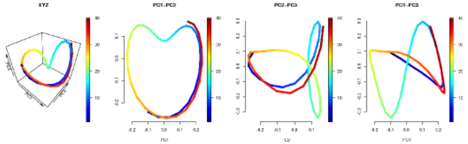



**HF**



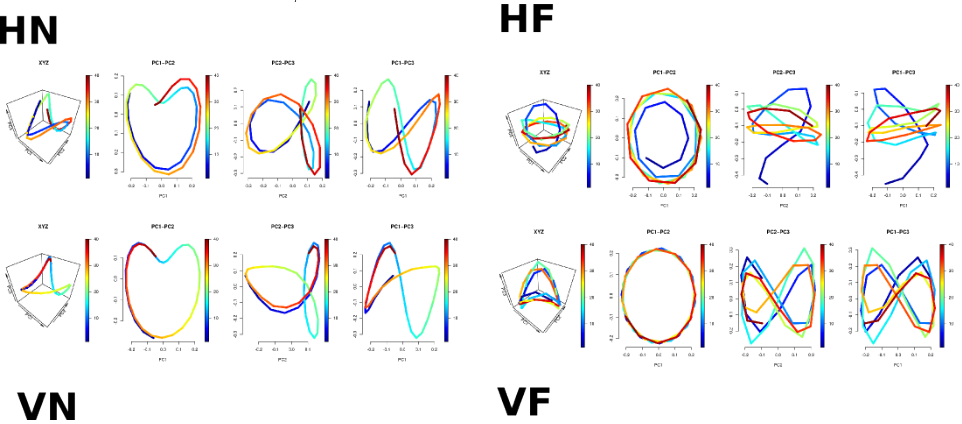

**VN**




**VF**

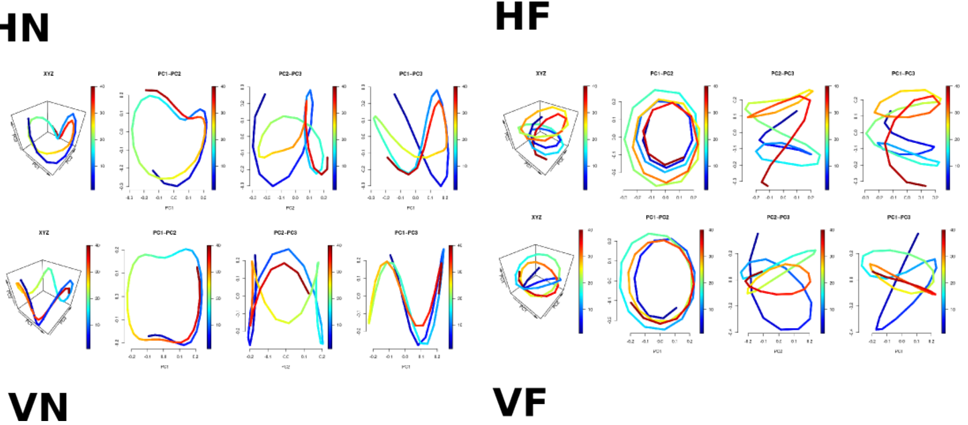
# RSS for NAO TRIAL 20 (sgAccX)

RSS with $m = 40$, $\tau = 10$



# RSS for P01 (sgAccX)

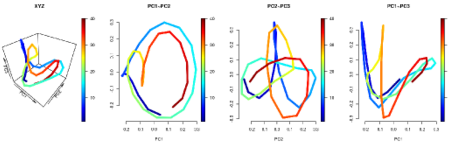
RSS with $m = 40$, $\tau = 10$



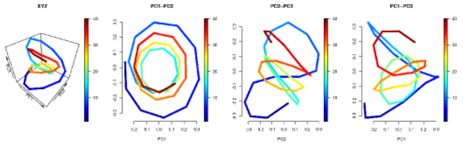
# RSS for P10 (sgAccX)

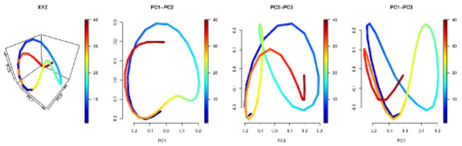
RSS with $m = 40$, $\tau = 10$

**HN**

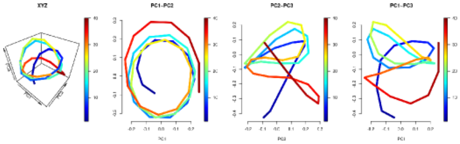



**HF**




**VN**



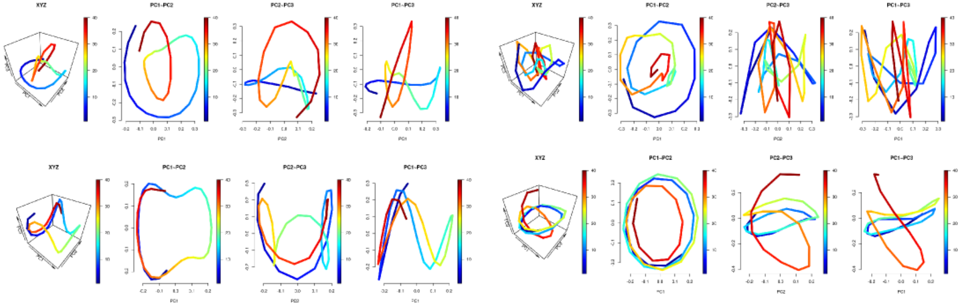

**VF**

# RSS for P20 (sgAccX)

RSS with $m = 40$, $\tau = 10$

**HN**

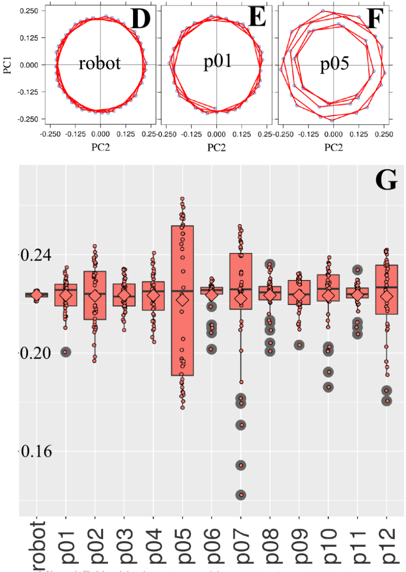
**HF**




**VN**

**VF**

# Euclidean Distances in the RSS ($m = 40$, $\tau = 10$)



# Outline

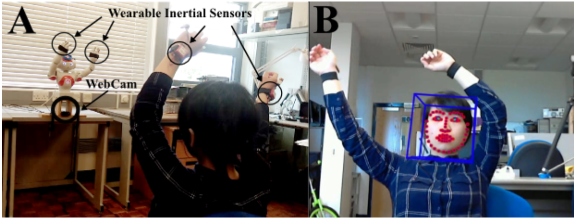
# Conclusions

* It has been proposed a metric based on the Euclidean distances in the RSS to quantify how close a participant imitate NAO.
* Pros and Cons of RSS

- (+) The RSS provide a visually a good representation of the variability of the activities.
- (-) The quality of the metric is debatable and needs further investigation.

# Future Work for 2017-2018

- Provide an intuitive explatation of the dynamic invariants;
- Perform further experiments with participants of different: age, gender, state of health, and;
- Use Convolutional Neural Networks to classify Movement Variability
- Front to Front Human-Robot Imitation with Inertial Sensor and OpenFace Framework



# QUESTIONS?

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You can download the sources of this presentation here:
https://github.com/mxochicale/PhD/tree/master/presentations/

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