

# Nonlinear analysis to quantify human movement variability from time-series data

Seminario del Depto. de Ciencias de la Computación  @todoscicese  
November 27, 2020; 12h00m GMT-8

---

Miguel Xochicale, PhD

 @\_mxochicale  @mxochicale

School of Biomedical Engineering and Imaging Sciences  
King's College London



This work is licensed under a Creative Commons "Attribution 4.0 International" license.  
Get source of this slides and example document from <https://github.com/mxochicale/seminario-cicese-27112020>.



# Contents

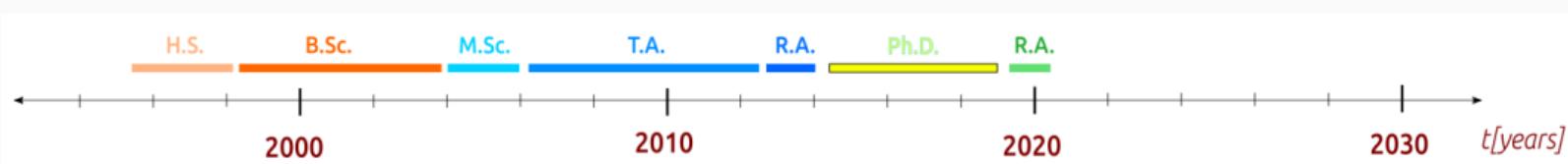
1. Short-bio
2. Nonlinear analysis to quantify human movement variability from time-series data
  - 2.1. Why Movement Variability?
  - 2.2. Nonlinear Methods
  - 2.3. Experiment/Results
  - 2.6. Conclusions
3. Extras
  - 3.1. Ultrasound Needle Tracking
  - 3.2. free-corTeX: a free CI framework for open scientific communication
  - 3.3. air4children

## Short-bio

---

# My journey in science

- (1996-1999) High School in Electronics
- (1999-2004) BSc in Electronics
- (2004-2006) MSc in Signal Processing
- (2006-2012) Teaching Associate in Mechatronics
- (2013-2014) Research Assistant in Robotics at INAOE
- (2014-2019) PhD student in Human-Robot Interaction at Uni of Bham
- (2019-present) Research Associate in Ultrasound-Guidance Intervention at KCL



Nonlinear analysis to quantify  
human movement variability from  
time-series data

---

# Few challenges when quantifying movement variability

## Theoretical challenges

- Modelling human movement (tasks, environments, agent, perception, action)
- Modelling human variability (complexity vs predictability)
- ?

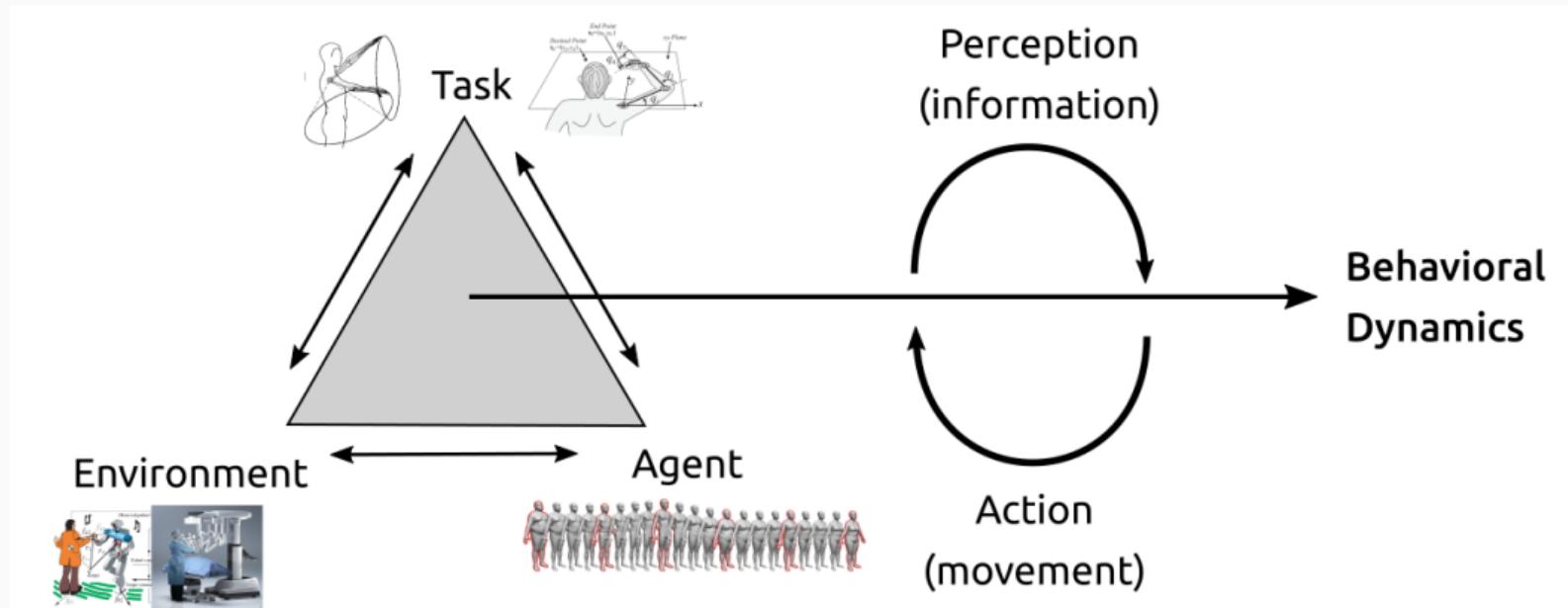
## Choosing the right tools

- Time-based domain,
- Frequency-based domain
- Nonlinear dynamics
- ?

## Technical challenges

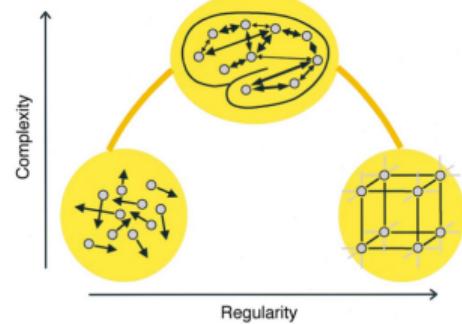
- non-stationarity,
- non-linearity,
- data length,
- sensor source,
- noise,
- ?

# Modeling Human Movement

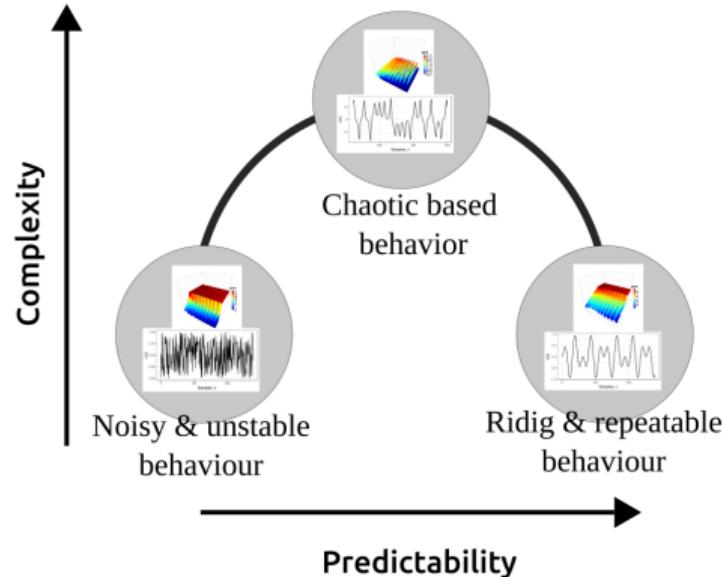


( Bernstein 1967 in The co-ordination and regulation of movements; Newell and Vaillancourt 2001 in Hum Mov Sci; Davids et al. 2003 in Sport Medicine; Warren 2006 in Psychological Review )

# Modelling Movement Variability



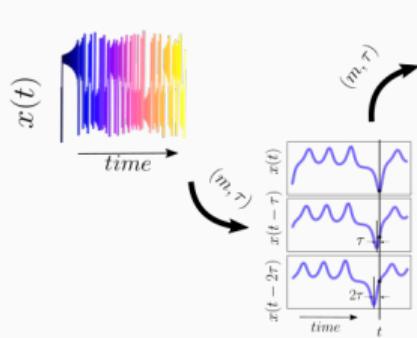
Tononi et. al 1998



Stergiou et al. 2006

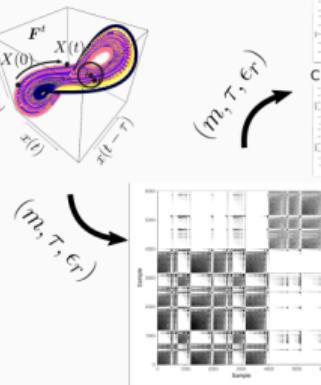
# Nonlinear Analysis

Time Series



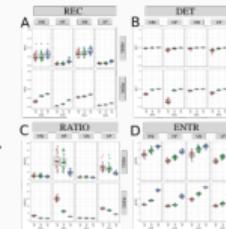
Uniform Time  
Delay-Embedding

Taken's Theorem

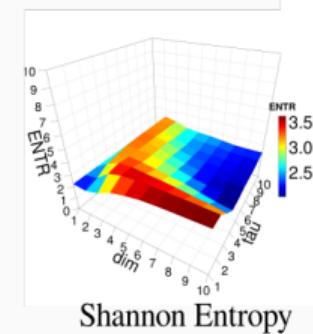


Recurrence Plots

RQA

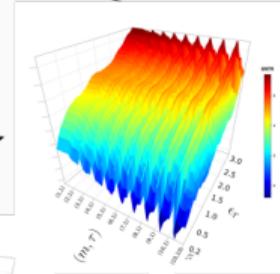


$(m, \tau, \epsilon_r)$



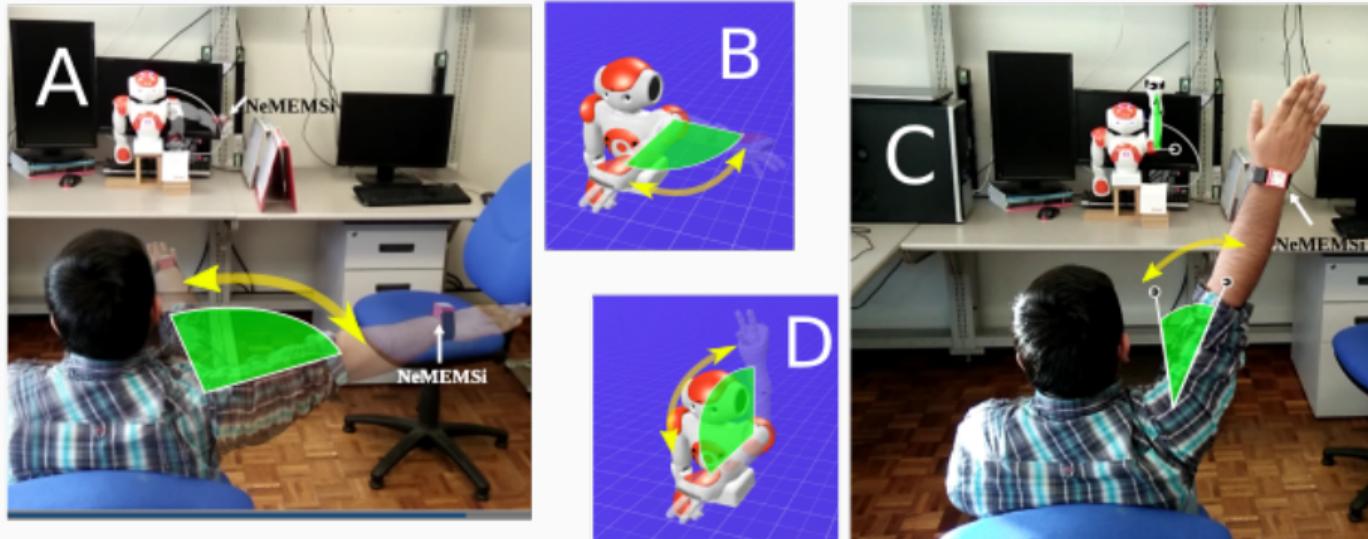
Shannon Entropy

3D RQA-ENTR



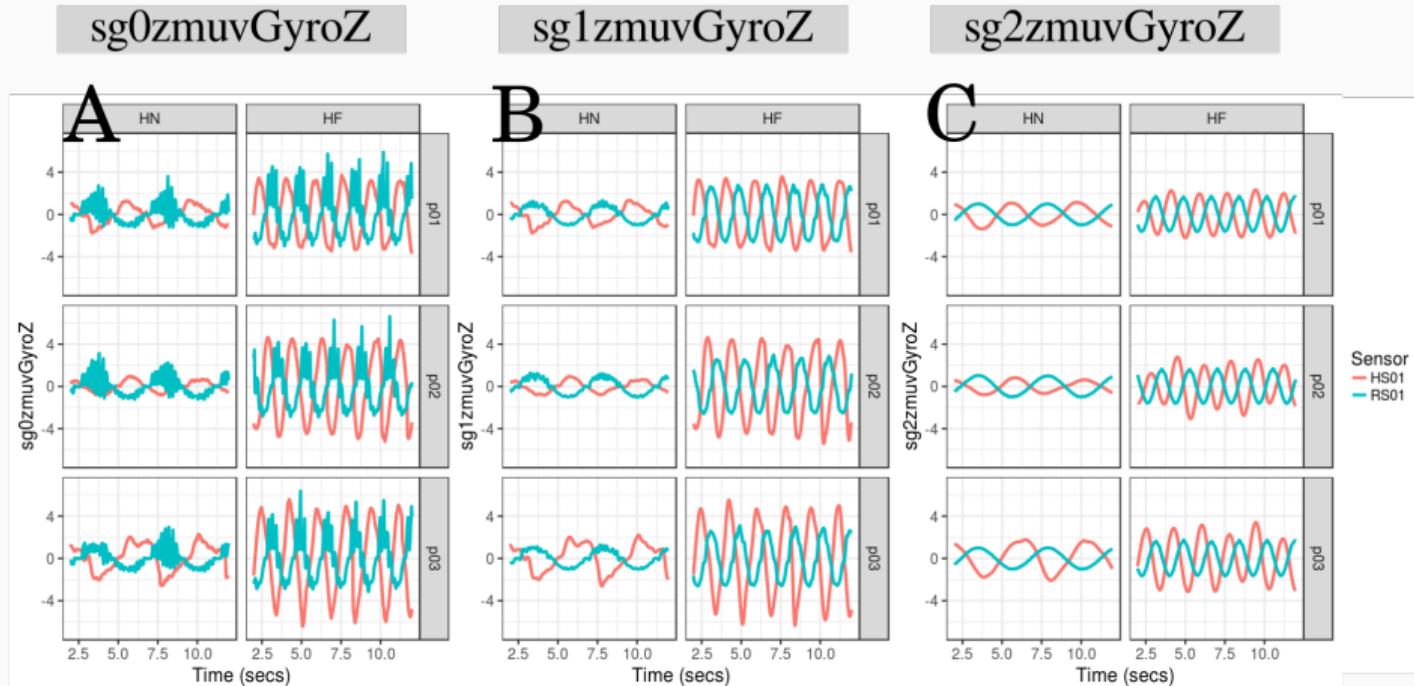
# Human-Humanoid Imitation Activities

20 participants with mean and standard deviation (SD) age of mean=19.8 (SD=1.39) years, being four females and sixteen males.



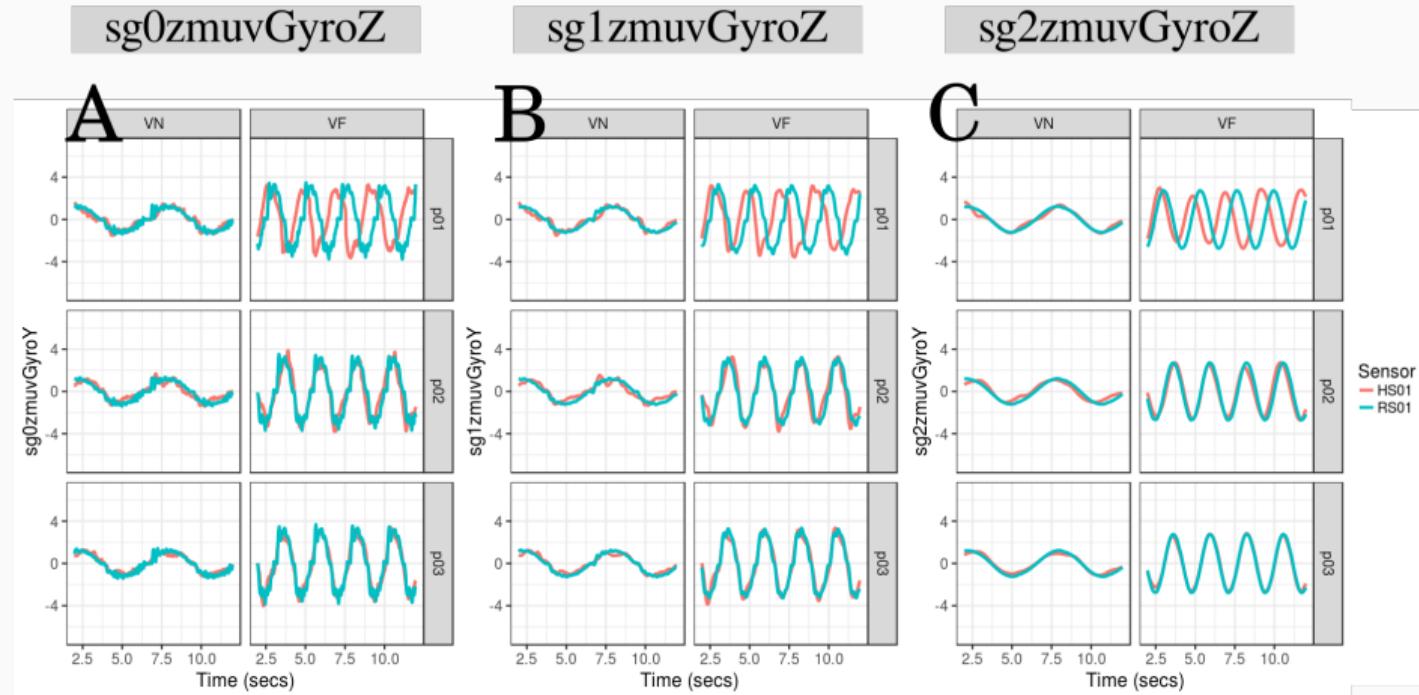
(A/C) Front-to-Front Human-Humanoid Imitation Activities of Horizontal/Vertical Movements, (B/D) NAO, humanoid robot, performing Horizontal/Vertical arm movements.

# From Raw to Smoothed Time Series



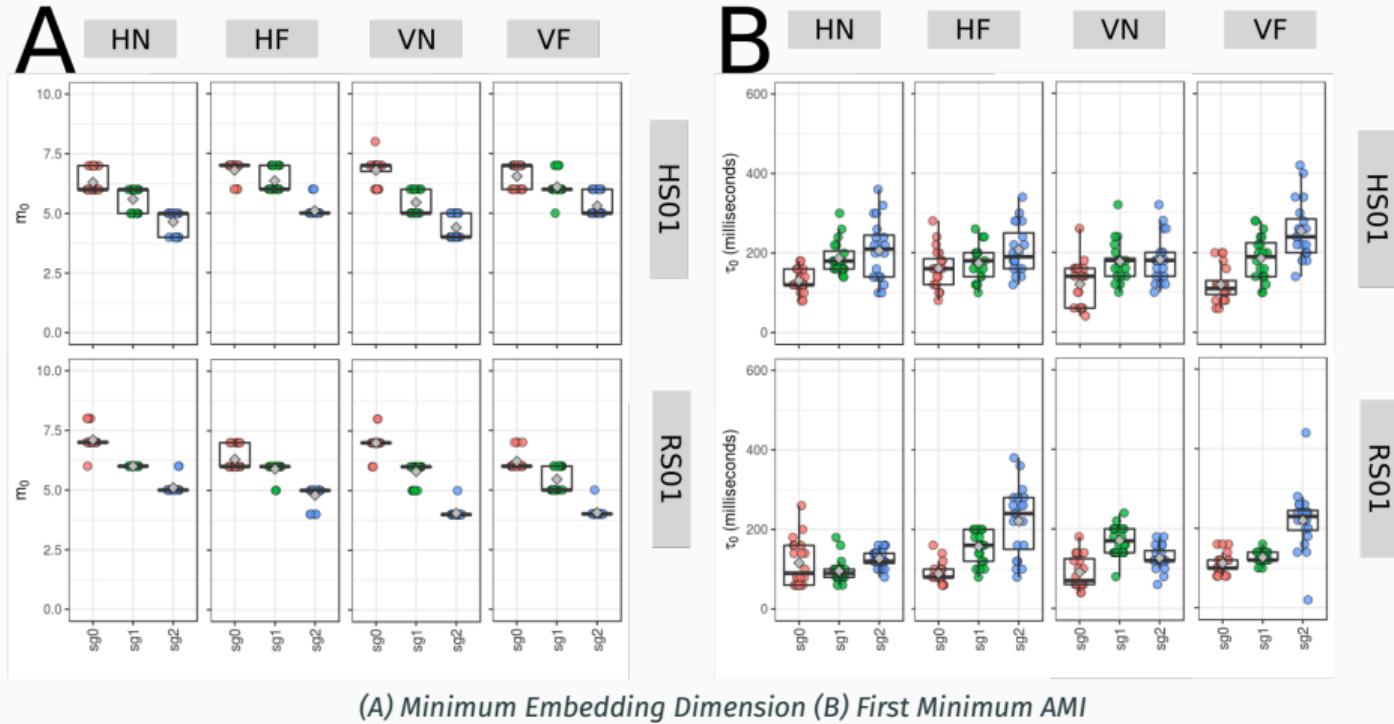
Time-series of horizontal movements for (A) normalised, (B)  $\text{sgolay}(p=5, n=25)$ , and (C)  $\text{sgolay}(p=5, n=159)$ .

# From Raw to Smoothed Time Series

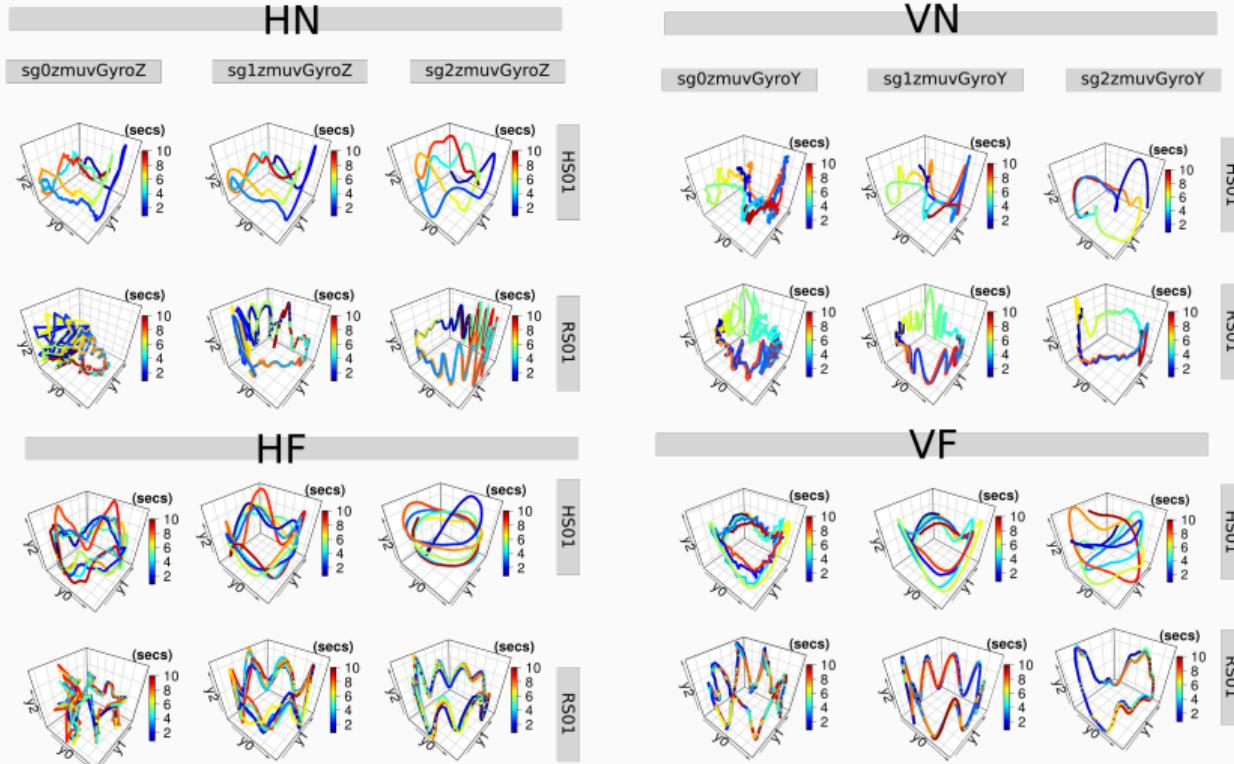


Time-series of vertical movements for (A) normalised, (B) **sgolay( $p=5, n=25$ )**, and (C) **sgolay( $p=5, n=159$ )**.

# Minimum Embedding Parameters

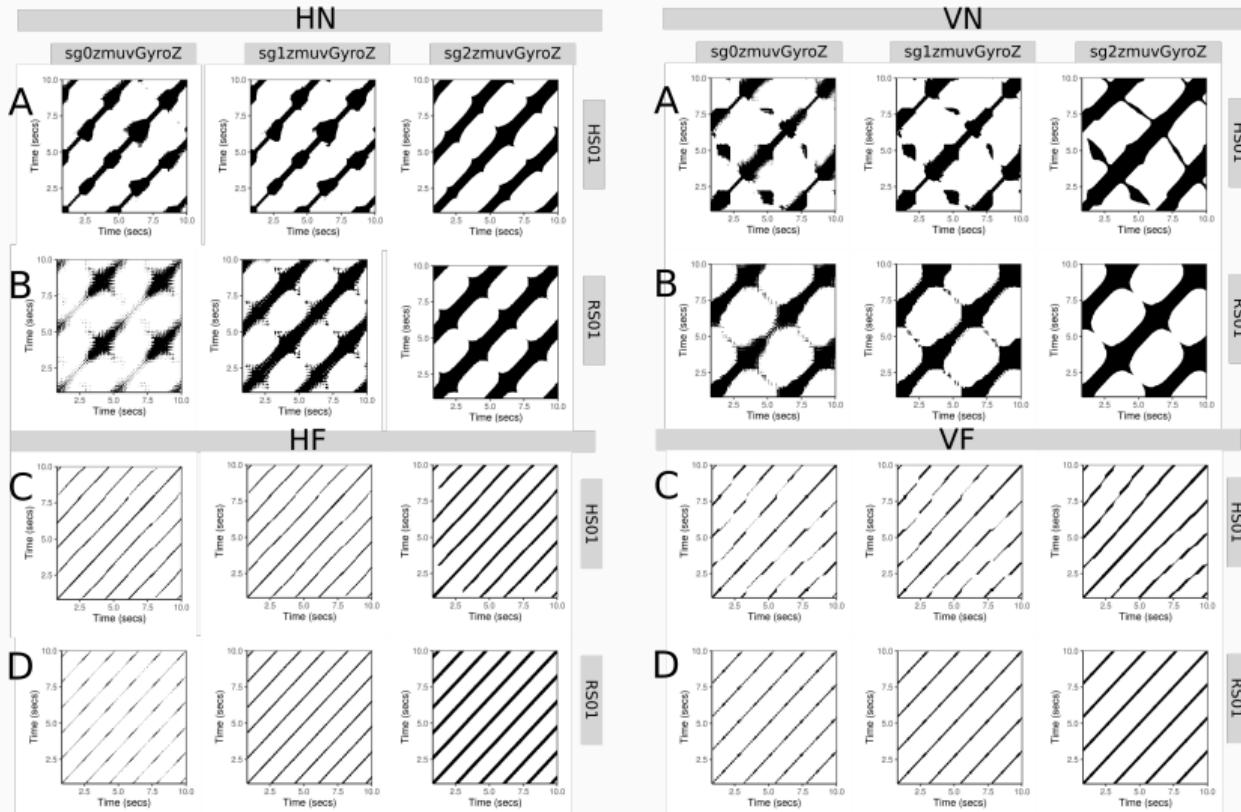


# Reconstructed State Spaces



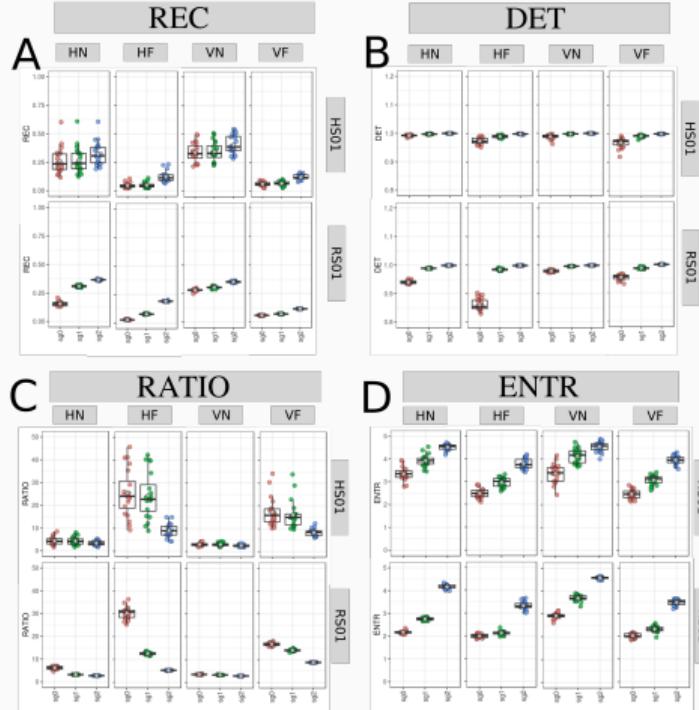
RSS for participant 01 computed with ( $m = 6, \tau = 8$ ) for different activities, signals and source of time-series data.

# Recurrence Plots



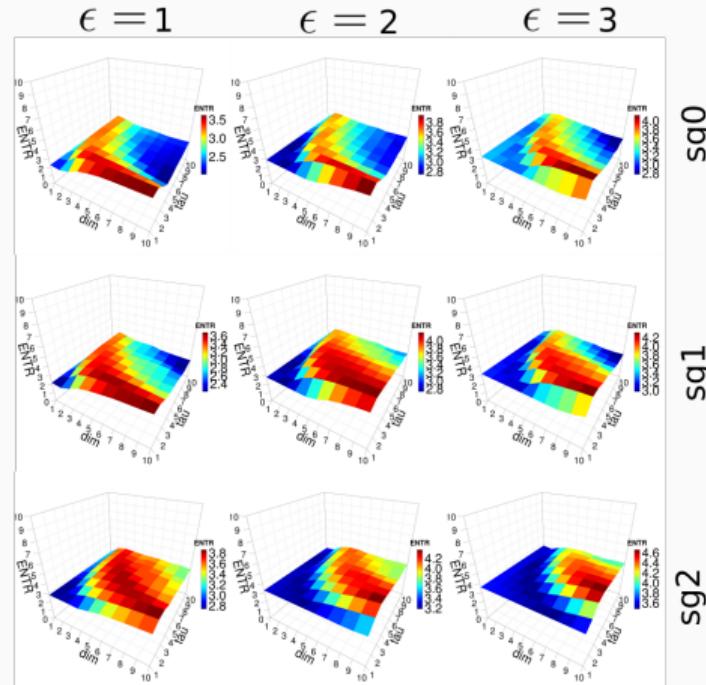
RP for participant 01 computed with ( $m = 6$ ,  $\tau = 8$ ,  $\epsilon = 1$ ) for different activities, signals and source of time-series data.

# Recurrence Quantification Analysis



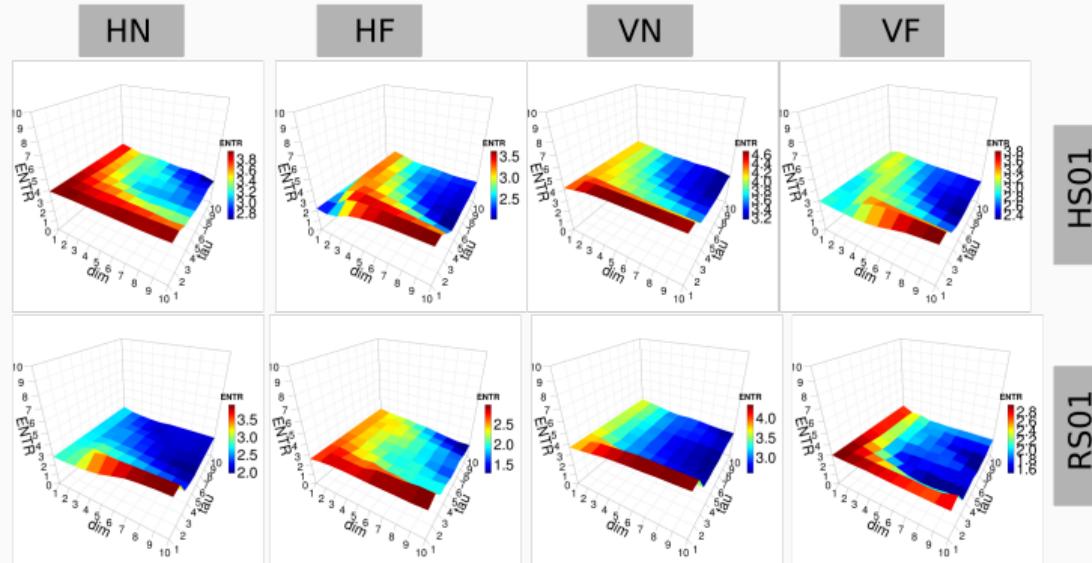
Box values of RQA computed with ( $m = 7$ ,  $\tau = 5$ ,  $\epsilon = 1$ ). These values are for 20 participants.

# RQA ENTR for $\epsilon$ thresholds & smoothness



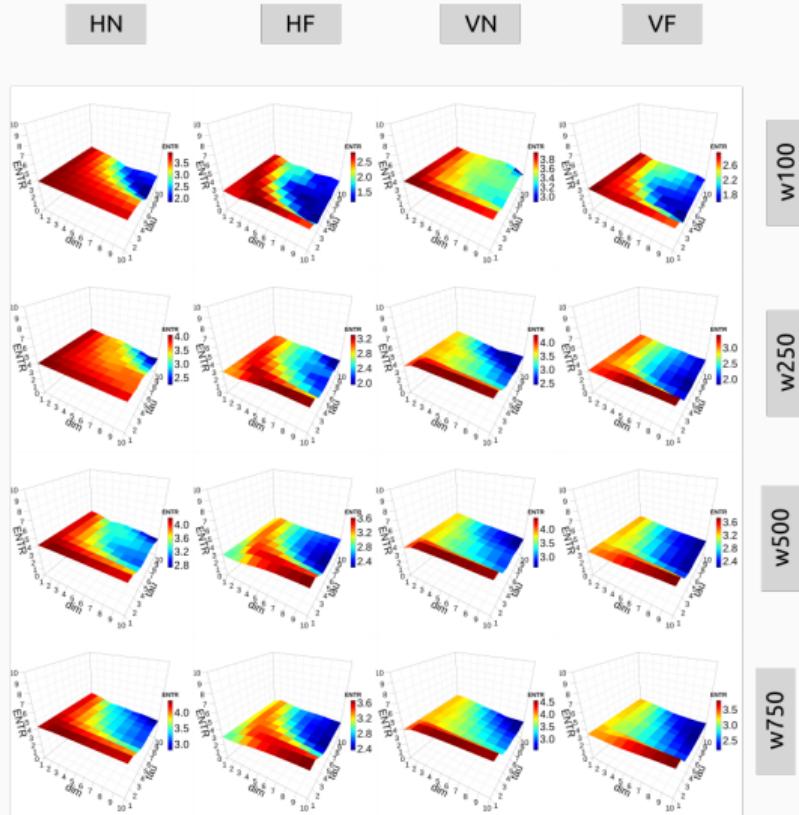
RQA ENTR values are for p03, sensor HS01, of a window size of 10-secs (500 samples).

# RQA ENTR for sensors and activities

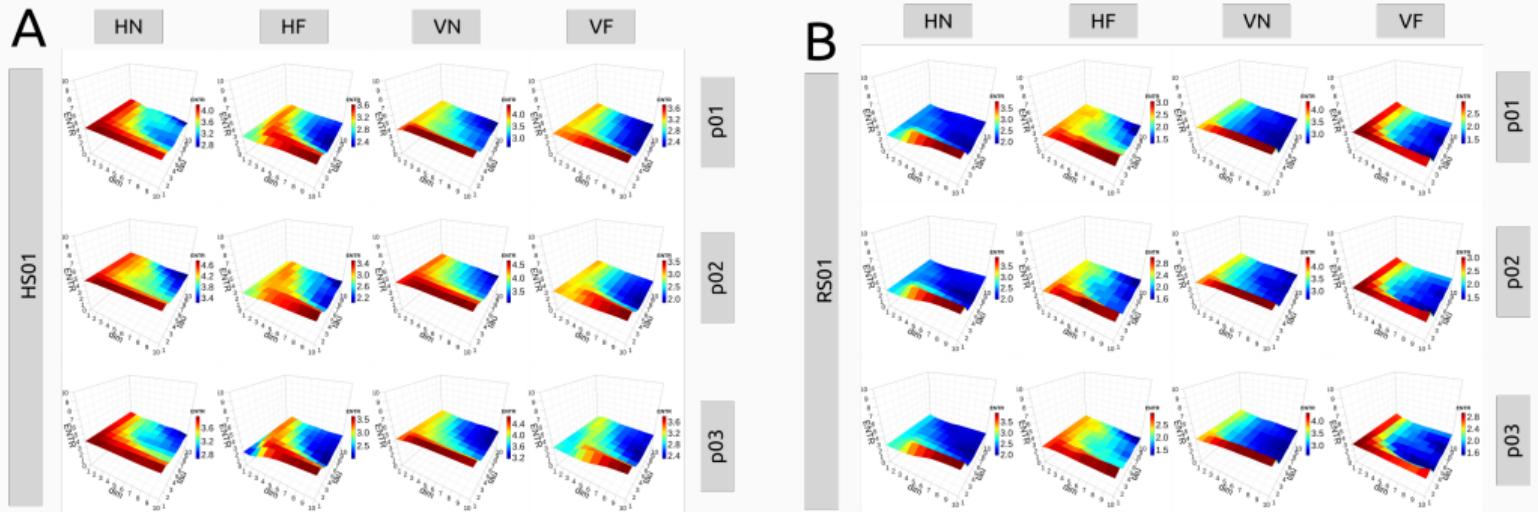


*RQA ENTR values are for p03, sg0 and window size of 10-secs (500 samples).*

# Window size lengths



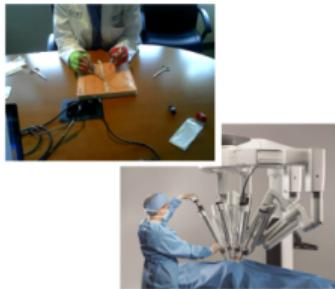
# Participants



Participants differences of 3D surface plots of RQA.

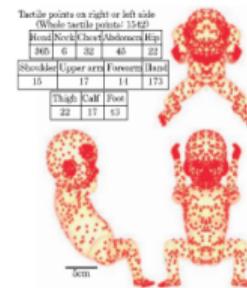
# Applications of Nonlinear Dynamics

## Quantification of skill learning



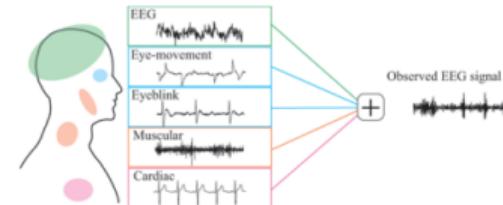
- \* Surgical Skills Assessment
- \* Robot-Assisted Surgery

## Fetal behavioral development



- \* General movements
- \* Arm/Legs Movs
- \* Hand/Face Contacts

## Nonlinear Biomedical Signal Processing



- \* EEG time series
- \* Heart rate variability
- \* Eye Movements

# Conclusions and future work

## Take away messages

- Nonlinear analysis tools can quantify different data time-series.
- Shannon entropy with 3D plot surfaces of RQA appear to be robust for real-word data (i.e. different time series structures, window length size and levels of smoothness).
- Therefore, Shannon entropy would be a potential good tool to quantify complexity of movement.

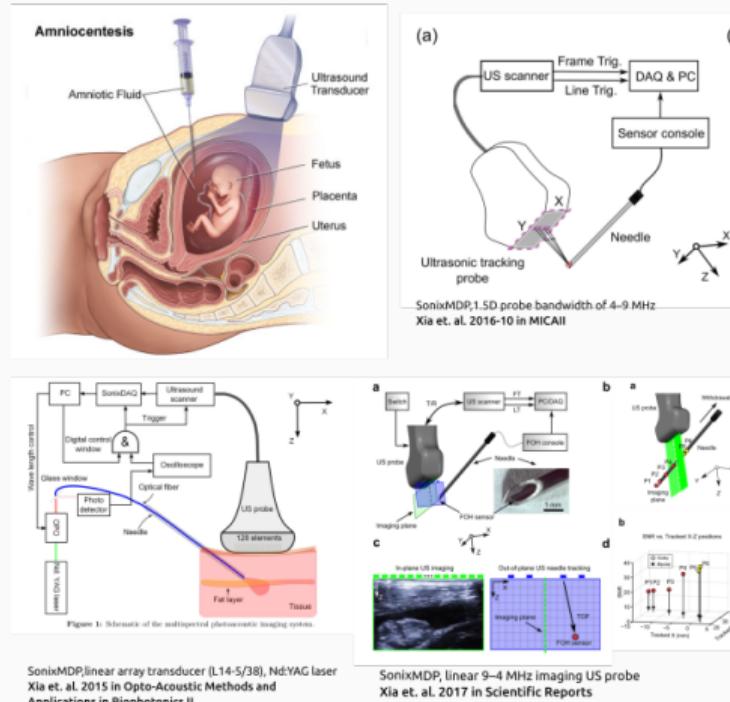
## Investigate

- other methodologies for state space reconstruction,
- the robustness of Entropy measurements with RQA, and
- variability in perception of velocity.

## Extras

---

# Ultrasound needle tracking



## Challenges

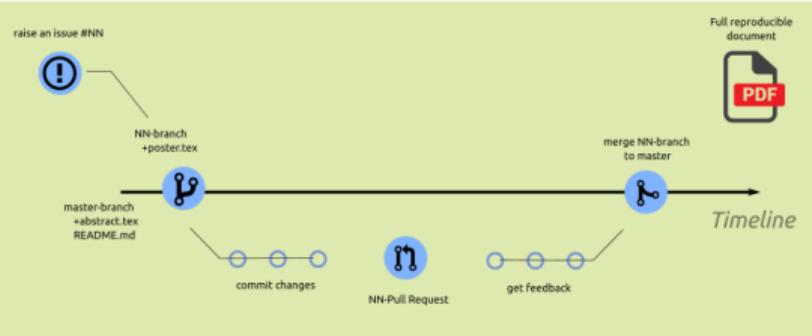
- In-plane and out-plane needle tracking
- Needle manipulation is impacted by the experience of the clinicians
- The anatomical view changes.

# free-corTeX: a free CI framework for open scientific communication

## Github Action

```
.github/workflows/main.yml
name: Compiling-TeX
jobs:
  build:
    - name: Compile Poster
      uses: xu-cheng/latex-action@v2
      with:
        root_file: main.tex
        working_directory: poster
    - name: Upload
      runs:
        # configure git
        # setup ssh
        # create branch
        # github action deploy
```

## Github Workflow



## Article Thesis CV Poster Slides



## free-corTeX

A free continuous integration framework for open scientific communication based-on LaTeX



[github.com/free-cortex/framework](https://github.com/free-cortex/framework)

# AIR4Children: Artificial Intelligence and Robotics for Children



Free teaching of AI and Robotics for Children with Open-Sourced Robots that are:

- Affordable,
- Educational, and
- Fun.

## References



Xochicale Miguel

Nonlinear methods to quantify Movement Variability in Human-Humanoid  
Interaction Activities

Looking for a right venue in an Open Access Journal

<https://arxiv.org/abs/1810.09249>

## Thanks!!! Questions?

Nonlinear analysis to quantify human movement variability from time-series data

<https://github.com/mxochicale/seminario-cicese-27112020>

---

Miguel Xochicale, PhD

School of Biomedical Engineering and Imaging Sciences  
King's College London



This work is licensed under a Creative Commons "Attribution 4.0 International" license.  
Get source of this slides and example document from <https://github.com/mxochicale/seminario-cicese-27112020>.

