

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

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Get source of this slides and example document from <https://github.com/mxochicale/seminario-cicese-27112020>.



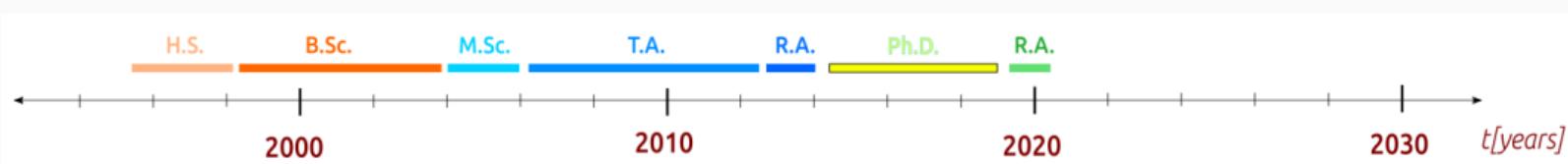
Contents

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)
- ?

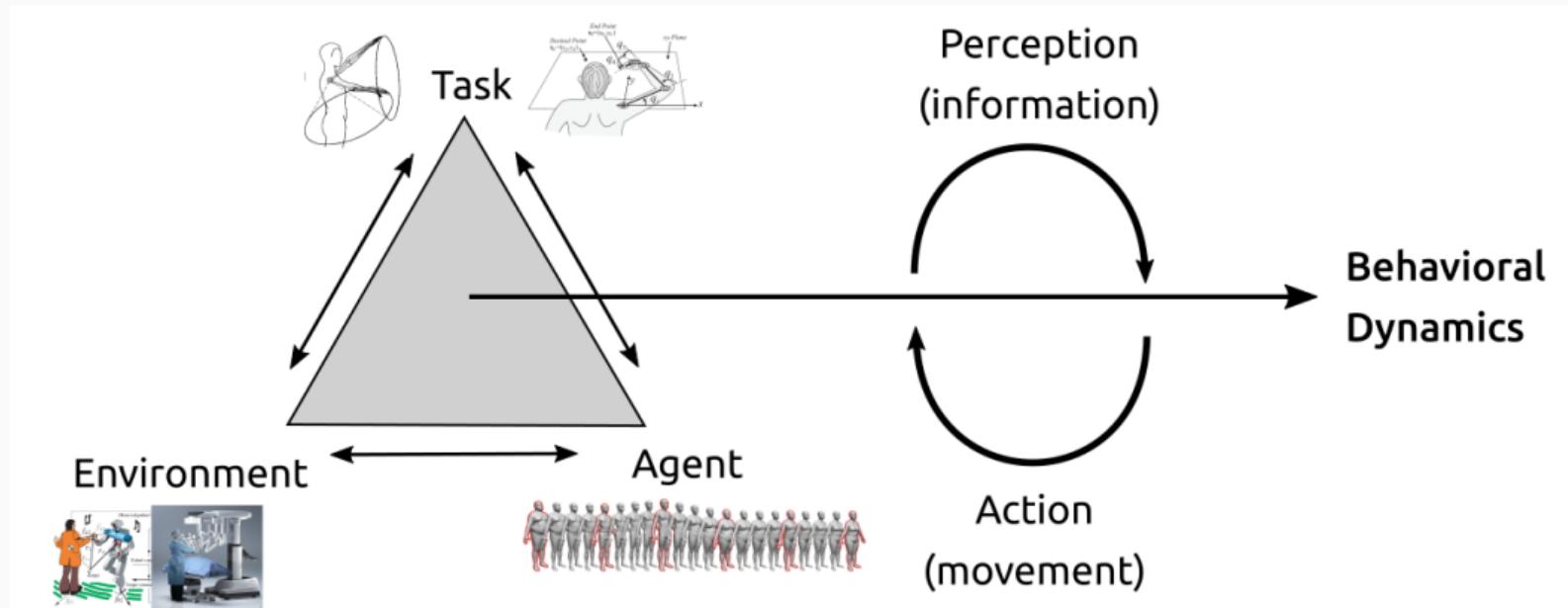
Choosing the right tools

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

Technical challenges

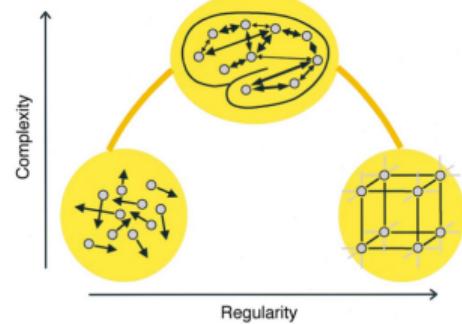
- non-stationarity,
- non-linearity,
- data length,
- sensor source,
- noise,
- ?

Modeling Human Movement

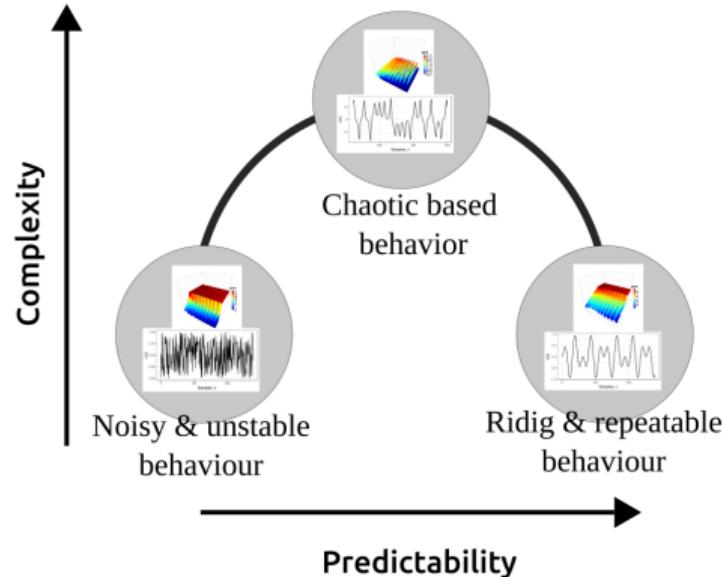


(Bernstein 1967 in The co-ordination and regulation of movements; Newell and Vaillancourt 2001 in Hum Mov Sci; Davids et al. 2003 in Sport Medicine; Warren 2006 in Psychological Review)

Modelling Movement Variability



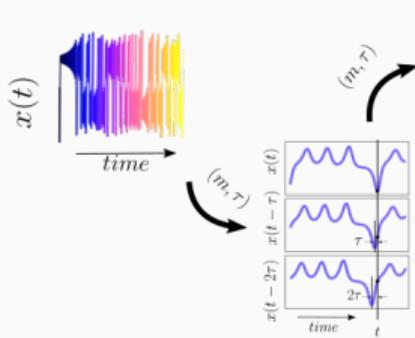
Tononi et. al 1998



Stergiou et al. 2006

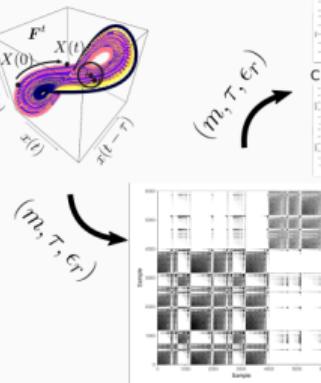
Nonlinear Analysis

Time Series



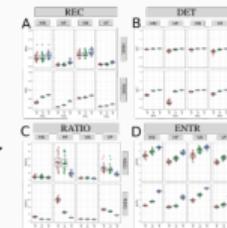
Uniform Time
Delay-Embedding

Taken's Theorem

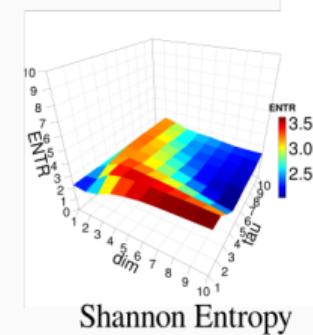


Recurrence Plots

RQA

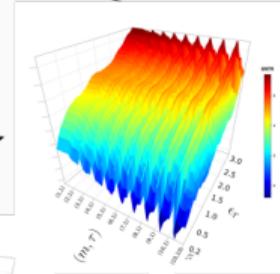


(m, τ, ϵ_r)



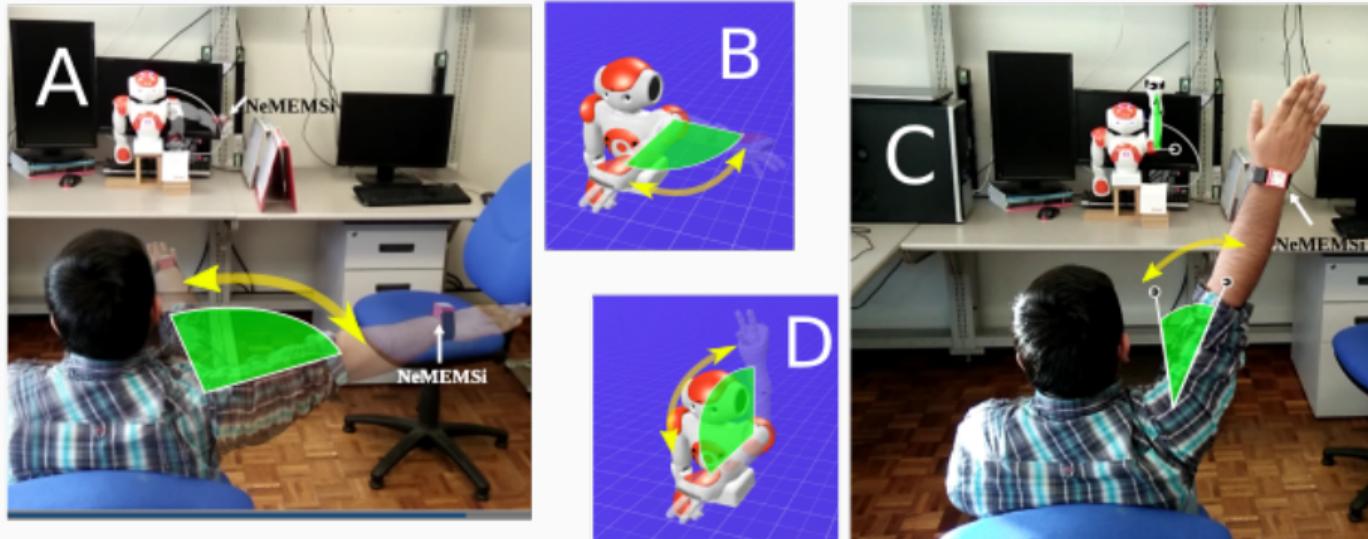
Shannon Entropy

3D RQA-ENTR



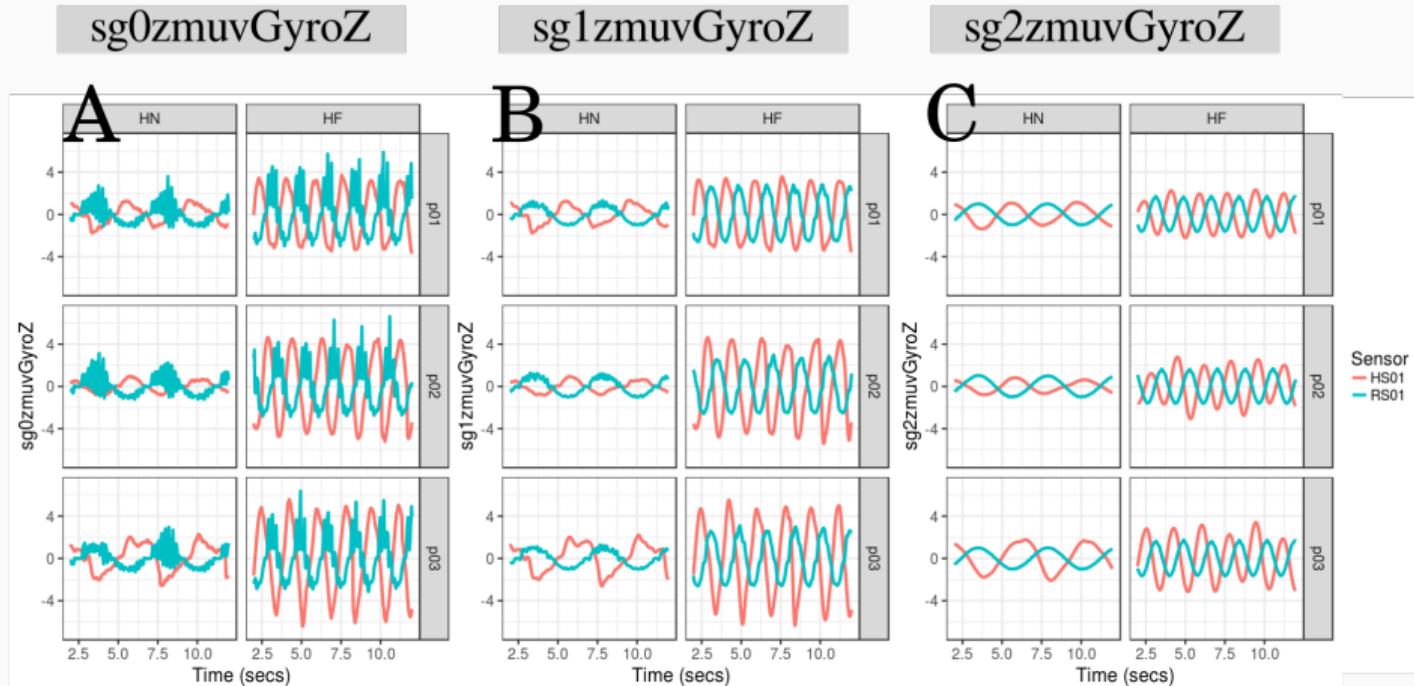
Human-Humanoid Imitation Activities

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



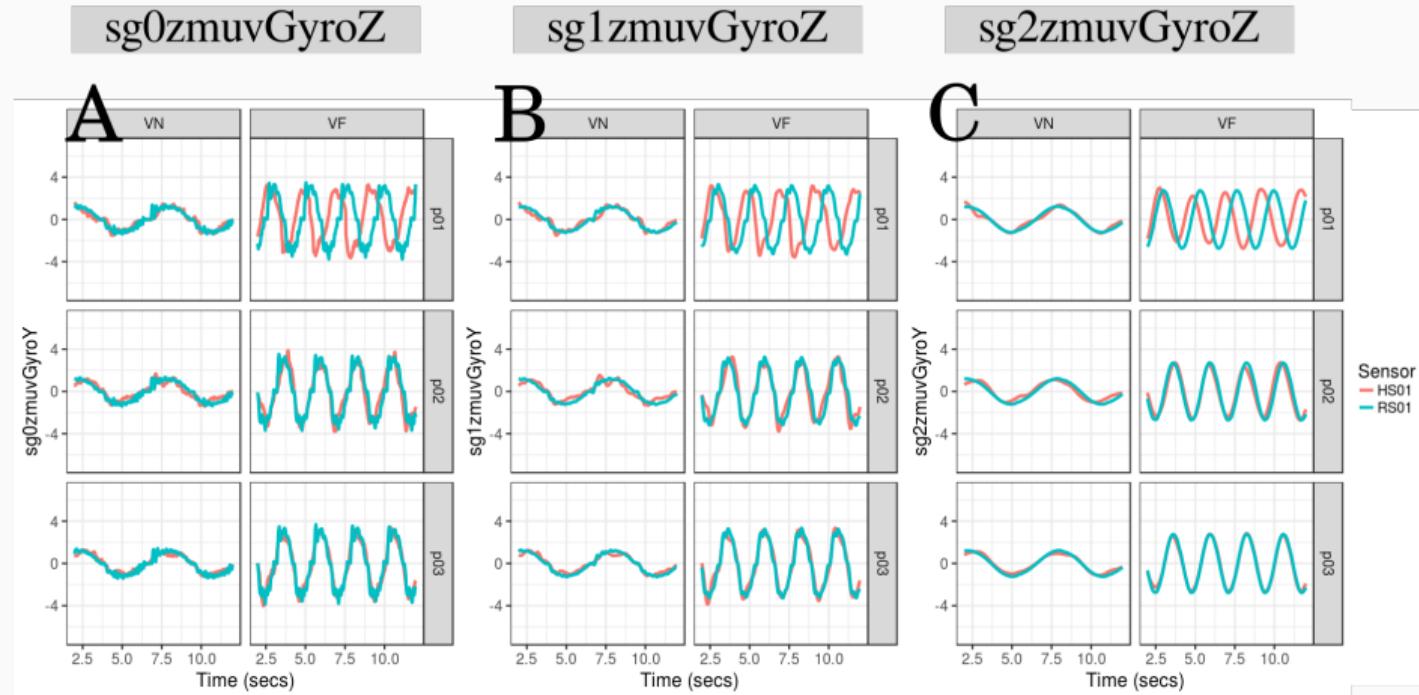
(A/C) Front-to-Front Human-Humanoid Imitation Activities of Horizontal/Vertical Movements, (B/D) NAO, humanoid robot, performing Horizontal/Vertical arm movements.

From Raw to Smoothed Time Series



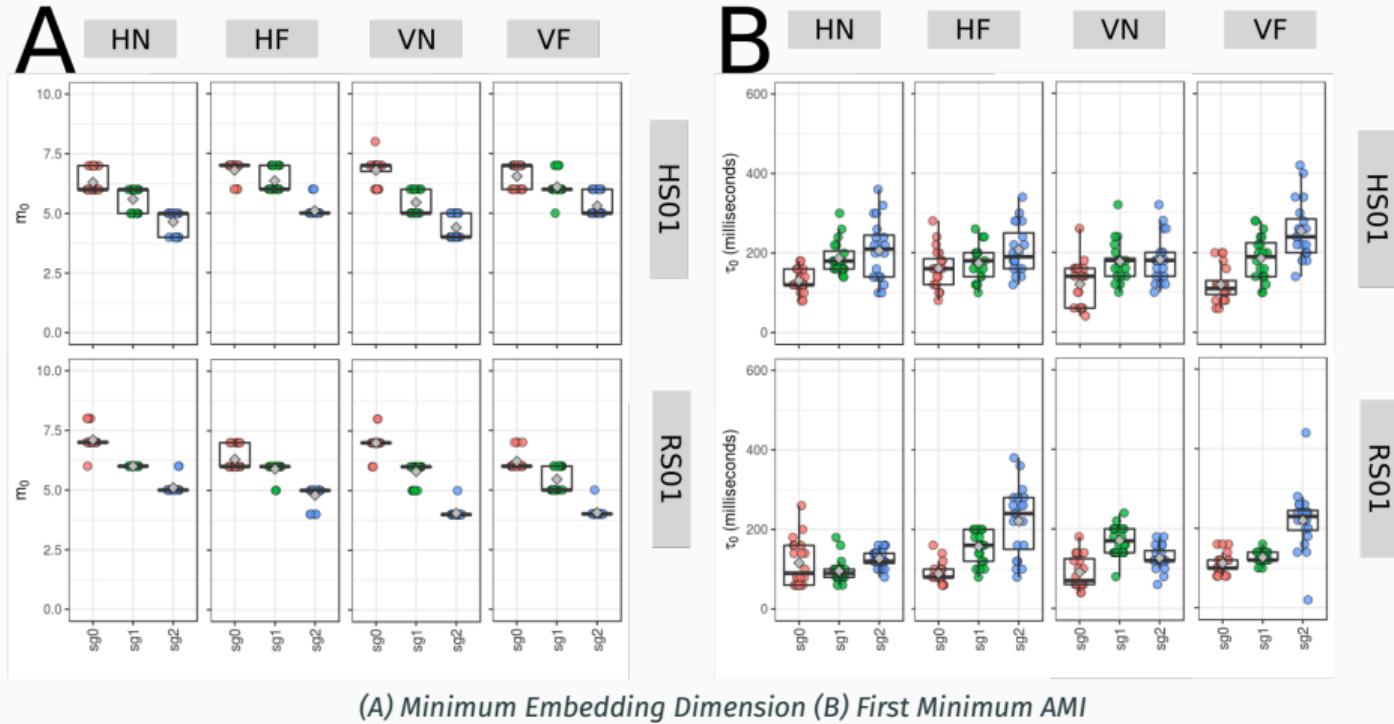
Time-series of horizontal movements for (A) normalised, (B) $\text{sgolay}(p=5, n=25)$, and (C) $\text{sgolay}(p=5, n=159)$.

From Raw to Smoothed Time Series

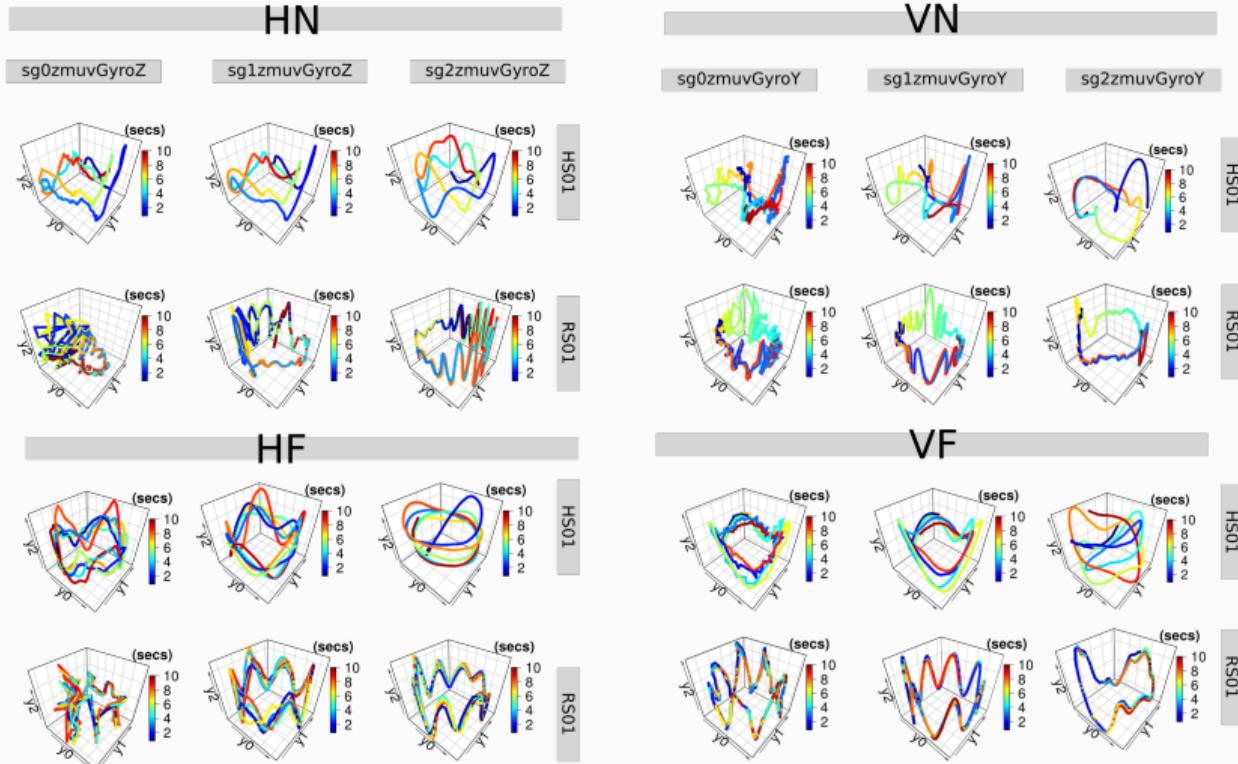


Time-series of vertical movements for (A) normalised, (B) **sgolay($p=5, n=25$)**, and (C) **sgolay($p=5, n=159$)**.

Minimum Embedding Parameters

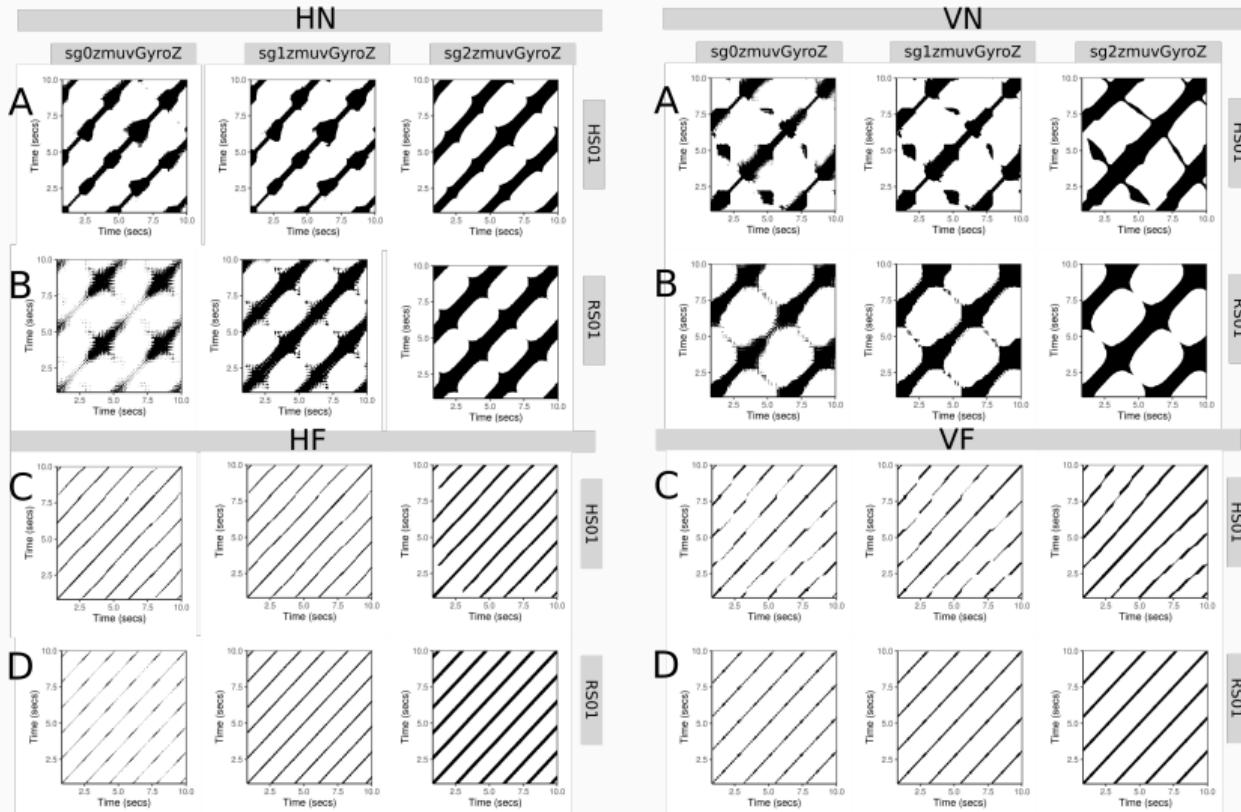


Reconstructed State Spaces



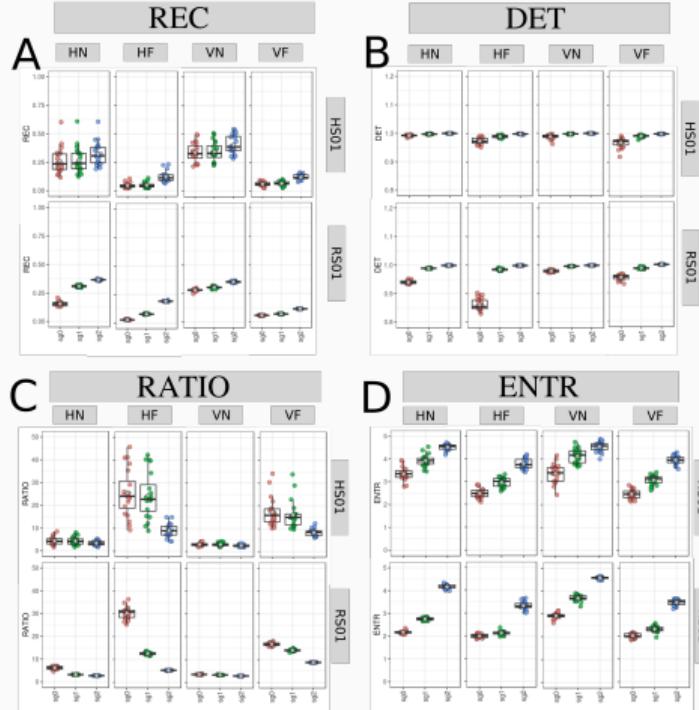
RSS for participant 01 computed with ($m = 6$, $\tau = 8$) for different activities, signals and source of time-series data.

Recurrence Plots



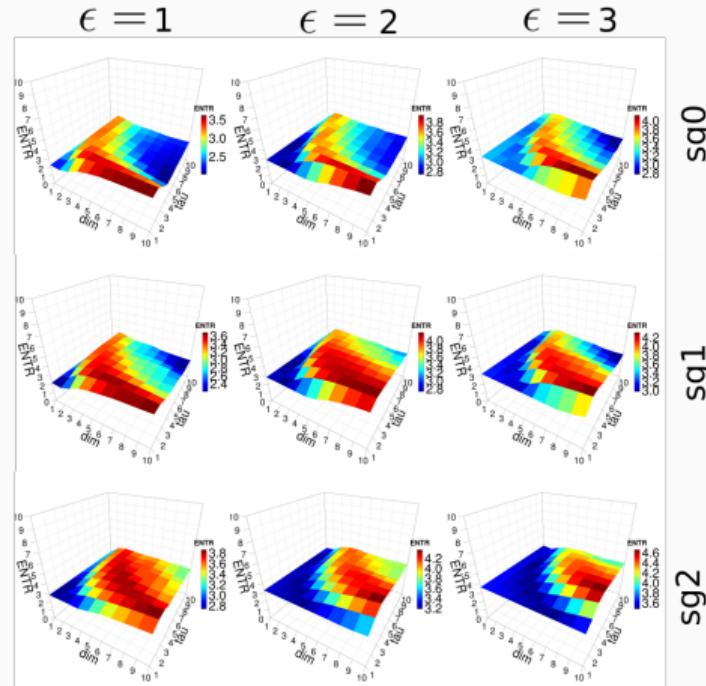
RP for participant 01 computed with $(m = 6, \tau = 8, \epsilon = 1)$ for different activities, signals and source of time-series data.

Recurrence Quantification Analysis



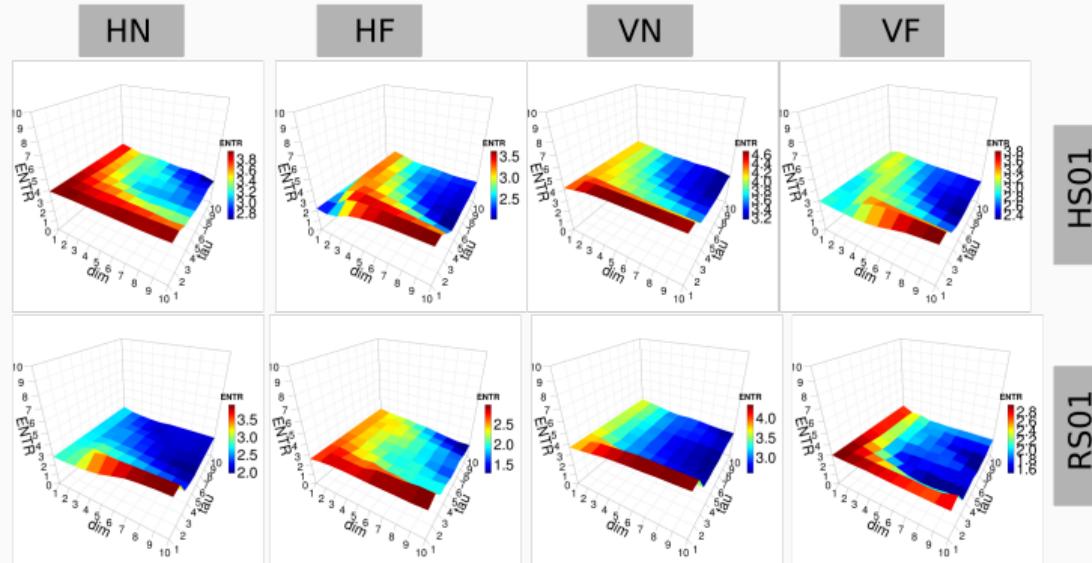
Box values of RQA computed with ($m = 7$, $\tau = 5$, $\epsilon = 1$). These values are for 20 participants.

RQA ENTR for ϵ thresholds & smoothness



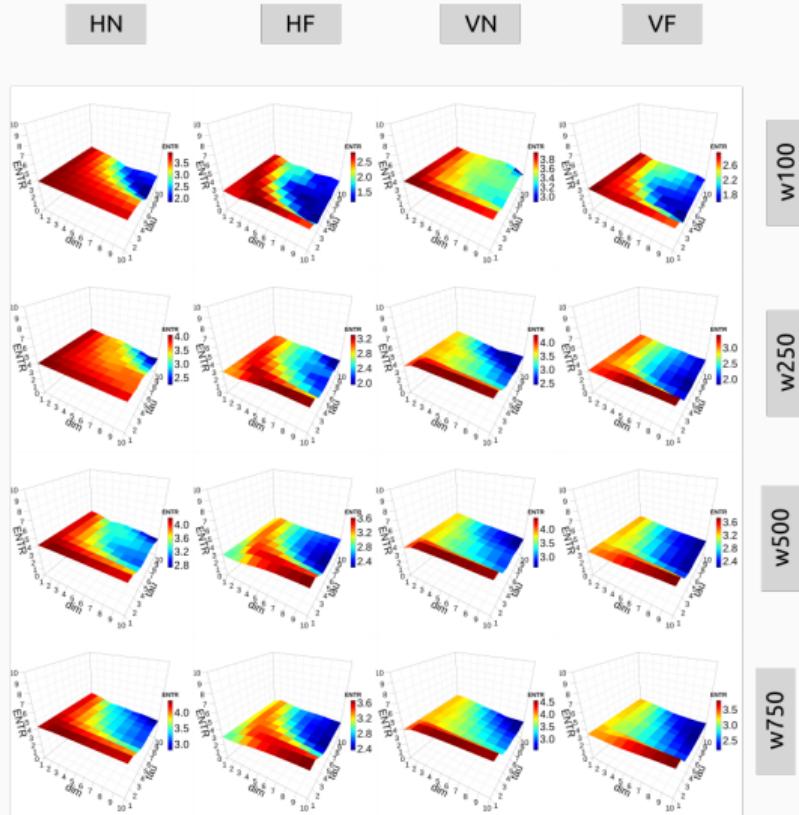
RQA ENTR values are for p03, sensor HS01, of a window size of 10-secs (500 samples).

RQA ENTR for sensors and activities

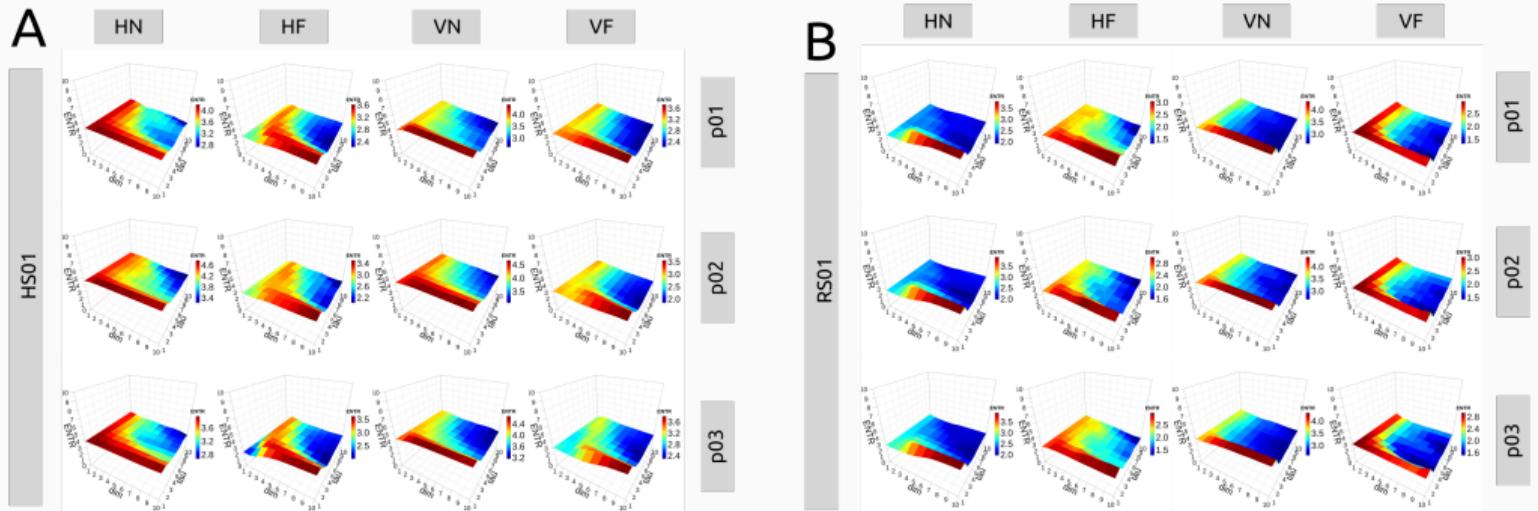


RQA ENTR values are for p03, sg0 and window size of 10-secs (500 samples).

Window size lengths



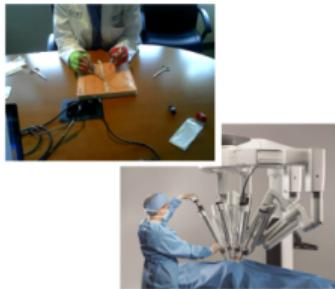
Participants



Participants differences of 3D surface plots of RQA.

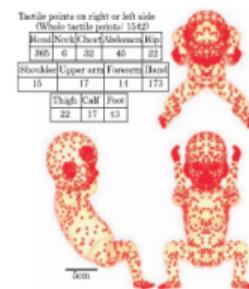
Applications of Nonlinear Dynamics

Quantification of skill learning



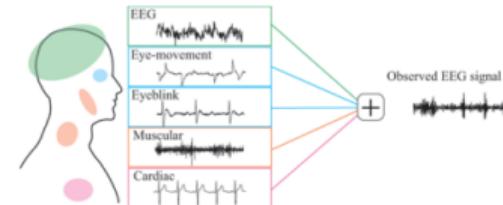
- * Surgical Skills Assessment
- * Robot-Assisted Surgery

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

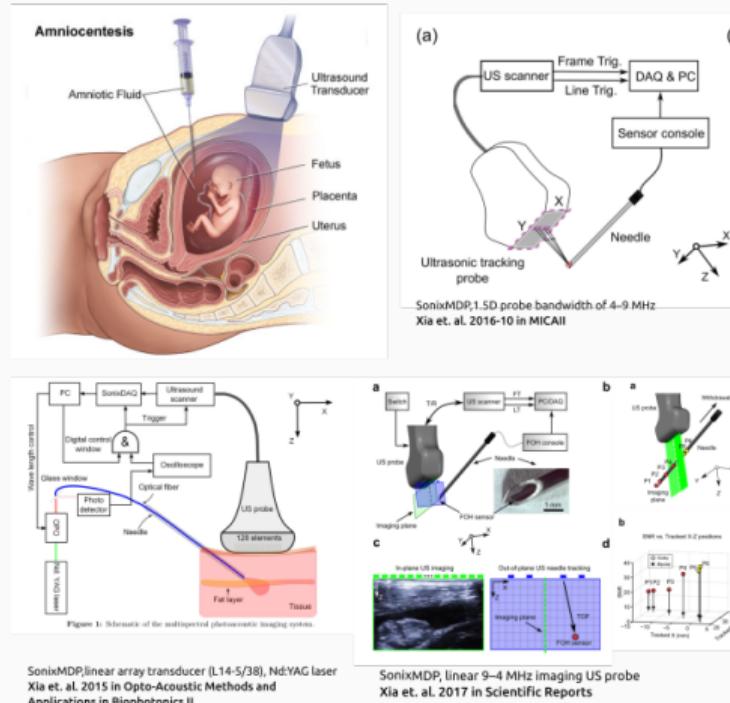
- Nonlinear analysis tools can quantify different data time-series.
- Shannon entropy with 3D plot surfaces of RQA appear to be robust for real-word data (i.e. different time series structures, window length size and levels of smoothness).
- Therefore, Shannon entropy would be a potential good tool to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

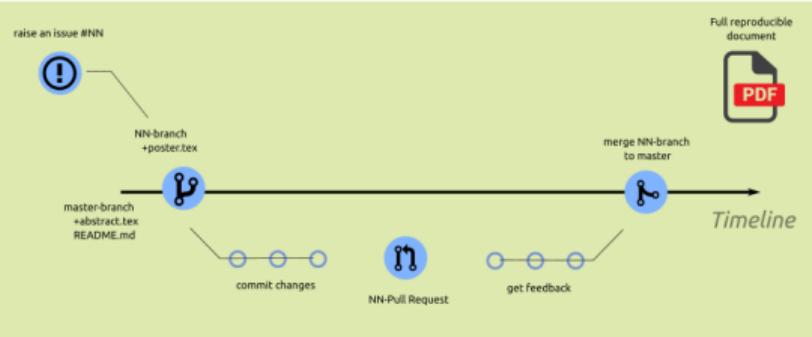
- In-plane and out-plane needle tracking
- Needle manipulation is impacted by the experience of the clinicians
- The anatomical view changes.

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



free-corTeX

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



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?

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