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

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

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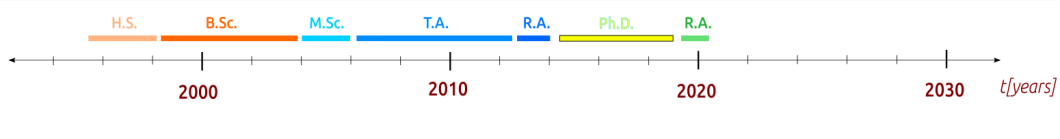
Contents

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)
- ?

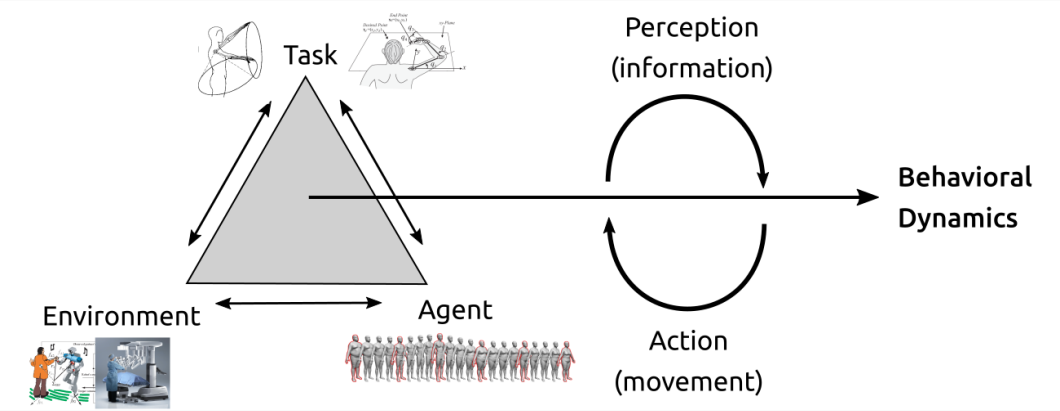
Choosing the right tools

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

Technical challenges

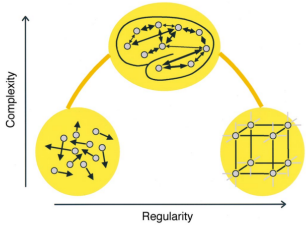
- non-stationarity,
- non-linearity,
- data length,
- sensor source,
- noise,
- ?

Modeling Human Movement

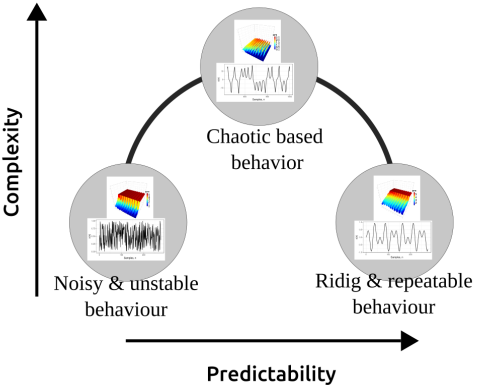


(Bernstein 1967 in **The co-ordination and regulation of movements**; Newell and Vaillancourt 2001 in **Hum Mov Sci**; Davids et al. 2003 in **Sport Medicine**; Warren 2006 in **Psychological Review**)

Modelling Movement Variability



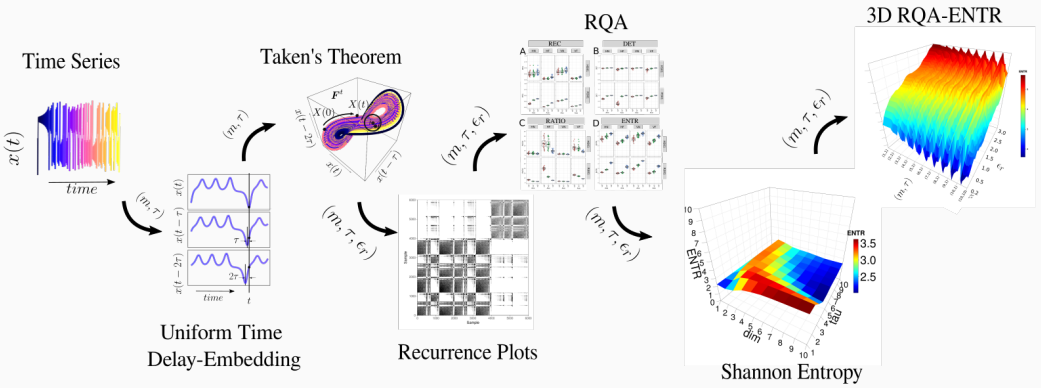
Tononi et. al 1998



Stergiou et al. 2006

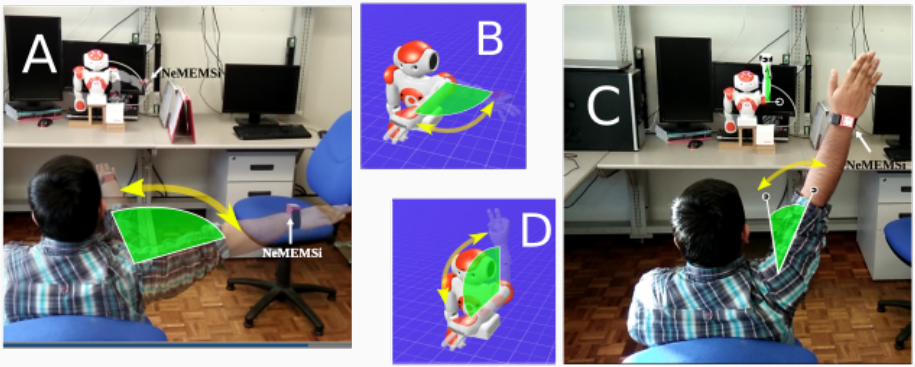
(Stergiou et al. 2006 in **Neurologic Physical Therapy**; Stergiou and Decker 2011 in **Human Movement Science**; Tononi et al. 1998 in **Trends in Cognitive Sciences**)

Nonlinear Analysis



Human-Humanoid Imitation Activities

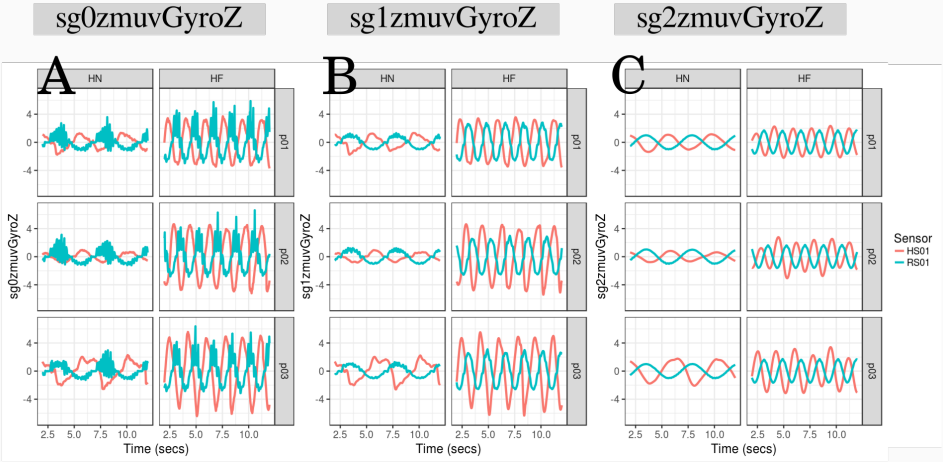
20 participants with mean and standard deviation (SD) age of mean=19.8 (SD=1.39) years, being four females and sixteen males.



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

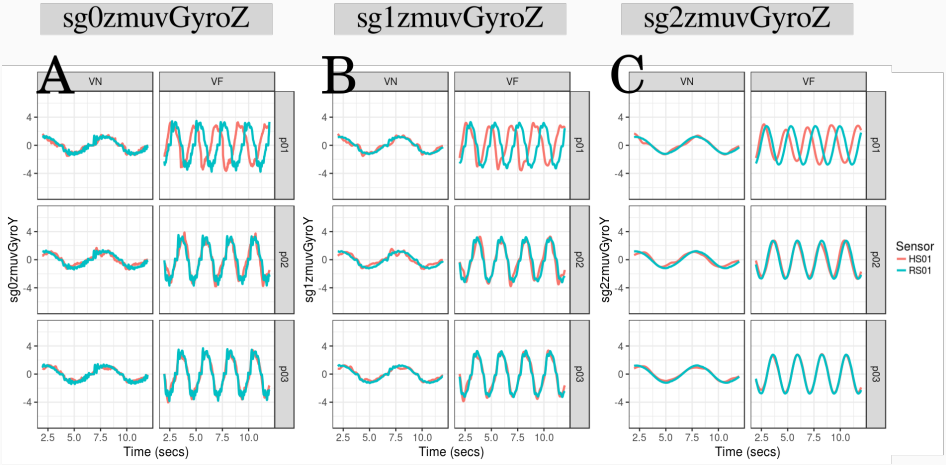
(Xochicale 2019 in PhD thesis)

From Raw to Smoothed Time Series



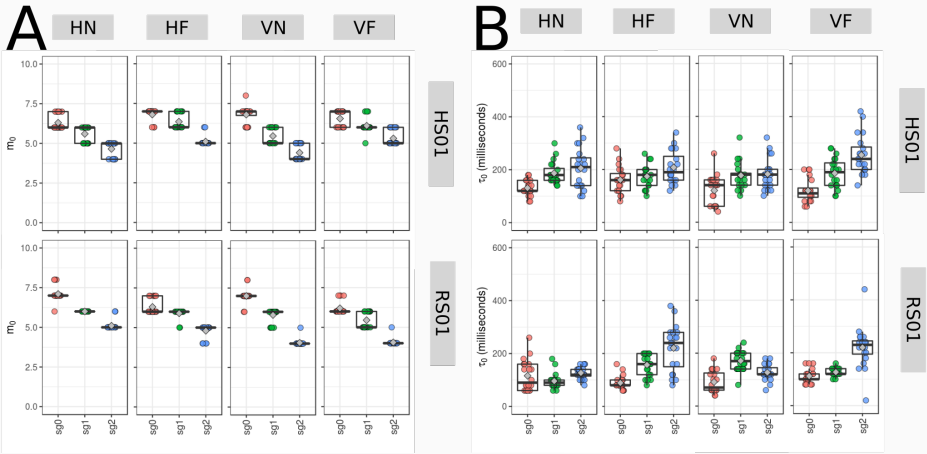
Time-series of horizontal movements for (A) normalised, (B) **`sgolay(p=5,n=25)`**, *and (C)* **`sgolay(p=5,n=159)`**.

From Raw to Smoothed Time Series



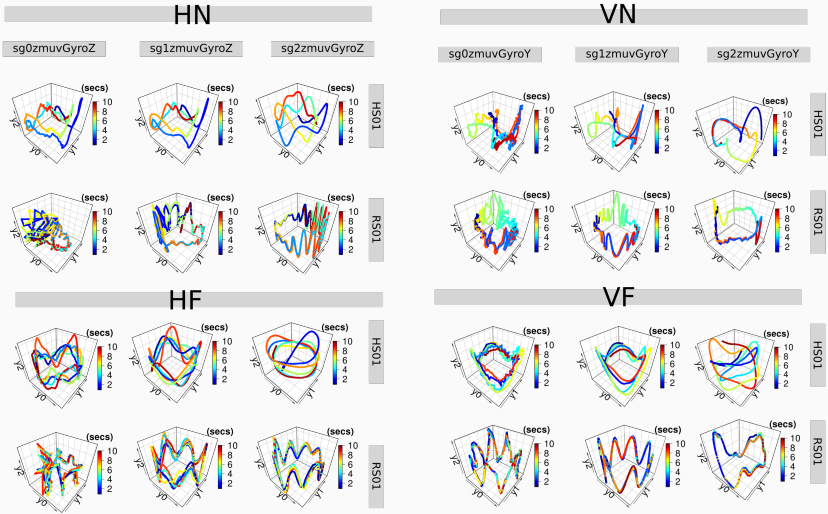
Time-series of vertical movements for (A) normalised, (B) **`sgolay(p=5,n=25)`**, *and (C)* **`sgolay(p=5,n=159)`**.

Minimum Embedding Parameters



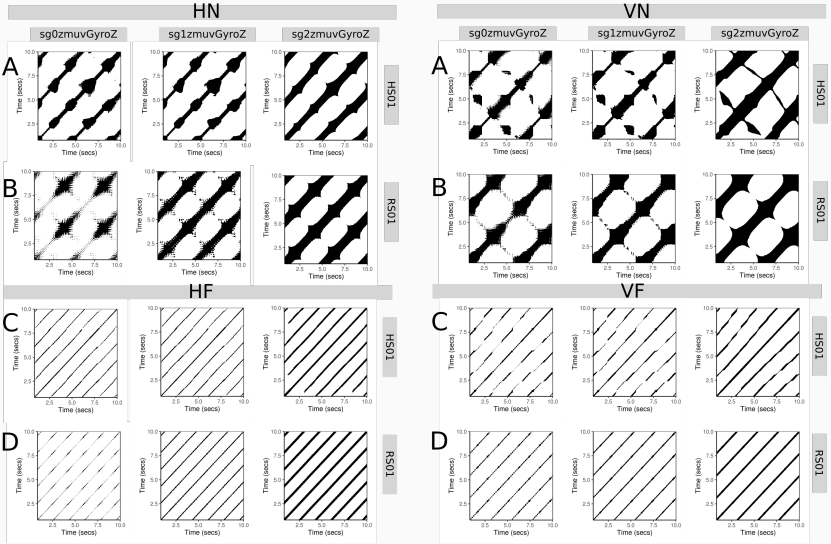
(A) Minimum Embedding Dimension (B) First Minimum AMI

Reconstructed State Spaces



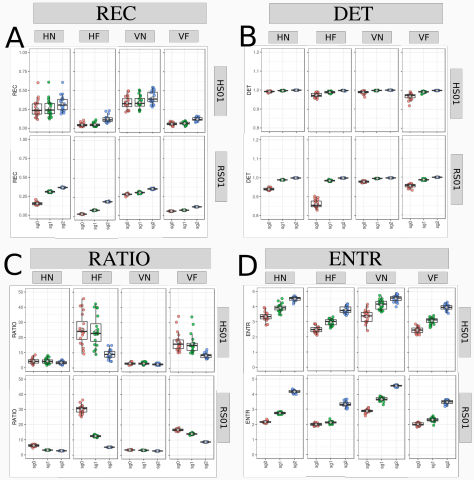
RSS for participant 01 computed with ($m = 6$, $\tau = 8$) for different activities, signals and source of time-series data.

Recurrence Plots



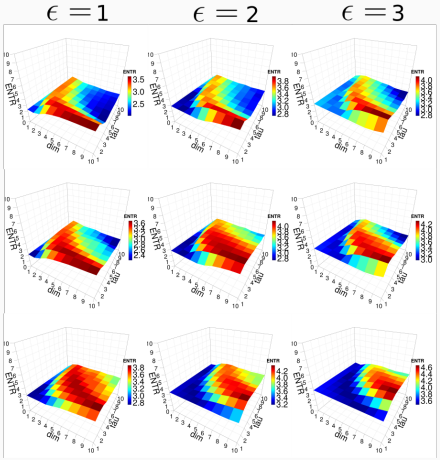
RP for participant 01 computed with ($m = 6$, $\tau = 8$, $\epsilon = 1$) for different activities, signals and source of time-series data.

Recurrence Quantification Analysis



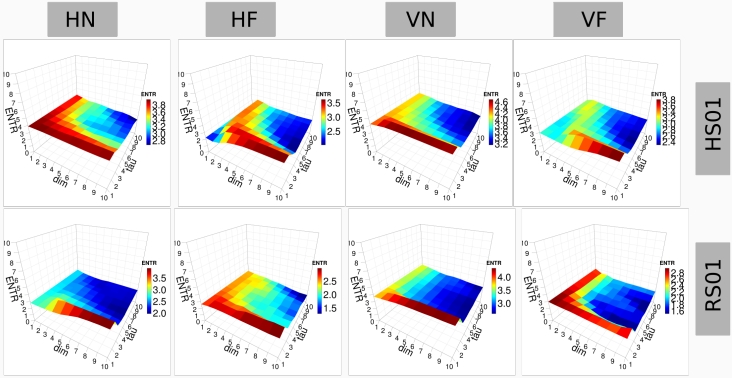
Box values of RQA computed with ($m = 7$, $\tau = 5$, $\epsilon = 1$). These values are for 20 participants.

RQA ENTR for ϵ thresholds & smoothness



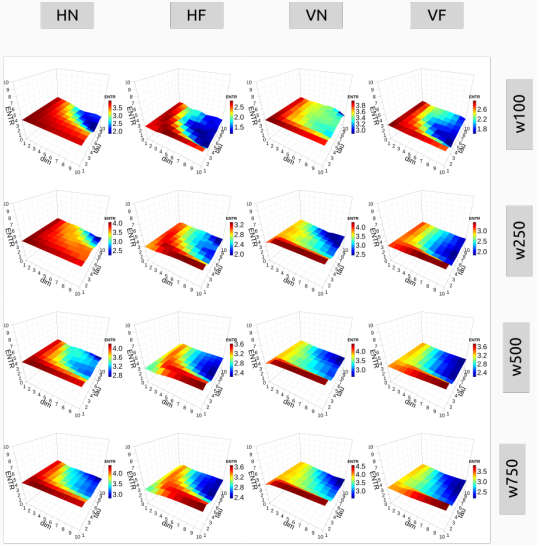
RQA ENTR values are for p03*, sensor* HS01*, of a window size of 10-secs (500 samples).*

RQA ENTR for sensors and activities



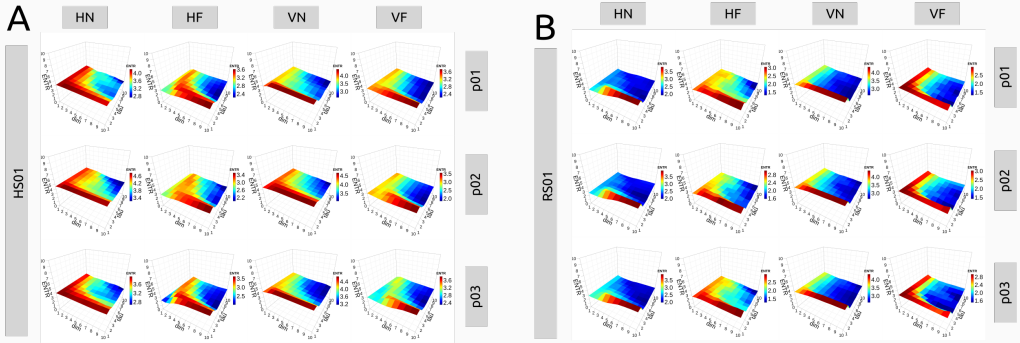
RQA ENTR values are for $p03$, $sg0$ *and window size of 10-secs (500 samples).*

Window size lengths



(Xochicale 2019 in **PhD Thesis**)

Participants



Participants differences of 3D surface plots of RQA.

Conclusions and future work

Take away messages

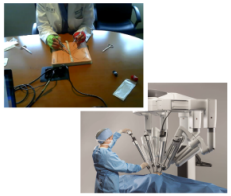
- Nonlinear analysis tools can quantify different data time-series.
- Shannon entropy with 3D plot surfaces of RQA appear to be robust for real-word data (i.e. different time series structures, window length size and levels of smoothness).
- Therefore, Shannon entropy would be a potential good tool to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

Investigate

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

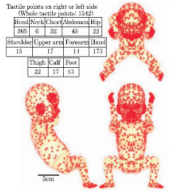
Applications of Nonlinear Dynamics

Quantification of skill learning



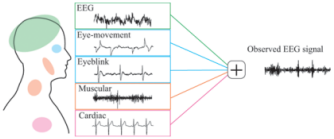
* Surgical Skills Assessment
* Robot-Assisted Surgery

Fetal behavioral development



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

Nonlinear Biomedical Signal Processing

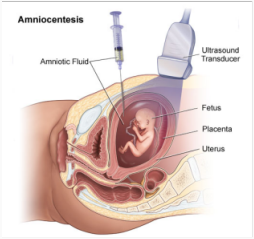


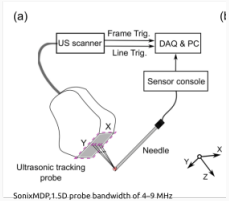
* EEG time series
* Heart rate variability
* Eye Movements

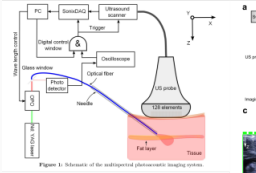
(Zia et al., 2017 in **Computer Assisted Radiology and Surgery**; Mori 2012 in **Development and Learning and Epigenetic Robotics**; Mitsukura et al., 2017 in **Electroencephalography**; Marwan et al. 2019 in **http://recurrence-plot.tk/**)

Extras

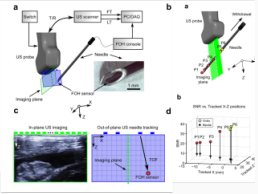
Ultrasound needle tracking







SonixMDP,linear array transducer (L14-5/38), Nd:YAG laser
Xia et. al. 2015 in Opto-Acoustic Methods and Applications in Biophotonics II

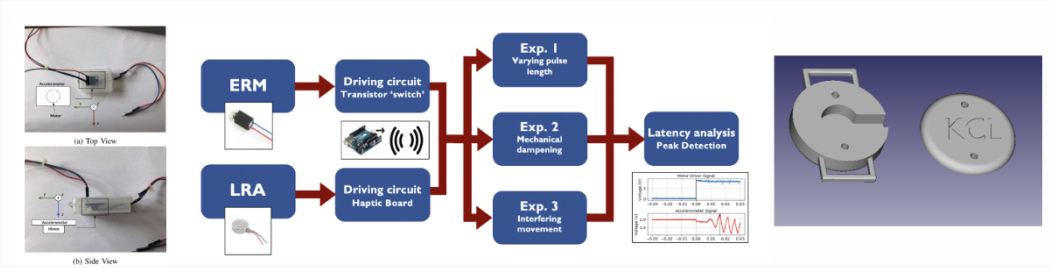


SonixMDP, linear 9–4 MHz imaging US probe
Xia et. al. 2017 in Scientific Reports

Challenges

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

Vibro-Tactile Stimulator for Dystonia Research



(MSc. report of Alexander Mitton in collaboration Christos Bergeles, Verity McClelland and Alan Worley)

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

Github Action

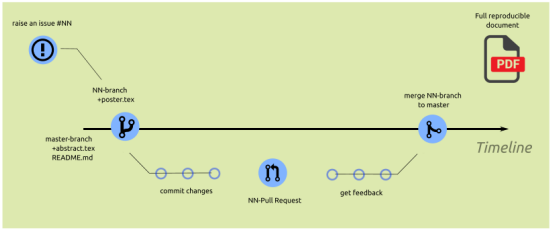
```
.github/workflows/main.yml

name: Compiling-TeX

jobs:
  build:

- name: Compile Poster
    uses: xu-cheng/latex-action@v2
    with:
      root_file: main.tex
      working_directory: poster
- name: Upload
    run: |
      # configure git
      # setup ssh
      # create branch
      # github action deploy
```

Github Workflow



Article Thesis

CV Poster

Slides

github.com/free-cortex/framework

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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`https://github.com/mxochicale/seminario-cicese-27112020`

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