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<https://github.com/mxochicale/slides-03052019>

Nonlinear Analysis to Quantify Movement Variability in Human-Humanoid Interaction

Miguel Xochicale

<https://github.com/mxochicale/>

My background
ooo

Ph.D.
oooooooooooo

Other Research Projects
ooooo

Conclusions
oo

References
ooo

Overview

1. My background
2. Ph.D.
3. Other Research Projects
4. Conclusions
5. References

MY BACKGROUND

EDUCATION

- Ph.D. in Computer Engineering
University of Birmingham (2014-2018)
- M.Sc. in Digital Signal Processing
INAOE, México (2004 - 2006)
- B.Eng. in Electronics
Puebla Institute of Technology, México (1999-2004)

EXPERIENCE

- 5 years in Human-Robot Interaction (2013-2018)
+1 Research Assistant in Robotics and +4 PhD in HRI
- 17 years in Computer Engineering (1999-2018)
+4 Electronics, +2 Digital Filters, +6 Mechatronics and +5 Computer Engineering

GNU/Linux [2005-present]

- * Ubuntu 12.04/14.04/16.04/18.04 (32/64 bit)

- * Raspbian (Wheezy/Jessie/Streech)

Single-board computers [2006-present]

- * Arduino (miniarduino, uno)

- * Beaglebone (720MHz ARM/2x46 headers)

- * RaspberryPi (2/3B+[1.2GHz/64bit])



Robots [2006-present]

- * OWI 535

- * PatrolBot

- * NAO V4 T2



SLAM [2013-2014]

- * PatrolBot

(800 wheel encoders/
Laser sick lms200 [\sim 4Hz])

- * Navigation (Aria/MRPT)

- * Montecarlo Localization

ROS [2013-present]

- * fuerte/groovy/kinetic/melodic
on Ubuntu 12.04/14.04/16.04

- * Packages:

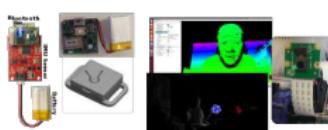
- razor_imu_9dof/openface_ros

Sensors [2007-present]

- * IMUs (razor9dof, MUSE)

- * Cameras

(Kinect 1 [color/depth],
pi-camera 2.1 [8Mp],
Logitech c930e [1080p])



Deep Learning [2018-present]

- * GANs, CNNs

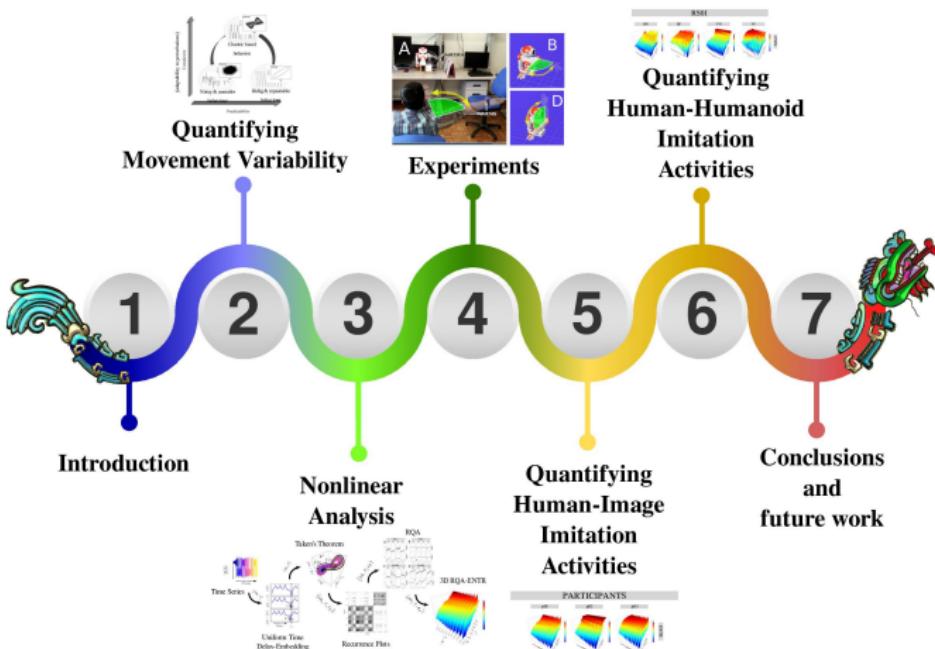
- * python 3.6, pytorch, tensorflow

- * GPU [GeForce GTX960]

- * CUDA 9.0, cuDNN

PH.D.

Thesis Outline



Modelling Movement Variability

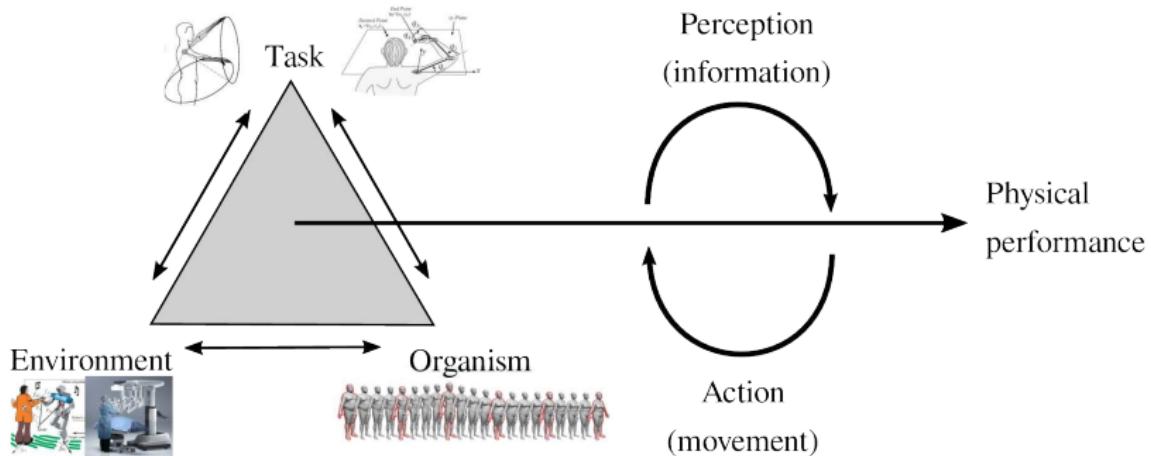


Figure 1: Newell's model of movement constraints

Modelling Movement Variability

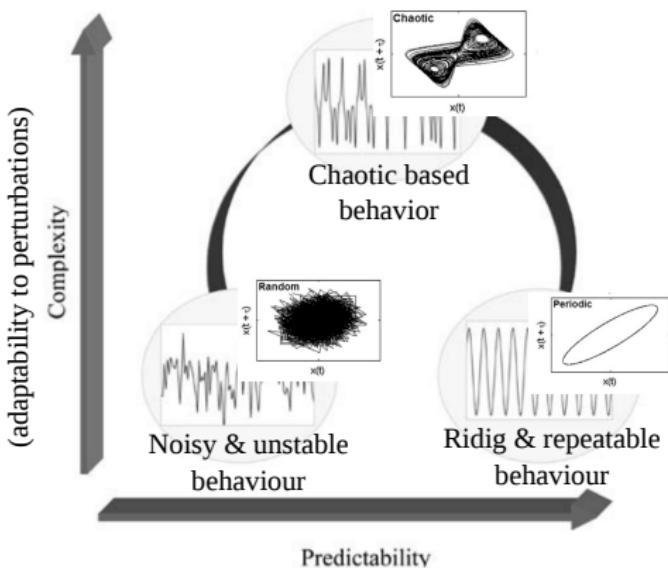


Figure 2: Theoretical Model of Optimal Movement Variability

Methods of Nonlinear Analysis to quantify MV

- Approximate Entropy (Pincus 1991, 1995)
- Sample Entropy (Richman and Moorman, 2000)
- Multiscale Entropy (Costa et al., 2002)
- Detrended Fluctuation Analysis (Peng et al., 1995)
- Largest Lyapunov exponent (Stergiou, 2016)
- Recurrence Quantification Analysis (Zbilut and Webber et al., 1992)

There is no best tool to measure MV and unification of tools is still an open question (Caballero et al. 2014; Wijnants et al. 2009) which led me **(i) to explore different methods of nonlinear analyses to quantify MV and (ii) to understand their strengths and weaknesses.**

Nonlinear Analysis

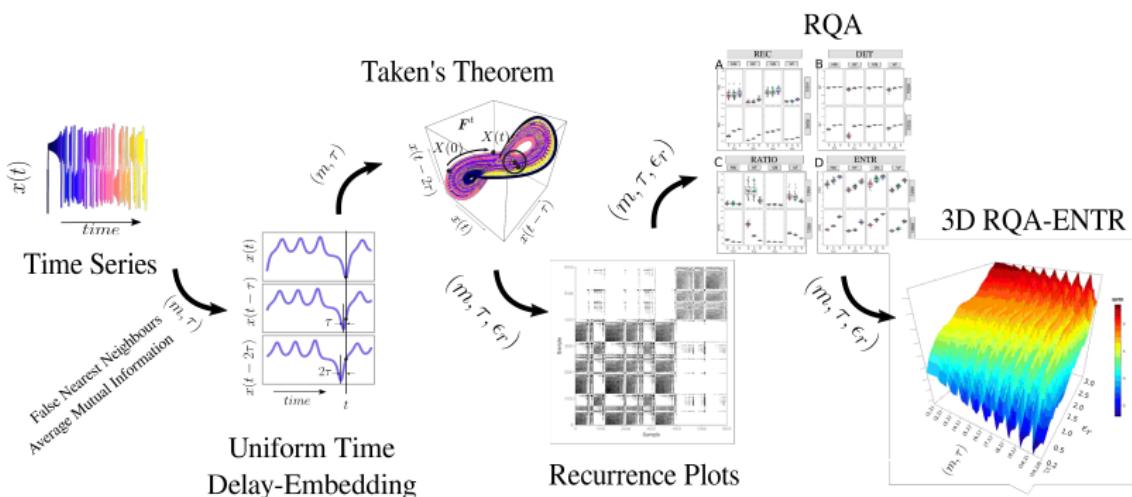


Figure is adapted from Xochicale 2019 in PhD thesis.

[Takens 1981 in **Dynamical Systems and Turbulence**; Casdagli 1991 in **Physica D**; Frank et al. 2010 in **AAAI Conference on Artificial Intelligence**; Sama et al. 2013 in **Neurocomputing**; Cao 1997 in **Physica D**; Kabiraj et al. 2012 in **Chaos**; Eckmann et al. 1987 in **Europhysics Letters**]

Human-Humanoid Imitation Activities

23 right-handed healthy participants were invited to imitate simple arm horizontal and vertical movements from an humanoid.

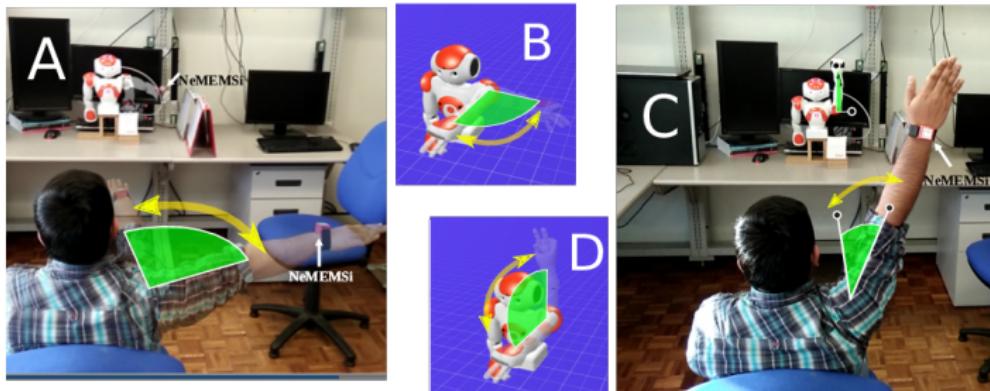


Figure 3: (A/C) Front-to-Front HHI for Horizontal/Vertical Movements.
(B/D) Humanoid robot performing Horizontal/Vertical arm movements

3D surface plots of RQA of Shannon entropy

1. Time series data

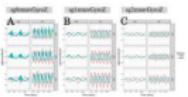
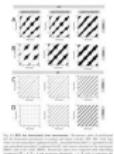


Fig. 4.1 Time series for horizontal eye movements. (A) raw movement data, (B) mean movement data, (C) standard deviation of movement data, (D) variance of movement data. Time series are only for three participants (p01, p02, p03), because the other participants did not have enough data to be included in the analysis. The same procedure was followed for vertical eye movements. The color bar indicates the scale of the data, available in [S1](#).

4. Recurrence Plots

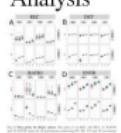


2. Embedding parameters

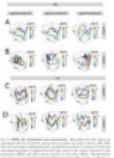


Fig. 4.3 Box plot of minimum embedding parameters. Box plots of (A) horizontal eye movement (HEM) and (B) vertical eye movement (VEM) with respect to the embedding dimension (m). The box plots are for three participants (p01, p02, p03) and were obtained from the first 100 samples. The same procedure was followed for vertical eye movement. The color bar indicates the scale of the data, available in [S2](#).

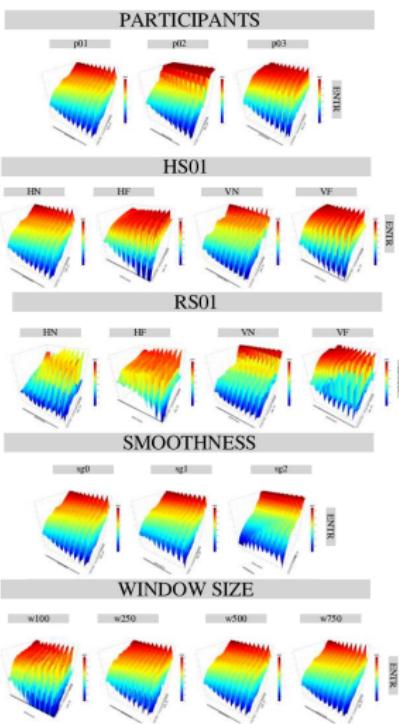
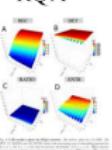
5. Recurrence Quantification Analysis



3. Taken's s Theorem



6. 3D surface plots of RQA



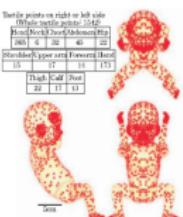
Applications

Quantification of skill learning



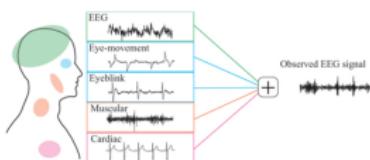
- * Surgical Skills Assessment
- * Robot-Assisted Surgery

Fetal behavioral development



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

Nonlinear Biomedical Signal Processing



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

FIRST Open Access PhD Thesis at UoB (since 1901)



<https://github.com/mxochicale/phd-thesis>

This screenshot shows the GitHub repository page for the PhD thesis. The repository name is 'mxochicale/phd-thesis'. The page includes a brief description: 'Nonlinear Analysis to Quantify Movement Variability in Human-Humanoid Interaction'. It lists several files and their commit history, including 'mxochicale_data' and 'mxochicale_code'. The repository has 14 stars and 14 forks.

This screenshot shows the Zenodo landing page for the thesis data. It displays the title 'Code and data' and a detailed description of the data, mentioning it was written in SBNU Linux Operating System and tested in Ubuntu 14.04.3 LTS and Ubuntu 16.04.2 LTS. It also provides a DOI link: <https://doi.org/10.5281/zenodo.1473140>. The page includes sections for 'Organisation of paths', 'Replication of results', and 'Clone github repository'.

OA DATA

- * Multidimensional Times-series
- 22 participants,
- 4 IMUs (6 axis), and
- 4 Activities.

OA SOFTWARE

- * R version 3.4.4 (2018-03-15)
- * R packages:

data.table

ggplot2

tseriesChaos

nonlinearTseries

RccArmadillo

- * GNU Octave 4.0.2

OA PhD Thesis

- * LaTeX project
- * Vector files



201
views
downloads

<https://doi.org/10.5281/zenodo.1473140>

Submitted: 26 October 2018

Seen once: 28 February 2019

OA Publications

PEER-REVIEW CONFERENCE PAPERS

- *Towards the Analysis of Movement Variability in Human-Humanoid Imitation Activities* (HAI2017)
- *Towards the Quantification of Human-Robot Imitation Using Wearable Inertial Sensors* (HRI2017)
- *Analysis of the Movement Variability in Dance Activities using Wearable Sensors* (WeRob2016)
- *Understanding Movement Variability of Simplistic Gestures Using an Inertial Sensor* (PerDis2016)

PREPRINTS & in preparation

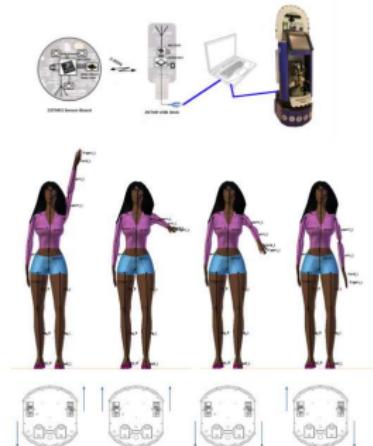
- *Strengths and weaknesses of Recurrence Quantification Analysis in the context of human-humanoid interaction* (ArXiv, October 2018) for Scientific Reports.
- *3D surface plots of RQA Shannon Entropy*
for Frontiers in Applied Mathematics and Statistics.

TALKS

- *Quantifying the Inherent Chaos of Human Movement Variability*
15th Experimental Chaos and Complexity Conference
- *Towards the Analysis of Movement Variability for Facial Expressions with Nonlinear Dynamics*
The 7th Consortium of European Research on Emotion Conference

OTHER RESEARCH PROJECTS

HRI Dance Demo (2013)



 [@mxochicale/tmr2013](https://github.com/mxochicale/tmr2013)



Awards

- * 1st Place at HOME category in the Mexican Tournament of Robotics 2013

OA Software

- * C++ Class

Hardware

- * Ubuntu 12.04 x64
- * Patrol Robot
- * ZTAR RF IMU

Libre Robotics (2014-ongoing)



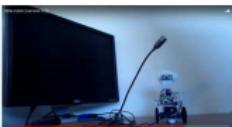
V00MAY2014



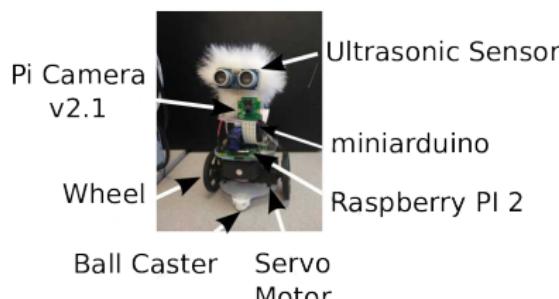
V02JULY2014



V01JUNE2014



V03APRIL2016



V04-DEC2017

Awards

* Selected from 125 applications from 35 countries for an international program of entrepreneurship

OS Software

- * C (arduino)
- * Racket

Hardware

- * Mini-arduino
- * Raspbian
- * Raspberry PI 3
- * Pi Camera 2.1



@librerobotics

Libre Robotics
Educational Robotics for learning and sharing knowledge to anyone (we want to build conditions for a better world)
About pages of user system or via source get... <https://sites.google.com/site/librerobotics/>

Repositories 1 A Project 0 Teams 0 Projects 0 Settings

Find a repository Type All Language All Customize search repositories [New](#)

OpenCat
Extract from Project@MECATE
A group of people who design and develop mechatronic robots, cat for STEM education and an educational service.

1 issue 1 file Updated on 24 Oct 2018

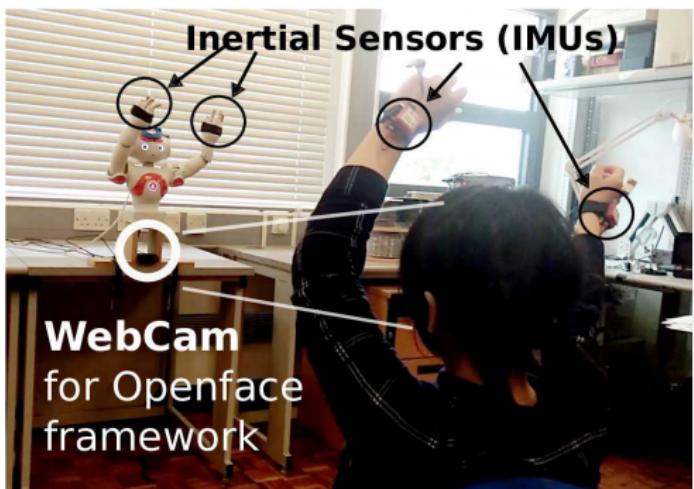
Top languages C++ 70% Racket 20% Python 10%

People [MANCHALE](#) Miguel Iñaki Acea
[Join someone](#)

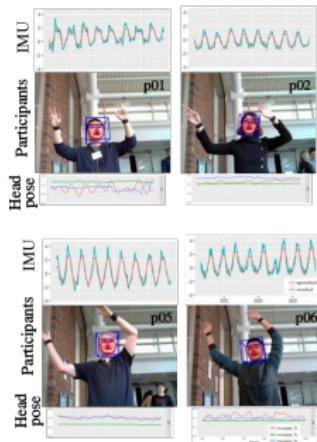
pocketsphinx
Updated on 17 Sept 2018

Issues 1 PRs 0 Last commit 1 day ago Updated on 14 Apr 2018

Quantifying Emotion and Movement Variability in HRI (2014-2018)



WebCam
for Openface
framework



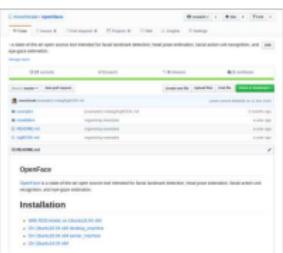
@hri-demos-uob/dance

OpenFace for ROS

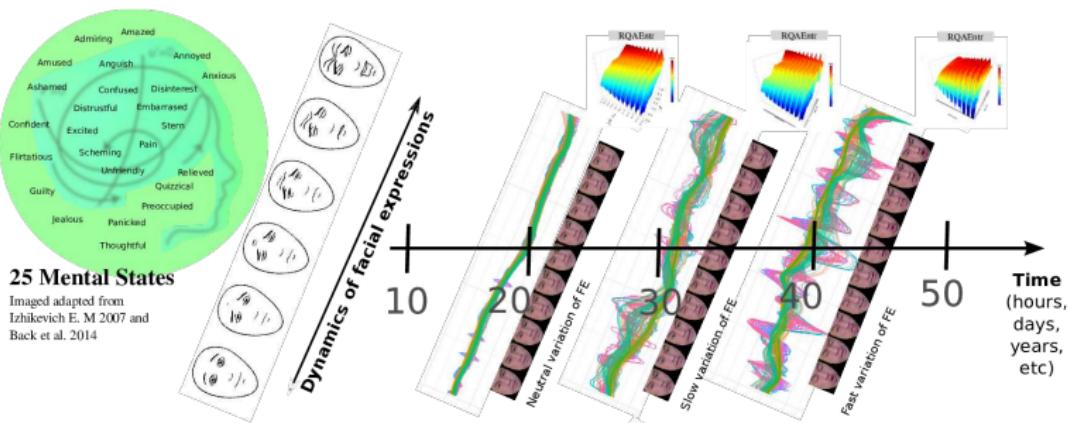
- * Eye Gaze Vectors
- * Head Pose
- * 2D Landmarks
- * 3D Landmarks
- * Action Units

Software/Hardware

- * Ubuntu 16.04 x64
- * ROS Kinetic
- * NAO V4 MODEL T14
- * Logitech Webcam C930e



Dynamic Facial Expressions with Shannon Entropy (2019-ongoing)



25 Mental States

Imaged adapted from
Izhikevich E. M 2007 and
Back et al. 2014

Open Access and Reproducibility

The only OA poster from
16 submissions to be
100% reproducible

OpenFace

- * Eye Gaze Vectors
- * Head Pose
- * 2D Landmarks
- * 3D Landmarks
- * Action Units

Software/Hardware

- * Ubuntu 16.04 x64
- * ROS Kinetic
- * NAO V4 MODEL T14
- * Logitech Webcam C930e



99

4

views

downloads

<https://doi.org/10.5281/zenodo.2559629>

Publication date: 8 February 2019
Seen: 8 March 2019



@mxochicale/mlds2019



CONCLUSIONS

Concluding Remarks

- What to quantify in movement variability?
Complexity of movement based on the degrees of freedom of a person performing a certain task in a defined environment.
- Which methods of nonlinear analysis are appropriate to quantify movement and how methods of nonlinear analysis are affected by real-world time series data ?
Shannon entropy using 3D surface plots of RQA appear to be robust to real-word data (i.e. different time series structures, window length size and levels of smoothness).
- What are these techniques good for?
Quantification of skill learning in HRI, dynamics of facial expressions, fetal behavioral development, or nonlinear biomedical signal processing.

REFERENCES

References



Xochicale Miguel

» Nonlinear Analysis to Quantify Movement Variability in
Human-Humanoid Interaction «

Open Access Ph.D. Thesis (2019)

<https://github.com/mxochicale/phd-thesis>



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