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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/>

## 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

- \* Ubuntu 12.04/14.04/16.04/18.04 (32/64 bit)
- \* Raspbian (Wheezy/Jessie/Streech)

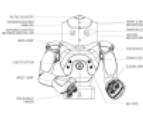
## Single-board computers

- \* Arduino (miniarduino, uno)
- \* Beaglebone (720MHz ARM/2x46 headers)
- \* RaspberryPi (2/3B+[1.2GHz/64bit])



## Robots

- \* OWI 535
- \* PatrolBot
- \* NAO V4 T2



## SLAM

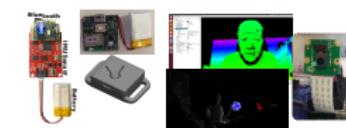
- \* PatrolBot  
(800 wheel encoders/  
Laser sick lms200 [~4Hz] )
- \* Navigation (Aria/MRPT)
- \* Montecarlo Localization

## ROS

- \* fuerte/groovy/kinetic/melodic  
on Ubuntu 12.04/14.04/16.04
- \* Packages:  
razor\_imu\_9dof/openface\_ros

## Sensors

- \* IMUs (razor9dof, MUSE)
- \* Cameras  
(Kinect 1 [color/depth],  
pi-camera 2.1 [8Mp],  
Logitech c930e [1080p])

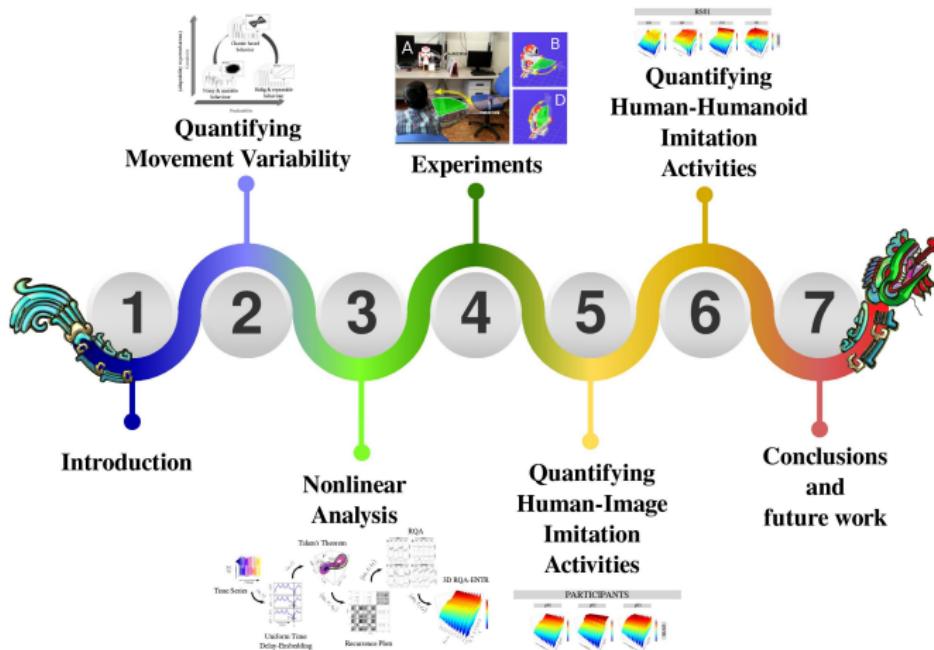


## Deep Learning

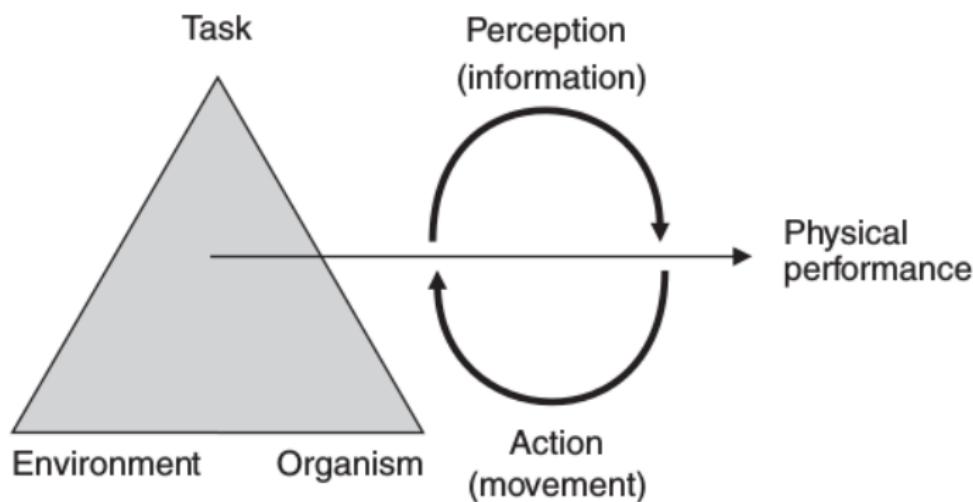
- \* GANs, CNNs
- \* python 3.6, pytorch, tensorflow
- \* GPU [GeForce GTX960]
- \* CUDA 9.0, cuDNN

PH.D.

# Thesis Outline

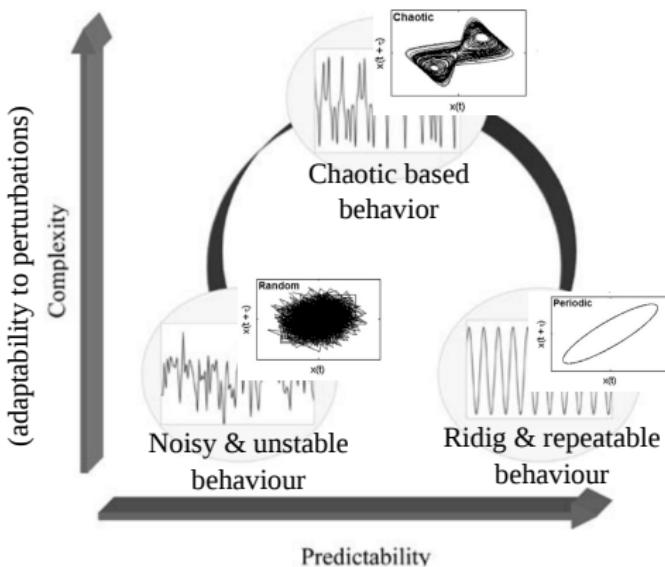


# Modelling Movement Variability



**Figure 1:** Newell's model of variability of physical performances

# Modelling Movement Variability



**Figure 2:** Theoretical Model of Optimal Movement Variability

# Nonlinear Analysis

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 nonlinear analyses to measure MV and (ii) to understand their strengths and weaknesses.

- 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)

# Nonlinear Analysis

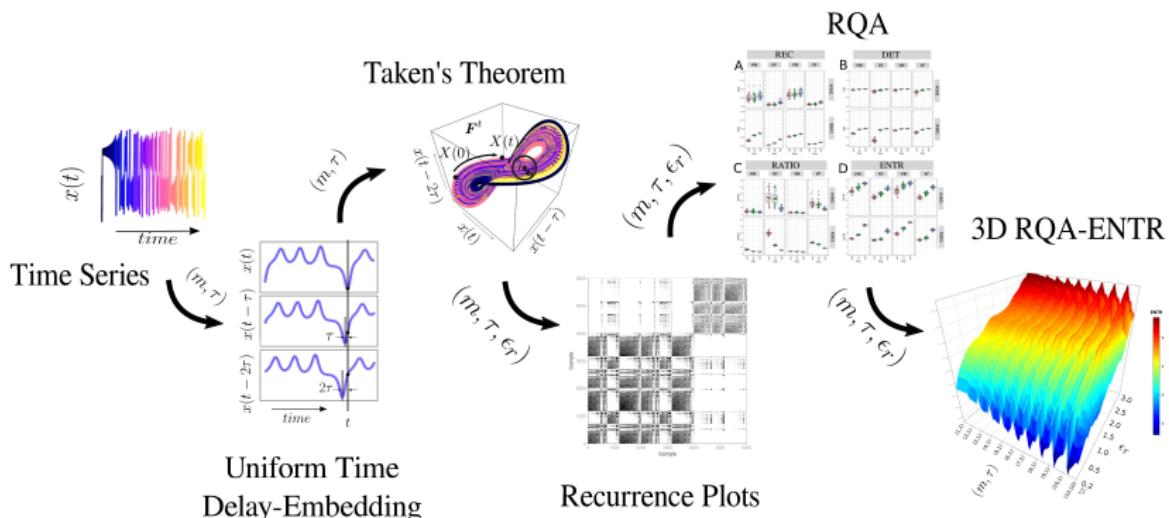
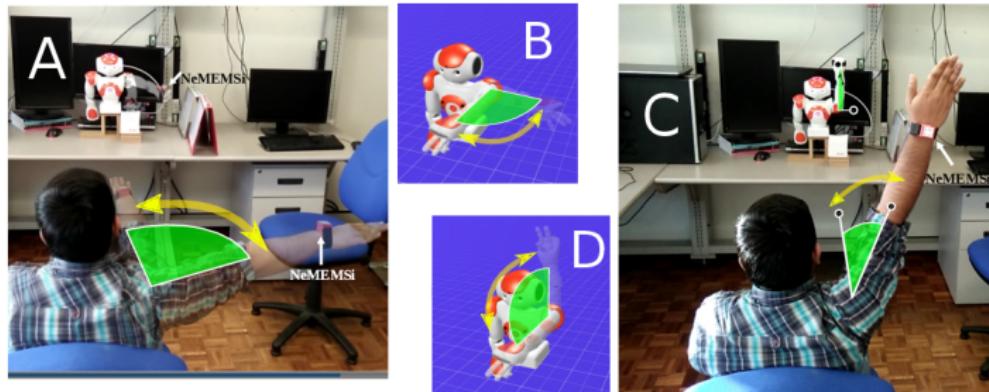


Figure is adapted from Xochicale 2018 in Preprint PhD thesis (Zenodo).

[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** ]

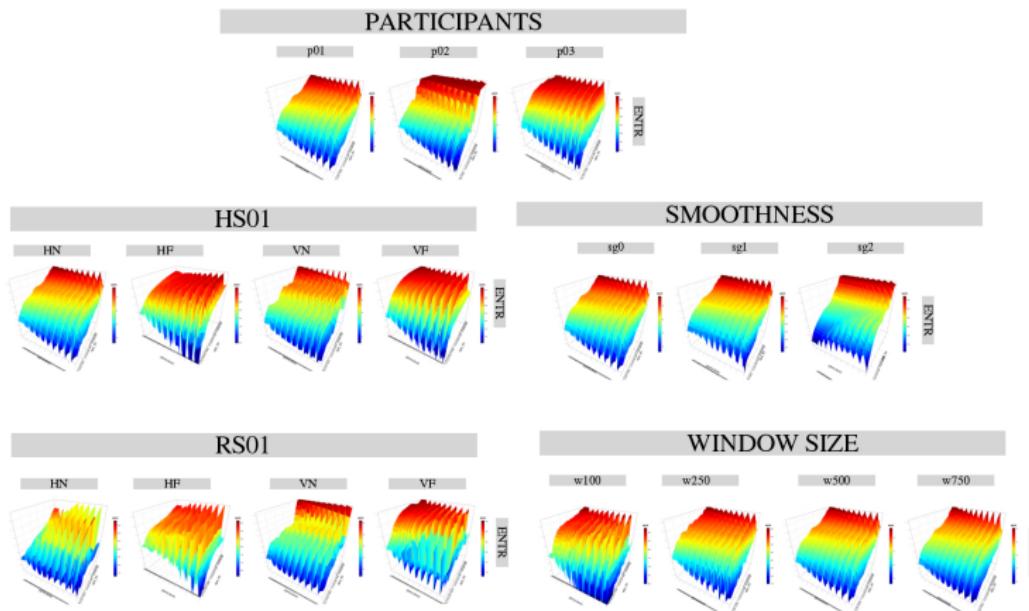
## Human-Humanoid Imitation Activities

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

# Results: 3D RQA entropies



# FIRST Open Access Preprint PhD Dissertation at UoB (since 1901)



@mxochicale/phd-thesis/

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

My open access PhD thesis (as submitted on 26th October 2018).

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- **acknowledgements** submissions 3 months ago
- **abstract** submissions 3 months ago
- **appendix** msc PhDThesis and highTICK.rmd 3 months ago
- **assessment** msc PhDThesis and highTICK.rmd 3 months ago
- **biography** submissions 3 months ago
- **chapters** msc PhDThesis and highTICK.rmd 3 months ago
- **chapter1** msc PhDThesis and highTICK.rmd 3 months ago
- **chapter2** msc PhDThesis and highTICK.rmd 3 months ago
- **chapter3** msc PhDThesis and highTICK.rmd 3 months ago
- **chapter4** msc PhDThesis and highTICK.rmd 3 months ago
- **chapter5** msc PhDThesis and highTICK.rmd 3 months ago
- **chapter6** msc PhDThesis and highTICK.rmd 3 months ago
- **chapter7** msc PhDThesis and highTICK.rmd 3 months ago
- **classes** thesis-class v3.75 4 months ago
- **declarator** submissions 3 months ago
- **dedicator** submissions 3 months ago
- **dependencies** submissions 3 months ago
- **draft-resources** submissions 3 months ago
- **figures** submissions 3 months ago
- **functions** pre-submissions 3 months ago
- **references** pre-submissions subpage-000 3 months ago
- **src** first commit 2 months ago
- **stats** pre-revisioned states 17 days ago
- **LICENSE** README and LICENSE 20 days ago
- **README** submissions 20 days ago
- **RELATIONS.rmd** submissions 20 days ago
- **USAGE.rmd** technical 22 months ago
- **Variables.rmd** first commit 2 months ago
- **highTICK.rmd** README and LICENSE 20 days ago
- **thesis-with-lau** submissions 3 months ago
- **thesis-without-lau** submissions 3 months ago

At **README.rmd**

**Open access PhD Dissertation**

This repository contains the source code of my PhD thesis as submitted on 26th October 2018.

These documents are available here: [https://doi.org/10.5281/zenodo.1473140](#).

Code and data for its replication is available here: [https://doi.org/10.5281/zenodo.1473140](#).

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@mxochicale/phd-thesis-code-data/

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

My open access PhD thesis code and data (as submitted on 26th October 2018).

Manage topics

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Code and data for my PhD thesis

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mxochicale/phd-thesis (https://github.com/mxochicale/phd-thesis)

Last commit 20 days ago

PhD thesis code and data

This repository contains code and data for my PhD thesis submitted on 26th October 2018.

**Citation**

If you use or adapt any of the files in this repository, use the following BibTeX as cite my PhD thesis:

```
@phdthesis{mxochicalePhdThesis2018,
  author = {Enriquez Regal},  

  day = {26},  

  month = {10},  

  year = {2018},  

  school = {University of Birmingham},  

  address = {Edgbaston, Birmingham, United Kingdom},  

  title = {Nonlinear Analyses to Quantify Movement Variability in Human-Made Environments},  

  type = {PhD Thesis},  

  note = {24 submitted, awaiting visa and further revisions},  

  doi = {10.5281/zenodo.1473140},  

  url = {https://doi.org/10.5281/zenodo.1473140}
}
```

**Notes**

I will be publishing and updating this repository while I am awaiting visa (probably for visa might be in January 2019 or February 2019).

**Contact**

If you have specific questions about the content of the code and data of this thesis, you can contact [mxochicale@me.com](mailto:mxochicale@me.com) or <https://orcid.org/0000-0002-1473-1400>. If your question might be relevant to other people, please instead open an issue.

## OA PhD Thesis

- \* LaTeX project
- \* Vector files

## OA CODE DATA

- \* R version 3.4.4 (2018-03-15)
- \* R packages:
  - data.table
  - ggplot2
  - tseriesChaos
  - nonlinearTseries
  - RccArmadillo
- \* GNU Octave 4.0.2
- \* Multidimensional Times-series  
22 participants,  
4 IMUs (6 axis), and  
4 Activities.


 201 122  
 • views ▲ downloads

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

Submitted: 26th October 2018

Seen: 28 February 2019

# 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

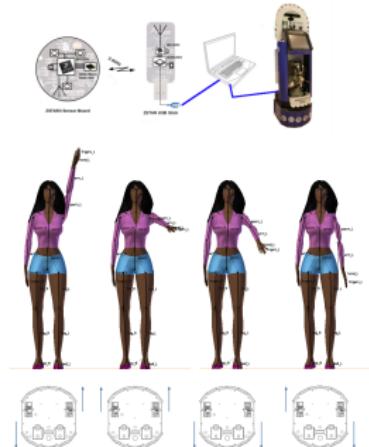
- Strengths and weaknesses of Recurrence Quantification Analysis in the context of human-humanoid interaction (ArXiv, October 2018)

## 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

A screenshot of a GitHub repository page. The repository name is "HRI Dance Demo (2013)". The page shows the repository's status (1 commit, 1 branch, 1 file, 1 issue), a file list (README.md, LICENSE, config.h, config.in, Makefile, main.cpp, main.h, main.in, test.cpp, test.h, test.in), and a preview of the README file which contains the text "HRI Dance Demo (2013)".

## 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)



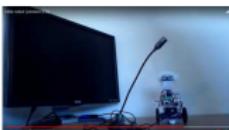
V00MAY2014



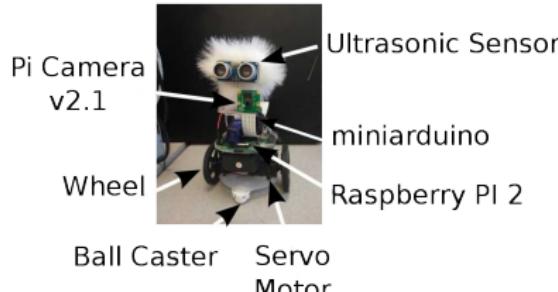
V02JULY2014



V01JUNE2014



V03APRIL2016



V04-DEC2017

## Awards

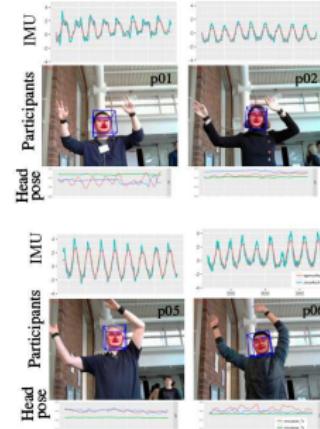
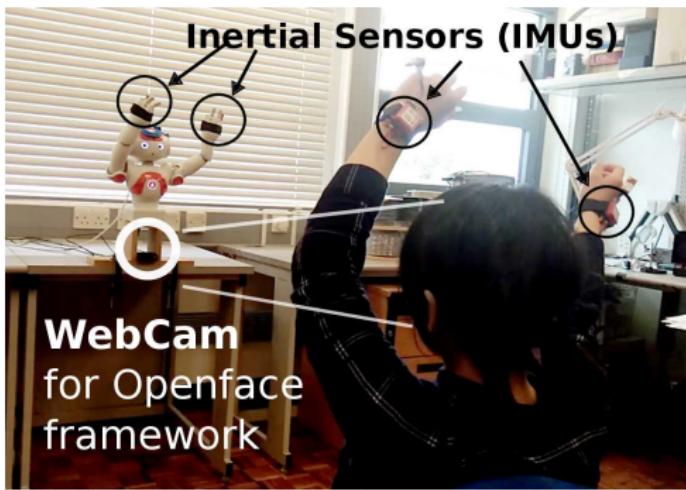
\* Selected from 125 applications from 35 countries for an international program of entrepreneurship

## OS Software

- \* C (arduino)
  - \* Racket
- ## Hardware
- \* Mini-arduino
  - \* Raspbian
  - \* Rasberry PI 3
  - \* Pi Camera 2.1

The screenshot shows the GitHub organization page for @librerobotics. It features a logo of a cat head inside a circle, followed by the handle '@librerobotics'. Below the handle, there's a brief description: 'Educational Robotics for learning and sharing knowledge to anyone (We want to build conditions for a better world)'. It lists several repositories: 'Libre Robotics' (selected), 'OpenCat', 'forums', and 'pocketphinx'. The 'Libre Robotics' repository has 1 star, 1 issue, and was updated on 24 Dec 2018. The 'OpenCat' repository has 1 star, 1 issue, and was updated on 7 Sept 2018. The 'forums' repository has 1 star, 1 issue, and was updated on 7 Sept 2018. The 'pocketphinx' repository has 1 star, 1 issue, and was updated on 1 Apr 2018. On the right side, there are sections for 'Top languages' (C++, Python, Racket), 'People' (miguel, miguel.kochicale), and a 'Create repository' button.

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



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

## OpenFace for ROS

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

## Software/Hardware

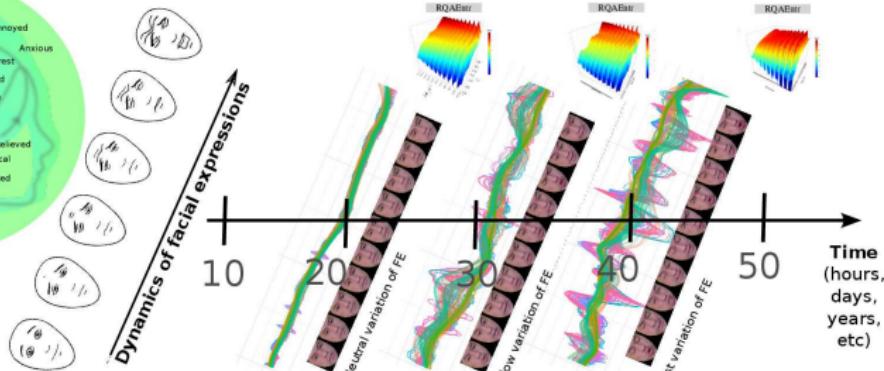
- \* Ubuntu 16.04 x64
- \* ROS Kinetic
- \* NAO V4 MODEL T14
- \* Logitech Webcam C930e

The screenshot shows the GitHub repository for OpenFace. It includes the repository name, a brief description, and sections for 'Code', 'Issues', 'Pull requests', 'Commits', 'Releases', and 'Topics'. Below these are sections for 'About this project', 'Collaborators', 'Contributors', and 'Funding'. The 'Code' section displays the file tree: 'src' (containing 'core', 'dlib', 'facenet', 'landmarks', 'models', 'openface', 'openpose', 'shape\_predictor', 'tf', 'util', 'video'), 'tests', 'docs', 'examples', 'scripts', 'scripts/face\_recognition', and 'scripts/face\_recognition/face\_recognition'. The 'About this project' section provides details about the project's purpose, dependencies, and installation instructions.

# Dynamic Facial Expressions with Shannon Entropy in HRI (2019-ongoing)



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



## OpenFace

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



99  
views  
4  
downloads

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

Publication date: 8 February 2019  
Seen: 8 March 2019

## Open Access and Reproducibility

My poster is the only one out of 16 submissions to be:  
\* 100% reproducible with OA tools

## Software/Hardware

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



@mxochicale/mlds2019



# CONCLUSIONS

# Conclusions

- Measurements of Entropy using RQA appear to be robust to real-word data (i.e. different time series structures, window length size and levels of smoothness )
- 3D surfaces of RQA are independent of either the type series or the selection of parameters.
- First open access thesis with data and code for its replication.

## 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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