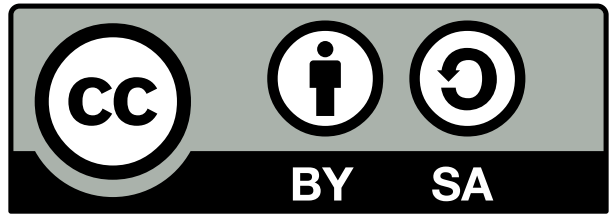


You can download the sources of this presentation here:

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

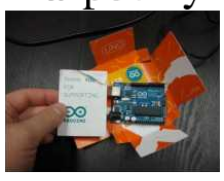
- 5 years in Human-Robot Interaction (2013-2018)
  +1 Research Assistant in Robotics and +4 PhD in HRI
- 17 years in Computer Engineering (1999-2018)
  +4 Electronics, +2 Digital Filters, +6 Mechatronics and +5 Computer Engineering

GNU/Linux [2005-present]

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

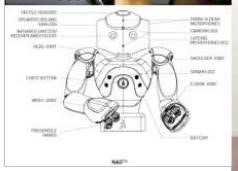
Single-board computers [2006-present]

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




Robots [2006-presnt]

* OWI 535
* PatrolBot
* NAO V4 T2


SLAM [2013-2014]

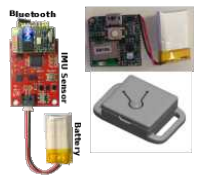
* PatrolBot
  (800 wheel encoders/
  Laser sick lms200 [~4Hz])
* Navigation (Aria/MRPT)
* Montecarlo Localization

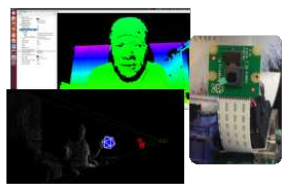
ROS [2013-present]

* 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])



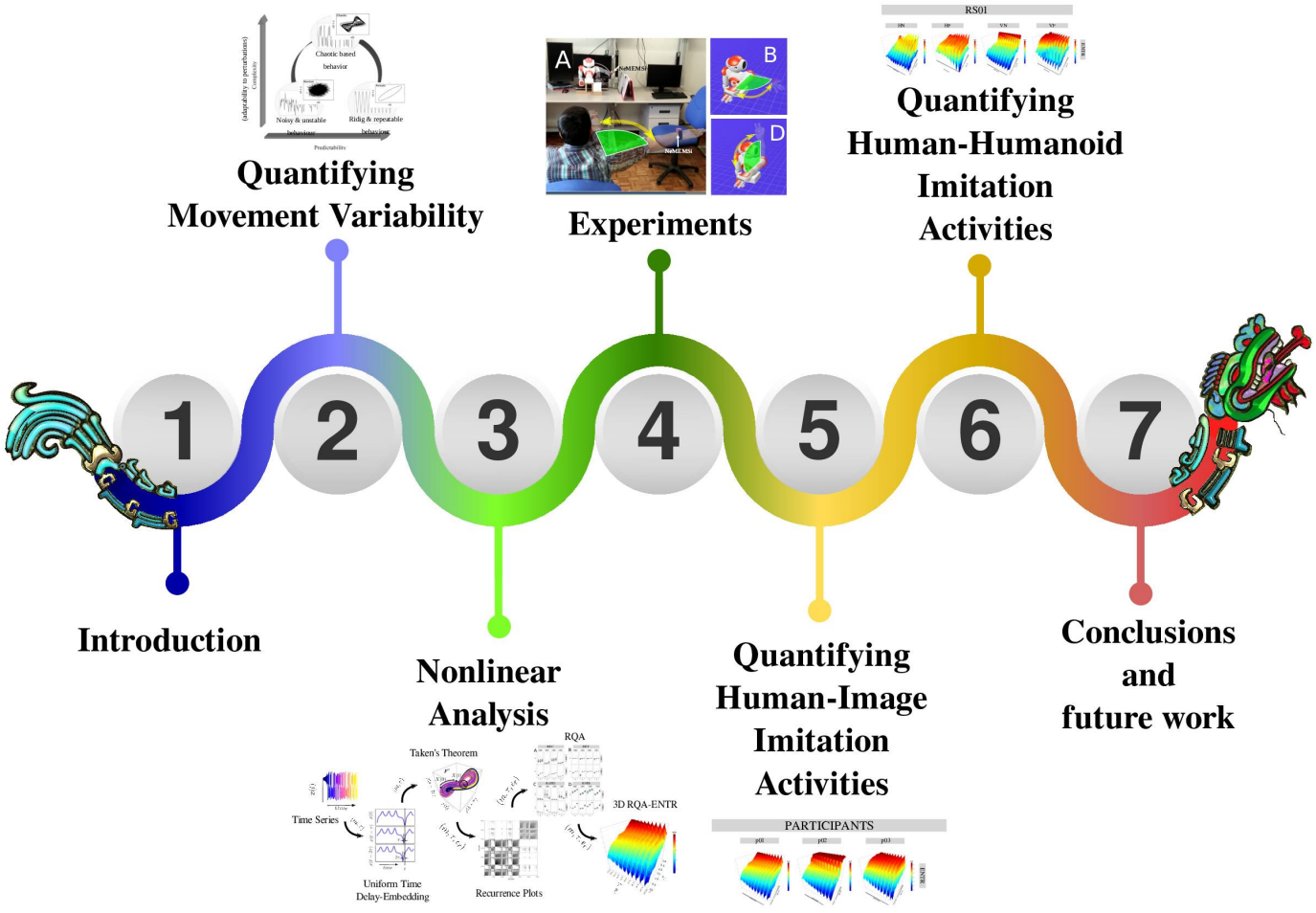


Deep Learning [2018-present]

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

PH.D.

Thesis Outline



Modelling Movement Variability

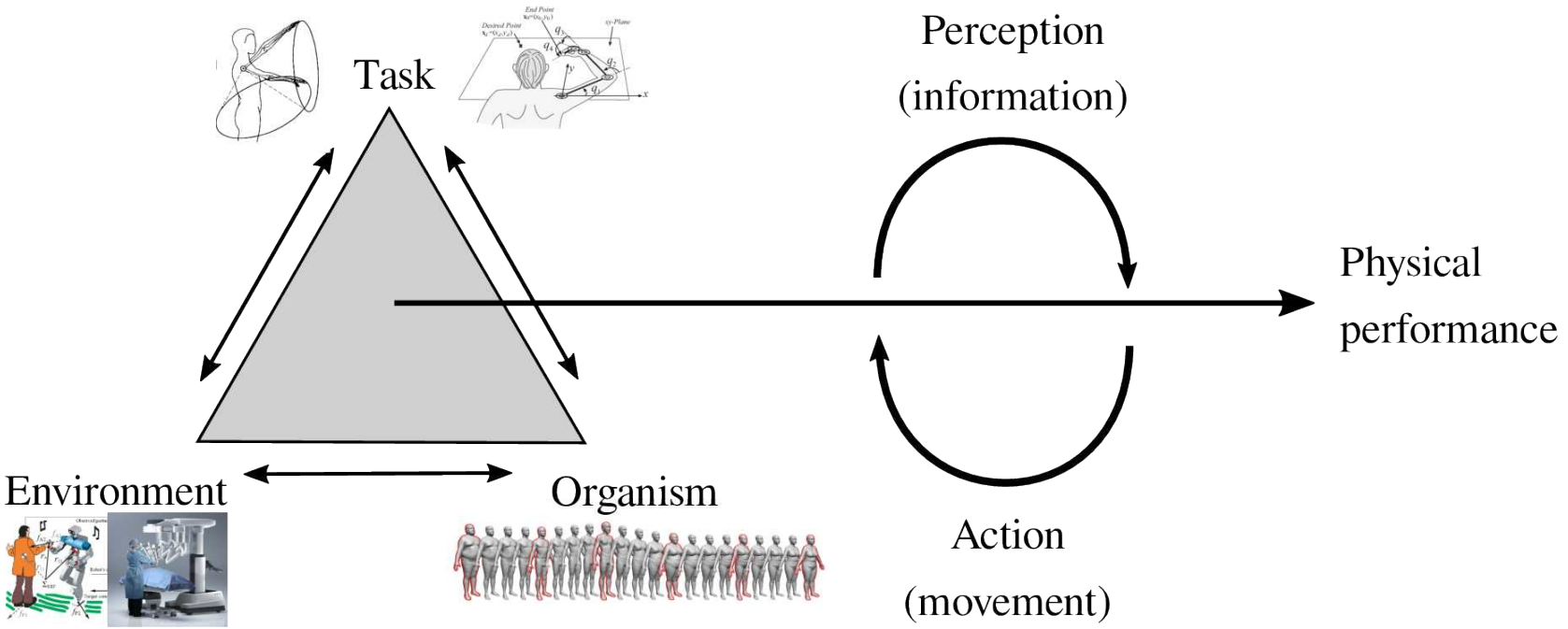


Figure 1: Newell's model of movement constrains

[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**]

Modelling Movement Variability

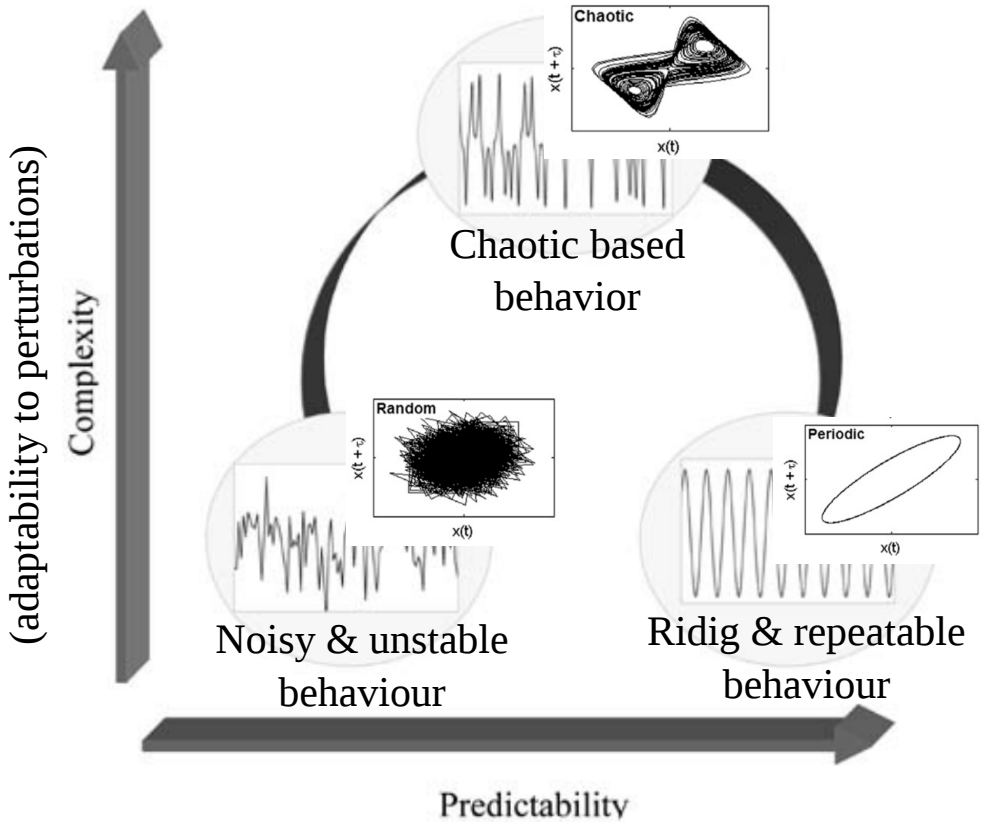


Figure 2: Theoretical Model of Optimal Movement Variability

[Stergiou et al. 2006 in **Neurologic Physical Therapy**; Stergiou and Decker 2011 in **Human Movement Science**]

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 Fluctation 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

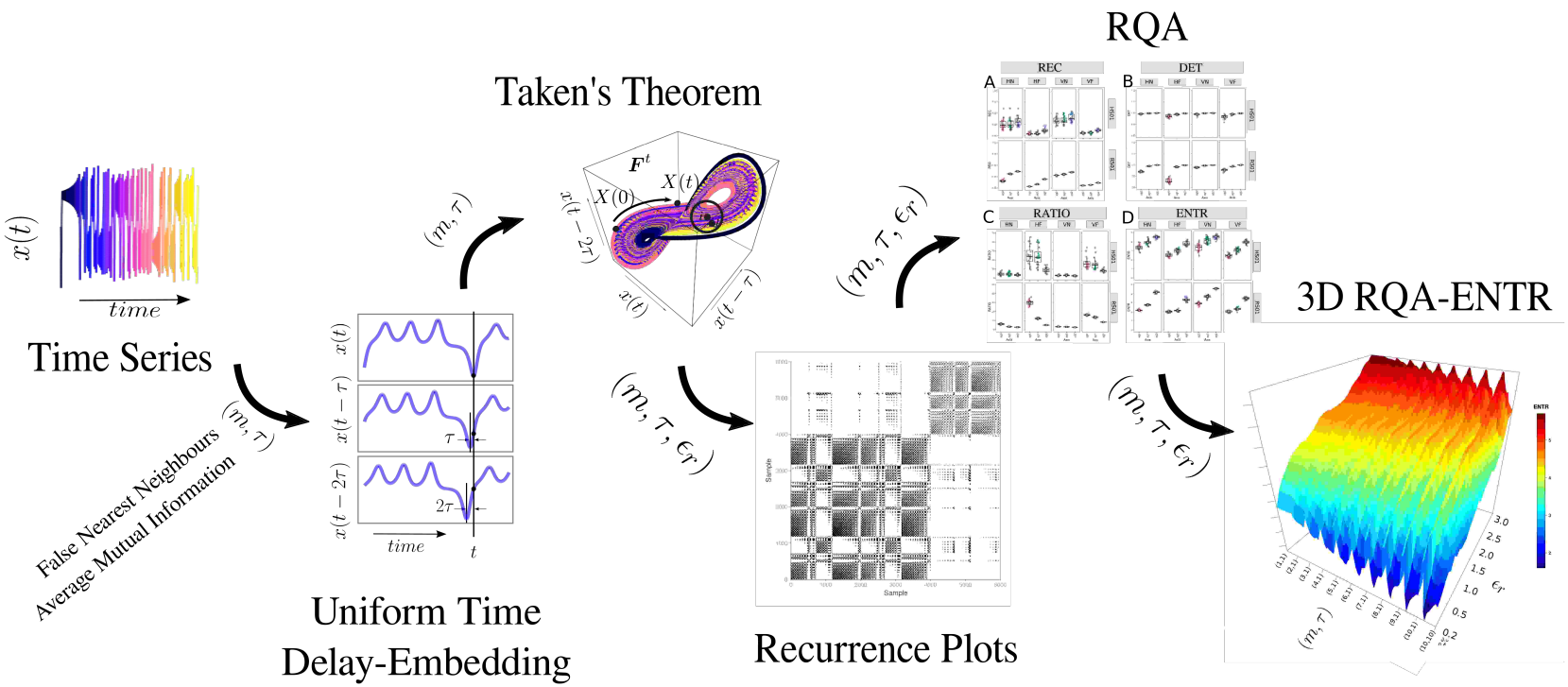


Figure is adapted from Xochicale 2019 in PhD thesis.

[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.

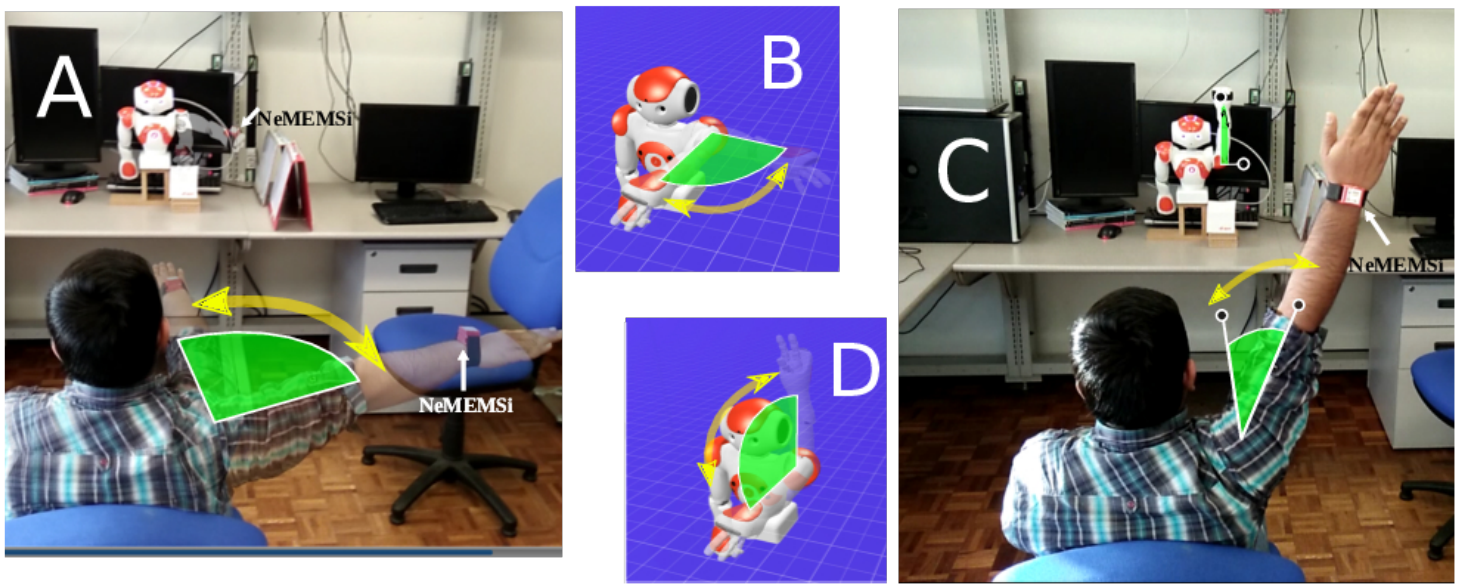
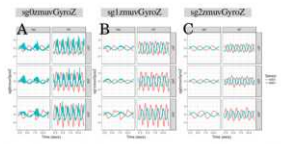


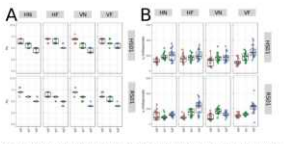
Figure 3: (A/C) Front-to-Front HHI for Horizontal/Vertical Movements. (B/D) Humanoid robot performing Horizontal/Vertical arm movements

3D surface plots of RQA of Shannon entropy

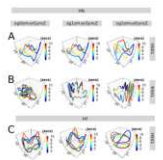
1. Time series data



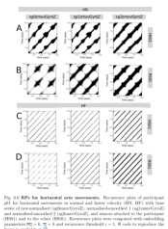
2. Embedding parameters



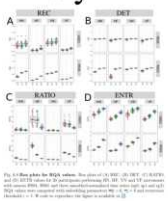
3. Taken''s Theorem



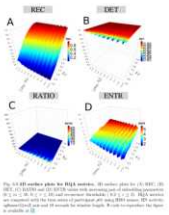
4. Recurrence Plots

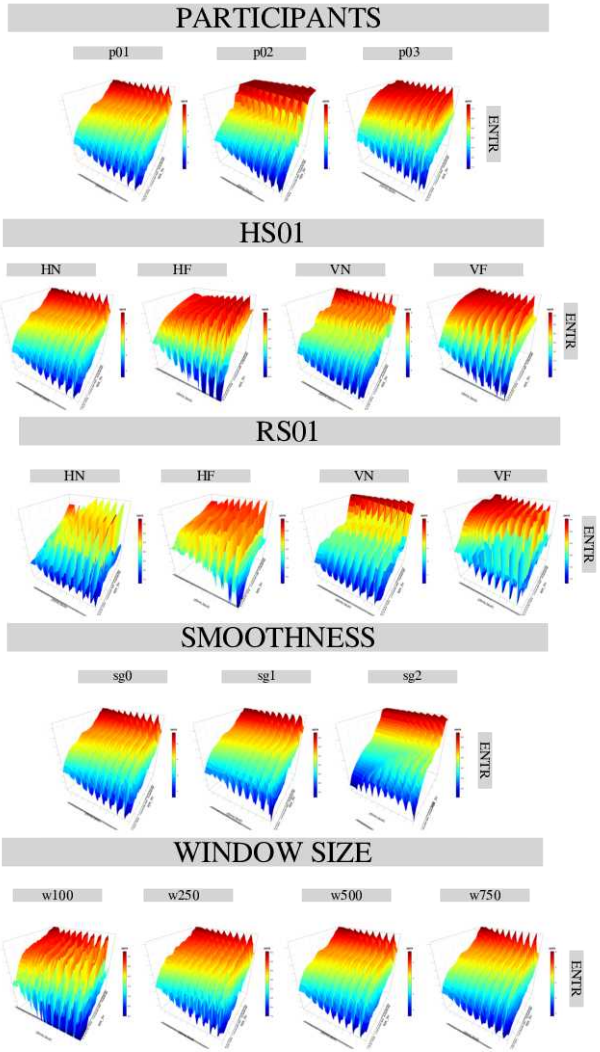


5. Recurrence Quantification Analysis



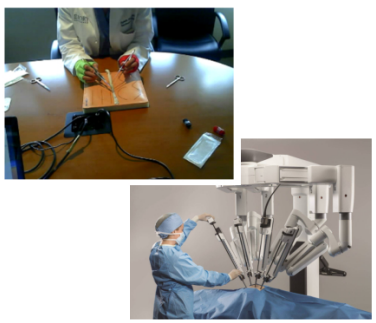
6. 3D surface plots of RQA





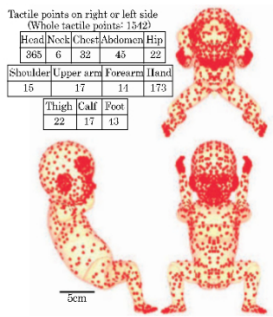
Applications

Quantification of skill learning



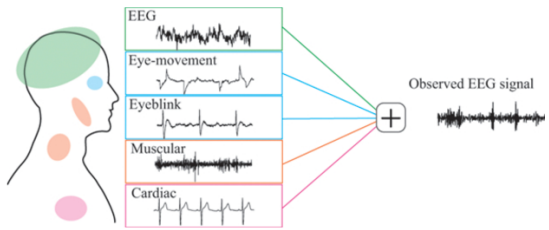
* Surgical Skills Assessment
* Robot-Assisted Surgery

Fetal behavioral development



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

Nonlinear Biomedical Signal Processing

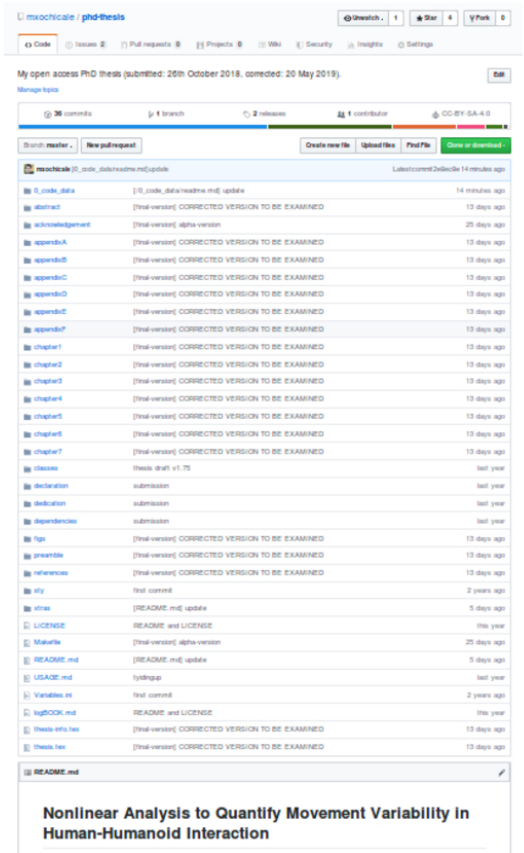


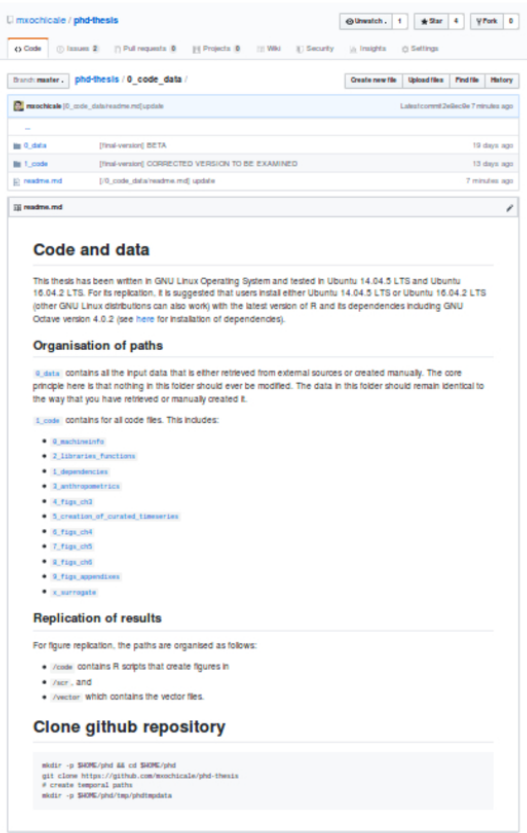
* EEG time series
* Heart rate variability
* Eye Movements

[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/**]

FIRST Open Access PhD Thesis at UoB (since 1901)

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





OA DATA

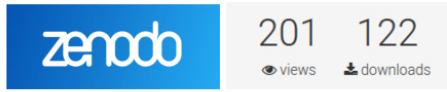
* Multidimensional Times-series
  22 participants,
  4 IMUs (6 axis), and
  4 Activities.

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



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

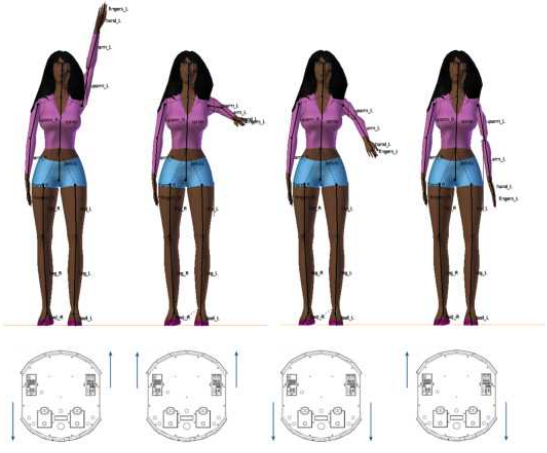
- *Strengths and weaknesses of Recurrence Quantification Analysis in the context of human-humanoid interaction* (ArXiv, October 2018) for Scientific Reports.
- *3D surface plots of RQA Shannon Entropy*
  for Frontiers in Applied Mathematics and Statistics.

TALKS

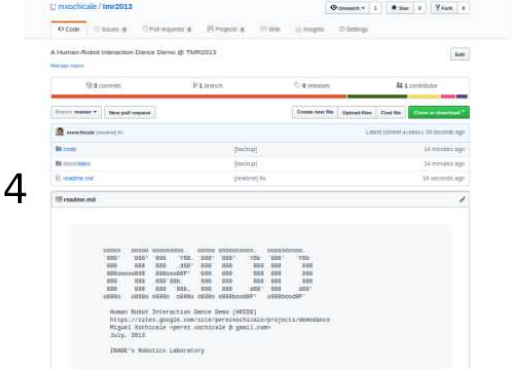
- *Quantifying the Inherent Chaos of Human Movement Variability*
  15th Experimental Chaos and Complexity Conference
- *Towards the Analysis of Movement Variability for Facial Expressions with Nonlinear Dynamics*
  The 7th Consortium of European Research on Emotion Conference

OTHER RESEARCH PROJECTS

HRI Dance Demo (2013)



@mxochicale/tmr2013



Awards

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

OA Software

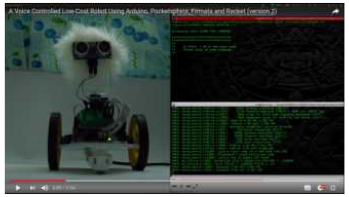
* C++ Class

Hardware

* Ubuntu 12.04 x64
* Patrol Robot
* ZTAR RF IMU

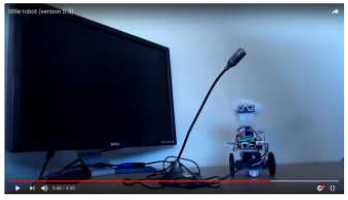
Libre Robotics (2014-ongoing)

V00MAY2014

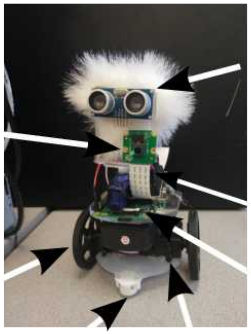


V02JULY2014

V01JUNE2014



V03APRIL2016



V04-DEC2017

Awards

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

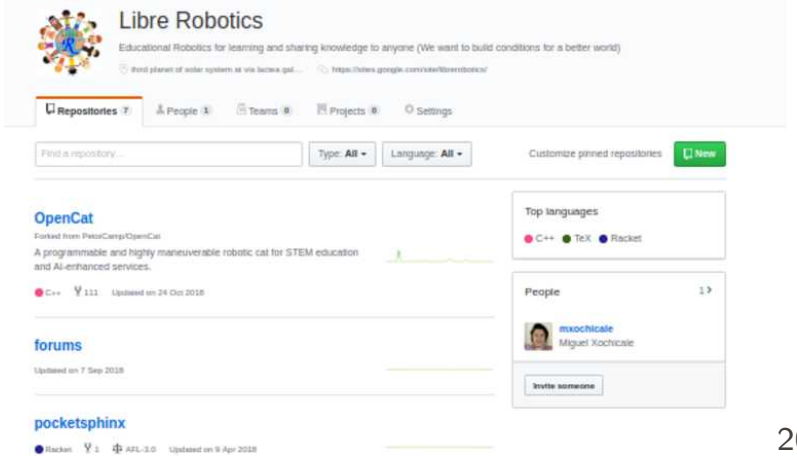
OS Software

* C (arduino)
* Racket

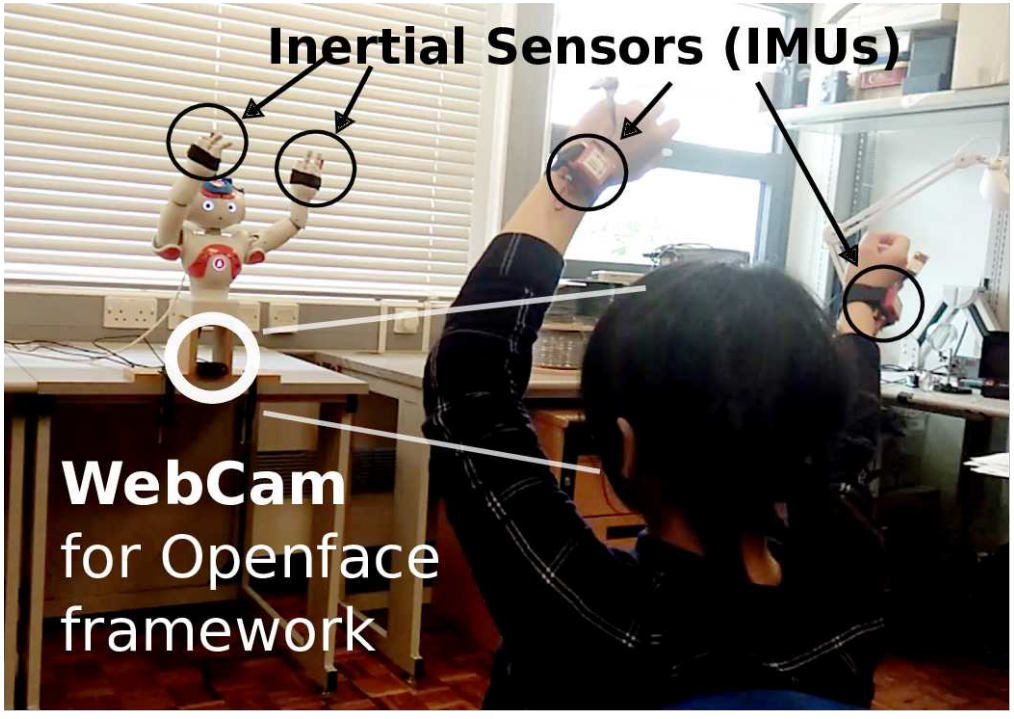
Hardware

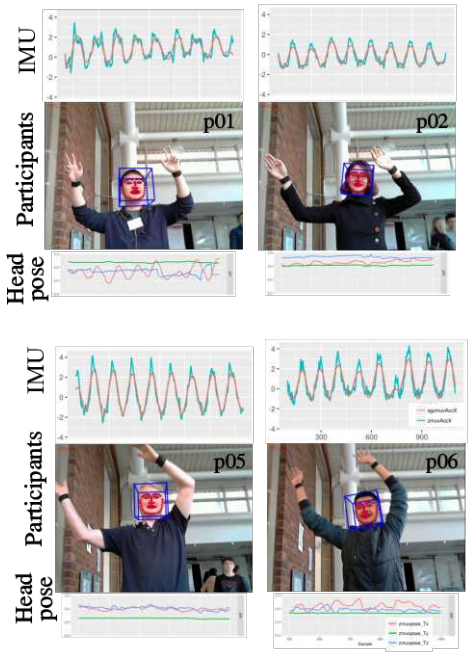
* Mini-arduino
* Raspbian
* Rasberry PI 3
* Pi Camera 2.1

@librerobotics



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

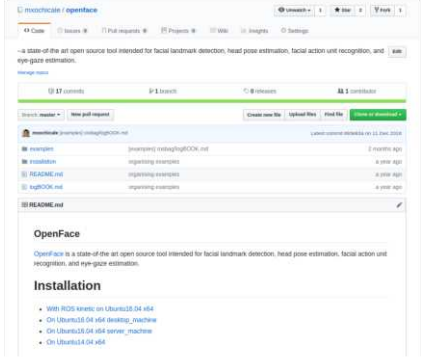




@hri-demos-uob/dance

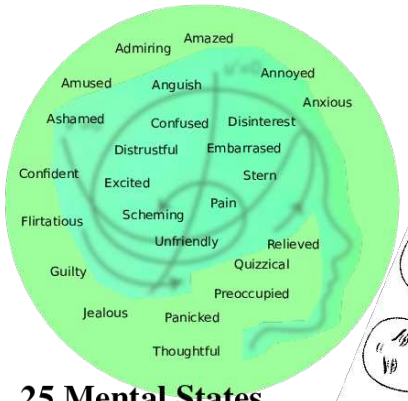
OpenFace for ROS
* Eye Gaze Vectors
* Head Pose
* 2D Landmarks
* 3D Landmarks
* Action Units

Software/Hardware
* Ubuntu 16.04 x64
* ROS Kinetic
* NAO V4 MODEL T14
* Logitech Webcam C930e



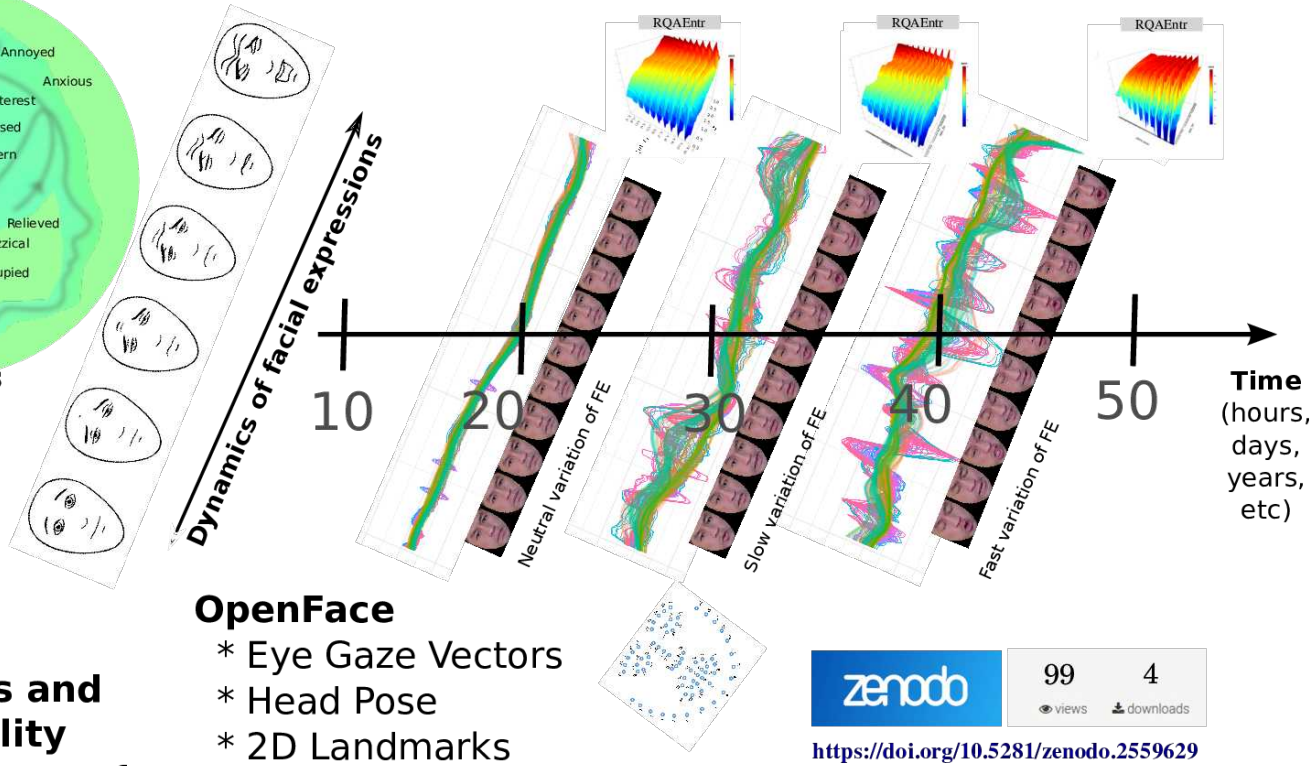
[Xochicale and Baber 2018 in **Consortium of European Research on Emotion**]

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

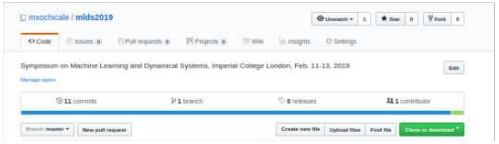
* Eye Gaze Vectors
* Head Pose
* 2D Landmarks
* 3D Landmarks
* Action Units

Software/Hardware

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

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 based on the degrees of freedom of a person, to perform a task in 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 ?
  Measurements of 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, fetal behavioral development, or nonlinear biomedical signal processing.

REFERENCES

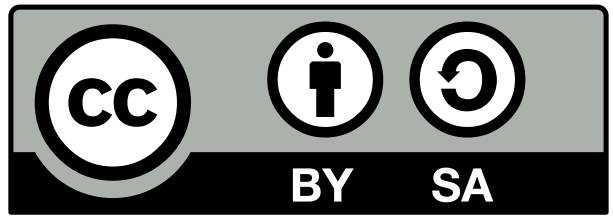
References

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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