Camilo Garcia Tenorio.

Ph.D.

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Professional Profile

Ph.D. in Mechanical and Electromechanical Engineering, with an emphasis on data-driven (Time-series) analysis and control of systems. Research focus on general control theory for non-linear systems. Currently working in Industry 4.0 solutions in a collaborative project between academy and industry. Interest in data-driven models from sensor data to produce solutions in a cloud server to subsequently design feedback loop controllers, optimization algorithms and anomaly detection methods to be deployed in edge computers. Experienced MATLAB programmer in the field of dynamical systems analysis and control.

Work Experience

2020–2023 **Researcher**, *Université de Mons/TECforLime*, Mons/Louvain-La-Neuve, Belgium

Researcher in data-driven methods for Industry 4.0 deployment. Design and deploy solutions for industrial lime production in kilns. Research funded by the BeWaRe fellowship program of the Walloon Region in Belgium.

○ Prepare and redact the project proposal that led to acquiring the Marie Curie grant.

○ Modeling of key variables (Temperatures, pressures, quality) based on the time-series data of the kilns. The models provide an approximation of the behavior of the process, an input useful for analysis of the system, control, and anomaly detection.

○ Research and development of data-driven modeling tools to capture the dynamics of the process. Specifically, improving the pqEDMD algorithm by adding optimization schemas that can deal with the uncertainty in the measurements and the numerical stability of the solution.

○ Development of the algorithm in Matlab and Python for the subsequent integration in cloud-based platforms, specifically, Microsoft Azure.

2015–2021 **Ph.D. Candidate**, *Universidad Nacional/Université de Mons*, Bogotá/Mons, Colombia/Belgique

Ph.D. In Mechanical and Electromechanical Engineering in a cotutelle agreement with University of Mons.

○ Analysis and control of nonlinear dynamical systems.

○ Development of modeling techniques based on time-series data of an arbitrary dynamical system. The main achievement of the development is the ability to capture complex nonlinear dynamics in a mathematical structure that is suitable for analysis and control.

- Analysis of complex nonlinear systems using the data-driven models. Specifically, some systems have multiple operating points, normally, it is desired to keep the process at one of these points, where the behavior is optimal. Therefore, the analysis tool is able to identify these operating points and determine the region of operation that guarantees that the process will converge to the desired behavior.
- Data-Driven control of complex process. The models that come from the time-series data of a process using my development are suitable to use as the basis for model predictive control (MPC) algorithms. Therefore, I also developed a variant of MPC that takes the data-driven approximation to make decision for driving the process to a desired point of operation.
- All the aforementioned achievements depend on the effective approximation of the behavior of a process using the time-series data. These approximations come from black-box models that rely on the selection of appropriate global approximation functions. The contribution of my thesis to this type of models is the systematic an effective selection of functions for the global approximation. As a consequence, my approach increases the numerical stability, and reduces the computational effort of the algorithm.
- Improvement of the extended dynamic mode decomposition (EDMD) algorithm by the systematic selection of black-box approximation functions. My development, called the pqEDMD is available on-line in my GitHub repository.
- Development of process analysis techniques based on the approximations.

2015–2015 Lecturer, *Universidad Distrital*, Bogotá, Colombia
Professor of the Control systems course of the electronics engineer program. Course in linear system analysis, transfer functions and Laplace transforms. Covering stability analysis, feedback controller design and frequency analysis. The functions of the position are:
- Course development, preparation of the course material, and assessment of students based on academic guidelines and objectives.
- Deliver lectures and tutorials in an engaging and effective manner.
- Ensure that the student group gets prepared in the aspects of classical control theory.

2013–2014 Graduate Teaching Assistant, *Los Andes University*, Bogotá, Colombia
Work as an assistant in different courses from the undergraduate program. The main tasks as an assistant are designing laboratory assignments, designing and evaluating class workshops and lecture different tutorials in subjects such as:
- Control Systems Analysis.
- Dynamical Systems.
- Electronic Instrumentation.
- Digital Electronics.

2014–2015 External Commercial Advisor, *Soluciones Automáticas*, Bogotá, Colombia
Work as an advisor commercializing equipment and software for automation from Mitsubishi Electric Automation. Performing tasks such as:
- Procurement of visits to maintain and expand the client base
- Make quotes
- Keep myself updated with the state of the art in automation technology

2011–2013 Staff, *Ernst & Young*, Bogotá, Colombia
Work in the IT Risk and Assessment ITRA department of the company performing tasks such as:

- o IT audit checking compliance with access and change management.
- o IT audit checking compliance with SOX controls.

2010–2011 **University Professional**, *Banco Agrario de Colombia*, Bogotá, Colombia
Work as an assistant to the presidency of the Bank, performing tasks such as:

- o Increase in the lawsuit output for book recovery. The automation of the project went from 2 lawsuits per lawyer, per day from a completely manual input to 20 lawsuits per layer, per day when the lawyer only had to check the automated lawsuit instead of writing it.
- o Participant of the credit factory project, this project main purpose is to reduce the time of approval of the different credit lines.
- o Assistant to the credit Vice Presidency, verifying the viability of the improvement proposals in the operative model of the Vice Presidency.

2010–2010 **Project Manager**, *Soluciones - Tecnología y Servicios*, Bogotá, Colombia
Plan and follow the different post sale tasks in the company, performing activities such as:

- o Active communication with the customer, account managers and service engineers in order to produce the documentation of the solution requirements.
- o Build schedules of the implementation of the solution, from the physical installation to the logical configuration of the switches, storage solutions and servers.
- o Monitoring the implementation tasks in order to ensure on time and on budget completion.

Formal Education

2021 **Ph.D., in Mechanical and Electromechanical Engineering**, *Unviersidad Nacional de Colombia*, Bogotá Colombia, In cotutelle with Université de Mons
Thesis on data-driven analysis and control of dynamical systems. Focus on the analysis of the multi stability phenomenon via the Koopman operator.

2021 **Ph.D., in Engineering Sciences**, *Université de Mons*, Mons Belgique, In cotutelle with Universidad Nacional de Colombia

2014 **M.Sc. in Electronics engineering**, *Universidad de Los Andes*, Bogotá, Colombia

2010 **Electronic Engineer**, *Universidad de Los Andes*, Bogotá Colombia

Complementary Studies

2021 **University Certificate in Artificial Intelligence (Hands on AI)**, *Université de Mons*, Mons, Belguique

2013 **Certification in Sales Management**, *"Universidad de la Sabana"*, Bogotá

2010 **Certification in Project Management**, *"Escuela Colombiana de Ingenieria Julio G."*, Bogotá

Languages

Spanish Mother Language

English 100%   *TOEFL (IBT) Score: 105/120*

Computer Skills

MATLAB 10+ Years of experience

Python 4 Years of experience

LaTeX	10+ Years of experience
Julia	1 Year of experience

Publications

2023 **Evaluation of the Regions of Attraction of Higher-Dimensional Hyperbolic Systems Using Extended Dynamic Mode Decomposition**, *Camilo Garcia-Tenorio, Duvan Tellez-Castro, Eduardo Mojica-Nava and Alain Vande Wouwer*, Automation, 4 (1) p. 57–77

2022 **Maximum Likelihood pqEDMD Identification**, *Camilo Garcia-Tenorio and Alain Vande Wouwer*, International Conference on System Theory, Control and Computing, Sinaia, Romania, p. 540–545

2022 **A Matlab Toolbox for Extended Dynamic Mode Decomposition Based on Orthogonal Polynomials and pq Quasi-Norm Order Reduction**, *Camilo Garcia-Tenorio and Alain Vande Wouwer*, Mathematics, 10 (20) p. 3859

2022 **Data-Driven Predictive Control of Interconnected Systems Using the Koopman Operator**, *Duvan Tellez-Castro, Camilo Garcia-Tenorio, Eduardo Mojica-Nava, Jorge Sofrony and Alain Vande Wouwer*, Actuators, 11 (6) p. 151

2022 **Extended Predictive Control of Interconnected Oscillators**, *Camilo Garcia-Tenorio and Alain Vande Wouwer*, International Conference on Control, Decision and Information Technologies, 1 p. 15–20

2022 **PFR Kiln Feature Selection for Modelling and Control**, *Camilo Garcia-Tenorio, Alain Vande Wouwer, Thomas Abbate, Laurent Rijmenans*, International Conference on System Theory, Control and Computing, p. 588–593

2021 **Analysis of the ROA of an anaerobic digestion process via data-driven Koopman operator**, *Camilo Garcia-Tenorio, Eduardo Mojica-Nava, Mihaela Sbarciog and Alain Vande Wouwer*, Nonlinear Engineering, 10 p. 109–131

2021 **Trigonometric Embeddings in Polynomial Extended Mode Decomposition—Experimental Application to an Inverted Pendulum**, *Camilo Garcia-Tenorio, Eduardo Mojica-Nava, Gilles Delansnay and Alain Vande Wouwer*, Mathematics, 10, 1119

2020 **Linearization in the Large of the Anaerobic Digestion Process Using a Reduced-Order Koopman Operator**, *Camilo Garcia-Tenorio, Mihaela Sbarciog, Eduardo Mojica-Nava, Alain Vande Wouwer*, IFAC-PapersOnLine, 53 (2) p. 16840–16845

2019 **Analysis of a class of hyperbolic systems via data-driven koopman operator**, *Camilo Garcia-Tenorio, Duvan Tellez-Castro, Eduardo Mojica-Nava, A Vande Wouwer*, International Conference on System Theory, Control and Computing, p. 566–571

2016 **Bond graph model-based for IDA-PBC**, *C Garcia-Tenorio, N Quijano, E Mojica-Nava, J Sofrony*, IEEE Conference on Control Applications, p. 1098–1103