Damien **Guého**

PhD, Aerospace Engineer ·

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Education

The Pennsylvania State University
University Park, PA, USA

Ph.D. in Aerospace Engineering — *2019 - 2022*

- Dissertation: *Data-driven Modeling for Analysis and Control of Dynamical Systems*
- Advisor: Prof. Puneet Singla

The Pennsylvania State University
University Park, PA, USA

M.S. in Aerospace Engineering — *2017 - 2019*

- Thesis: *Learning Capabilities of Neural Networks and Keplerian Dynamics*
- Advisors: Prof. Puneet Singla and Prof. Robert Melton

École Centrale de Lyon
Lyon, France

Diplôme d'Ingénieur (M.S. and B.S. in Engineering Sciences) — *2015 - 2017*

- Multidisciplinary studies in Maths, Physics, Computer Science, Fluid Mechanics, EE, ME, Economics, Management, English, etc.

Research Experience

My research focuses on a wide range of topics in data-driven analysis and control of dynamical systems, with particular interests for high-dimensional and complex dynamical systems, data-driven system identification, reduced-order modeling, uncertainty quantification, stochastic analysis and model-based control. I also acquired a rich expertise in astrodynamics, conjunction assessment, and optimal control.

Geminus.ai
Cambridge, MA, USA

R&D Engineer — *Since 2022*

- **Application of tensor algebra for the identification of high-dimensional systems and dynamics with process parameters**
  Combining tensor algebra with popular system identification techniques unlocks better computational efficiency in the modeling of high-dimensional dynamical systems as well as new algorithmic techniques for systems with process parameters.

- **Distinct plant/controller data-driven identification framework for closed-loop dynamics**
  Accurate and distinct modeling of process and controller dynamics arises in cases where a system may be operating in closed-loop and only closed-loop data are available for identification or if an open-loop model of the system is required to be identified from closed-loop data for the purpose of structural analysis or controller re-design. This work introduces a framework for the identification of closed-loop system and observer/controller dynamics from experimental data only. The system, observer gain, and controller gain Markov parameters are recovered from the identified observer/controller Markov parameters and a state-space model of the system as well as the corresponding observer and controller gains are identified using a state-space identification method such as the time-varying eigensystem realization algorithm. Modal parameters including frequencies, dampings, mode shapes at the sensor locations are then recovered from the open-loop system matrices. When the mission requirements as well as the associated optimal controller change, a new controller based on a new mission scenario can be designed and integrated within the closed-loop dynamics given the identified model.

Control and Analysis of Stochastic Systems (CASS) Lab
University Park, PA, USA

Research Assistant — *2017 - 2022*

Here are some current Ph.D. and Masters level research projects:

- **Development of a unified and robust data-driven framework for reduced-order modeling and system identification**
  The objective is to develop a computationally fast, robust and accurate data-driven framework (as a Python package) that combines the latest techniques in time-varying subspace realization methods, sparse representation and embeddings. Eventually, I would like this framework to be operated real-time, with real-time data collection, process, visualization, and all achieved on-board (applications for autonomous aerospace vehicles, space missions). I want to extend the system identification module with an estimation and uncertainty quantification module, a real-time learning module, and a data-driven control and parameters update module. The research work and the implementation is still in progress and useful documentation to the project can be found at:
  - Python package: https://pypi.org/project/systemID/
  - Documentation: https://damiengueho.github.io/SystemID/index.html
  - Source code: https://github.com/damiengueho/SystemID

- **Development of an educational and tutorial website for system identification of dynamical systems**
  This project is to expose as many people (undergraduate/graduate students and professional, engineers) in the field of aerospace to data-driven modeling and system identification of dynamical systems. This website offers theoretical knowledge for dynamical systems and time-domain system identification as well as a full section that allows the user to apply the concepts of linear system identification to online real-time simulations. Pick a premade system or build your own system, define all the parameters yourself, pick and input signal and launch the simulation. You'll be able to see the results of the identification process and access all the relevant quantities involved. The version 2 of this website is scheduled to launch in February 2022 (with many new features!) and to be hosted on Penn State servers.
  - Website: http://www.systemidtechnologies.com

- **Reduced-order modeling and analysis for high-fidelity aero-thermo-servo-elasticity (ATSE) simulation for hypersonic vehicles**
  This research work is on the development of new algorithms to study the nonlinear coupled dynamics between structural dynamics, heat transfer, and hypersonic aerothermodynamics. Several subspace realization techniques as well as embeddings and sparse representation methods are used to provide a linear-time varying model or a sparse model to reproduce the aerothermoelastic response of a hypersonic vehicle and to study the effect of a bifurcation parameter. To validate the developed approach, numerical simulations involving the nonlinear dynamics of a heated panel model as well as high-fidelity simulations are considered. This eventually will enable accurate hypersonic aerothermoelastic analysis and control with tractable computational cost.

- **Optimal Feedback Control under Uncertainty for Hypersonic Re-Entry Vehicles**
  The objective of this work is to establish flexible, accurate and navigable flight trajectories for hypersonic vehicles without human interference. On a larger scale, the idea is to accurately plan the path of super-fast vehicles from one point to another while accounting for multi-physics dynamical models and any path or actuation constraints. In this project involving several Universities, I have been developing methods using optimal open-loop solutions to derive appropriate feedback control structure from over an complete dictionary of basis functions with the help of sparse approximation tools. A planar hypersonic maneuver corresponding to maximizing the terminal velocity of the payload has been considered to validate the proposed approach and simulation results clearly demonstrate the efficacy of the method in providing optimal feedback control law for prescribed uncertainty in boundary conditions and model parameters.

- **Computationally Efficient Approach for Stochastic Reachability Set Analysis**
  This research work aims to study the significant challenges associated to automating the decision support system of maneuvering Unmanned Autonomous Systems (UAS) in presence of nonlinearities, uncertainties associated with system parameters, states and external disturbances together with an embedded control input. Three different probabilistic approaches to compute the reachability sets for a class of discrete time nonlinear systems are investigated and I have been involved in developing two of these approaches. In the first approach, the central idea is to pose the computation of the state density function at any time as the convolution of two probability density functions to avoid the exponential growth in samples while in the second approach, a quadrature method utilizes the Conjugate Unscented Transform (CUT) to compute the probability density function.

- **Optimal Spacecraft Docking Maneuver Using Direct and Indirect Collocation Method and Heuristic Optimization**
  Originally started as a class project, this work used an indirect method combined with a heuristic approach to solve an optimal spacecraft docking maneuver problem. Theoretically, the indirect method presents the difficulty that the problem size is large due to discretization of the costates in addition to requiring good enough initial guesses for the costates variables. With one classmate, we presented a new approach where a heuristic optimization (HO) algorithm is used beforehand to generate a sufficiently accurate initial guess for the costates variables used for the collocation method applied later on.

- **Statistical Orbit Determination Class Project**
  The project aims at developing a software to create tracking data of a satellite from multiple tracking sites around the Earth. I used observation data to statistically determine the nominal orbit/tracking parameters and perturbations such as the gravitational parameter, J2, the mean radius of Earth, the drag coefficient of the satellite and the locations of the tracking stations. The final goal was to obtain parameter values and covariances using both a batch filter and a sequential estimation filter for method comparison.

Professional Experience

Geminus.AI, Modeling and Methods Group

Boston, MA

R&D Engineer

August 2022 –

- My role is to explore and develop new methods and algorithms in the field of modeling. More precisely, I advance the understanding of data-driven modeling and deliver robust tools to pursue the ambition of complete unsupervised identification of dynamical systems from data
- The industrial applications are very diverse and span from computational fluid dynamics cases, structural analysis, chemical processes, energy plants, up to the study of generic high-dimensional nonlinear dynamical processes
- By combining the most recent AI/ML approaches with fundamental techniques derived from system analysis, we equip customers across many industries with tools to accelerate and control simulation and historical models, better predict the future, optimize as well as quantify uncertainties

CNES (Centre National d'Études Spatiales), LASS Laboratory

Toulouse, France

Intern

May 2018 – July 2018

- Investigated different methods to develop an accurate, reliable and efficient method to compute a certified orbital collision probability between two spacecrafts involved in a short-term encounter under Gaussian-distributed uncertainty
- Derived an analytic expression for the probability integral by use of Laplace transforms and D-finite functions
- Surveyed different methods to extend this work to long term and multiple encounters
- Defined a framework to approximately reconstruct the support of the initial collision-prone states in a two-objects long-term encounter

Teaching Experience

AERSP 597 - System Identification

University Park, PA, USA

Co-instructor

Spring 2021

Co-taught the graduate level course *AERSP 597 - System Identification* with Dr. P. Singla. Shared the duties for lectures, homework assignments and exams. Responsible for grading and half of the office hours. Gave lectures on nonlinear system identification, embeddings and Koopman operator, observer-controller system identification. Taught practical implementation of system identification algorithms in Python.

AERSP 305 - Aerospace Structures *University Park, PA, USA*

Teaching Assistant *Spring 2018*

Responsible for 10h/week of lab sessions on aerospace structures and vibrations. This involves guiding 25 students every week in performing experiments, grading reports and providing theoretical background as support from the materials taught in class.

AERSP 313 - Aerospace Analysis *University Park, PA, USA*

Teaching Assistant *Fall 2017*

Class of 130+ students. Responsible for grading, office hours and writing homework assignments with 3 other TAs. Responsible for review sessions before exams.

Publications

Journal Papers

- **D. Guého**, P. Singla, M. Majji, and R. G. Melton. "A Filtered Integral Formulation of the Sparse Model Identification Problem". In: *Journal of Guidance, Control, and Dynamics* 45.2 (2022), pp. 232–247. DOI: https://doi/abs/10.2514/1.G005952.

PhD Dissertation

- **D. Guého**. "Data-Driven Modeling for Analysis and Control of Dynamical Systems". PhD thesis. The Pennsylvania State University, 2022.

Conference Proceedings

- **D. Guého**, M. Brownell, and P. Singla. "Data-Driven Time-Varying Eigensystem Realization Algorithm With Data-Correlation". In: AIAA SCITECH 2023 Forum. 2023. DOI: https://doi.org/10.2514/6.2023-2072.
- M. Vedantam, C. A. Vargas Venegas, **D. Guého**, P. Singla, and M. R. Akella. "On-Board Optimal Feedback Controller Generation for Hypersonic Re-Target Scenarios". In: AIAA SCITECH 2023 Forum. 2023. DOI: https://doi.org/10.2514/6.2023-2639.
- M. Brownell, **D. Guého**, R. Eapen, and P. Singla. "Time-Varying Perturbation Model Identification in the Neighborhood of CR3BP Periodic Orbits". In: 2022 AIAA/AAS Astrodynamics Specialist Conference. 2022.
- **D. Guého** and P. Singla. "Towards a data-driven bilinear Koopman operator for controlled nonlinear systems and sensitivity analysis". In: Dynamic Data-driven Applications Systems (DDDAS) 2022. 2022.
- **D. Guého**, P. Singla, and D. Huang. "Application of the Time-Varying Koopman Operator for Bifurcation Analysis in Hypersonic Aerothermoelasticity". In: 2022 AIAA SciTech Forum and Exposition. 2022. DOI: https://doi.org/10.2514/6.2022-0655.
- **D. Guého**, P. Singla, D. Huang, and M. Majji. "Model-Order Reduction in Hypersonic Aerothermoelasticity Using Time-Varying Koopman Operator". In: 2022 Joint Army Navy NASA Air Force (JANNAF) Meeting. Newport News, VA, 2022.
- **D. Guého**, M. Majji, and P. Singla. "Data-Based Modeling and Control of Dynamical Systems: Parameter Estimation". In: 60th IEEE Conference on Decision and Control. 2021. DOI: https://doi.org/10.1109/CDC45484.2021.9682951.
- **D. Guého**, P. Singla, and D. Huang. "Sparse Nonlinear System Identification for Hypersonic Aerothermoelastic Analysis with Stochastic Loads". In: 2021 AIAA SciTech Forum and Exposition. 2021. DOI: https://doi.org/10.2514/6.2021-1609.
- **D. Guého**, P. Singla, and D. Huang. "Time-varying Linear Reduced Order Model for Hypersonic Aerothermoelastic Analysis". In: 2021 AIAA SciTech Forum and Exposition. 2021. DOI: https://doi.org/10.2514/6.2021-1706.
- **D. Guého**, P. Singla, and M. Majji. "Time-Varying Koopman Operator Theory for Nonlinear Systems Prediction". In: 60th IEEE Conference on Decision and Control. 2021. DOI: https://doi.org/10.1109/CDC45484.2021.9683082.
- **D. Guého**, P. Singla, M. Majji, and J.-N. Juang. "Advances in System Identification: Theory and Applications". In: 60th IEEE Conference on Decision and Control. 2021. DOI: https://doi.org/10.1109/CDC45484.2021.9683394.
- **D. Guého**, D. Schwab, P. Singla, and R. G. Melton. "A Comparison of Parametric and Non-Parametric Machine Learning Approaches for the Uncertain Lambert Problem". In: 2020 AIAA SciTech Forum and Exposition. 2020. DOI: https://doi.org/10.2514/6.2020-1911.
- **D. Guého**, P. Singla, and R. G. Melton. "Data-driven sparse approximation for the identification of nonlinear dynamical systems: applications in astrodynamics". In: *Spaceflight Mechanics 2020*. Advances in the Astronautical Sciences. Escondido, CA: Univelt Inc., 2020.
- A. Jain, **D. Guého**, and Singla. "A Computationally Efficient Approach for Stochastic Reachability Set Analysis". In: 2020 AIAA SciTech Forum and Exposition. 2020. DOI: https://doi.org/10.2514/6.2020-0851.
- **D. Guého**, G. He, P. Singla, and R. G. Melton. "Optimal Spacecraft Docking Maneuver Using Direct and Indirect Collocation Method and Particle Swarm Optimization". In: *AAS/AIAA Astrodynamics Specialist Conference, 2018*. Advances in the Astronautical Sciences. Escondido, CA: Univelt Inc., 2019, pp. 1875–1894.
- **D. Guého**, P. Singla, and R. G. Melton. "Investigation of different neural network architectures for dynamic system identification: Applications to orbital mechanics". In: *Spaceflight Mechanics 2019*. Advances in the Astronautical Sciences. Maui, HI: Univelt Inc., 2019, pp. 1789–1803.
- A. Jain, **D. Guého**, P. Singla, and M. R. Akella. "Stochastic Reachability Analysis for the Hypersonic Re-entry Problem". In: *Spaceflight Mechanics 2019*. Advances in the Astronautical Sciences. Escondido, CA: Univelt Inc., 2019, pp. 2455–2476.
- **D. Guého**, P. Singla, and R. G. Melton. "Learning capabilities of neural networks and Keplerian dynamics". In: Advances in the Astronautical Sciences. AAS/AIAA Astrodynamics Specialist Conference, 2018. Escondido, CA: Univelt Inc., 2018, pp. 2293–2310. DOI: http://www.univelt.com/book=7138.
- J. A. Reiter, **D. Guého**, D. B. Spencer, P. Singla, and R. G. Melton. "Reconstruction of Non-Cooperative Spacecraft Maneuvers During Observation Gaps From Angles-Only Measurements Using Machine Learning". In: 69th International Astronautical Congress. Bremen, Germany, 2018. DOI: http://iafastro.directory/iac/archive/browse/IAC-18/A6/9/44066/.

Professional Activities and Affiliations

Affiliations

AIAA, AAS, IEEE, Member

Conferences

Jan 2024	**AIAA SciTech**, Reviewer	*Orlando, FL, USA*
Dec 2023	**IEEE Conference on Decision and Control (CDC)**, Reviewer	*Singapore*
Jan 2023	**AIAA SciTech**, Reviewer	*National Harbor, MD, USA*
Jun 2022	**American Control Conference**, Reviewer	*Atlanta, GA, USA*
Jan 2022	**AIAA SciTech**, Reviewer	*San Diego, CA, USA*
Dec 2021	**IEEE Conference on Decision and Control**, Reviewer	*Austin, TX, USA*
Dec 2021	**IEEE Conference on Decision and Control**, Author for the tutorial session: Fundamentals of Data-Driven Modeling and Control	*Austin, TX, USA*
Aug 2021	**AAS/AIAA Astrodynamics Specialist Conference**, Session Chair	*Virtual*

Journals

2022	**The Journal of the Astronautical Sciences**, Reviewer
2022	**Journal of Guidance, Control and Dynamics**, Reviewer

Honors & Awards

2022	**2022, Guidance, Navigation, and Control (GNC) TC Graduate Award**, to help support the future aerospace professionals.	*State College, PA, USA*
2021	**Alpha Musser/Ross Scholarship, Alpha Fire Company**, scholarship to recognize the importance of continuing education and to assist members and their children in the pursuit of post-secondary education.	*State College, PA, USA*
2020	**Alpha Musser/Ross Scholarship, Alpha Fire Company**, scholarship to recognize the importance of continuing education and to assist members and their children in the pursuit of post-secondary education.	*State College, PA, USA*
2020	**AIAA/AAS Breakwell Award**, to encourage and promote research activity in space flight mechanics and astrodynamics. Conference Paper Award. Costs for the 2020 AIAA/AAS Astrodynamics Conference covered.	*Lake Tahoe, CA, USA*
2018	**AIAA Diversity Scholarship**, costs for the 2018 AIAA SciTech Forum covered.	*Orlando, FL, USA*

Volunteering and Extracurricular Activities

Alpha Fire Company *State College, PA, USA*

Volunteer Firefighter *September 2018 - August 2022*

Volunteer Firefighter since September 2018. Joined the Engine Company after completed the in-house Engine PERT program in January 2019. I participated in the Truck PERT program in Fall 2019. Certifications include:

- Firefighter I
- FEMA IS-00700.b and IS-00100.c
- CPR and AED Provider

Skills

Computing Skills

Languages	Python, Matlab, Simulink, LaTeX, HTML, CSS, JavaScript
OS	MacOS, Windows, basics of GNU/Linux
Softwares	Docker, Git, Gitlab

Language Skills

French	Native
English	Fluent