# Tom S. Bertalan

Research Software Engineer · Bioreactor Controls · Neural networks for Nonlinear Dynamics

*West Boston, MA*

(256) 613-3760 | Tom@TomBertalan.com | TomSB.net | TSBertalan | Tom-Bertalan-00764640

*Machine learning and dynamical systems researcher specialized in neural system identification and unsupervised representations. Proficient in handling high-dimensional time-series data for both offline parameter optimization and online execution.*

## SKILLS

**Libraries, frameworks, & tools**

- Python/C++/Java
- NumPy+SciPy+Matplotlib
- Pytorch/TensorFlow/Keras
- Linux, shell scripting, and git
- VSCode/Eclipse+PyDev
- Aspen DMC3 Controls
- OPC-UA, ROS, and sockets

**Areas of Expertise and Training**

- Nonlinear dynamics of time series data
- Deep learning and ML
- Dimension reduction and representation learning
- Probabilistic modeling and theory
- Computer vision
- Research presentation and dissemination
- Trainee and peer mentoring

**Other Skills and Interests**

- Home automation with Arduino, Raspberry Pi, and 3D printing
- Solo and orchestral violin performance
- Windsurfing and small-boat sailing

## PROFESSIONAL EXPERIENCE AND RESEARCH AREAS

**University of Massachusetts** *Lowell, MA*

Research Software Engineer *1/2024-Present*

- ***Model Predictive Control of CHO Bioreactor***
  - Collect targeted experimental data from a 3-liter bioreactor, characterizing dynamics and responses to control inputs.
  - Supervise the implementation of more rigorous simulation methods for a SBML-encoded bioreactor digital twin.
  - Develop an optimal online model-predictive controller in Aspen DMC to maximize combined quality attributes.
  - Lead weekly group meetings, targeting both academic publication and technolgoy transfer to industry partners

**Johns Hopkins University** *Baltimore, MD*

Postdoctoral Fellow *3/2020-1/2024*

- ***Time Series and PDE Analysis with Neural ODEs***
  - Advanced SotA for neural DEs for time series, including CNNs for PDEs; conceived a novel loss function for Hamiltonian systems.
  - Cut RNN inference burn-in from 25 to 5 samples using manifold learning.
  - Derived custom gradients for nets with constraints; promoted theory on error scaling laws; applications in biomanufacturing.
  - Parallelized neural PDE solution sensitivity analysis using SLURM on GPU cluster.
- ***Biophysical Experiment and Simulation Enhancement***
  - Led a team of biophysics and ML experts in creating a suite of Python/MATLAB simulation and data processing tools.
  - Created a GUI for Bayesian experimental design; mentored team members on its use and maintenance.
- ***Robotic Systems Development and Upgrades***
  - Developed a variational autoencoder for end-to-end robotic localization.
  - Used Blender to create synthetic datasets for alternate-view synthesis.
  - Upgraded rover with IMU and RealSense, resulting in enhanced odometry for RTAB-MAP SLAM.
  - Trained a U-net on both open and custom datasets for real-time (>10hz) on-board semantic segmentation of drivable space.
  - Calibrated camera intrinsics for projective geometry of segmented point clouds.
  - Profiled depth/segmentation pipeline to ensure pure-GPU inference for real-time inference.
- ***Special Projects and Innovations***
  - Automated conversion of seminar announcements to ICS files via OpenAI API, including curation of a 19.7k-word fine-tuning dataset.
  - Administered lab GPU server for maximum uptime and ease of access for multiple concurrent users.
  - Stood up local Llama2 inference server for various internal automation tasks via REST API over VPN.
  - Wrote specifications and solicited bids for an upcoming multi-GPU training server destined for datacenter colocation.

**The Massachusetts Institute of Technology** *Cambridge, MA*

Postdoctoral Associate *3/2018-3/2020*

- ***Autonomous Vehicle Design and Pathfinding***
  - Developed a model AV with firmware-level speed sensing and control commanded by checksummed bus communications.
  - Designed a jerk-minimizing path planner capable of planing up to two lane switches ahead at 47 mph.
  - Leveraged Ipopt and CppAD to push a model-predictive path follower to a latency of 67 ms in simulation.
  - Wrote wrapper APIs for using video games as robotic simulations.
  - Detected dashcam obstacles via windowed SVM.

- ***Nonlinear dynamics in neuroscience***
  - Wrote object-oriented library for fine- and coarse-grained simulation of neuronal dynamics.
  - Analyzed bifurcation and resonance behavior of a mammalian circadian rhythm model.
  - Played a key role in acquiring a $1.8M grant for an industry-academic partnership.

**Princeton University** *Princeton, NJ*

NSF Research Assistant *9/2012-3/2018*

Built a rover for particle-filter SLAM with LIDAR; using Gazebo and ROS. Created a custom library for visualizing OpenCV pipelines and execution-time computation graph pruning. Simulated thousands of neurons in vectorized Numpy and MATLAB; and social agents in OpenMP-accelerated C++.

**The University of Alabama** *Tuscaloosa, AL*

Student Research Assistant *9/2009-5/2012*

Created a 10-node Beowulf cluster in PHP, explored CUDA for PDE acceleration, and developed a LAMP-based social network. Simulated hierarchy formation in social animals as input to wet-lab experiments. Authored a multigrid subsurface-flow solver with CUDA acceleration.

## EDUCATION & TRAINING

**Institutions**

- **Johns Hopkins University** ***2020 - 2024***
  Postdoctoral Fellow *Che. & Bio. Eng.*
- **The Massachusetts Institute of Technology** ***2018 - 2020***
  Postdoctoral Associate *Mech. Engr.*
- **Princeton University** ***2012 - 2018***
  NSF Research Fellow *PhD & MA, Che. & Bio. Eng.*
- **The University of Alabama** ***2008 - 2012***
  Student Research Assistant *BS Che. & Bio. Eng.; Minor in Math*

**Awards**

- Princeton Program in Plasma Science and Technology research and academic fellowship
- National Science Foundation research fellowship
- William R. Schowalter fund for scholarly conferences
- National merit finalist scholarship
- University honors program and president's list
- $\Phi\mathrm{H}\Sigma$, $\Omega\mathrm{X}\mathrm{E}$, and $\mathrm{T}\mathrm{B}\Pi$ honor societies

**Teaching**

- Volunteered in a recurring summer course for high-school seniors and freshmen on employing ROS, OpenCV, and CNNs for lane detection and traffic sign recognition.
- Supervised operations and measurment activities in junior Chemical & Biological Engineering practicum.
- Lectured, held office hours, and graded assignments in senior differential equations course.

## SELECTED PUBLICATIONS

*A longer list of publications and presentations is available upon request.*

**Transformations establishing equivalence across neural networks: when have two networks learned the same task?**
Thomas Bertalan, Felix Dietrich, Ioannis Kevrekidis
***2024; in press*** *Chaos*

**Implementation and (Inverse Modified) Error Analysis for implicitly-templated ODE nets**
Aiqing Zhu, Beibei Zhu, Tom Bertalan, Yifa Tang, Ioannis Kevrekidis
***2024; in press*** *SIAMDS*

**Data-driven and Physics Informed Modelling of Chinese Hamster Ovary (CHO) Cell Bioreactors**
Tianqi Cui, Tom Bertalan, Nelson Ndahiro, Pratik Khare, Michael Betenbaugh, Costas Maranas, Ioannis Kevrekidis
***2024*** *Comp. & Chem. Engr.*

**Certified Invertibility in Neural Networks via Mixed-Integer Programming**
Tianqi Cui, Tom Bertalan, George J. Pappas, Manfred Morari, Ioannis Kevrekidis, Mahyar Fazlyab
***2023*** *L4DC 2023 — PMLR*

**Learning emergent PDEs in a learned emergent space**
Felix Kemeth, Tom Bertalan, Thomas Thiem, Seungjoon Moon, Carlo Laing, Ioannis Kevrekidis
***2022*** *Nature Comm.*

**Initializing LSTM internal states via manifold learning**
Felix Kemeth, Tom Bertalan, Nikolaos Evangelou, Tianqi Cui, Saurabh Malfani, Ioannis Kevrekidis
***2021*** *Chaos*

**Local conformal autoencoder for standardized data coordinates**
Erez Peterfreund, Ofir Lindenbaum, Felix Dietrich, Tom Bertalan, Matan Gavish, Ioannis Kevrekidis, Ronald Coifman
***2020*** *PNAS*

**On Learning Hamiltonian Systems from Data**
Tom Bertalan, Felix Dietrich, Igor Mezic, and Ioannis Kevrekidis
***2019*** *Chaos*

# PUBLICATIONS

**Machine Learning Approaches to Problem Well-Posedness** — *In Preparation*
Tom Bertalan, George Kevrekidis, Elizaveta Rebrova, Siddhartha Mishra, Yannis Kevrekidis

**Data-driven and Physics Informed Modelling of Chinese Hamster Ovary (CHO) Cell Bioreactors** — *2024, Comp. & Chem. Engr.*
Tianqi Cui, Tom Bertalan, Nelson Ndahiro, Pratik Khare, Michael Betenbaugh, Costas Maranas, Ioannis Kevrekidis

**Implementation and (Inverse Modified) Error Analysis for implicitly-templated ODE nets** — *2024; in press, SIAMDS*
Aiqing Zhu, Beibei Zhu, Tom Bertalan, Yifa Tang, Ioannis Kevrekidis

**Transformations establishing equivalence across neural networks: when have two networks learned the same task?** — *2024; in press, Chaos*
Thomas Bertalan, Felix Dietrich, Ioannis Kevrekidis

**Certified Invertibility in Neural Networks via Mixed-Integer Programming** — *2023, L4DC 2023 — PMLR*
Tianqi Cui, Tom Bertalan, George J. Pappas, Manfred Morari, Ioannis Kevrekidis, Mahyar Fazlyab

**Some of the variables, some of the parameters, some of the times, with some things known: Identification with partial information** — *2023, Comp. & Chem. Engr.*
Saurabh Malani, Tom Bertalan, Tianqi Cui, Michael Betenbaugh, Jose L. Avalos, Ioannis Kevrekidis

**Learning effective stochastic differential equations from microscopic simulations: linking stochastic numerics to deep learning** — *2023, Chaos*
Felix Dietrich, Alexei Makeev, George Kevrekidis, Nikolaos Evangelou, Tom Bertalan, Sebastian Reich, Ioannis Kevrekidis

**Learning emergent PDEs in a learned emergent space** — *2022, Nature Comm.*
Felix Kemeth, Tom Bertalan, Thomas Thiem, Seungjoon Moon, Carlo Laing, Ioannis Kevrekidis

**Personalized Algorithm Generation: A Case Study in Meta-Learning ODE Integrators** — *2022, SIAM J. Sci. Comp.*
Y. Guo, Felix Dietrich, Tom Bertalan, D. T. Doncevic, M. Dahmen, Ioannis Kevrekidis, Qianxiao Li

**Initializing LSTM internal states via manifold learning** — *2021, Chaos*
Felix Kemeth, Tom Bertalan, Nikolaos Evangelou, Tianqi Cui, Saurabh Malfani, Ioannis Kevrekidis

**Development of closures for coarse-scale modeling of multiphase and free surface flows using machine learning** — *2021, APS Bulletin*
Cristina Linares, Tom Bertalan, Eleni Koronaki, Jicai Lu, Gretar Tryggvason, Ioannis Kevrekidis

**Global and local reduced models for interacting, heterogeneous agents** — *2021, Chaos*
Thomas Thiem, Felix Kemeth, Tom Bertalan, Carlo Liang, Ioannis Kevrekidis

**Local conformal autoencoder for standardized data coordinates** — *2020, PNAS*
Erez Peterfreund, Ofir Lindenbaum, Felix Dietrich, Tom Bertalan, Matan Gavish, Ioannis Kevrekidis, Ronald Coifman

**Emergent spaces for coupled oscillators** — *2020, Front. in Comp. Neuro.*
Thomas Thiem, Mahdi Kooshkbaghi, Tom Bertalan, Carol Laing, Ioannis Kevrekidis

**On Learning Hamiltonian Systems from Data** — *2019, Chaos*
Tom Bertalan, Felix Dietrich, Igor Mezic, and Ioannis Kevrekidis

**An Emergent Space for Distributed Data with Hidden Internal Order through Manifold Learning** — *2017, IEEE Access*
Felix Kemeth, Sindre Haugland, Felix Dietrich, Tom Bertalan, Kevin Höhlein, Qianxiao Li, Erik Bollt, Ronen Talmon, Katharina Krischer, and Ioannis Kevrekidis

**Coarse-grained descriptions of dynamics for networks with both intrinsic and structural heterogeneities** — *2017, Front. in Comp. Neuro.*
Tom Bertalan, Yan Wu, Carlo Laing, C. William Gear, and Ioannis Kevrekidis.

**Dimension reduction in heterogeneous neural networks: Generalized Polynomial Chaos (gPC) and ANalysis-Of-VAriance (ANOVA)** — *2016, Euro. Phys. J., Special Topics*
Minseok Choi, Tom Bertalan, Carlo Laing, and Ioannis Kevrekidis.

**OpenMG: a new multigrid implementation in Python** — *2014, Num. Lin. Alg. with App.*
Tom Bertalan, Akand Islam, Roger Sidje, and Eric Carlson

# PRESENTATIONS

**Symbolic regression and modular neural differential equations for bioprocess engineering and robotics** — *2024*
Tom Bertalan, Jaeweon Lee, Zhao Wang, Seongkyu Yoon, Ioannis Kevrekidis — *MLDS 4 (poster)*

**Certified Invertibility in Neural Networks via Mixed-Integer Programming** — *2023*
Tianqi Cui, Tom Bertalan, George J. Pappas, Manfred Morari, Ioannis Kevrekidis, Mahyar Fazlyab — *Learning for Dyn. Sys.*

**Coarse-grained and emergent distributed-parameter systems from data** — *2021*
Hassan Arbabi, Felix Kemeth, Tom Bertalan, Ioannis Kevrekidis — *American Control Conf.*

**Data-driven model reduction and discovery** — *2020*
Thomas Thiem, Tom Bertalan, Felix Kemeth, Yorgos Psarellis, Ioannis Kevrekidis — *AIChE*

**Dynamical-systems-guided learning of PDEs from data** — *2020*
Hassan Arbabi, Tom Bertalan, Anthony Roberts, Ioannis Kevrekidis — *AIChE*

**On the data-driven discovery and calibration of closures** — *2020*
Seungjoon Lee, Yorgos Psarellis, Constantinos Siettos, Tom Bertalan,Daniel Amchin, Tapomoy Bhattacharjee, Sujit Datta, Ioannis Kevrekidis — *AIChE*

**Connections between residual networks and explicit numerical integrators, and applications to identification of noninvertible dynamical systems** — *2020*
Tianqi Cui, Tom Bertalan, Yorgos Psarellis, Ioannis Kevrekidis — *AIChE*

**Neural network approach to reduced order modeling of multiphase flows** — *2020*
Cristina Linares, Tom Bertalan, Seungjoon Lee, Jicai Lu, Gretar Tryggvason, Ioannis Kevrekidis — *APS Div. of Fluid Dyn.*

**PDE+PINN: Learning and Solving a PDE at the Same Time** — *2020*
Tom Bertalan, Felix Kemeth, Tianqi Cui, Ioannis Kevrekidis — *AIChE*

**Learning Partial Differential Equations from Discrete Space Time Data: Convolutional and Recurrent Networks, and Their Relations to Traditional Numerical Methods** — *2019*
Tom Bertalan, Felix Dietrich, Thomas Thiem, Rob Farber, Ioannis Kevrekidis, Anthony Roberts — *AIChE*

**Recurrent Neural Networks, Numerical Integrators and Nonlinear System Identification** — *2018*
Tom Bertalan, Rob Farber, Thomas Thiem, Felix Dietrich, Ioannis Kevrekidis — *AIChE*

**Coarse-Scale PDEs from Microscopic Observations Via Machine Learning** — *2019*
Seungjoon Lee, Mahdi Kooshkbaghi, Constantinos Siettos, Tom Bertalan, and Ioannis Kevrekidis — *AIChE*

**When Have Two Networks Learned the Same Task? Data-Driven Transformations between System Representations** — *2019*
Tom Bertalan, Felix Dietrich, Thomas Thiem, Ioannis Kevrekidis — *AIChE*

**Coarse modeling of circadian rhythms in heterogeneous neural networks** — *3017; 2016*
Tom Bertalan, C. William Gear, Yannis G. Kevrekidis, Michael Henson, Erik Herzog, and Carlo Laing — *Dyn. Days 2017; AIChE*

**Coarse-graining of heterogeneous neural dynamics** — *2015*
Tom Bertalan, Minseok Choi, Carlo Laing, Ioannis Kevrekidis — *AIChE*

**Heterogeneity and reduction for complex network dynamics** — *2014*
Ioannis Kevrekidis, Alexander Holiday, Tom Bertalan, and Carlo Laing — *AIChE*

**Polynomial representations of populations with multiple heterogeneities** — *2014*
Tom Bertalan, Yan Wu, Brianna Hnath, and Yannis Kevrekidis — *Princeton Grad. Student Symp.*

**Coarse-graining Network Dynamics** — *2013*
Alexander Holiday and Tom Bertalan — *Network Front.*

**nSpyres: an open-source, Python-based framework for simulation of flow through porous media** — *2012*
Eric Carlson, Akand Islam, Francis Dumkwu, and Tom Bertalan — *Interpore 2012*

**OpenMG: a new multigrid implementation in Python** — *2012*
Tom Bertalan, Akand Islam, Roger Sidje, and Eric Carlson — *Proc. 11$^{th}$ Python in Sci. Conf.*

**ESIM: a framework for simulation of dominance hierarchy formation in small animal groups** — *2012*
Tom Bertalan and Ryan Earley — *UA Hon. Undergr. Res. Conf.*

**An open-source computing cluster for virtual experiments with variable parameters** — *2011*
Tom Bertalan and Eric Carlson — *UA Hon. Undergr. Res. Conf.*