

# Tom S. Bertalan

POSTDOCTORAL FELLOW AT JOHNS HOPKINS WHITING SCHOOL OF ENGINEERING

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*ML and dynamical systems researcher with expertise in neural system identification and unsupervised learning.*

## Skills

### Libraries, frameworks, & tools

- Python/C++
- NumPy+SciPy+Matplotlib
- Pytorch/TensorFlow/Keras
- Linux and shell scripting
- Git/Subversion
- VSCode/Eclipse+PyDev
- Scikit-Learn

### Areas of Expertise and Training

- Computer vision
- Dimension reduction and representation learning
- Deep learning and ML
- Probabilistic modeling and theory
- Nonlinear dynamics of time series data
- Scientific computing
- 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

### Johns Hopkins University

Baltimore, MD

POSTDOCTORAL FELLOW

3/2020-Present

- **Time Series and PDE Analysis with Neural ODEs**
  - Advanced neural DEs for time series, including CNNs for PDEs; with a novel loss function for Hamiltonian systems.
  - Cut RNN inference burn-in from 25 to 5 samples through manifold learning.
  - Derived custom gradients for nets with constraints; put forward theory on error scaling laws, plus biomanufacturing applications.
- **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 multi-view synthesis.
  - Upgraded rover with IMU and RealSense, resulting in enhanced odometry for RTAB-MAP SLAM.
  - Engineered a two-step training protocol for real-time (>10hz) onboard neural segmentation of drivable space by U-net, leveraging both open and custom datasets.
  - Constructed GPS-navigable hexacopter from 3D-printed parts.
  - Estimated depth and segmentation by pre-trained transformer networks in simulation.
  - Optimized projective geometry settings for enhanced point cloud segmentation.
  - Streamlined depth-segmentation pipeline for GPU-exclusive, 10Hz execution.
- **Special Projects and Innovations**
  - Automated conversion of seminar announcements to ICS files with OpenAI API, including curation of a 19.7k-word dataset.
  - Administered lab GPU server for maximum uptime, ease of access for multiple concurrent users.
  - 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, and noise-rejecting communication protocols.
  - Crafted 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 67 ms latency in simulation.
  - Taught summer courses on OpenCV, ROS, and CNNs for lane detection, path following, and traffic sign recognition.
  - Wrote wrapper APIs for using video games as robotic simulations.
  - Detected dashcam obstacles via windowed SVM.
  - Designed compute board mounting brackets in CAD for 3D printing.
- **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

NSF RESEARCH ASSISTANT

Princeton, NJ

9/2012-3/2018

- **Robotic Hardware, Integration, and Computer Vision Software Development**
  - Built a differential-drive rover for research in particle-filter SLAM via LIDAR, against a ROS baseline.
  - Modeled robot in Gazebo for fast algorithm prototyping.
  - Architected an OpenCV library inspired by TensorFlow 1 for compile-time optimization of graph-structured pipelines.
- **High-Performance Computation for Neuroscience and Behavioral Ecology**
  - Coarse-grained bifurcation analysis of simulations of up to several thousand Biological neurons, using measure-orthogonal polynomial expansion..
  - Used OpenMP to accelerate C++ object-oriented simulation animal social dynamics.

## The University of Alabama

STUDENT RESEARCH ASSISTANT

Tuscaloosa, AL

9/2009-5/2012

- **High-Performance Computing Cluster Development**
  - Created a 10-node Beowulf cluster from scratch in PHP using surplus hardware.
  - Explored CUDA for PDE acceleration.
  - Built a social network for collaborative storywriting on a LAMP stack.
- **Advanced Simulation Techniques**
  - Simulated hierarchy formation in social animals, generating hypotheses for future wet-lab experiments.
  - Wrote and presented a multigrid subsurface-flow solver.

## Education & Training

### Institutions

- |  |                        |
|--|------------------------|
| • <b>Johns Hopkins University</b>                  | 2020 - Present         |
| Postdoctoral Fellow                                | ChBE                   |
| • <b>The Massachusetts Institute of Technology</b> | 2018 - 2020            |
| Postdoctoral Associate                             | ME                     |
| • <b>Princeton University</b>                      | 2012 - 2018            |
| NSF Research Fellow                                | PhD & MA, ChBE         |
| • <b>The University of Alabama</b>                 | 2008 - 2012            |
| Student Research Assistant                         | BS ChBE; 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
- $\Phi\chi\Sigma$ ,  $\Omega\chi E$ , and  $TBII$  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 measurement activities in junior Chemical & Biological Engineering practicum.
- Instructed in recitation, office hours, and grading as assistant instructor for senior differential equations course.

## Selected Publications

*A longer list of 19 publications and 21 presentations is available upon request.*

### Implementation and (Inverse Modified) Error Analysis for implicitly-templated ODE nets

Aiqing Zhu, Beibei Zhu, [Tom Bertalan](#), Yifa Tang, Ioannis Kevrekidis

*Under Review*  
*arXiv:2303.17824*

### Transformations between deep neural networks

[Tom Bertalan](#), Felix Dietrich, Ioannis Kevrekidis

*Under Review*  
*arXiv:2007.05646*

### 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*

## All Publications

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### Machine Learning Approaches to Problem Well-Posedness

Tom Bertalan, George Kevrekidis, Elizaveta Rebrova, Siddhartha Mishra, Yannis Kevrekidis

*In Preparation*

### 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

*Under Review*  
*arXiv:2305.03257*

### Implementation and (Inverse Modified) Error Analysis for implicitly-templated ODE nets

Aiqing Zhu, Beibei Zhu, Tom Bertalan, Yifa Tang, Ioannis Kevrekidis

*Under Review*  
*arXiv:2303.17824*

### Transformations between deep neural networks

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*Under Review*  
*arXiv:2007.05646*

### 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*

### Some of the variables, some of the parameters, some of the times, with some things known: Identification with partial information

Saurabh Malani, Tom Bertalan, Tianqi Cui, Michael Betenbaugh, Jose L. Avalos, Ioannis Kevrekidis

2023  
*Comp. & Chem. Engr.*

### Learning effective stochastic differential equations from microscopic simulations: linking stochastic numerics to deep learning

Felix Dietrich, Alexei Makeev, George Kevrekidis, Nikolaos Evangelou, Tom Bertalan, Sebastian Reich, Ioannis Kevrekidis

2023  
*Chaos*

### Learning emergent PDEs in a learned emergent space

Felix Kemeth, Tom Bertalan, Thomas Thiem, Seungjoon Moon, Carlo Laing, Ioannis Kevrekidis

2022  
*Nature Comm.*

### Personalized Algorithm Generation: A Case Study in Meta-Learning ODE Integrators

Y. Guo, Felix Dietrich, Tom Bertalan, D. T. Doncevic, M. Dahmen, Ioannis Kevrekidis, Qianxiao Li

2022  
*SIAM J. Sci. Comp.*

### Initializing LSTM internal states via manifold learning

Felix Kemeth, Tom Bertalan, Nikolaos Evangelou, Tianqi Cui, Saurabh Malfani, Ioannis Kevrekidis

2021  
*Chaos*

### Development of closures for coarse-scale modeling of multiphase and free surface flows using machine learning

Cristina Linares, Tom Bertalan, Eleni Koronaki, Jicai Lu, Gretar Tryggvason, Ioannis Kevrekidis

2021  
*APS Bulletin*

### Global and local reduced models for interacting, heterogeneous agents

Thomas Thiem, Felix Kemeth, Tom Bertalan, Carlo Liang, 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*

### Emergent spaces for coupled oscillators

Thomas Thiem, Mahdi Kooshkbaghi, Tom Bertalan, Carol Laing, Ioannis Kevrekidis

2020  
*Front. in Comp. Neuro.*

### On Learning Hamiltonian Systems from Data

Tom Bertalan, Felix Dietrich, Igor Mezic, and Ioannis Kevrekidis

2019  
*Chaos*

### An Emergent Space for Distributed Data with Hidden Internal Order through Manifold Learning

Felix Kemeth, Sindre Haugland, Felix Dietrich, Tom Bertalan, Kevin Höhle, Qianxiao Li, Erik Bollt, Ronen Talmon, Katharina Krischer, and Ioannis Kevrekidis

2017  
*IEEE Access*

### Coarse-grained descriptions of dynamics for networks with both intrinsic and structural heterogeneities

Tom Bertalan, Yan Wu, Carlo Laing, C. William Gear, and Ioannis Kevrekidis.

2017  
*Front. in Comp. Neuro.*

### Dimension reduction in heterogeneous neural networks: Generalized Polynomial Chaos (gPC) and ANalysis-Of-Variance (ANOVA)

Minseok Choi, Tom Bertalan, Carlo Laing, and Ioannis Kevrekidis.

2016  
*Euro. Phys. J., Special Topics*

## OpenMG: a new multigrid implementation in Python

Tom Bertalan, Akand Islam, Roger Sidje, and Eric Carlson

2014

*Num. Lin. Alg. with App.*

## Presentations

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### **Certified Invertibility in Neural Networks via Mixed-Integer Programming**

Tianqi Cui, [Tom Bertalan](#), George J. Pappas, Manfred Morari, Ioannis Kevrekidis, Mahyar Fazlyab

2023  
*Learning for Dyn. Sys.*

### **Coarse-grained and emergent distributed-parameter systems from data**

Hassan Arbabi, Felix Kemeth, [Tom Bertalan](#), Ioannis Kevrekidis

2021  
*American Control Conf.*

### **Data-driven model reduction and discovery**

Thomas Thiem, [Tom Bertalan](#), Felix Kemeth, Yorgos Psarellis, Ioannis Kevrekidis

2020  
*AIChE*

### **Dynamical-systems-guided learning of PDEs from data**

Hassan Arbabi, [Tom Bertalan](#), Anthony Roberts, Ioannis Kevrekidis

2020  
*AIChE*

### **On the data-driven discovery and calibration of closures**

Seungjoon Lee, Yorgos Psarellis, Constantinos Siettos, [Tom Bertalan](#), Daniel Amchin, Tapomoy Bhattacharjee, Sujit Datta, Ioannis Kevrekidis

2020  
*AIChE*

### **Connections between residual networks and explicit numerical integrators, and applications to identification of noninvertible dynamical systems**

Tianqi Cui, [Tom Bertalan](#), Yorgos Psarellis, Ioannis Kevrekidis

2020  
*AIChE*

### **Neural network approach to reduced order modeling of multiphase flows**

Cristina Linares, [Tom Bertalan](#), Seungjoon Lee, Jicai Lu, Gretar Tryggvason, Ioannis Kevrekidis

2020  
*APS Div. of Fluid Dyn.*

### **PDE+PINN: Learning and Solving a PDE at the Same Time**

[Tom Bertalan](#), Felix Kemeth, Tianqi Cui, Ioannis Kevrekidis

2020  
*AIChE*

### **Learning Partial Differential Equations from Discrete Space Time Data: Convolutional and Recurrent Networks, and Their Relations to Traditional Numerical Methods**

[Tom Bertalan](#), Felix Dietrich, Thomas Thiem, Rob Farber, Ioannis Kevrekidis, Anthony Roberts

2019  
*AIChE*

### **Recurrent Neural Networks, Numerical Integrators and Nonlinear System Identification**

[Tom Bertalan](#), Rob Farber, Thomas Thiem, Felix Dietrich, Ioannis Kevrekidis

2018  
*AIChE*

### **Coarse-Scale PDEs from Microscopic Observations Via Machine Learning**

Seungjoon Lee, Mahdi Kooshkbaghi, Constantinos Siettos, [Tom Bertalan](#), and Ioannis Kevrekidis

2019  
*AIChE*

### **When Have Two Networks Learned the Same Task? Data-Driven Transformations between System Representations**

[Tom Bertalan](#), Felix Dietrich, Thomas Thiem, Ioannis Kevrekidis

2019  
*AIChE*

### **Coarse modeling of circadian rhythms in heterogeneous neural networks**

[Tom Bertalan](#), C. William Gear, Yannis G. Kevrekidis, Michael Henson, Erik Herzog, and Carlo Laing

2017; 2016  
*Dyn. Days 2017; AIChE*

### **Coarse-graining of heterogeneous neural dynamics**

[Tom Bertalan](#), Minseok Choi, Carlo Laing, Ioannis Kevrekidis

2015  
*AIChE*

### **Heterogeneity and reduction for complex network dynamics**

Ioannis Kevrekidis, Alexander Holiday, [Tom Bertalan](#), and Carlo Laing

2014  
*AIChE*

### **Polynomial representations of populations with multiple heterogeneities**

[Tom Bertalan](#), Yan Wu, Brianna Hnath, and Yannis Kevrekidis

2014  
*Princeton Grad. Student Symp.*

### **Coarse-graining Network Dynamics**

Alexander Holiday and [Tom Bertalan](#)

2013  
*Network Front.*

### **nSpyres: an open-source, Python-based framework for simulation of flow through porous media**

Eric Carlson, Akand Islam, Francis Dumkwu, and [Tom Bertalan](#)

2012  
*Interpore 2012*

### **OpenMG: a new multigrid implementation in Python**

[Tom Bertalan](#), Akand Islam, Roger Sidje, and Eric Carlson

2012  
*Proc. 11<sup>th</sup> Python in Sci. Conf.*

### **ESIM: a framework for simulation of dominance hierarchy formation in small animal groups**

[Tom Bertalan](#) and Ryan Earley

2012  
*UA Hon. Undergr. Res. Conf.*

# An open-source computing cluster for virtual experiments with variable parameters

Tom Bertalan and Eric Carlson

2011  
UA Hon. Undergr. Res. Conf.

## References

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### **Yannis Kevrekidis**

Bloomberg Distinguished Professor

### **Stas Shvartsman**

Professor of Molecular Biology

### **Ryan Earley**

Associate Professor of Biological sciences

### **Johns Hopkins University**

*ChBE, Applied Mathematics and Statistics*

### **Princeton University**

*ChBE, the Lewis-Sigler Institute for Integrative Genomics*

### **The University of Alabama**

*Biological Sciences*