Varad Deshmukh

CONTACT INFORMATION

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RESEARCH INTERESTS

Deep Learning, Topological Data Analysis, Space Weather and Dynamical Systems

EDUCATION

University of Colorado, Boulder, Boulder, CO

Ph.D., Computer Science — August 2017–June 2022 (Expected)

- Advisors: Prof. Elizabeth Bradley, Prof. James Meiss and Dr. Thomas Berger
- GPA - 3.93/4.0
- Courses: Deep Learning, Networks Analysis and Modeling, Chaotic Dynamics.

University of California, Santa Barbara, Santa Barbara, CA

M.S., Computer Science — September 2011–April 2013

- Topic: *Matrix Reduction Techniques for Ordinary Differential Equations in Chemical Systems*
- Advisors: Prof. John Gilbert and Prof. Linda Petzold
- GPA - 3.9/4.0

College of Engineering, Pune, Pune, India

B.Tech., Computer Engineering — June 2007–June 2011

- Project Topic: *Techniques for Benchmarking of Computer Micro-Architecture*
- Advisors: Dr. Shrirang Karandikar and Mr. Shirish Gosavi
- GPA - 9.2/10.0

PUBLICATIONS

1. **Varad Deshmukh**, Elizabeth Bradley, Joshua Garland & James Meiss. Towards Automatic Extraction and Characterization of Scaling Regions. (*In Preparation*)
2. **Varad Deshmukh**, Natasha Flyer & Thomas Berger. A Hybrid Deep Learning Approach for Reducing False Positives in the Solar Flare Prediction Problem. (*In Preparation*)
3. **Varad Deshmukh**, Srinivas Baskar, Thomas Berger, James D. Meiss & Elizabeth Bradley. Using Computational Topology and Machine Learning for Solar Flare Prediction. (*In Preparation*)
4. **Varad Deshmukh**, Thomas Berger, Elizabeth Bradley & James D. Meiss. 2020. Shape-based Feature Engineering as an Effective Methodology for Machine Learning-based Solar Eruption Prediction. *Innovative Applications of Artificial Intelligence 2021.*
5. **Varad Deshmukh**, Elizabeth Bradley, Joshua Garland, and James D. Meiss. A Curvature-Based Heuristic for Delay Reconstruction. *Chaos: An Interdisciplinary Journal of Nonlinear Science* 30 (6), 12.
6. **Deshmukh V**, Berger TE, Bradley E & Meiss JD. 2020. Leveraging the mathematics of shape for solar magnetic eruption prediction. *J. Space Weather Space Clim.* **10**, 13.
7. **Varad Deshmukh**, Nishchay Mhatre and Shrirang Karandikar. "FIRA - A novel method for benchmarking the cache hierarchy." *COMPUTE 2012 : 1^{st} Annual Conference of ACM Pune Professional Chapter, Pune*, 2012.
8. **Varad Deshmukh**, Nishchay Mhatre and Shrirang Karandikar. "Techniques for Benchmarking of CPU Micro-Architecture for Performance Evaluation." *18^{th} Annual International Conference on High Performance Computing: Student Research Symposium, Bangalore*, 2011.
9. Nishchay Mhatre, Mohit Karve, Rahul Bedarkar, Shravan Aras, Sanjeev MK, Gautam Akiwate, **Varad Deshmukh**. "Modular Generic Low Cost On Board Computer System for Nano/Pico Satellites." *62^{nd} International Astronautical Congress, Cape Town*, 2010.

Selected Talks

1. Leveraging Topological Data Analysis and Deep Learning for Solar Flare Prediction.
   Varad Deshmukh, Elizabeth Bradley, James Meiss and Thomas Berger.
   - *Innovative Applications of Artificial Intelligence Conference,* February 2021.
   - *American Geophysical Union,* December 2020.
   - *Stanford Solar Seminar, Palo Alto, CA,* September 2020.
   - *American Geophysical Union, San Francisco, CA,* December 2019.
   - *Machine Learning in Heliophysics, Amsterdam, Netherlands,* September 2019.
2. Using curvature to understand the structure of dynamics.
   Varad Deshmukh, Elizabeth Bradley, Joshua Garland and James Meiss.
   - *SIAM Dynamical Systems, Snowbird, UT, May 2019.*
   - *Santa Fe Institute, Santa Fe, NM,* April 2019. (Invited)
3. **Deshmukh V**, Bradley E and Bagenal F. Nonlinear time-series analysis of solar-wind data from Voyager 2 and New Horizons, *Voyager/New Horizons Workshop, 2018; John Hopkins University Applied Physics Laboratory, Laurel, MD.*

Awards & Achievements

- Outstanding Researcher Award in the Department of Computer Science, University of Colorado Boulder
- Co-I for NASA O2R Grant 80NSSC20K1404 (496,260$): *"Application of Topological Data Analysis and Computational Geometry to Recurrent Deep Learning Algorithms for Solar Eruption Prediction"*; 2020-2022. PI: Dr. Thomas Berger
- NSF Award AGS 2001670 (792,387$): *"Harnessing the Data Revolution in Space Physics: Topological Data Analysis and Deep Learning for Improved Solar Eruption Prediction"*; 2020-2023. PI: Prof. Liz Bradley[1]
- Dean Graduate Assistantship Award at University of Colorado, Boulder, 2017
- Best Paper Award at the 18^{th} Annual International Conference on High Performance Computing, Bangalore: Student Research Symposium, 2011
- Computing Division Winner at the Jed-I Project Challenge, Indian Institute of Science, 2011 (1500$)
- Indian Institute of Technology - Joint Entrance Examination, 2007 – All India Rank 1503

Inventions

1. **Varad Deshmukh**, Stephen Muckle, Bryan Huntsman, Veena Sambasivan, Srivatsa Vaddagiri. 2016. Temporary frequency adjustment of mobile device processors based on task migration. U.S. Patent 9,400,518, filed October 10, 2013, and issued July 26, 2016.

Research Experience

Extracting and Characterizing Scaling Regions — *June 2020 – Present*

- Developed a novel method for characterizing scaling regions for various dynamical systems applications such as computing Lyapunov exponents and the correlation dimension. This method may be easily generalized to applications outside dynamical systems like estimating the exponents of super-linear scaling and power-law functions.

Applications of Topological Data Analysis (TDA) — *June 2018 – Present*

- Featurizing sunspot magnetic field data using TDA to improve ML-based solar flare forecasting. Using various ML techniques, I demonstrated that TDA-based features perform better than the expert-suggested physics-based ones. I am currently investigating techniques for effectively featurizing persistence diagrams that improves ML accuracy.
- Characterizing food distribution in honeybees. Using TDA together with a moving average changepoint detection algorithm, our method automatically identifies three phases of food distribution from experimental data: an initial low clustering amongst the bees prior to food exchange, a high clustering food exchange phase, and a final low clustering final phase post-exchange. This analysis will be used to understand interesting scientific questons, for example, the dependence of food distribution time on the bee density. I am also using TDA to validate home-grown agent-based models designed to mimic the behavior of honeybees as observed in experiments.

[1] As a graduate student, I worked closely with the PIs on developing ideas, preparing the literature survey, conducting initial experiments and writing the proposal.

Machine Learning and Heliophysics *June 2018 – Present*

- Processing sunspot evolution videos using deep learning to predict a solar flare occurrence.
- Developing deep learning models like MLPs, CNNs, LSTMs and ERTs for solar flare forecasting.
- Using persistent homology for extracting novel features from sunspot images to improve forecasting.
- Employing Gaussian Process-based hyperparameter tuning for optimizing prediction models.
- Using dimensionality reduction methods such as PCA and autoencoder variants for sunspot image classification and improving flare forecasting.

Application of Curvature to Dynamical Systems *January 2018 – June 2020*

- Applying local and aggregated curvature to understand the behavior of dynamical systems such as identification of unstable hyperbolic equilibrium points. Demonstrated applications of aggregated curvature in delay co-ordinate embedding: the process of reconstructing a higher dimensional dynamical system from scalar time-series data.
- Developed a novel curvature-based heuristic to estimate the embedding delay that generates better reconstructions than average mutual information-based heuristic — the standard technique used in literature .

Predicting the Dynamics of Operating Systems *June 2017 – June 2018*

- Proposed a method to predicting the task load on a CPU core in a multi-core system using non-linear time-series analysis to improve system performance. Two NSF proposals were submitted as part of this project.

Matrix Reduction Techniques for Ordinary Differential Equations *June 2012 – April 2013*

- Developed model order reduction techniques to speed up numerical simulation of ODEs.
- Combined novel threshold-based Jacobian reduction techniques with a graph-based sparse matrix solver to optimize the linear solver procedure of implicit ODE schemes.

Swayam – Pico-satellite Design *May 2008 – May 2011*

- Control Systems team lead for design and construction of a communication pico-satellite for enabling communication between ships and ground stations, launched by the Indian Space Research Organization in June, 2016.
- Developed models for satellite orbit, geomagnetic field, and passive magnetic control system to study satellite dynamics post-launch. The passive magnetic control system is the first of its kind for Indian satellites.
- Project web-site : `http://www.coep.org.in/csat/`

Industry Experience

National Renewable Energy Laboratory, Golden, CO

Intern *May 2018 – August 2018*

International Business Machines, Austin, TX

Hardware Performance Analyst *August 2015 – June 2017*

Qualcomm Inc., San Diego, CA

Software Engineer *June 2013 – August 2015*

Qualcomm Inc., San Diego, CA

Engineering Intern *June 2012 – September 2012*

Tata Computational Research Laboratories, Pune, India

Intern *May 2010 – August 2010*

Teaching Experience

Teaching Assistant Spring 2020
CSCI 2270 - Data Structures
University of Colorado, Boulder

Teaching Assistant Fall 2017
CSCI 3104 - Algorithms
University of Colorado, Boulder

Teaching Assistant Winter 2013
CS 140 - Parallel Scientific Computing
University of California, Santa Barbara

Reader Spring 2012
CS 240 - Applied Parallel Computing
University of California, Santa Barbara

Mentoring Experience

B.S. Thesis, Computer Science Spring 2021
Theo Lincke
Project: Featurizing Persistence Diagrams of Sunspot Magnetograms for ML-based Solar Flare Prediction.

M.S. Independent Study, Computer Science Fall 2020 — Spring 2021
Srinivas Baskar
Project: ML-based Evaluation of Shape-based Feature Engineering Approach for Solar Flare Prediction.

Discovery Learning Apperenticeship Program Fall 2020 — Spring 2021
Samuel Razumovskiy
Project: An Autoencoder Approach to Classifying Active Regions.

LASP REU Summer Internship Program Summer 2020
Erika Bartosiewicz
Project: Dataset Preparation for Machine Learning-based Active Region Classification.

LASP REU Summer Internship Program Summer 2019
Sara Housseal
Project: Active Region Magnetic Field Compression and Reconstruction using Principal Component Analysis.

Skills

Programming Languages
C, C++, Python, Java, Bash shell scripting, MATLAB, R

Tools and Libraries
PYTORCH, SCIKIT-LEARN, ASTROPY, PHETS, GUDHI, MPI, CUDA, CILK++