


Vaibhav Karve, PhD

Senior Data Scientist
Data Science Directorate
SimSpace Corporation

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Research Interests

data science, computational graph theory, topology, boolean satisfiability, logic, algorithms, formal math, type theory
interactive theorem proving

Education

PhD in Mathematics

University of Illinois at Urbana-Champaign

Integrated BS-MS in Mathematics

Indian Institute of Science Education and Research – Kolkata
Recipient of the *Director's gold medal*

Publications

- **V. Karve**, A.N. Hirani.
GraphSAT – a decision problem connecting satisfiability and graph theory (2019), [arXiv: 1905.02754](https://arxiv.org/abs/1905.02754).
- **V. Karve**, D. Yager, M. Abolhelm, D.B. Work, R.B. Sowers.
Seasonal Disorder in Urban Traffic Patterns: a Low Rank Analysis,
Journal of Big Data Analytics in Transportation (2020), [doi.org/ 10.1007/s11464-020-07500-0](https://doi.org/10.1007/s11464-020-07500-0).
- **V. Karve**, A.N. Hirani.
The complete set of minimal simple graphs that support unsatisfiable 3-CNFs
Discrete Applied Mathematics (2020), [doi.org/ 10.1016/j.dam.2020.05.008](https://doi.org/10.1016/j.dam.2020.05.008).
- Y. Wu, G. Shindnes, **V. Karve**, D. Yager, D.B. Work, A. Chakraborty, R.B. Sowers.
Congestion Barcodes: Exploring the Topology of Urban Congestion Using Persistent Homology (2020), [arXiv: 2005.02754](https://arxiv.org/abs/2005.02754).

Developed Software

graphsat: A python package that recognizes clauses, Cnfs, graphs, hypergraphs, and multi-hypergraphs. The package implements local graph-rewriting, graph-satchecking, calculation of graph disjunctions, as well as checking of new reduction rules. It was created as a companion software to my PhD thesis. GitHub: [/vaibhavkarve/graphsat](https://github.com/vaibhavkarve/graphsat). [doi.org/ 10.5281/zenodo.4281111](https://doi.org/10.5281/zenodo.4281111).

multihypergraph: A python package for graph theory that supports looped- multi- and hyperedges. PyPI: [/multihypergraph](https://pypi.org/project/multihypergraph/)

Model theory in lean: A model theory implementation in the Lean theorem prover. Joint work with E. Blanchard, S. Harman, P. Hieronymi, N. Ravi, J. Schargorodsky, K. Thompson, N. Wultraat, T. Xu, F. Zhao. GitHub: [/vaibhavkarve/igl](https://github.com/vaibhavkarve/igl)

Programming Skills

Languages

Python, Lean theorem prover, SageMath, Octave, ELisp, Bash, Make

Software

L^AT_EX, plain T_EX, CoCalc, Docker, Emacs, Git, GitHub/GitLab, Jupyter, Gurobi (linear program solver), XPPaut (differential equation numerical solver)

R E

Senior Data Scientist at SimSpace Corporation

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Project Lead

Data science projects in Cybersecurity and CyberRisk

Data Science Directorate, SimSpace Corporation, Boston MA

PhD Thesis

Graphical structure of unsatisfiable Boolean formulae 

Advisor: Dr. Anil Hirani

University of Illinois at Urbana-Champaign

- Fall 2017: funded by the David G. Bourgin fellowship.
- Defined a translation map from boolean satisfiability instances into multi-hyper-graphs.
- Wrote a python package that computes CNFs (sentences in conjunctive normal form) as well as multi-hyper-graphs.
- Attempting a forbidden-graph characterization for satisfiability.

Graduate Research Assistant

Fall

Forbidden graph characterization for satisfiability

Advisor: Dr. Anil Hirani

University of Illinois at Urbana-Champaign

- Used forbidden-graph characterization to demonstrate a finite obstruction set for satisfiability.

Summer Graduate School

July

Invited to Representations of High Dimensional Data summer graduate school

Mathematical Sciences Research Institute (MSRI) in Berkeley, California

Graduate Research Assistant

Summer 2016, Spring 2017

Non-negative matrix factorization of New York taxi traffic

Advisor: Dr. Richard Sowers and Dr. Daniel Work

University of Illinois at Urbana-Champaign

- Analyzed taxi traffic data from New York city with special focus towards compression and estimation.
- Used Sparse Non-negative Matrix Factorization to extract some of the most popular traffic trends in New York.
- Gained new insights into traffic dynamics, with a view towards aiding urban planning and extreme-event predictive algorithms.

NSF Program for Interdisciplinary and Industrial Internships at Illinois (PI) Intern

Summer 2015, Summer 2016

Recognizing patterns in New York taxi traffic

Advisor: Dr. Richard Sowers and Dr. Daniel Work

Funded by NSF, University of Illinois at Urbana-Champaign

- Analyzed taxi traffic data from New York city.
- Applied Persistent Homology tools to generate bar-codes that can characterize the traffic dataset.

MS thesis

Classification of Stable Exterior Forms

Advisor: Dr. Saugata Bandyopadhyay

Indian Institute of Science Education and Research – Kolkata

- A complete classification of all stable exterior forms was sought over both the real and complex fields. This involved finding the orbits, stabilizers and normal forms for each case, under the action of $GL(V)$ through pullback.

Canada Mitacs intern

Summer 2014

Unitary Representations of Super-Conformal Algebra

Advisor: Dr. Hadi Salmasian
University of Ottawa

- Construction of the Super-Virasoro algebra, which arises as a \mathbb{Z} gradation of the central extension of a Lie algebra of differential operators, called the Witt algebra, was studied. This algebra arises naturally from the calculations of string theory.
- The unitary representation for the Super-Conformal current algebra, seen as a semi-direct product of the Super-Virasoro and the Super-Loop algebras was found.

IISER research intern

Mathematical Modeling of Calcium Ion Oscillations due to Membrane Fluxes in Pancreatic Cells

Advisor: Dr. Pranay Goel

Indian Institute of Science Education and Research – Pune

- A minimal model was developed, as a variation of the class- Li-Rinzel model to explain the anomalously *slower* oscillations observed in pancreatic cells. The numerical integration software XPPaut was employed for solving the differential equations involved and generating the bifurcation diagrams needed.
- The model was able to reproduce all experimental data on the reaction of these cells to CPA, oleate and EGTA accurately.
- This work was in collaboration with Dr. Arthur Sherman and Dr. Les Satin.

IISER research intern

Summer

Mathematical Modeling of One-Carbon and Glutathione Cycle

Advisor: Dr. Pranay Goel

Indian Institute of Science Education and Research – Pune

- The literature on existing models of the glutathione cycle was studied and the equations were successfully simplified, making them more tractable for any future work on this system.

T M

Graduate Teaching Assistant – Merit Program for Emerging Scholars

Fall , Spring , Fall , Spring

Calculus I, II, III and Differential Equations

University of Illinois at Urbana-Champaign

- The Merit Program for Emerging Scholars targets students with high potential who are members of groups, such as ethnic minorities and women, who tend to be underrepresented in the areas of science, mathematics and engineering.
- Taught in active-learning formats.

Teaching Assistant

April - ,

INMAS : Workshop on Modeling and Optimization (online)

Workshop instructor: Alexander Estes

- INMAS provides high quality training and internship experiences that broaden career opportunities for students in the Mathematical Sciences by bringing powerful computational and modeling tools to bear on industry's most pressing problems.
- The workshop introduced optimization models and methods for solving linear programming and mixed integer linear programming using the Gurobi optimization solver.

Illinois Geometry Lab Mentor

Spring , Fall , -

University of Illinois at Urbana-Champaign

- The Illinois Geometry Lab at UIUC aims to enhance and support undergraduate research within the department and to engage local, state and national communities through outreach.
- : Led a team of undergraduates in a research project titled *Theorem proving in Lean*. The project aims to formalize model theory in Lean.
GitHub: [/vaibhavkarve/igl](https://github.com/vaibhavkarve/igl)
- - : Led a team of undergraduates in a research project that visualized urban traffic patterns temporally and spatially, using matrix factorization algorithms as well as persistent homology.

IGL–UniHigh Summer Research PI

Summer

Interactive theorem proving in Lean: formalizing Euclidean and Hilbertian geometry

Illinois Geometry Lab, University of Illinois at Urbana-Champaign

- Led a week summer research project with high-school seniors.

- We formalized Euclid’s and Hilbert’s axioms in the Lean interactive theorem prover. GitHub: [/vaibhavkarve/leanteach](#) .

Graduate Teaching Assistant
 Computational Mathematics
 University of Illinois at Urbana-Champaign

Spring
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 Spring

- Conceptualized and designed the course with Dr. Anil Hirani.
- Course utilizes innovative teaching platforms like CoCalc to teach programming in Python and SageMath to undergraduates.
- Topics covered include network and graph algorithms, topological data analysis, computer algebra and cryptography algorithms.

Graduate Teaching Assistant
 Calculus III
 University of Illinois at Urbana-Champaign

Fall
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 Spring

- Taught in active-learning, discussion-based formats.

Summer Illinois Math Camp – instructor and course designer
 Classical Constructions: Learn to draw algebra
 University of Illinois at Urbana-Champaign

Summer

- Designed and taught a week-long course for th through th grade students.
- Course description: What can we do with a compass and a straightedge? These simple tools can be used to create shapes, do arithmetic and prove fun facts about geometry. This course taught students geometry as the ancient Greeks saw it, using only tools that were available then.

Undergraduate Teaching Assistant
 Real Analysis, Calculus I and II
 Indian Institute of Science Education and Research – Kolkata

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F

David G. Bourgin Mathematics Fellowship
 Department of Mathematics, University of Illinois at Urbana-Champaign

Fall

Gene H. Golub Summer Research Fellowship
 Department of Mathematics, University of Illinois at Urbana-Champaign

Summer

Innovation in Science Pursuit for Inspired Research (INSPIRE) Fellowship
 Awarded by Department of Science & Technology, Government of India

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A

Departmental TA Instructional Award
 Department of Mathematics, University of Illinois at Urbana-Champaign

Honorable Mention – Image of Research Competition
 Graduate College, University of Illinois at Urbana-Champaign
 Awarded for visualizing Kaprekar’s process

Listed on *Teachers Ranked as Excellent*
 Center for Innovation in Teaching and Learning, University of Illinois at Urbana-Champaign

Fall
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 Spring
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 Fall
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 Spring
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 Fall
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 Spring

IGL Research Award*
 Illinois Geometry Lab, Department of Mathematics, University of Illinois at Urbana-Champaign
 *awarded to Manhattan Traic IGL research team

Fall

People’s Choice Award

Research Live! Competition, University of Illinois at Urbana-Champaign

Director's Gold Medal

Indian Institute of Science Education and Research – Kolkata

C C

Dramatics

Active member of the dramatics club at IISER Kolkata, having conceptualized, scripted, acted in and directed over a dozen plays.