

# Topological Data Analysis and Machine Learning Theory

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## 1 Persistent homology

Perhaps the most important idea in applied algebraic topology is persistence. It is a response to the first difficulty that one encounters in attempting to assign topological invariants to statistical data sets: that the topology is not robust and has a sensitive dependence on the length scale at which the data set is being considered. The solution is to calculate the topology (specifically the homology) at all scales simultaneously, and to encode the relationship between the different scales in an algebraic invariant called the persistence diagram. The effective algorithm for doing so was published in 2000 by Edelsbrunner, Letscher and Zomorodian [2]. Topological data analysis would not be possible without this tool.

Since then, persistence has been developed and understood quite extensively. Cohen-Steiner, Edelsbrunner and Harer [3] proved the important (and nontrivial) theorem that the persistence diagram is stable under perturbations of the initial data. Zomorodian and Carlsson [7] studied persistence algebraically, identifying the points of the persistence diagram with indecomposable summands of a module over the polynomial ring  $k[t]$ , the monomial  $t$  representing a change of scale by a fixed increment. Generalising this approach using polynomial rings with two or more variables, they showed that the corresponding situation with two or more independent length scales is in some sense algebraically intractable, with no complete descriptive invariants available. Carlsson and de Silva [1] showed that persistence can be made to work over “non-monotone” parameters, in contrast to “monotone” parameters such as length scale; this is known as zigzag persistence. Bubenik and Scott [4] have described and studied persistence in terms of category theory.

**Measured view.** In becoming familiar with the literature on persistence, one quickly realises that the existing mathematical foundations are dependent on certain strong finiteness assumptions. For instance, one can do persistence on the sublevelsets of a function on a compact manifold, but it is usually assumed that the function be a Morse function. This ensures that the resulting persistent data is finite: each sublevelset has finite-dimensional homology, and there are only finitely many essentially distinct levels, separated by the critical points. In computational terms, this is a perfectly natural assumption (a computer can only handle finite data), but for some of the theoretical work this assumption is

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## **Topological Data Analysis And Machine Learning Theory:**

**Topology in Real-World Machine Learning and Data Analysis** Kathryn Hess,Frédéric Chazal,Umberto Lupo,2022-11-07

**Topological Data Analysis with Applications** Gunnar Carlsson,Mikael Vejdemo-Johansson,2021-12-16 The continued and dramatic rise in the size of data sets has meant that new methods are required to model and analyze them This timely account introduces topological data analysis TDA a method for modeling data by geometric objects namely graphs and their higher dimensional versions simplicial complexes The authors outline the necessary background material on topology and data philosophy for newcomers while more complex concepts are highlighted for advanced learners The book covers all the main TDA techniques including persistent homology cohomology and Mapper The final section focuses on the diverse applications of TDA examining a number of case studies drawn from monitoring the progression of infectious diseases to the study of motion capture data Mathematicians moving into data science as well as data scientists or computer scientists seeking to understand this new area will appreciate this self contained resource which explains the underlying technology and how it can be used

Deep Learning Theory and Applications Donatello Conte,Ana Fred,Oleg Gusikhin,Carlo Sansone,2023-07-30 This book consists of the refereed proceedings of the 4th International Conference on Deep Learning Theory and Applications DeLTA 2023 held in Rome Italy from 13 to 14 July 2023 The 9 full papers and 22 short papers presented were thoroughly reviewed and selected from the 42 qualified submissions The scope of the conference includes such topics as models and algorithms machine learning big data analytics computer vision applications and natural language understanding

*Advances in Soft Computing* Lourdes Martínez-Villaseñor,Roberto A. Vázquez,Gilberto Ochoa-Ruiz,2025-10-23 The two volume set LNAI 16221 and 16222 constitutes the proceedings of the 4th Mexican International Conference on Artificial Intelligence MICA 2025 held in Guanajuato Mexico November 3 2025 The 65 full papers presented in these proceedings were carefully reviewed and selected from 119 submissions The papers presented in these two volumes are organized in the following topical sections Part I Machine Learning Natural Language Processing and Neural Networks Part II Applications Pattern Recognition Computer Vision Image Processing and Bioinformatics Medical Applications

Molecular Dynamics Simulations in Statistical Physics: Theory and Applications Hiqmet Kamberaj,2020-03-20 This book presents computer simulations using molecular dynamics techniques in statistical physics with a focus on macromolecular systems The numerical methods are introduced in the form of computer algorithms and can be implemented in computers using any desired computer programming language such as Fortran 90 C C and others The book also explains how some of these numerical methods and their algorithms can be implemented in the existing computer programming software of macromolecular systems such as the CHARMM program In addition it examines a number of advanced concepts of computer simulation techniques used in statistical physics as well as biological and physical systems Discussing the molecular dynamics approach in detail to enhance readers understanding of the use of this method in

statistical physics problems it also describes the equations of motion in various statistical ensembles to mimic real world experimental conditions Intended for graduate students and research scientists working in the field of theoretical and computational biophysics physics and chemistry the book can also be used by postgraduate students of other disciplines such as applied mathematics computer sciences and bioinformatics Further offering insights into fundamental theory it as a valuable resource for expert practitioners and programmers and those new to the field

### **Foundations of Probability**

**Theory** Himadri Deshpande, 2025-02-20 Foundations of Probability Theory offers a thorough exploration of probability theory s principles methods and applications Designed for students researchers and practitioners this comprehensive guide covers both foundational concepts and advanced topics We begin with basic probability concepts including sample spaces events probability distributions and random variables progressing to advanced topics like conditional probability Bayes theorem and stochastic processes This approach lays a solid foundation for further exploration Our book balances theory and application emphasizing practical applications and real world examples We cover topics such as statistical inference estimation hypothesis testing Bayesian inference Markov chains Monte Carlo methods and more Each topic includes clear explanations illustrative examples and exercises to reinforce learning Whether you re a student building a solid understanding of probability theory a researcher exploring advanced topics or a practitioner applying probabilistic methods to solve real world problems this book is an invaluable resource We equip readers with the knowledge and tools necessary to tackle complex problems make informed decisions and explore probability theory s rich landscape with confidence

### *Deep Learning Theory*

*and Applications* Ana Fred, Allet Hadjali, Oleg Gusikhin, Carlo Sansone, 2024-08-20 The two volume set CCIS 2171 and 2172 constitutes the refereed papers from the 5th INternational Conference on Deep Learning Theory and Applications DeLTA 2024 which took place in Dijon France during July 10 11 2024 The 44 papers included in these proceedings were carefully reviewed and selected from a total of 70 submissions They focus on topics such as deep learning and big data analytics machine learning and artificial intelligence etc

### Mathematical Principles of Topological and Geometric Data Analysis

Parvaneh Joharinad, Jürgen Jost, 2023-07-29 This book explores and demonstrates how geometric tools can be used in data analysis Beginning with a systematic exposition of the mathematical prerequisites covering topics ranging from category theory to algebraic topology Riemannian geometry operator theory and network analysis it goes on to describe and analyze some of the most important machine learning techniques for dimension reduction including the different types of manifold learning and kernel methods It also develops a new notion of curvature of generalized metric spaces based on the notion of hyperconvexity which can be used for the topological representation of geometric information In recent years there has been a fascinating development concepts and methods originally created in the context of research in pure mathematics and in particular in geometry have become powerful tools in machine learning for the analysis of data The underlying reason for this is that data are typically equipped with some kind of notion of distance quantifying the differences between data points Of

course to be successfully applied the geometric tools usually need to be redefined generalized or extended appropriately Primarily aimed at mathematicians seeking an overview of the geometric concepts and methods that are useful for data analysis the book will also be of interest to researchers in machine learning and data analysis who want to see a systematic mathematical foundation of the methods that they use

**Topological Data Analysis for Scientific Visualization** Julien Tierny,2018-01-16 Combining theoretical and practical aspects of topology this book provides a comprehensive and self contained introduction to topological methods for the analysis and visualization of scientific data Theoretical concepts are presented in a painstaking but intuitive manner with numerous high quality color illustrations Key algorithms for the computation and simplification of topological data representations are described in detail and their application is carefully demonstrated in a chapter dedicated to concrete use cases With its fine balance between theory and practice Topological Data Analysis for Scientific Visualization constitutes an appealing introduction to the increasingly important topic of topological data analysis for lecturers students and researchers

[A Machine Learning Approach to a Problem in Exploratory Data Analysis](#) Jorge Muruzabal,1992

**Machine Learning and Data Mining in Pattern Recognition** ,1999

*Automation Equipment and Systems* Wen Zhe Chen,Pin Qiang Dai,Yong Lu Chen,Ding Ning Chen,Zheng Yi Jiang,2012-02-27 Selected peer reviewed papers from the 3rd international Conference on Manufacturing Science and Engineering ICMSE 2012 March 27 29 2012 Xiamen China

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**Federally Supported Mathematical Models** Gary Fromm,William L. Hamilton,Diane E. Hamilton,1975

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