

Algebraic Geometry And Statistical Learning Theory

Algebraic Geometry And Statistical Learning Theory Algebraic geometry and statistical learning theory are two seemingly disparate fields of mathematics that, upon closer examination, reveal profound interconnectedness. Algebraic geometry, traditionally rooted in the study of solutions to polynomial equations and the geometric structures they form, provides a powerful language for understanding complex algebraic structures. Statistical learning theory, on the other hand, is a cornerstone of modern data science and machine learning, offering frameworks to analyze the generalization capabilities of learning algorithms. In recent years, the intersection of these domains has garnered increasing attention, leading to novel insights into the structure of learning models, the complexity of hypothesis classes, and the geometric nature of data representations. This article explores the rich interplay between algebraic geometry and statistical learning theory, highlighting foundational concepts, key developments, and promising research directions.

Foundations of Algebraic Geometry

Basic Concepts and Definitions

Algebraic geometry studies algebraic varieties—geometric objects defined as the solutions to systems of polynomial equations over fields such as the real or complex numbers. Key concepts include:

- Affine varieties:** The set of common zeros of a collection of polynomials in affine space.
- Projective varieties:** Varieties considered within projective space, allowing for the treatment of points at infinity.
- Ideals and coordinate rings:** Algebraic structures capturing the polynomials vanishing on a variety, enabling translation between geometric and algebraic perspectives.
- Morphisms:** Structure-preserving maps between varieties that reflect geometric transformations.

Complexity and Classifications

Classifying varieties by properties such as dimension, singularity, and genus provides a way to understand their complexity and behavior. Notable classifications include:

- Smooth vs. singular varieties
- Rational, elliptic, and higher-genus varieties
- Minimal models and birational equivalences

Computational Algebraic Geometry

Advances in

algorithms and computational tools, such as Gröbner bases, have made it possible to manipulate polynomial systems efficiently. These tools facilitate:

- Solving polynomial equations numerically and symbolically
- Analyzing the structure of algebraic varieties
- Computing dimensions, intersections, and singularities

Principles of Statistical Learning Theory

Fundamental Concepts

Statistical learning theory provides a rigorous framework to analyze the ability of algorithms to learn from data. Key principles include:

- Hypothesis spaces:** Sets of functions or models that an algorithm searches over to fit data.
- Empirical risk minimization (ERM):** Choosing models that minimize error on training data.
- Generalization bounds:** Theoretical guarantees on the performance of models on unseen data.

Complexity Measures

To understand a model's capacity and prevent overfitting, various measures are used:

- VC dimension:** A measure of the capacity of a hypothesis class based on its shattering ability.
- Rademacher complexity:** Quantifies the richness of a class of functions with respect to a probability distribution.
- Covering numbers and metric entropy:** Measures of the size of a hypothesis space in terms of approximation granularity.

Learning Algorithms and Guarantees

The theory provides insights into:

- Algorithm design for classification and regression tasks¹.
- Trade-offs between model complexity and data size².
- Probabilistic bounds ensuring high-performance learning with limited data³.

3 Intersections of Algebraic Geometry and Statistical Learning Theory

Algebraic Models in Machine Learning

Many models in machine learning are inherently algebraic, or can be approximated by algebraic varieties:

- Neural networks:** Certain architectures can be viewed as parameter spaces with algebraic constraints, leading to polynomial representations of their decision boundaries.
- Polynomial classifiers:** Classification models using polynomial decision functions naturally relate to algebraic varieties.
- Tensor decompositions and algebraic varieties:** Used in deep learning and signal processing for model identifiability and complexity analysis.

Algebraic Geometry for Model Complexity and Capacity Analysis

Algebraic geometry provides tools to analyze the complexity of hypothesis spaces:

- Dimension theory:** Determines the degrees of freedom in a model class, impacting its capacity and generalization potential.
- Singularity analysis:** Identifies regions where models behave irregularly, affecting learnability and stability.
- Degree and intersection theory:** Quantify the complexity of algebraic decision boundaries, influencing sample complexity bounds.

Geometric Representation of Data and Learning Algorithms Understanding data and models via geometric and algebraic structures helps in: Visualizing high-dimensional data as algebraic varieties Designing kernels and feature maps based on algebraic invariants Analyzing the optimization landscapes of neural networks through algebraic geometry Recent Developments and Applications Algebraic Methods in Deep Learning Recent research leverages algebraic geometry to understand deep neural networks: Studying the algebraic structure of neural network decision boundaries 4 Using algebraic invariants to analyze network expressivity Applying algebraic topology and geometry to understand the loss landscape's critical points Algebraic Geometry in Model Selection and Regularization Algebraic techniques assist in: Identifying minimal models via algebraic invariants Designing regularization schemes that respect the algebraic structure of models Ensuring interpretability by constraining models to known algebraic varieties Future Directions Potential avenues for further exploration include: Developing algebraic complexity measures tailored for modern deep learning1. models Integrating algebraic geometric insights into scalable learning algorithms2. Applying algebraic topology and geometry to unsupervised and reinforcement3. learning Enhancing theoretical understanding of model generalization via algebraic4. invariants Conclusion The confluence of algebraic geometry and statistical learning theory offers a fertile ground for advancing both theoretical understanding and practical capabilities in machine learning. Algebraic geometry provides a rigorous language to describe the structure and complexity of models, while statistical learning theory offers the probabilistic framework to analyze their generalization. Together, these fields enable a deeper comprehension of the geometric nature of data and models, paving the way for more robust, interpretable, and efficient learning systems. As research continues to unfold at this intersection, it promises to yield innovative tools and insights that will shape the future of artificial intelligence and data science. QuestionAnswer How does algebraic geometry contribute to understanding the structure of machine learning models? Algebraic geometry helps analyze the geometric and algebraic properties of model parameter spaces, such as the varieties formed by the solutions to polynomial equations, enabling a deeper understanding of model identifiability, complexity, and the behavior of learning algorithms. 5 What role do algebraic varieties play in the study of neural network

decision boundaries? Neural network decision boundaries can often be characterized as algebraic varieties, allowing researchers to analyze their complexity, stability, and generalization properties using tools from algebraic geometry. Can algebraic geometry methods be used to analyze the VC dimension of certain hypothesis classes? Yes, algebraic geometry provides techniques to study the capacity of hypothesis classes, such as polynomial threshold functions, by examining the dimensions and degrees of associated algebraic varieties, leading to more precise bounds on VC dimension. How are algebraic methods applied in understanding the optimization landscapes in statistical learning? Algebraic geometry helps characterize critical points, singularities, and the topology of loss surfaces by modeling them as algebraic varieties, which can inform the design of optimization algorithms and their convergence properties. What is the significance of polynomial kernels in algebraic geometry and their impact on learning theory? Polynomial kernels map data into high-dimensional polynomial feature spaces, which can be studied as algebraic varieties; this perspective aids in understanding the expressive power of kernel methods and their capacity to fit complex functions. How does the concept of algebraic complexity influence the generalization ability of models in statistical learning? Algebraic complexity measures the degree and size of algebraic descriptions of models; lower algebraic complexity often correlates with better generalization, as simpler algebraic structures tend to be less prone to overfitting. In what ways can algebraic geometry assist in feature selection and dimensionality reduction in high-dimensional data? By analyzing the algebraic structure of data manifolds and varieties, algebraic geometry can identify intrinsic dimensions and relevant features, leading to more effective feature selection and reduced model complexity. Are there recent advances connecting algebraic geometry with deep learning theory? Yes, recent research explores the algebraic structure of deep networks, such as the algebraic varieties formed by network functions, providing insights into expressivity, identifiability, and the geometry of learned representations. How do algebraic invariants help in understanding the robustness of statistical models? Algebraic invariants, like degree and dimension of associated varieties, can quantify the stability and robustness of models under perturbations, aiding in the design of models that are resilient to noise and adversarial attacks. Can algebraic geometry techniques help in establishing

bounds on sample complexity for learning problems? Yes, algebraic geometry can be used to analyze the complexity of hypothesis classes by studying the degrees and dimensions of the corresponding algebraic varieties, leading to tighter bounds on the number of samples needed for successful learning.

Algebraic Geometry And Statistical Learning Theory 6

Algebraic Geometry and Statistical Learning Theory: An Interdisciplinary Nexus

In the rapidly evolving landscape of data science and theoretical mathematics, the intersection between algebraic geometry and statistical learning theory has emerged as a fertile ground for groundbreaking insights. Traditionally viewed as distinct disciplines—one rooted in pure mathematics, the other in applied statistics—recent developments have illuminated profound connections that hold promise for both fields. This article explores the intricate links between algebraic geometry and statistical learning theory, highlighting their synergistic potential, foundational concepts, and emerging research frontiers.

--- Introduction: Bridging Pure Mathematics and Data Science

The explosion of data-driven applications has catalyzed a paradigm shift in how we understand and model complex phenomena. Statistical learning theory (SLT) serves as the theoretical backbone of modern machine learning, providing principles for training models, understanding generalization, and assessing capacity. Meanwhile, algebraic geometry, concerned with the study of solutions to polynomial equations and their geometric structures, has historically been regarded as an abstract branch of mathematics with limited direct applications. However, the recent convergence of these fields reveals that algebraic structures underpin many models and algorithms in machine learning. For example, the geometry of parameter spaces, the algebraic nature of neural network functions, and the combinatorial complexity of model classes are all areas where algebraic geometry offers valuable insights. Conversely, techniques from statistical learning promote understanding of the complexity and feasibility of algebraic models in data analysis. This interdisciplinary dialogue not only deepens theoretical understanding but also enhances practical tools for model design, complexity control, and interpretability in machine learning.

--- Foundational Concepts in Algebraic Geometry Relevant to Learning Theory

Before delving into specific applications, it is essential to establish key algebraic geometry concepts relevant to the context of statistical learning.

Algebraic Varieties and Polynomial Equations

At the heart of algebraic

geometry lie algebraic varieties—geometric objects defined as the solution sets to systems of polynomial equations. Formally, an algebraic variety over a field (such as the real or complex numbers) is the set of all solutions to a finite set of polynomial equations:
$$V(f_1, f_2, \dots, f_m) = \{ x \in \mathbb{K}^n : f_i(x) = 0, \text{ for all } i \}$$
 These varieties encode rich geometric structures and serve as models for understanding the shape and complexity of parameter spaces in machine learning.

Algebraic Geometry And Statistical Learning Theory 7 models. Ideals, Coordinate Rings, and Morphisms

- Ideals: Sets of polynomials vanishing on a variety, capturing algebraic constraints.
- Coordinate Rings: The quotient of polynomial rings by ideals, representing functions on the variety.
- Morphisms: Structure-preserving maps between varieties, analogous to functions or transformations in model spaces.

Understanding these algebraic objects enables characterization of the geometry of model classes, especially those defined by polynomial equations.

Singularities and Dimension

- Singularities: Points where the variety fails to be smooth, often corresponding to complex behaviors or symmetries in models.
- Dimension: The number of independent parameters or degrees of freedom within an algebraic set, related to model complexity.

These concepts help quantify the capacity of models and their behavior under data constraints.

--- Connections Between Algebraic Geometry and Statistical Learning Theory

The relationship between algebraic geometry and learning theory manifests across multiple dimensions—model complexity, identifiability, parameter estimation, and generalization bounds.

Algebraic Model Classes in Machine Learning

Many models in machine learning are inherently algebraic:

- Polynomial Regression: Parameters are coefficients of polynomial functions.
- Neural Networks: Certain classes, such as shallow or polynomial-activation networks, can be viewed as algebraic varieties.
- Tensor Decompositions: The set of tensors with fixed rank form algebraic varieties known as secant varieties.
- Kernel Methods: Feature maps associated with algebraic kernel functions relate to algebraic structures.

Studying these models through algebraic geometry allows for precise characterization of their capacity, identifiability, and expressiveness.

Parameter Spaces and Geometric Complexity

The parameter space of a model often admits an algebraic structure. For instance, the set of all possible parameters that produce a particular output configuration can be represented as an algebraic variety.

Analyzing its properties—dimension, singularities, Algebraic Geometry And Statistical Learning Theory 8 irreducibility—can inform:

- Model Capacity: Variations in the dimension relate to the degrees of freedom.
- Identifiability: Singularities may correspond to parameters that produce indistinguishable outputs.
- Optimization Landscape: Algebraic geometry insights can reveal the structure of loss surfaces.

Algebraic Geometry in Understanding Generalization and Capacity Classical capacity measures like VC dimension have algebraic counterparts:

- Algebraic Complexity: The degree and dimension of the defining polynomials influence the model's capacity.
- Bounding Generalization Error: Geometric invariants can be employed to derive bounds based on the algebraic complexity of the hypothesis class.

Recent research has leveraged these concepts to develop algebraic analogs of classical capacity measures, providing a more nuanced understanding of how model geometry influences learning performance. --- Recent Advances and Applications The interface of algebraic geometry and statistical learning has seen several notable developments.

Algebraic Geometric Methods in Neural Network Analysis Researchers have modeled neural networks as algebraic functions, analyzing the algebraic variety of functions realizable by a given network architecture. Key findings include:

- Expressive Power: Degree and dimension of the associated variety correspond to the network's capacity.
- Identifiability and Parameter Recovery: Singularities in the variety can signal issues in uniquely recovering parameters from outputs.
- Training Dynamics: Algebraic geometry tools help understand the structure of local minima and saddle points.

Tensor Decomposition and Algebraic Geometry Tensor methods underpin many modern applications, from recommender systems to signal processing. The set of tensors of fixed rank forms an algebraic variety called a secant variety. Understanding its structure yields insights into:

- Model Identifiability: Conditions under which tensor decompositions are unique.
- Complexity of Learning: Degrees and dimensions inform the difficulty of fitting tensor models.
- Algorithmic Design: Geometric properties guide the development of efficient algorithms.

Algebraic Geometry in Kernel Methods and Feature Spaces Some kernel functions induce feature spaces with algebraic structures, enabling the use of algebraic geometry to study their properties. For example:

- Algebraic Kernels: Those Algebraic Geometry And Statistical Learning Theory 9 associated with polynomial or rational functions relate to

algebraic varieties. – Feature Space Geometry: Analyzing the algebraic structure helps understand the capacity and generalization behavior of kernel methods. --- Challenges and Future Directions Despite promising progress, integrating algebraic geometry fully into statistical learning theory faces notable challenges: – Computational Complexity: Many algebraic geometric computations are NP-hard or infeasible for high-dimensional models. – Extension to Noisy Data: Algebraic models are inherently idealized; real-world data often introduce noise, complicating the geometric picture. – Bridging Theory and Practice: Translating geometric insights into scalable algorithms remains an ongoing effort. Future research directions include: – Developing efficient algorithms for algebraic model analysis. – Extending algebraic geometric frameworks to probabilistic and noisy settings. – Applying algebraic tools to deep learning architectures for interpretability and robustness. – Formalizing capacity measures based on algebraic invariants. --- Conclusion: A Promising Interdisciplinary Frontier The synergy between algebraic geometry and statistical learning theory offers a compelling avenue for advancing both theoretical understanding and practical capabilities in machine learning. By revealing the geometric and algebraic structures underlying models, researchers can better analyze capacity, interpretability, and generalization—core concerns in the age of complex, high-dimensional data. As computational methods improve and theoretical frameworks mature, the integration of these disciplines promises to unlock new paradigms in model design, analysis, and optimization. Embracing algebraic geometry as a toolset for understanding the geometry of learning models could herald a new era of mathematically principled, interpretable, and efficient machine learning systems. --- References

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--- The convergence of algebraic geometry and statistical learning theory is poised to

redefine our understanding of complex models and their capacities, pushing the boundaries of what machine learning can achieve through rigorous mathematical insights. algebraic geometry, statistical learning theory, machine learning, polynomial equations, model complexity, geometric data analysis, kernel methods, algebraic varieties, Algebraic Geometry And Statistical Learning Theory 10 generalization bounds, data modeling

Differential Geometry in Statistical Inference Geometry and Statistics Algebraic Geometry and Statistical Learning Theory Differential Geometry and Statistics Differential Geometry in Statistical Inference Geometry Driven Statistics Geometric Modeling in Probability and Statistics Statistical Methods: The Geometric Approach Stochastic Geometry The Geometry of Multivariate Statistics Geometric Structures of Statistical Physics, Information Geometry, and Learning Differential Geometrical Foundations of Information Geometry: Geometry of Statistical Manifolds and Divergences Algebraic and Geometric Methods in Statistics Stochastic Geometry, Spatial Statistics and Random Fields Quantum Geometry Journal of the Royal Statistical Society Differential-Geometrical Methods in Statistics Fractals, Random Shapes and Point Fields Geometry and Topology in Hamiltonian Dynamics and Statistical Mechanics Geometrization of Statistical Theory Shun'ichi Amari Sumio Watanabe M.K. Murray Shun'ichi Amari Ian L. Dryden Ovidiu Calin David J. Saville Wilfrid S. Kendall Thomas D. Wickens Frédéric Barbaresco Hiroshi Matsuzoe Paolo Gibilisco Evgeny Spodarev Jan Ambjørn Royal Statistical Society (Great Britain) Shun-ichi Amari Dietrich Stoyan Marco Pettini C. T. J. Dodson Differential Geometry in Statistical Inference Geometry and Statistics Algebraic Geometry and Statistical Learning Theory Differential Geometry and Statistics Differential Geometry in Statistical Inference Geometry Driven Statistics Geometric Modeling in Probability and Statistics Statistical Methods: The Geometric Approach Stochastic Geometry The Geometry of Multivariate Statistics Geometric Structures of Statistical Physics, Information Geometry, and Learning Differential Geometrical Foundations of Information Geometry: Geometry of Statistical Manifolds and Divergences Algebraic and Geometric Methods in Statistics Stochastic Geometry, Spatial Statistics and Random Fields Quantum Geometry Journal of the Royal Statistical Society Differential-Geometrical Methods in Statistics Fractals, Random Shapes and Point Fields

Geometry and Topology in Hamiltonian Dynamics and Statistical Mechanics Geometrization of Statistical Theory *Shun'ichi Amari Sumio Watanabe M.K. Murray Shun'ichi Amari Ian L. Dryden Ovidiu Calin David J. Saville Wilfrid S. Kendall Thomas D. Wickens Friedrich Barbaresco Hiroshi Matsuzoe Paolo Gibilisco Evgeny Spodarev Jan Ambjorn Royal Statistical Society (Great Britain) Shun-ichi Amari Dietrich Stoyan Marco Pettini C. T. J. Dodson*

geometry and statistics volume 46 in the handbook of statistics series highlights new advances in the field with this new volume presenting interesting chapters written by an international board of authors provides the authority and expertise of leading contributors from an international board of authors presents the latest release in the handbook of statistics series updated release includes the latest information on geometry and statistics

sure to be influential this book lays the foundations for the use of algebraic geometry in statistical learning theory many widely used statistical models and learning machines applied to information science have a parameter space that is singular mixture models neural networks hmms bayesian networks and stochastic context free grammars are major examples algebraic geometry and singularity theory provide the necessary tools for studying such non smooth models four main formulas are established 1 the log likelihood function can be given a common standard form using resolution of singularities even applied to more complex models 2 the asymptotic behaviour of the marginal likelihood or the evidence is derived based on zeta function theory 3 new methods are derived to estimate the generalization errors in bayes and gibbs estimations from training errors 4 the generalization errors of maximum likelihood and a posteriori methods are clarified by empirical process theory on algebraic varieties

several years ago our statistical friends and relations introduced us to the work of amari and barndorff nielsen on applications of differential geometry to statistics this book has arisen because we believe that there is a deep relationship between statistics and differential geometry and moreover that this relationship uses parts of differential geometry

particularly its higher order aspects not readily accessible to a statistical audience from the existing literature it is in part a long reply to the frequent requests we have had for references on differential geometry while we have not gone beyond the path breaking work of Amari and Barndorff-Nielsen in the realm of applications our book gives some new explanations of their ideas from a first principles point of view as far as geometry is concerned in particular it seeks to explain why geometry should enter into parametric statistics and how the theory of asymptotic expansions involves a form of higher order differential geometry the first chapter of the book explores exponential families as flat geometries indeed the whole notion of using log likelihoods amounts to exploiting a particular form of flat space known as an affine geometry in which straight lines and planes make sense but lengths and angles are absent we use these geometric ideas to introduce the notion of the second fundamental form of a family whose vanishing characterises precisely the exponential families

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a timely collection of advanced original material in the area of statistical methodology motivated by geometric problems dedicated to the influential work of Kanti V. Mardia this volume celebrates Kanti V. Mardia's long and influential career in statistics a common theme unifying much of Mardia's work is the importance of geometry in statistics and to highlight the areas emphasized in his research this book brings together 16 contributions from high profile researchers in the field geometry driven statistics covers a wide range of application areas including directional data shape analysis spatial data climate science fingerprints image analysis computer vision and bioinformatics the book will appeal to statisticians and others with an interest in data motivated by geometric considerations summarizing the state of the art examining some new developments and presenting a vision for the future geometry driven statistics will enable the reader to broaden knowledge of important research areas in statistics and gain a new appreciation of the work and influence of Kanti V.

mardia

this book covers topics of informational geometry a field which deals with the differential geometric study of the manifold probability density functions this is a field that is increasingly attracting the interest of researchers from many different areas of science including mathematics statistics geometry computer science signal processing physics and neuroscience it is the authors hope that the present book will be a valuable reference for researchers and graduate students in one of the aforementioned fields this textbook is a unified presentation of differential geometry and probability theory and constitutes a text for a course directed at graduate or advanced undergraduate students interested in applications of differential geometry in probability and statistics the book contains over 100 proposed exercises meant to help students deepen their understanding and it is accompanied by software that is able to provide numerical computations of several information geometric objects the reader will understand a flourishing field of mathematics in which very few books have been written so far

this book is a novel exposition of the traditional workhorses of statistics analysis of variance and regression the key feature is that these tools are viewed in their natural mathematical setting the geometry of finite dimensions the authors to introduce ourselves dave saville is a practicing statistician working in agricultural research graham wood is a university lecturer involved in the teaching of statistical methods each of us has worked for sixteen years in our current field features of the book people like pictures one picture can present a set of ideas at a glance while a series of pictures each building on the last can unify a wealth of ideas such a series we present in this text by means of a systematic geometric approach to the presentation of the theory of basic statistical methods this approach fills the void between the traditional extremes of the cookbook approach and the matrix algebra approach providing an elementary but at the same time rigorous view of the subject it combines the virtues of the traditional methods while avoiding their vices

stochastic geometry involves the study of random geometric structures and blends geometric probabilistic and statistical methods to provide powerful techniques for modeling and analysis recent developments in computational statistical analysis particularly markov chain monte carlo have enormously extended the range of feasible applications stochastic geometry likelihood and computation provides a coordinated collection of chapters on important aspects of the rapidly developing field of stochastic geometry including

- o a crash course introduction to key stochastic geometry themes
- o considerations of geometric sampling bias issues
- o tessellations
- o shape
- o random sets
- o image analysis
- o spectacular advances in likelihood based inference now available to stochastic geometry through the techniques of markov chain monte carlo

a traditional approach to developing multivariate statistical theory is algebraic sets of observations are represented by matrices linear combinations are formed from these matrices by multiplying them by coefficient matrices and useful statistics are found by imposing various criteria of optimization on these combinations matrix algebra is the vehicle for these calculations a second approach is computational since many users find that they do not need to know the mathematical basis of the techniques as long as they have a way to transform data into results the computation can be done by a package of computer programs that somebody else has written an approach from this perspective emphasizes how the computer packages are used and is usually coupled with rules that allow one to extract the most important numbers from the output and interpret them useful as both approaches are particularly when combined they can overlook an important aspect of multivariate analysis to apply it correctly one needs a way to conceptualize the multivariate relationships that exist among variables this book is designed to help the reader develop a way of thinking about multivariate statistics as well as to understand in a broader and more intuitive sense what the procedures do and how their results are interpreted presenting important procedures of multivariate statistical theory geometrically the author hopes that this emphasis on the geometry will give the reader a coherent picture into which all the multivariate techniques fit

machine learning and artificial intelligence increasingly use methodological tools rooted in statistical physics conversely limitations and pitfalls encountered in ai question the very foundations of statistical physics this interplay between ai and statistical physics has been attested since the birth of ai and principles underpinning statistical physics can shed new light on the conceptual basis of ai during the last fifty years statistical physics has been investigated through new geometric structures allowing covariant formalization of the thermodynamics inference methods in machine learning have begun to adapt these new geometric structures to process data in more abstract representation spaces this volume collects selected contributions on the interplay of statistical physics and artificial intelligence the aim is to provide a constructive dialogue around a common foundation to allow the establishment of new principles and laws governing these two disciplines in a unified manner the contributions were presented at the workshop on the joint structures and common foundation of statistical physics information geometry and inference for learning which was held in les houches in july 2020 the various theoretical approaches are discussed in the context of potential applications in cognitive systems machine learning signal processing

this up to date account of algebraic statistics and information geometry explores the emerging connections between the two disciplines demonstrating how they can be used in design of experiments and how they benefit our understanding of statistical models in particular exponential models this book presents a new way of approaching classical statistical problems and raises scientific questions that would never have been considered without the interaction of these two disciplines beginning with a brief introduction to each area using simple illustrative examples the book then proceeds with a collection of reviews and some new results written by leading researchers in their respective fields part iii dwells in both classical and quantum information geometry containing surveys of key results and new material finally part iv provides examples of the interplay between algebraic statistics and information geometry computer code and proofs are also available online where key examples are developed in further detail

this volume provides a modern introduction to stochastic geometry random fields and spatial statistics at a post graduate level it is focused on asymptotic methods in geometric probability including weak and strong limit theorems for random spatial structures point processes sets graphs fields with applications to statistics written as a contributed volume of lecture notes it will be useful not only for students but also for lecturers and researchers interested in geometric probability and related subjects

describes random geometry and applications to strings quantum gravity topological field theory and membrane physics

published papers whose appeal lies in their subject matter rather than their technical statistical contents medical social educational legal demographic and governmental issues are of particular concern

from the reviews in this lecture note volume the author describes his differential geometric approach to parametrical statistical problems summarizing the results he had published in a series of papers in the last five years the author provides a geometric framework for a special class of test and estimation procedures for curved exponential families the material and ideas presented in this volume are important and it is recommended to everybody interested in the connection between statistics and geometry metrika 1 more than hundred references are given showing the growing interest in differential geometry with respect to statistics the book can only strongly be recommended to a geodesist since it offers many new insights into statistics on a familiar ground manuscripta geodaetica 2

there has been an increasing interest in the statistical analysis of geometric objects and structures in many branches of science and engineering in recent years the aim of this book is to present these statistical methods for practical use by non mathematicians by outlining the mathematical ideas rather than concentrating on detailed proofs the clarity of exposition ensures that the book will be a valuable resource for researchers and practitioners in many scientific disciplines who wish to use these methods in their work in particular the book is suited to materials scientists geologists

environmental scientists and biologists

It is a special pleasure for me to write this foreword for a remarkable book by a remarkable author. Marco Pettini is a deep thinker who has spent many years probing the foundations of Hamiltonian chaos and statistical mechanics in particular phase transitions from the point of view of geometry and topology. It is in particular the quality of mind of the author and his deep physical as well as mathematical insights which make this book so special and inspiring. It is a must for those who want to venture into a new approach to old problems or want to use new tools for new problems. Although topology has penetrated a number of fields of physics, a broad participation of topology in the clarification and progress of fundamental problems in the above mentioned fields has been lacking. The new perspectives topology gives to the above mentioned problems are bound to help in their clarification and to spread to other fields of science. The sparsity of geometric thinking and of its use to solve fundamental problems when compared with purely analytical methods in physics could be relieved and made highly productive using the material discussed in this book. It is unavoidable that the physicist reader may have then to learn some new mathematics and be challenged to a new way of thinking but with the author as a guide he is assured of the best help in achieving this that is presently available.

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