Discovering Causal Structure From Observations

This volume is a contribution to the ongoing debate on the distinction between a 'context of justification' and a 'context of discovery'. It is meant for researchers and advanced students in philosophy of science, and for natural and social scientists interested in foundational topics. Spanning a wide range of disciplines, it combines the viewpoint of philosophers and scientists and casts a new interdisciplinary perspective on the problem of observation and experimentation.

During the past 25 years, a great deal of research and theory has addressed the development of young children's understanding of mental states such as knowledge, beliefs, desires, intentions, and emotions. Although developments in children's understanding of the mind subsequent to early childhood has received less attention, in recent years a growing body of research has emerged examining understanding of psychological functioning during middle and late childhood. Combined with the literature on adolescent epistemological development, this research provides a broader picture of age-related changes in children's understanding of the mind. Guided by the goals of describing developmental changes in children's concepts of cognitive functioning and identifying sources of information that contribute to learning about cognition, Children's Discovery of the Active Mind organizes empirical literature concerning the development of children's knowledge of cognitive activities from early childhood to adolescence and

presents a conceptual framework that integrates children's introspective activities with social influences on development. Bringing together theoretical and empirical work from developmental, cognitive, and social psychology, the author argues that rather than depending upon a single source of information, developmental progress is driven by combinations of children's conceptual knowledge of mental functioning, children's phenomenological awareness of their own cognitive activities, and children's social experience.

Human beings are active agents who can think. To understand how thought serves action requires understanding how people conceive of the relation between cause and effect, between action and outcome. In cognitive terms, how do people construct and reason with the causal models we use to represent our world? A revolution is occurring in how statisticians, philosophers, and computer scientists answer this question. Those fields have ushered in new insights about causal models by thinking about how to represent causal structure mathematically, in a framework that uses graphs and probability theory to develop what are called causal Bayesian networks. The framework starts with the idea that the purpose of causal structure is to understand and predict the effects of intervention. How does intervening on one thing affect other things? This is not a question merely about probability (or logic), but about action. The framework offers a new understanding of mind: Thought is about the effects of intervention and cognition is thus intimately tied to actions that take place either in the actual physical

world or in imagination, in counterfactual worlds. The book offers a conceptual introduction to the key mathematical ideas, presenting them in a non-technical way, focusing on the intuitions rather than the theorems. It tries to show why the ideas are important to understanding how people explain things and why thinking not only about the world as it is but the world as it could be is so central to human action. The book reviews the role of causality, causal models, and intervention in the basic human cognitive functions: decision making, reasoning, judgment, categorization, inductive inference, language, and learning. In short, the book offers a discussion about how people think, talk, learn, and explain things in causal terms, in terms of action and manipulation.

This book argues for the place of capacities within an grounds of meaning, not method. Yet it is questions of method that should concern the modern empiricist: can capacities be measured? Cartwright argues that they are measured if anything is. Stanford University's Gravity-Probe-B will measure capacities in a cryogenic dewar deep in space. More mundanely, we use probabilities to measure capacities, and the assumptions required to ensure that probabilities are a reliable instrument are investigated in the opening chapters of this book, where the early methods of econometrics set a model. The last chapter applies lessons about probabilities and capacities to quantum mechanics and the Bell inequalities. The central thesis throughout is that capacities not only can be admitted by empiricists, but indeed must

be - otherwise the empirical methods of modern science will make no sense.
Partial Least Squares (PLS) is an estimation method and an algorithm for latent variable path (LVP) models. PLS is a component technique and estimates the latent variables as weighted aggregates. The implications of this choice are considered and compared to covariance structure techniques like LISREL, COSAN and EQS. The properties of special cases of PLS (regression, factor scores, structural equations, principal components, canonical correlation, hierarchical components, correspondence analysis, three-mode path and component analysis) are examined step by step and contribute to the understanding of the general PLS technique. The proof of the convergence of the PLS algorithm is extended beyond two-block models. Some 10 computer programs and 100 applications of PLS are referenced. The book gives the statistical underpinning for the computer programs PLS 1.8, which is in use in some 100 university computer centers, and for PLS/PC. It is intended to be the background reference for the users of PLS 1.8, not as textbook or program manual.
This book compiles leading research on the development of explainable and interpretable machine learning methods in the context of computer vision and machine learning. Research progress in computer vision and pattern recognition has led to a variety of modeling techniques with almost human-like performance. Although these models have obtained astounding results, they are limited in their explainability and interpretability: what is the rationale behind the decision made? what in the model

structure explains its functioning? Hence, while good performance is a critical required characteristic for learning machines, explainability and interpretability capabilities are needed to take learning machines to the next step to include them in decision support systems involving human supervision. This book, written by leading international researchers, addresses key topics of explainability and interpretability, including the following: · Evaluation and Generalization in Interpretable Machine Learning · Explanation Methods in Deep Learning · Learning Functional Causal Models with Generative Neural Networks · Learning Interpreatable Rules for Multi-Label Classification · Structuring Neural Networks for More Explainable Predictions · Generating Post Hoc Rationales of Deep Visual Classification Decisions · Ensembling Visual Explanations · Explainable Deep Driving by Visualizing Causal Attention · Interdisciplinary Perspective on Algorithmic Job Candidate Search · Multimodal Personality Trait Analysis for Explainable Modeling of Job Interview Decisions · Inherent Explainability Pattern Theory-based Video Event Interpretations

This book constitutes the refereed proceedings of the Second International Symposium on Benchmarking, Measuring, and Optimization, Bench 2019, held in Denver, CO, USA, in November 2019. The 20 full papers and 11 short papers presented were carefully reviewed and selected from 79 submissions. The papers are organized in topical sections named: Best Paper Session; AI Challenges on Cambircon using AIBenc; AI Challenges on RISC-V using AIBench; AI Challenges on X86 using

AIBench; AI Challenges on 3D Face Recognition using AIBench; Benchmark; AI and Edge; Big Data; Datacenter; Performance Analysis; Scientific Computing.

The world has seen several financial and economic crises in the past few years. Psychological, ethical and philosophical levels of causal analysis have been discussed, and in this context, an interest in classical thinkers has emerged. The work of Aristotle has influenced writers from Marx and Menger to Amartya Sen. This book introduces us to Aristotle's thought on 'the economic' and on its influences on economists. First, it focuses on Aristotle ?s ideas, situating Aristotle in his historical context, describing his positions on the economic and analysing what kind of reality the economic is, its relation with ethics and with politics. Then, it determines what kind of science is concerned with the economic. Later, it analyses related topics and shows the influence of Aristotle's ideas on contemporary economists. It concludes by highlighting the Aristotelian contributions to today's economy. This scholarly volume offers important new insights into the Aristotelian approach to the economy itself, as well as to the idea of economics as a science, bringing Aristotle's views to bear on the modern economy.

Volume 43 of Advances in Child Development and Behavior includes chapters that highlight some of the most recent research in the area of Rational

Constructivism. Each chapter provides in-depth discussions, and this volume serves as an invaluable resource for Developmental or educational psychology researchers, scholars, and students. Chapters that highlight some of the most recent research in the area Rational Constructivism discussed in detail Quantum machine learning investigates how quantum computers can be used for data-driven prediction and decision making. The books summarises and conceptualises ideas of this relatively young discipline for an audience of computer scientists and physicists from a graduate level upwards. It aims at providing a starting point for those new to the field, showcasing a toy example of a quantum machine learning algorithm and providing a detailed introduction of the two parent disciplines. For more advanced readers, the book discusses topics such as data encoding into quantum states, quantum algorithms and routines for inference and optimisation, as well as the construction and analysis of genuine ``quantum learning models''. A special focus lies on supervised learning, and applications for near-term quantum devices.

The Encyclopedia of Epidemiology presents state-of-the-art information from the field of epidemiology in a less technical and accessible style and format. With more than 600 entries, no single reference provides as comprehensive a resource in as focused and appropriate manner. The entries cover every major

facet of epidemiology, from risk ratios to case-control studies to mediating and moderating variables, and much more. Relevant topics from related fields such as biostatistics and health economics are also included.

Big Data in Omics and Imaging: Integrated Analysis and Causal Inference addresses the recent development of integrated genomic, epigenomic and imaging data analysis and causal inference in big data era. Despite significant progress in dissecting the genetic architecture of complex diseases by genome-wide association studies (GWAS), genome-wide expression studies (GWES), and epigenome-wide association studies (EWAS), the overall contribution of the new identified genetic variants is small and a large fraction of genetic variants is still hidden. Understanding the etiology and causal chain of mechanism underlying complex diseases remains elusive. It is time to bring big data, machine learning and causal revolution to developing a new generation of genetic analysis for shifting the current paradigm of genetic analysis from shallow association analysis to deep causal inference and from genetic analysis alone to integrated omics and imaging data analysis for unraveling the mechanism of complex diseases. FEATURES Provides a natural extension and companion volume to Big Data in Omic and Imaging: Association Analysis, but can be read independently. Introduce causal inference theory to genomic, epigenomic and

imaging data analysis Develop novel statistics for genome-wide causation studies and epigenome-wide causation studies. Bridge the gap between the traditional association analysis and modern causation analysis Use combinatorial optimization methods and various causal models as a general framework for inferring multilevel omic and image causal networks Present statistical methods and computational algorithms for searching causal paths from genetic variant to disease Develop causal machine learning methods integrating causal inference and machine learning Develop statistics for testing significant difference in directed edge, path, and graphs, and for assessing causal relationships between two networks The book is designed for graduate students and researchers in genomics, epigenomics, medical image, bioinformatics, and data science. Topics covered are: mathematical formulation of causal inference, information geometry for causal inference, topology group and Haar measure, additive noise models, distance correlation, multivariate causal inference and causal networks, dynamic causal networks, multivariate and functional structural equation models, mixed structural equation models, causal inference with confounders, integer programming, deep learning and differential equations for wearable computing, genetic analysis of function-valued traits, RNA-seq data analysis, causal networks for genetic methylation analysis, gene expression and methylation

deconvolution, cell –specific causal networks, deep learning for image segmentation and image analysis, imaging and genomic data analysis, integrated multilevel causal genomic, epigenomic and imaging data analysis.

This investigation into causal modelling presents the rationale of causality, i.e. the notion that guides causal reasoning in causal modelling. It is argued that causal models are regimented by a rationale of variation, nor of regularity neither invariance, thus breaking down the dominant Human paradigm. The notion of variation is shown to be embedded in the scheme of reasoning behind various causal models. It is also shown to be latent – yet fundamental – in many philosophical accounts. Moreover, it has significant consequences for methodological issues: the warranty of the causal interpretation of causal models, the levels of causation, the characterisation of mechanisms, and the interpretation of probability. This book offers a novel philosophical and methodological approach to causal reasoning in causal modelling and provides the reader with the tools to be up to date about various issues causality rises in social science.

One of the true classics in Marketing is now thoroughly revised and updated. "Marketing Theory" is both evolutionary and revolutionary. As in earlier editions, Shelby Hunt focuses on the marketing discipline's multiple stakeholders. He

articulates a philosophy of science-based 'tool kit' for developing and analyzing theories, law-like generalizations, and explanations in marketing science. Hunt adds a new dimension to the book, however, by developing arguments for the position that Resource-Advantage Theory provides the foundation for a general theory of marketing and a theoretical foundation for business and marketing strategy. Also new to this edition are four chapters adapted and updated from Hunt's "Controversy in Marketing Theory" that analyze the 'philosophy debates' within the field, including controversies with respect to scientific realism, qualitative methods, truth, and objectivity.

Information is a recognized fundamental notion across the sciences and humanities, which is crucial to understanding physical computation, communication, and human cognition. The Philosophy of Information brings together the most important perspectives on information. It includes major technical approaches, while also setting out the historical backgrounds of information as well as its contemporary role in many academic fields. Also, special unifying topics are high-lighted that play across many fields, while we also aim at identifying relevant themes for philosophical reflection. There is no established area yet of Philosophy of Information, and this Handbook can help shape one, making sure it is well grounded in scientific expertise. As a side benefit, a book like this can facilitate contacts and collaboration among diverse academic milieus sharing a common interest in information. • First overview of the formal and technical issues involved in the philosophy of information • Integrated

presentation of major mathematical approaches to information, form computer science, information theory, and logic • Interdisciplinary themes across the traditional boundaries of natural sciences, social sciences, and humanities.

Presenting an introduction to computing and advice on computer applications, this book examines hardware and software with respect to the needs of the social scientist. It offers a framework for the use of computers, with focus on the 'work station', the center of which is a personal computer connected to networks by a telephone-based modem.

The first comprehensive structural equation modeling (SEM) handbook, this accessible volume presents both the mechanics of SEM and specific SEM strategies and applications. The editor, contributors, and editorial advisory board are leading methodologists who have organized the book to move from simpler material to more statistically complex modeling approaches. Sections cover the foundations of SEM; statistical underpinnings, from assumptions to model modifications; steps in implementation, from data preparation through writing the SEM report; and basic and advanced applications, including new and emerging topics in SEM. Each chapter provides conceptually oriented descriptions, fully explicated analyses, and engaging examples that reveal modeling possibilities for use with readers' data. Many of the chapters also include access to data and syntax files at the companion website, allowing readers to try their hands at reproducing the authors' results.

These two volumes set LNCS 8421 and LNCS 8422 constitutes the refereed proceedings of the 19th International Conference on Database Systems for Advanced Applications, DASFAA 2014, held in Bali, Indonesia, in April 2014. The 62 revised full papers presented together with 1 extended abstract paper, 4 industrial papers, 6 demo presentations, 3 tutorials and 1 panel

paper were carefully reviewed and selected from a total of 257 submissions. The papers cover the following topics: big data management, indexing and query processing, graph data management, spatio-temporal data management, database for emerging hardware, data mining, probabilistic and uncertain data management, web and social data management, security, privacy and trust, keyword search, data stream management and data quality. Discovering Causal Structure: Artificial Intelligence, Philosophy of Science, and Statistical Modeling provides information pertinent to the fundamental aspects of a computer program called TETRAD. This book discusses the version of the TETRAD program, which is designed to assist in the search for causal explanations of statistical data. or alternative models. This text then examines the notion of applying artificial intelligence methods to problems of statistical model specification. Other chapters consider how the TETRAD program can help to find god alternative models where they exist, and how it can help detect the existence of important neglected variables. This book discusses as well the procedures for specifying a model or models to account for non-experimental or quasi-experimental data. The final chapter presents a description of the format of input files and a description of each command. This book is a valuable resource for social scientists and researchers.

The three volume set LNAI 9851, LNAI 9852, and LNAI 9853 constitutes the refereed proceedings of the European Conference on Machine Learning and Knowledge Discovery in Databases, ECML PKDD 2016, held in Riva del Garda, Italy, in September 2016. The 123 full papers and 16 short papers presented were carefully reviewed and selected from a total of 460 submissions. The papers presented focus on practical and real-world studies of machine learning, knowledge discovery, data mining; innovative prototype implementations or mature

systems that use machine learning techniques and knowledge discovery processes in a real setting; recent advances at the frontier of machine learning and data mining with other disciplines. Part I and Part II of the proceedings contain the full papers of the contributions presented in the scientific track and abstracts of the scientific plenary talks. Part III contains the full papers of the contributions presented in the industrial track, short papers describing demonstration, the nectar papers, and the abstracts of the industrial plenary talks.

We are happy to present the first volume of the Handbook of Defeasible Reasoning and Uncertainty Management Systems. Uncertainty pervades the real world and must therefore be addressed by every system that attempts to represent reality. The representation of uncertainty is a ma jor concern of philosophers, logicians, artificial intelligence researchers and com puter sciencists, psychologists, statisticians, economists and engineers. The present Handbook volumes provide frontline coverage of this area. This Handbook was produced in the style of previous handbook series like the Handbook of Philosoph ical Logic, the Handbook of Logic in Computer Science, the Handbook of Logic in Artificial Intelligence and Logic Programming, and can be seen as a companion to them in covering the wide applications of logic and reasoning. We hope it will answer the needs for adequate representations of uncertainty. This Handbook series grew out of the ESPRIT Basic Research Project DRUMS II, where the acronym is made out of the Handbook series title. This project was financially supported by the European Union and regroups 20 major European research teams working in the general domain of uncertainty. As a fringe benefit of the DRUMS project, the research community was able to create this Hand book series, relying on the DRUMS participants as the core of the authors for the Handbook together with external international experts.

This volume offers selected papers exploring issues arising from scientific discovery in the social sciences. It features a range of disciplines including behavioural sciences, computer science, finance, and statistics with an emphasis on philosophy. The first of the three parts examines methods of social scientific discovery. Chapters investigate the nature of causal analysis, philosophical issues around scale development in behavioural science research, imagination in social scientific practice, and relationships between paradigms of inquiry and scientific fraud. The next part considers the practice of social science discovery. Chapters discuss the lack of genuine scientific discovery in finance where hypotheses concern the cheapness of securities, the logic of scientific discovery in macroeconomics, and the nature of that what discovery with the Solidarity movement as a case study. The final part covers formalising theories in social science. Chapters analyse the abstract model theory of institutions as a way of representing the structure of scientific theories, the semi-automatic generation of cognitive science theories, and computational process models in the social sciences. The volume offers a unique perspective on scientific discovery in the social sciences. It will engage scholars and students with a multidisciplinary interest in the philosophy of science and social science.

The AI conference series is the premier event sponsored by the Canadian - ciety

for the Computational Studies of Intelligence / Soci ?et ?e canadienne pour l' ?etude d'intelligence par ordinateur. Attendees enjoy our typically Canadian - mosphere –hospitable and stimulating. The Canadian AI conference showcases the excellent research work done by Canadians, their international colleagues, and others choosing to join us each spring. International participation is always high; this year almost 40% of the submitted papers were from non-Canadian - searchers. We accepted 24 papers and 8 poster papers from 52 full-length papers submitted. We also accepted eight of ten abstracts submitted to the Graduate Student Symposium. All of these accepted papers appear in this volume. The Canadian AI Conference is the oldest continuously-held national AI c- ference in the world. (ECCAI's predecessor, AISB, held meetings in 1974, but these have since become international.) Conferences have been held biennially since 1976, and annually since 2000. AI 2002 again joined its sister Canadian computer science conferences, Vision Interface and Graphics Interface, enri- ing the experience for all participants. The joint meeting allows us to stay - formed about other areas, to make new contacts, and perhaps to investigate cross-disciplinary research. This year the conferences was held on the beautiful campus of the University of Calgary, and many participants took the opportunity to tour nearby Ban? and the magni?cent Rocky Mountains.

Computing Handbook, Third Edition: Computer Science and Software Engineering mirrors the modern taxonomy of computer science and software engineering as described by the Association for Computing Machinery (ACM) and the IEEE Computer Society (IEEE-CS). Written by established leading experts and influential young researchers, the first volume of this popular handbook examines the elements involved in designing and implementing software, new areas in which computers are being used, and ways to solve computing problems. The book also explores our current understanding of software engineering and its effect on the practice of software development and the education of software professionals. Like the second volume, this first volume describes what occurs in research laboratories, educational institutions, and public and private organizations to advance the effective development and use of computers and computing in today's world. Research-level survey articles provide deep insights into the computing discipline, enabling readers to understand the principles and practices that drive computing education, research, and development in the twenty-first century.

Updated and expanded, Bayesian Artificial Intelligence, Second Edition provides a practical and accessible introduction to the main concepts, foundation, and applications of Bayesian networks. It focuses on both the causal discovery of

networks and Bayesian inference procedures. Adopting a causal interpretation of Bayesian networks, the authors dis

Contemporary Psychometrics features cutting edge chapters organized in four sections: test theory, factor analysis, structural equation modeling, and multivariate analysis. The section on test theory includes topics such as multidimensional item response theory (IRT), the relationship between IRT and factor analysis, estimation and testing of these models, and basic measurement issues that are often neglected. The factor analysis section reviews the history and development of the model, factorial invariance and factor analysis indeterminacy, and Bayesian inference for factor scores and parameter estimates. The section on structural equation modeling (SEM) includes the general algebraic-graphic rules for latent variable SEM, a survey of goodness of fit assessment, SEM resampling methods, a discussion of how to compare correlations between and within independent samples, dynamic factor models based on ARMA time series models, and multi-level factor analysis models for continuous and discrete data. The final section on multivariate analysis includes topics such as dual scaling of ordinal data, model specification and missing data problems in time series models, and a discussion of the themes that run through all multivariate methods. This tour de force through contemporary psychometrics

will appeal to advanced students and researchers in the social and behavioral sciences and education, as well as methodologists from other disciplines.
This volume features the complete text of the material presented at the Twenty-Fourth Annual Conference of the Cognitive Science Society. As in previous years, the symposium included an interesting mixture of papers on many topics from researchers with diverse backgrounds and different goals, presenting a multifaceted view of cognitive science. The volume includes all papers, posters, and summaries of symposia presented at this leading conference that brings cognitive scientists together. The 2002 meeting dealt with issues of representing and modeling cognitive processes as they appeal to scholars in all subdisciplines that comprise cognitive science: psychology, computer science, neuroscience, linguistics, and philosophy.
Understanding causal structure is a central task of human cognition. Causal learning underpins the development of our concepts and categories, our intuitive theories, and our capacities for planning, imagination and inference. During the last few years, there has been an interdisciplinary revolution in our understanding of learning and reasoning: Researchers in philosophy, psychology, and computation have discovered new mechanisms for learning the causal structure of the world. This new work provides a rigorous, formal basis for theory theories

of concepts and cognitive development, and moreover, the causal learning mechanisms it has uncovered go dramatically beyond the traditional mechanisms of both nativist theories, such as modularity theories, and empiricist ones, such as association or connectionism.

This book provides a comprehensive examination of how theory of mind develops. Building on previous work, this book pulls together' all that we have learned in the past 25 years to make sense of this powerful everyday theory. This book includes chapters on evolution and the brain bases of theory of mind; updated treatments and explanations of theory; infant theory of mind as the platform for developments in later childhood; and later developments from middle childhood to adulthood, including how we understand extraordinary minds such as those that belong to gods, superheroes, or supernatural beings.

William H. Starbuck is one of the most creative, productive, and wide-ranging writers in management and organization studies. His work spans three decades and encompasses a whole variety of issues, yet it has never been collected together in one place. This book does just that - bringing together his most seminal writings, prefaced by a personal reflection on some of the themes and conclusions of that emerge from this, and the context in which they were written. What emerges from this is a picture of organizations and their strategies that emphasizes the characteristics of real-life human beings: their idiosyncratic preferences, their distrust for each other, their struggele for dominance, their personal interests which don't always coincide with the interests of the organization, and the internal politicking and contests between interest groups that take place in organizations. Some chapters review research

literature, some report empirical findings, some propose conceptual reformulations, and some offer advice to managers. This book will be a unique guide to the work of an influential thinker in management and organization studies, and will be of interest to academics, researchers, and students of management, strategy, and organization studies.

This volume focuses on the abuse of statistical inference in scientific and statistical literature, as well as in a variety of other sources, presenting examples of misused statistics to show that many scientists and statisticians are unaware of, or unwilling to challenge the chaotic state of statistical practices.;The book: provides examples of ubiquitous statistical tests taken from the biomedical and behavioural sciences, economics and the statistical literature; discusses conflicting views of randomization, emphasizing certain aspects of induction and epistemology; reveals fallacious practices in statistical causal inference, stressing the misuse of regression models and time-series analysis as instant formulas to draw causal relationships; treats constructive uses of statistics, such as a modern version of Fisher's puzzle, Bayesian analysis, Shewhart control chart, descriptive statistics, chi-square test, nonlinear modeling, spectral estimation and Markov processes in quality control.

Recent arguments concerning the nature of causation in evolutionary theory, now often known as the debate between the 'causalist' and 'statisticalist' positions, have involved answers to a variety of independent questions – definitions of key evolutionary concepts like natural selection, fitness, and genetic drift; causation in multi-level systems; or the nature of evolutionary explanations, among others. This Element offers a way to disentangle one set of these questions surrounding the causal structure of natural selection. Doing so allows us to clearly reconstruct the approach that some of these major competing interpretations of

evolutionary theory have to this causal structure, highlighting particular features of philosophical interest within each. Further, those features concern problems not exclusive to the philosophy of biology. Connections between them and, in two case studies, contemporary metaphysics and philosophy of physics demonstrate the potential value of broader collaboration in the understanding of evolution.

In 2020 fand der jährliche Workshop des Faunhofer IOSB und the Lehrstuhls für interaktive Echtzeitsysteme statt. Vom 27. bis zum 31. Juli trugen die Doktorranden der beiden Institute über den Stand ihrer Forschung vor in Themen wie KI, maschinellen Lernen, computer vision, usage control, Metrologie vor. Die Ergebnisse dieser Vorträge sind in diesem Band als technische Berichte gesammelt. - In 2020, the annual joint workshop of the Fraunhofer IOSB and the Vision and Fusion Laboratory of the KIT was hosted at the IOSB in Karlsruhe. For a week from the 27th to the 31st July the doctoral students of both institutions presented extensive reports on the status of their research and discussed topics ranging from computer vision and optical metrology to network security, usage control and machine learning. The results and ideas presented at the workshop are collected in this book.

A concise and self-contained introduction to causal inference, increasingly important in data science and machine learning. The mathematization of causality is a relatively recent development, and has become increasingly important in data science and machine learning. This book offers a self-contained and concise introduction to causal models and how to learn them from data. After explaining the need for causal models and discussing some of the principles underlying causal inference, the book teaches readers how to use causal models: how to compute intervention distributions, how to infer causal models from observational and

interventional data, and how causal ideas could be exploited for classical machine learning problems. All of these topics are discussed first in terms of two variables and then in the more general multivariate case. The bivariate case turns out to be a particularly hard problem for causal learning because there are no conditional independences as used by classical methods for solving multivariate cases. The authors consider analyzing statistical asymmetries between cause and effect to be highly instructive, and they report on their decade of intensive research into this problem. The book is accessible to readers with a background in machine learning or statistics, and can be used in graduate courses or as a reference for researchers. The text includes code snippets that can be copied and pasted, exercises, and an appendix with a summary of the most important technical concepts.

Linear structural equation models (SEMs) are multivariate models which encode direct causal effects. We focus on SEMs in which unobserved latent variables have been marginalized and only observed variables are explicitly modeled. In this thesis, we study three problems where the distribution of the stochastic errors in the SEMs, and thus the corresponding data, are non-Gaussian. Throughout, we utilize graphical models to represent the causal structure. First, we consider estimation of model parameters using an empirical likelihood framework when the causal structure is known. Asymptotically, under very mild conditions on the error distributions, this approach yields normal estimators and well calibrated confidence intervals and hypothesis tests. However, the procedure can be computationally expensive and suffer from poor performance when the sample size is small. We propose several modifications to a naive procedure and show that empirical likelihood can be an attractive alternative to existing methods when the data is non-Gaussian. The models considered in this section correspond to

general mixed graphs. We then consider the problem of estimating the underlying structure. Most of the previous work on causal discovery focuses on estimating an equivalence class of graphs rather than a specific graph. However, Shimizu et al. (2016) show that under certain conditions, when the errors are non-Gaussian, the exact causal structure can be identified. We extend these results in two ways. In Chapter 3, we show that when there is no unobserved confounding and the causal structure is suitably sparse, the identification results can be extended to the high-dimensional setting where the number of variables exceed the number of observations. The models considered correspond to directed acyclic graphs (DAGs) with bounded in-degree. In Chapter 4, we show that non-Gaussian errors also allow for identification of the specific graph when unobserved confounding occurs in a restricted way. In particular, we consider the case where the underlying model corresponds to a bow-free acyclic path diagram (BAP). The proposed method consistently estimates the underlying structure, and unlike previous results does not require the number of latent variables or distribution of the errors to be specified in advance.

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