

2 Low-Rank Approximation

Low-rank approximation tries to find an approximation to a given matrix, where the approximation matrix has a lower rank compared to the original matrix. This is useful for mathematical modeling and data compression. Mathematically, given a matrix M , we try to find $\hat{M}$ in the following optimization problem,

$$\underset{\hat{M}}{\operatorname{argmin}} \|M - \hat{M}\|_F \quad \text{subject to} \quad \operatorname{rank}(\hat{M}) \leq k \quad (1)$$

where $\|A\|_F = \sqrt{\sum_i \sum_j a_{ij}^2}$ is the Frobenius norm, i.e., the sum of squares of all entries in the matrix, followed by a square root.

This problem can be solved using Singular Value Decomposition (SVD). Specifically, let $M = U\Sigma V^T$, where $\Sigma = \operatorname{diag}(\sigma_1, \dots, \sigma_n)$. Then a rank- k approximation of M can be written as $\hat{M} = U\hat{\Sigma}V^T$, where $\hat{\Sigma} = \operatorname{diag}(\sigma_1, \dots, \sigma_k, 0, \dots, 0)$. In this problem, we aim to perform this approximation method on gray-scale images, which can be thought of as a 2D matrix.

- (a) Using the image `low-rank_data/face.jpg`, perform a rank-5, rank-20, and rank-100 approximation on the image. Show both the original image as well as the low-rank images you obtain in your report.
- (b) Now perform the same rank-5, rank-20, and rank-100 approximation on `low-rank_data/sky.jpg`. Show both the original image as well as the low-rank images you obtain in your report.
- (c) In one plot, plot the Mean Squared Error (MSE) between the rank- k approximation and the original image for both `low-rank_data/face.jpg` and `low-rank_data/sky.jpg`, for k ranging from 1 to 100. Be sure to label each curve in the plot. The MSE between two images $I, J \in \mathbb{R}^{m \times n}$ is

$$\operatorname{MSE}(I, J) = \sum_{i,j} (I_{i,j} - J_{i,j})^2. \quad (2)$$

Low Rank Approximation Low Rank Approximation

AW Rasmussen



Low Rank Approximation Low Rank Approximation:

Low Rank Approximation Ivan Markovsky, 2011-11-19 Data Approximation by Low complexity Models details the theory algorithms and applications of structured low rank approximation Efficient local optimization methods and effective suboptimal convex relaxations for Toeplitz Hankel and Sylvester structured problems are presented Much of the text is devoted to describing the applications of the theory including system and control theory signal processing computer algebra for approximate factorization and common divisor computation computer vision for image deblurring and segmentation machine learning for information retrieval and clustering bioinformatics for microarray data analysis chemometrics for multivariate calibration and psychometrics for factor analysis Software implementation of the methods is given making the theory directly applicable in practice All numerical examples are included in demonstration files giving hands on experience and exercises and MATLAB examples assist in the assimilation of the theory [Machine Learning, Low-Rank](#)

[Approximations and Reduced Order Modeling in Computational Mechanics](#) Felix Fritzen, David Ryckelynck, 2019-09-18 The use of machine learning in mechanics is booming Algorithms inspired by developments in the field of artificial intelligence today cover increasingly varied fields of application This book illustrates recent results on coupling machine learning with computational mechanics particularly for the construction of surrogate models or reduced order models The articles contained in this compilation were presented at the EUROMECH Colloquium 597 Reduced Order Modeling in Mechanics of Materials held in Bad Herrenalb Germany from August 28th to August 31st 2018 In this book Artificial Neural Networks are coupled to physics based models The tensor format of simulation data is exploited in surrogate models or for data pruning Various reduced order models are proposed via machine learning strategies applied to simulation data Since reduced order models have specific approximation errors error estimators are also proposed in this book The proposed numerical examples are very close to engineering problems The reader would find this book to be a useful reference in identifying progress in machine learning and reduced order modeling for computational mechanics [Low Rank Matrix Approximation Using the](#)

[Lanczos Bidiagonalization Process](#) Horst D. Simon, Hongyuan Zha, 1997 Abstract Low rank approximation of large and or sparse matrices is important in many applications We show that good low rank matrix approximations can be directly obtained from the Lanczos bidiagonalization process without computing singular value decomposition We also demonstrate that a so called one sided reorthogonalization process can be used to maintain adequate level of orthogonality among the Lanczos vectors and produce accurate low rank approximations This technique reduces the computational cost of the Lanczos bidiagonalization process We illustrate the efficiency and applicability of our algorithm using numerical examples from several application areas **Low-rank Approximation in Preconditioner Design** Vladimir Meňkov, 1998

[Dynamic Low-rank Approximation of Tensors](#) Othmar Koch, Christian Lubich, 2009 *Low-Rank and Sparse Modeling for Visual Analysis* Yun Fu, 2014-10-30 This book provides a view of low rank and sparse computing especially approximation

recovery representation scaling coding embedding and learning among unconstrained visual data The book includes chapters covering multiple emerging topics in this new field It links multiple popular research fields in Human Centered Computing Social Media Image Classification Pattern Recognition Computer Vision Big Data and Human Computer Interaction Contains an overview of the low rank and sparse modeling techniques for visual analysis by examining both theoretical analysis and real world applications Non-negative Matrix Factorization Techniques Ganesh R. Naik,2015-09-25 This book collects new results concepts and further developments of NMF The open problems discussed include e g in bioinformatics NMF and its extensions applied to gene expression sequence analysis the functional characterization of genes clustering and text mining etc The research results previously scattered in different scientific journals and conference proceedings are methodically collected and presented in a unified form While readers can read the book chapters sequentially each chapter is also self contained This book can be a good reference work for researchers and engineers interested in NMF and can also be used as a handbook for students and professionals seeking to gain a better understanding of the latest applications of NMF

Handbook of Robust Low-Rank and Sparse Matrix Decomposition Thierry Bouwmans,Necdet Serhat Aybat,El-hadi Zahzah,2016-05-27 Handbook of Robust Low Rank and Sparse Matrix Decomposition Applications in Image and Video Processing shows you how robust subspace learning and tracking by decomposition into low rank and sparse matrices provide a suitable framework for computer vision applications Incorporating both existing and new ideas the book conveniently gives you one stop access to a number of different decompositions algorithms implementations and benchmarking techniques Divided into five parts the book begins with an overall introduction to robust principal component analysis PCA via decomposition into low rank and sparse matrices The second part addresses robust matrix factorization completion problems while the third part focuses on robust online subspace estimation learning and tracking Covering applications in image and video processing the fourth part discusses image analysis image denoising motion saliency detection video coding key frame extraction and hyperspectral video processing The final part presents resources and applications in background foreground separation for video surveillance With contributions from leading teams around the world this handbook provides a complete overview of the concepts theories algorithms and applications related to robust low rank and sparse matrix decompositions It is designed for researchers developers and graduate students in computer vision image and video processing real time architecture machine learning and data mining Seismic Imaging Methods and Applications for Oil and Gas Exploration Yasir Bashir,Deva Prasad Ghosh,Amir Abbas Babasafari,Abdul Rahim Md Arshad,Seyed Yaser Moussavi Alashloo,Abdul Halim Latiff,Rosita Hamidi,Shiba Rezaei,Teresa Ratnam,Chico Sambo,2022-03-16 Seismic Imaging Methods and Application for Oil and Gas Exploration connects the legacy of field data processing and imaging with new research methods using diffractions and anisotropy in the field of geophysics Topics covered include seismic data acquisition seismic data processing seismic wave modeling high resolution imaging and

anisotropic modeling and imaging This book is a necessary resource for geophysicist working in the oil and gas and mineral exploration industries as well as for students and academics in exploration geophysics Provides detailed methods that are used in the industry including advice on which methods to use in specific situations Compares classical methods with the latest technologies to improve practice and application in the real world Includes case studies for further explanation of methods described in the book **Advances in Visual Computing** George Bebis,Vishal Patel,Jinwei Gu,Julian

Panetta,Yotam Gingold,Kyle Johnsen,Mohammed Safayet Arefin,Soumya Dutta,Ayan Biswas,2025-01-21 This two volume set LNCS 15046 and 15047 constitutes the refereed proceedings of the 17th International Symposium ISVC 2024 held at Lake Tahoe NV USA during October 21 23 2024 The 54 full papers and 12 poster papers were carefully reviewed and selected from 120 submissions A total of 8 papers were also accepted for oral presentation in special tracks from 15 submissions The papers cover the following topical sections Part I Deep Learning Computer Graphics Video Analysis and Event Recognition Motion and Tracking Detection and Recognition Visualization and Medical Image Analysis Part II Segmentation Recognition Generalization in Visual Machine Learning Vision and Robotics for Agriculture Virtual Reality Applications and Poster

Handbook of Variational Methods for Nonlinear Geometric Data Philipp Grohs,Martin Holler,Andreas Weinmann,2020-04-03 This book covers different current research directions in the context of variational methods for non linear geometric data Each chapter is authored by leading experts in the respective discipline and provides an introduction an overview and a description of the current state of the art Non linear geometric data arises in various applications in science and engineering Examples of nonlinear data spaces are diverse and include for instance nonlinear spaces of matrices spaces of curves shapes as well as manifolds of probability measures Applications can be found in biology medicine product engineering geography and computer vision for instance Variational methods on the other hand have evolved to being amongst the most powerful tools for applied mathematics They involve techniques from various branches of mathematics such as statistics modeling optimization numerical mathematics and analysis The vast majority of research on variational methods however is focused on data in linear spaces Variational methods for non linear data is currently an emerging research topic As a result and since such methods involve various branches of mathematics there is a plethora of different recent approaches dealing with different aspects of variational methods for nonlinear geometric data Research results are rather scattered and appear in journals of different mathematical communities The main purpose of the book is to account for that by providing for the first time a comprehensive collection of different research directions and existing approaches in this context It is organized in a way that leading researchers from the different fields provide an introductory overview of recent research directions in their respective discipline As such the book is a unique reference work for both newcomers in the field of variational methods for non linear geometric data as well as for established experts that aim at to exploit new research directions or collaborations Chapter 9 of this book is available open access under a CC BY 4 0 license at link

springer com Linear Algebra for Data Science, Machine Learning, and Signal Processing Jeffrey A. Fessler, Raj Rao Nadakuditi, 2024-05-16 Master matrix methods via engaging data driven applications aided by classroom tested quizzes homework exercises and online Julia demos *Ensemble Machine Learning* Cha Zhang, Yunqian Ma, 2012-02-17 It is common wisdom that gathering a variety of views and inputs improves the process of decision making and indeed underpins a democratic society Dubbed ensemble learning by researchers in computational intelligence and machine learning it is known to improve a decision system's robustness and accuracy Now fresh developments are allowing researchers to unleash the power of ensemble learning in an increasing range of real world applications Ensemble learning algorithms such as boosting and random forest facilitate solutions to key computational issues such as face recognition and are now being applied in areas as diverse as object tracking and bioinformatics Responding to a shortage of literature dedicated to the topic this volume offers comprehensive coverage of state of the art ensemble learning techniques including the random forest skeleton tracking algorithm in the Xbox Kinect sensor which bypasses the need for game controllers At once a solid theoretical study and a practical guide the volume is a windfall for researchers and practitioners alike *Proceedings of Sixth International Congress on Information and Communication Technology* Xin-She Yang, Simon Sherratt, Nilanjan Dey, Amit Joshi, 2021-09-16 This book gathers selected high quality research papers presented at the Sixth International Congress on Information and Communication Technology held at Brunel University London on February 25 26 2021 It discusses emerging topics pertaining to information and communication technology ICT for managerial applications e governance e agriculture e education and computing technologies the Internet of things IoT and e mining Written by respected experts and researchers working on ICT the book offers a valuable asset for young researchers involved in advanced studies The book is presented in four volumes **Machine Learning and Mathematical Models for Single-Cell Data Analysis** Le Ou-Yang, Xiaofei Zhang, Jiajun Zhang, Jin Chen, Min Wu, 2022-11-29 **Matrix Information Geometry** Frank Nielsen, Rajendra Bhatia, 2012-08-07 This book presents advances in matrix and tensor data processing in the domain of signal image and information processing The theoretical mathematical approaches are discussed in the context of potential applications in sensor and cognitive systems engineering The topics and application include Information Geometry Differential Geometry of structured Matrix Positive Definite Matrix Covariance Matrix Sensors Electromagnetic Fields Acoustic sensors and Applications in Cognitive systems in particular Data Mining Languages and Compilers for Parallel Computing Hironori Kasahara, Keiji Kimura, 2013-04-05 This book constitutes the thoroughly refereed post conference proceedings of the 25th International Workshop on Languages and Compilers for Parallel Computing LCPC 2012 held in Tokyo Japan in September 2012 The 16 revised full papers 5 poster papers presented with 1 invited talk were carefully reviewed and selected from 39 submissions The focus of the papers is on following topics compiling for parallelism automatic parallelization optimization of parallel programs formal analysis and verification of parallel programs parallel runtime systems task parallel libraries

parallel application frameworks performance analysis tools debugging tools for parallel programs parallel algorithms and applications *Advanced Concepts for Intelligent Vision Systems* Wilfried Philips,Dan Popescu,Paul Scheunders,2007-08-18 This book constitutes the refereed proceedings of the 9th International Conference on Advanced Concepts for Intelligent Vision Systems ACIVS 2007 held in Delft The Netherlands August 2007 Coverage includes noise reduction and restoration segmentation motion estimation and tracking video processing and coding camera calibration image registration and stereo matching biometrics and security medical imaging image retrieval as well as classification and recognition The Application of Radiomics and Artificial Intelligence in Cancer Imaging Jiuquan Zhang,Hong Huang,Wenli Cai,2022-03-21

Model Reduction and Approximation Peter Benner,Albert Cohen,Mario Ohlberger,Karen Willcox,2017-07-06 Many physical chemical biomedical and technical processes can be described by partial differential equations or dynamical systems In spite of increasing computational capacities many problems are of such high complexity that they are solvable only with severe simplifications and the design of efficient numerical schemes remains a central research challenge This book presents a tutorial introduction to recent developments in mathematical methods for model reduction and approximation of complex systems Model Reduction and Approximation Theory and Algorithms contains three parts that cover I sampling based methods such as the reduced basis method and proper orthogonal decomposition II approximation of high dimensional problems by low rank tensor techniques and III system theoretic methods such as balanced truncation interpolatory methods and the Loewner framework It is tutorial in nature giving an accessible introduction to state of the art model reduction and approximation methods It also covers a wide range of methods drawn from typically distinct communities sampling based tensor based system theoretic This book is intended for researchers interested in model reduction and approximation particularly graduate students and young researchers

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