人工智能与最优化前沿研讨会

程

序

册

主办单位：南开大学陈省身数学研究所

南开大学数学科学学院

南开大学数学交叉科学中心

2024 年 10 月 18 日- 21 日

中国 • 天津

目录

一、会议指南

报到和会议

- 报到时间：2024 年 10 月 18 日 10:00 至 20:00。
- 报到地点：南开大学嘉园宾馆。
- 会议地址：南开大学陈省身数学研究所二楼 216 教室。

入校及就餐

- 参会代表在会议期间出入校园请携带身份证，配合学校门岗出入请刷身份证。
- 参会代表会议期间请在嘉园餐厅用餐，时间如下：

  早餐: 7:00-8:00；　午餐: 12:00-13:00；　晚餐: 17:30-18:30。

二、会议组织

会议学术委员会

主任：祁力群 （杭州电子科技大学 ）

戴彧虹 （中国科学院数学与系统科学研究院 ）

委员：陈小君 （香港理工大学 ）

董 彬 （北京大学 ）

韩德仁 （北京航空航天大学 ）

胡旭东 （中国科学院数学与系统科学研究院 ）

刘 歆 （中国科学院数学与系统科学研究院 ）

孙德锋 （香港理工大学 ）

文再文 （北京大学 ）

杨新民 （重庆师范大学 ）

印卧涛 （阿里巴巴达摩院 ）

会议组织委员会：

杨庆之 （南开大学 ）

吴春林 （南开大学 ）

魏益民 （复旦大学 ）

黄正海 （天津大学 ）

刘新为 （河北工业大学 ）

凌 晨 （杭州电子科技大学 ）

王宜举 （曲阜师范大学 ）

曾 超 （南开大学 ）

赵雨菲 （南开大学 ）

乐航睿 （南开大学 ）

郭朕臣 （南开大学 ）

张道平 （南开大学 ）

会议秘书：

李红琴（南开大学）

唐云飞（南开大学）

三、会议日程

会议地点：省身楼 2 楼 216 教室。

日期	时间	内容
10 月 18 日	全天	报到注册
10 月 19 日（上午）	08:30-09:00	开幕式和合影
	09:00-10:20	主持人：凌晨
	09:00-09:40	祁力群（香港理工大学和杭州电子科技大学） Unit Dual Quaternion Directed Graph and Formation Control
	09:40-10:20	黎稳（华南师范大学数学科学学院） Triple Decomposition based tensor completion joint with non-local similarity
	10:20-10:30	茶歇
	10:30-11:30	主持人：范金燕
	10:30-11:00	叶颀（华南师范大学） Composite Algorithms of Data-driven and Model-driven Methods in Banach Spaces
	11:00-11:30	贾志刚（江苏师范大学） From Compressed Sensing to Color Video Inpainting
10 月 19 日	11:30-14:00	午餐休息
10 月 19 日（下午）	14:00-15:40	主持人：黄正海
	14:00-14:40	王宜举（曲阜师范大学） A Data Distribution Information Combined SVM Model for Binary Classification Problem
	14:40-15:10	喻高航（杭州电子科技大学） Sketching Methods for Large-Scale Tensor Decomposition with Applications
	15:10-15:40	陈中明（杭州电子科技大学） Tensor Train Completion via Riemannian Optimization on the Quotient Geometry
	15:40-15:50	茶歇

	15:50-17:20	主持人：汪仲文
	15:50-16:20	陈艳男（华南师范大学） A Direct Method for Solving the Triple Decomposition of Third-Order Tensors
	16:20-16:50	李红海（江西师范大学） Polynomials of hypergraphs
	16:50-17:20	陈海滨（曲阜师范大学） Recent Advances in Polynomial Optimization Based on Structure Tensors
日期	**时间**	**内容**
10 月 20 日（上午）	08:30-09:50	主持人：吴春林
	08:30-09:10	董彬（北京大学） PDEformer: Towards a Foundation Model for Solving Parametric PDEs and Beyond
	09:10-09:50	常安（福州大学） MT-product of tensors, spectral radius and walks of hypergraphs
	09:50-10:00	茶歇
	10:00-11:40	主持人：魏益民
	10:00-10:40	孔令臣（北京交通大学） Fast Online Elastic Net Subspace Clustering via a Novel Dictionary Update Strategy
	10:40-11:10	徐君（南开大学统计与数据科学学院） 通过近似和显存共享的反向传播算法降低微调阶段的显存负担
	11:10-11:40	李欣欣（吉林大学） A Semismooth Newton-Type Method for the Nearest Doubly Stochastic Matrix Problem
10 月 20 日	11:40-14:00	午餐休息
10 月 20 日（下午）	14:00-15:40	主持人：李声杰
	14:00-14:40	王卿文（上海大学） Generalized hand-eye calibration equation and its application

	14:40-15:10	宋义生（重庆师范大学） Positive definiteness of fourth order tensors
	15:10-15:40	李寒宇（重庆大学） Fast and Accurate Generalized Tensor Network Decomposition
	15:40-15:50	茶歇
	15:50-17:20	主持人：邢文训
	15:50-16:20	石磊（复旦大学） Learning Operators with Stochastic Gradient Descent in General Hilbert Spaces
	16:20-16:50	常慧宾（天津师范大学） 基于自适应权重的 CT 金属伪影校正
	16:50-17:20	王玖鳞（南开大学数学科学学院） Near-Optimal Convex Simple Bilevel Optimization with a Bisection Method
日期	**时间**	**内容**
10 月 21 日（上午）	08:30-11:30	自由讨论

四、报告题目和摘要

10 月 19 日（上午）

报告题目： Unit Dual Quaternion Directed Graph and Formation Control

报告人： 祁力群（香港理工大学和杭州电子科技大学）

报告摘要： We first study the multi-agent formation control problem in a directed graph. Th relative configurations are expressed by unit dual quaternions (UDQs). We call such a weighted directed graph a unit dual quaternion directed graph (UDQDG). We show that a desired relative configuration scheme is reasonable in a UDQDG if and only if for any cycle in this directed graph, the product of relative configurations of the forward arcs, and inverses of relative configurations of the backward arcs, is equal to 1. We then show that a desired relative configuration scheme in a directed connected graph is reasonable if and only if the dual quaternion Laplacian is similar to the unweighted Laplacian of the directed graph. Then for a reasonable desired relative configuration scheme, we build the relationship between the desired formation and the eigenvector corresponding to the zero eigenvalue. A numerical method and a control law are presented. We then study general weighted directed graphs (WDG). Ordinary graphs, gain graphs, signed directed graphs, complex weighted directed graphs and UDQDGs are special cases of WDGs. A general theory of WDG is presented.
This is a joint work with Chunfeng Cui and Chen Ouyang.

报告题目： Triple Decomposition based tensor completion joint with non-local similarity

报告人： 黎稳（华南师范大学数学科学学院）

报告摘要： In this talk, we propose a tensor completion via triple decomposition joint with non-local self-similarity, which is brought by denoise method BM3D (block matching 3D), and then we design a block successive upper-bound minimization (BSUM) algorithm to solve the proposed model. The convergence analysis of the algorithm is also discussed. Numerical experiments on real-world datasets demonstrate the good cooperation and complementarity between non-local self-similarity and low rankness of triple decomposition.

报告题目：Composite Algorithms of Data-driven and Model-driven Methods in Banach Spaces

报告人：叶颀（华南师范大学）

报告摘要：In this presentation, we introduce a novel mathematical framework for machine learning that integrates data-driven and model-driven methods. Typically, data-driven methods are employed to implement black-box algorithms, while model-driven methods are utilized for white-box algorithms. The primary concept involves leveraging the local information from multimodal data and multiscale models to develop global approximate solutions through learning algorithms. The utilization of composite algorithms offers an alternative approach to exploring the mathematical theory of machine learning. This includes investigating interpretability through approximation theory, nonconvexity and nonsmoothness through optimization theory, generalization and overfitting through regularization theory. For our computational medicine project focusing on pancreatic cancer, we investigate the composite algorithm involving image processing and modeling simulation.

报告题目：From Compressed Sensing to Color Video Inpainting

报告人：贾志刚（江苏师范大学）

报告摘要：The color video inpainting problem is one of the most challenging problem in the modern imaging science. It aims to recover a color video from a extremely low ratio of clean or noised pixels. However, there are less of models that can simultaneously preserve the coupling of color channels and the evolution of color video frames. In this academic presentation, we will introduce a new robust quaternion tensor completion (RQTC) model to solve this challenging problem. The main idea is to build a quaternion tensor optimization model to recover a low-rank quaternion tensor that represents the targeted color video and a sparse quaternion tensor that represents noise. To solve the case without low-rank property, we introduce a new low-rank learning RQTC model, which rearranges similar patches clustered by a quaternion learning method into sub-tensors satisfying the prior low-rank assumption. The exact recovery theory is derived for high-order RQTC and fast algorithms are also proposed with global convergence guarantees. We will start with compression sensing and end with looking ahead to AI methods for color video inpainting.

10 月 19 日（下午）

报告题目： A Data Distribution Information Combined SVM Model for Binary Classification Problem

报告人：王宜举（曲阜师范大学）

报告摘要：By taking the data distribution information combined with the data sampling information into account,we establish an enhanced SVM model for binary classification problem in this talk.Since more deeper data structure information is employed,the proposed model exhibits more robustness as it not only minimizes the worst-case misclassification probability,but also minimizes the number of misclassified samples. With the aid of the projection penalty and the alternating minimization technique,we design a dual type algorithm for the model.The efficiency and performance of the proposed model and the algorithm are validated via theoretical analysis as well as some illustrative numerical examples.

报告题目： Sketching Methods for Large-Scale Tensor Decomposition with Applications

报告人：喻高航（杭州电子科技大学）

报告摘要： Large tensors are frequently encountered in various fields such as computer vision, scientific simulations, sensor networks, and data mining. However, these tensors are often too large for convenient processing, transfer, or storage. Fortunately, they typically exhibit a low-rank structure that can be leveraged through tensor decomposition. However, performing large-scale tensor decomposition can be time-consuming. Sketching is a useful technique to reduce the dimensionality of the data.In this talk, we present some efficient two-sided sketching methods for large-scale tensor low-rank decomposition. A rigorous theoretical analysis is also conducted to assess the approximation error of the proposed method. Specifically, we improve the proposed method with power iteration to achieve more precise approximate solutions. Extensive numerical experiments and comparisons on low-rank approximation of synthetic large tensors and real-world data like color images and grayscale videos illustrate the efficiency of the proposed approach in terms of both CPU time and approximation accuracy.

报告题目： Tensor Train Completion via Riemannian Optimization on the Quotient Geometry

报告人：陈中明（杭州电子科技大学）

报告摘要： In this paper, we study the Riemannian algorithms for solving the tensor completion problem. The low-rank tensor completion problem refers to the problem of recovering the target tensor from partial observations. We considered a special type of tensor in tensor train format: except for the last core tensor, the left expansions of other core tensors are orthogonal. Due to the orthogonality, we can establish a set of Riemannian metrics which are all well-defined on the quotient manifold. We also present a new class of retractions with good numerical performance. Based on the new quotient manifold structure, we propose the Riemannian gradient descent method and the Riemannian conjugate gradient method for the tensor completion problem. Numerical results show that our algorithms are competitive with other existing algorithms.

报告题目： A Direct Method for Solving the Triple Decomposition of Third-Order Tensors

报告人：陈艳男（华南师范大学）

报告题目： A direct method is proposed first to compute a complex-valued triple decomposition of a third-order tensor. There are three assumptions: (i) The triple rank L of an I*J*K dimensional tensor satisfies L*L $\leqslant$ min(I, J, K); (ii) Two factor tensors of the triple decomposition are generic; (iii) The third factor tensor has linearly independent fibers. If I $\approx$ J $\approx$ K, the computational cost of the proposed direct method is about O(I^3L^2) flops in total. Further, a sufficient condition for the essential uniqueness of the triple decomposition of a tensor is established under these assumptions. Numerical experiments illustrate that the proposed direct method is at least ten times faster than alternating least squares and optimization-based iterative methods. Finally, we display applications of the proposed direct method with triple tensors in large-scale videos and stochastic partial differential equations.

报告题目： Polynomials of hypergraphs

报告人：李红海（江西师范大学）

报告题目： In this talk we discuss characteristic and matching polynomials of uniform hypergraphs and present some interesting properties between them and related to eigenvalues of hypergraphs, in which some classical results in the literature are generalized to uniform hypergraphs and an elegant conjecture by Clark-Cooper can be resolved completely.

报告题目： Recent Advances in Polynomial Optimization Based on Structure Tensors

报告人：陈海滨（曲阜师范大学）

报告题目： We will consider several recent progress on POPs based on high order structure tensors. In this report, it mainly includes the following three topics, and details are listed below: 1.Completely positive reformulations of POP with linear inequality constraints. For this purpose, we first demonstrate that the POPs can be lifted into a new kind of convex optimization problems with variables being the combination of symmetric rank-1 tensors. By this lifted model, we provide a general characterization of POPs with linear inequality constraints that can be formulated as a conic program over the cone of CPTs. 2.Proximal alternating minimization method for two kinds of fourth degree POPs. We first consider the bi-quadratic optimization problem (Bi-QOP) over compact sets. Then, we consider another kind of nonconvex non-homogeneous POP from practical applications. 3.Dinkelbach method for homogeneous single ratio fractional programming and its applications. For this purpose, we consider a kind of homogeneous POP with high degree, the full convergence sequence and convergence rate for PAM are given.

10 月 20 日（上午）

报告题目： PDEformer: Towards a Foundation Model for Solving Parametric PDEs and Beyond

报告人： 董彬（北京大学）

报告摘要： Deep learning has emerged as a dominant approach in machine learning and has achieved remarkable success in various domains such as computer vision and natural language processing. Its influence has progressively extended to numerous research areas within the fields of science and engineering. In this presentation, I will outline our work on the design and training of a foundation model, named PDEformer, which aims to serve as a flexible and efficient solver across a spectrum of parametric PDEs. PDEformer is specifically engineered to facilitate a range of downstream tasks, including but not limited to parameter estimation and system identification. Its design is tailored to accommodate applications necessitating repetitive solving of PDEs, where a balance between efficiency and accuracy is sought.

报告题目： MT-product of tensors, spectral radius and walks of hypergraphs

报告人： 常安（福州大学）

报告摘要： It is well known that the number of walks between a pair of vertices in a graph can be obtained by means of calculating the power of its adjacency matrix, in which the element on the cross position of the row and column corresponding to these two vertices is just what desired number. In this talk, our goal is to generalize this fundamental result to the uniform hypergraphs. To reach this goal, we first present the definition of a new tensor product which is called MT-product of tensors and discuss the operation laws on it. Then by the MT-product of tensors, the powers of tensors can be naturally defined recursively. On this basis, we provide a method to calculate the number of walks between each pair of vertices of a uniform hypergraph via the power of its adjacency tensor, and present an upper bound on the spectral radius of a hypergraph in terms of the number of walks. This is the joint work with Dr.Hou Yuan.

报告题目： Fast Online Elastic Net Subspace Clustering via a Novel Dictionary Update Strategy

报告人：孔令臣（北京交通大学）

报告摘要： In recent years, online subspace clustering has emerged as a critical tool for real-time analysis of data streams in various applications such as video surveillance and social media analytics. While traditional subspace clustering methods may not adequately capture the complex and varying structures in dynamically changing data streams. In this paper, a fast online elastic net subspace clustering model with block diagonal property is introduced, which can be adapted to varying data characteristics while maintaining robustness against noise and outliers. Furthermore, the dynamic nature of online data requires that the model update its parameters efficiently without reprocessing the entire dataset. To meet this need, an alternating direction method of multipliers method with a novel dictionary update strategy based on support point is designed. This dictionary update strategy not only enhances the adaptability of the model by selectively updating the dictionary atoms that best represent the current data characteristics but also significantly enhances the computational efficiency. Moreover, we rigorously prove the convergence of the algorithm, thereby ensuring its reliability and stability in practical applications. Finally, extensive numerical experiments demonstrate that the proposed method not only improves the accuracy of subspace clustering, but also maintains scalability, making it suitable for real-time and large-scale data processing tasks.

报告题目：通过近似和显存共享的反向传播算法降低微调阶段的显存负担

报告人：徐君（南开大学统计与数据科学学院）

报告摘要：将预训练模型微调到下游任务是人工智能大模型应用的一个重要问题。在微调阶段，大规模的参数量会带来巨大的显存负担。本文致力于从激活函数和层归一化入手降低微调阶段的显存负担。为此，我们提出了近似反向传播理论。这为解耦反向传播训练中的前向过程和反向过程提供了理论支持。我们将近似反向传播理论应用到了 GELU 和 SiLU 激活函数上，推导出了显存高效的替代激活函数，ReGELU2 和 ReSiLU2。它们保持了前向过程不变，但是使用了阶梯函数作为反向过程中的导数。此外，我们还提出了显存共享的反向传播策略。它使相邻的两个网络层可以共享同一个激活显存，由此减少了激活显存冗余。我们的方

法既没有引入额外的计算量也没有降低训练效率。我们在预训练的视觉模型和语言模型上做了大量的实验，实验结果证实了我们的方法最多可以降低 30%左右的峰值显存占用。

报告题目：A Semismooth Newton-Type Method for the Nearest Doubly Stochastic Matrix Problem

报告人：李欣欣（吉林大学）

报告摘要：In this talk, we study a semismooth Newton-type method for the nearest doubly stochastic matrix problem where the nonsingularity of the Jacobian can fail. The optimality conditions for this problem are formulated as a system of strongly semismooth functions. We show that the nonsingularity of the Jacobian does not hold for this system. By exploiting the problem structure, we construct a modified two step semismooth Newton method that guarantees a nonsingular Jacobian matrix at each iteration, and that converges to the nearest doubly stochastic matrix quadratically.

10 月 20 日（下午）

报告题目： Generalized hand-eye calibration equation and its application

报告人： 王卿文（上海大学）

报告摘要： In the field of robotics research, a crucial applied problem is the hand-eye calibration issue, which involves solving the matrix equation AX = YB. However, this matrix equation is merely a specific case of the generalized Sylvester-type dual quaternion matrix equation AX-YB=C, which also holds significant applications in system and control theory. Therefore, we in this talk establish the solvability conditions of this generalized Sylvester-type dual quaternion matrix equation and provide a general expression for its solutions when it is solvable.

As an example of applications, we design a scheme for color image encryption and decryption based on the generalized Sylvester-type dual quaternion matrix equation. From the experiment, it can be observed that the decrypted images are almost identical to the original images.

Therefore, the encryption and decryption scheme designed using this dual quaternion matrix equation is highly feasible.

报告题目： Positive definiteness of fourth order tensors

报告人： 宋义生（重庆师范大学）

报告摘要： The most general scalar potential of two real scalar fields and a Higgs boson defines a 4th-order three-dimensional symmetric tensor. Hence, the boundedness of such a scalar potential from below involves the positive (semi-)definiteness of the corresponding tensor. In this report, we therefore mainly discuss analytic expressions of positive (semi-)definiteness for such a special tensor. First, an analytically necessary and sufficient condition is given to test the positive (semi-)definiteness of a 4th-order two-dimensional symmetric tensor. Furthermore, by means of such a result, the analytic necessary and sufficient conditions of the boundedness from below are obtained for a general scalar potential of two real scalar fields and the Higgs boson. Several classes of special 4th-order tensors, the analytic necessary and sufficient conditions of the positive (semi-)definiteness also are given.

报告题目： Fast and Accurate Generalized Tensor Network Decomposition

报告人：李寒宇（重庆大学）

报告摘要： Tensor network is a fundamental data modeling approach to discover the hidden low-rank patterns in tensors and has attracted significant attention in many fields. This work investigates the generalized tensor network (GTN) decomposition, which allows various famous loss functions. We develop a fast and accurate framework of all-at-once optimization for computing the generalized decomposition. It includes a unified way to find gradient and Hessian approximation as well as a more efficient method for the latter devised by exploiting the sparsity and multilinear structure. Further, the framework also incorporates a unified way with two accelerated techniques for implicitly estimating Hessian approximations for large-scale tensors. To facilitate understanding, we obtain the corresponding results for two well-known GTN decompositions. The adaptability and flexibility of GTN decomposition and the effectiveness of our framework are demonstrated on synthetic data and real-world problems. The acceleration of efficient methods for Hessian approximation is also evaluated on synthetic data.

报告题目： Learning Operators with Stochastic Gradient Descent in General Hilbert Spaces

报告人：石磊（复旦大学）

报告摘要： This study investigates leveraging stochastic gradient descent (SGD) to learn operators between general Hilbert spaces. We propose weak and strong regularity conditions for the target operator to depict its intrinsic structure and complexity. Under these conditions, we establish upper bounds for convergence rates of the SGD algorithm and conduct a minimax lower bound analysis, further illustrating that our convergence analysis and regularity conditions quantitatively characterize the tractability of solving operator learning problems using the SGD algorithm. It is crucial to highlight that our convergence analysis is still valid for nonlinear operator learning. We show that the SGD estimator will converge to the best linear approximation of the nonlinear target operator. Moreover, applying our analysis to operator learning problems based on vector-valued and real-valued reproducing kernel Hilbert spaces yields new convergence results, thereby refining the conclusions of existing literature.

报告题目：基于自适应权重的 CT 金属伪影校正

报告人：常慧宾（天津师范大学）

报告摘要： The existence of metal artifacts severely affects the quality of CT reconstruction, posing challenges to subsequent analysis and diagnosis. This report will share our team's newly proposed adaptive and learned weight-based metal artifact correction and reconstruction methods, and demonstrate the effectiveness of the method with a large amount of simulation and actual data.

报告题目：Near-Optimal Convex Simple Bilevel Optimization with a Bisection Method

报告人：王玖鳞（南开大学数学科学学院）

报告摘要： This talk presents a study on a class of simple bilevel optimization problems, where we aim to minimize a composite convex function at the upper level, subject to a composite convex problem at the lower level. Existing methods either provide asymptotic guarantees for the upper-level objective or exhibit slow sublinear convergence rates. We introduce a bisection algorithm designed to find solutions that are \epsilon_f-optimal for the upper-level and \epsilon_g-optimal for the lower-level objectives. Each iteration employs a binary search approach to narrow the interval by assessing the feasibility of an inequality system. Under mild conditions, our approach attains a near-optimal convergence rate, matching the optimal rate in unconstrained smooth or composite convex optimization when disregarding logarithmic factors. Numerical experiments further demonstrate the effectiveness of our method.

五、周边交通

学校地址：天津市南开区卫津路 94 号，邮编：300071。

注意：南门不开，请从东门或西南门进入校园。出租车不能进校园。

交通：

1. 天津滨海国际机场乘坐地铁 2 号线（曹庄方向）至“天津站”换乘地铁 3 号线（南站方向）至“天塔站”下车，步行至南开大学。

2. 天津站乘坐地铁 3 号线（南站方向）至“天塔站”下车步行至南开大学，或乘坐公交 8 路、832 路至八里台（南开大学东门）。

3. 天津南站乘坐地铁 3 号线（小淀方向）至“天塔站”下车步行至南开大学。

4. 天津西站乘坐地铁 1 号线（双林方向）至“营口道站”换乘地铁 3 号线（南站方向）至“天塔站”下车，步行至南开大学，或在西站南广场乘坐公交 859 路至八里台（南开大学东门）下车。