UMI2022 年度会议（线上）

程 序 册

南开大学

2022 年 10 月 28-29 日

主办单位

南开大学数学科学学院

协办单位

数学图像联盟

中国工业与应用数学学会数学与医学交叉学科专业委员会

浙江师范大学

论坛组委会

吴春林	南开大学	薛运华	南开大学
赵雨菲	南开大学	高冰	南开大学
张道平	南开大学	袁景	浙江师范大学

UMI2022（线上会议）日程表

2022 年 10 月 28 日（星期五）上午 **腾讯会议号：**973 736 060	
08:20-08:30	**开幕式** **主持人：**吴春林
08:30-09:00	**沈纯理教授纪念活动** **主持人：**孔德兴
学术报告 I	
主持人：付树军	
09:00-09:30	孔德兴 浙江大学 具有可解释性的人机协同智能诊断新范式
09:30-10:00	李康安 上海市第一人民医院 高危肺结节的影像学特征与 CT 引导下消融治疗
10:00-10:10	**茶歇**
学术报告 II	
主持人：沈超敏	
10:10-10:40	何炳生 南京大学 一类适用范围更广和便于推广的交替方向法

10:40-11:10	黄峰 东软医疗人工智能与临床创新研究院 MDAAS（Meta+Data+AIAdoptedService）赋能医学影像----元宇宙、大数据和人工智能在医学影像中应用的探讨
主持人：薛运华	
11:10-11:40	应时辉 上海大学 流形赋值的纵向形状数据分析
11:40-12:10	庞彤瑶 新加坡国立大学 Unsupervised Deep Learning for Image Restoration
12:15	**午餐**
2022 年 10 月 28 日（星期五）下午 **腾讯会议号：**973 736 060	
学术报告III	
主持人：李宏伟	
13:45-14:15	孙剑 西安交通大学 Optimal Transport in Machine Learning
14:15-14:45	陈冲 中国科学院数学与系统科学研究院 Spatiotemporal Imaging with Large Diffeomorphic Deformations
主持人：刘君	
14:45-15:15	孟德宇 西安交通大学 针对底层视觉任务的噪声建模方法
15:15-15:45	庞志峰 河南大学 膝关节置换术中的图像分割系统

15:45-15:55	**茶歇**
学术报告 IV	
主持人：常慧宾	
15:55-16:25	台雪成　Oxford-CityU 香港心脑血管健康工程中心（CoCHE） A Color Elastica Model for Vector-Valued Image Regularization
16:25-16:55	彭亚新 上海大学 基于语义正则的图像分割方法
主持人：段玉萍	
16:55-17:25	李爻 哈尔滨工业大学 Interpreable Deep Learning on SSVEP-based Brain-computer Interface
17:25-17:55	董彬 北京大学 机理与数据融合的计算成像
18:00	**晚餐**
2022 年 10 月 29 日（星期六）上午 **腾讯会议号：**223 802 318	
学术报告 V	
主持人：魏素花	
08:30-09:00	陈韵梅 University of Florida Learning regularizations with high data heterogeneity for generalizable MRI reconstruction
主持人：赵雨菲	
09:00-09:30	纪辉 新加坡国立大学 Self-supervised deep learning for Inverse Problems in Imaging

09:30-10:00	文有为 湖南师范大学 Convex variant Mumford-Shah model for image segmentation based on Bayesian inference
10:00-10:10	**茶歇**
学术报告 VI	
主持人：陆遥	
10:10-10:40	沈定刚 上海科技大学 AI-based Infant Brain MRI Analysis and Dynamic Brain Development Atlas Reconstruction(婴幼儿脑影像智能分析与动态脑发育图谱构建)
10:40-11:10	陈锋 智能技术引领重塑战伤救治新体系
主持人：曾超	
11:10-11:40	包承龙 清华大学 The Moments of Orientation Estimations Considering Molecular Symmetry in cryo-EM
11:40-12:10	梁经纬 上海交通大学 A Framework for Analyzing Variance Reduced Stochastic Gradient Methods and a New One for Non-smooth Non-convex Optimization
12:15	**午餐**
2022 年 10 月 29 日（星期六）下午 **腾讯会议号：**223 802 318	
学术报告 VII	
主持人：石玉英	
13:45-14:15	姚正安 中山大学 短临天气预报

14:15-14:45	曾铁勇 香港中文大学 Image deblurring and blind deblurring
主持人：高冰	
14:45-15:15	金正猛 南京邮电大学 Variational Variance Maximization Method: Theory and Applications
15:15-15:45	贵鹿颖 南京理工大学 Histopathology image analysis of pancreatic ductal adenocarcinoma based on weakly-supervised few-shot learning
15:45-15:55	**茶歇**
学术报告 VIII	
主持人：袁景	
15:55-16:25	李纯明 电子科技大学 图像分割的数学模型、算法与应用
16:25-16:55	姚文娟 哈尔滨工业大学 Fractional-Order Reaction Diffusion System for the Multiplicative Noise Removal
主持人：张道平	
16:55-17:25	金其余 内蒙古大学 Edge adaptive hybrid regularization model for image deblurring
17:25-17:55	王泽龙 国防科技大学 雷达图像特征增强的深度网络方法
18:00	**晚餐**

报告题目与摘要

The Moments of Orientation Estimations Considering Molecular Symmetry in cryo-EM

包承龙 清华大学

Abstract: The orientation statistics are important during the reconstruction process of three-dimensional structures of biological macromolecules. Existing approaches establish the orientation statistics in S^2 or SO(3), while the molecular symmetry has not been explored. In this talk, we propose a novel method for estimating the mean and variance of orientations by considering the symmetry of macromolecules. Using the tools from non-unique-game, the proposed non-convex formulation can be relaxed as a SDP. Moreover, a rounding procedure is developed for determining the representatives. Experimental results show that our method can almost ideally obtain the global minima and the proper representatives.

Spatiotemporal Imaging with Large Diffeomorphic Deformations

陈冲 中国科学院数学与系统科学研究院

Abstract: Spatiotemporal imaging is critical in realistic applications, such as tomographic imaging of the heart or lung in medicine. As an example in PET/CT cardiac imaging, when data is acquired over a relatively long period of time, the unknown motion of the organs leads to severe degradation in image quality. Furthermore, to reduce the radiation or conduct fast scanning, the low-dose or sparse sampling is often required. Hence, such image reconstruction with high spatial and temporal resolutions becomes particularly important but very challenging. We will talk about our recent advances on mathematical modeling and computation for the image reconstruction in spatiotemporal imaging, including joint image reconstruction and motion estimation, LDDMM consistent growth model, indirect image registration, sequentially indirect image registration.

智能技术引领重塑战伤救治新体系

陈锋

Abstract: 未来战争形态向“多域战”“马赛克战”进化，战场呈现去中心化、模糊前后方、全时全域高强度对抗的新形态，逐级后送、分级救治的传统卫勤保障模式难以适应。未来新型作战模式需匹配新一代战伤救治体系，即灵活机动、自主协同、按需集成、富有弹性的“分布式协同”新体系，最大化释放智能技术红利，推动智能战救技术能力生成。

Learning regularizations with high data heterogeneity for generalizable MRI reconstruction

陈韵梅 University of Florida

Abstract: In this work we developed a generalizable MRI reconstruction method in the meta-learning framework. The main idea is to learn a regularization function in a nonconvex and

nonsmooth variational model for MRI image reconstruction, which is parameterized by two sets of parameters: a task-invariant set for common feature encoding and a task-specific part to account for the variations in the heterogeneous data. The network architecture follows exactly a convergent learnable optimization algorithm for solve the variational model. The network is trained by a bilevel optimization algorithm to prevent overfitting and improve generalizability. A series of experimental results on heterogeneous MRI data sets indicate that the proposed method generalizes well to the reconstruction problems whose undersampling patterns and trajectories are not present during training.

机理与数据融合的计算成像

董彬 北京大学

Abstract: 计算成像关心的问题是如何有效的感知数据并重建高质量的图像以辅助人们进行决策，这包含了三个环节：图像感知、图像重建和图像分析。传统的图像感知以硬件设计为主，而图像重建和分析是数学与统计方法的主战场。长久以来这三个步骤的发展相对独立，融通性较弱，但在机器学习（尤其是深度学习）得以长足发展的今天，这一状况在逐渐的发生改变。本报告主要围绕深度学习给计算成像所带来的机遇与挑战展开，介绍如何将传统的图像重建算法与深度学习方法相结合来设计数据驱动与任务驱动的成像算法，从而实现计算成像三个环节的有机融合。

Histopathology image analysis of pancreatic ductal adenocarcinoma based on weakly-supervised few-shot learning

贵鹿颖 南京理工大学

Abstract: Histopathology image is the gold standard for cancer detection and diagnosis, and its analysis requires strong expertise due to its high complexity. Pathologists need to search for useful information from pathology images of huge size for disease diagnosis in clinical applications. Further, the analysis of pathology images can also predict the trend and prognosis of the disease. The development of deep neural networks has led to many breakthroughs in automatic histopathology image analysis. These methods are highly dependent on the availability of a large number of pixel-level labels, which are labor-intensive and time-consuming to obtain. To address these challenges, we investigated algorithms for histopathology image analysis with few coarse-grained labels. Applied to analysis of histopathology images for pancreatic ductal adenocarcinoma(PDAC), we quantified the phenomenon of perineural invasions, and established a correlation between perineural invasions and the prognosis of PDAC through a retrospective study of a cohort of PDAC patients.

一类适用范围更广和便于推广的交替方向法

何炳生 南京大学

Abstract: 通常所说的交替方向法(ADMM)，是对增广拉格朗日乘子法(ALM)进行松弛，用来处理等式约束的可分离凸优化问题。ADMM直接推广到三块和三块以上的可分离问题，其收敛性就无法得到保证。这个报告里给出两个预测-校正的ADMM类方法，它们的预测相当于交替

方向法的自然推广；所需的额外校正，形式非常简单计算也特别方便。新方法既可以用来求解等式约束问题，又可以用来求解不等式约束问题，还可以直接推广到求解任意多块的可分离问题。对经典 ADMM擅长求解的两块可分离的等式约束凸优化问题，用新方法求解也毫不逊色。由于应用范围广又便于向多块问题推广，新方法将会更受用户欢迎!

MDAAS（Meta+Data+AIAdoptedService）赋能医学影像----元宇宙、大数据和人工智能在医学影像中应用的探讨

黄峰 东软医疗人工智能与临床创新研究院

Abstract: 元宇宙、大数据和人工智能在医学影像领域的应用，把医学影像的挖掘和展示带到到了新的空间，同时对数学建模以及算法也提出了新的挑战。本汇报综述了元宇宙、大数据和人工智能对医学影像中的已有应用，并探讨了近期会实现的新应用以及东软医疗正在进行的相关研究。

Self-supervised deep learning for Inverse Problems in Imaging

纪辉 新加坡国立大学

Abstract: While deep learning has become a prominent tool for solving many challenging problems in imaging science, most existing methods are supervised over a dataset with ground-truth images. Such a prerequisite on the access to many ground-truth images limits the wider applicability of deep learning in many domains, e.g. medicine and science. Recently, there is an increasing interest on developing deep learning methods for solving inverse imaging problems without requiring the access to truth images. In this talk, we will introduce a general self-supervised deep learning framework for solving general inverse imaging problems, where the main ingredient are the neutralization of Bayesian inference and data augmentation techniques for handling noisy labels. Extensive experiments showed that the proposed self-supervised deep learning method can compete well against existing supervised-learning-based solutions to many tasks in imaging, including image denoising, image deblurring, compressed sensing, and phase retrieval.

Edge adaptive hybrid regularization model for image deblurring

金其余 内蒙古大学

Abstract: Parameter selection is crucial to regularization-based image restoration methods. Generally speaking, a spatially fixed parameter for the regularization term does not perform well for both edge and smooth areas. A larger parameter for the regularization term reduces noise better in smooth areas but blurs edge regions, while a small parameter sharpens edge but causes residual noise. In this paper, an automated spatially adaptive regularization model, which combines the harmonic and TV terms, is proposed for the image reconstruction from noisy and blurred observation. The proposed model detects the edges and then spatially adjusts the parameters of Tikhonov and TV regularization terms for each pixel according to the edge information. Accordingly, the edge information matrix will also be dynamically updated during the iterations.

Computationally, the newly-established model is convex, which can be solved by the semi-proximal alternating direction method of multipliers (sPADMM) with a linear convergence rate. Numerical simulation results demonstrate that the proposed model effectively preserves the image edges and eliminates the noise and blur at the same time.

Variational Variance Maximization Method: Theory and Applications

金正猛 南京邮电大学

Abstract: In this talk, I will discuss our recent progress on variational variance maximization method for image processing. Also, the associated mathematical theory and applications including image decolorization and fusion are presented here.

图像分割的数学模型、算法与应用

李纯明 电子科技大学

Abstract: 图像分割是计算机视觉与医学图像分析等图像相关领域中的最重要的基础性问题之一，并且在很多领域中都有十分重要的应用，一直吸引着来自计算机、自动化、生物医学工程和数学等领域的科研人员对其进行研究，提出了多种多样的图像分割方法。然而，图像分割至今仍是个很有挑战性的问题，还是一个活跃的研究课题。变分法、偏微分方程、随机场和图论等数学方法被广泛应用与图像分割问题的研究。近年来，随着深度学习的兴起，伴随着大数据和算力的发展，基于深度学习的图像分割方法被广泛地研究和应用。本报告主要以医学图像为例，回顾不同时期的图像分割方法和研究潮流及其优缺点。重点介绍有一定理论基础的数学方法和一些经典的数学模型与算法，以及报告人的近期研究成果。最后现场演示报告人最近开发的一种新方法，并浅谈其研究与应用展望。

高危肺结节的影像学特征与 CT 引导下消融治疗

李康安 上海市第一人民医院

Abstract: 随着现代影像学的发展和健康筛查的普及，原发性肺癌和肺转移瘤的早期发现率明显地提高。早期诊断、早期治疗是影响原发性非小细胞肺癌 (non-small cell lung cancer，NSCLC)和肺转移瘤 (尤其是寡转移瘤)患者预后的关键。局部精准地微创或无创治疗是肺部恶性肿瘤治疗发展的重要方向，以电视辅助胸腔镜手术(video-assisted thoracoscopic surgery，VATS)为代表的微创手术和以 立体定向放射治疗(stereotactic body radiation therapy，SBRT)为代表的无创治疗的 广泛应用，使得肺部恶性肿瘤的治疗疗效有了较大提高，但是 VATS 和 SBRT 均有一定的局限性。为弥补现有微创或无创治疗手段的不足，新的局部治疗方法应运而生，包括影像引导下热消融(image-guided thermal ablation，IGTA)治疗等。IGTA 技术主要包括射频消融(radiofrequency ablation，RFA)、微波消融(microwave ablation，MWA)、冷冻消融和激光消融。IGTA 在治疗肺部肿瘤方面具有定位精准、创伤小、疗效确切、安全性高、可重复性强、并发症少、费用低等特点，已经应用于原发性肺癌和肺转移瘤的治疗，每年接受 IGTA 治疗的病例数迅速增加。目前在 IGTA 常用的 4 种技术中，我国在 MWA 治疗肺癌方面处于国际领先。

Interpreable Deep Learning on SSVEP-based Brain-computer Interface

李爻 哈尔滨工业大学

Abstract: Currently, most of the high-performance models for frequency recognition of steady-state visual evoked potentials (SSVEPs) are linear. However, SSVEPs collected from different channels can have non-linear relationship among each other. Linearly combining electroencephalogram (EEG) from multiple channels is not the most accurate solution in SSVEPs classification. To further improve the performance of SSVEP-based brain-computer interface (BCI), we propose a convolutional neural network-based non-linear model, i.e. convolutional correlation analysis (Conv-CA). Different from pure deep learning models, Conv-CA use convolutional neural networks (CNNs) at the top of a self-defined correlation layer. The CNNs function on how to transform multiple channel EEGs into a single EEG signal. The correlation layer calculates the correlation coefficients between the transformed single EEG signal and reference signals. The CNNs provide non-linear operations to combine EEGs in different channels and different time. And the correlation layer constrains the fitting space of the deep learning model. Conv-CA has good explainability since its inputs of the correlation layer can be analyzed for visualizing what the model learnt from the data. The structure of combining neural networks and unsupervised features has the potential to be applied to the classification of other signals.

A Framework for Analyzing Variance Reduced Stochastic Gradient Methods and a New One for Non-smooth Non-convex Optimization

梁经纬 上海交通大学

Abstract: Over the past years, stochastic optimization methods are becoming increasingly popular in traditional areas including inverse problems and signal/image processing. In this talk, I will introduce SPRING, a novel stochastic version of proximal alternating linearized minimization (PALM) algorithm for solving a class of non-smooth and non-convex optimization problems which arise in many statistical machine learning, computer vision and imaging applications. Theoretically, I will show that our proposed method with variance-reduced stochastic gradient estimators, such as SAGA and SARAH, achieves state-of-the-art oracle complexities. Numerical experiments on sparse non-negative matrix factorization, sparse principal component analysis and blind image deconvolution are also presented to demonstrate the efficiency of our algorithm.

针对底层视觉任务的噪声建模方法

孟德宇 西安交通大学

Abstract: 针对底层视觉处理的任务，如图像去噪等，传统模型驱动的方法大多采用 MAP 模型的不确定性概率框架构建，其具有相对清晰的解释性，有利于对领域知识与数据理解较好的问题针对性构建合理模型，获得良好求解效果。然而现代数据驱动方法采用端到端的确定性模式处理问题，依赖于预先收集的大量训练数据，此类方法在各项底层视觉任务中全面超越传统模型驱动方法。本报告将特别从噪声建模的角度，一方面尝试分析模型驱动与数据驱动的各自适用场合与有效性前提，另一方面提出一种不确定性深度学习方法，尝试将两种方法论统一在统一概率框架下，从而达到数据驱动与模型驱动方法论优势互补，功能相互折衷

的目标。

Unsupervised Deep Learning for Image Restoration

庞彤瑶 新加坡国立大学

Abstract: Recently, deep learning has become a prominent tool for solving image restoration problems. Most of the deep learning methods are supervised, which requires the collection of paired truth/measurement data. In some scenarios, it is challenging and even impossible to collect such data pairs containing the clean images. To relax the requirement on data collection, we proposed several unsupervised deep learning methods that only use the obtained measurements for training. Our methods are widely applicable to many image restoration problems and achieve state of the art performance.

膝关节置换术中的图像分割系统

庞志峰 河南大学

Abstract: 人工膝关节置换(TKA)是在近代人工髋关节成功应用于病人后逐渐发展起来的一种治疗膝关节疾病的新技术，它能非常有效地根除晚期膝关节病痛，极大地提高病人的生活质量。随着新技术辅助 TKA 相关研究的深入，如何提高工作效率以及降低时间、人力及物力等各项准备成本，也成为当前研究热点。基于 CT 的 TKA 术前三维规划中，对膝关节 CT 图像数据的准确分割与重建是关键环节，但目前分割处理一般由数据处理工程师完成，这一过程耗时费力.针对上述问题，本报告试图从预处理技术，图像分割和 3D 重建以及可视化等四个角度阐述团队研发的膝关节置换术中的图像分割系统，进而为 3D 打印出的膝关节模型去定制具有个性化的人工膝关节假体提供技术方案。

AI-based Infant Brain MRI Analysis and Dynamic Brain Development Atlas Reconstruction

沈定刚 上海科技大学

Abstract: The increasing availability of infant brain MRI data, such as the data collected from the Baby Connectome Project (BCP), affords unprecedented opportunities for precise charting of dynamic early brain developmental trajectories in understanding normative and aberrant brain growth. However, most existing neuroimaging analysis tools, which are mainly developed for adult brains, are not suitable for infant brains, due to extremely low tissue contrast and regionally-heterogeneous dynamic changes of imaging appearance, brain shape and folding in the infant brains. In this talk, I will introduce our over 10 years of experience in developing learning-based computational analysis methods for quantitative characterization of baby brain development, as well as reconstruction of dynamic brain structural and functional development atlases. Neuroscience applications of these methods in advancing our understanding of the baby brains will be also introduced.

Optimal Transport in Machine Learning

孙剑 西安交通大学

Abstract: Optimal transport is originally proposed to transport the mass between two probability

measures with minimal costs. It has widely investigated from theory to algorithms and applications, e.g., distribution transform/matching, Wasserstein distance, partial differential equations (Monge–Ampère Equations), deep generative models, etc. In this talk, I will briefly introduce the optimal transport, and present our preliminary research on optimal transport with keypoints-based guidance and data mass reweighting for improving generalization ability of deep learning methods.

A Color Elastica Model for Vector-Valued Image Regularization

台雪成 Oxford-CityU 香港心脑血管健康工程中心（CoCHE）

Abstract: Models related to the Euler's elastica energy have proven to be useful for many applications including image processing. Extending elastica models to color images and multichannel data is a challenging task, as stable and consistent numerical solvers for these geometric models often involve high order derivatives. Like the single channel Euler's elastica model and the total variation models, geometric measures that involve high order derivatives could help when considering image formation models that minimize elastic properties. In the past, the Polyakov action from high energy physics has been successfully applied to color image processing. Here, we introduce an addition to the Polyakov action for color images that minimizes the color manifold curvature. The color image curvature is computed by applying the Laplace--Beltrami operator to the color image channels. When reduced to gray-scale images, while selecting appropriate scaling between space and color, the proposed model minimizes Euler's elastica operating on the image level sets. Finding a minimizer for the proposed nonlinear geometric model is a challenge we address in this paper. Specifically, we present an operator-splitting method to minimize the proposed functional. The nonlinearity is decoupled by introducing three vector-valued and matrix-valued variables. The problem is then converted into solving for the steady state of an associated initial-value problem. The initial-value problem is time split into three fractional steps, such that each subproblem has a closed form solution, or can be solved by fast algorithms. The efficiency and robustness of the proposed method are demonstrated by systematic numerical experiments.

雷达图像特征增强的深度网络方法

王泽龙 国防科技大学

Abstract: 深度神经网络由于其强大的特征表达能力，在图像与信号处理中扮演着越来越重要的角色。报告针对雷达图像的特征增强问题，聚焦深度神经网络在雷达图像处理相关应用中面临训练数据较少以及缺乏图像真值等主要困难，提出了雷达图像特征增强的两种深度网络模型，即深度图像先验特征增强网络与自监督学习的特征增强网络。深度图像先验特征增强网络利用深度图像先验从单幅雷达图像中提取表征目标信息的低频特征，一定程度上解决了训练过程中缺少真值的问题。同时，结合伯努利采样设计了一种自监督训练的深度神经网络，能够适用于单张训练图像的极端条件。实验结果表明了上述深度网络方法在特定环境下的有效性。

Convex variant Mumford-Shah model for image segmentation based on Bayesian inference

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Abstract: Mumford-Shah 模型是最重要的图像分割模型之一。为了克服 Mumford-Shah 模型非凸性造成数值计算的困难，众多变体相继提出，如光滑化和阈值化两步法(SaT)。然而图像的分割效果往往依赖于模型参数的选取。在本报告中，我们介绍如何应用贝叶斯推断方法选取模型参数。

Fractional-Order Reaction Diffusion System for the Multiplicative Noise Removal

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Abstract: A fractional-order nonlinear reaction diffusion system is proposed to remove the multiplicative Gamma noise. The new reaction diffusion system consists of three equations: the regularized Perona and Malik (PM) equation, which is used for presmoothing the image that is contaminated by noise; the time-delay regularization equation, which is used for incorporating the past information into the diffusion process and adjusting oversmoothing; and the fractional-order diffusion equation, which is used for removing the multiplicative Gamma noise and maintaining texture. The new reaction diffusion system is coupled, leading to the difficulty in theoretical analysis. To this end, we use decoupled and Schauder's fixed-point theorem to obtain the existence and uniqueness of weak solution of the system. The explicit finite difference scheme is employed to implement the fractional-order nonlinear reaction diffusion system. In addition, we test both texture images and nontexture images. Experimental results show that the new model achieves a better trade-off between denoising performance and texture preservation than the other three models.

短临天气预报

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Abstract: 主要阐述流体力学、计算热力学、数学建模、人工智能和大数据分析在天气预报中的应用。

流形赋值的纵向形状数据分析

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Abstract: 在现实应用领域中存在大量数据或者数据的观测分布在特定的低维流形上。因此，如何对这样的数据进行内蕴分析就成为一个重要问题。本报告在数据观测构成低维流形的假设下，从模型和数据双驱动的角度建立流形上的半参回归模型，特别地，部分线性模型。进一步，给出模型的渐进性分析。进一步，通过引入随机因素，构建流形上的混合效应模型。在此基础上，提出一个异常点判断依据。最后，通过在多个流形观测实际问题上的数值实验验证所提模型有更高的逼近精度。

Image deblurring and blind deblurring

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Abstract: Image deblurring is important task in computer vision. We will discuss some related issues such as kernel-error, quaternion representation and blind deblurring.