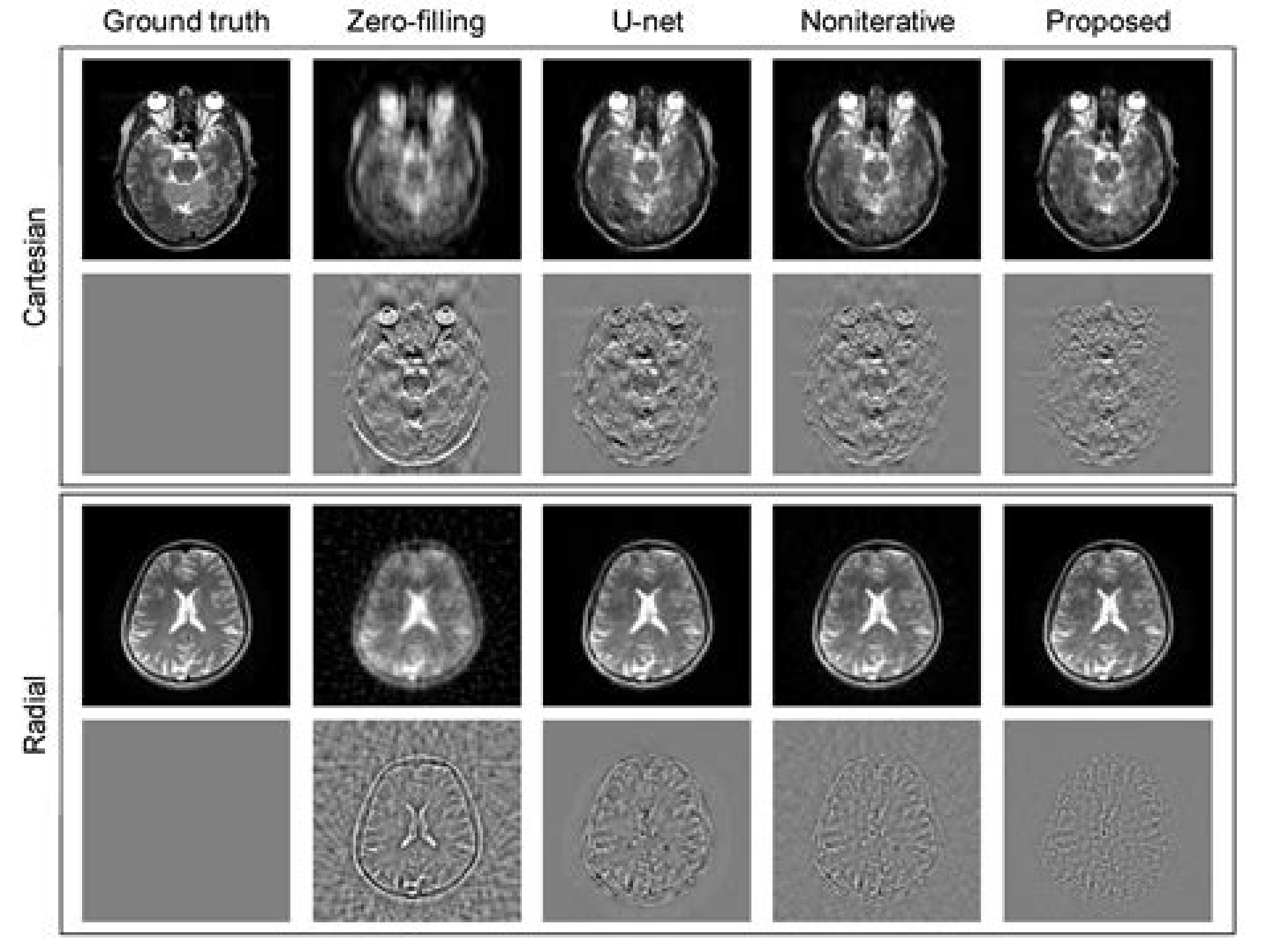
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# Compressed Sensing For Magnetic Resonance Image Reconstruction

Nguyen Van Le

**Compressed Sensing For Magnetic Resonance Image Reconstruction:**

**Compressed Sensing for Magnetic Resonance Image Reconstruction** Angshul Majumdar,2015-02-26 Expecting the reader to have some basic training in liner algebra and optimization the book begins with a general discussion on CS techniques and algorithms It moves on to discussing single channel static MRI the most common modality in clinical studies It then takes up multi channel MRI and the interesting challenges consequently thrown up in signal reconstruction Off line and on line techniques in dynamic MRI reconstruction are visited Towards the end the book broadens the subject by discussing how CS is being applied to other areas of biomedical signal processing like X ray CT and EEG acquisition The emphasis throughout is on qualitative understanding of the subject rather than on quantitative aspects of mathematical forms The book is intended for MRI engineers interested in the brass tacks of image formation medical physicists interested in advanced techniques in image reconstruction and mathematicians or signal processing engineers *Compressed Sensing Magnetic Resonance Image Reconstruction Algorithms* Bhabesh Deka,Sumit Datta,2018-12-29 This book presents a comprehensive review of the recent developments in fast L1 norm regularization based compressed sensing CS magnetic resonance image reconstruction algorithms Compressed sensing magnetic resonance imaging CS MRI is able to reduce the scan time of MRI considerably as it is possible to reconstruct MR images from only a few measurements in the k space far below the requirements of the Nyquist sampling rate L1 norm based regularization problems can be solved efficiently using the state of the art convex optimization techniques which in general outperform the greedy techniques in terms of quality of reconstructions Recently fast convex optimization based reconstruction algorithms have been developed which are also able to achieve the benchmarks for the use of CS MRI in clinical practice This book enables graduate students researchers and medical practitioners working in the field of medical image processing particularly in MRI to understand the need for the CS in MRI and thereby how it could revolutionize the soft tissue imaging to benefit healthcare technology without making major changes in the existing scanner hardware It would be particularly useful for researchers who have just entered into the exciting field of CS MRI and would like to quickly go through the developments to date without diving into the detailed mathematical analysis Finally it also discusses recent trends and future research directions for implementation of CS MRI in clinical practice particularly in Bio and Neuro informatics applications Magnetic Resonance Image Reconstruction Mehmet Akcakaya,Mariya Ivanova Doneva,Claudia Prieto,2022-11-04 Magnetic Resonance Image Reconstruction Theory Methods and Applications presents the fundamental concepts of MR image reconstruction including its formulation as an inverse problem as well as the most common models and optimization methods for reconstructing MR images The book discusses approaches for specific applications such as non Cartesian imaging under sampled reconstruction motion correction dynamic imaging and quantitative MRI This unique resource is suitable for physicists engineers technologists and clinicians with an interest in medical image reconstruction and MRI Explains the underlying principles of MRI reconstruction

along with the latest research Gives example codes for some of the methods presented Includes updates on the latest developments including compressed sensing tensor based reconstruction and machine learning based reconstruction

Accelerating Cardiac MRI Compressed Sensing Image Reconstruction Using Graphics Processing Units Majid Sabbagh,2016 Cardiac magnetic resonance imaging MRI has become a crucial part of monitoring patients with congenital heart diseases An important limitation of cardiac MRI using the prominent 3D steady state free precession 3D SSFP sequence is its long scan time Compressed sensing CS algorithm reduces the scan time by undersampling the data but increases the image reconstruction time because a non linear optimization problem must be iteratively solved to estimate the missing data and reconstruct the images The growing demand for reducing the examination time in cardiac MRI led us to investigate opportunities to accelerate this non linear optimization problem to facilitate the migration of CS into the clinical environment Using undersampled 3D SSFP datasets acquired from five patients we compared the speed and output quality of CS image reconstruction algorithm using a Central Processing Unit CPU a CPU with OpenMP parallelization and two different Graphics Processing Unit GPU platforms Reconstruction time had a mean of 13 1 minutes with a standard deviation of 3 8 minutes for the CPU a mean of 11 5 minutes with a standard deviation of 3 6 minutes for the CPU with OpenMP parallelization a mean of 2 2 minutes with a standard deviation of 0 3 minutes for the CPU with OpenMP plus NVIDIA k20m GPU and a mean of 1 7 minutes with a standard deviation of 0 3 minutes for the CPU with OpenMP plus NVIDIA k40m GPU The quality of images reconstructed on GPU and on CPU as assessed by image subtraction was comparable Furthermore necessary steps for implementation of rapid CS image reconstruction in the clinical environment are discussed

*Proceedings of 3rd International Conference on Computer Vision and Image Processing* Bidyut B. Chaudhuri,Masaki Nakagawa,Pritee Khanna,Sanjeev Kumar,2019-10-31 This book is a collection of carefully selected works presented at the Third International Conference on Computer Vision Image Video Formation and Display Image Video Filtering Restoration Enhancement and Super resolution Image Video Coding and Transmission Image Video Storage Retrieval and Authentication Image Video Quality Transform based and Multi resolution Image Video Analysis Biological and Perceptual Models for Image Video Processing Machine Learning in Image Video Analysis Probability and uncertainty handling for Image Video Processing and Motion and Tracking **Compressed Sensing and Experiment Design in Magnetic Field Based Imaging** Mirco Grosser,2023 This work investigates the use of compressed sensing to reduce measurement times in magnetic resonance imaging MRI and magnetic particle imaging MPI To this end a flexible yet performant image reconstruction framework is developed Based on this an efficient reconstruction scheme for non Cartesian MRI is proposed and a low rank based method for the estimation of MPI system matrices is developed Finally an experiment design framework is developed to obtain optimized sampling patterns for both MRI and MPI Soft Computing for Problem Solving Jagdish Chand Bansal,Kedar Nath Das,Atulya Nagar,Kusum Deep,Akshay Kumar Ojha,2018-12-14 This two volume book presents outcomes of the 7th

International Conference on Soft Computing for Problem Solving SocProS 2017 This conference is a joint technical collaboration between the Soft Computing Research Society Liverpool Hope University UK the Indian Institute of Technology Roorkee the South Asian University New Delhi and the National Institute of Technology Silchar and brings together researchers engineers and practitioners to discuss thought provoking developments and challenges in order to select potential future directions The book presents the latest advances and innovations in the interdisciplinary areas of soft computing including original research papers in the areas including but not limited to algorithms artificial immune systems artificial neural networks genetic algorithms genetic programming and particle swarm optimization and applications control systems data mining and clustering finance weather forecasting game theory business and forecasting applications It is a valuable resource for both young and experienced researchers dealing with complex and intricate real world problems for which finding a solution by traditional methods is a difficult task *MRI* Angshul Majumdar,Rabab Ward,2018-09-03 The field of magnetic resonance imaging MRI has developed rapidly over the past decade benefiting greatly from the newly developed framework of compressed sensing and its ability to drastically reduce MRI scan times MRI Physics Image Reconstruction and Analysis presents the latest research in MRI technology emphasizing compressed sensing based image reconstruction techniques The book begins with a succinct introduction to the principles of MRI and then Discusses the technology and applications of T1rho MRI Details the recovery of highly sampled functional MRIs Explains sparsity based techniques for quantitative MRIs Describes multi coil parallel MRI reconstruction techniques Examines off line techniques in dynamic MRI reconstruction Explores advances in brain connectivity analysis using diffusion and functional MRIs Featuring chapters authored by field experts MRI Physics Image Reconstruction and Analysis delivers an authoritative and cutting edge treatment of MRI reconstruction techniques The book provides engineers physicists and graduate students with a comprehensive look at the state of the art of MRI Computer Vision – ECCV 2018 Vittorio Ferrari,Martial Hebert,Cristian Sminchisescu,Yair Weiss,2018-10-05 The sixteen volume set comprising the LNCS volumes 11205 11220 constitutes the refereed proceedings of the 15th European Conference on Computer Vision ECCV 2018 held in Munich Germany in September 2018 The 776 revised papers presented were carefully reviewed and selected from 2439 submissions The papers are organized in topical sections on learning for vision computational photography human analysis human sensing stereo and reconstruction optimization matching and recognition video attention and poster sessions **Regularized Image Reconstruction in Parallel MRI with MATLAB** Joseph Suresh Paul,Raji Susan Mathew,2019-11-05 Regularization becomes an integral part of the reconstruction process in accelerated parallel magnetic resonance imaging pMRI due to the need for utilizing the most discriminative information in the form of parsimonious models to generate high quality images with reduced noise and artifacts Apart from providing a detailed overview and implementation details of various pMRI reconstruction methods Regularized image reconstruction in parallel MRI with MATLAB examples interprets regularized

image reconstruction in pMRI as a means to effectively control the balance between two specific types of error signals to either improve the accuracy in estimation of missing samples or speed up the estimation process The first type corresponds to the modeling error between acquired and their estimated values The second type arises due to the perturbation of k space values in autocalibration methods or sparse approximation in the compressed sensing based reconstruction model Features Provides details for optimizing regularization parameters in each type of reconstruction Presents comparison of regularization approaches for each type of pMRI reconstruction Includes discussion of case studies using clinically acquired data MATLAB codes are provided for each reconstruction type Contains method wise description of adapting regularization to optimize speed and accuracy This book serves as a reference material for researchers and students involved in development of pMRI reconstruction methods Industry practitioners concerned with how to apply regularization in pMRI reconstruction will find this book most useful **Novel Applications of Compressed Sensing to Magnetic Resonance Imaging & Spectroscopy** Sairam Geethanath,2011 In this work three novel applications of compressed sensing to MRI have been developed and implemented which accomplish reduction in acquisition time thereby also enabling increased spatial and or temporal resolution The first application is for reducing the acquisition time of conventional 1H magnetic resonance spectroscopic imaging MRSI which requires alongeracquisition time than conventional MRI The implementation involved exploiting the inherent sparsity of the MRSI data in the wavelet domain by the use of Daubechies wavelet This was demonstrated on an in vitro phantom 6 healthy human brain MRSI data sets 2 brain and prostate cancer data sets The reconstructions were quantified by the use of the root mean square error metric and subsequent statistical comparison of the metabolite intensities based on one way ANOVA followed by Bonferroni s multiple comparison test It was found that the implementation resulted in statistically significant differences at an acceleration of 10X and was considered the limit of the implementation The implementation showed no significant differences until 5X This indicates that CS has a potential to reduce conventional MRSI acquisition time by 80% This reduction in time could be used to increase the spatial resolution of the scan or acquire harder to detect metabolites through increased averaging Dynamic contrast enhanced MRI DCE MRI is a MRI method that involves serial acquisition of images before and after the injection of a contrast agent Therefore it requires both high spatial and temporal resolution The second application aims at accomplishing these requirements through the use of CS and comparing it with the widely used method of key hole imaging with respect to the choice of sampling masks and acceleration Three sampling masks were designed for both approaches and reconstructions were performed at 2X 3X 4X and 5X A semi automatic segmentation procedure was followed to obtain regions of well and poorly perfused tissue and the results were compared using the RMSE metric and a voxel wise paired t test The results of these tests showed that CS based masks performed better as compared to their key hole counterparts and the sampling mask based on data thresholding performed the best However the exact implementation of this mask is impractical but an approximate solution was

implemented for accelerating 3D gradient echo imaging The third application that has been developed in this work relates to the acceleration of sweep imaging with Fourier transform SWIFT which is a novel MR method facilitating the visualization of short T2 species which can yield important information about certain tissuessuch as cartilage In this project CS was applied to a resolution phantom and 5 human knee data sets acquired using SWIFT based imaging and accelerated up to 5X The errors of reconstruction were quantified by RMSE and it was found that reconstructions at 5X maintained fidelity A semi automatic segmentation procedure was followed to segment the ligaments and adjoining structures and the number of segmented voxels was compared for the full data reconstruction and the accelerated cases The 5X reconstruction showed a percentage difference of approximately 17% and was considered the limit of the implementation **Machine Learning for Medical Image Reconstruction** Nandinee Haq,Patricia Johnson,Andreas Maier,Tobias Würfl,Jaejun Yoo,2021-09-29 This book constitutes the refereed proceedings of the 4th International Workshop on Machine Learning for Medical Reconstruction MLMIR 2021 held in conjunction with MICCAI 2021 in October 2021 The workshop was planned to take place in Strasbourg France but was held virtually due to the COVID 19 pandemic The 13 papers presented were carefully reviewed and selected from 20 submissions The papers are organized in the following topical sections deep learning for magnetic resonance imaging and deep learning for general image reconstruction **Compressed Sensing for MRI** Mariya Doneva,2011 This work explores and extends the concept of applying compressed sensing to MRI Asuccessful CS reconstruction requires incoherent measurements signal sparsity and a nonlinearsparsity promoting reconstruction To optimize the performance of CS the acquisition thesparsifying transform and the reconstruction have to be adapted to the application of interest This work presents new approaches for sampling signal sparsity and reconstruction which areapplied to three important applications dynamic MR imaging MR parameter mapping andchemical shift based water fat separation The methods presented in this work allow to more fully exploit the potential of compressedsensing to improve imaging speed Future development of these methods and combination withexisting techniques for fast imaging holds the potential to improve the diagnostic quality ofexisting clinical MR imaging techniques and to open up opportunities for entirely new clinicalapplications of MRI Quantitative Magnetic Resonance Imaging Nicole Seiberlich,Vikas Gulani,Adrienne Campbell-Washburn,Steven Sourbron,Mariya Ivanova Doneva,Fernando Calamante,Houchun Harry Hu,2020-11-18 Quantitative Magnetic Resonance Imaging is a go to reference for methods and applications of quantitative magnetic resonance imaging with specific sections on Relaxometry Perfusion and Diffusion Each section will start with an explanation of the basic techniques for mapping the tissue property in question including a description of the challenges that arise when using these basic approaches For properties which can be measured in multiple ways each of these basic methods will be described in separate chapters Following the basics a chapter in each section presents more advanced and recently proposed techniques for quantitative tissue property mapping with a concluding chapter on clinical applications The reader will learn

The basic physics behind tissue property mapping How to implement basic pulse sequences for the quantitative measurement of tissue properties The strengths and limitations to the basic and more rapid methods for mapping the magnetic relaxation properties T1 T2 and T2 The pros and cons for different approaches to mapping perfusion The methods of Diffusion weighted imaging and how this approach can be used to generate diffusion tensor maps and more complex representations of diffusion How flow magneto electric tissue property fat fraction exchange elastography and temperature mapping are performed How fast imaging approaches including parallel imaging compressed sensing and Magnetic Resonance Fingerprinting can be used to accelerate or improve tissue property mapping schemes How tissue property mapping is used clinically in different organs Structured to cater for MRI researchers and graduate students with a wide variety of backgrounds Explains basic methods for quantitatively measuring tissue properties with MRI including T1 T2 perfusion diffusion fat and iron fraction elastography flow susceptibility enabling the implementation of pulse sequences to perform measurements Shows the limitations of the techniques and explains the challenges to the clinical adoption of these traditional methods presenting the latest research in rapid quantitative imaging which has the possibility to tackle these challenges Each section contains a chapter explaining the basics of novel ideas for quantitative mapping such as compressed sensing and Magnetic Resonance Fingerprinting based approaches Research Highlights Iowa State University. Department of Electrical and Computer Engineering,2010 **Performance Analysis Between Two Sparsity Constrained Mri Methods** Nibal Arzouni,2012 One of the most important challenges in dynamic magnetic resonance imaging MRI is to achieve high spatial and temporal resolution when it is limited by system performance It is desirable to acquire data fast enough to capture the dynamics in the image time series without losing high spatial resolution and signal to noise ratio Many techniques have been introduced in the recent decades to achieve this goal Newly developed algorithms like Highly Constrained Backprojection HYPR and Compressed Sensing CS reconstruct images from highly undersampled data using constraints Using these algorithms it is possible to achieve high temporal resolution in the dynamic image time series with high spatial resolution and signal to noise ratio SNR In this thesis we have analyzed the performance of HYPR to CS algorithm In assessing the reconstructed image quality we considered computation time spatial resolution noise amplification factors and artifact power AP using the same number of views in both algorithms and that number is below the Nyquist requirement In the simulations performed CS always provides higher spatial resolution than HYPR but it is limited by computation time in image reconstruction and SNR when compared to HYPR HYPR performs better than CS in terms of SNR and computation time when the images are sparse enough However HYPR suffers from streaking artifacts when it comes to less sparse image data **High-resolution Optogenetic Functional Magnetic Resonance Imaging Powered by Compressed Sensing and Parallel Processing** Nguyen Van Le,2012 Optogenetic functional magnetic resonance imaging ofMRI 1 is a powerful new technology that enables precise control of brain circuit elements while monitoring their causal

outputs To bring ofMRI to its full potential it is essential to achieve high spatial resolution with minimal distortions With our proposed compressed sensing CS enabled method high spatial resolution ofMRI images can be obtained with a large field of view FOV without increasing spatial distortions and the amount of acquired data The ofMRI data were sampled with passband balanced steady state free precession b SSFP 8 17 fast stack of spiral sequence in order to achieve ultra high spatial resolution images in a short amount of time Interleaves of data were randomly collected The images were recovered from the undersampled k space data by solving an unconstrained convex optimization problem which balances the trade off between data consistency and sparsity The optimization problem can be solved by gradient descent combined with backtracking line search algorithms Discrete cosine transform DCT were chosen as a sparsifying transform The ofMRI image reconstruction was processed in parallel on a graphics processing unit GPU using C C language supported by NVIDIA CUDA engine in order to achieve short reconstruction time An existing nonequispaced fast Fourier transform NFFT algorithm 13 14 was modified for our GPU parallel processing purpose The results demonstrate that the compressed sensing reconstructed image has higher resolution while maintaining a precise activation map compared to a fully sampled low resolution image with the same amount of data and scan time A 4 D image can be reconstructed in less than fifteen minutes which allows compressed sensing ofMRI to become a practical application Reconstruction-Free Compressive Vision for Surveillance Applications Henry Braun,Pavan Turaga,Andreas Spanias,Sameeksha Katoch,Suren Jayasuriya,Cihan Tepedelenlioglu,2019-05-02 Compressed sensing CS allows signals and images to be reliably inferred from undersampled measurements Exploiting CS allows the creation of new types of high performance sensors including infrared cameras and magnetic resonance imaging systems Advances in computer vision and deep learning have enabled new applications of automated systems In this book we introduce reconstruction free compressive vision where image processing and computer vision algorithms are embedded directly in the compressive domain without the need for first reconstructing the measurements into images or video Reconstruction of CS images is computationally expensive and adds to system complexity Therefore reconstruction free compressive vision is an appealing alternative particularly for power aware systems and bandwidth limited applications that do not have on board post processing computational capabilities Engineers must balance maintaining algorithm performance while minimizing both the number of measurements needed and the computational requirements of the algorithms Our study explores the intersection of compressed sensing and computer vision with the focus on applications in surveillance and autonomous navigation Other applications are also discussed at the end and a comprehensive list of references including survey papers are given for further reading *Novel Compressed Sensing Algorithms with Applications to Magnetic Resonance Imaging* Yue Hu,2014 Magnetic Resonance Imaging MRI is a widely used non invasive clinical imaging modality Unlike other medical imaging tools such as X rays or computed tomography CT the advantage of MRI is that it uses non ionizing radiation In addition MRI can provide images with multiple contrast by

using different pulse sequences and protocols However acquisition speed which remains the main challenge for MRI limits its clinical application Clinicians have to compromise between spatial resolution SNR and scan time which leads to sub optimal performance The acquisition speed of MRI can be improved by collecting fewer data samples However according to the Nyquist sampling theory undersampling in k space will lead to aliasing artifacts in the recovered image The recent mathematical theory of compressed sensing has been developed to exploit the property of sparsity for signals images It states that if an image is sparse it can be accurately reconstructed using a subset of the k space data under certain conditions Generally the reconstruction is formulated as an optimization problem The sparsity of the image is enforced by using a sparsifying transform Total variation TV is one of the commonly used methods which enforces the sparsity of the image gradients and provides good image quality However TV introduces patchy or painting like artifacts in the reconstructed images We introduce novel regularization penalties involving higher degree image derivatives to overcome the practical problems associated with the classical TV scheme Motivated by novel reinterpretations of the classical TV regularizer we derive two families of functionals which we term as isotropic and anisotropic higher degree total variation HDTV penalties respectively The numerical comparisons of the proposed scheme with classical TV penalty current second order methods and wavelet algorithms demonstrate the performance improvement Specifically the proposed algorithms minimize the staircase and ringing artifacts that are common with TV schemes and wavelet algorithms while better preserving the singularities Higher dimensional MRI is also challenging due to the above mentioned trade offs We propose a three dimensional 3D version of HDTV 3D HDTV to recover 3D datasets One of the challenges associated with the HDTV framework is the high computational complexity of the algorithm We introduce a novel computationally efficient algorithm for HDTV regularized image recovery problems We find that this new algorithm improves the convergence rate by a factor of ten compared to the previously used method We demonstrate the utility of 3D HDTV regularization in the context of compressed sensing denoising and deblurring of 3D MR dataset and fluorescence microscope images We show that 3D HDTV outperforms 3D TV schemes in terms of the signal to noise ratio SNR of the reconstructed images and its ability to preserve ridge like details in the 3D datasets To address speed limitations in dynamic MR imaging which is an important scheme in multi dimensional MRI we combine the properties of low rank and sparsity of the dataset to introduce a novel algorithm to recover dynamic MR datasets from undersampled k t space data We pose the reconstruction as an optimization problem where we minimize a linear combination of data consistency error non convex spectral penalty and non convex sparsity penalty The problem is solved using an iterative three step alternating minimization scheme Our results on brain perfusion data show a signicant improvement in SNR and image quality compared to classical dynamic imaging algorithms Page vii ix **Advances in Compressed Sensing for Magnetic Resonance Imaging** Mariya Doneva,2010

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