1ST

WINTER SCHOOL IN IMAGING SCIENCE BOOK OF ABSTRACTS

19 - 22 JANUARY, 2016

HIGH 1 RESORT, GANGWON-DO, KOREA

NRF National Research Foundation of Korea

A3IP

CSE @ YONSEI

SAMSUNG

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Organizing Committee

Jong Chul Ye KAIST, Korea
Jin Keun Seo Yonsei University, Korea
Taeuk Jeong Yonsei University, Korea

Organized by

A3 Foresight Program: Modeling and Computation of Applied Inverse Problems
Medical Image Computing Group

NRF National Research Foundation of Korea
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Winter School Program

Venue: Mountain Seminar Room B-2 (B wing of Mountain Condominium in High 1 Resort)

Day 1 – January 19 (Tuesday)

Time	Program
17:00 – 20:00	**Registration & Group Meeting** • A3IP Group • Medical Imaging Group • Computational Fluid Dynamics Group • Scientific Computing Group
17:00 – 20:00	**Dinner : Mountain Cafeteria**
19:00 – 20:30	**Special Sessions** **[Medical Imaging]** **Clinical Electrical Impedance Tomography; Monitoring Lung ventilation & Measuring Body Fat** • **Eung Jae Woo** Kyung Hee University, Korea Is EIT ready for clinical applications? • **Kyounghun Lee** Yonsei University, Korea Boundary artifact elimination using correlation in electrical impedance tomography • **Liangdong Zhou** Yonsei University, Korea Principal component analysis based Spatiotemporal Lung EIT • **Bukweon Kim** Yonsei University, Korea EIT Software • **Seungri Lee** Yonsei University, Korea Abdominal EIT • **Tong In Oh** Kyung Hee University, Korea Screening and Treatment Monitoring based on Conductivity Spectrum

Day 2 – January 20 (Wednesday)

Time	Program
07:00 – 08:15	**Breakfast : Mountain Cafeteria**
08:15 – 09:15	**Plenary Talk 1** (Computerized Tomography) • **Ken Taguchi** Johns Hopkins, USA Photon-counting CT: Toward material-specific low-dose imaging

09:15– 09:30	**Coffee Break**
09:30 – 10:00 **10:00 – 10:30** **10:30 – 11:00** **11:00 – 11:30**	**General Session 1** (CT Reconstruction) • **Seungryong Cho** KAIST, Korea A single scan dual-energy cone-beam CT in many-view under-sampling frame • **Jongduk Baek** Yonsei University, Korea CT image quality evaluation : from Fourier based metric to Image based metric • **Se Young Chun** UNIST, Korea Transmission Tomographic Image Reconstruction using Optimization Transfer: Application to Joint Attenuation / Activity Image Reconstruction for TOF PET • **Hao Gao** Shanghai Jiaotong University, China 5D respiratory motion model based image reconstruction algorithm for 4D cone-beam computed tomography
11:30 – 11:45	**Group Photo**
11:45 – 16:30	**Free time**
16:30 – 18:00	**Contributed Talks & Posters Session** • **Tongxing Li** Southeast University, China On the transmission eigenvalue problem for inhomogeneous absorbing media with mixed boundary condition • **Yuchan Wang** Southeast University, China On the reconstruction of boundary impedance of heat conduction system from nonlocal measurement • **Hyung Suk Park** Yonsei University, Korea Analytical Metal Artifact Corrector for Polychromatic X-ray CT Characterization of Metal Artifacts for Polychromatic X-ray CT • **Sungmin Lee** Yonsei University, Korea Metal artifact reduction method for circular cone-beam CT based on a beam hardening corrector. • **Chul Hee Han** Yonsei University, Korea Cone Beam Artifacts Reduction Algorithm using Dual Energy Spectrum - Simulation Study • **Shinkook Choi** Yonsei University, Korea Comparison of cone beam artifacts reduction : Two pass algorithm vs TV-based iterative algorithm • **Minah Han** Yonsei University, Korea A New Channel Design of Channelized Hotelling Observer and Internal Noise Optimization to Match Human Observer
18:00 – 19:00	**Dinner : Mountain Cafeteria**

19:00 – 20:30	**A3 Meeting** Chinese-Japanese-Korean A3 members
	• **Jijun Liu** Southeast University, China Inverse Scattering Problems: the Effect of Boundary Impedance • **Jie Yu** Fudan University, China Homogenization of coupled systems arising in steel hardening • **Jinchang Zheng** Fudan University, China Novel method for 2D interface identification on near-field inverse scattering with periodic structures • **Litao Ding** Fudan University, China Posterior contraction rates in Bayesian inversion with weighted operators • **Masaaki Uesaka** The University of Tokyo, Japan Γ-limit of a variational problem of a discrete system valued in S^1 • **Manabu Machida** The University of Tokyo, Japan Transport-based optical tomography • **Chang-Ock Lee** KAIST, Korea An Algorithm Based on Sinogram Surgery for CT Artifact Reduction • **Jun Yeb Lee** Ewha Womans University, Korea High order operator splitting methods for the phase field equations • **Hyeuknam Kwon** Yonsei University, Korea Spectroscopic EIT : Application to abdomen

Day 3 – January 21 (Thursday)

Time	Program
07:00 – 08:15	**Breakfast : Mountain Cafeteria**
08:15 – 09:15	**Plenary Talk 2** (Magnetic Resonance Imaging) • **Ricardo Otazo** NYU, USA MRI in the post-Nyquist era: Sparse sampling and reconstruction
09:15– 09:30	**Coffee Break**
09:30 – 10:00 10:00 – 10:30 10:30 – 11:00 11:00 – 11:30	**General Session 2** (MR Imaging) • **Jong Chul Ye** KAIST, Korea Accelerated MRI using annihilating filter based low-rank Hankel matrix (ALOHA) approach • **HyungJoon Cho** UNIST, Korea Synergistic combination of multi spin echoes and sparse sampling techniques • **Sung-Hong Park** KAIST, Korea Susceptibility-weighted magnetic resonance imaging • **Dong Liang** Shenzhen Institutes of Advanced Technology, China Accelerated MR parameter mapping

11:30 – 17:00	**Free time**
17:00 – 18:00	**A3 Meeting** Chinese-Japanese-Korean A3 members
	• **Xiang Xu** Zhejiang University, China Wellposedness of Piezotronics in p-n junctions • **Yue Lu** Fudan University, China Convergence analysis for regularized ranking algorithms • **Zehui Wu** Fudan University, China Alternating direction method of multiplier with scaling for linear inverse problems • **Yikan Liu** The University of Tokyo, Japan An inverse source problem for fractional diffusion equations • **Jaeseong Jang** Yonsei University, Korea Reconstruction of Blood Flow in the Left Ventricle using Doppler Echocardiography • **Gen Nakamura** Inha University, Korea Inversion at the Boundary for Dynamic Elastic Equation
18:00 – 19:00	**Dinner : Mountain Cafeteria**
19:00 – 20:30	**GPU Hand-on Experiment Session**

Day 4 – January 22 (Friday)

Time	Program
07:00 – 08:15	**Breakfast : Mountain Cafeteria**
09:30 – 11:00	**Direction for Industrial Mathematics** **Next Winter School Committee Meeting**

※ The schedule may be changed depending on the circumstances.

ABSTRACT

Special Session: Medical imaging

Clinical Electrical Impedance Tomography; Monitoring Lung ventilation & Measuring Body Fat

Eung Jae Woo Kyung Hee University, Korea

Title: Is EIT ready for clinical applications?

Abstract:

The human body is an electrically conducting object with various ions and charge-carrying molecules in complicated structures of cells, tissues, and organs. The electrical conductivity is a passive material property determined by the concentration and mobility of the charge carriers. It appears in Ohm's law to describe the relation between the current density and the electric field intensity. Since the conductivity is influenced by the structure, pathology, function, and metabolism of cells, tissues, and organs, its imaging has been actively investigated in the field of electrical impedance tomography (EIT). In EIT, electrical currents are injected into the body and induced voltages are measured on the body surface to produce cross-sectional images of internal conductivity distributions. For the last 30 years, however, its clinical applications have been hindered by the technical difficulties related with the ill-posedness of the corresponding image reconstruction problem. In the first half of this talk, we will briefly review what we have learned from the 30 years of EIT research.

Recent technical progress in EIT hardware and software developments have matured the technology for a few carefully chosen clinical applications. Commercial clinical EIT systems appeared for lung imaging of a mechanically ventilated patient. In the second half of the talk, we will discuss our strategy for commercializing the state-of-the-art EIT technology. Making a right choice of application area is a key to successful commercialization. Commercial clinical EIT system developments for real-time imaging of lung ventilation and perfusion, sleep apnea monitoring, and abdominal fat imaging will be described.

Kyounghun Lee Yonsei University, Korea

Title: Boundary artifact elimination using correlation in electrical impedance tomography

Abstract:

This paper presents a way of eliminating boundary artifacts for lung imaging in electrical impedance tomography(EIT). Due to the thorax movements during ventilation, lung EIT is suffered from the boundary shape error, electrode position error and bad contact condition of electrode with skin. These phenomena affect to reconstruction images as artifacts especially near the boundary. Using correlations between the columns of the sensitivity matrix, we remove the artifact related data from the EIT-data. We also propose a conductivity reconstruction algorithm based on the correlations. Numerical and actual experiment results validate the performance of the algorithm.

Liangdong Zhou Yonsei University, Korea

Title: Principal component analysis based Spatiotemporal Lung EIT

Abstract:

Lung EIT aims to imaging conductivity change of the lungs. Regularization is needed in the standard linearized reconstruction algorithm due to its inherent nature of ill-posedness of EIT problem. Spatial regularization is insucient to achieve robust imaging since it doesn't consider the smooth change of conductivity in time domain. We propose to apply principal component analysis to the low band-pass ltered EIT data to give additional temporal regularization to the standard linearized reconstruction algorithm. Experiments show that the proposed method gives more robust reconstruction results.

Bukweon Kim Yonsei University, Korea

Title: EIT Software

Abstract:

When doing experiment of EIT, we need to control how the current are injected, gather data, calculate with data, and show the calculated image all at same time. In order to do all these things in right way, we get some help from machines and programs. I will be talking about the programming part of EIT. EIT control program need to be able to do at least 3 things. It must be able to give order to machine, collect data from machine and do the things we want from those data. Before doing anything else we have to check whether we can give orders to machine or not. This work contains checking connection and making sure any exceptions are handled.

After checking all the orders are given properly, now we give the desired order to machine and receive the data desired. If order is given right, this should work without any problem. But we have to check and know what the meaning of these data are.

Finally, we handle the data and produce the result we want by program. This part usually takes most time of calculation so time to time this part gets delayed from real time. In order to overcome this problem, we have to give good look at thread communication and tell which should be done and when it should be done. Saving is also a time consuming work for computer. so this also must be treated separately from calculation, which is also just about thread communication.

Seungri Lee Yonsei University, Korea

Title: Abdominal EIT

Abstract:

We investigate an absolute conductivity reconstruction algorithm to estimate abdominal fatness by using electrical impedance tomography (EIT). The proposed reconstruction algorithm is a depth-based method with taking account of electrode configuration, current patterns. Since there are drawbacks of static EIT, e.g. sensitive to the boundary geometry and electrode position errors, we use a handheld 3D scanner which can provide domain geometry. The numerical simulations are conducted to demonstrate the proposed method.

Tong In Oh Kyung Hee University, Korea

Title: Screening and Treatment Monitoring based on Conductivity Spectrum

Abstract:

Various living tissue has a special structure including cellular membrane, intra-cellular fluid and extra-cellular fluid. These contents and their structure provide the different conductivity and ionic current flow. Therefore, the conductivity spectrum and its anisotropy are highly depended on the type of tissue and its physiological and pathological status. Recently, clinicians and patients request the new theragnosis method for cancer in order to improve the accuracy of screening and to apply treatment after detecting the cancer immediately. Tissue at the targeted point can be characterized using conductivity spectrum measured by focused bioimpedance spectroscopy probe. From scanning the suspicious region, we could estimate the cancerous region. Another important diagnostic information for cancer screening is to estimate the cancer stage. We could estimate the depth and volume of cancerous tissue using the admittivity scanning probe including the high density electrode array. It provides the additional advice to determine a treatment plan. After detecting the cancerous tissue, image-guided thermal interventional therapy is used for treatment. They commonly control the temperature raising to destroy the targeted tissue using RF current, laser, ultrasound, and microwave. It requires monitoring method during and after the procedure. Electrical conductivity is highly depended on the temperature and it can discriminate the ablated tissue from the cancerous tissue. We will show the possibility of treatment monitoring method to achieve complete healing.

Plenary Talk 1

Computerized Tomography

Ken Taguchi Johns Hopkins, USA

Title: Photon-counting CT: Toward material-specific low-dose imaging

Abstract:

The development of energy-sensitive photon-counting x-ray detectors (PCD) has created great excitement in x-ray and x-ray CT systems. Such innovative new x-ray detectors count individual photons and sort them into selected energy bins. It is said that PCDs will not only improve anatomical or functional CT imaging significantly but also provide an opportunity for molecular CT imaging and low-dose CT. On the side of enthusiasm, a lot of questions are being asked. Are count rates of PCDs sufficient for intense x-ray flux of CT systems? Is the current energy resolution sufficient? What are the imaging technologies that need to be developed for PCD-CT and what are the remaining issues? When will the first commercial PCD-CT system be introduced?

Aiming at providing answers to the questions listed above, we will review the current status and perspectives of the imaging technologies for PCD-CT. Methods to model, calibrate, and compensate for the non-ideal properties of PCDs will be discussed. Algorithms to reconstruct images from spectral data will be presented.

General Session 1

CT Reconstruction

Seungryong Cho KAIST, Korea

Title: A single scan dual-energy cone-beam CT in many-view under-sampling frame

Abstract:

Sparse sampling method is one viable option to low-dose CT, and has been actively investigated in terms of both reconstruction algorithm and physical realization of the sampling. Sparse-view sampling is a straightforward way and is considered a feasible solution particularly to various cone-beam CT applications. Recently, we have proposed and developed another type of sparse sampling scheme, which is called many-view under-sampling (MVUS). In the MVUS scheme, the x-ray beam is partially blocked by multiple radio-opaque strips thereby reducing the radiation dose to the patient. Its feasibility and experimental implementation in CBCT systems will be presented. In addition, it will be demonstrated that dual-energy imaging from a single MVUS scan is possible.

Jongduk Baek Yonsei University, Korea

Title: CT image quality evaluation : from Fourier based metric to Image based metric

Abstract:

With the introduction of X-ray flat panel detectors, cone-beam computed tomography (CBCT) has been widely used and accelerated the utilization of three-dimensional (3-D) images for clinical diagnosis. The diagnostic accuracy is closely related to the imaging performance, and thus the optimization of imaging systems and image processing algorithms has been an important issue. For linear reconstruction (e.g., FDK), image quality or imaging performance can be evaluated by Fourier based metrics (MTF, NPS, and NEQ), and these metrics can be utilized for a task based image quality assessment. In this talk, I will cover three sub topics : 1) A method to measure 3D MTF of a CBCT system, 2) sphere phantom approach to measure directional MTF of a Tomosynthesis system, and 3) slice direction dependent detectability of CBCT images. Especially in subtopic 3, it will be shown that the axial and coronal slices of CBCT images reconstructed by FDK show different detectability for various signal sizes.

Se Young Chun UNIST, Korea

Title: Transmission Tomographic Image Reconstruction using Optimization Transfer: Application to Joint Attenuation / Activity Image Reconstruction for TOF PET

Authors: Se Young Chun(UNIST), Kyeong Yun Kim(Seoul National University),
Jae Sung Lee(Seoul National University), Jeffrey A Fessler(University of Michigan – Ann Arbor)

Abstract:
Many state-of-the-art image reconstruction algorithms for low dose CT have used weighted least square based data fidelity terms. However, desiring much lower radiation dose for CT and improving energy-resolution in spectral CT detectors may lead to lower signal-to-noise ratio (SNR) of measurements (per energy bin). Low SNR data usually requires Poisson model based data fidelity terms for accurate image reconstruction. In this talk, we will review optimization transfer methods for transmission tomography with Poisson noise model, especially focusing on separable quadratic surrogate (SQS) algorithm. Then, we will show one example for using the SQS algorithm in our recent work on joint attenuation and activity image reconstruction from TOF PET data using alternating direction method of multipliers framework.

Hao Gao Shanghai Jiaotong University, China

Title: 5D respiratory motion model based image reconstruction algorithm for 4D cone-beam computed tomography

Abstract:
4D cone-beam computed tomography (4DCBCT) reconstructs a temporal sequence of CBCT images for the purpose of motion management or 4D treatment in radiotherapy. However the image reconstruction often involves the binning of projection data to each temporal phase, and therefore suffers from deteriorated image quality due to inaccurate or uneven binning in phase, e.g., under the non-periodic breathing. A 5D model has been developed as an accurate model of (periodic and non-periodic) respiratory motion. That is, given the measurements of breathing amplitude and its time derivative, the 5D model parametrizes the respiratory motion by three time-independent variables, i.e., one reference image and two vector fields. In this work we aim to develop a new 4DCBCT reconstruction method based on 5D model. Instead of reconstructing a temporal sequence of images after the projection binning, the new method reconstructs time-independent reference image and vector fields with no requirement of binning. The image reconstruction is formulated as a optimization problem with total variation regularization on both reference image and vector fields, and the problem is solved by the proximal alternating minimization algorithm, during which the split Bregman method is used to reconstruct the reference image, and the Chambolle's duality-based algorithm is used to reconstruct the vector fields. The convergence analysis of the proposed algorithm is provided for this nonconvex problem. Validated by the simulation studies, the new method has significantly improved image reconstruction accuracy due to no binning and reduced number of unknowns via the use of the 5D model.

Contributed Talks & Poster Session

Tongxing Li Southeast University, China

Title: On the transmission eigenvalue problem for inhomogeneous absorbing media with mixed boundary condition

Authors : Tongxing Li (Southeast University), Jijun Liu (Southeast University)

Abstract:

The interior transmission eigenvalue problems (ITEPs) came originally from the scattering problems of incident waves for inhomogeneous media. Consider the transmission eigenvalue problem for the wave scattering by a dielectric inhomogeneous absorbing obstacle lying on a perfect conducting surface. We prove that the transmission eigenvalues exist and form a discrete set for inhomogeneous non-absorbing media, by using analytic Fredholm theory. Then, for inhomogeneous media with small absorption, we prove that the transmission eigenvalues also exist and form a discrete set by using perturbation theory. Consider the ITEPs for Maxwell's equations governing the electromagnetic wave scattering in the media with inhomogeneous microstructure, we prove that the eigenpairs of ITEPs for oscillating media converge to those of the homogenized system as the period goes to zero and the real transmission eigenvalues converge to the corresponding ones of the homogenized problem.

Yuchan Wang Southeast University, China

Title: On the reconstruction of boundary impedance of heat conduction system from nonlocal measurement

Authors: Jijun Liu(Southeast University), Yuchan Wang(Southeast University)

Abstract:

Consider the reconstruction of the Robin impedance coefficient of the heat conduction system in 2-dimensional spatial domain from the time-average measurement specified on the boundary. By applying the potential representation of solution, this nonlinear inverse problem is transformed into an ill-posed integral system coupling the density function for potential and the unknown boundary impedance. The conditional stability as well as the uniqueness for this inverse problem is established from the integral system. Then we propose to find the boundary impedance by solving a non-convex regularizing optimization problem. The well-posedness of this optimization problem together with the convergence property of the minimizer is analyzed. Finally, based on the singularity decomposition of the potential representation of the solution, two iteration schemes with their numerical realizations are proposed to solve this optimization problem.

Hyung Suk Park Yonsei University, Korea

Title: Analytical Metal Artifact Corrector for Polychromatic X-ray CT

Abstract:
X-ray computed tomography (X-ray CT) is the most widely used tomographic imaging technique in the field of dental and medical radiography. In spite of the excellent resolution and contrast of the cross-sectional images, its advantage is partly limited by the metallic object-related artifacts in the images. In this poster, we proposes a new method to correct metal artifacts for polychromatic X-ray CT without degrading intact anatomical images. Without prior knowledge of the spectrum parameters or energy-dependent attenuation coefficients, the proposed correction allows the background CT image (i.e., the image before its corruption by beam-hardening artifacts) to be extracted from the uncorrected CT image. Computer simulations and phantom experiments demonstrate the effectiveness of the proposed method to alleviate metal artifacts due to beam hardening.

Hyung Suk Park Yonsei University, Korea

Title: Characterization of Metal Artifacts for Polychromatic X-ray CT

Abstract:
In X-ray CT, metal artifact reduction remains a challenging issue due to the serious difficulties in analyzing the X-ray data. Metal artifacts are mainly caused by the beam-hardening of polychromatic X-ray photon beams, which causes mismatch between the actual sinogram data (or X-ray data) and the data model being the Radon transform of the unknown attenuation distribution in the CT reconstruction algorithm. In this poster, we provide a rigorous characterization of metal artifacts in X-ray CT using the notion of the Wave-front set from micro-local analysis.

Sungmin Lee Yonsei University, Korea

Title: Metal artifact reduction method for circular cone-beam CT based on a beam hardening corrector

Abstract:
This paper aims to remove metal artifacts on cone-beam CT with circular orbit. We generalize the MAR method introduced by Park to 3D CBCT with circular trajectory. We found that the 2D beam hardening corrector is generalized to 3D beam hardening corrector by replacing the Radon transform and backprojection to cone-beam projection and cone-beam backprojection, respectively. Numerical simulation and experiments show the validity of the proposed method.

Chul Hee Han Yonsei University, Korea

Title: Cone Beam Artifacts Reduction Algorithm using Dual Energy Spectrum - Simulation Study

Abstract:

We propose a new method to reduce cone beam artifacts using Dual Energy Spectrum in a Cone Beam Computed Tomography (CBCT). To reduce artifacts without changing of data acquisition geometry of CBCT, we focus on the given Two-pass algorithm. Then, we modify threshold based Extreme Density (ED) Materials Segmentation Process of the Two-pass algorithm with Dual Energy Material Decomposition based on polynomial fitting and Total-Variation Iterative Reconstruction. This enables the exact segmentation of ED Materials in large cone angles over 10 degree and noisy cases resulting in better cone beam artifacts reduction performance. To validate the proposed method, we simulate with Defrise phantom containing two types of rods under noisy conditions. For quantitative evaluation, we compare RMSE (Root Mean Square Error) of the Two-pass algorithm and the proposed algorithm. Simulation results show an excellent artifact reduction performance on the proposed algorithm, demonstrating the effectiveness compared to the Two-pass algorithm.

Shinkook Choi Yonsei University, Korea

Title: Comparison of cone beam artifacts reduction : Two pass algorithm vs TV-based iterative algorithm

Abstract:

In a cone beam CT system, the severity of the cone beam artifacts is increased as the cone angle increases. To reduce the cone beam artifacts, several algorithms have been proposed. In this paper, we used two pass algorithm and Gradient-Projection-Barzilai-Borwein (GPBB) algorithm to reduce the cone beam artifacts, and compared their performance using structural similarity (SSIM) index. The results show that two pass algorithm reduced the cone beam artifacts with small residual errors, but GPBB algorithm completely removed the cone beam artifacts and restored the original shape of the objects.

Minah Han Yonsei University, Korea

Title: A New Channel Design of Channelized Hotelling Observer and Internal Noise Optimization to Match Human Observer

Abstract:

We proposed a new channel design of Channelized Hotelling observer (CHO) and optimal internal noise model to predict the detection performance of the human observer for different signal sizes, contrasts and noise structures. In this study, Gaussian signals whose width are 2, 4, 6 and 8, and three different noise structures (i.e., white, low-passed and high-passed) were used for SKE (signal known exactly) / BKE (background known exactly) detection tasks. Then, human observer study was performed and modelled by the CHO. To match the detection performance of the CHO with that of the human observer, we performed brute-force searching to find optimal channel parameters and level of internal noise by assuming uniform channel internal noise model. Our results showed that the CHO with optimized channel parameters and internal noise level provided good agreement with the detection performance of the human observer.

Plenary Talk 2

Magnetic Resonance Imaging

Ricardo Otazo NYU, USA

Title: MRI in the post-Nyquist era: Sparse sampling and reconstruction

Abstract:

Recent developments during the last decade in the field of applied mathematics have started to change the way we think about image acquisition and reconstruction in MRI. The conventional approach of acquiring one k-space sample per image pixel (Nyquist rate) is inefficient and rather wasteful since the information content is usually much lower than the number of pixels. The introduction of compressed sensing, which attempts to sample at the information rate rather than at the Nyquist rate by exploiting image sparsity and incoherent sampling, started a new era in the development of rapid, efficient and information-rich MRI techniques. This talk will discuss the fundamentals of compressed sensing MRI and recent developments and extensions such as low-rank matrix completion, low-rank plus sparse (L+S) reconstruction, reconstruction of additional dimensions, model-based reconstruction, among others. The application of compressed sensing based methods to clinical problems of interest will be also discussed.

General Session 2

MR imaging

Jong Chul Ye KAIST, Korea

Title: Accelerated MRI using annihilating filter based low-rank Hankel matrix (ALOHA) approach

Abstract:

Parallel MRI (pMRI) and compressed sensing MRI (CS-MRI) have been considered as two distinct reconstruction problems. In this talk, an annihilating filter based low-rank Hankel matrix approach (ALOHA) is proposed as a general framework which unifies pMRI and CS-MRI as a weighted k-space interpolation problem. Our framework exploits an annihilating filter relationship originating from the sparsity in the transform domain as well as from parallel acquisition physics. This results in a rank-deficient Hankel structured matrix, whose missing data can be recovered with a low rank structured matrix completion algorithm after a k-space weighting. In particular, when the underlying image can be sparsified with a wavelet transform, the low rank matrix completion problem can be solved with a multi-scale pyramid resulting in efficient computation. Using the theoretical results from the latest compressed sensing literatures, we showed that the required sampling rates for ALOHA in both single and parallel imaging are nearly optimal. Experimental results with in vivo data for single/multi-coil imaging as well as dynamic imaging confirmed that the proposed method outperforms the state-of-the-art pMRI and CS-MRI. By reformulating the pMRI and CS-MRI as a weighted k-space interpolation problem that can be solved using a low rank Hankel structured matrix completion, the generalized ALOHA framework provides better insight into MRI reconstruction problems.

HyungJoon Cho UNIST, Korea

Title: Synergistic combination of multi spin echoes and sparse sampling techniques

Abstract:

There are great interests in accelerating MR acquisition times. Hardware-wise, parallel acquisitions became standard configuration. Signal processing-wise, recent sparse sampling holds great potential and under intense investigations. MR physics-wise, multi spin echo techniques can add significant reduction. In this talk, we present several examples on synergistic combination of multi spin echo and sparse sampling techniques in acquiring MR image as well as quantitative MR parameters of interest. Future directions of this approach will also be discussed.

Sung-Hong Park KAIST, Korea

Title: Susceptibility-weighted magnetic resonance imaging

Abstract:

Magnetic susceptibility, one measure of magnetic properties of a material, is heterogeneous in our body. Sometimes it causes susceptibility artifacts in gradient echo-based imaging, but also works as intrinsic contrast sources such as blood oxygenation level-dependent (BOLD) contrast. BOLD contrast is generated by paramagnetic property of deoxyhemoglobin (dHb) and used in functional MRI and venography. In this seminar, BOLD contrast will be demonstrated for high-resolution functional MRI and also visualization of tiny small veins of 20μm-diameter in vivo at ultrahigh magnetic field. Also discussed will be mathematical model for advancement of BOLD venography to potential measurement of venous oxygen saturation level and diameter. Some mathematical issues in MR imaging with susceptibility will be briefly introduced and discussed.

Dong Liang Shenzhen Institutes of Advanced Technology, China

Title: Accelerated MR parameter mapping

Abstract:

Quantitative measurement of relaxation times of tissue, such as longitudinal (T1) and transverse (T2) relaxation times, promises to offer better tissue characterization comparing with the conventional qualitative MRI. One major practical limitation that often arises in MR parameter mapping is the long data acquisition time since MR parameter mapping experiments often involve acquisition of a sequence of images with variable contrast-weightings. In this talk, we will introduce our work on accelerating MR parameter mapping by using some prior information such as parametric model, sparsity and low rank.

A3 Meeting

Jijun Liu Southeast University, China

Title: Inverse Scattering Problems: the Effect of Boundary Impedance

Abstract:
For given incident plan waves, the scattered wave outside of an obstacle is governed by the Helmholtz equation in frequency domain. The inverse scattering problems aim to detect the obstacle property such as boundary shape and type from some information about the scattered wave. In the case that the obstacle boundary is of impedance type, the inverse scattering problems need to identify both the boundary shape and the boundary impedance simultaneously. In this talk, we will introduce our recent works for inverse scattering problems of an obstacle with impedance boundary. We will present the reconstruction schemes and show some influence of the impedance distribution on the shape reconstruction performance. Numerical implementations are also given.

Jie Yu Fudan University, China

Title: Homogenization of coupled systems arising in steel hardening

Abstract:
In this talk, we summarize the steel hardening on distribution of austenite and martensite into a mathematical model governed by a coupled system where a diffusion equation focuses on the macro scale and a Maxwell equation on the micro scale. A homogenized system is established with certain error estimates between both systems.

Jinchang Zheng Fudan University, China

Title: Novel method for 2D interface identification on near-field inverse scattering with periodic structures

Abstract:
In this talk, we investigate interface recovery on near-field inverse scattering with periodic structures. By appropriate assumptions, we directly use the idea that the total field is a combination of waves of different frequencies, and the resulting algorithm can be used iteratively on a single data to fully extract its information. Under our framework, the measure error can be alliviated by more measurement, shorter measure distance, and we also have the quantative expression of error and resolution, by which we propose the condition for breaking resolution limit. The numerical results verify our analysis and shed light on the efficiency of the proposed methods.

Litao Ding Fudan University, China

Title: Posterior contraction rates in Bayesian inversion with weighted operators

Abstract:
We study the Bayesian approach for recovery of intermediate temperature profile in backward heat equations. By assuming a Gaussian prior and Gaussian noise, the posterior distribution can be formulated in Gaussian as well. Our focus is the marginal posterior contraction rates. Previous constraction rates focus on the recovery of the initial condition which is of logrithmic types whereas we verify Holder type contraction rates with weighted operators.

Yue Lu Fudan University, China

Title: Convergence analysis for regularized ranking algorithms

Abstract:
The problem of ranking has recently attracted much attention because of its importance in the application of machine learning. We study the supervised ranking problem within the framework of regularization theory and investigate a specific algorithm which can be employed to overcome the intrinsic ill-posedness. We prove a sharper convergence rate compared to some existing studies.

Zehui Wu Fudan University, China

Title: Alternating direction method of multiplier with scaling for linear inverse problems

Abstract:
Alternating direction method of multiplier(ADMM) is an efficient and popular method for solving optimization problems due to its decomposability. ADMM with scaling can also be implemented to solve linear inverse problems. We prove the convergence of ADMM with scaling and provide further discussion on error estimates of noisy observations. Numerical experiments in image deblurring with convex penalty terms confirm the theoretical predictions.

Xiang Xu Zhejiang University, China

Title: Wellposedness of Piezotronics in p-n junctions

Abstract:
In this talk, the mathematical modeling and analysis of piezotronics in p-n junctions will be discussed. P-N junction is a typical nano electrical mechanical system(NEMS) in nano devices. The underlying mechanics coupled with piezoelectricity could be described by piezotronics which is developed recently in nanomaterials community. The wellposedness of the model problem is obtained by utilizing Garlerkin method and energy estimates.

Masaaki Uesaka The University of Tokyo, Japan

Title: Γ-limit of a variational problem of a discrete system valued in S^1

Abstract:
We consider the variational problem of the function from 1-dimensional lattice to S^1. We propose this discrete model as the energy model for a screw dislocation of crystal lattice. We show the explicit representation of the Γ-limit of this model as the lattice length tends to 0. We compare our result with the similar problem of the function valued in **R**.

Manabu Machida The University of Tokyo, Japan

Title: Transport-based optical tomography

Abstract:
Optical tomography is an imaging modality which uses near-infrared light. Although light in biological tissue obeys the radiative transport equation, usually the diffusion equation is used since the radiative transport equation is difficult to solve. In this talk, we will consider optical tomography based on the radiative transport equation without making diffusion approximation. We will make use of the recently obtained fundamental solution to the three-dimensional radiative transport equation.

Yikan Liu The University of Tokyo, Japan

Title: An inverse source problem for fractional diffusion equations

Abstract:
Time-fractional diffusion equations have gained increasing popularity within the last decade due to their significance in modeling the anomalous diffusion phenomena in heterogeneous media. In this talk, we investigate a related inverse problem on determining the temporal component in the source term by single-point observation data, which is applicable to the identification of a time-dependent contaminant source. Employing the fractional homogenization principle, we prove the uniqueness and stability for the inverse problem based on a newly established strong maximum principle. Numerically, we develop an iterative method by utilizing a monotone reconstruction operator.

Chang-Ock Lee KAIST, Korea

Title: An Algorithm Based on Sinogram Surgery for CT Artifact Reduction

Abstract:
There are several types of artifacts in CT images. The streaking artifact caused by the metallic objects (dental implants, surgical clips, or steel-hip) is one of the major artifacts in CT image and it limits the applications of CT. We propose an algorithm for reducing the streaking artifacts in CT images. We do sinogram surgery, iteratively, to remove the metallic effect in the sinogram using the basic principle of CT image reconstruction. We apply our algorithm for the parallel beam CT model and fanbeam CT model. The numerical experiments show that our algorithm reduces the metal artifacts effectively even for the phantom of complex model such as dental shape in both CT models and for the phantom with noise. Furthermore, we apply our algorithm to resolve another problematic phenomenon of CT: ring artifact. We analyze the simulation results both quantitatively and qualitatively.

Jun Yeb Lee Ewha Womans University, Korea

Title: High order operator splitting methods for the phase field equations

Abstract:
The phase-field method has recently emerged as a powerful computational approach for modeling and predicting mesoscale morphological and microstructure evolution in materials. Numerous numerical algorithms have been developed to improve accuracy and numerical stability of the phase-field method. We propose simple and stable high order operator splitting methods. A core idea of the methods is to decompose the original equation into linear and nonlinear subequations, in which the linear subequation has a closed-form solution in the Fourier space. We apply a nonlinear Newton-type iterative method to solve the nonlinear subequation at the implicit time level and thus a considerably large time step can be used. By combining these subequations, we achieve the first-, second, and high order accuracy in time. We present numerical experiments to show the accuracy and efficiency of the proposed methods.

Hyeuknam Kwon Yonsei University, Korea

Title: Spectroscopic EIT : Application to abdomen

Abstract:
In this research, we present the reconstruction method of visualizing absolute admittivity image of assessing abdominal adipose tissue using electrical impedance tomography (EIT). By the aid of adjusting electrode configuration and current injection patterns, the proposed method can be constructed with the estimated domain geometry. To alleviate the major drawbacks of static EIT being sensitive to the boundary geometry and electrode position errors, we use a handheld 3D scanner. Moreover, we analytically exhibits the fundamental mechanisms underlying the fact that effective biological tissue electrical properties and their frequency dependence reflect the tissue composition. A homogenization theory is introduced to express the effective admittivity of cell suspensions. The performance of the proposed method were demonstrated with numerical simulations.

Jaeseong Jang Yonsei University, Korea

Title: Reconstruction of Blood Flow in the Left Ventricle using Doppler Echocardiography

Abstract:

For the evaluation of left ventricular (LV) function, echocardiographic images have been widely used to measure related indexes. However, many LV indexes are not related with a swirling blood flow pattern which is a characteristic blood flow pattern inside LV but geometrical variations of LV. We present a reconstruction model for visualizing three-dimensional (3D) blood flow inside LV. By combining the color Doppler data and Navier-Stokes equations, a reconstruction model is designed to assimilate reconstructed velocity components with the Doppler data. A synthetic intra-cardiac blood flow is simulated with a LV domain reconstructed by echocardiographic images and Doppler data of the flow is imitated by a simple model. Using our reconstruction model with the imitated Doppler data, we try to reconstruct blood flow velocity and compare the reconstruction to the synthetic flow.

Gen Nakamura Inha University, Korea

Title: Inversion at the Boundary for Dynamic Elastic Equation

Abstract:

In this talk, we will provide an inversion formula at the boundary for the inverse boundary value problem for a dynamical isotropic elastic system of equations in three dimensional space. More precisely taking the the full symbol of the dynamical Dirichlet to Neumann map, we will give an explicit inversion formulae to recover the Lam e moduli and density of the system and all their derivatives at the boundary from the full symbol of the dynamical Dirichlet to Neumann map. The uniqueness for identifying the Lame moduli and density was proved in 2000. Since then giving the inversion formulae to recover these has been left open for 15 years.

We will also provide a layer stripping algorithm which can approximately propagate the Dirichlet to Neumann map inside a near surface layer of the boundary of a domain in which the system is given.

The key for these are to link the dynamical Dirichlet to Neumann map to the Dirichlet to Neumann map for the elliptic boundary value problem containing a large parameter via a finite Laplace transform. Here the large parameter is nothing but the Laplace variable.

GPU Hand-on Experiment Session

Bio Imaging & Signal Processing Lab (BISPL) KAIST, Korea

To participate in 'GPU Hand-on Experiment Session', you have to bring a laptop computer which a NVIDIA GPU device is mounted in. If the GPU device is already mounted in your desktop computer, we suggest to use a remote access program to control your desktop computer in the laptop. "Term viewer" is recommended as the remote access program, it can be downloaded at https://www.teamviewer.com. If you use the windows remote access program, the GPU device does not work in your computer.

[NOTICE]

YOU HAVE TO INSTALL ALL FILES PREVIOUSLY, BECAUSE A INSTALLATION TIME IS TOO LONG.

Setting up Development Environment

1. O/S Platform is **Windows.**
2. Install the latest **NVIDIA Driver.** [1]
3. Install the latest **CUDA Toolkit.** [2]
4. Install the **MATLAB 2014** or **MATLAB 2015.** [3]
4. Install the **Visual Studio 2012** or **Visual Studio 2013.** [3]

[1] Download the NIVDIA Driver http://www.nvidia.com/Download/index.aspx.
[2] Download the CUDA Toolkit https://developer.nvidia.com/accelerated-computing-toolkit.
[3] Even though it is possible to using lower versions of MATLAB and Visual Studio, it is required to a difference setting up process. In this session, we do not consider the difference setting up process for the low versions.

[NOTICE]

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Computer Specifications for Parallel Computing, based on MATLAB

Requirements

1. Requires **MATLAB.**
2. **CUDA-enabled NVIDA GPU** with compute capability 2.0 or higher.
3. Latest **CUDA driver.**

*Check the CUDA-Enable GPU at https://developer.nvidia.com/cuda-gpus.

Recommendation

1. For GPU engine's architecture, **Kepler** or **Maxwell** architecture is recommended.

*Check the detailed specifications at http://www.geforce.com/hardware.

EX) **GeForce 980M**

[NOTICE]

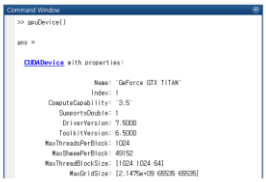
YOU HAVE TO CHECK INSTALLATION PREVIOUSLY, BECAUSE YOU CAN NOT JOIN THE EXPERIMENT SESSION IF THE INSTALLATION IS UNCOMPLETED.

Test the Parallel Computing, based on MATLAB

1. In MATLAB command window, type "**gpuDevice()**".
   If "CUDADevice with properties: ..." is printed out, then the Environment Setting is completed successfully.

Fig. Typing "gpuDevice()" at Command Window, then checking "CUDADevice with properites: ...".

Development Environments	
CUDA-enabled NVIDA GPU	GeForce GTX TITAN
MATLAB version	MATLAB 2015a
VISUAL STUDIO version	VISUAL STUDIO 2013
CUDA TOOLKIT version	CUDA TOOLKIT v7.0



Test the Parallel Computing, based on MATLAB (cont.)

2. To check Built-in Function on a GPU, type **a left red text box** on a script file, then execute the script file.
   If the script file works normally, then several messages will be printed out on the command window.

* DO NOT EXPLAIN THE DETAIL SYNTEX AT THIS TIME.

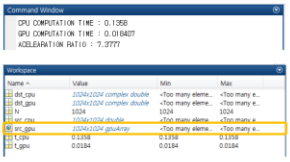
```
% MATRIX SIZE
% Depends on the size, computation time & ratio are changed.
N               = 1024;

% CPU COMPUTATION
tic;
src_cpu         = phantom(N, N);
dst_cpu         = fft(src_cpu);
t_cpu           = toc;

% GPU COMPUTATION
tic;
src_gpu         = gpuArray(src_cpu);
dst_gpu         = fft(src_gpu);
dst_gpu         = gather(dst_gpu);
t_gpu           = toc;

% DISPLAY
disp['CPU COMPUTATION TIME : ' num2str(t_cpu)];
disp['GPU COMPUTATION TIME : ' num2str(t_gpu)];
disp['ACELLERATION RATIO : ' num2str(t_cpu/t_gpu)];
```

Fig. If the script file is worked normally, then messages will be printed out at the command window.



* **gpuArray : To execute the Built-in Function on a GPU**

Test the Parallel Computing, based on MATLAB (cont.)

3. To check running MEX-Function containing CUDA code, follow the below steps.

   1. MEX source file which includes CUDA code must have **a name with the extension *.cu**, not *.c nor *.cpp.

   - Example of a MEX-file containing CUDA code [1] at:
   matlabroot/toolbox/distcomp/gpu/extern/src/mex/mexGPUExample.cu

   [1] *This example multiplies every element in the input array by 2 to get the values in the output array.*

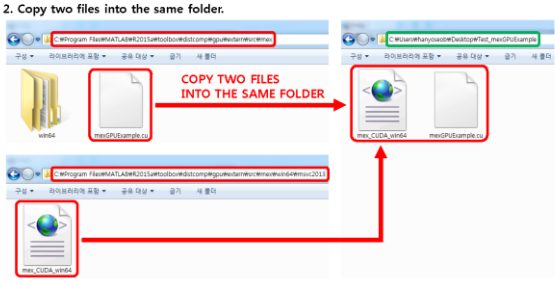
   2. Before you compile MEX-file, copy the provided "mex_CUDA_win64.xml" file from **the specified location, into the same folder as MEX source file.**

   - For Windows platforms with Visual Studio 2012:
   matlabroot/toolbox/distcomp/gpu/extern/src/mex/win64/msvc2012/mex_CUDA_win64.xml
   - For Windows platforms with Visual Studio 2013:
   matlabroot/toolbox/distcomp/gpu/extern/src/mex/win64/msvc2013/mex_CUDA_win64.xml

Test the Parallel Computing, based on MATLAB (cont.)

3. To check running MEX-Function containing CUDA code, follow the below steps.

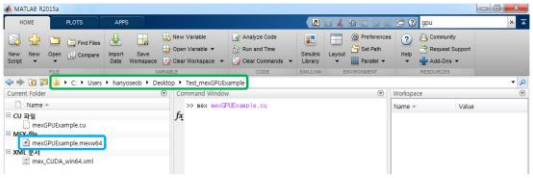
   1. 2. Copy two files into the same folder.



Test the Parallel Computing, based on MATLAB (cont.)

3. To check running MEX-Function containing CUDA code, follow the below steps.

   3. By typing **the command "mex mexGPUExample.cu"**, the MEX source file can be compiled.
   If the compiling is completely finished, then **mexGPUExample.mexw64** file is created at the same folder.



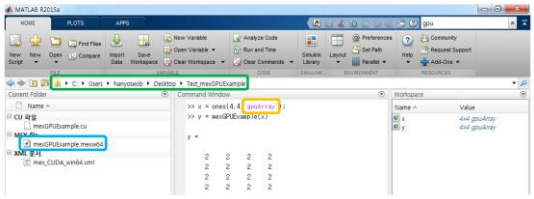
Test the Parallel Computing, based on MATLAB (cont.)

3. To check running MEX-Function containing CUDA code, follow the below steps.

   4. To run the mexGPUExample function, type those commands at the command window.

```
>> x = ones(4,4,'gpuArray');
>> y = mexGPUExample(x)
```

If the function works normally, then the result will be shown as **the Fig.**



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