17th International Meeting on Fully 3D Image Reconstruction in Radiology and Nuclear Medicine

Fully 3D 2023 Conference Program

- Schedule
- Committee Members
- Abstracts

Stony Brook Medicine

Schedule

Monday, July 17, 2023		Time
	Welcome	9-9:20 am
D1-K	Keynote 1	9:20-10 am
D1-1	Spectral CT	10:30 am-12:10 pm
D1-2	CT 1	1:30-3:30 pm
D1-3	CT and AI 1	4-5:20 pm
	Poster Available	7-8 pm
Tuesday, July 18, 2023		
D2-K	Keynote 2	9-10 am
D2-1	PET	10:30 am-12:30 pm
D2-P1	Poster Session 1	1:30-3 pm
D2-P2	Poster Session 2	3:30-5 pm
	Poster Available	7-8 pm
Wednesday, July 19, 2023		
D3-K	Keynote 3	9-10 am
D3-1	PET and AI	10:30 am-12:30 pm
D3-P1	Poster Session 3	1:30-3 pm
D3-P2	Poster Session 4	3:30-5 pm
	Poster Available	7-8 pm
Thursday, July 20, 2023		
D4-1	Nuclear Medicine	9-11 am
D4-K	Keynote 4	11:30 am-12:30 pm
D4-2	Other Reconstruction	1:30-3:30 pm
	Poster Session/Travel to Banquet	4-5:30 pm
Friday, July 21, 2023		
D5-1	CT and AI 2	9-11 am
	Awards and Closing	11 am-12 pm

Committee Members

Organization Committee Co-Chairs

Jerome Liang • Paul Vaska • Chuan Huang

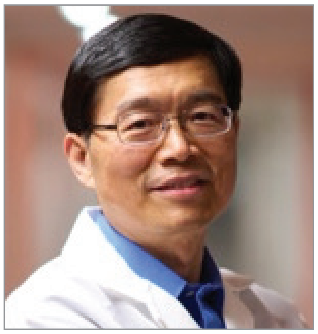
Scientific Committee

Evren Asma	Canon Medical Research USA
Ti Bai	University of Texas Southwestern Medical Center
Freek Beekman	Dept. Radiation Science & Technology, Section Biomedical Imaging, TU Delft
Yannick Berker	Siemens Healthcare GmbH
Richard E. Carson	Yale University
Shaojie Chang	Mayo Clinic
Guang-Hong Chen	University of Wisconsin in Madison
Margaret Daube-Witherspoon	University of Pennsylvania
Bruno De Man	GE Research
Michel Defrise	VUB
Joyita Dutta	University of Massachusetts Amherst
Matthias J Ehrhardt	University of Bath
Georges El Fakhri	Harvard Medical School, Massachusets General Hospital
Jeffrey A. Fessler	University of Michigan
Eric Frey	Johns Hopkins University
Grace Gang	Johns Hopkins University
Hewei Gao	Tsinghua University
Yongfeng Gao	United Imaging Healthcare
Kuang Gong	Massachusets General Hospital
Jens Gregor	University of Tennessee
Grant T. Gullberg	University of California San Francisco
Chuan Huang	Emory University/Stony Brook University
Brian Hutton	University College London
Xun Jia	Johns Hopkins University
Jakob Sauer Jørgensen	Technical University of Denmark (DTU)
Marc Kachelriess	German Cancer Research Center (DKFZ)
Joel Karp	UPenn
Paul Kinahan	University of Washington
Michael King	Univ of Mass Chan Medical School
Thomas Koehler	Philips Research Hamburg
Hiroyuki Kudo	University of Tsukuba
Patrick La Riviere	The University of Chicago
Tobias Lasser	Technical University of Munich
Yusheng Li	UIH America
Jerome Zhengrong Liang	Stony Brook University
Yihuan Lu	United Imaging Healthcare at Shanghai
Hongbing Lu	Fourth Military Medical University
Jianhua Ma	Southern Medical University
Nicole Maass	Siemens Healthineers

Committee Members

Samuel Matej	University of Pennsylvania
Scott Metzler	University of Pennsylvania
Stephen Moore	University of Pennsylvania
Xuanqin Mou	Xi'an Jiaotong University
Klaus Muller	Stony Brook University
Peter Noël	University of Pennsylvania
Frederic Noo	University of Utah
Johan Nuyts	KU Leuven
Jed D. Pack	GE Research
Tinsu Pan	The University of Texas, MD, Anderson Cancer Center
Xiaochuan Pan	University of Chicago
Vladimir Panin	Siemens Medical Solutions USA
Amir Pourmorteza	Emory University
Jinyi Qi	UC Davis
Magdalena Rafecas	University of Luebeck
Andrew Reader	King's College London
Ahmadreza Rezaei	KU Leuven
Cyril Riddell	GE Healthcare
Georg Schramm	Stanford University
Kuangyu Shi	University of Bern
Emil Sidky	The University of Chicago
Arkadiusz Sitek	Massachusetts General Hospital
Mark Slifstein	Stony Brook University
Web Stayman	Johns Hopkins University
Karl Stierstorfer	Siemens Healthcare GmbH
Suleman Surti	University of Pennsylvania
Ken Taguchi	Johns Hopkins University
Xiangyang Tang	Emory University School of Medicine
Benjamin Tsui	Retired from Johns Hopkins University in May 2020
Paul Vaska	Stony Brook University
Dimitris Visvikis	INSERM
Jing Wang	UT Southwestern Medical Center
Guobao Wang	University of California Davis Health
Adam Wang	Stanford University
Wenli Wang	Avant Tomography Consulting LLC
Ge Wang	RPI
Yuxiang Xing	Tsinghua University
Wei Xu	Brookhaven National Laboratory
Hengyong Yu	UML
Zhou Yu	Canon Medical Research USA
Larry Zeng	Utah Valley University
Hao Zhang	Memorial Sloan Kettering Cancer Center
Jian Zhou	Canon Medical Research USA

Keynote Speaker



Keynote: Monday, July 17 (9-10 am)

Photoacoustic, Light-Speed, and Quantum Imaging

Lihong V. Wang, Ph.D., Bren Professor

Andrew and Peggy Cherng Department of Medical Engineering,
Department of Electrical Engineering,
California Institute of Technology

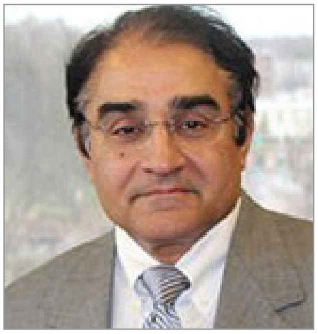
ABSTRACT We developed photoacoustic tomography (PAT) to peer deep into biological tissue. PAT provides in vivo functional, metabolic, molecular, and histologic imaging across the scales of organelles through organisms. We also developed light-speed compressed ultrafast photography (CUP) to record 219 trillion frames per second, orders of magnitude faster than commercially available camera technologies. CUP can record in real time the fastest phenomenon in nature, namely, light propagation for the first time and can be slowed down for slower phenomena such as neural conduction. We are exploring quantum entanglement for imaging.

PAT physically combines optical and ultrasonic waves. Conventional high-resolution optical imaging of scattering tissue is restricted to depths within the optical diffusion limit (~1 mm). PAT beats this limit and provides centimeter-scale deep penetration at high ultrasonic resolution and high optical contrast by sensing molecules. Broad applications include early-cancer detection and brain imaging. The annual conference on PAT has become the largest in SPIE's 20,000-attendee Photonics West since 2010.

CUP with a single exposure can image transient events occurring on a time scale down to 10s of femtoseconds. Akin to traditional photography, CUP is receive-only—avoiding specialized active illumination required by other single-shot ultrafast imagers. CUP can be coupled with front optics ranging from microscopes to telescopes for widespread applications in both fundamental and applied sciences, ranging from biology to cosmophysics. Quantum imaging at the Heisenberg limit improves spatial resolution linearly with the number of quanta, faster than the square-root standard quantum limit.

BIOGRAPHY Lihong Wang earned his Ph.D. degree at Rice University, Houston, Texas under the tutelage of Robert Curl, Richard Smalley, and Frank Tittel. He is Bren Professor of Medical Engineering and Electrical Engineering, Andrew and Peggy Cherng Medical Engineering Leadership Chair, and Executive Officer (aka Department Chair) of Medical Engineering at California Institute of Technology. His book entitled "Biomedical Optics: Principles and Imaging," one of the first textbooks in the field, won the 2010 Joseph W. Goodman Book Writing Award. He also edited the first book on photoacoustic tomography. He has published 590 peer-reviewed articles in journals, including Nature (Cover story), Science, PNAS, and PRL, and has delivered 580 keynote, plenary, or invited talks. His Google Scholar h-index and citations have reached 152 and 100K, respectively. His laboratory was the first to report in vivo/functional photoacoustic tomography (Top 2 cited in photoacoustics), 3D photoacoustic microscopy (Top 2 cited in photoacoustics), photoacoustic endoscopy, photoacoustic reporter gene imaging, the photoacoustic Doppler effect, the universal photoacoustic reconstruction algorithm (widely adopted), microwave-induced thermoacoustic tomography, ultrasound-modulated optical tomography, time-reversed ultrasonically encoded optical focusing, compressed ultrafast photography (70 trillion frames/s, world's fastest real-time camera), and open-source Monte Carlo simulation of light transport in tissues (widely cited, celebrated by the Journal of Biomedical Optics in 2022). Photoacoustic imaging broke through the long-standing diffusion limit on the penetration of optical imaging, providing the only technology for noninvasive multiscale biochemical, functional, and molecular imaging from organelles to humans at high resolution. The technology has been commercialized by dozens of companies for both preclinical and clinical imaging (FDA approved for breast imaging). He chairs the annual conference on Photons plus Ultrasound, the largest conference at the annual 20,000-attendee Photonics West. He was the Editor-in-Chief of the Journal of Biomedical Optics. He received the NSF CAREER, NIH FIRST, NIH Director's Pioneer, NIH Director's Transformative Research, and NIH/NCI Outstanding Investigator awards. He also received the OSA C.E.K. Mees Medal, IEEE Technical Achievement Award, IEEE Biomedical Engineering Award, SPIE Britton Chance Biomedical Optics Award, IPPA Senior Prize, and OSA Michael S. Feld Biophotonics Award for "seminal contributions" to photoacoustic tomography and lightspeed imaging. He is a Fellow of the AAAS, AIMBE, Electromagnetics Academy, IAMBE, IEEE, OSA, and SPIE as well as a Foreign Fellow of COS. An honorary doctorate was conferred on him by Lund University, Sweden. He was inducted into the National Academy of Inventors and the National Academy of Engineering. Keynote Tuesday, July 18 (9AM – 10 AM) NIBIB-Sponsored Research: Medical Imaging Technologies & Related Artificial Intelligence.

Keynote Speaker



Keynote: Tuesday, July 18 (9-10 am)

NIBIB-Sponsored Research: Medical Imaging Technologies and Related Artificial Intelligence Applications

Kris Krishna Kandarpa, MD, PhD

Director of Research Sciences and Strategic Directions at
National Institute of Biomedical Imaging & Bioengineering /NIH

ABSTRACT This talk will discuss trends & accomplishments in various medical imaging technologies funded by NIBIB. Sample projects will be highlighted to demonstrate innovative approaches in advancing medical imaging. Recent major developments in Artificial Intelligence applications in medical imaging will also be discussed.

BIOGRAPHY Kris Krishna Kandarpa, M.D., Ph.D. (Engineering Science.), is a cardiovascular and interventional radiologist and Director of Research Sciences and Strategic Directions at National Institute of Biomedical Imaging & Bioengineering /NIH. Prior to joining the NIH, he was CMO/CSO/EVP-R&D at Delcath Systems, Inc., Manhattan, NY, a manufacturer of minimally invasive combination device/drug treatments for liver tumors. Prior to his industry sojourn, he served as a tenured Professor & Chair of Radiology, University of Massachusetts Medical School & Radiologist-in-Chief of UMass-Memorial Health Care, where he established the Center for Innovative Imaging & Intervention. Earlier, at the Weill Medical College of Cornell University, he was a Professor of Radiology, Chief of Service & CVIR Director at The New York Presbyterian Hospital, and simultaneously an adjunct professor at the College of Physicians and Surgeons of Columbia University. Prior to New York, he was associate professor at the Harvard Medical School & co-director of CVIR at the Brigham & Women's Hospital, while also serving on faculty member at the Harvard-MIT Health Sciences & Technology Program, in Boston, MA. Dr. Kandarpa was an active biomedical researcher during his academic carrier, has published extensively, and lectured world-wide. He has served as Chair of the Research & Education Foundation of the Society of Interventional Radiology (SIRREF) and was on the board of the Academy of Radiology Research (ARBIR), when it helped establish NIBIB at the NIH. He is the author a text book entitled Peripheral Vascular interventions, which has been translated into Chinese and the popular Handbook of Interventional Radiologic Procedures, whose 6 th edition is to be released in May 2023, and which has been translated into six foreign languages.

Keynote Speaker

Keynote: Wednesday, July 19 (9-10 am)

Regulatory Science for Evaluation of Medical Imaging Devices

Bahaa Ghammraoui, PhD

Medical Imaging Scientist
US Food and Drug Administration

ABSTRACT In this keynote speech, I will discuss the critical role of regulatory science in the field of medical imaging. I will focus on the work conducted at the FDA's Office of Science and Engineering Laboratories (OSEL) and Division of Imaging, Diagnostics, and Software Reliability (DIDSR). I will discuss the urgent need for new tools to assess AI algorithms in medical imaging, including the potential limitations of traditional testing methods in the age of AI, and the accuracy of CAD algorithms using novel deep learning techniques. I will touch upon the importance of pediatric-specific evaluations and the development of task-based assessments for deep learning in CT denoising. Additionally, I will highlight the advancements in using computational modeling for device evaluation, specifically through the VICTRE project. I will conclude by discussing the advancements in evaluating spectral x-ray imaging systems with photon-counting detectors. All of the above will be anchored in the current regulatory landscape for medical imaging devices and will include resources to relevant FDA Guidance documents.

BIOGRAPHY Dr. Ghammraoui is a Medical Imaging Scientist at the US Food and Drug Administration. He conducts research in medical imaging modalities and imaging physics to support FDA's regulatory mission. He has a particular focus on evaluating spectral imaging and AI applications in CT. He is also the acting liaison to IEC TC62 Working Group #44, where he actively participates in the development of standards for dual-energy X-ray radiography.

He earned his PhD in Physics from the National Institute of Applied Sciences in Lyon, France, in 2012. He completed his research at the Atomic Energy Commission's LETI Laboratory in Grenoble. He is an active contributor to his field, having authored over 30 peer-reviewed articles on X-ray spectral imaging and holding 4 patents. He has also shared his insights at numerous national and international conferences, particularly regarding the intersection of spectral imaging and AI applications in CT.

Keynote Speaker

Keynote: Thursday, July 19 (11:30 am-12:30 pm)

Deep Learning-based MRI Reconstruction: A Radiologist's Perspective

Yvonne W. Lui, MD

Professor and Vice Chair of Research, Department of Radiology
NYU Grossman School of Medicine and the Vilcek Institute of Graduate Biomedical Sciences

ABSTRACT Deep learning has quickly revolutionized MR image reconstruction and gone quickly from an idea to clinical reality with all major equipment vendors and multiple start ups entering the space. The impact on image quality and imaging speed has been impressive. I will discuss some basics of deep learning-based MR reconstruction as well as some deep learning-based image enhancement as well as talk about the limitations and discuss some novel possible ways forward.

BIOGRAPHY Yvonne W. Lui, MD is Professor and Vice Chair of Research for the Department of Radiology at NYU Grossman School of Medicine and the Vilcek Institute of Graduate Biomedical Sciences. She previously served as the Chief of Neuroradiology in the department for 7 years and as the inaugural Associate Chair for Artificial Intelligence, building an innovative program to leverage technological advances in machine learning for medical imaging. A native of New York City, Dr. Lui is a graduate of Swarthmore College and Yale University where she studied Physics and Medicine. She completed her residency and fellowship at NYU. She leads a world-renown radiology research program known for being a leader in imaging technology development and innovative translational research. The program ranks consistently in the top 10 in the nation for NIH-funding and there are over 35 faculty and 100 non-faculty personnel including postdoctoral fellows and research scientists. She serves as the collaboration lead on major research partnerships with both academia and industry including NYU Courant Institute and Center for Data Science, Siemens Healthineers, and Facebook AI Research. Dr. Lui is a NIH-funded researcher in translational neuroimaging to study traumatic brain injury. She serves on multiple NIH scientific review committees, is Past President of the New York Roentgen Society (NYRS), former oral board examiner for the American Board of Radiology (ABR) and a member of their Standard Setting Committee, member of the board of directors of the American Society of Neuroradiology (ASNR), and Senior Editor for the American Journal of Neuroradiology (AJNR). She is the current President of the ASNR.

D1-1: Spectral CT – July 17, 2023 10:30-12:10

Moderators: *Webster Stayman/Yuxiang Xing*

Talk order based on the first name of the first author.

D1-1-1: Dual-Energy CT with Two-Orthogonal-Limited-Arc Scans 10:30-10:50

Buxin Chen (The University of Chicago), Zheng Zhang (The University of Chicago), Dan Xia (The University of Chicago), Emil Sidky (The University of Chicago) and Xiaochuan Pan (The University of Chicago)

ABSTRACT In this work, we investigate dual-energy CT with non-overlapping two-orthogonal-limited-arc (TOLA) scans. The TOLA scan configuration consists of two limited-angular-range (LAR) arcs of low- and high-kVp scans whose center lines are orthogonal to each other. Real dual-energy data are collected from a clinical CT scanner in axial mode, and reconstructed from by use of a one-step method for accurate reconstruction with minimized LAR and beam-hardening (BH) artifacts. The method encompasses a constrained optimization problem with directional-total-variation (DTV) constraints on the monochromatic images and the DTV algorithm, as a new instance derived from the non-convex primal-dual (ncPD) algorithm for numerically solving the optimization problem. Qualitative and quantitative evaluations are carried out including the assessment of artifacts reduction, profile plots, and mean pixel values in the basis images. Results suggest that the proposed one-step method can reconstruct from LAR data collected with two orthogonal arcs of as low as 60 degrees each and obtain monochromatic images that are visually and quantitatively close to the reference monochromatic image from full-angular-range data of 360 degrees.

D1-1-2: 3D Photon Counting CT Image Super-Resolution Using Conditional Diffusion Model 10:50 - 11:10

Chuang Niu (Rensselaer Polytechnic Institute), Christopher Wiedeman (Rensselaer Polytechnic Institute), Mengzhou Li (Rensselaer Polytechnic Institute), Jonathan Maltz (GE HealthCare) and Ge Wang (Rensselaer Polytechnic Institute)

ABSTRACT This study aims to improve photon counting CT (PCCT) image resolution using denoising diffusion probabilistic models (DDPM). Although DDPMs have shown superior performance when applied to various computer vision tasks, their effectiveness has yet to be translated to high-dimensional CT super-resolution. To train DDPMs in a conditional sampling manner, we first leverage CatSim to simulate realistic lower-resolution PCCT images from high-resolution CT scans. Since maximizing DDPM performance is time-consuming for both inference and training, especially on high-dimensional PCCT data, we explore both 2D and 3D networks for conditional DDPM and apply methods to accelerate training. In particular, we decompose the 3D task into efficient 2D DDPMs and design a joint 2D inference in the reverse diffusion process that synergizes 2D results of all three dimensions to make the final 3D prediction. Experimental results show that our DDPM achieves improved results versus baseline reference models in recovering high-frequency structures, suggesting that a framework based on realistic simulation and DDPM shows promise for improving PCCT resolution.

D1-1-3: 3D Deep-Learning-Based Image Registration Correction Network with Performance Assessment using Tres Estimation For Dual-Energy CT

11:10-11:30

Rui Liao (Washington University in St. Louis), Tao Ge (Washington University in St. Louis), Maria Medrano (Stanford University), Jeffrey Williamson (Washington University in St. Louis), Bruce Whiting (University of Pittsburgh), David Politte (Washington University in St. Louis) and Joseph O'Sullivan (Washington University in St. Louis)

ABSTRACT Deformable image registration (DIR) has been widely used in radiotherapy treatment planning, including proton therapy. However, quantitative assessment of the 3D DIR accuracy for real patient data is a challenging problem due to the lack of known ground-truth landmark correspondences between the source and target data. In this paper, a 3D deep-learning- based multi-modality image registration correction network (RCN) is proposed to automatically quantify the accuracy performance of a given DIR algorithm result using the target registration error (TRE) estimation. The proposed network can further refine the initial result with the dense map (same resolution and size as the input images) of the TREs acquired from the quality assessment to achieve higher accuracy and more robustness when applied to other imaging systems. The proposed convolutional neural network is a supervised approach trained using a simulated virtual human body phantom called the XCAT dataset. The proposed RCN method is evaluated using both the simulated dataset and some real patient clinical data from different CT imaging systems. The simulated test dataset with known ground truth shows an approximately 41% decrease in the TRE after the correction. Despite the fact that the RCN was trained using a digital anthropomorphic phantom without tissue heterogeneity, the validation results on real patient data indicate an accurate estimation for the TRE of our initial iterative DIR method and improvement of registration results after the correction.

D1-1-4: Design of Scatter-Decoupled Material Decomposition for Multi-Energy Blended CBCT Using Spectral Modulator with Flying Focal Spot

11:30-11:50

Yifan Deng (Tsinghua University) and Hewei Gao (Tsinghua University)

ABSTRACT In X-ray cone-beam computed tomography (CT), spectral modulator with flying focal spot (SMFFS) technology could be a promising low-cost approach to accurately solving the X-ray scattering problem and physically enabling multi-energy imaging in a unified framework, with no significant misalignment in data sampling of spectral projections. In this work, we advance this technology for spectral cone-beam CT (CBCT) and analyze the design of Scatter-Decoupled Material Decomposition (SDMD) for the blended multi-energy projection and twisted scatter-spectral challenge based on a scatter similarity hypothesis of SMFFS. Physics experiments on a tabletop CBCT system using a GAMMEX multi-energy CT phantom, are carried out to demonstrate the feasibility of our proposed SDMD method for CBCT spectral imaging with SMFFS. In the physics experiments, the mean relative errors in selected ROI for virtual monochromatic image (VMI) are 0.9% for SMFFS, and 5.3% and 16.9% for 80/120 kV dual-energy cone-beam scan with and without scatter correction, respectively

D1-1-5: An Attenuation Field Network for Cone-Beam Breast CT with a Laterally-Shifted Detector In Short Scan

11:50-12:10

Zhiyang Fu (The University of Arizona), Hsin Wu Tseng (The University of Arizona) and Srinivasan Vedantham (The University of Arizona)

ABSTRACT In cone-beam computed tomography (CBCT), it is common to acquire data that is truncated laterally using asymmetrically mounted (laterally-shifted) detectors to extend the imaging field of view. Our group recently demonstrated the feasibility of this geometry in a prone, dedicated, high-resolution (0.22 mm) breast CBCT system using full-scan acquisition. In this work, we propose to acquire short-scan data in conjunction with laterally-shifted detector geometry to enable the transition to an upright breast CT system. To this end, a self-supervised attenuation field network (AFN) is proposed to train on such incomplete data. The trained AFN can generate attenuation images or projection data. The synthesized projections can be further used in any reconstruction method. We evaluated the technique using 50 clinical breast CBCT datasets. Qualitative and quantitative results show that AFN can enable short-scan, laterally-shifted detector geometry for dedicated breast CBCT imaging. This can be potentially expanded to other CBCT applications.

Moderators: *J. Seungryong Cho/Xiaochuan Pan*
Talk order based on the first name of the first author.

D1-2-1: An Update To Elsa – An Elegant Framework for Tomographic Reconstruction 13:30-13:50

David Frank (TUM School of Computation, Information and Technology, Technical University of Munich, Munich, Germany), Jonas Jelten (TUM School of Computation, Information and Technology, Technical University of Munich, Munich, Germany) and Tobias Lasser (TUM School of Computation, Information and Technology, Technical University of Munich, Munich, Germany

ABSTRACT In tomographic reconstruction, many different imaging modalities can be expressed using similar mathematical concepts. Our framework elsa, which we already presented previously~\cite{Lasser19}, builds on this fact, and provides both a unified mathematical framework and a set of common reconstruction algorithms. These can be applied to various imaging modalities, such as X-ray attenuation computed tomography (CT), Phase-Contrast CT, and (anisotropic) Dark- Field CT. Developed by our team, elsa is written in modern C++17, it utilizes the CMake build system for reliability and ease of use. It also provides a Python interface for rapid prototyping. Here, we will present an overview of new features, which include among others new optimization algorithms, the 3D FORBILD phantom, and support for grating-based Phase-Contrast CT to elsa. Further, a short demonstration of elsa's capabilities to reconstruct a real-world 3D X-ray attenuation CT dataset is given.

D1-2-2: High-Resolution CT Using Super-Short Zoom-In Partial Scans (Zips) and Cross-Correction of Missing Data 13:50-14:10

Eri Haneda (GE Research-Healthcare), Bruno De Man (GE Research-Healthcare) and Lin Fu (GE Research-Healthcare)

ABSTRACT The Zoom-In Partial Scans (ZIPS) is a recently introduced CT scanning scheme that utilizes the high geometric magnification in off-center scanning regions to boost the spatial resolution of clinical CT. ZIPS performs two complimentary partial scans of a region of interest, then merges the partial data into a high-resolution image. In this paper, we extend ZIPS to more dose-efficient and practical scanning scenarios. First, to minimize patient dose, each partial scan is limited to a 90-degree scan instead of a conventional 180+fan scan. Second, we account for lateral truncation due to the off-center position and the limited size of the CT detector array. Lastly, to fully realize the resolution capability of ZIPS, the two partial scans need to be accurately registered to compensate for the table/patient translation between the two partial scans. Results show the effectiveness of ZIPS in these challenging conditions and much improved resolution relative to a conventional centered CT scan.

D1-2-3: X-Ray Dark-Field Imaging at the Human Scale: Helical Computed Tomography and Surview Imaging 14:10-14:30

Jakob Haeusele (TU Munich), Clemens Schmid (TU Munich), Manuel Viermetz (TU Munich), Nikolai Gustschin (TU Munich), Tobias Lasser (TU Munich), Thomas Koehler (Philips Research) and Franz Pfeiffer (TU Munich)

ABSTRACT X-ray imaging is a widely adopted diagnostic tool that uses the attenuation as contrast generating mechanism. Grating- based X-ray dark-field imaging is an interferometric approach that unlocks an additional contrast mechanism. Unlike conventional X-ray techniques, dark-field imaging is also capable of measuring the so-called linear diffusion coefficient. This measure of a sample's small-angle scattering strength yields additional information about a sample's microstructure, which otherwise could not be resolved directly. While initial clinical studies are already being carried out for human chest dark-field radiography, dark-field computed tomography (CT), which is capable of yielding unobstructed 3D views, has only recently been brought to the human scale: With a first prototype system, we demonstrated the feasibility to implement a Talbot-Lau interferometer on a clinical CT system to perform dark-field imaging with clinical acquisition time and field of view. Until now, this prototype was limited to axial scans. In this work, we present our advancements in extending the setups capabilities to also support other modes of acquisition, namely surview and helical scans. The new capabilities of the updated dark-field CT scanner are demonstrated using an anthropomorphic thorax phantom.

D1-2-4: Optimizing CT Scan Geometries With and Without Gradients 14:30-14:50

Mareike Thies (Friedrich-Alexander-Universität Erlangen-Nürnberg), Fabian Wagner (Friedrich-Alexander-Universität Erlangen-Nürnberg), Noah Maul (Friedrich-Alexander-Universität Erlangen-Nürnberg), Laura Pfaff (Friedrich-Alexander- Universität Erlangen-Nürnberg), Linda-Sophie Schneider (Friedrich-Alexander-Universität Erlangen-Nürnberg), Christopher Syben (Fraunhofer Development Center X-Ray Technology EZRT) and Andreas Maier (Friedrich- Alexander-Universität Erlangen-Nürnberg)

ABSTRACT In computed tomography (CT), the projection geometry used for data acquisition needs to be known precisely to obtain a clear reconstructed image. Rigid patient motion is a cause for misalignment between measured data and employed geometry. Commonly, such motion is compensated by solving an optimization problem that, e.g., maximizes the quality of the reconstructed image with respect to the projection geometry. So far, gradient-free optimization algorithms have been utilized to find the solution for this problem. Here, we show that gradient-based optimization algorithms are a possible alternative and compare the performance to their gradient-free counterparts on a benchmark motion compensation problem. Gradient-based algorithms converge substantially faster while being comparable to gradient-free algorithms in terms of capture range and robustness to the number of free parameters. Hence, gradient-based optimization is a viable alternative for the given type of problems

D1-2-5: A Joint Processing Strategy for Image Quality Improvement in 3D Digital Subtraction Angiography 14:50-15:10

Xiaoxuan Zhang (Hospital of the University of Pennsylvania Department of Radiology), Xiao Jiang (Johns Hopkins University Department of Biomedical Engineering), Matthew Tivnan (Johns Hopkins University Department of Biomedical Engineering), J. Webster Stayman (Johns Hopkins University Department of Biomedical Engineering) and Grace J. Gang (Hospital of the University of Pennsylvania Department of Radiology)

ABSTRACT Three-dimensional digital subtraction angiography (3D-DSA) is a widely adopted technique for clinical evaluation of contrast-enhanced vasculatures. The distribution of a contrast agent such as iodine is often estimated via temporal subtraction. Advancements in spectral imaging technologies such as photon counting detectors offer new opportunities to improve DSA image quality. In this work, we propose a novel joint processing strategy to achieve an iodine image using two-bin spectral measurements from a photon counting detector acquired both the pre- and post-contrast injection. Simulation studies were performed using a digital phantom with iodine-enhanced vessels. The proposed method was compared with temporal subtraction and conventional spectral imaging using just the post-contrast measurements. Imaging performance was evaluated in terms of noise-resolution tradeoffs. Preliminary findings have shown measurably improved image quality given by joint processing, reducing noise by 40% and 70% compared to temporal subtraction and conventional spectral imaging, respectively.

D1-2-6: C-Arm CT Imaging of the Head with the Sine-Spin Trajectory: Evaluation of Cone-Beam Artifacts from Computer-Simulated Data of Voxelized Patient Models 15:10-15:30

Zijia Guo (University of Utah), Michael Manhart (Siemens Healthcare GmbH), Philipp Bernhardt (Siemens Healthcare GmbH), Bernd Schreiber (Siemens Healthcare GmbH), Julie DiNitto (Siemens Medical Solutions) and Frederic Noo (University of Utah)

ABSTRACT Three-dimensional cone-beam CT imaging of the head is valuable in neuro-interventional radiology, particularly to detect brain hemorrhages and visualize regions of ischemia. To improve image quality, a new data acquisition geometry, called here the sine-spin trajectory, was recently shown to be clinically feasible and meritorious over the classical circular short- scan. In this work, we assess the performance of the sine-spin trajectory in terms of cone-beam artifacts only, using voxelized patient models to retain the complexity of the human head anatomy and the task of interest (low contrast brain imaging). Our results show strong superiority of the sine-spin trajectory over the circular short-scan. They also show strong robustness to relative positioning between sine-spin and head, and to variations in skull thickness, making altogether the sine-spin trajectory highly attractive for head imaging in neuro-interventional radiology.

Moderators: *Ge Wang/Bruno De Man*
Talk order based on the first name of the first author.

D1-3-1: Diffusion Posterior Sampling-based Reconstruction for Stationary CT Imaging of Intracranial Hemorrhage

16:00-16:20

Alejandro Lopez Montes (Department of Biomedical Engineering. Johns Hopkins University, Baltimore, MD, USA), Thomas McSkimming (Department of Biomedical Engineering. Johns Hopkins University, Baltimore, MD, USA), Wojciech Zbijewski (Department of Biomedical Engineering. Johns Hopkins University, Baltimore, MD, USA), Anthony Skeats (Micro-X, Adelaide, SA, Australia), Chris Delnooz (Micro-X, Adelaide, SA, Australia), Brian Gonzales (Micro-X, Adelaide, SA, Australia), Mia Maric (Micro-X, Adelaide, SA, Australia), Jeffrey H. Siewerdsen (Department of Biomedical Engineering. Johns Hopkins University, Baltimore, MD, USA) and Alejandro Sisniega (Department of Biomedical Engineering. Johns Hopkins University, Baltimore, MD, USA)

ABSTRACT Stationary CTs with x-ray source arrays offer point-of-care imaging but are challenged by limited sampling. Novel learned diffusion models for image synthesis can enable accurate posterior sampling-based reconstruction in undersampling scenarios. This work presents a modified reverse diffusion sampling that approximates the posterior sampling via conditional score matching model that enforces data consistency using an unconditionally trained diffusion model for image synthesis. The method was evaluated for visualization of intracranial hemorrhage on a stationary scanner with 31 x-ray sources and 160 deg angular span. Results in simulation studies with11 head/brain datasets and synthetic hemorrhage inserts showed improved visualization of anatomical features and blood. Structural similarity (SSIM) measurements yielded SSIM > 0.87 for extremely limited sampling acquisition protocols and ~10% increase compared to PWLS. Diffusion posterior sampling poses a new tool for image reconstruction in systems with highly limited sampling and a promising step towards point-of-care stroke imaging.

D1-3-2: Deep Learning-Based Metal Object Removal In Four-Dimensional Cardiac CT

16:20- 16:40

Pengwei Wu (GE Research - Healthcare), Elliot McVeigh (Dept. of Bioengineering, Medicine, Radiology at University of California San Diego) and Jed Pack (GE Research - Healthcare)

ABSTRACT Metal objects in human hearts such as pacing leads can result in severe artifacts in reconstructed 4D CT images and hinder the development of fully automatic whole-heart functional analysis algorithms. These artifacts are difficult to remove with the conventional two-pass metal artifacts reduction (MAR) methods due to non-uniform cardiac motion over the heart cycle. In this work, a pure image domain processing pipeline was developed to generate metal and motion artifacts free 4D CT images without accessing projection domain data. Most of the current deep learning-based MAR methods are supervised learning methods trained with emulated data and suffer from performance degradation when being translated to real patient data. To address this (domain shift) issue, we propose a new generative adversarial network that utilizes both, (i) labeled "hybrid" data (i.e., metal free clinical data augmented with emulated metal objects) and (ii) unlabeled real patient data, through a domain discriminator. The resulting metal-free images were then processed sequentially with a partial angle reconstruction-based motion estimation method. Experimental results from real patient data confirmed the benefit of using both "hybrid" and real patient data, which resulted in a 57.6% and 43.2% improvement respectively in a uniformity metric compared to hybrid data only and real patient data only approaches. Application of the proposed processing pipeline led to significantly reduced metal and motion artifacts, resulting in images suitable for downstream automatic cardiac functional analysis tasks (e.g., LV segmentation, LV function, cardiac perfusion).

D1-3-3: Patch-Based Denoising Diffusion Probabilistic Model for Sparse-View CT Reconstruction 16:40-17:00

Wenjun Xia (Rensselaer Polytechnic Institute), Wenxiang Cong (Rensselaer Polytechnic Institute) and Ge Wang (Rensselaer Polytechnic Institute)

ABSTRACT For sparse-view computed tomography (CT), the neural networks have limited ability to remove the artifacts with only information in the image domain. The introduction of sinogram can achieve a better anti-artifact performance, but it inevitably requires the feature maps of the whole image to be put into video memory, which makes handling large-scale or three-dimensional (3D) data a great challenge. In this paper, we propose a patch-based denoising diffusion probabilistic model (DDPM) for sparse-view CT reconstruction. A DDPM network based on patches extracted from fully sampled projection data is trained and then used to inpaint the down-sampled projection data. The network does not require paired full-sampled and down-sampled data, enabling unsupervised learning. And the processing of the data is patch-based, which can be distributedly deployed, overcoming the challenge of processing large-scale and 3D data. The experiments also show that the proposed method can achieve excellent anti-artifact performance while maintaining the texture details.

D1-3-4: A General Solution for CT Metal Artifacts Reduction: Deep Learning, Normalized MAR, or Combined? 17:00-17:20

Yanfei Mao (Philips Healthcare), Mark Selles (Amsterdam University Medical Centre; Isala Hospital), Michael Westmore (Philips Healthcare), Joemini Poudel (Philips Healthcare) and Martijn Boomsma (Isala Hospital)

ABSTRACT Many approaches have been proposed recently for reduction of metal artifacts in CT images, especially the deep learning-based metal artifact reduction (MAR) method. In this work, we evaluated three metal artifact reduction methods, namely an image-based deep learning method, a hybrid method combining deep learning and normalized MAR, as well as the traditional linear interpolation-based normalized MAR method. Each method was evaluated using clinical images with commonly encountered metal implants, including joint prosthesis, dental fillings, spine screw, and pacemaker. Both the image-based deep learning method and the hybrid method show great potential to provide a general solution to different types of metal implants. Strength and limitation of each method were discussed as well. To our knowledge, this is the first paper that comparing these three methods side by side on various metal implants.

D2-1: PET 1 – July 18, 2023 10:30-12:30

Moderators: *Margaret Daube-Witherspoon/Emil Sidky*

Talk order based on the first name of the first author.

D2-1-1: Convergent ADMM Plug and Play PET Image Reconstruction 10:30-10:50

Florent Sureau (BioMaps, Université Paris-Saclay, CEA, CNRS, Inserm, SHFJ, 91401 Orsay, France), Mahdi Latreche (Institut Denis Poisson, Université d'Orléans, UMR CNRS 7013, 45067 Orléans, France) and Claude Comtat (BioMaps, Université Paris-Saclay, CEA, CNRS, Inserm, SHFJ, 91401 Orsay, France)

ABSTRACT In this work, we investigate hybrid PET reconstruction algorithms based on coupling a model-based variational reconstruction and the application of a separately learnt Deep Neural Network operator (DNN) in an ADMM Plug and Play framework. Following recent results in optimization, fixed point convergence of the scheme can be achieved by enforcing an additional constraint on network parameters during learning. We propose such an ADMM algorithm and show in a realistic 18F-FDG synthetic brain exam that the proposed scheme indeed leads experimentally to convergence to a meaningful fixed point. When the proposed constraint is not enforced during learning of the DNN, the proposed ADMM algorithm was observed experimentally not to converge.

D2-1-2: Tomographic Image Reconstruction of Triple Coincidences in PET 10:50-11:10

Nerea Encina (Nuclear Physics Group and IPARCOS, University Complutense of Madrid), Alejandro Lopez-Montes (JHU Department of Biomedical Engineering, Johns Hopkins University), Jorge Cabello (Siemens Medical Solutions USA, Inc), Hasan Sari (Department of Nuclear Medicine, Bern University Hospital), George Prenosil (Department of Nuclear Medicine, Bern, Bern University Hospital), Maurizio Conti (Siemens Medical Solutions USA, Inc) and Joaquin L. Herraiz (Nuclear Physics Group and IPARCOS, University Complutense of Madrid)

ABSTRACT Triple coincidences in PET occur when three gamma-rays are detected within the same time and energy window in a PET scanner. They can be produced from many different sources, and if not handled properly, these triple coincidences are just reconstructed as two separate double coincidences. One of them will correspond to an annihilation pair and contribute to the signal, but the other one will just add background to the image degrading the image quantification accuracy. In this work, we evaluate the performance of different methods to reconstruct these triple coincidences, using both simulations and real acquisitions with 18F, 68Ga, and 124I from preclinical and clinical PET scanners. The spatial resolution, contrast, and noise of the reconstructed images from triple coincidences were compared against those obtained with standard double coincidences. Our results confirm that, as expected, triple coincidences have a lower signal-to-noise ratio compared to double coincidences, and if they are reconstructed as a V-shaped LOR (VLOR), their reconstruction has a slower convergence. Other proposed methods may provide better results. This work shows the importance of proper handling and reconstruction of triple coincidence, as they can be as high as randoms in high- sensitivity PET scanners.

D2-1-3: Synergistic PET/CT Reconstruction Using a Joint Generative Model 11:10-11:30

Noel Jeffrey Pinton (LaTIM, INSERM UMR 1101, Université de Bretagne Occidentale, 29238 Brest, France), Alexandre Bousse (LaTIM, INSERM UMR 1101, Université de Bretagne Occidentale, 29238 Brest, France), Zhihan Wang (LaTIM, INSERM UMR 1101, Université de Bretagne Occidentale, 29238 Brest, France), Catherine Cheze-Le-Rest (Nuclear Medicine Department, Poitiers University Hospital, F-86022, Poitiers, France), Voichita Maxim (Université de Lyon, INSA-Lyon, UCBL 1, UJM-Saint Etienne, CNRS, Inserm, CREATIS UMR 5220, U1294, F-69621, LYON, France), Claude Comtat (BioMaps, Université Paris-Saclay, CEA, CNRS, Inserm, SHFJ, 91401 Orsay, France), Florent Sureau (BioMaps, Université Paris-Saclay, CEA, CNRS, Inserm, SHFJ, 91401 Orsay, France) and Dimitris Visvikis (LaTIM, INSERM UMR 1101, Université de Bretagne Occidentale, 29238 Brest, France)

ABSTRACT We propose in this work a framework for synergistic positron emission tomography (PET)/computed tomography (CT) reconstruction using a joint generative model as a penalty. We use a synergistic penalty function that promotes PET/CT pairs that are likely to occur together. The synergistic penalty function is based on a generative model, namely beta-variational autoencoder (β-VAE). The model generates a PET/CT image pair from the same latent variable which contains the information that is shared between the two modalities. This sharing of inter-modal information can help reduce noise during reconstruction. Our result shows that our method was able to utilize the information between two modalities. The proposed method was able to outperform individually reconstructed images of PET (i.e., by maximum likelihood expectation maximization (MLEM)) and CT (i.e., by weighted least squares (WLS)) in terms of peak signal-to-noise ratio (PSNR). Future work will focus on optimizing the parameters of the β-VAE network and further exploration of other generative network models.

D2-1-4: Dynamic Spatiotemporal Clustering for Factor Analysis in Dynamic Structures 11:30- 11:50

Valerie Kobzarenko (Department of Computer Science, Florida Institute of Technology, Melbourne, FL), Rostyslav Boutchko (Lawerence Berkeley National Laboratory), Uttam M. Shrestha (Department of Radiology and Biomedical Imaging, University of California, San Francisco, CA), Grant T. Gullberg (Department of Radiology and Biomedical Imaging, University of California, San Francisco, CA), Youngho Seo (Department of Radiology and Biomedical Imaging, University of California, San Francisco, CA) and Debasis Mitra (Department of Computer Science, Florida Institute of Technology, Melbourne, FL)

ABSTRACT We propose a dynamic PET analysis methodology that improves on top of previously established non-matrix factorization algorithms. Our primary innovation is the improved factor initialization approach and subsequent data driven spatial masking. The initialization detects subsets of voxels whose time-activity curves capture essential features of underlying dynamics. The dynamic binary mask developed based on the initialization work removes portions of background to unmix the factors prior to performing factor analysis of dynamic structures. We use a simulated dataset for our initial validation. Our workflow is applied to clinical dynamic cardiac PET data reconstructed with filtered back projection algorithm. In both simulated and real patient data, our algorithm is efficient in identifying different tissues based on inherent tracer dynamics, as demonstrated by the comparison of initialization only improvement to our full workflow. The extension of this methodology can enhance the relevance and applicability of dynamic imaging in the clinical domain.

D2-1-5: Consistency Equations in Native Coordinates and Autonomous Timing Calibration for 3D TOF PET with Depth of Interaction 11:50-12:10

Yusheng Li (United Imaging Healthcare America) and Hongdi Li (United Imaging Healthcare America)

ABSTRACT Fully 3D time-of-flight (TOF) PET scanners with depth-of-interaction (DOI) offer the potential of previously unachievable image quality in clinical PET imaging applications. Timing calibration is critical to achieve the best possible imaging performance, and maximize the benefit of TOF PET scanners. In this work, we present an autonomous timing calibration for 3D TOF PET with DOI using intrinsic TOF data consistency. The data space for 3D TOF PET data with DOI is seven- dimensional while the object space is three-dimensional. First, we derive TOF consistency equations in native coordinates to characterize the entangled redundancy and rich structure of 3D DOI TOF data. We then develop an autonomous timing calibration as an application of the TOF consistency equations. Time offsets on a per-crystal-DOI basis, can be computed by solving the two linear timing offset equations involving two TOF moments—the zeroth and first TOF moments. The proposed autonomous timing calibration can be applied to 3D DOI TOF data acquired with an arbitrary tracer distribution, which eliminates the need for a specialized data acquisition. To evaluate the method, we perform numerical simulations of a generic 2D DOI TOF PET with a brain phantom, and the time offsets were accurately computed by solving a Fredholm integral equation of the second type.

D2-1-6: Simultaneous Reconstruction of Activity and Attenuation Map with TOF-PET Emission Data 12:10-12:30

Zhimei Ren (University of Chicago), Emil Sidky (University of Chicago), Rina Barber (University of Chicago), Chien-Min Kao (University of Chicago) and Xiaochuan Pan (University of Chicago)

ABSTRACT In this work, we study the simultaneous reconstruction of the activity and attenuation maps using only time-of-flight (TOF) positron emission tomography (PET). We model data in emission with a Poisson distribution and obtain estimates of both maps via the total variation (TV)-constrained maximum likelihood estimator (MLE). We propose using the alternating direction method of multipliers (ADMM) algorithm to solve the resulting nonconvex optimization problem; the performance of our proposed estimator is demonstrated in a two-dimensional TOF-PET simulation and compared with the maximum likelihood activity and attenuation (MLAA) algorithm.

Moderator: *Larry Zeng*

Talk order based on the first name of the first author.

D2-P1-1: High Performance Spherical CNN for Medical Image Reconstruction and Denoising

Amirreza Hashemi (Department of Radiology, Massachusetts General Hospital & Harvard Medical School), Yuemeng Feng (Department of Radiology, Massachusetts General Hospital & Harvard Medical School) and Hamid Sabet (Department of Radiology, Massachusetts General Hospital & Harvard Medical School)

ABSTRACT Convolutional neural network (CNN) has shown tremendous success in post-processing of a variety of tomography medical imaging systems. CNNs are reliable in dealing with feature learning, handling noise, and handling non-linearity and high dimensional data. However, the efficiency of the conventional CNN largely depends on the undiminished and proper training set. To address this issue, in this work, we aim to investigate the potential for equivariant networks in order to reduce the dependency of CNN on the respective training set. We examine the equivariant CNN on spherical signals for tomographic medical imaging problems. We show higher quality and the computational efficiency of spherical- CNN on denoising and reconstruction of benchmark problems, e.g., we report an order of magnitude difference in the computational cost of same quality image reconstruction using spherical-CNN compared with CNN. Also, we discuss the possibilities of such a network for broader tomography applications, especially applications with omnidirectional representation.

D2-P1-2: 3D Deep Learning Based Cone Beam Artifact Correction for Axial CT

Artyom Tsanda (Hamburg University of Technology, Germany; Philips Research, Hamburg, Germany), Sebastian Wild (Philips Research, Hamburg, Germany), Stanislav Zabic (Philips CT Research & Advanced Development, Cleveland, OH, USA), Thomas Koehler (Philips Research, Hamburg, Germany), Rolf Bippus (Philips Research, Hamburg, Germany), Kevin M. Brown (Philips CT Research & Advanced Development, Cleveland, OH, USA) and Michael Grass (Philips Research, Hamburg, Germany)

ABSTRACT Axial multi-detector computed tomography addresses multiple important clinical applications. At the same time, it suffers from cone-beam artifacts. These artifacts appear due to data insufficiency and get more pronounced with increasing axial coverage. In this paper, we propose to train a 3D convolutional neural network to correct for cone-beam artifacts of axial multi-detector CT systems with 16 cm coverage.The approach relies on the simulation of cone-beam artifacts, patch-based training, mixed precision technology, and the 3D U-net model architecture. The method is tested using both simulated and real data. While being less accurate on average in terms of the root mean square error, we achieve better artifact suppression at the extreme compared to the second pass approach commonly used in the field.

D2-P1-3: Data-Driven Approach for Metal Artifact Reduction in Dental Cone-Beam CT with an Extra-Condition of Intra-Oral Scan Data

Chang Min Hyun (Yonsei University), Kiwan Jeon (National Institute for Mathematical Sciences) and Hyoung Suk Park (National Institute for Mathematical Sciences)

ABSTRACT In dental cone-beam computed tomography (CBCT), the presence of metallic inserts such as implants, crowns, and dental fillings causes severe streaking and shading artifacts in a CT image, which consequently prevent the accurate restoration of teeth and bones. Existing metal artifact reduction (MAR) methods have limitations in their ability to preserve morphological structures of teeth in reconstructed CT images. This study presents a novel data-driven approach for MAR in dental CBCT that takes advantage of radiation-free intra-oral scan (IOS) data as an extra- condition for CT image reconstruction. The IOS data play a crucial role by providing sophisticated knowledge for teeth morphological structure and dentition in such a way of acting as an appropriate condition during MAR. We adopt a conditional generative adversarial network framework, where a metal artifact corrector is trained to generate a metal artifact-free image sampled from the target distribution (i.e., the distribution of metal-free CBCT images) under the condition of IOS data. Realistic simulations were performed to show the usefulness and effectiveness of the proposed MAR method.

D2-P1-4: Simulated Deep CT Characterization of Liver Metastases with High-Resolution FBP Reconstruction

Christopher Wiedeman (Rensselaer Polytechnic Institute), Peter Lorraine (GE Research - Healthcare), Ge Wang (Rensselaer Polytechnic Institute), Richard Do (Memorial Sloan Kettering Cancer Center), Amber Simpson (Queen's University), Jacob Peoples (Queen's University) and Bruno De Man (GE Research - Healthcare)

ABSTRACT Computed tomography is used for monitoring colorectal cancer and its possible progression into liver metastases, but crucial metastasis image features are scanning and reconstruction parameter dependent. We propose a simulation pipeline for studying imaging parameters and their impact on liver metastasis features. This virtual pipeline superimposes metastasis shapes (generated using a fractal approach) on realistic liver regions for scanning via CatSim. Synthetic metastases images generated with our pipeline were used to train and validate deep neural networks to recover metastasis characteristics: internal heterogeneity, edge sharpness, and edge fractal dimension. We also propose filtered back projection using a high-frequency kernel (designed to preserve more high-resolution information), which yielded significantly better edge sharpness and fractal dimension characterization compared to standard reconstructions ($p<0.05$). Our novel virtual framework can be used for further study of imaging feature preservation, and our results indicate the possibility of optimizing the reconstruction for enhanced AI-based anatomical feature characterization.

D2-P1-5: Analysis of Detectability Index of Infarct Models in Spectral Dual-Layer CBCT

Dirk Schäfer (Philips Research Hamburg), Fredrik Ståhl (Department of Neuroradiology, Karolinska University Hospital, Stockholm), Artur Omar (Medical Radiation Physics and Nuclear Medicine, Karolinska University Hospital, Stockholm) and Gavin Poludniowski (Department of Clinical Science, Intervention and Technology, Karolinska Institute, Huddinge)

ABSTRACT Dual-energy CBCT C-arm imaging is a new imaging modality, which may provide a variety of different spectral results in the interventional suite. We analyze model observers, i.e. the detectability index, of different infarct models, to get insight into which spectral reconstruction may be best suited for identifying infarcts prior to an intervention treating acute stroke patients. MTF and NPS measurements have been performed on a clinical dual-layer (DL) CBCT prototype system and used for model observer analysis. Infarct models with reconstruction dependent contrast amplitude are investigated using a variety of standard and spectral reconstructions. Clinical examples of subjects with small and large infarcts imaged on the same DL-CBCT system are compared visually and be means of CNR analysis of the infarcts to the results of the model observers. The model observer representing most closely a human reader prefers VMI images at higher keV values, and the same trend is obtained with simple CNR analysis. This result is partially substantiated by the CNR analysis of the clinical patient data.

D2-P1-6: Monte Carlo-Free Deep Scatter Estimation (DSE) with a Linear Boltzmann Transport Solver for Image Guidance in Radiation Therapy

Fabian Jäger (German Cancer Research Center), Joscha Maier (German Cancer Research Center), Pascal Paysan (Varian Medical Systems Imaging Lab, GmbH), Michal Walczak (Varian Medical Systems Imaging Lab, GmbH) and Marc Kachelrieß (German Cancer Research Center)

ABSTRACT Scatter correction methods in clinical use often require first-pass reconstruction and subjected to artifacts and truncation. We use the deep scatter estimation (DSE) to predict the scatter signal of an on-board CBCT system in the projection domain. To demonstrate that DSE can be trained with scatter estimates other than those from Monte Carlo simulations. The projections and the scatter distribution for training was calculated with a fast-linear Boltzmann transport equation (LBTE) solver. Training and validation of the neural network used simulated data, while testing was done on simulations as well as phantom measurements. We benchmarked DSE against a kernel-based scatter correction and the LBTE which was used to generate the training data. For the simulated scans, DSE outperforms the kernel and LBTE methods using the mean absolute error compared to a scatter-free reconstruction. For the measurements no scatter free scan is available, again, the DSE shows less visible scatter artifacts.

D2-P1-7: Circulation Federated Learning Network for Multi-site Low-dose CT Image Denoising

Hao Wang (Southern Medical University), Ruihong He (Southern Medical University), Jingyi Liao (Southern Medical University), Zhaoying Bian (Southern Medical University), Dong Zeng (Southern Medical University) and Jianhua Ma (Southern Medical University)

ABSTRACT Deep learning (DL) has attracted great attention in the medical imaging field as a promising solution for high-fidelity CT image reconstruction in low-dose cases. Meanwhile, most of the existing DL-based methods are centralized machine learning frameworks with the need to centralize the data for training. These methods have poor generalization for the privacy policies. Federated learning (FL) can address privacy concerns by using local CT datasets without transferring data. The FL-based CT reconstruction performance still has room for improvement due to the limited capability of the global server. In addition, the absence of labeled data in the global server could also degrade the performance. In this work, to improve FL-based CT reconstruction performance, we first propose a novel federated learning framework with a circulation mode for low-dose CT image denoising, and the newly proposed framework is termed as Circulation FL, i.e., Ci- FL. Specifically, there is no fixed global server in the presented Ci-FL. Each local client can be regarded as the global server in each FL network training wherein the labeled data in the global server can help network training efficiently. The rest ones are regarded as the local client constructing an FL framework in each circulation node. With each site trained as a global server in the framework, we obtain the desired Ci-FL network. Experiments on multi-sites CT datasets clearly demonstrate enhanced reconstruction performance of the proposed Ci-FL against site-specific and traditional federated methods in terms of qualitative and quantitative assessments.

D2-P1-8: Evaluation of CatSim's Physics Models for Spatial Resolution

Jiayong Zhang (GE Research - Healthcare), Mingye Wu (GE Research - Healthcare), Paul Fitzgerald (GE Research - Healthcare), Steve Araujo (GE Research - Healthcare) and Bruno De Man (GE Research - Healthcare)

ABSTRACT Simulation tools are crucial for efficient development of X-ray/CT imaging systems, but sophisticated and well- characterized simulators are proprietary to imaging equipment manufacturers. An open-source version of CatSim is now available as part of XCIST. We believe this is the first open-source X-ray/CT simulator that includes sophisticated modeling capability for all critical system components and physical processes. Once validated, this simulator will allow academic groups and small commercial companies to evaluate new CT technologies with minimal investment. Detailed evaluation of CatSim is currently ongoing. Spatial resolution is one of the most important system performance characteristics to model correctly, and accurate simulation requires sophisticated models for focal spot and detector geometry and detector physics. We have now developed such models and have evaluated agreement between empirical measurements and analogous simulations in the projection and image domains. We constructed physical and analogous virtual phantoms for each domain. We achieved good agreement in both domains, with average errors <5% and worst-case errors <10%. This represents a strong step toward full validation of CatSim's simulation performance.

D2-P1-9: Optimizing Reconstruction for Preservation of Perfusion Defects in Deep-Learning Denoising for Reduced-Dose Cardiac SPECT

Junchi Liu (Department of Electrical and Computer Engineering, Illinois Institute of Technology), Yongyi Yang (Department of Electrical and Computer Engineering, Illinois Institute of Technology), Hendrik Pretorius (Department of Radiology, University of Massachusetts Medical School) and Michael A. King (Department of Radiology, University of Massachusetts Medical School)

ABSTRACT In cardiac SPECT perfusion imaging deep learning (DL) denoising methods have been found to be highly effective for noise suppression in reduced-dose studies. However, as with conventional image filtering, DL denoising may also cause potential signal loss in the reconstructed images as a trade-off to reduced noise level. In this work, we investigate for the first time the feasibility of improving the preservation of perfusion defect signals in DL denoising by controlling the level of post-reconstruction smoothing in reduced-dose SPECT studies. In the experiments we demonstrated this approach with quarter-dose data from a set of 895 clinical acquisitions. The quantitative results indicate that use of a higher spatial resolution in the reduced-dose images than that of the standard-dose target can achieve both better preservation in defect signals and higher detection accuracy of perfusion defects after DL processing.

D2-P1-10: Development of a Solvability Map

Larry Zeng (Utah Valley University) and Ya Li (Utah Valley University)

ABSTRACT From time to time, it is necessary to determine whether there are sufficient measurements for the image reconstruction task especially when a non-standard scanning geometry is used. When the imaging system can be approximately modeled as a system of linear equations, the condition number of the system matrix indicates whether the entire system can be stably solved as a whole. When the system as a whole cannot be stably solved, the Moore-Penrose pseudo inverse matrix can be evaluated through the singular value decomposition (SVD) and then a generalized solution can be obtained. However, these methods are not practical because they require the computer memory to store the whole system matrix, which is often too large to store. Also, we do not know if the generalized solution is good enough for the application in mind. This paper proposes a practical image solvability map, which can be obtained for any practical image reconstruction algorithm in medical imaging. This image solvability map measures the reconstruction errors for each location using a large number of computer-simulated random phantoms. In other words, the map is generated by a Monte Carlo approach.

D2-P1-11: Task-based Generation of Optimized Projection Sets using Differentiable Ranking

Linda-Sophie Schneider (Friedrich-Alexander Universität Erlangen-Nürnberg), Mareike Thies (Friedrich-Alexander Universität Erlangen-Nürnberg), Christopher Syben (Fraunhofer Development Center X-Ray Technology EZRT), Richard Schielein (Fraunhofer Development Center X-Ray Technology EZRT), Mathias Unberath (Johns Hopkins University, Baltimore) and Andreas Maier (Friedrich-Alexander Universität Erlangen-Nürnberg)

ABSTRACT We present a method for selecting valuable projections in computed tomography (CT) scans to enhance image reconstruction and diagnosis. The approach integrates two important factors, projection-based detectability and data completeness, into a single feed-forward neural network. The network evaluates the value of projections, processes them through a differentiable ranking function and makes the final selection using a straight-through estimator. Data completeness is ensured through the label provided during training. The approach eliminates the need for heuristically enforcing data completeness, which may exclude valuable projections. The method is evaluated on simulated data in a non-destructive testing scenario, where the aim is to maximize the reconstruction quality within a specified region of interest. We achieve comparable results to previous methods, laying the foundation for using reconstruction-based loss functions to learn the selection of projections.

D2-P1-12: Three-Dimensional Maps of the Tomographic Incompleteness of Cone-Beam CT Scanner Geometries

Matthieu Laurendeau (Univ Lyon, CREATIS / Université Grenoble Alpes, TIMC / THALES AVS FRANCE), Laurent Desbat (Univ. Grenoble Alpes, CNRS, UMR 5525, VetAgro Sup, Grenoble INP, TIMC, 38000 Grenoble, France), Guillaume Bernard (Thales AVS, Moirans, France), Frédéric Jolivet (Thales AVS, Moirans, France), Sébastien Gorges (Thales AVS, Moirans, France), Fanny Morin (Thales AVS, Moirans, France) and Simon Rit (Univ Lyon, CREATIS)

ABSTRACT New generations of X-ray sources based on carbon nanotubes (CNT) enable the design of multi-sources computed tomography (CT) scanners. CT scanners with CNT often use a limited number of stationary sources and corresponding projections. Three-dimensional CT theory evaluates whether a given continuous source trajectory provides sufficient data for stable reconstruction of an imaged object. This paper extends a local incompleteness metric to derive a three- dimensional map and quantify tomographic incompleteness for a finite set of sources. We illustrate this incompleteness with a dedicated phantom. The reconstructed CT images of the phantom match the results predicted by the incompleteness map.

D2-P1-13: Sparse-view CT Spatial Resolution Enhancement via Denoising Diffusion Probabilistic Models

Nimu Yuan (University of California, Davis), Jian Zhou (Canon Medical Research USA, INC) and Jinyi Qi (University of California, Davis)

ABSTRACT The temporal resolution of x-ray computed tomography (CT) is limited by the scanner rotation speed and detector readout time. One approach to reduce the readout time is to acquire fewer projections. However, reconstruction using sparse-view data could result in a loss of spatial resolution loss and reconstruction artifacts that could impact the accuracy of clinical diagnoses. Therefore, improving the spatial resolution of sparse-view CT (SVCT) is of great practical value. The aim of this study is to investigate the potential of using denoising diffusion probabilistic models (DDPMs) to eliminate noise and streaky artifacts while preserving fine details and enhancing textures in SVCT images. The DDPM was trained on a simulated dataset and its effectiveness was evaluated on both simulated and real data. The results of the study showed that the DDPM was successful in not only suppressing noise and artifacts, but also significantly enhancing the texture of the CT images.

D2-P1-14: Implementing FFS as a Method to Acquire More Information at a Reduced Dose in CT Scanners

Piotr Pluta (Czestochowa University of Technology), Akyl Swaby (University of California, Santa Cruz) and Robert Cierniak (Czestochowa University of Technology)

ABSTRACT This paper presents an original approach to image reconstruction based on FFS (Flying Focal Spot) technology where the X-ray source is configured to have a focal spot that is variable in position. The geometry of spiral CT scanners presents problems for traditional (in particular FDK type) reconstruction methods due to the non-equiangular distribution of X-rays in a given cone beam. This reason completely excludes this traditional approach that can be used. Therefore, we propose to reduce the scheme of perceiving x-ray in the geometry of the system to a lower level of abstraction where these problems will naturally not occur. Relative to this proposal, we can reconstruct an image from projections with a non- equiangular distribution in three-dimensional space, which FFS technology gives us. This method is based on principles of statistical model-based iterative reconstruction (MBIR) where the reconstruction problem is formulated as a shift- invariant system (a continuous-to-continuous data model). Due to its unique design, it can systematically deliver selected reconstructive slices that are immediately required in clinical diagnostics. Finally, by applying this method, we have a fully reconstructed image of the patient in 3D and, if necessary, we can increase the resolution z-plane to the limits where nothing new adds to the quality of the 3D reconstructed image (physical limits of a given CT scanners). Additionally without having to update already reconstructed sections, which is an incredible advantage in saving reconstruction time, which is extremely important during emergency CT examinations.

D2-P1-15: Node-Based Motion Estimation Algorithm for Cardiac CT Imaging

Seongjin Yoon (iTomography), Alexander Katsevich (University of Central Florida), Michael Frenkel (iTomography), Qiulin Tang (Canon Medical Research USA), Liang Cai (Canon Medical Research USA), Jian Zhou (Canon Medical Research USA) and Zhou Yu (Canon Medical Research USA)

ABSTRACT Proposed is a semi-iterative whole heart Motion Estimation (ME) algorithm. ME is performed in an iterative fashion in small neighborhoods of motion nodes. Location of the nodes is selected according to a new scheme. Then the nodes are ordered in a tree-like structure based on spatial proximity. The motion of each node is described by a parameterized model, and the motion model at each node is estimated almost independently of the motion of the other nodes. ME at the nodes is performed sequentially according to the selected ordering. During ME, we reconstruct local patches, which are small volumes centered at the motion nodes. Reconstruction is done using short-scan data and the current motion model. Selecting the best motion model is performed by minimizing a motion artifact metric (MAM). Our MAM is the sum of two terms. The first one measures similarity between patches reconstructed from two different short-scan ranges. The second term measures image sharpness at reference phase. Once ME for all nodes is complete, a global motion model is computed by interpolating the estimated local models. Finally, the global model is used for motion compensation in an FDK algorithm. Numerical experiments show that the algorithm is robust and provides good image quality.

D2-P1-16: Learning a Dual-Domain Harmonization Network for Low-dose CT Image Reconstruction across Scanner Changes

Shixuan Chen (Southern Medical University), Yinda Du (Southern Medical University), Boxuan Cao (Southern Medical University), Shengwang Peng (Southern Medical University), Ji He (Guangzhou Medical University), Yaoduo Zhang (Guangzhou Medical University), Zhaoying Bian (Southern Medical University), Dong Zeng (Southern Medical University) and Jianhua Ma (Southern Medical University)

ABSTRACT Deep learning (DL) have shown great potential in the low-dose CT imaging field. Existing works show that DL-based CT denosing/reconstruction methods can obtain high-quality CT images at low-dose cases, and outperform traditional model-based methods. However, existing DL-based methods are generally designed based on the dataset from one site, hindering their application to the new dataset from other site with limited generalization performance. The main reason is that there exists variation across scanners, acquisition protocols and patient populations. This could lead to data heterogeneity among different centers and low efficiency in downstream task. To address this issue, in this work, we present a Dual Domain Harmonization Network (DuDoHNet) with consideration of the filter kernel style in the sinogram domain and image style in the image domain. Specifically, multilayer perceptron (MLP) is introduced to characterize difference between the source domain and target domain and PatchGAN is used to model the semantic information between the source domain and target domain. Finally, the presented DuDoHNet allows for reconstructing high-fidelity CT images to reduce confounding data variation and preserve semantic information from different scanners. Experiments on the CT dataset with four different filter kernels from two scanners demonstrate that the presented DuDoHNet outperforms the image-based harmonization networks qualitatively and quantitatively.

D2-P1-17: Translating Sparse Sinogram Measurements into Reconstruction Patches without Geometry Information via the Attention Mechanism

Theodor Cheslerean-Boghiu (School of Computation, Information and Technology, Technical University of Munich, Munich, Germany), Franz Pfeiffer (Department of Physics, School of Natural Sciences, Technical University of Munich, Munich, Germany) and Tobias Lasser (School of Computation, Information and Technology, Technical University of Munich, Munich, Germany)

ABSTRACT Deep learning based algorithms for X-ray computed tomography reconstruction often rely on domain-transfer modules that use tomographic operators to perform the forward- and backprojection. The used operators restrict the trained network to one single reconstruction geometry. In this manuscript we propose to train a network on sinogram-image pairs without explicitly using a domain-transfer module based on a forward-backward projector. We train the network to implicitly learn the geometry only from image pairs using the attention mechanism, similar to a machine translation problem in natural language processing. We run a simple experiment to show that an attention-based architecture is able to implicitly learn geometrical information only from sinogram-image pairs and produce the corresponding reconstruction.

D2-P1-18: Multi-material Decomposition with Triple Layer Flat-Panel Detector CBCT using Model-based and Deep Learning Approaches

Xiao Jiang (Johns Hopkins University), Xiaoxuan Zhang (University of Pennsylvania), J. Webster Stayman (Johns Hopkins University) and Grace Gang (University of Pennsylvania)

ABSTRACT Spectral CT has been investigated widely for a range of diagnostic applications with increasing potential interest for cone- beam CT (CBCT) applications. Current CBCT technology has largely focused on flat-panel detectors due to their relatively small form factor and ease of integration within a compact gantry that fits well in an interventional suite. The recent commercial availability of triple-layer flat panel detectors has provided a new avenue for spectral CBCT. In particular, while many spectral systems are limited to two channels with different energy sensitivity (e.g. dual layer detectors, kV- switching systems, etc.), a triple-layer system has the potential to be able to perform three material decomposition without additional constraints. Unfortunately, the spectral separation of a triple-layer panel is modest leading to a relatively ill-conditioned material decomposition problem (which consequently can be highly noise magnifying). In this work, we explore the possibility of three material decomposition and CBCT using a triple-layer panel and two sophisticated processing approaches: 1) model-based projection-domain material decomposition and 2) deep-learning- based projection-domain decomposition. Both approaches use simple filtered-backprojection of material line integral estimates to form 3D material maps. A simulation study with realistic measurement models is conducted using anthropomorphic phantoms and three material bases (water, calcium, and exogenous gadolinium contrast agent). A preliminary performance evaluation of reconstructed phantom data is provided to illustrate the potential of spectral CBCT using triple-layer detectors.

D2-P1-19: Wavelet-Based Stabilized Score Generative Models

Yanyang Wang (the Department of Biomedical Engineering, Sun-Yat-sen University), Weiwen Wu (the Department of Biomedical Engineering, Sun-Yat-sen University) and Ge Wang (The Department of Biomedical Engineering, Rensselaer Polytechnic Institute)

ABSTRACT Score-based generative model demonstrates strong performance in solving under-determined inverse problems. However, in the field of medical imaging, it is difficult to obtain high-quality datasets for model training. The experiment demonstrates that if the training samples are perturbed with noise, the data distribution gradient of the SGM is corrupted. It makes the reverse process of recovering images be unstable, resulting in further compromising the reconstruction performance. To address this challenge, we proposed a general unsupervised technique by incorporating the compressed sensing knowledge into the SGM for stable training. The results demonstrates our proposed method can not only reconstruct the high-quality images without clean data training, but also greatly improve the sampling stability.

D2-P1-20: Using Translational Stable Diffusion Probabilistic Model (TranSDPM) to Improve the Longitudinal Resolution in Computed Tomography

Yongfeng Gao (UIH America), Liyi Zhao (United Imaging Healthcare), Wenjing Cao (United Imaging Healthcare), Yuan Bao (United Imaging Healthcare), Jian Xu (UIH America) and Guotao Quan (United Imaging Healthcare)

ABSTRACT The ability of computed tomography (CT) to clearly distinguish between structures along the z-axis, referred to as the longitudinal resolution, can be limited in some scenarios. Super Resolution (SR) is a crucial challenge in the field of computer vision and image processing, where the objective is to generate a high-quality, high-resolution (HR) image from a low-resolution (LR) input. This task is challenging due to the loss of information and degradation that occurs during the process of downscaling the image, including blurring and noise. In this study, we introduce an innovative solution using a Translational Stable Diffusion Probabilistic Model (TranSDPM) to address the SR challenge in CT images. The diffusion denoise model is built on the concept of non-linear diffusion, which enables the propagation of information from the LR image to the HR image by modeling the degradation process through a Markov chain. This approach has the advantage of preserving the structural information in the LR image, leading to enhanced super-resolution performance and suppressing the noise at the same time. The effectiveness of the proposed method is rigorously evaluated on publicly available datasets at the full dose and a quarter dose demonstrating its superiority and robustness.

D2-P1-21: Deep Spectrum Complex-valued Neural Network for Large-scaled Objects Super-resolution Reconstruction

Zirong Li (School of Biomedical Engineering, Sun Yat-sen University) and Weiwen Wu (School of Biomedical Engineering, Sun Yat-sen University)

ABSTRACT Computed Tomography (CT) has been widely used in industrial high-resolution non-destructive testing, but it is difficult to obtain high-resolution images for large-scale objects due to its physical limitation. To address this problem, many super- resolution deep learning networks have been proposed to map the low-resolution image to the high-resolution counterpart in the image domain. Although those methods achieve a certain effect on the main body of the image, the small structures and detail would be inevitably damaged. For restoring small structures and detail better, we find that high-frequency components are easier to be recovered in the frequency domain. Therefore, a deep spectrum complex- valued neural network has been proposed to take advantage of both global information in the image domain and high- frequency information in the frequency domain. In addition, by exploring the symmetrical property of the spectrum, we design a novel learning strategy to reduce weight parameters in the frequency domain.

D2-P2: Poster Session 2 – July 18, 2023 15:30-17:00

Moderator: *Qiu Huang*

Talk order based on the first name of the first author.

D2-P2-1: Hybrid Geometric Calibration in 3D Cone-Beam with Sources on a Plane

Anastasia Konik (TIMC-GMCAO, Université Grenoble Alpes), Laurent Desbat (TIMC-GMCAO, Université Grenoble Alpes) and Yannick Grondin (SurgiQual Institute)

ABSTRACT In this work, we describe a new self-calibration algorithm in the case of 3D cone-beam geometry with sources on a plane parallel to the detector plane. This algorithm is hybrid, so it combines data consistency conditions (DCCs) and the partial knowledge on the pattern of the calibration cage. We explain how we build this algorithm with the modelling of calibration markers by Diracs and the generalization of existing DCCs for this geometry to distributions. This new method can work with truncated projections if the marker projections are not truncated. With this hybrid approach, we build an analytical self-calibration algorithm based on DCCs, robust to projection truncations. We show numerical experiments.

D2-P2-2: Evaluating Spectral Performance for Quantitative Contrast-Enhanced Breast CT with a GaAs Photon-Counting Detector: A Simulation Approach

Bahaa Ghammraoui (Division of Imaging, Diagnostics and Software Reliability (DIDSR), US FDA), Muhammad Ghani (Division of Imaging, Diagnostics and Software Reliability (DIDSR), US FDA), Andreu Badal (Division of Imaging, Diagnostics and Software Reliability (DIDSR), US FDA) and Stephen J. Glick (Division of Imaging, Diagnostics and Software Reliability (DIDSR), US FDA)

ABSTRACT Quantitative contrast-enhanced breast computed tomography (CT) has the potential to enhance the diagnosis and management of breast cancer. The traditional methods involve dual-exposure images with different incident spectra to obtain two spectrally separated measurements, which can be used for material discrimination, comes at the expense of increased patient dose and susceptibility to motion artifacts. An alternative approach, using Photon Counting Detectors (PCD), allows for acquisition of multiple energy levels in a single exposure, reducing these issues. GaAs is a particularly promising material for breast PCD-CT due to its high quantum efficiencies and reduction of fluorescence X-rays escaping the pixel within the breast imaging energy range.

This simulation study evaluated the spectral performance of a GaAs photon-counting detector (PCD) for quantitative iodine contrast-enhanced breast CT. Utilizing both projection-based and image-based material decomposition methods, the study produced material-specific images of the breast and used the iodine component images to estimate iodine intake. The accuracy and precision of the method for estimating iodine concentration in breast CT images were assessed for different material decomposition methods, incident spectra, and mean glandular dose (MGD).

The results showed that the GaAs PCD had comparable performance to an ideal PCD in terms of Root Mean Squared Error (RMSE), precision, and accuracy of estimating the iodine intake in the breast. Furthermore, the results demonstrated the effectiveness of both material decomposition methods (projection-and image-based) in making accurate and precise iodine concentration predictions using a GaAs-based photon counting breast CT system, with better performance when applying the projection-based material decomposition approach. The study highlights the potential of GaAs-based photon counting breast CT systems as a viable alternative to traditional imaging methods in terms of material decomposition and iodine concentration estimation.

D2-P2-3: Millisecond CT: A Dual Ring Stationary CT System and its Reconstruction

Changyu Chen (Department of Engineering Physics, Tsinghua University), Yuxiang Xing (Department of Engineering Physics, Tsinghua University), Li Zhang (Department of Engineering Physics, Tsinghua University) and Zhiqiang Chen (Department of Engineering Physics, Tsinghua University)

ABSTRACT In this paper, we proposed a new concept of stationary CT system (Multi-Segment Dual-Ring Stationary CT, MSDR-CT). MSDR-CT consists of a source ring and a detector ring that can be implemented conveniently by splicing multiple segments of distributed sources and detectors. With advanced multi-spot X-ray source techniques, X-rays will be fired from different spots sequentially or simultaneously in a programmable manner. Hence, MSDR-CT enables ultra-fast and flexible data acquisition modes which presents great potential in pushing the temporal resolution to the order of millisecond for dynamic imaging. As a proof-of-concept study, we deducted a Hilbert transform analytical reconstruction method in a differentiation-backprojection-filtration format for this system configuration. Furthermore, the discontinuity between segments in the source or detector rings is a protogenetic problem for its practical implementation. A preliminary correction method is proposed to address this problem. Simulated experimental results with the Shepp-Logan phantom confirmed the feasibility of MSDR-CT.

D2-P2-4: Improving the Detective Quantum Efficiency of Detectors in Cone Beam Computed Tomography Using a Hybrid Direct-Indirect Flat-Panel Imager

Corey Orlik (Stony Brook University), Adrian Howanksy (Stony Brook University), Sébastien Léveillé (Analogic Canada Corporation), Salman Arnab (Analogic Canada Corporation), Jann Stavro (Stony Brook University), Scott Dow (Stony Brook University), Amirhossein Goldan (Stony Brook University), Safa Kasap (University of Saskatchewan), Kenkichi Tanioka (Stony Brook University) and Wei Zhao (Stony Brook University)

ABSTRACT Intraoperative volumetric imaging with cone beam computed tomography (CBCT) is now widely used for vascular, neurosurgical, and selective internal radiotherapy procedures to guide decision-making and for verification. As its utility grows, there is increasing demand for CBCT to provide the highest performance in spatial and contrast resolution at the lowest possible dose. Tradeoffs in these parameters are principally limited by the detective quantum efficiency (DQE) and modulation transfer function (MTF) of its active matrix flat panel imager (AMFPI). This work investigates these performance metrics for a novel direct-indirect "hybrid" AMPFI under conditions encountered in CBCT imaging. Experimental measurements from a prototype Hybrid AMFPI showed DQE(0) approaching 0.90 and 0.75 at RQA5 and RQA9, respectively. Temporal performance measurements show minimal degradation (lag and ghosting below 2%). To our knowledge, these mark the highest combined MTF and DQE for an energy-integrating imager to date under CBCT imaging conditions.

D2-P2-5: Spherical Acquisition Trajectories for X-Ray Computed Tomography with a Robotic Sample Holder

Erdal Pekel (Department of Computer Science, School of Computation, Information and Technology, Technical University of Munich), Martin Dierolf (Department of Physics, School of Natural Sciences, Technical University of Munich), Franz Pfeiffer (Department of Physics, School of Natural Sciences, Technical University of Munich) and Tobias Lasser (Department of Computer Science, School of Computation, Information and Technology, Technical University of Munich)

ABSTRACT In this work we present an X-ray computed tomography setup that integrates a seven degree of freedom robotic arm as a sample holder. The path planning and robot control algorithms are optimized for seamless execution of spherical trajectories. A precision manufactured sample holder part is attached to the robotic arm for the calibration procedure. We present experimental results with the robotic sample holder where a sample measurement on a spherical trajectory achieves improved reconstruction quality compared to a conventional circular trajectory. The proposed system is a step towards higher image reconstruction quality in flexible X-ray CT systems.

D2-P2-6: Geometric Constraints Enable Self-Supervised Sinogram Inpainting in Sparse-View Tomography

Fabian Wagner (Friedrich-Alexander-Universität Erlangen-Nürnberg), Mareike Thies (Friedrich-Alexander-Universität Erlangen-Nürnberg), Noah Maul (Friedrich-Alexander-Universität Erlangen-Nürnberg), Laura Pfaff (Friedrich-Alexander-Universität Erlangen-Nürnberg), Oliver Aust (Friedrich-Alexander-Universität Erlangen-Nürnberg), Sabrina Pechmann (Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Forchheim), Christopher Syben (Fraunhofer Development Center X-Ray Technology EZRT, Erlangen) and Andreas Maier (Friedrich-Alexander-Universität Erlangen-Nürnberg).

ABSTRACT The diagnostic quality of computed tomography (CT) scans is usually restricted by the induced patient dose, scan speed, and image quality. Sparse-angle tomographic scans reduce radiation exposure and accelerate data acquisition, but suffer from image artifacts and noise. Existing image processing algorithms can restore CT reconstruction quality but often require large training data sets or can not be used for truncated objects. This work presents a self-supervised projection inpainting method that allows learning missing projective views via gradient-based optimization. By reconstructing independent stacks of projection data, a self-supervised loss is calculated in the CT image domain and used to directly optimize projection image intensities to match the missing tomographic views constrained by the projection geometry. Our experiments on real X-ray microscope (XRM) tomographic mouse tibia bone scans show that our method improves reconstructions by 3.1–7.4%/7.7–17.6% in terms of PSNR/SSIM with respect to the interpolation baseline. Our approach is applicable as a flexible self-supervised projection inpainting tool for tomographic applications.

D2-P2-7: An Investigation on the Detection Task Performance of Deep Learning-Based Streak Artifacts Reduction Methods

Hojin Jung (Department of Artificial Intelligence, College of Computing, Yonsei University), Minwoo Yu (Department of Artificial Intelligence, College of Computing, Yonsei University) and Jongduk Baek (Department of Artificial Intelligence, College of Computing, Yonsei University)

ABSTRACT In X-ray computed tomography(CT), sparse-view CT has been proposed as a way to reduce a radiation dose. However, sparse-view CT generates streak artifacts that degrade image quality (IQ). To address this problem, various deep learning (DL)-based methods for streak artifacts reduction have been developed. To assess the performance of streak artifacts reduction methods, root mean square error (RMSE) and structural similarity index measure (SSIM) are commonly adopted. However, these two assessments cannot guarantee superiority in terms of diagnostic task performance. In this work, we performed a signal detection task using a convolutional neural network (CNN)-based ideal observer (IO) to evaluate the diagnostic IQ of streak artifacts reduction methods. We compared the performances of three DL-based streak artifacts methods with two differences: the domain where the input of CNN was defined and where the loss function was computed. Our result shows that the methods utilizing CNN in the image domain outperform the methods utilizing CNN in the sinogram domain in terms of SSIM, and RMSE. On the contrary, the methods utilizing CNN in the sinogram domain performed better IO performance of the detection task than the methods utilizing CNN in the image domain.

D2-P2-8: Coded Array Beam X-ray Imaging Based on Spatio-sparsely Distributed Array Sources

Jiayu Duan (Xi'an Jiaotong University), Yang Li (Xi'an Jiaotong University), Song Kang (Sun Yat-sen University), Guofu Zhang (Sun Yat-sen University), Jianmei Cai (Xi'an Jiaotong University), Chengyun Wang (Sun Yat-sen University), Jun Chen (Sun Yat-sen University) and Xuanqin Mou (Xi'an Jiaotong University)

ABSTRACT Traditional X-ray tubes and their usage patterns suffer from problem of overheating which results in limitations of heavy, bulk and expensive. In this paper, we proposed coded array beam X-ray imaging (CABI) method using very low power array X-ray source that consists of a number of spot sources arranged in a line or a plane. Each spot source in the array just covers a small part of the object. A number of coded array beams are radiated for imaging while in each radiation multiple sources simultaneously lighting. Therefore array source works in a very low power state. High density and virtually rotational projections are reconstructed from the coded projections by CABI for CT and tomosynthesis. Theoretical analysis proves that sparse array source is capable for high density reconstruction. Hence just a small number of coded lighting modes are needed for imaging and the source power is further decreased. Experiments validate feasibility of CABI method. Particularly, with CABI, a flat-panel X-ray tube chip works stably for a long time in room temperature without cooling. This study shows a promising modality for the next generation of the X-ray imaging.

D2-P2-9: Abdominal and Pelvic CBCT-based Synthetic CT Generation for Gas Bubble Motion Artifact Reduction and Hounsfield Unit Correction for Radiotherapy

Kai Wang (University of Texas Southwestern Medical Center) and Jing Wang (University of Texas Southwestern Medical Center)

ABSTRACT The motion of gas bubbles (gastrointestinal gas) in the abdominal and pelvic region can produce significant artifacts on the cone-beam CT (CBCT) for radiotherapy clinics, which adversely affects the imaging quality and limits the process of image-guided radiotherapy and CBCT-based adaptive planning. In this study, we first tested the effectiveness of cycle generative adversarial network (cycleGAN) for improving CBCT image quality and Hounsfield unit (HU) accuracy of abdominal and pelvic scans by synthetase of high-quality CT images based on the image content of CBCT images. The improved image quality of the synthetic CT (sCT) on both gas bubble artifact reduction and HU correction compared to the original CBCT demonstrated that cycleGAN is a promising tool for onboard CBCT image quality improvement, which can potentially increase the treatment precision of radiotherapy.

D2-P2-10: Refine 3D Object Reconstruction from CT Projection via Differential Mesh Rendering

Le Shen (Tsinghua University), Yuxiang Xing (Tsinghua University) and Li Zhang (Tsinghua University)

ABSTRACT 3D object reconstruction from medical images is essential in clinical medicine, such as orthopedics surgery and cardiovascular disease diagnosis. Conventional approaches to reconstruct a 3D object contains two main steps: 1) segment a target in a medical image and generate its mask by the marching cubes algorithm, 2) extract a 3D mesh from the mask. Due to the discretization error of reconstruction algorithms and the uncertainty of the segmentation, the resulting 3D objects are often inconsistent with reality. To alleviate this issue, an alternative is to reconstruct the 3D objects represented by a parametric model or geometric primitives directly from projection data. Differential rendering has recently been adopted in tomographic reconstruction problems and achieves superior results. In this work, we investigated the feasibility of triangle mesh object reconstruction via differential rendering and our preliminary results demonstrated its potential value for applications in clinical CT imaging.

D2-P2-11: Unifying Supervised and Unsupervised Methods for Low-dose CT Reconstruction: A General Framework

Ling Chen (Shanghai JiaoTong University), Zhishen Huang (Amazon), Yong Long (Shanghai JiaoTong University) and Saiprasad Ravishankar (Michigan State University)

ABSTRACT Recent application of deep learning methods for image reconstruction provides a data-driven approach to address the challenge raised by undersampled measurements or various types of noise. In this work, we propose a general learning framework for X-ray computed tomography (CT) image reconstruction that combines supervised and unsupervised learned models. We leverage both a dictionary learning-based unsupervised solver and supervisedly trained neural network reconstructors in two incarnations of the proposed framework to simulate a fixed-point iteration process. Our experimental results for denoising low-dose CT (LDCT) images demonstrate promising performance of the proposed general framework compared to our recent parallel and cascading SUPER methods for LDCT.

D2-P2-12: Multi-Class Maximum Likelihood Expectation-Maximization List-Mode Image Reconstruction: an Application to Three-Gamma Imaging

Jiayu Duan (Xi'an Jiaotong University), Yang Li (Xi'an Jiaotong University), Song Kang (Sun Yat-sen University), Guofu Zhang (Sun Yat-sen University), Jianmei Cai (Xi'an Jiaotong University), Chengyun Wang (Sun Yat-sen University), Jun Chen (Sun Yat-sen University) and Xuanqin Mou (Xi'an Jiaotong University)

ABSTRACT Our contribution focuses at improving the image reconstruction process for specific Compton imaging systems able to detect multiple classes of events for nuclear imaging. Methods to retrieve activity maps were proposed for existing prototypes of such systems, mostly using maximum likelihood expectation-maximization (MLEM), but none actually compute the MLEM solution. Some exploit the fully detected events only, and other combine several classes of detected events in a suboptimal way. In this paper, we first introduce a general framework for the reconstruction of a single activity map from multi-class events, and we provide the suited list-mode MLEM update equation. We then consider the case of XEMIS2, a preclinical prototype of a Compton telescope for three-gamma imaging, for which classes of partial detections coexist with the full detection class. As a preliminary step towards effective multi-class reconstruction, we generate a sensitivity map for all classes using a dedicated Monte Carlo simulator.

D2-P2-13: Neural Network-based Single-material Beam-hardening Correction for X-ray CT in Additive Manufacturing

Obaidullah Rahman (Oak Ridge National Laboratory), Singanallur V. Venkatakrishnan (Oak Ridge National Laboratory), Zackary Snow (Oak Ridge National Laboratory), Thomas Feldhausen (Oak Ridge National Laboratory), Ryan Dehoff (Oak Ridge National Laboratory), Vincent Paquit (Oak Ridge National Laboratory), Paul Brackman (Carl Zeiss Industrial Metrology, LLC) and Amirkoushyar Ziabari (Oak Ridge National Laboratory)

ABSTRACT Beam-hardening (BH) artifacts are ubiquitous in X-ray CT scans of additively manufactured (AM) metal components. While linearization approaches are useful for correcting beam-hardened data from single material objects, they either require a calibration scan or detailed system and material composition information. In this paper, we introduce a neural network-based, material-agnostic method to correct beam-hardening artifacts. We train a neural network to map the acquired beam-hardened projection values and the corresponding estimated thickness of the object based on an initial segmentation to beam-hardening related parameters, which can be used to compute the coefficients of a linearizing correction polynomial. A key strength of our approach is that, once the network is trained, it can be used for correcting beam hardening from a variety of materials without any calibration scans or detailed system and material composition information. Furthermore, our method is robust to errors in the estimated thickness due to the typical challenge of obtaining an accurate initial segmentation from reconstructions impacted by BH artifacts. We demonstrate the utility of our method to obtain high-quality CT reconstructions from a collection of AM components – suppressing cupping and streaking artifacts.

D2-P2-14: Robust PET-CT Respiratory-Mismatch Correction Based on Modeled Image Artifact Evaluation and Anatomical Reshaping

Raz Carmi (GE Healthcare), Nasma Mazzawi (GE Healthcare), Gali Elkin-Basudo (GE Healthcare), Lilach Shay Levi (GE Healthcare), Danielle Ezuz (GE Healthcare) and Yariv Grobshtein (GE Healthcare)

ABSTRACT Respiratory mismatch in clinical PET-CT is a common source of image artifacts due to inaccurate attenuation-correction, which typically seen as erroneously low tracer uptake in the lower lung regions and adjacent organs. Various approaches were suggested to mitigate this problem but achieving practical, efficient, and robust solution is still non-trivial. We propose a clinically practical method to correct respiratory mismatch effects, based on modeled image artifact evaluation and anatomical reshaping. In this method, standard reconstructed PET-CT images are evaluated, and relevant potential artifacts are analyzed. The artifact analysis result in key parameters that control the CT image reshaping model, which is based on predictable respiratory motion pattern, and provides corrected attenuation map for final PET image reconstruction. Testing the method on numerous and diverse patient studies, in terms of imaging characteristics and clinical protocols, demonstrates accurate and robust artifact elimination; this with either TOF or high-sensitivity non-TOF advanced PET systems.

D2-P2-15: A New Analysis and Compensation Method for Charge Sharing in PCD

Shengzi Zhao (Tsinghua University), Katsuyuki Taguchi (Johns Hopkins University School of Medicine) and Yuxiang Xing (Tsinghua University)

ABSTRACT Photon counting detectors (PCDs) have strong benefit to spectral information in computed tomography (CT). However, their application is limited by charge sharing and pile-up. We proposed a new analysis about how charge sharing affected the detected counts of photons pixel by pixel. Assuming uniform charge sharing probabilities for all detector pixels, the model addressed different charge sharing events according to their sources and destinations. From the analysis, we could see that the charge sharing correction problem was always ill-posed for conventional detectors. By providing coincidence counts of photons in more channels, MEICC detectors made the problem over-determined. We verified the above analysis by compensating charge sharing with polynomial fitting and a neural network. With MEICC data, the compensated results had smaller bias and NRMSE than results from conventional ones. The analytical model provided general insights to solve charge sharing compensation and other methods might be developed accordingly.

D2-P2-16: Deep Learning Model for SPECT of Thyroid Cancer Using a Compton Camera

Shuo Han (University of Massachusetts Lowell), Yongshun Xu (University of Massachusetts Lowell), Dayang Wang (University of Massachusetts Lowell), Ge Wang (Rensselaer Polytechnic Institute) and Hengyong Yu (University of Massachusetts Lowell)

ABSTRACT Thyroid cancer is a malignant tumor which is the most common malignant tumor in the head and neck region. Early diagnosis is crucial for optimal prognosis. Compton camera-based single photon emission computed tomography (SPECT) is a new avenue to study organ functions and pathologies in this context. Compared to gamma camera-based SPECT, Compton camera requires no mechanical collimation and in principle rejects no gamma ray photon. Hence, radiation dose efficiency and/or signal-to-noise ratio will be improved by orders of magnitude for screening and follow-up scans of patients. However, image reconstruction for Compton camera-bases SPECT is challenging, and there is no analytic reconstruction approach. To address this issue, here we propose a deep learning approach to obtain high-resolution image by deblurring weighted backprojection image. Our simulation results show that the proposed framework can effectively deblur backprojection images and produce high-resolution SPECT images.

D2-P2-17: Deep Learning Reconstruction Improves Image Quality for Cone-Beam X-Ray Luminescence Computed Tomography

Tianshuai Liu (Fourth Military Medical University), Shien Huang (Fourth Military Medical University), Junyan Rong (Fourth Military Medical University), Wangyang Li (Fourth Military Medical University) and Hongbing Lu (Fourth Military Medical University)

ABSTRACT As an emerging hybrid imaging modality, cone-beam X-ray luminescence computed tomography (CB-XLCT) has been proposed based on the development of X-ray excitable nanoparticles. Owing to the complicated excitation process and high scattering of light propagation in biological tissues, the CB-XLCT inverse problem is inherently ill-conditioned. Here, an end-to-end three-dimensional deep encoder–decoder network(DeepCB-XLCT) is proposed to improve the quality of CB-XLCT reconstruction. It directly establishes the nonlinear mapping relationship between the inside X-ray excitable nanoparticles distribution and the boundary fluorescent signal distribution. Thus the reconstruction inaccuracy caused by the simplified linear model can be effectively reduced by the proposed network. Phantom experiments with two targets were carried out, and the results demonstrated that the DeepCB-XLCT network could improve image quality and significantly reduce reconstruction time compared with conventional methods.

D2-P2-18: Characterization of Cysts and Solid Masses Using Direct-Indirect Dual-Layer Flat-Panel Detector

Xiaoyu Duan (Stony Brook Medicine), Hailiang Huang (Stony Brook Medicine) and Wei Zhao (Stony Brook Medicine)

ABSTRACT Dual-energy (DE) mammography and DE digital breast tomosynthesis provide spectral information, which could be utilized to conduct material decomposition for lesion characterization. Distinguishing solid masses and cysts has the potential to improve diagnostic accuracy and reduce the call back rate for cysts. We proposed a direct-indirect dual-layer flat-panel detector (DLFPD) to acquire low-energy and high-energy images simultaneously, with the benefit of no patient motion between LE and HE exposures. This DLFPD incorporates existing state-of-the-art direct (a-Se) and indirect (CsI) FPDs for breast x-ray imaging, which promises rapid clinical translation. The feasibility of distinguishing solid masses and cysts with direct-indirect DLFPD was validated using projection-based material decomposition method, which decompose masses and cysts into aluminum (Al) and polymethyl methacrylate (PMMA).

D2-P2-19: United Imaging PET Reconstruction Toolbox

Yihuan Lu (United Imaging Healthcare), Yang Lv (United Imaging Healthcare), Qing Ye (United Imaging Healthcare), Liuchun He (United Imaging Healthcare), Gang Yang (United Imaging Healthcare), Yue Li (United Imaging Healthcare), Chen Sun (United Imaging Healthcare), Duo Zhang (United Imaging Healthcare), Huifang Xie (United Imaging Healthcare), Chen Xi (United Imaging Healthcare), Yilin Liu (United Imaging Healthcare), Yizhang Zhao (United Imaging Healthcare), Yong Zhao (United Imaging Healthcare), Hao Liu (United Imaging Healthcare), Hancong Xu (United Imaging Healthcare), Xunzhen Yu (United Imaging Healthcare), Yu Ding (United Imaging Healthcare) and Yun Dong (United Imaging Healthcare)

ABSTRACT United Imaging Healthcare (UIH) molecular imaging provides a variety of PET/CT and PET/MR solutions. These systems not only provide a superior image quality to help clinicians in disease diagnosis, but also yield unique opportunities for researchers to explore uncharted territories. To facilitate research activities of the nuclear medicine community, we built a United Imaging PET Reconstruction Toolbox (URT). URT consists of five components: 1) Configurable iterative reconstruction platform, which provides conventional and state-of-art image reconstruction algorithms; 2) Kinetic modeling and parametric imaging, which supports region of interest (ROI) analysis or parametric imaging; 3) Patient motion correction (MC). URT provides a comprehensive MC solution; 4) AI-based image analysis. URT provides several task-specific AI models; 5) Monte-Carlo simulation (MCS). URT provides an ultra-fast MCS tool for simulating dynamic PET with realistic patient motion. URT currently supports the uMI Panorama system, and will gradually support all the UIH scanner models in the future.

D2-P2-20: Hybrid U-Net and Swin-Transformer Network for Limited-angle Image Reconstruction of Cardiac Computed Tomography

Yongshun Xu (University of Massachusetts Lowell), Shuo Han (University of Massachusetts Lowell), Dayang Wang (University of Massachusetts Lowell), Ge Wang (Rensselaer Polytechnic Institute), Jonathan Maltz (GE Healthcare) and Hengyong Yu (University of Massachusetts Lowell)

ABSTRACT Cardiac computed tomography is widely used in the diagnosis of cardiovascular disease, the leading global cause of morbidity and mortality. Diagnostic confidence depends strongly on the temporal resolution of the images. To freeze heart motion, one can reduce the scanning time by acquiring limited-angle projections, but this leads to increased noise and non-motion-related artifact. The ability to reconstruct high quality images from limited-angle projections is thus highly desirable. However, this is a difficult, ill-posed problem. With the development of deep learning networks, such as U-Net and transformer networks, much success has been achieved on many image processing tasks. Here, we propose a hybrid model based on U-Net and Swin-transformer networks. U-Net has the potential to restore structural information lost due to missing projection data and related artifacts, while the Swin-transformer can gather a more detailed feature distribution. We demonstrate, through application to synthetic XCAT data, that our proposed method outperforms the state-of-the-art competing deep learning-based methods.

D2-P2-21: Preliminary Study of Image Reconstruction from Limited-Angular-Range Data in Spectral-Spatial Electron Paramagnetic Resonance Imaging

Zheng Zhang (The University of Chicago), Buxin Chen (The University of Chicago), Dan Xia (The University of Chicago), Emil Sidky (The University of Chicago), Boris Epel (The University of Chicago), Zhiwei Qiao (Shanxi University), Howard Halpern (The University of Chicago) and Xiaochuan Pan (The University of Chicago)

ABSTRACT Continuous-wave (CW) electron paramagnetic resonance imaging (EPRI) yields information about both spatial distribution and spectral shape of unpaired electrons. Its signal-to-noise ratio can be enhanced by using a Zeeman-modulation (ZM) scheme. Limited angular range (LAR) scans can reduce the strength of the magnetic field gradient or scanning time in CW-ZM EPRI, but they often result in artifacts or biases in images reconstructed using conventional algorithms such as filtered back projection (FBP). In this study, an optimization-based algorithm was developed for accurate reconstruction of four-dimensional (4D) spatial-spectral (SS) images directly from LAR data in CW-ZM EPRI. The reconstruction was formulated as an image directional-total-variation (DTV) constrained, data-L2-minimization problem, and a DTV algorithm was developed to solve it. The DTV algorithm was applied to both simulated and real data with various LAR scans and evaluated using visual and quantitative metrics. Results indicate that 4D SS images can be reconstructed directly from LAR data, with results comparable to those obtained from standard, full-angular-range scans in CW-ZM EPRI. The DTV algorithm has potential for enabling and optimizing CW-ZM EPRI with minimal imaging time and artifacts by acquiring data in LAR scans.

D2-P2-22: Abdominal Organ Segmentation Based on VVBP-Tensor in Sparse-view CT Imaging

Zixuan Hong (Southern Medical University), Chenglin Ning (Southern Medical University), Zhaoying Bian (Southern Medical University), Dong Zeng (Southern Medical University) and Jianhua Ma (Southern Medical University)

ABSTRACT Abdominal organ segmentation is critical in abdomen lesion diagnosis, radiotherapy, and follow-up. It is time-consuming and expensive for oncologists to delineate abdominal organs efficiently and accurately. Deep learning (DL)-based strategies have been shown great potential for abdominal organ segmentation and then manual delineation efforts reduction. It should be noted that most of the DLbased segmentation methods are constructed via full-view CT images which are reconstructed through multiple views projections at normal dose. Meanwhile, the radiation dose effect is a major concern in the CT imaging, especially for the full-view CT acquisition. Then, the accumulated radiation dose of the training CT dataset is also serious. Lowering radiation dose, i.e., sparse view sampling, is an effective way in the CT imaging. It is challenging to delineate the abdominal organs in the sparse-view CT images due to the artifacts. In this work, to achieve this goal, we add the effort to segment organ directly from the sparse-view CT measurements. Specifically, we first construct the VVBP-tensor from the sparse-view measurements. Based on the above dataset, we construct a VVBP-Tensor segmentation network (VVBP-SegNet). Experimental results on simulated dataset demonstrate that the proposed VVBP-SegNet obtains best segmentation results than the other competing methods in qualitative and quantitative assessments. This can provide a new insightful strategy for abdominal organ segmentation in the sparse view CT imaging.

D3-1: PET and AI – July 19, 2023 10:30-12:30

Moderators: *Samuel Matej/Georg Schramm*

Talk order based on the first name of the first author.

D3-1-1: Recovery of the Spatially-Variant Deformations in Dual-Panel Pet Systems Using Deep-Learning 10:30-10:50

Juhi Raj (Radiology Department, University of Pennsylvania, Philadelphia, United States), Mael Millardet (Radiology Department, University of Pennsylvania, and Siemens Medical Solutions USA, Inc.), Evgeny Kozyrev (Radiology Department, University of Pennsylvania, Philadelphia, United States), Srilalan Krishnamoorthy (Radiology Department, University of Pennsylvania, Philadelphia, United States), Joel S. Karp (Radiology Department, University of Pennsylvania, Philadelphia, United States), Suleman Surti (Radiology Department, University of Pennsylvania, Philadelphia, United States) and Samuel Matej (Radiology Department, University of Pennsylvania, Philadelphia, United States)

ABSTRACT Dual panel PET systems, such as Breast-PET (B-PET) scanner developed at University of Pennsylvania, exhibit asymmetric and anisotropic spatially-variant deformations in the reconstructed images due to the limited-angle data and strong depth of interaction effects for the oblique LORs inherent in such systems. In our previous work, we studied TOF effects and image-based spatially-variant PSF resolution models within dual-panel PET reconstruction to reduce these deformations. Although the application of such models led to better and more uniform quantification of small lesions across the field of view, the efficacy of such an approach is limited to small objects, such as point sources and small lesions. On the other hand, large object deformations caused by the limited-angle reconstruction cannot be corrected with the PSF modeling alone. In this work, we investigate the ability of the deep-learning networks to recover such strong spatially-variant image deformations of dual-panel systems using analytically simulated data from a dual-panel system.

D3-1-2: End-to-End Deep Learning Pet Reconstruction from Histo-Images for Non-Rigid Motion Correction

10:50-11:10

Maël Millardet (Department of Radiology, University of Pennsylvania), Vladimir Panin (Siemens Medical Solutions USA), Deepak Bharkhada (Siemens Medical Solutions USA), Josh Schaefferkoetter (Siemens Medical Solutions USA), Evgeny Kozyrev (Department of Radiology, University of Pennsylvania), Juhi Raj (Department of Radiology, University of Pennsylvania), Maurizio Conti (Siemens Medical Solutions USA) and Samuel Matej (Department of Radiology, University of Pennsylvania)

ABSTRACT End-to-end deep learning PET reconstruction is becoming increasingly important. One of its most promising applications is motion correction, where deep learning reconstruction could be used for both motion vector estimation and final reconstruction. However, several issues remain to be resolved, including whether to perform motion correction in image space after separate reconstruction of each motion gate (imageMC) or in data space prior to reconstruction (dataMC). In this study, we propose to compare these two approaches and compare the final reconstruction performed by deep learning versus OSEM. We found that the deep learning reconstruction was less noisy, at the cost of slightly reduced contrast, but had an overall higher signal-to-noise ratio. imageMC performed better than dataMC, but this could be due to how the motion vector fields are calculated and requires further study for lower count levels and different ways of calculating the motion vector fields.

D3-1-3: Deep Kernel Representation Learning for High-Temporal Resolution Dynamic Pet Image Reconstruction

11:10-11:30

Siqi Li (University of California Davis) and Guobao Wang (University of California Davis)

ABSTRACT Dynamic positron emission tomography (PET) imaging with high temporal resolution (HTR) presents a challenge for tomographic reconstruction due to the limited count level in each short frame. The kernel methods have been demonstrated to be effective in suppressing noise for low-count dynamic PET data using data-driven spatial or spatiotemporal kernels. However, the construction of these existing kernels follows an empirical process. Our recent work has developed a trainable form for the spatial kernel representation and demonstrated image quality improvement in the spatial domain. In this paper, we further extend the concept to the temporal domain and combine it with the trained spatial kernels. The resulting deep spatiotemporal kernel method is directly applicable to single subjects in dynamic PET imaging. Results from computer simulation and patient studies indicate that the proposed deep kernel method can effectively improve image quality and surpass the performance of existing kernel methods for HTR dynamic PET image reconstruction.

D3-1-4: CT-free Total-body PET Segmentation 11:30-11:50

Song Xue (University of Bern, Inselspital), Christoph Clement (University of Bern, Inselspital), Rui Guo (Ruijin Hospital, Shanghai Jiao Tong University School of Medicine), Marco Viscione (University of Bern, Inselspital), Axel Rominger (University of Bern, Inselspital), Biao Li (Ruijin Hospital, Shanghai Jiao Tong University School of Medicine) and Kuangyu Shi (University of Bern, Inselspital)

ABSTRACT Low-dose positron emission tomography (PET) imaging is made possible with the use of high sensitivity PET/computed tomography (CT) scanners with a long axial field of view (FOV). However, using CT for anatomical localization in this process imposes a considerable radiation burden. We aim to achieve total-body PET multi-organ segmentation on non-corrected PET imaging using a deep learning (DL) approach as a step towards true CT-free PET imaging. Total-body 18F-FDG PET images of 114 patients scanned with a Siemens Biograph Vision Quadra were used for the development. The ground-truth multi-organ segmentation labels were generated using the CT images as input to the Multi-Organ Objective Segmentation (MOOSE) software. A 3D U-Net-like network was trained on the non-attenuation and non-scatter corrected PET images. Three nuclear medicine physicians independently assessed the utility of the results in a clinical setting. The trained model achieved an average Dice similarity coefficient (DSC) of 0.82 on the test dataset. These preliminary results show an accurate overlap between the MOOSE-generated labels and our predicted organ segmentations: 70% of targeted organs achieved DSCs of more than 0.80, whereas a few organs exhibited lower scores (e.g., bladder [0.70], thyroid [0.69] and pancreases [0.59]). The visual readings conducted by three nuclear medicine physicians confirmed the usability of the generated segmentations for anatomical localization. In conclusion, our study demonstrates the possibility of total-body PET multi-organ segmentation using a deep learning-based method that does not require the anatomical information from CT.

D3-1-5: Anatomical MRI-guided Deep-learning Low-count Pet Image Recovery without the Need for Training Data – A PET/MR Study 11:50-12:10

Tianyun Zhao (Stony Brook University), Thomas Hagan (Stony Brook University) and Chuan Huang (Emory University)

ABSTRACT The advent of simultaneous PET/MRI enables the possibility of using MRI to guide PET image reconstruction/recovery. Deep-learning approaches have been explored in low-count PET recovery, with current approaches focusing on supervised learning, which requires a large amount of paired low-count and full-count training data. A recently proposed unsupervised learning image-recovery approach does not require such data sets but relies on the optimal loss function. In this work, we developed an unsupervised learning-based PET image recovery approach using anatomical MRI as input and a novel loss function. Our method achieved better image recovery in both global image similarity metrics and regional standard uptake value (SUV) accuracy on FDG scans.

D3-1-6: VAE Constrained MR Guided PET Reconstruction 12:10-12:30

Valentin Gautier (CREATIS, INSA-Lyon, Université Lyon 1), Claude Comtat (BioMaps, Université Paris-Saclay, CEA, CNRS, Inserm, SHFJ, 91401 Orsay, France), Florent Sureau (BioMaps, Université Paris-Saclay, CEA, CNRS, Inserm, SHFJ, 91401 Orsay, France), Alexandre Bousse (LaTIM, INSERM U1101, Université de Bretagne Occidentale, 29238 Brest, France), Louise Friot-Giroux (CREATIS, INSA-Lyon, Université Lyon 1), Voichita Maxim (CREATIS, INSA-Lyon, Université Lyon 1) and Bruno Sixou (CREATIS, INSA-Lyon, Université Lyon 1)

ABSTRACT In this work, we investigate a deep learning PET-MR joint reconstruction method based on the ADMM algorithm. The a priori information to regularize the inverse problem is obtained with a VAE trained with high-quality images. Adaptive choice of the Lagrangian parameter ensures good convergence properties of the method. The proposed approach is tested on simple cases. It outperforms the classi- cal MLEM for high noise levels.

Moderator: *Larry Zeng*
Talk order based on the first name of the first author.

D3-P1-1: Effect of Cone-Beam CT Artifacts in the Training Data on the Outcome of Deep Learning Denoising

Andriy Andreyev (Carl Zeiss X-Ray Microscopy), Parisa Asadi (Carl Zeiss X-Ray Microscopy), Faguo Yang (Carl Zeiss X-Ray Microscopy) and Matthew Andrew (Carl Zeiss X-Ray Microscopy)

ABSTRACT Deep Learning denoising is increasingly popular to refine the image quality in tomographic imaging. It typically requires training from the images themselves. Very often the images are not artifact-free. Especially, in cone-beam CT with circular scan trajectories, by the nature of cone beam geometry, measured line integrals diverge and the image reconstruction accuracy diminishes very quickly. In this paper, we try to answer the question of whether we should avoid artifact regions when training Deep Learning models, as applied to CT image denoising. We use simulated phantom data as well as real data examples.

D3-P1-2: Support Vector Classifier for Metal Detection in CBCT Images

Bernhard Brendel (Philips Research Hamburg), Vithal Trivedi (Philips Image Guided Therapy, Best), Hans Rosink (Philips Image Guided Therapy, Best) and Dirk Schäfer (Philips Research Hamburg)

ABSTRACT Fast classification methods are of interest to decide if computationally expensive processing methods like metal artifact correction (MAC) should be launched automatically to improve interventional C-arm cone beam CT (CBCT) images. Simple threshold-based classification methods are possible if the voxel values of the CBCT image represent HU values. If this is not the case (e.g., to reduce calibration effort) these methods are not reliable. We present a classification method that makes no assumption on the quantitative voxel value scale of an image. It is based on a coarse histogram of min-max normalized voxel values. A linear support vector classifier (SVC) is used to separate the histograms of images without metal from those of image with metal. Tests on datasets of a cadaver study led to very good classification rates of 99-100%.

D3-P1-3: Filter-independent CNN-based CT Image Denoising

Christian Wülker (Philips Research), Nikolas D. Schnellbächer (Philips Research), Frank Bergner (Philips Research), Kevin M. Brown (Philips Healthcare) and Michael Grass (Philips Research)

ABSTRACT Different reconstruction filters are used in CT imaging to promote sharpness or suppress noise, for example. Designing machine-learning algorithms for CT image processing that can be used with different reconstruction filters, however, remains a challenge. In particular, it has recently been reported that CT image denoising based on convolutional neural networks (CNNs) generalizes poorly to different reconstruction filters and corresponding noise power spectra (NPS). While it is conceivable to train different CNNs for different reconstruction filters each in a dedicated manner, in this paper we argue that such a machine-learning algorithm for image denoising can and should be made fully independent of the reconstruction filter, instead. In particular, we show that it is well possible to train a single CNN-based denoising model for a standard ramp filter, and obtain the desired filter characteristics in the denoised images through an additional fast post-processing step. This is demonstrated both by visual and quantitative comparison using a clinical CT scan of the abdomen.

D3-P1-4: Computed Tomography Image Reconstruction with Different Styles of Multiple Kernels via Deep Learning

Danyang Li (Southern Medical University), Yuting Wang (Sun Yat-sen University Cancer Center), Dong Zeng (Southern Medical University) and Jianhua Ma (Southern Medical University). in M. Brown (Philips Healthcare) and Michael Grass (Philips Research)

ABSTRACT Computed tomography image efficiently helps diagnose potential problems or diseases before symptoms appear with the specific reconstruction kernel. Different reconstruction kernels produce CT images with different styles which exhibit various anatomical structure information. However, the standard reconstruction algorithms would reach the limit of its capacity for reconstructing the CT images with multiple image styles of different kernels, i.e., the multikernel style image reconstruction task. In this work, we design a deep learning network for accurate and efficient multi-kernel style image reconstruction task in low-dose CT imaging. The sorted view-by-view back-projection measurements at low-dose are fed into the deep learning network to reconstruct CT images with a bundle of various kernels. We demonstrate the feasibility of our deep learning network on Mayo CT dataset. The experimental results demonstrate that our deep learning network efficiently solves the simultaneous multi-kernel style image reconstruction issue.

D3-P1-5: Dynamic Contrast Peak Estimation by Gamma-Variate-Convolution Model for Autonomous Cardiac CT Triggering

Eri Haneda (GE Research-Healthcare), Pengwei Wu (GE Research-Healthcare), Isabelle Jansen (GE Research-Healthcare), Jed Pack (GE Research-Healthcare), Albert Hsiao (University of California San Diego), Elliot McVeigh (University of California San Diego) and Bruno De Man (GE Research-Healthcare)

ABSTRACT In cardiac CT, it is important to time the scan when the target chambers and vessels are near their peak contrast enhancement. In traditional bolus tracking, this timing is based on the increasing phase of observed time-intensity curve measured in a single region-of-interest (typically in the left heart) and is done empirically by imposing a diagnostic delay after the intensity reaches a pre-defined threshold. We are interested in more accurately predicting contrast peak enhancement of the left heart by analyzing the early contrast dynamics in both the right and left heart from pulsed-mode projections. We define a gamma-variate-convolution (GVC) model and we fit this model to the increasing phase up to the peak of the intensity curves in the right heart and the beginning phase of the left heart to predict the peak enhancement time of the left chambers. Myocardial perfusion CT datasets were analyzed to show that the model fits real patient CT contrast dynamics well. The same data was used to demonstrate prediction of the bolus peak enhancement time based on the early observation of bolus time-intensity curves of the heart halves. These times were compared with the optimal time, as defined by the bolus peak prediction time using full intensity measurements. The error was smaller than 2.5 sec in all cases.

D3-P1-6: PARALLELPROJ – An Open-Source Framework for Fast Calculation of Projections in Tomography

Georg Schramm (Stanford University) and Fernando Boada (Stanford University)

ABSTRACT In this work, we present a new open source framework, called parallelproj, for fast parallel calculation of projections in tomography using multiple CPUs or GPUs. This framework implements forward and back projection functions in sinogram and listmode using Joseph's method, which is also extended for time-of-flight PET projections. In a series of tests related to PET image reconstruction using data from a state-of-the-art clinical PET/CT system, we benchmark the performance of the projectors in non-TOF and TOF, sinogram and listmode. We find that the GPU mode offers acceleration factors between 20 and 60 compared to the multi CPU mode and that OSEM listmode reconstruction of real world PET data sets is possible within a couple of seconds using a single state-of-the-art consumer GPU.

D3-P1-7: On a Cylindrical Scanning Modality in Three-Dimensional Compton Scatter Tomography

James Webber (Brigham and Women's Hospital)

ABSTRACT We present injectivity and microlocal analyses of a new generalized Radon transform, R, which has applications to a novel scanner design in 3-D Compton Scattering Tomography (CST), which we also introduce here. Using Fourier decomposition and Volterra equation theory, we prove that R is injective and show that the image solution is unique. Using microlocal analysis, we prove that R satisfies the Bolker condition, and we investigate the edge detection capabilities of R. This has important implications regarding the stability of inversion and the amplification of measurement noise. This paper provides the theoretical groundwork for 3-D CST using the proposed scanner design.

D3-P1-8: Limited-Angle CT Reconstruction using Implicit Neural Representation with Learned Initialization

Jooho Lee (Yonsei University) and Jongduk Baek (Yonsei University)

ABSTRACT Limited-angle computed tomography (CT) is one of the major challenges in imaging reconstruction problems. To tackle this ill-posed inverse problem, various supervised deep learning based approaches have been proposed and shown impressive results. However, these methods have fundamental weaknesses such as the blurring effect caused by L2 loss, and difficulty in gathering a large amount of paired data in clinical practice. In this work, we propose a novel self-supervised limited-angle CT reconstruction algorithm, which effectively addresses the aforementioned limitations. We utilize the coordinate-based neural representation to obtain the missing angle data. In addition, we integrate the prior knowledge of CT image into the network via learned initialization, which dramatically enhanced the reconstruction quality. The numerical results demonstrate the superior performance of the proposed method compared to other conventional methods. We believe the presented self-supervised and patient-specific algorithm suggests a paradigm shift for limited-angle CT research based on deep learning.

D3-P1-9: Fast X-ray Diffraction Tomographic Imaging for Characterizing Biological Tissues

Kaichao Liang (Department of Engineering Physics, Tsinghua University, Beijing, China), Li Zhang (Department of Engineering Physics, Tsinghua University, Beijing, China) and Yuxiang Xing (Department of Engineering Physics, Tsinghua University, Beijing, China)

ABSTRACT X-ray diffraction (XRD) provides material specific XRD pattern for material identification. The XRD signal characterizes light materials much better compared with traditional attenuation signal in X-ray transmission imaging. Recent researches developed various XRD tomography (XRDT) methods to acquire pixel-wise XRD patterns in a 2D cross-section for an object. The applications of XRD have been promoted in biological sample inspections. However, it takes several hours for current XRDT systems to gain high-resolution images. In this work, we combined the mechanism of coded-aperture with rotational scan to form a fast data acquisition solution and propose a system referred as a sparse-view coded-aperture XRDT. This system shortens scan time to less than 40 minutes based on our laboratory equipment that is much faster compared with several hours of pencil-beam XRDT, while maintaining similar spatial resolution. Practical experiments on breast sample inspection and kidney stone analysis verified the clinical value of the proposed system.

D3-P1-10: PAConvformer: U-Shaped Locally Enhanced Transformer for Sparse PAT Reconstruction

Li He (School of Life Science and Technology, Xidian University), Li Ma (School of Life Science and Technology, Xidian University), Xu Cao (School of Life Science and Technology, Xidian University), Shouping Zhu (School of Life Science and Technology, Xidian University) and Yihan Wang (School of Life Science and Technology, Xidian University)

ABSTRACT The use of multi-detection channel sparse sampling to acquire photoacoustic signals excited by tissues in parallel, with a view to effectively suppressing the obvious bar reconstruction artifacts introduced by conventional imaging algorithms while significantly reducing system cost and complexity, and thus reconstructing high quality multispectral initial sound pressure images with high spatial and temporal resolution, is an urgent problem to be solved in the promotion of functional photoacoustic tomography in clinical applications. Balancing computational cost and imaging quality, sparse PAT reconstruction combined with convolutional neural networks has been widely studied and applied. However, due to the local nature of the operation, it is difficult for convolutional neural networks to extract the long-range dependencies that exist in continuous structures in PAT images, and the self-attention-based Transformer network has the ability to extract such dependencies by calculating the attention score within the whole image or a larger region. On the other hand, the local details in PAT images contain potential specific local physiological information, and it is beneficial to retain some of the localization operations. Therefore, this study proposes an advanced U-shaped Convolution-Transformer hybrid network-PAConvformer, which takes into account local detail recovery and global dependency of PAT images, to improve the quality of sparse PAT reconstruction images. Specifically, the standard hierarchical visual Transformer Block is optimized as follows: (1).Attention score calculation is optimized to prevent the attention map from being dominated by a small number of pixels; (2). MLP layer in the standard Transformer Block is replaced with an efficient convolutional layer-conx to enhance the detail information; (3). Adding patchnorm before and after the Patch Embedding layer to improve the robustness of the model. Through testing and statistics on the in vivo mouse dataset, the proposed model significantly improves the reconstruction quality (~50% improvement in SSIM and ~5dB improvement in PSNR) compared with the classical UBP reconstruction. The proposed model also achieves the best results compared to other advanced convolutional networks used for tomographic imaging. Intermediate layer feature similarity analysis demonstrates the better long-range modeling capability of the proposed model. Further ablation experiments show that the series of optimizations made to the network are effective.

D3-P1-11: Basis Image Filtering Enables Subpixel Resolution in Photon-Counting CT

Luca Terenzi (KTH Royal Institute of Technology), Per Lundhammar (KTH Royal Institute of Technology) and Mats Persson (KTH Royal Institute of Technology)

ABSTRACT In this proof-of-concept work, we propose a method to further increase spatial resolution and contrast in the material decomposition approach for photon counting computed tomography (PCCT). By using different weights in the frequency domain of the two basis images obtained from a simulated phantom of water and aluminum, we improve the resolution of the reconstructed image and thereby correctly resolve the line patterns even after the first zero of the MTF. From the results, the proposed method manages to increase the modulation up to 80-200% depending on the amount of cross-talk in the detector, while correctly resolving the line pattern at low and high frequencies. To the best of our knowledge, this is the first demonstration of resolution improvement by differential basis image filtering, and this technique allows further enhancing the diagnostic quality of PCCT images.

D3-P1-12: Realistic CT Noise Modeling for Deep Learning Training Data Generation and Application to Super-Resolution

Mengzhou Li (Rensselaer Polytechnic Institute, Troy, NY, USA), Peter W. Lorraine (GE Research, Niskayuna, NY, USA), Jed Pack (GE Research, Niskayuna, NY, USA), Ge Wang (Rensselaer Polytechnic Institute, Troy, NY, USA) and Bruno De Man (GE Research, Niskayuna, NY, USA)

ABSTRACT Much progress has been made in deep learning-based CT image processing, while little attention has been paid on inserted noise for network training. Additive Gaussian noise model is widely used in existing studies due to its simplicity and efficiency for large training data generation despite its distinctly uncorrelated texture compared to real CT noise. However, in this study we find that this unmatched noise could significantly degrade the inference performance on clinical images with real CT noise. Specifically, we investigate the impact of noise modeling on deep learning-based super-resolution (SR) in terms of noise type/level/anisotropy to emphasize the importance of realistic noise insertion. To address this challenge, we also provide a step-by-step recipe for fast generation of large datasets with realistic CT noise by modulating white noise in the frequency domain with a predetermined analytical formula modeling a realistic 3D noise power spectrum (NPS).

D3-P1-13: Combining Spectral CT Technologies To Improve Iodine Quantification In Pediatric Imaging

Olivia Sandvold (University of Pennsylvania), Leening Liu (University of Pennsylvania), Nadav Shapira (University of Pennsylvania), Amy Perkins (Philips Healthcare), J. Webster Stayman (Johns Hopkins University), Grace Gang (University of Pennsylvania), Roland Proksa (Philips GmbH Innovative Technologies) and Peter Noel (University of Pennsylvania)

ABSTRACT Compared to conventional computed tomography (CT), spectral CT provides additional information through the quantification of iodine-based contrast material for tissue perfusion. Various spectral CT designs are used to enable advanced analysis capabilities. Although current designs work for adult and pediatric imaging, there is still room for customization to improve spectral performance and dose for pediatric imaging. Our goal is to investigate the impact of a theoretical hybrid spectral CT system, the combination of individual technologies, on improving sensitivity and decreasing noise when estimating iodinated contrast agents in pediatric imaging. To accomplish this task, we combine dedicated K-edge filter designs with a dual-layer spectral CT to estimate the spectral performance of this hybrid combination. Results show up to 17.3% decreased iodine quantification noise and increased iodine SNR by 120% with holmium prefiltration. This study provides preliminary insights into the application of hybrid CT technologies for improving quantification in pediatric spectral CT.

D3-P1-14: Formulation of the ML-EM Algorithm Based on the Continuous-to-continuous Data Model

Robert Cierniak (Czestochowa University of Technology)

ABSTRACT This abstract shortly presents a new ML-EM approach to the reconstruction problem for positron emission tomography. The conception proposed here is based on a continuous-to-continuous data model, where a forward model present in the reconstruction problem is formulated as a shift-invariant system. The main aim of this report is to show proof for this new conception that it is based on probabilistic fundamentals. That is important because this reconstruction problem is formulated taking into consideration the statistical properties of signals obtained in the PET technique.

D3-P1-15: A Generic Software Design for Computed Tomography in Modern C++

Shiras Abdurahman (Institute for Medical Engineering and Research Campus STIMULATE, Otto-von-Guericke-Universität, Magdeburg, Germany), Robert Frysch (Institute for Medical Engineering and Research Campus STIMULATE, Otto-von-Guericke-Universität, Magdeburg, Germany), Tim Pfeiffer (Institute for Medical Engineering and Research Campus STIMULATE, Otto-von-Guericke-Universität, Magdeburg, Germany), Oliver Beuing (AMEOS Klinikum Bernburg, Bernburg, Germany) and Georg Rose (Institute for Medical Engineering and Research Campus STIMULATE, Otto-von-Guericke-Universität, Magdeburg, Germany

ABSTRACT In this paper, we propose a flexible software design for CT systems of various detector and acquisition geometries using modern C++. It is based on the generic design of CT data processing algorithms utilizing a high-level abstraction of CT geometry. We also introduce a new toolkit, GCT, to reconstruct images from the parallel-beam (1D and 2D), fan-beam (line and arc-shaped detectors), cone-beam (flat-panel and cylindrical detectors), and rebinned projections using FBP/FDK algorithm demonstrating that the proposed design can be used for the development of scalable and maintainable CT reconstruction software.

D3-P1-16: Folded-VVBP Tensor Network for Sparse-view CT Image Reconstruction

Sungho Yun (Korea Advanced Institute of Science and Technology), Dain Choi (Korea Advanced Institute of Science and Technology), Seoyoung Lee (Korea Advanced Institute of Science and Technology) and Seungryong Cho (Korea Advanced Institute of Science and Technology)

ABSTRACT In this work, we present a new approach to sparse-view computed tomography (CT) image reconstruction that is based on supervised deep learning in backprojection tensor domain. Recently, view-by-view backprojection (VVBP) network was introduced for low-dose CT image reconstruction. The VVBP tensor has a structure self-similarity and a predictable artifact distribution, which can contribute to reducing image artifacts. However, the VVBP network requires a heavy computational load due to its high dimensional feature and diverse data distribution. In this study, we introduce a 'Folded-VVBP' algorithm that compresses the original signal while enhancing the structure self-similarity. The proposed folding technique not only decreases the computational burden related to the VVBP tensor but also increases the performance of the network. Additionally, we employ squeeze-and-excitation implemented residual-encoder-decoder convolutional neural network (SE-RED-CNN) as the network architecture to fully utilize the Folded-VVBP. Our proposed algorithm was compared with the original VVBP network and a single image-domain network. The Folded-VVBP outperformed others in terms of artifact removal.

D3-P1-17: X-Ray Small Angle Tensor Tomography

Weijie Tao (Shanghai Jiao Tong University), Li Lyu (Shanghai Jiao Tong University), Yongjin Sung (University of Wisconsin- Milwaukee), Grant T. Gullberg (University of California San Francisco), Michael Fuller (TF Instruments), Youngho Seo (University of California San Francisco) and Qiu Huang (Shanghai Jiao Tong University)

ABSTRACT Previous approaches using X-ray dark-field imaging to obtain a tensor representation of small angle scatter in tissue involved first reconstructing the coefficients of a fixed vector field at each voxel, then fitting a Gaussian tensor representation of the small-angle scatter to the reconstructed vector space. A recent simulation study (Graetz [1]) demonstrated that small angle scatter can be represented by a linear tensor model to recover orientations with an accuracy of less than 1°. Based on this observation, we developed an iterative algorithm that reconstructs a symmetric 2nd rank tensor of small angle scatter from scalar projections of visibility measurements obtained from grating stepping acquisitions. The novelty is the design of a data acquisition method and reconstruction algorithm that provides estimates of tensor representation of small angle scatter. Its relation to medical imaging involves using the small angle scattering properties of X-ray interactions with tissue micro-structure to identify lesions with negligible density variation relative to surrounding tissues.

D3-P1-18: kV Scattered X-Ray Imaging for Real-Time Imaging and Tumor Tracking in Lung Cancer Radiation Therapy

Xiaoyu Hu (UT Southwestern Medical Center), Yuncheng Zhong (UT Southwestern Medical Center), Kai Yang (Massachusetts General Hospital) and Xun Jia (Johns Hopkins University)

ABSTRACT Tumor tracking is an important task in image-guided radiation therapy for lung cancer. This study investigated the feasibility of Kilo-voltage Real-time Imaging with Scatter Photons (KRISP) using a photon-counting detector (PCD) to measure Compton-scattered x-ray photon signals for real-time volumetric image and tumor tracking during treatment delivery. We used a 120 kV x-ray slice beam to irradiate a slice containing the tumor. We acquired the photons scattered off this plane using a PCD with a parallel-hole collimator. Using a prior CT image as prior information, we formulated the image reconstruction problem as an optimization problem with respect to the deformation vector field between the prior image and the real-time image. The problem was solved via a forward-backward splitting (FBS) algorithm. We conducted an initial evaluation on KRISP using a CIRS lung phantom. It was found that the reconstructed image can capture tumor motion information with a root mean square error of 1.2 mm. Radiation exposure and interference from scattered photons from the mega-voltage therapeutic beam were also investigated.

D3-P1-19: Limited-angle CT Imaging with a Non-uniform Angular Sampling Technique

Yinghui Zhang (Capital Normal University), Hongwei Li (Capital Normal University), Xing Zhao (Capital Normal University) and Ke Chen (University of Liverpool)

ABSTRACT Non-uniform angular sampling for CT imaging has the ability to select the most informative projection angles such that better images could be reconstructed. In this paper, a non-uniform angular sampling technique is proposed for limited-angle CT reconstruction which allocates more projections close to the start and end of the angular range. Numerical experiments show that, compared with conventional uniform sampling, the proposed non-uniform sampling technique achieves better reconstruction quality consistently.

D3-P1-20: Conversion of the Mayo LDCT Data to Synthetic Equivalent through the Diffusion Model for Training Denoising Networks with a Theoretically Perfect Privacy

Yongyi Shi (Biomedical Imaging Center, Rensselaer Polytechnic Institute) and Ge Wang (Biomedical Imaging Center, Rensselaer Polytechnic Institute)

ABSTRACT Deep learning techniques are widely used in the medical imaging field; for example, low-dose CT denoising. However, all these methods usually require a large number of data samples, which are at risk of privacy leaking, expensive, and time-consuming. Because privacy and other concerns create challenges to data sharing, publicly available CT datasets are up to only a few thousand cases. Generating synthetic data provides a promising alternative to complement or replace training datasets without patient-specific information. Recently, diffusion models have gained popularity in the computer vision community with a solid theoretical foundation. In this paper, we employ latent diffusion models to generate synthetic images from a publicly available CT dataset – the Mayo Low-dose CT Challenge dataset. Then, an equivalent synthetic dataset was created. Furthermore, we use both the original Mayo CT dataset and the synthetic dataset to train the RED-CNN model respectively. The results show that the RED-CNN model achieved similar performance in the two cases, which suggests the feasibility of using synthetic data to conduct the low-dose CT research. Additionally, we use the latent diffusion model to augment the Mayo dataset. The results on the augmented dataset demonstrate an improved denoising performance.

Moderator: *Wenli Wang*

Talk order based on the first name of the first author.

D3-P2-1: Improving CT Image Segmentation Accuracy Using StyleGAN Driven Data Augmentation

Arjun Krishna (Stony Brook University), Soham Bhosale (Stony Brook University), Ge Wang (Rensselaer Polytechnic Institute) and Klaus Mueller (Stony Brook University)

ABSTRACT Medical Image Segmentation is a useful application for medical image analysis including detecting diseases and abnormalities in imaging modalities such as MRI, CT etc. Deep learning has proven to be promising for this task but usually has a low accuracy because of the lack of appropriate publicly available annotated or segmented medical datasets. In addition, the datasets that are available may have a different texture because of different dosage values or scanner properties than the images that need to be segmented. This paper presents a StyleGAN-driven approach for segmenting publicly available large medical datasets by using readily available extremely small annotated datasets in similar modalities. The approach involves augmenting the small segmented dataset and eliminating texture differences between the two datasets. The dataset is augmented by being passed through six different StyleGANs that are trained on six different style images taken from the large non-annotated dataset we want to segment. Specifically, style transfer is used to augment the training dataset. The annotations of the training dataset are hence combined with the textures of the non-annotated dataset to generate new anatomically sound images. The augmented dataset is then used to train a U-Net segmentation network which displays a significant improvement in the segmentation accuracy in segmenting the large non-annotated dataset.

D3-P2-2: Simultaneous Dual-Nuclide Imaging Based on Software-Based Triple Coincidence Processing

Bo Wen (School of Life Science and Technology, Xidian University, Shaanxi 710126, China), Yu Shi (School of Life Science and Technology, Xidian University, Shaanxi 710126, China), Yirong Wang (Department of Nuclear Medicine, Xijing Hospital), Xi'an, Shaanxi 710032, China), Jianwei Zhou (School of Life Science and Technology, Xidian University, Shaanxi 710126, China), Fei Kang (Department of Nuclear Medicine, Xijing Hospital), Xi'an, Shaanxi 710032, China) and Shouping Zhu (School of Life Science and Technology, Xidian University, Shaanxi 710126, China)

ABSTRACT PET dual-nuclide simultaneous imaging is an advanced functional imaging technique. Most of the existing dual-nuclide imaging techniques either use extra detectors to detect prompt gammas or employ dynamic acquisition protocol to distinguish between nuclides. However, they also cause the problems of complex system structure and complicated data acquisition process. In this paper, we used a software-based coincidence processing method to realize simultaneous dual-nuclide imaging. In order to evaluate the effectiveness of the dual-nuclide method, phantom and mouse experiments of 18F/124I were performed on the in-house quad-panel PET system. In the phantom experiment, the separation images of dual-nuclide showed good separation. In the mouse experiment, the separated images of 124I and 18F showed different activity distributions in the thyroid, heart and bladder, which were consistent with the single-nuclide reconstructed images. This work demonstrates the feasibility of dual-nuclide simultaneous imaging using a software-based triple coincidence processing method in a conventional PET system.

D3-P2-3: Positron-Range Correction for an On-Chip PET Scanner using Deep Learning

Christoph Clement (Department of Nuclear Medicine, Inselspital, University of Bern, Bern, Switzerland), Gabriele Birindelli (Department of Nuclear Medicine, Inselspital, University of Bern, Bern, Switzerland), Fiammetta Pagano (EP Department, CERN, Geneva, Switzerland & Physics Department, University of Milano-Bicocca, Milan, Italy), Marco Pizzichemi (EP Department, CERN, Geneva, Switzerland & Physics Department, University of Milano-Bicocca, Milan, Italy), Marianna Kruithof-De Julio (Department for Biomedical Research, Inselspital, University of Bern, Bern, Switzerland), Sibylle Ziegler (Department of Nuclear Medicine, University Hospital, Ludwig Maximilian University of Munich, Munich, Germany), Axel Rominger (Department of Nuclear Medicine, Inselspital, University of Bern, Bern, Switzerland), Etiennette Auffray (EP Department, CERN, Geneva, Switzerland) and Kuangyu Shi (Department of Nuclear Medicine, Inselspital, University of Bern, Bern, Switzerland)

ABSTRACT Organs-on-Chips (OOCs) are a novel technology that aim to mimic the functions and physiology of human organs in a laboratory setting. Positron Emission Tomography (PET) is a widely-used imaging modality that enables non-invasive monitoring of biological processes in vivo. However, the spatial resolution of current smallscale PET systems is not sufficient for OOC imaging. One of the main factors limiting the spatial resolution of a PET scanner is the positron range, which is the distance that a positron travels before it collides with an electron. In this study, we present a novel Deep Learning (DL)-based approach for correcting the positron-range effect in our previously introduced On-Chip PET scanner. We created a dataset of pairs of non-corrected and corrected images using a Monte-Carlo simulation of a realistic OOC phantom and a fully three-dimensional Maximum-Likelihood Expectation-Maximization (MLEM) iterative reconstruction algorithm. Our results demonstrate the effectiveness of the DL-based positron-range correction algorithm in improving the overall quality of the reconstructed images. This approach has the potential to be a valuable tool for advancing the study of 3D models in radiopharmaceutical research.

D3-P2-4: Generation of Photon-counting Spectral CT Images Using a Score-based Diffusion Model

Dennis Hein (KTH Royal Institute of Technology) and Mats Persson (KTH Royal Institute of Technology)

ABSTRACT Deep learning is playing an increasingly important role in medical imaging. One important factor for the development and evaluation of high performing and robust networks is the availability of large and diverse datasets. However, this availability is lacking for novel technologies such as photon-counting spectral CT. One way of generating synthetic data is using score-based diffusion models, a novel class of generative models that have recently shown to perform on par with, or outperform, generative adversarial networks. This paper explores the possibility of utilizing a score-based diffusion model to generate photon-counting spectral CT images. We train a network to generate a pair of 70 and 100 keV virtual monoenergetic images from which we can subsequently recover material basis images via a simple linear transformation. Our results are very encouraging as the resulting network is able to generate realistic output with limited data and training time and with minimal hyperparameter tuning.

D3-P2-5: Unrolled Three-Operator Splitting for Parameter-Map Learning in Low Dose X-ray CT Reconstruction

Evangelos Papoutsellis (Finden Ltd), Andreas Kofler (Physikalisch-Technische Bundesanstalt (PTB)), Kostantinos Papafitsoros (Queen Mary University of London), Fabian Altekrüger (Humboldt-Universität zu Berlin, Technische Universität Berlin), Fatima Antarou Ba (Technische Universität Berlin), Christoph Kolbitsch (Physikalisch-Technische Bundesanstalt (PTB)), David Schote (Physikalisch-Technische Bundesanstalt (PTB)), Clemens Sirotenko (Weierstrass Institute for Applied Analysis and Stochastics) and Felix Frederik Zimmermann (Physikalisch-Technische Bundesanstalt (PTB)

ABSTRACT We propose a method for fast and automatic estimation of spatially dependent regularization maps for total variation-based (TV) tomography reconstruction. The estimation is based on two distinct sub-networks, with the first sub-network estimating the regularization parameter-map from the input data while the second one unrolling T iterations of the Primal-Dual Three-Operator Splitting (PD3O) algorithm. The latter approximately solves the corresponding TV-minimization problem incorporating the previously estimated regularization parameter-map. The overall network is then trained end-to-end in a supervised learning fashion using pairs of clean-corrupted data but crucially without the need of having access to labels for the optimal regularization parameter-maps.

D3-P2-6: Volumetric Breast Density Measurement Using Dual-energy Digital Breast Tomosynthesis with Dual-shot and Dual-layer Technique

Hailiang Huang (Stony Brook Medicine), Xiaoyu Duan (Stony Brook Medicine) and Wei Zhao (Stony Brook Medicine)

ABSTRACT Volumetric breast density (VBD) has been conventionally measured on mammogram or digital breast tomosynthesis (DBT) projection image acquired using single x-ray energy spectrum, which could be greatly impacted by different breast compressions. We aim to develop a method for reproducible VBD measurement using dual-energy (DE) material decomposition with DE DBT, which uses both conventional dual-shot (DS) technique for image acquisition and a dual-layer (DL) detector to minimize patient motion in clinical practice. In-silico experiments were conducted using a virtual clinical trial software (VICTRE) with digital breast phantom and image simulations. The breast attenuations in high- and low-energy image were calibrated using analytical calculations for DS and DL technique. Our results show consistent VBD measurements among all projection angles and reproducible measurements for breast under different compressions. For DL technique, a correction method was applied to reduce the uncertainty in the decomposed thickness map and VBD map.

D3-P2-7: Assessing the Mechanical Properties of Acutely Injured Lungs: A Comparative Study of Traditional and Novel Ventilation Techniques Utilizing Computed Tomographic (CT) Imaging

Jian Gao (University of Iowa), Emmanuel A. Akor (University of Iowa), Andrea F. Cruz (University of Iowa), Bin Han (University of Iowa), Junfeng Guo (University of Iowa), Sarah E. Gerard (University of Iowa), Jacob Herrmann (University of Iowa), David W. Kaczka (University of Iowa)

ABSTRACT Acute Respiratory Distress Syndrome (ARDS) is a leading cause of respiratory failure, resulting in significant morbidity and mortality. Present treatment strategies mainly utilize mechanical ventilation, which, despite its effectiveness, can inadvertently result in ventilator-induced lung injury (VILI), due to non-uniform strain distribution and heterogeneous gas exchange. In this study, we utilized quantitative computed tomographic (qCT) imaging to investigate the pathophysiology of a porcine model of ARDS, and its response to different ventilation strategies, including conventional mechanical ventilation (CMV), high frequency oscillatory ventilation (HFOV), and multi-frequency ventilation (MFV). We evaluated baseline conditions and subsequent responses to oleic acid-induced lung injury over a nine-hour period, using biomarkers (blood oxygen index, pH, PaO2: FO2) as well as static CT imaging to quantify regional and global aeration. Preliminary results indicated a significant decrease in blood oxygen index in the HFOV and MFV groups compared to the CMV group. We are employing 3D CT image registration to examine regional mechanics and parenchymal deformation under CMV, SFOV, and MFV. Our goal is to identify a correlation between the ventilation strategies and the severity of VILI by analyzing the mechanical properties of the lungs. Our findings will aid in refining ARDS ventilation strategies and enhance our basic understanding of different ventilation approaches to improve patient outcomes.

D3-P2-8: Fitting a 2D Mesh to X-ray Measurements

Jannes Merckx (University of Antwerp), Jan Sijbers (University of Antwerp) and Jan De Beenhouwer (University of Antwerp)

ABSTRACT A triangular mesh is a collection of triangles connected by mutual edges that can be used to represent surfaces and interfaces between different composites of an object. This representation is potentially more efficient than a voxel grid. Furthermore, a mesh-based representation can greatly reduce partial volume effects. Manufactured objects, produced based on a CAD model, do not match this model perfectly due to production mistakes. This paper introduces two algorithms for fitting meshes to X-ray measurements, thus minimising partial volume effects. Even though the eventual goal is the extension to 3D, a 2D proof-of-concept is presented here, where vertices are placed on interfaces by using their corresponding mesh triangles as pixels for a polyethylene triangle. Possible applications of this are greatly reducing partial volume effects and adapting surface meshes to X-ray projections

D3-P2-9: Projection-based CBCT Motion Correction using Convolutional LSTMs

Joscha Maier (German Cancer Research Center (DKFZ)), Timothy Herbst (German Cancer Research Center (DKFZ)), Stefan Sawall (German Cancer Research Center (DKFZ)), Marcel Arheit (Varian Medical Systems Imaging Lab, GmbH), Pascal Paysan (Varian Medical Systems Imaging Lab, GmbH) and Marc Kachelrieß (German Cancer Research Center (DKFZ)

ABSTRACT Due to the limited temporal resolution of CBCT scans, CBCT reconstructions often suffer from motion artifacts. To address this issue, existing approaches typically estimate displacement vector fields in image domain to compensate for the present motion. However, since reconstruction artifacts may impair the performance of such approaches, we propose to overcome this limitation by operating in projection domain. To do so, we make use of a neural network which is trained to map the projections of a moving patient to projections of a static patient that is frozen in a fixed motion state. In this work, this mapping is trained using 4D CBCT simulations to account for respiratory motion. Subsequently, the network can be applied repeatedly to predict projections for different motion states of the respiratory cycle. In our experiments, these reconstructions show only minor motion artifacts and differ by less than 15 HU on average from an ideal reference.

D3-P2-10: Quantitative Dual-Energy Spectral CT at Ultra-Low Dose

Kevin Brown (Philips) and Stanislav Zabic (Philips)

ABSTRACT We address the clipping-induced bias problem arising from electronic noise in energy-integrating Spectral CT at ultra-low dose, and we show that with proper treatment these kind of systems can deliver quantitative Spectral CT images even at ultra-low dose levels.

D3-P2-11: Neural Network Guided Sinogram-Domain Iterative Algorithm for Artifact Reduction

Larry Zeng (Utah Valley University)

ABSTRACT Artifact reduction or removal is a challenging task when the artifact creation physics are not well modeled mathematically. One of such situations is metal artifacts in X-ray CT when the metallic material is unknown and the X-ray spectrum is wide. In this paper, a neural network is used to act as the objective function for iterative artifact reduction when the artifact model is unknown. A hypothetical unpredictable projection data distortion model is used to illustrate the proposed approach. The model is unpredictable, because is controlled by a random variable. A convolutional neural network is trained to recognize the artifacts. The trained network is then used to compute the objective function for an iterative algorithm, which tries to reduce the artifacts in a computed tomography (CT) task. The objective function is evaluated in the image domain. The iterative algorithm for artifact reduction is in the projection domain. A gradient descent algorithm is used for the objective function optimization. The associated gradient is calculated with the chain rule. The images after the iterative treatment show the reduction of artifacts. The methodology of using a neural network as an objective function has potential value for situations where a human developed model is difficult to describe the underlying physics. Applications in medical imaging are expected to be benefit from this methodology.

D3-P2-12: Improved Resolution on Existing CT Scanners by Utilizing Off-Center Scan Regions and Zoom-In Partial Scans (ZIPS)

Lin Fu (GE Research - Healthcare), Eri Haneda (GE Research - Healthcare), Stephen Araujo (GE Research - Healthcare), Ryan Breighner (Hospital for Special Surgery) and Bruno De Man (GE Research - Healthcare)

ABSTRACT Recently, the Zoom-In Partial Scans (ZIPS) scheme was introduced to boost the spatial resolution of clinical CT scanners. Contrary to the conventional wisdom that a region of interest should be centered in the field of view for the best resolution, in ZIPS the ROI is intentionally placed some distance away from the iso-center to gain higher geometrical magnification, which in turn brings higher resolution. Despite promising simulation results, it remains an open question whether ZIPS is effective on real CT systems, where complicated practical constrains may impact theoretical assumptions. In this paper, we implement the proposed ZIPS scheme on a GE Revolution CT and evaluate image resolution using phantoms and cadaveric bone samples. Clear improvement of the visibility of fine features and trabecular details is observed when comparing ZIPS to the conventional scans at the center. To our knowledge, this is the first demonstration on clinical CT that the resolution of off-center scans can outperform that of a conventional centered scan.

D3-P2-13: One-cycle 4D-CT Reconstruction with Two-level Motion Field INR

Muge Du (Department of Engineering Physics, Tsinghua University, Beijing, China), Li Zhang (Department of Engineering Physics, Tsinghua University, Beijing, China), Le Shen (Department of Engineering Physics, Tsinghua University, Beijing, China), Yinong Liu (Department of Engineering Physics, Tsinghua University, Beijing, China), Shuo Wang (Department of Engineering Physics, Tsinghua University, Beijing, China) and Yuxiang Xing (Department of Engineering Physics, Tsinghua University, Beijing, China)

ABSTRACT One-cycle 4D-CT reconstruction can largely reduce scanning time and radiation dose, but the reconstruction can be ill-posed with sparse-view and limited-angle problems. We proposed a novel implicit neural representation (INR) for one-cycle 4D-CT featured by a basic deformation model combining a two-level motion field INR to a template attenuation field INR, and a shortcut for capturing non-deformable motion. The two-level design in the motion field INR includes global-local division for motion, and pattern-strength modeling for local motion. Besides, a Fourier-Domain-Error rendering loss is proposed to train INR-based CT reconstruction. The method is evaluated in simulated one-cycle cardiac and lung 4D-CT datasets. It outperforms PICCS with huge advantages and is able to reconstruct high-quality dynamic volumes with rich details. The proposed method brings potential for significant dose reduction by one-cycle 4D-CT.

D3-P2-14: From Coordinate System Mapping to Deep Feature Mapping: A Generative Deep Learning Approach for Pixel-level Alignment of Images in Rotation-to-rotation DECT

Peng Wang (Shanghai United Imaging Healthcare Co., Ltd) and Guotao Quan (Shanghai United Imaging Healthcare Co., Ltd)

ABSTRACT Dual-energy computed tomography (DECT) is of great clinical significance, but available acquisition technologies usually demand the most advanced hardware or system design. Single-source sequential (rotation-to-rotation) dual energy scanning protocol is feasible for most CT instruments but suffers from poor temporal resolution. Random displacement and deformation of a patient are almost unavoidable during the measurement. Mismatch of the dual energy images limits the potential clinical application with further spectral analysis. Conventional registration methods are time- and computational power- consumed, and hard to achieve pixel-level alignment. We propose a generative approach to produce a perfectly aligned dual energy set in the image domain instead of registration. We discuss the statistical image mapping method based on histogram and exploit the feasibility of integration with deep learning strategy. The spectral transfer was implemented at the feature level with statistical information. Dual-energy images present different attenuation and contrast, which could be viewed as a semi-cross-modal image transfer task. Thus, this proposed network would be a possible framework for other cross-modality medical image alignment tasks instead of using the registration method.

D3-P2-15: Motion Estimation in Parallel-Beam Linogram Geometry Using Data Consistency Conditions

Sasha Gasquet (Université Grenoble Alpes and Tiama), Laurent Desbat (Université Grenoble Alpes) and Pierre-Yves Solane (Tiama)

ABSTRACT Data consistency conditions (DCCs) express the redundancy in the projections. In X-ray computed tomography, the most common conditions are expressed pairwise on the projections or as equality between projection-based moments and polynomials. The latter is better known in the parallel-beam geometry as the Helgason-Ludwig consistency conditions (HLCCs). The DCCs are often used to self-calibrate radiography systems. In this paper, we adjust data consistency conditions to a time-dependent model of the data in the parallel linogram geometry. We show that it is not possible to estimate the parameters of a uniform motion of a translating object using the DCCs. However, we show that we can estimate the average speed with prior information on the object's center of mass. Then, we model and estimate the parameters of a periodical variation of the motion. Finally, we run simulations to assess the performances of our method.

D3-P2-16: Protocol Variation Network for Low-dose CT image denoising with Different kVp Settings and Anatomical Regions

Shixuan Chen (Southern Medical University), Yinda Du (Southern Medical University), Boxuan Cao (Southern Medical University), Shengwang Peng (Southern Medical University), Ji He (Guangzhou Medical University), Yaoduo Zhang (Guangzhou Medical University), Zhaoying Bian (Southern Medical University), Dong Zeng (Southern Medical University) and Jianhua Ma (Southern Medical University)

ABSTRACT Computed tomography (CT) is a useful diagnostic tool for diseases and injuries detection in clinics. With an increase in the utilization of CT examinations, there is a concern about the general population's radiation exposure. Deep learning (DL)-based methods are efficient to lower radiation dose without sacrificing CT image quality, and have potential to achieve great reconstruction performance. However, these DL-based methods are sensitive to CT protocol selection, i.e., kVp settings and anatomy to be examined. In this work, we propose a protocol variation network (PV-Net) for low-dose CT image denoising to consider the heterogeneity within the different kVp settings and anatomical structures. Specifically, the proposed PV-Net models the characteristics of the CT data, i.e., noise distribution and anatomical structures in the network. Experimental results on the CT datasets demonstrate that the proposed PV-Net leads to improved reconstruction performance with kVp and anatomical structure variations, compared with the other competing methods.

D3-P2-17: Towards Deep-Learning Partial Volume Correction for SPECT

Theo Kaprelian (Université de Lyon, CREATIS; CNRS UMR5220; Inserm U1044; INSA-Lyon; Université Lyon 1; Centre Léon Bérard, France), Ane Etxebeste (Université de Lyon, CREATIS; CNRS UMR5220; Inserm U1044; INSA-Lyon; Université Lyon 1; Centre Léon Bérard, France) and David Sarrut (Université de Lyon, CREATIS; CNRS UMR5220; Inserm U1044; INSA-Lyon; Université Lyon 1; Centre Léon Bérard, France)

ABSTRACT Partial Volume Effect impacts the spatial resolution of SPECT images. We investigated the feasibility of a deep learning-based Partial Volume Correction method (PVCNet) that compensates for the effect of collimator blurring on 2D projections, before reconstruction. A large dataset containing 600,000 pairs of synthetic projections was generated and used to train a Pix2Pix model. Scatter and attenuation were not yet considered. On reconstructed images of single spherical sources, the network was able to reduce the size of the volume below which activity is only partially recovered: Recovery Coefficient was close to 1 for a 24 mm diameter sphere while conventional Resolution Modeling method led to RC=0.76. On IEC phantom, even if RC values were not always better, PVCNet achieved a Normalized Mean Absolute Error reduction of about 30% compared to Resolution Modeling.

D3-P2-18: Deep Learning-based "Stopping Power Ratio" Mapping for Proton Therapy

Wenxiang Cong (Rensselaer Polytechnic Institute (RPI)), Manudeep Kalra (Massachusetts General Hospital), Harald Paganetti (Massachusetts General Hospital) and Ge Wang (Rensselaer Polytechnic Institute (RPI))

ABSTRACT Proton therapy is to maximize radiation dose on a tumor site while minimizing its damage to surrounding vital organs in a patient. The quality of proton therapy relies on accurate and reliable dose calculation. During proton therapy, the position of the Bragg peak is estimated in terms of the stopping power ratio (SPR). Inaccurate SPR leads to an uncertain range of proton delivery. Here we propose a machine learning-based method to directly map a clinical CT image to the associated SPR map using an improved residual neural network (ImResNet) model. Our ImResNet can model a more complicated nonlinear relationship than ResNet and is dedicated to this application. Specifically, based on the elemental composition of human tissues, material decomposition is performed from dual-energy CT (DECT) to form a training dataset to optimize the parameters of ImResNet in the supervised fashion. In this pilot study, we quantitatively evaluate the proposed approach on simulated and clinical CT images. Results show that this approach achieves an accurate SPR estimation.

D3-P2-19: Asymmetrical Dual-Cycle Adversarial Network for Material Decomposition and Synthesis of Dual-energy CT Images

Xinrui Zhang (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Ailong Cai (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Shaoyu Wang (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Ningning Liang (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Yizhong Wang (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Junru Ren (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Lei Li (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University) and Bin Yan (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University)

ABSTRACT Dual-energy computed tomography (DECT) can identify the material properties with its excellent material quantitative analysis ability. However, the application of DECT is restricted by the problems of inaccuracy of energy spectrum estimation, non-linearity and inconsistency of imaging geometry, which will lead to the degradation of material distribution images. Hence, deep learning (DL)-based methods have become the state-of-the-art technique in DECT rely on its excellent feature recognition performance in the case of few spectrum prior. In this work, we propose an asymmetrical Dual-Cycle adversarial network (ADCNet) for both material decomposition and synthesis of dual-energy CT images, which has certain advantages in spectral CT multi-task parallel, improvement of image quality and radiation dose reduction. The experimental results show that the cycle framework achieves the adversarial learning of dual networks, and promotes the quality of generated images by introducing multiple mechanisms. Compared with the traditional DL-based methods, the proposed method has outstanding qualitative and quantitative indicators.

D3-P2-20: Prior Information Enhanced Adversarial Learning for kVp Switching CT

Yizhong Wang (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Ailong Cai (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Ningning Liang (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Shaoyu Wang (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Junru Ren (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Xinrui Zhang (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University), Lei Li (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University) and Bin Yan (Department of Henan Key Laboratory of Imaging and Intelligent Processing, Information Engineering University)

ABSTRACT Dual energy computed tomography (DECT) can provide both structural and material information of the scanned object, and has been widely used in the medical field. However, patients may suffer from genetic damage and cancer under long-term high radiation dose of x-ray exposure. To reduce radiation dose and ensure optimal hardware cost. This work studies the switching technology based on the x-ray tube voltage (kVp), which only requires the traditional energy integration detector and the ray source. However, the kVp switching technology faces the problems of low sampling rate of each energy spectrum and the spatial misalignment of projection data of different energy spectrum. Thus, this study introduces an adversarial learning mechanism and proposes a Prior Information enhanced Projection data Inpainting Network (PINet). The experimental results show that the PINet framework is a promising approach for sparse-view angle DECT imaging.

D3-P2-21: A Metal Artifacts Reducing Method Using Intra-Oral Scan Data for Dental Cone-Beam CT

Yuyang Wang (Tsinghua University) and Liang Li (Tsinghua University)

ABSTRACT In cone-beam computed tomography (CBCT), metal implants produce severe artifacts during imaging, causing serious damage to the clinical structure and information of the teeth, reducing imaging quality, and ultimately affecting subsequent clinical treatment. However, currently, although there are many metal artifact reduction (MAR) methods, they still lack in preserving tooth structure. The proposed MAR method combines CBCT data and intra-oral scan data to better guide the segmentation of metal areas and comprehensively use projection domain and image domain data to remove metal artifacts. The experiment results are presented to demonstrate the feasibility of the proposed approach. We propose a novel MAR method that uses intraoral scan data for the first time in the analysis and processing of projection domain data, thus accurately reconstructing 3D dental images.

D4-1: Nuclear Medicine – July 20, 2023 09:00-11:00

Moderators: *Michael King/Jinyi Qi*

Talk order based on the first name of the first author.

D4-1-1: Ability of Exponential Data Consistency Conditions to Detect Motion in SPECT Despite Other Physical Effects 09:00-09:20

Antoine Robert (CREATIS), David Sarrut (CREATIS), Ane Etxebeste (CREATIS), Jean Michel Létang (CREATIS) and Simon Rit (CREATIS)

ABSTRACT Exponential data consistency conditions (eDCCs) are equations that express the redundancy of information between exponential projections. Exponential projections can be derived from parallel SPECT projections and be used to detect and correct for patient motion during the acquisition. However, other physical effects such as collimator resolution, scatter or noise could also introduce inconsistencies in the projections. The purpose of this work was to evaluate the impact of these effects on the eDCCs. We used ray-tracing and Monte Carlo simulations to generate different sets of projections and compared their consistency with two metrics based on eDCCs: the absolute relative difference and a noise-aware metric that takes into account the acquisition noise. The collimator resolution, the scatter and the movement increase significantly the error in the eDCCs. The noise-aware metric was more sensitive to patient motion than other effects.

D4-1-2: 3D PET-DIP Reconstruction with Relative Difference Prior Using a SIRF-Based Objective 09:20-09:40

Imraj Singh (University College London), Riccardo Barbano (University College London), Željko Kereta (University College London), Bangti Jin (University College London), Kris Thielemans (University College London) and Simon Arridge (University College London)

ABSTRACT Deep Image Prior (DIP) is an unsupervised deep learning technique that does not require ground truth images. For the first time, 3D PET reconstruction with DIP is cast as a single optimisation via penalised maximum likelihood estimation, with a log-likelihood data-fit and an optional Relative Difference Prior term. Experimental results show that although unpenalised DIP optimisation trajectory performs well in high count data, it can fail to adequately resolve lesions in lower count settings. Introducing the Relative Difference Prior into the objective function the DIP trajectory can yield notable improvements.

D4-1-3: Image Reconstruction and CT-less Attenuation Correction for the Walk-through Total-Body PET System 09:40-10:00

Jens Maebe (Ghent University), Meysam Dadgar (Ghent University), Maya Abi Akl (Ghent University) and Stefaan Vandenberghe (Ghent University)

ABSTRACT A new PET scanner design, the walk-through total-body PET, has recently been proposed. It consists of two flat, vertically placed, 74 by 106 cm panels made up of monolithic BGO detectors. This new scanner design will offer a lower cost, high patient throughput alternative to existing total-body PET scanners. This study investigates the image reconstruction of the NEMA image quality phantom in two configurations of the scanner: fixed and rotating. In addition, two methods for CT-less attenuation correction in the system are explored: the use of a transmission source and estimation of the attenuation coefficients from the emission data itself. The fixed scanner configuration offers higher sensitivity, but streaking artifacts are observed due to the limited angle problem, which are solved in the rotating configuration. CT-less attenuation correction also proves to be feasible, with generally better image quality observed with the addition of a transmission source.

D4-1-4: Pairwise Data Consistency Conditions for the Exponential Fanbeam Transform 10:00-10:20

Richard Huber (Univ. Grenoble Alpes, CNRS, Grenoble INP, TIMC, 38000 Grenoble, France), Rolf Clackdoyle (Univ. Grenoble Alpes, CNRS, Grenoble INP, TIMC, 38000 Grenoble, France) and Laurent Desbat (Univ. Grenoble Alpes, CNRS, Grenoble INP, TIMC, 38000 Grenoble, France)

ABSTRACT Data consistency conditions (DCCs) for projection operators have been of great relevance in the field of tomography, as they allow the determination of measured data's feasibility prior to reconstruction. Particularly useful are DCCs comparing two projections, accordingly called pairwise DCCs (PDCCs). Such conditions compute certain linear functionals dependent on individual projections, whose values must coincide for consistency to hold. For many projection operators, such PDCCs are known, but for the exponential fanbeam transform – which is relevant for SPECT – they are not. We show mathematically that no condition of this type can exist for a pair of exponential fanbeam projections. Moreover, we present a novel type of pairwise data consistency conditions, requiring that the difference between certain linear functionals of two projections lie in a specified interval, instead of coinciding as they would in classical PDCCs. This new condition is substantiated by numerical experiments on some phantoms.

D4-1-5: Preliminary De-Multiplexing of Projection Images Using Temporal Shuttering in a Brain-Dedicated SPECT System 10:20-10:40

Sophia Pells (UMass Chan Medical School), Navid Zeraatkar (Siemens Medical Solutions), Kesava S. Kalluri (UMass Chan Medical School), Stephen S. Moore (Perelman School of Medicine, University of Pennsylvania), Micaehla May (James C. Wyant College of Optical Sciences, The University of Arizona), Lars R. Furenlid (James C. Wyant College of Optical Sciences, The University of Arizona), Phillip H. Kuo (Department of Medical Imaging, The University of Arizona) and Michael A. King (UMass Chan Medical School)

ABSTRACT Mulitplexing can increase sensitivity in SPECT imaging, but comes at the cost of increased ambiguity and can lead to image-degrading artefacts during reconstruction. Here, an algorithm was used to correct for multiplexing in projection images. A modified model of the brain-dedicated multi-pinhole AdaptiSPECT-C system was used to test the performance of the de-multiplexing algorithm with digital phantoms. AdaptiSPECT-C has the ability to shutter each of its 120 pinholes independently, so the de-multiplexing algorithm was tested for acquisitions with and without a multiplex-free projection frame. The de-multiplexing algorithm was shown to improve the uniformity in reconstructed images of a uniform sphere of activity for both acquisition modes, and uniformity was improved further with the inclusion of a multiplexing-free projection frame. In addition, the de-multiplexing algorithm improved the structural similarity and activity recovery in a brain perfusion phantom.

D4-1-6: Task-based Assessment of Deep Networks for Sinogram Denoising with a Transformer-based Observer 10:40-11:00

Yongyi Shi (Biomedical Imaging Center, Rensselaer Polytechnic Institute), Ge Wang (Biomedical Imaging Center, Rensselaer Polytechnic Institute) and Xuanqin Mou (Institute of Image Processing and Pattern Recognition, Xi'an Jiaotong University)

ABSTRACT A variety of supervised learning methods are available for low-dose CT denoising in the sinogram domain. Traditional model observers are widely employed to evaluate these methods. However, the sinogram domain evaluation remains an open problem for deep learning-based low-dose CT denoising and other tasks. Since each lesion in medical CT images corresponds to a narrow sinusoidal strip in the sinogram domain, here we propose a transformer-based model observer to evaluate sinogram-domain-based supervised learning methods. The numerical results indicate that our transformer-based model well-approximates the Laguerre-Gauss channelized Hotelling observer (LG-CHO) for a signal-known-exactly (SKE) and background-known-statistically (BKS) task. The proposed model observer is employed to assess two classic CNN-based sinogram denoising methods. This transformer-based observer model has potential to be further developed as a guidance for deep analysis in the sinogram domain.

D4-2: Other Recon – July 20, 2023 13:30-15:30

Moderators: *Marc Kachelrieß/Kuang Gong*

Talk order based on the first name of the first author.

D4-2-1: Fast Reconstruction of Positronium Lifetime Image by the Method of Moments 13:30-13:50

Bangyan Huang (Department of Biomedical Engineering, University of California, Davis) and Jinyi Qi (Department of Biomedical Engineering, University of California, Davis)

ABSTRACT The lifetime of ortho-positroniums can be influenced by the microstructure and the concentration of bio-active molecules in human tissue, thereby providing valuable information for better understanding of disease progression and treatment response. There is currently a lack of efficient lifetime image reconstruction methods. Existing methods are either computationally intensive or have poor spatial resolution. This paper presents a fast lifetime image reconstruction method called SIMPLE-Moment, which can reconstruct ortho-positronium lifetime images with a computational time equivalent to that of reconstructing three standard PET activity images. The implementation of this method requires minimal modification to the conventional ordered subset expectation maximization (OSEM) algorithm. A Monte Carlo simulation study using GATE demonstrates that the proposed method can reconstruct high-resolution lifetime images using a PET scanner with an existing time-of-flight (TOF) resolution.

D4-2-2: Real-time Liver Tumor Localization via Combined Optical Surface Imaging and Angle-agnostic X-ray Imaging 13:50-14:10

Hua-Chieh Shao (The University of Texas Southwestern Medical Center), Yunxiang Li (The University of Texas Southwestern Medical Center), Jing Wang (The University of Texas Southwestern Medical Center), Steve Jiang (The University of Texas Southwestern Medical Center) and You Zhang (The University of Texas Southwestern Medical Center)

ABSTRACT Real-time image-guided radiotherapy improves treatment accuracy by localizing tumors and adapting to their intra-treatment motion. However, real-time imaging of liver tumors is challenged by rapid tumor motion (due to respiration). The temporal resolution required for capturing motion and treatment adaptation (< 500ms) results in extreme under-sampling for desired 3D imaging. Furthermore, liver tumor localization is also challenged by the diminished tumor/normal-liver-tissue x-ray contrast. We developed a deep learning-based, deformable registration-driven framework (Surf-X360-Bio) to localize 3D liver tumors in real-time, using optical surface imaging and an arbitrary-angle x-ray projection. By Surf-X360-Bio, the liver boundary motion was first estimated through a cascaded surface and angle-agnostic x-ray imaging model (Surf-X360). Using the solved liver boundary motion, a Bio model further localized the liver tumor through biomechanical modeling. Surf-X360-Bio demonstrated fast (<250ms inference time), accurate (mean error < 2.1mm), and robust liver tumor localizations at arbitrary x-ray angles for real-time, markerless tumor tracking.

D4-2-3: Limited Scanning Arc Image Reconstruction with Weighted Anisotropic TV Minimization 14:10-14:30

Leo Zhang (Department of Radiology, University of Chicago), Emil Sidky (Department of Radiology, University of Chicago), John Paul Phillips (Department of Radiology, University of Chicago), Zheng Zhang (Department of Radiology, University of Chicago), Buxin Chen (Department of Radiology, University of Chicago), Dan Xia (Department of Radiology, University of Chicago) and Xiaochuan Pan (Department of Radiology, University of Chicago)

ABSTRACT In this work, an algorithm for limited angular range scanning is developed based on data discrepancy constrained, weighted anisotropic total variation (WATV) minimization. The constraint on the data discrepancy allows for mismatch between the project data and its estimate, and a weighting parameter controls the relative strength of ATV regularization in directions parallel and perpendicular to the scanning arc. Standard unweighted ATV is a special case of the considered optimization problem. The algorithm is demonstrated on noiseless projection data in order to investigate the accuracy of the proposed inverse problem solution as a function of the weighting parameter. The results show that the optimal recovery is found for a weighting parameter that imposes greater directional TV regularization along the direction parallel to the scan arc.

D4-2-4: An Accretion Method to Regularize Digital Breast Tomosynthesis Reconstruction 14:30-14:50

Leonardo Coito Pereyra (Department of Medical Imaging, Radboud University Medical Center, Nijmegen), Ioannis Sechopoulos (Department of Medical Imaging, Radboud University Medical Center, Nijmegen) and Koen Michielsen (Department of Medical Imaging, Radboud University Medical Center, Nijmegen)

ABSTRACT Digital breast tomosynthesis suffers from limited angle artifacts which mean that the distribution of fibro-glandular tissue is severely limited in the direction of the missing data. We present a regularization method based on the accretion of fibro-glandular tissue which is inspired by particle accretion phenomenon with attractive interactions.

In our proposed method, we consider the fraction of fibro-glandular tissue at each voxel to correspond to the number of particles with attractive interactions so that the particles of one voxel would be attracted to those of a neighboring voxel, thus generating a redistribution among voxels. The method is combined with a polychromatic reconstruction algorithm with material decomposition where the accretion can be applied to the fibro-glandular image component.

Quantitative evaluation found that the reconstructed glandularity was 0.17 on average, ranging between 0.09 and 0.29, and difference with the ground truth was 0.01 on average, ranging between -0.04 and 0.06. The DSC of the fibro-glandular structures in the phantoms and after reconstruction was 0.58 on average, ranging between 0.46 and 0.67.

D4-2-5: Simulations of Immuno-Contrast CT to Optimize Spectral Instrumentation and Nanoparticle Contrast Agent Materials 14:50-15:10

Matthew Tivnan (Johns Hopkins University), Grace Gang (Hospital of the University of Pennsylvania) and J. Webster Stayman (Johns Hopkins University)

ABSTRACT The current standard for preclinical evaluation of new antibody-tagged nanomedicines is positron emission tomography (PET) where the animals are divided into two groups, with one receiving the antibody nanoparticle and the other receiving a reference nanoparticle. However, there is significant mouse-to-mouse variation which means many mice must be scanned to make statistically significant claims about the effect of the antibody. With spectral CT and basis material decomposition one can potentially image the reference and antibody nanoparticles simultaneously in a single mouse. We propose a new type of functional imaging called Immuno-Contrast CT in which the reference nanoparticle distribution is subtracted from the antibody nanoparticle distribution to highlight the differential immuno-functional impact of the antibody. In this work we use physics simulations to jointly optimize contrast agent materials and spectral CT instrumentation for immuno-contrast CT. Our results show this optimization significantly reduces noise in the immuno-contrast images.

D4-2-6: On The Optimal Selection of Energy Thresholds for Quantification of Gold Concentration in Photon-Counting-Based CT

15:10-15:30

Xiaoyu Hu (UT Southwestern Medical Center), Yuncheng Zhong (UT Southwestern Medical Center), Kai Yang (Massachusetts General Hospital) and Xun Jia (Johns Hopkins University)

ABSTRACT Quantitative material decomposition is one of the advantages offered by photon-counting-based dual-energy CT (DECT) or multi-energy CT (MECT). For this task, it is important to determine proper thresholds that separate energy channels to minimize the decomposition error of the material of interest. We developed an analytical expression for the error that considered the projection noise level and mathematical properties of the material decomposition matrix and proposed to use that to determine optimal energy thresholds. Comprehensive simulations were performed to verify this idea in an example problem of quantifying gold concentration. We simulated x-ray projections of a phantom with various inserts containing gold solutions under a 140 kVp x-ray tube voltage, a range of photon counts from 4000 to 128000 per pixel, and enumerated possible energy thresholds. Simulation results showed that the optimal energy channels that minimize the error of the gold image were (30,42] and (42, 140] keV for DECT, and (30,42], (42,62] and (62, 140] keV for MECT with three channels. The optimal thresholds estimated by the proposed method matched the simulation results for both DECT and MECT cases.

D5-1: CT and AI 2 – July 21, 2023 9:00-11:00

***Moderators:** Jing Wang/Grace J. Gang*

Talk order based on the first name of the first author.

D5-1-1: Novel Lung CT Image Synthesis at Full Hounsfield Range with Expert Guided Visual Turing Test

9:00-9:20

Arjun Krishna (Stony Brook University), Shanmukha Yenneti (Stony Brook University), Ge Wang (Rensselaer Polytechnic Institute) and Klaus Mueller (Stony Brook University)

ABSTRACT Conventional image quality metrics are unsuitable to evaluate the realism and medical accuracy of synthetically generated CT images. We describe an approach based on the concept of Visual Turing Test that engages medical professionals to assess the generated images and provide useful feedback that can inform the generative process. We first describe our approach for synthesizing large numbers of novel and diverse CT images across the full Hounsfield range using a very small annotated dataset of around thirty patients and a large non-annotated dataset with high resolution medical images. Using an anatomy exploration interface we can generate CT images with anatomies that were non-existent within either of the datasets, without compromising accuracy and quality. Our approach works for all Hounsfield windows with minimal depreciation in anatomical plausibility. We then describe our Visual Turing Test methodology in detail and show results we have obtained.

D5-1-2: Deep-Projection-Extraction Based Reconstruction for Interior Tomography

9:20-9:40

Changyu Chen (Department of Engineering Physics, Tsinghua University), Li Zhang (Department of Engineering Physics, Tsinghua University), Yuxiang Xing (Department of Engineering Physics, Tsinghua University) and Zhiqiang Chen (Department of Engineering Physics, Tsinghua University)

ABSTRACT Interior tomography is a typical strategy for radiation dose reduction in computed tomography (CT), where only a certain region-of-interest (ROI) is scanned. However, given the truncated projection data, ROI reconstruction by conventional analytical algorithms may suffer from severe cupping artifacts. In this paper, we proposed a new Deep-Projection-Extraction based Reconstruction (DPER) for interior tomography. DPER works in dual domains where a sinogram-domain network (SDNet) estimates the contribution of the exterior region to the truncated projection and an image-domain network (IDNet) further mitigates artifacts. Unlike extrapolation-based methods, SDNet is intended to obtain a complete ROI-only sinogram via extraction instead of a fully non-truncated sinogram for both the ROI and exterior regions. We validated DPER with simulation on low-dose CT data. Results indicate that DPER can disclose more reliable structures, and achieve better image quality with better generalization performance than extrapolation-based methods.

D5-1-3: When iRadonMAP Meets Federated Learning: Partially Parameter-sharing Strategy for Robust Low-dose CT Image Reconstruction Across Scanners 9:40-10:00

Shixuan Chen (Southern Medical University), Yinda Du (Southern Medical University), Boxuan Cao (Southern Medical University), Ji He (Guangzhou Medical University), Yaoduo Zhang (Guangzhou Medical University), Zhaoying Bian (Southern Medical University), Dong Zeng (Southern Medical University) and Jianhua Ma (Southern Medical University)

ABSTRACT Image reconstruction from low-dose measurements has been playing an important role in low-dose CT imaging. Deep learning models have been shown to be successful in low-dose CT reconstruction over traditional methods. Recently, a reconstruction framework for Radon inversion with deep learning (i.e., iRadonMAP) is developed to transfer low-dose measurement into CT images directly and efficiently. The iRadonMAP implements the theoretical inverse Radon inversion alongside the image transformation between sinogram and image domais in a network. However, the iRadonMAP is sensitive to protocol-specific perturbations, i.e., geometric model, mAs settings and kVp settings, and it fails to reconstruct the high-fidelity CT images from low-dose measurements across different scanners simultaneously. This might reduce the iRadonMAP generalization. In this work, to address this issue, we constructed a federated learning (FL) framework with iRadonMAP embedded to produce high-quality CT images across different scanners. For simplicity, the proposed framework is denoted as FL-iRadonMAP, i.e., federated learning with iRadonMAP. Specifically, in the FL framework, all clients have normal-dose images/corresponding low-dose sinograms pairs from different scanners to train the iRadonMAP in each local model. Different from traditional FL, the server has a large amount of labeled data, i.e., normal dose/corresponding low-dose CT image pairs, and the labeled data are used to train the global model that enforces the local client to learn different protocol perturbations in each local model. In each client, only the parameters in the image domain of the iRadonMAP are collected and aggregated to the server to obtain global model. We evaluate the presented FL-iRadonMAP on four different CT datasets, and the experimental results confirm that the proposed FL-iRadonMAP has significantly improved performance, preserving the detail texture and suppressing noise-induced artifacts in the CT images across scanners.

D5-1-4: Improved CT Image Resolution Using Deep Learning with Non-Standard Reconstruction Kernels and CatSim Training Data 10:00-10:20

Somesh Srivastava (GE Research – Healthcare, Bangalore), Mengzhou Li (Department of Biomedical Engineering, Rensselaer Polytechnic Institute, Troy, NY), Lin Fu (GE Research – Healthcare, Niskayuna, NY), Ge Wang (Department of Biomedical Engineering, Rensselaer Polytechnic Institute, Troy, NY) and Bruno De Man (GE Research – Healthcare, Niskayuna, NY)

ABSTRACT Deep-learning (DL) super-resolution methods have recently shown encouraging results in improving the clarity of fine anatomical details in CT images. In this work, we explore the feasibility of using images generated with a high-frequency reconstruction kernel as the input to a DL network to boost the resolution capability of CT. Specifically, we use an "edge kernel", which is not routinely used to reconstruct clinical CT images due to its high level of noise and artifacts, but its higher-resolution image details may be exploited by a DL network. Then, we introduce the SRCAN2 network that takes both Edge and Bone kernel images as inputs to improve the super-resolution capability of DL. Also, we introduce a numerical method for generating super-resolution training data using the CatSim simulation environment. The results show that the proposed DL super-resolution method substantially improves the visual sharpness of CT images relative to the inputs. The modulation transfer function 10% threshold frequency can be increased by up to 56%. We further applied non-linear image quality metrics to characterize the contrast- and anatomy-dependent behavior of the DL network and obtained promising results.

D5-1-5: Convolutional Sparse Coding and Dictionary Learning for Improving X-Ray Computed Tomography Image Quality

10:20-10:40

Victor Bussy (Paris-Saclay University, CEA, LIST), Caroline Vienne (Paris-Saclay University, CEA, LIST), Julie Escoda (Paris-Saclay University, CEA, LIST) and Valérie Kaftandjian (Laboratory of Vibrations and Acoustics, INSA-Lyon, Villeurbanne)

ABSTRACT This paper evaluates the potential of convolutional sparse coding (CSC) for reducing artefacts in 3DCT images in the case of sparse acquisition configuration. The proposed CSC method is tested on additive-manufactured metallic samples, which present unique challenges for denoising applications due to the fine structure of the material. Results indicate that CSC outperforms traditional dictionaries in denoising performance and computation speed, making it a promising method for large-scale tomographic imaging applications.

D5-1-6: A Deep Learning Approach to Estimate and Compensate Motion in Non-contrast Head CT Scan

10:40-11:00

Zhennong Chen (Massachusetts General Hospital and Harvard Medical School), Quanzheng Li (Massachusetts General Hospital and Harvard Medical School) and Dufan Wu (Massachusetts General Hospital and Harvard Medical School)

ABSTRACT Patient's head motion is a major source of image artifacts in the head CT. The motion artifacts can be compensated by accurate motion estimation and compensation during the image reconstruction. Partial angle reconstruction (PAR)-based method is well-known for motion estimation in CT. In this study, we propose the first PAR-based deep learning (DL) method to estimate and compensate the motion in the head CT. We designed a DL pipeline to estimate the motion from PARs built by the CT sinogram. In our simulation study with relatively heavy motion, the proposed method achieved good accuracy on the motion parameter estimation, with a mean absolute error (MAE) of 1mm in head translation and 1° in rotation. The MAE of the reconstructed CT images was also reduced from 130 to 54 HU. Simulation results demonstrate that the proposed method has promise to tackle the motion problem in clinical head CT.