Ministry of Science and ICT

IITP Institute of Information & Communications Technology Planning & Evaluation

APPLICATION FORM
(JOINT RESEARCH)
HIGH POTENTIAL INDIVIDUALS GLOBAL TRAINING PROGRAM)

AGREEMENT
As stated above, I submit this application form to IITP that conducts "High Potential Individuals Global Training Program" supported by Ministry of Science, ICT in South Korea. IITP may disclose the information below to the public for the purpose of providing information and matching a research partnership between your institute and a Korean university. * IITP : Institute for Information & communications Technology Planning & Evaluation

Printed Name of Chief of Research	Dong Hye Ye	Date(mm-dd-yyyy)	01-30-2020
Signature of Chief of Research	[signature]		

☞ ***(Note)*** *This application is to identify the willingness to participate in this research and to find a research partnership for research institutes in Korea. Therefore, in its sole discretion, it is acceptable to contain only minimal information. (max. 3 pages)*

1. Research Title	Deep Learning for CT Metal Artifact Reduction and Segmentation						
2. Research Area	**A.I.**	**Big Data**	**Cloud Computing**	**Block Chain**	**AR/ VR**	**ICT/SW Convergence**	**Other ICT /SW**
	X						
3. Chief of research	Title	Assistant Professor	Contact	E-mail: donghye.ye@marquette.edu			
	Name	Dong Hye Ye		Tel: +1-414-288-4114			
4. Affiliation	Name	Marquette University	Classification	(X) University ( ) Research Institute ( ) Industry ( ) ETC.			
5. Capacity for students (5 or less)	2	**Support for students (*all necessary*)**	(X) Visa support (X) Research Mentoring (X) Research Space (X) Accessibility to Research equipment				

6. Research Objective	- Developing a Computed Tomography (CT) Metal Artifact Reduction (MAR) and Segmentation methods using the deep neural networks
7. Research Summary	Non-invasive imaging technology allows images of the internal structures of a patient to be obtained without performing an invasive procedure on the patient. CT scanning is widely used in non-invasive imaging due to its reliability, efficiency, and image quality. Such CT systems rely on various physical principles (such as the line-integral of X-ray projection through the target volume) to acquire data and to represent the observed internal features of the patient. CT scan can suffer from beam hardening effects. In medical imaging, water-based beam hardening corrections are usually performed as data preprocessing, based on the high concentration of water-like materials (e.g., soft tissues) in human body. However, in the presence of high-density materials from dental filling, and joint replacements, water-based corrections become insufficient, degrading the diagnostic quality. High-density materials such as metal are usually composed of elements with high atomic numbers, which attenuate low-energy X-ray photons at much higher rates, leading to more severe beam hardening effects found in water. Scattering noise is also more prominent with dense materials, collectively causing metal artifacts. Metal artifact reduction (MAR) algorithms have been developed to meet the challenge. A common assumption is that projections from rays passing through metal are heavily corrupted, and image reconstruction would be improved by synthetic replacement data. However synthetic replacement data can cause secondary blurring in non-metal image, sacrificing image resolution. Alternatively, material decomposition inspired methods were proposed to reduce metal artifacts. These methods approximate sinogram biases with polynomials of two basis materials as data pretreatment. However, they are usually limited by the degrees of freedom when it comes to existence of multiple materials. Image-domain artifact correction, developed by GE Healthcare with the PI (Dr. Dong Hye Ye), has shown promise in MAR by incorporating estimation / segmentation for material classification from CT. In this method, MAR and segmentation can be done in a unified optimization framework by simultaneously estimating image segmentation and low-order polynomial coefficients in data projection for metal artifact reduction. However, this method is not data-driven and therefore may not achieve consistency across varied reconstruction applications. An intelligent observer, with enough experience in comparing the image produced with and without metal artifacts, may be able to predict the latter image form the former. Thorough knowledge of noise characteristics of beam hardening effects and of anatomical features of human tissue may permit this expert, with virtual eraser and pencil, to correct the deficiencies from metal artifacts. The transformation accomplished by this expert will be very difficult to describe analytically because there may never have been an equation involved. Experts have learned the relationship through observation of large numbers of images of both types and have incorporated this information into their intelligence. Machine learning has reached a level of maturity at which it may provide automated solution to this problem. Particularly, deep convolutional neural networks (CNN) are being studied and applied widely in many computer vision tasks and have shown great potential to adapt to CT de-noising problem. For example, the PI de-noises a CT image using a CNN trained on noisy and clean 3D image patches. The key aspect in this method is deep learning of the difference between a conventional CT reconstruction and a higher quality version.

	In this proposal, we employ deep learning to generate a target reconstruction without metal artifacts from beam-hardening corrupted tomographic scan data. The deep convolutional neural network is trained specifically from sinogram/image pairs with and without metal presence. For instance, a CNN is trained from sinogram with and without metal insertion of the same subject to generate a function that removes the metal artifact in the CT image. The trained network is then applied to any sinogram/image to produce an MAR image with higher image quality in terms of texture. Besides MAR, we will also develop deep-learning U-Net based segmentation and integrate it into joint MAR/segmentation optimization framework toward the synergistic effects. Developing deep learning-based CT MAR/segmentation methods may have multiple primary benefits. First, the proposed approach may naturally address the deficiency of long computation time in MAR/segmentation, producing in milliseconds results on multi-GPU hardware. Second, this type of processing may provide advantages over the pure sinogram-domain processing, such as producing more consistent and pleasing imaging textures to radiologist or avoiding artifacts. Third, with improved image quality, our CT system will become clinically more valuable with reduced radiation dosage and better CT imaging risk/benefit trade-off.
8. Need for funding from Korean government	The market for CT systems is rapidly growing driven by the needs for non-invasive diagnostic image, being forecast to reach $12 billion in 2023. A few non-Korean vendors such as GE Healthcare dominate the market for CT systems. Therefore, developing CT systems by Korean institute can significantly save royalty paid to non-Korean vendors for CT system. Recent R&D trend in developing CT system is to incorporate the knowledge in large database into CT image processing to improve the performance. Thanks to advance in deep learning (e.g., deep neural network), it is easier to build non-linear statistical models from sample datasets for the purposes of data-driven predictions. The CT metal artifact reduction (MAR) / Segmentation algorithms with deep learning can provide desired image quality characteristics that are typically obtained using a computationally intensive algorithm with substantially reduced computational requirements or overhead. This can lead to improved patient care in the diagnostic imaging. The PI has been collaborating with GE Healthcare for developing CT MAR / Segmentation algorithms with deep learning. The PI received the best paper award runner-up in ICIP 2015 by developing joint approach for CT MAR / Segmentation and the extended works were published in various premier journals such as IEEE TMI and TCI. Global cooperative R&D with Korean expert in deep learning for medical imaging can facilitate the development of deep learning-based CT MAR / Segmentation algorithm. For example, Dr. Sang Hyun Park's group in DGIST (our potential Korean collaborator) has been a pioneer in deep learning for brain MRI segmentation, winning a prestigious MICCAI BRATS Challenge in 2018. There will be a synergistic effect in this joint Korea-US research project with large CT projection/image database provided by GE Healthcare.
9. Request for Korean Universities	- Korean university will send graduate students whose research interest lies in deep learning and medical image processing. The selection of students studying abroad should be conducted after mutual consultation. Korean university will cooperate as much as possible to prepare for VISA.