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	Duckbong Kim	Date(mm-dd-yyyy)	01-28-2020
Signature of Chief of Research	Duckbong Kim		

☞ *(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	Development of real-time control algorithm based on reinforcement learning for a metal additive manufacturing process using multi-modal process signature measurements						
2. Research Area	**A.I.**	**Big Data**	**Cloud Computing**	**Block Chain**	**AR/ VR**	**ICT/SW Convergence**	**Other ICT /SW**
	X	X					
3. Chief of research	Title	Assistant Professor		Contact	E-mail : dkim@tntech.edu		
	Name	Duckbong Kim			Tel : +1-931-372-3327		
4. Affiliation	Name	Tennessee Technological University		Classification	(X) University ( ) Research Institute ( ) Industry ( ) ETC.		
5. Capacity for students (5 or less)	3 or 4		**Support for students** ***(all necessary)***		(X) Visa support (X) Research Mentoring (X) Research Space (X) Accessibility to Research equipment		

6. Research Objective	The research goal is to develop the real-time control algorithm based on reinforcement learning for a metal additive manufacturing process using multi-modal process signature measurements.
7. Research Summary	A reinforcement learning, one of machine learning techniques, looks promising as a feasible solution for reducing and fixing the unwanted defects after training a set of metal additive manufacturing (AM) process parameters (e.g., power, moving speed, and layer thickness) for the real-time optimal control. The area where the arc energy source in a metal AM process interacts with metal wire is called the "weld-pool" and "heat-affected zone (HAZ)." It is a complex physical phenomenon, since it is related to physical properties in the arc energy source (e.g., power, mode, and wavelength) and wire material (e.g., thermal conductivity, emissivity, and diameter). The characterization of the melt-pool features (e.g., maximum temperature, size, length, and depth) is very important for validating the integrity of the melt-pool and layer, detecting defects (e.g., balls, cracks), controlling the process, and analyzing part properties (e.g., microstructure analysis and tensile strength) for process verification and part validation (quality assurance). The features of the melt-pool and the bead (e.g., regularity and crack) will be analyzed for performing the model-based reinforcement learning for real-time optimal control. In metal AM, robust in-situ monitoring and control systems are desired to detect part imperfections and reduce the uncertainty of part performance. Recent advances in AM offer the ability to minimize undesired defects such as a balling, porosity, cracking and other anomalies. However, research efforts on real-time monitoring and control of a metal AM is significantly lacking due to the difficulties in acquisition of technically meaningful data and lack of knowledge in a metal AM process/materials. In this project, real-time control algorithms for a metal 3D printing will be developed. The steps are as follows: (1) with respect to the different manufacturing conditions (e.g., single bead, inclined-wall, and multi-bead/multi-layer blocks), a huge amount of thermometrically calibrated image stacks as well as process signatures (i.e., current, voltage, and feed rate) are generated from the metal AM process using a computer vision system as well as real time measurement system; (2) melt-pool features, such as maximum temperature, length, size, and depth, are extracted and analyzed at each frame from the thermometrically calibrated image stacks; (3) reinforcement learning models will be developed by enabling an agent to learn in a WAAM process using trial and error feedback (e.g., anomaly and normal beads); and (4) a multi-objective decision support algorithm for the real-time control will be established.
8. Need for funding from Korean government	Through the mutual exchange of research between Tennessee Technology University (TTU) and Korean university, the main objective of this program is to provide Korean university researchers (i.e., graduate students) with research opportunities, allowing insight into the practical applications of their education and research and bridging the gap among government, academia, and industry to aid in the development of a diverse, globally competitive science, technology, engineering, and

	math (STEM) workforce. The research focus will be on big data-driven machine learning techniques focusing on technology-intensive manufacturing (e.g., smart manufacturing, additive manufacturing, and data analytics). In addition, this program will lead activities that contribute to professional growth and development in STEM areas. Ultimately, the proposed program is expected to contribute to future innovation in data science and advanced manufacturing, such as smart manufacturing, and provide the foundation for increasing industrial competitiveness and its economic success. The PI has multidisciplinary research experience in advanced design and manufacturing, including metal AM, smart manufacturing, digital thread for AM, data analytics for AM, and development and calibration of high dynamics range imaging (HDRI)- and bidirectional reflectance distribution function (BRDF)-based machine vision systems. Before joining Tennessee Technological University (TTU), the PI was involved in four projects at National Institute of Standards and Technology (NIST) from Oct. 2011 to Jul. 2016: (1) Testbed Development for Sustainable Manufacturing, (2) Sustainable Modeling and Optimization, (3) Systems Integration for Additive Manufacturing, and (4) Modeling Methodology for Smart Manufacturing. Based on the PI's extensive educational and research experience in advanced manufacturing as well as data science, his goal is to develop a new initiative for workforce development, focusing on technology-intensive manufacturing processes by benchmarking the NIST smart manufacturing and AM programs. This will familiarize the Korean students with the emerging technology-intensive manufacturing and data science disciplines and help prepare a future workforce equipped with new skills and knowledge. The philosophy and methods employed will significantly promote self-thinking and team-working abilities and encourage the students to pursue careers in artificial intelligence-based on big data as well as the advanced manufacturing process (e.g., metal AM).
9. Request for Korean Universities	I will cooperate with Korean universities as much as possible to prepare for the J-1 visa and accommodate the exchanging research students in my laboratory for the successful completion of this research. For this big data management and machine learning implementation, the research team will utilize the TTU high performance computing (HPC) hardware and software (see Facilities, Equipment, and Other Resources). The hardware consists of 40 CPU compute nodes, each with 28 CPU cores (Intel Xeon E5-2680v4, 2.4 GHz) and 4 GPU compute nodes, each with 28 CPU cores (Intel Xeon E5-2680v4, 2.4 GHz). A machine learning framework, such as TensorFlow with Keras, will be utilized.