Seungmin Lee

Research Prof.
School of Electronics Engineering
Kyungpook National University
80, Daehak-ro
Buk-gu, Daegu 41566
Republic of Korea

Phone: +82-10-4733-7524
Office: No.724, IT 1 building in KNU
Email: lsm1106@knu.ac.kr, lsm871106@gmail.com

Interest

I specialize in the fields of image processing and bio-signal processing. During the early part of my Ph.D. course, I focused on defect detection in TFT-LCD images. Building on this expertise, I extended my research to the detection of abnormal heartbeats in ECG signals. This research encompassed various aspects, including fiducial point detection, feature extraction, and the detection and classification of abnormal heartbeats.

More recently, my research has delved into the field of digital twin technology, where I have effectively utilized my signal processing experience. I am dedicated to replicating the capabilities of high-performance devices within lightweight embedded systems, with the goal of achieving low-power and cost-effective digital twinning. This research seeks to bridge the gap between high-performance digital twins and resource-constrained embedded systems. Currently, I am engaged in a project focused on the digital twinning of particulate matter sensors.

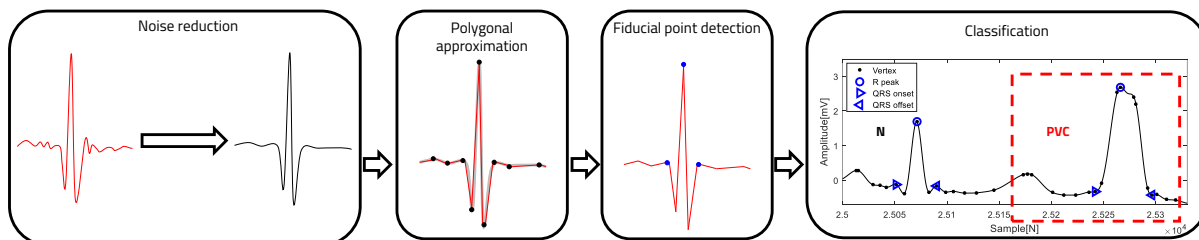## 1. Research on ECG abnormal heartbeat Detection and Classification

Figure 1: Research steps for detecting and classifying abnormal heartbeats in ECG signals

① Noise reduction preprocessing in the frequency domain using FFT[1].

② Optimized linear approximation using dynamic programming[1,2].

② Feature extraction from linear-approximated vertices[3].

③ Fiducial point detection using features from linear-approximated vertices[4,5].

■ Shape-based abnormal beat detection using waveform similarity.

■ Feature-based abnormal beat detection using fiducial point detection.

■ ECG data compression using fiducial points from linear approximation.

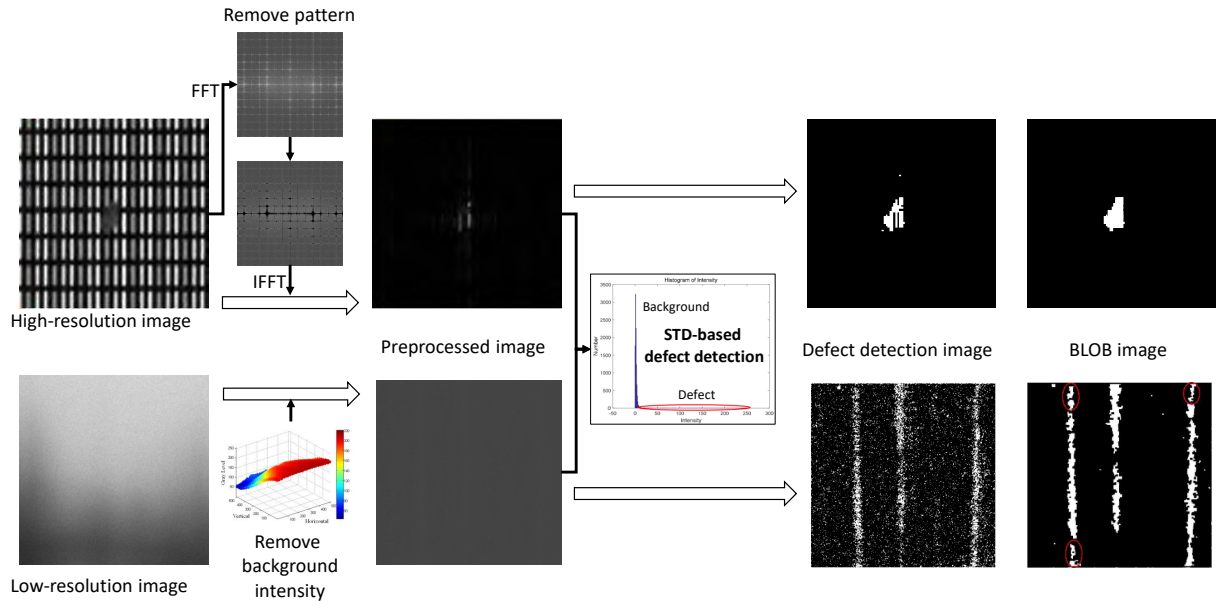## 2. Research on TFT-LCD Defect Detection

Figure 2: Research steps for cell pattern removal using FFT and defect detection using STD in high-resolution TFT-LCD

- TFT-LCD image quality assessment using MATLAB GUI.
- Optical image quality assessment using MATLAB GUI.
- Removing cell patterns in high-resolution TFT-LCD image using FFT.
- Removing uneven background intensity using morphological pair operations.
- Standard deviation(STD) and adaptive STD-based defect detection algorithm.
- Median absolute deviation(MAD) and histogram-based MAD(HMAD)-based defect detection algorithm.
- Binary large object(BLOB) segmentation using morphological pair operations.

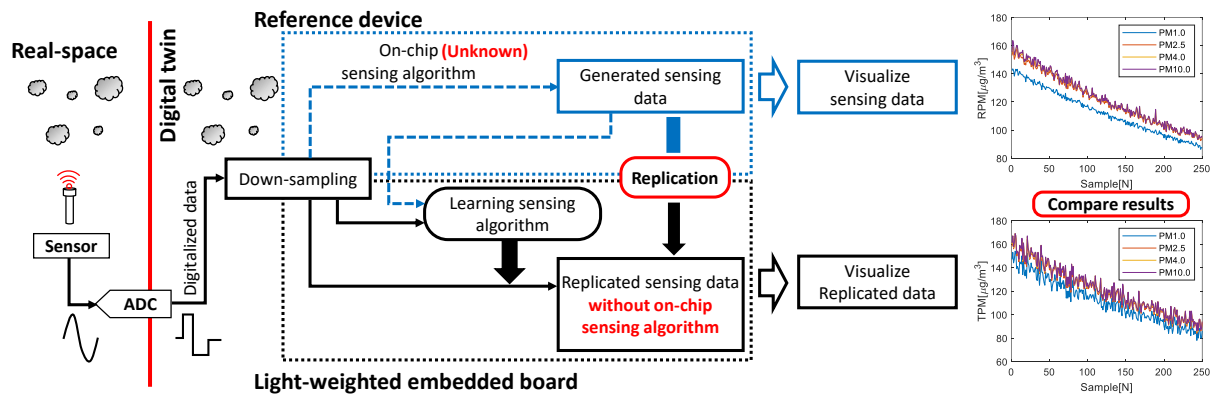## 3. Research on Digital Twinning for Light-weighted Devices

Figure 3: Research for replicating high-performance devices algorithm within light-weighted embedded devices in particulate matter sensing device

■ Determine a data acquisition algorithm from ADC raw data obtained from photodiode sensor to estimate dust concentration.

■ Replicating high-performance sensor algorithm using singular-value-decomposition(SVD).

■ Noise suppression algorithm based on LSTM neural networks.

EDUCATION

KNU(KYUNGPOOK NATIONAL UNIVERSITY)   DAEGU, S.KOREA

PH.D. IN SCHOOL OF ELECTRONICS ENGINEERING   MAR. 2013 - FEB. 2018

   Thesis Title : Knowledge-based arrhythmia classification using linear approximation of ECG signal

   Adviser : Kil Houm Park

   Area of Study : Image Processing, Defect Detection, Bio Signal Analysis, ECG Analysis

KNU(KYUNGPOOK NATIONAL UNIVERSITY)   DAEGU, S.KOREA

M.S. IN MATHEMATICS   MAR. 2010 - FEB. 2012

   Thesis Title : Mean Shift Based on Matrix Means

   Adviser : Yongdo Lim

   Area of Study : Linear Algebra, Numerical Analysis

KNU(KYUNGPOOK NATIONAL UNIVERSITY)   DAEGU, S.KOREA

B.S. IN MATHEMATICS   MAR. 2006 - FEB. 2010

   Area of Study : Linear Algebra, Numerical Analysis

CURRENT POSITIONS

   Research Prof. School of Electronics Engineering, Kyungpook National University, Mar. 2024 - present.

PUBLICATIONS

INTERNATIONAL JOURNAL

Lead-author: 10
Co-author: 2

■ S Lee, J Kwon, D Park, "Optimized Replication of ADC-based Particle Counting Algorithm with Reconfigurable Multi-Variables in Pseudo-Supervised Digital Twining of Reference Dust Sensor Systems," Sensors, vol. 23, no. 12, pp. 5557-5572, 2023.

■ S Lee, J Kwon, D Park, "Runtime Tracking-Based Replication of On-Chip Embedded Software Using Transfer Function Learning for Dust Particle Sensing Systems," IEEE Access, vol. 11, pp. 32167-32175, 2023.

■ S Lee, D Park, "Comparative Neural Network based on Template Cluster for Automated Abnormal Beat Detection in Electrocardiogram Signals," Human-centric Computing and Information Sciences, vol. 12, no. 51, pp. 1-17, 2022.

■ S Lee, D Park, "Abnormal Beat Detection from Unreconstructed Compressed Signals Based on Linear Approximation in ECG Signals Suitable for Embedded IoT Devices," Journal of Ambient Intelligence and Humanized Computing, vol. 13, pp. 4705-4717, 2022.

■ S Lee, D Park, "Adaptive ECG Signal Compression Method Based on Look-Ahead Linear Approximation for Ultra Long-Term Operating of Healthcare IoT Devices," Human-centric Computing and Information Sciences, vol. 11, no. 30, pp. 1-15, 2021.

■ S Lee, D Park, "A Real-Time Abnormal Beat Detection Method Using a Template Cluster for the ECG Diagnosis of IoT Devices," Human-centric Computing and Information Sciences, vol. 11, no. 04, pp. 1-16, 2021.

■ D. Lee, S Lee, S. Oh, D Park, "Energy-Efficient FPGA Accelerator With Fidelity-Controllable Sliding-Region Signal Processing Unit for Abnormal ECG Diagnosis on IoT Edge Devices," IEEE Access, vol. 9, pp. 122789-122800, 2021.

■ S Lee, D Park, "Efficient Template Cluster Generation for Real-Time Abnormal Beat Detection in Lightweight Embedded ECG Acquisition Devices," IEEE Access, vol. 9, pp. 70596-70605, 2021.

■ S Lee, Y Jeong, J Kwak, D Park, KH Park, "Advanced Real-Time Dynamic Programming in the Polygonal Approximation of ECG Signals for a Lightweight Embedded Device," IEEE Access, vol. 7, pp. 162850-162861, 2019.

■ S Lee, Y Jeong, D Park, B-J Yun, KH Park, "Efficient Fiducial Point Detection of ECG QRS Complex Based on Polygonal Approximation," Sensors, vol. 18, no. 12, pp. 1-16, 2018.

■ Y Jeong, S Lee, D Park, KH Park, "Accurate Age Estimation Using Multi-Task Siamese Network-Based Deep Metric Learning for Front Face Images," Symmetry, vol. 10, no. 9, pp. 1-15, 2018.

■ S Lee, D Park, KH Park, "QRS Complex Detection Based on Primitive," Journal of Communications and Networks, vol. 19, no. 5, pp. 442-450, 2017.

DOMESTIC JOURNALS

Lead-author: 12
Co-author: 7

■ S Lee, D Park, "Lightweight Algorithm for Digital Twin based on Diameter Measurement using Singular-Value-Decomposition," IEMEK Journal of Embedded Systems and Applications, vol. 18, no. 3, pp. 117-124, 2023.

■ S Lee, D Park, "Improved Dynamic Programming in Local Linear Approximation Based on a Template in a Lightweight ECG Signal-Processing Edge Device," Journal of Information Processing Systems, vol. 18, no. 1, pp. 97-114, 2022.

■ J Bae, M Kwak, K Noh, D Lee, S Lee, D Park, "Comparative Learning based Deep Learning Algorithm for Abnormal Beat Detection using Imaged Electrocardiogram Signal," Journal of the Korea Institute of Information and Communication Engineering, vol. 26, no. 1, pp. 30-40, 2022.

■ S Lee, KH Park, "Median-based abnormal heartbeat detection using histogram for arrhythmia reading ," Journal of Advanced Marine Engineering and Technology , vol. 45, no. 6, pp. 411-417, 2021.

■ D Lee, S. Lee, D Park, "Adaptive Processing Algorithm Allocation on OpenCL-based FPGA-GPU Hybrid Layer for Energy-Efficient Reconfigurable Acceleration of Abnormal ECG Diagnosis," Journal of the Korea Institute of Information and Communication Engineering, vol. 25, no. 10, pp. 1279-1286, 2021.

■ S Lee, KH Park, D Park, "Communication-Power Overhead Reduction Method Using Template-Based Linear Approximation in Lightweight ECG Measurement Embedded Device," IEMEK Journal of Embedded Systems and Applications, vol. 15, no. 5, pp. 205-214, 2020.

■ C Chang, S Lee, KH Park, "Sequential Defect Region Segmentation according to Defect Possibility in TFT-LCD Image," Journal of Korea Multimedia Society, vol. 23, no. 5, pp. 633-640, 2020.

■ S Lee, KH Park, "Abnormal heartbeat detection based on shape and interval deformation for arrhythmia reading," Journal of the Korean Society of Marine Engineering, vol. 43, no. 9, pp. 761-767, 2019.

■ S Lee, KH Park, "Defect detection according to MAD in TFT-LCD panel image," Journal of Korean Institute of Intelligent Systems, vol. 28, no. 3, pp. 225-230, 2018.

■ S Lee, KH Park, "Defect enhancement algorithm based on saliency map in TFT-LCD cell image," Journal of the Korean Society of Marine Engineering, vol. 41, no. 9, pp. 908-913, 2017.

■ YT Jung, S Lee, KH Park, "Defect detection based on periodic cell pattern elimination in TFT-LCD cell images," Journal of the Korean Society of Marine Engineering, vol. 41, no. 3, pp. 251-257, 2017.

■ J Kim, S Lee, GS Ryu, JH Lee, KH Park, "Hierarchical Authentication Algorithm Using Curvature Based Fiducial Point Extraction of ECG Signals," Journal of the Korea Multimedia Society, vol. 20, no. 3, pp. 465-473, 2017.

■ S Lee, KH Park, "STD Defect Detection Algorithm by Using Cumulative Histogram in TFT-LCD Image," Journal of the Korea Multimedia Society, vol. 19, no. 8, pp. 1288-1296, 2016.

■ JH Kim, S Lee, KH Park, "P-Waves and T-Wave Detection Algorithm in the ECG Signals Using Step-by-Step Baseline Alignment," Journal of the Korea Multimedia Society, vol. 19, no. 6, pp. 1034-1042, 2016.

■ JH Kim, S Lee, KH Park, "Stepwise Detection of the QRS Complex in the ECG Signal," The Journal of Korean Institute of Communications and Information Sciences, vol. 41, no. 2, pp. 244-248, 2016.

■ S Lee, JS Kim, KH Park, "PVC Detection Based on the Distortion of QRS Complex on ECG Signal," The Journal of Korean Institute of Communications and Information Sciences, vol. 40, no. 4, pp. 731-735, 2015.

■ S Lee, C Ryu, KH Park, "Adaptive Detection of Unusual Heartbeat According to R-wave Distortion on ECG Signal," Journal of The Institute of Electronics and Information Engineers, vol. 51, no. 9, pp. 2086-2090, 2014.

■ S Lee, TH Kim, KH Park, "Sequential Defect Detection According to Defect Possibility in TFT-LCD Panel Image," Journal of The Institute of Electronics and Information Engineers, vol. 51, no. 4, pp. 799-803, 2014.

■ CD Jung, S Lee, BJ Yun, JJ Lee, I Choi, KH Park, "TFT-LCD Defect Detection Using Mean Difference Between Local Regions Based on Multi-scale Image Reconstruction," Journal of the Korea Multimedia Society, vol. 15, no. 4, pp. 439-448, 2012.

INTERNATIONAL CONFERENCE

■ S Lee, and D Park, "SVD-based Particulate Matter Estimation using LSTM-based Post-processing for Collaborative Virtual Sensor Systems," In 2023 International Conference on Mobile Computing and Ubiquitous Networking (ICMU), pages 1-2, Kyoto, Japan, Dec. 2023.

■ J Bae, M Kwak, K Noh, D Lee, S Lee, and D Park, "A Study on the Effectiveness of the Comparative Neural Network Model for Abnormal Beat Detection in Electrocardiogram Signals," In 2021 IEEE International Conference on Consumer Electronics-Asia (ICCE-Asia), pages 1-2, Gangwon, Korea, Nov. 2021.

■ S Lee, D Lee, and D Park, "Binary Classification for Linear Approximated ECG Signal in IoT Embedded Edge Device," In 2021 Twelfth International Conference on Ubiquitous and Future Networks (ICUFN), pages 103-105, Jeju Island, Korea, Sep. 2021.

■ D Lee, S Lee, and D Park, "FPGA-based Cloudification of ECG Signal Diagnosis Acceleration," In 2021 Twelfth International Conference on Ubiquitous and Future Networks (ICUFN), pages 236-238, Jeju Island, Korea, Sep. 2021.

■ S Lee and D Park, "Enhanced Dynamic Programming for Polygonal Approximation of ECG Signals," In 2020 IEEE 2nd Global Conference on Life Sciences and Technologies (LifeTech), pages 121-122, Osaka, Japan, Mar. 2020.

■ J Kwak, S Lee, J Cho, and D Park, "Lightweight Polygonal Approximation-Based ECG Signal Pro-

cessing Platform," In 2019 IEEE Intl Conf on Pervasive Intelligence and Computing (PiCom), pages 819-824, Fukuoka, Japan, Aug. 2019.

■ S Lee, Y Jeong, J Kwak, D Park, and KH Park,"Efficient Communication Overhead Reduction Using Polygonal Approximation-Based ECG Signal Compression," In 2019 International Conference on Artificial Intelligence in Information and Communication (ICAIIC), pages 58-61, Okinawa, Japan, Feb 2019.

PROJECT EXPERIENCE

1. RESEARCH ON ECG ABNORMAL HEARTBEAT DETECTION AND CLASSIFICATION
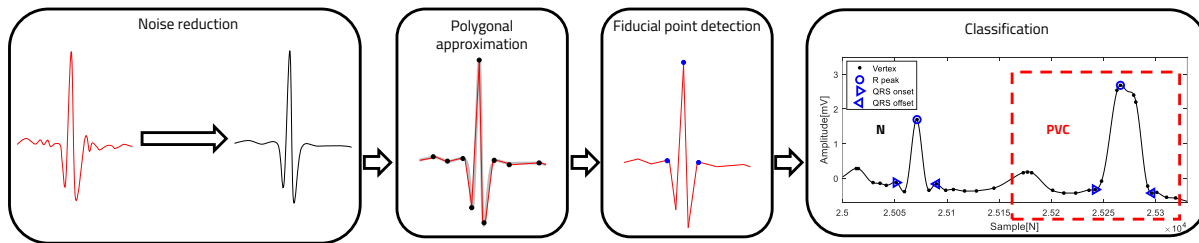
Figure 4: Research steps for detecting and classifying abnormal heartbeats in ECG signals

KOREA EVALUATION INSTITUTE OF INDUSTRIAL TECHNOLOGY(KEIT)   APR.2013-NOV.2014

INSTITUTE FOR INFORMATION & COMMUNICATION TECHNOLOGY PROMOTION(IITP)
DEC.2014-AUG.2016

Position : Researcher

Developed an ECG fiducial point detection algorithm

Developed an effective construction algorithm of feature space based on fiducial point detection results.

Developed an detecting algorithm of abnormal heartbeat

NATIONAL RESEARCH FOUNDATION OF KOREA(NRF)   JUN.2013-MAY.2016

NATIONAL RESEARCH FOUNDATION OF KOREA(NRF)   MAY.2015-APR.2017

Position : Senior researcher

ECG database construction and analysis

Developed an ECG fiducial point detection algorithm

Developed an effective construction algorithm of feature space based on fiducial point detection results.

Developed an classification method of abnormal heartbeat

NATIONAL RESEARCH FOUNDATION OF KOREA(NRF)   SEP.2018-AUG.2020

Position : Principal Investigator

ECG database construction and analysis

Developed an ECG fiducial point detection algorithm

Developed an effective construction algorithm of feature space based on fiducial point detection results.

Developed an classification method of abnormal heartbeat

NATIONAL RESEARCH FOUNDATION OF KOREA(NRF)   JUN.2020-MAY.2023

  Position : Principal Investigator

  ECG database construction and analysis

  Developed an ECG fiducial point detection algorithm

  Developed an effective construction algorithm of feature space based on fiducial point detection results.

  Developed an classification method of abnormal heartbeat

NATIONAL RESEARCH FOUNDATION OF KOREA(NRF)   JUN.2020-FEB.2021

  Position : Senior researcher

  ECG database construction and analysis

  Developed an ECG fiducial point detection algorithm

  Developed an effective construction algorithm of feature space based on fiducial point detection results.

  Developed an classification method of abnormal heartbeat

2. RESEARCH ON TFT-LCD DEFECT DETECTION
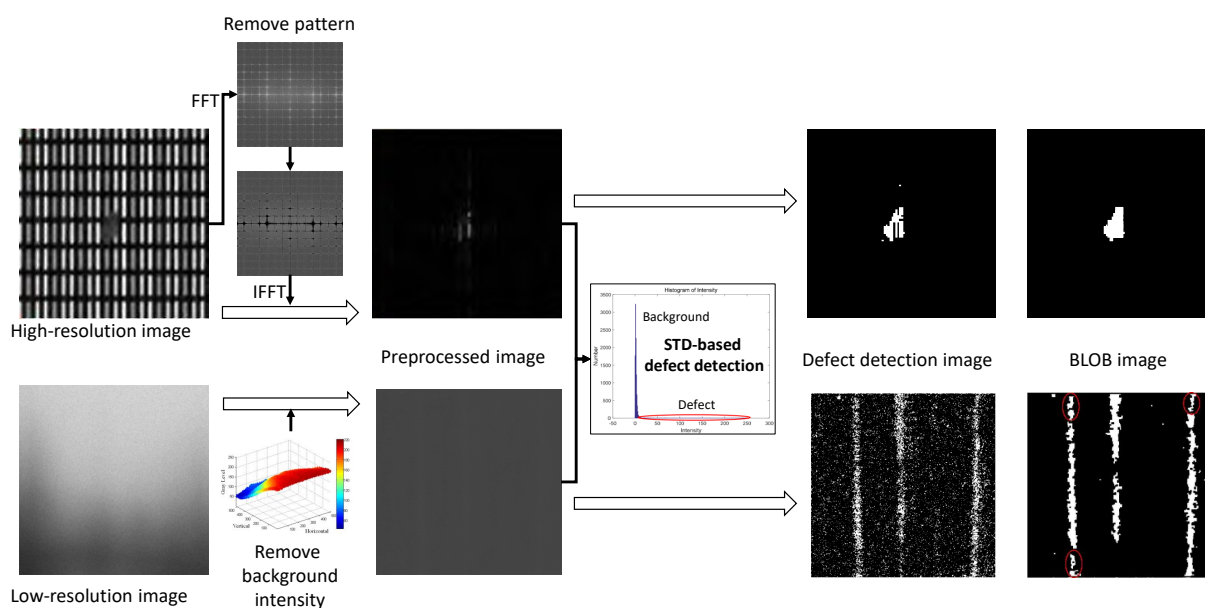
Figure 5: Research steps for cell pattern removal using FFT and defect detection using STD in high-resolution TFT-LCD

LG DISPLAY   JUN.2010-DEC.2011

  Position : Assistant

  Developed an algorithm of feature value extraction

  Developed a GUI for image input and acquire feature value

  Developed a GUI for measurement for image quality assessment

Position : Senior researcher

Developed an cell pattern remove algorthm on high-resolution TFT-LCD image

Developed an background intensity flow remove algorithm on low-resolution TFT-LCD image

Developed an effective method for defect detection on low and high resolution TFT-LCD image

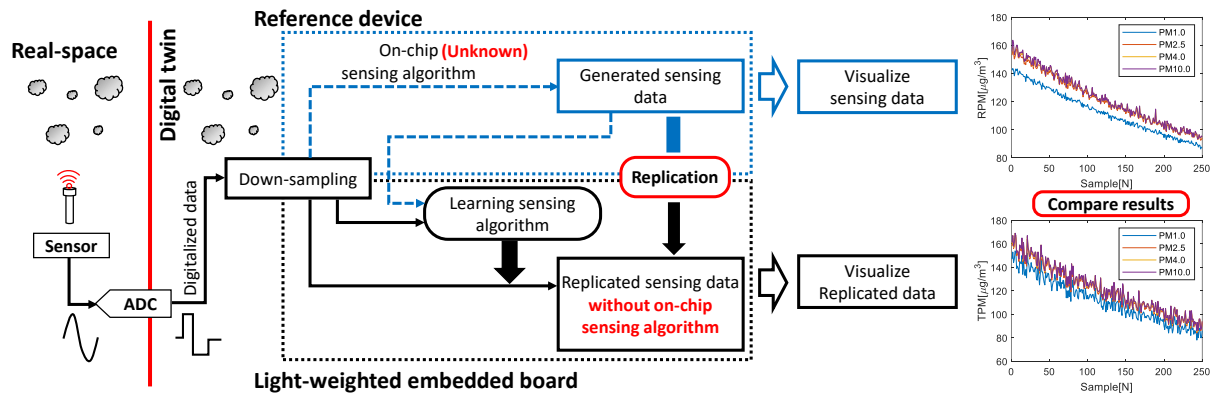3. Research on Digital Twinning for Light-weighted Devices

Figure 6: Research for replicating high-performance devices algorithm within light-weighted devices in particulate matter sensing device

Position : Principal Investigator

Dust sensor device construction and analysis

Developed a dust sensing algorithm which replicates high-performance device's unknown algorithm within light-weighted embedded devices

Developed an effective construction algorithm of noise reduction based on artificial neural network

Research Fund

Title: A Research on the Fiducial Point Detection and Arrhythmia Classification based on Linear Approximation of ECG Signal

- Position : Principle Investigator (PI)
- Period: Jun. 2020-May. 2023
- Budget: KRW 150,000,000
- Teams: 1 Ph.D.

Title: A Research on the Fiducial Point Detection Method based on Linear Approximation for Arrhythmia Classification and Signal Compression of ECG Signal

- Position : Principle Investigator (PI)
- Period: Sep. 2018-Aug. 2020
- Budget: KRW 90,000,000
- Teams: 1 Ph.D.

Skills

MATLAB

References

Daejin Park   Professor

School of Electronics Engineering

Kyungpook National University

(82) 10-7529-1231, boltanut@knu.ac.kr

Kil-Houm Park   Professor

School of Electronics Engineering

Kyungpook National University

(82) 10-3555-7403, khpark@ee.knu.ac.kr