**Advanced Machine Learning Algorithms for Signal and Image Processing**

Data Science and AI research comprises all stages from data acquisition and data management to machine learning and data analysis algorithm development to data analytics and data-driven applications. In the era of digitalization and big data, this research is fundamental for developing data-driven methods and efficient and innovative solutions to problems across all engineering disciplines. One important focus area is the development of efficient machine learning and deep learning technologies for real-world signal processing in embedded systems. Further application areas include biomedical signal analysis, patient-specific diagnostics in healthcare, predictive maintenance, structural health monitoring, remote sensing, smart cities, autonomous robots with enhanced control and adaptability, autonomous driving, and computer vision applications.

**Recent Research:**

Current and future research prospects include devising new core machine learning paradigms and applications to develop autonomous, real-time, and intelligent solutions processing biomedical, remote sensing, and electrical data from sensors. Recent application domains include real-world problems such as near real-time analysis of remote sensing imagery, personalized and advanced warning systems for healthcare, patient-specific biomedical signal processing and analysis, biomedical and audio signal restoration, and early fault diagnosis and domain adaptation for predictive maintenance. Developed tools and technologies based on data science and AI in these fields enhance the efficient use of resources, optimal running of processes, better prediction of adverse events, and adaptability to changes, which are critical in improving the sustainability and resilience of systems.

Examples of recent and /or ongoing research include:

- T Ince, S Beninati, O Devecioglu, S Frasier, M Gabbouj (2024). Water Region Segmentation in SAR Images Based on Compact Operational UNets. IGARSS 2024 Proceedings, 9295-9299.
- Blind Restoration of Real-World Audio by 1D Progressive Operational GANs (T Ince, O Devecioglu, S Kiranyaz, and M Gabbouj), arXiv preprint arXiv:2212.14618, 2022.
- S Kiranyaz, J Malik, M Yamac, M Duman, I Adalioglu, E Guldogan, T Ince, M Gabbouj (2023). Super Neurons. IEEE Transactions on Emerging Topics in Computational Intelligence. doi:10.1109/TETCI.2023.3314658.
- Robust Peak Detection for Holter ECGs by Self-Organized Operational Neural Networks (M Gabbouj, S Kiranyaz, T Ince, J Malik, MU Zahid, M Chowdhury, A Khandakar, A Tahir), IEEE Transactions on Neural Networks and Learning Systems, TNNLS-2021-P-16170, doi: 10.1109/TNNLS.2022.3158867, 2022.
- Self-organized Operational Neural Networks with Generative Neurons (S Kiranyaz, J Malik, HB Abdallah, T Ince, A Iosifidis, M Gabbouj), Neural Networks, 140:294-308, doi: 10.1016/j.neunet.2021.02.028, 2021.
- Operational Neural Networks (S Kiranyaz, T Ince, A Iosifidis, M Gabbouj), Neural Computing and Applications, 32, 6645–6668, 2020.
- Personalized Monitoring and Advance Warning System for Cardiac Arrhythmias (S Kiranyaz, T Ince, M Gabbouj), Scientific Reports - Nature, 7, doi: 10.1038/s41598-017-09544-z, 2017.

- Real-Time Motor Fault Detection by 1D Convolutional Neural Networks (T Ince, S Kiranyaz, L Eren, M Askar, M Gabbouj), IEEE Transactions on Industrial Electronics, 63(11), 7067 – 7075, 2016.
- A Generic and Robust System for Automated Patient-specific Classification of Electrocardiogram Signals (T Ince, S Kiranyaz, M Gabbouj), IEEE Transactions on Biomedical Engineering 56(5), 1415-1426, 2009.
- Method and apparatus for performing motor-fault detection via convolutional neural networks, US Patent 10,586,153, June 2016.
- Personalized ECG monitoring for early detection of cardiac abnormalities, US Patent 10,856,763, March 2017.
- Operational Neural Networks and Self-Organized Operational Neural Networks with Generative Neurons, U.S. Patent App. No: 17/566,281, Dec. 2021.
- Generalized Operational Perceptrons: New Generation Artificial Neural Networks, US Patent 12,033,071, 2024.

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