FUSION_EN.md - Grip

Intelligent Multisensory Data Fusion at the Edge

Course in German/English

Semester hours per week:	4
Credit Points:	5 ECTS
Pre-requisites:	Differential equations, signal processing, machine learning, embedded programming
Event Type:	Lecture with Exercises/Lab
Semester rotation:	Winter semester and summer semester
Workload:	150h, of which: 65h attendance, 85h post-processing of the course material and exam preparation
Contribution to the goals of the course:	Data fusion is a fundamental process in many scientific and technical applications. It is defined as a multi-step process that focuses on the association, correlation, and combination of data and information from different sources. The goal is to gain higher accuracy and better knowledge than would be possible using a single sensor alone. In this course, we analyze and discuss multisensor fusion techniques, architectures, and functional aspects of data association, correlation, and combination. A strong focus of the lecture is the practical implementation of such algorithms on resource constrained devices (running at the edge). The theoretical background will be supported by practical examples and applications following the online EdgeImpulse curricula.
Learning Objective:	To learn the motivation and benefits of sensor fusion, data reliability, data correlation, and finally data combination in various scenarios. The whole spectrum of approaches from signal processing to neural networks will be described comparatively and supported by practical implementations using EdgeImpulse platform. Some tips and tricks for the practical use of the algorithms for data fusion are given (e.g. data fusion for anomaly detection, object identification etc.).
Key Qualifications:	The implementation (mathematical description and programming) of data fusion algorithms (classical and machine learning-based) for 1-dimensional data (time series) and also higher dimensional data (image data) in concrete detection, classification, prediction scenarios. The evaluation of data fusion algorithms in the world of edge devices.
Lectures:	In the lecture, step-by-step (complex) algorithms for data fusion in both low and high dimensions are presented, spanning from traditional signal processing towards machine learning and deep learning algorithms. The algorithms are described mathematically and implemented practically in software using the EdgeImpulse Studio and Arduino-based embedded platforms. **Part 1: Data Fusion Classification, Functionality, Architectures** • Monomodal and Multimodal Data Fusion • Centralized and Decentralized Data Fusion • Signal Level Data Fusion (Anomaly detection) • Feature Level Data Fusion (Object detection) • Decision Level Data Fusion (Object classification) • Local and Global Data Fusion (Edge versus cloud data fusion) **Part 2: Common methods and state of the art** • Signal processing methods for data fusion (Signal processing, Kalman Filters, Complementary filters) • Learning data fusion systems (Bayesian fusion, Spiking Neural Networks, Deep Learning)

Laboratory work:	• Kalman Filters and Basic Digital Signal Processing • Clustering, feature engineering • Convolutional Neural Networks • Early, intermediate and late fusion using Deep Neural Networks • Spiking Neural Networks
Literature:	• Hall, David Lee, and Sonya AH McMullen. Mathematical techniques in multisensor data fusion. Artech House, 2004. • Hymel S, Banbury C, Situnayake D, Elium A, Ward C, Kelcey M, Baaijens M, Majchrzycki M, Plunkett J, Tischler D, Grande A. Edge Impulse: An MLOps Platform for Tiny Machine Learning. arXiv preprint arXiv:2212.03332. 2022 Nov 2. • EdgeImpulse Courseware - https://github.com/edgeimpulse/courseware-embedded-machine-learning • Mitchell, Harvey B. Multi-sensor data fusion: an introduction. Springer Science & Business Media, 2007. • Liggins II, Martin, David Hall, and James Llinas, eds. Handbook of multisensor data fusion: theory and practice. CRC press, 2017.
Remarks:	Students in this course will learn how to select mathematical tools and algorithms appropriate for the data fusion to be solved, implement (program) algorithms on embedded edge devices, and evaluate fusion performance of the various algorithms.
Performance Record:	Practical software (team) project and final 10-minute presentation.
Module responsible::	Prof. Dr. Ing. Cristian Axenie