Institute of Medical Informatics, Biometry, and Epidemiology

Chair of Digital Health

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Research focus

- Wearable health systems
- Context recognition
- Digital Biomarker estimation
- Digital Twins of humans and systems

Structure of the Chair

Professorship: 1
Personnel: 11

- Scientists: 9 (thereof funded externally: 6)
- Graduate students: 5

Research

The Chair of Digital Health is pursuing research on sensor-based embedded medical systems, including wearables and implants. Research is done on machine learning algorithms to estimate Digital Biomarkers and decision support systems related to patient behavior, physiology, and exposure in out-of-lab settings. Work focuses on algorithms for context awareness and knowledge mining from clinical, multimodal data to support diagnosis and treatment. The algorithm bandwidth stretches from time series analysis to dynamically adaptive pattern modeling. A further strand of research addresses novel digital design methods and procedures to implement wearable and implantable sensor and actuator systems, employing digital co-simulation of digital human twins and system twins, 3D printing, and multi-process additive manufacturing methods. In collaborative projects with various medical and industry partners, novel algorithms, models, and technology are getting validated.

Wearable medical systems

Mobile and wearable systems provide access to health-related patient behavior and exposure information, thus support medical professionals and patients in diagnosis and treatment. The Chair investigates the potential of new wearable and implantable systems that provide specific and reliable health, behavior, and exposure data. Among the wearable device developments are 3D-printed regular-look smart eyeglasses with frame-integrated electronics and sensors to continuously acquire physiological data (e.g. heart beat via in-frame optical sensors), behavior (e.g. meal timing via in-frame acoustic sensors), and exposure (e.g. ambient light via optical sensors). Another development of the Chair is the GastroDigitalShirt that is being investigated in a clinical study for acoustic monitoring of the intestinal tract. With its continuous, long-term monitoring of the abdomen and algorithms to interpret the acoustic signal patterns, the diagnosis of inflammatory bowel diseases will be supported.

GastroDigitalShirt system with embedded microphone array and computing device won the 2019 DGVS Innovation Award "Digital Gastroenterology". The system is being evaluated in a clinical study at UK Erlangen (Baronetto et al., 2020).

Context recognition

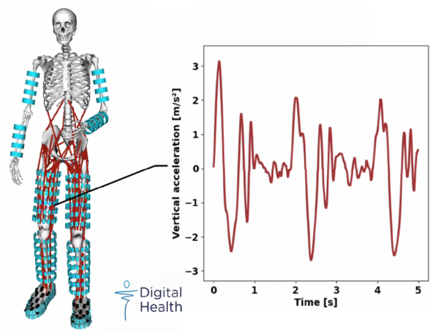
The Chair develops and evaluates new algorithms to analyze large, multi-modal continuous time series from mobile and wearable sensor systems. Research activities include pattern spotting of rare known patterns and mining of new relationship/association rules among events in data. Recent investigations combined context information and compressive sensing techniques to create a dynamically adaptive pattern recognition system for resource-constrained embedded systems, in particular wearables and implants. Investigations on the new context-adaptive sensing approach yielded energy savings of more than 50% compared to state-of-the-art non-adaptive systems and still improve significantly over sub-Nyquist sampling methods. The results are vial for future medical systems, as size and continuous runtime are directly related to the required energy storage.
The Chair is furthermore investigates dynamic design space exploration methods that include runtime-adaptive algorithms, where static approximations do not yield tight bounds. Instead, our system simulations include complexity estimation and sensor data to estimate the performance loss in under-powered systems.

Digital Biomarker estimation

Digital Biomarkers often combine different pattern analysis algorithms to estimate clinical relevant parameters in unsupervised, free-living conditions, thus supporting decision making by patients and/or medical professionals. The Chair develops methods for estimating new Digital Biomarkers and procedures to derive known ones with mobile and wearable systems, in collaboration with clinical partners. For example, from body-worn motion sensor data, we developed a novel biomarker to analyze the convergence prognosis between affected and less-affected body sides in hemiparesis patients, called Convergence Point (CP). In addition, a range-of-motion marker was developed in collaboration with therapists, based on quantifying upper extremity postures assumed over measurement days, called Cubic Quantizer. Currently, various smartphone app projects explore platform-independent designs in connections with a new course "Digital Health" and seminar "Digital Health App Design", which have been well-received by students in computer science and medical engineering.

Co-simulate digital human twins

The Chair's research on digital human twins has intensified in topology modeling and dynamic body motion analysis. A particular interest is to co-simulate digital health twins with technical twins of medical systems, to maximize insight and system design optimization before physical prototyping and testing. For example, gait motion twins of athletes and patients with a hemiparesis, e.g. after stroke, were co-simulated with wearable inertial sensor systems to evaluate sensor position and Digital Biomarker estimation performance, e.g. stride duration and step count. The investigation is a first step towards exploiting the potential of digital twin and co-simulation. Further projects on digital human twins are under preparation.



Example co-simulation of digital human twins and system twins. Virtual inertial sensors, e.g. acceleration, are being simulated to explore robust body locations and Digital Biomarker estimations (Derungs & Amft, 2020).

COVID-19 and Digital Health

Prof. Amft is a co-founder of the "Corona Datenspende" initiative of the Robert Koch Institute. The initiative is leading worldwide, having more than 500k users that provide resting heart rate and step count data of their wearable device. No other initiative has gained so many participants. The data shows that wearable data can anticipate COVID-19 reports by approx. one week. Another initiative of the Chair is a novel behavior simulation approach that describes proximity between individuals in a virtual world. The simulation framework enables us to estimate the performance of digital and manual contact tracing as well as study intervention methods, such as the closure of restaurants and schools.

System modeling

Modeling of body-worn systems becomes an important research area for our Chair. So far, the Chair has been investigating system modeling already, either to estimate performance before implementing prototypes or to personalize wearable systems. For example, head modeling and head parameter estimation was used to fit eyeglasses frame sensors to anatomically relevant positions at the head.

Teaching

The Chair of Digital Health contributes to education in Computer Science, minor in Medicine, and in Medical Engineering curricula, through courses, exercises, seminars, and practicals. Among the course offerings are foundational classes on ubiquitous sensor technology, biomedical signal processing, context recognition, and selected topics in machine learning. In addition, applied offerings include seminars and internships on wearable medical system design, 3D printing, and monitoring studies. Within the Medical Engineering curriculum, the Chair provides education for all tracks, covering medical devices, electronics, and computer science. The Chair utilizes their currently available laboratory rooms to let a few students each year explore and learn about novel personal medical device construction and fabrication technologies and methods.
Bachelor's and Master's theses topics as well as PhD theses are offered, crossing disciplines of engineering and computer science with medicine.

Selected publications

Amft, O., Lopera Gonzalez, L.I., Lukowicz, P., Bian, S., and Burggraf, P. (2020). Wearables To Fight COVID-19: From symptom tracking to contact tracing. IEEE Pervasive Computing 19, 53–60.

Derungs, A., and Amft, O. (2020). Estimating wearable motion sensor performance from personal biomechanical models and sensor data synthesis. Nat Sci Rep 10.

Baronetto, A., Graf, L.S., Fischer, S., Neurath, M.F., and Amft, O. (2020). GastroDigitalShirt: A Smart Shirt for Digestion Acoustics Monitoring. In ISWC '20: Proceedings of the 2020 International Symposium on Wearable Computers, (Virtual Conference: ACM), pp. 17–21.

Lopera Gonzalez, L.I., Derungs, A., and Amft, O. (2019). A Bayesian Approach to Rule Mining. arXiv.org.

Schiboni, G., Suarez, J.C., Zhang, R., and Amft, O. (2020). DynDSE: Automated Multi-Objective Design Space Exploration for Context-Adaptive Wearable IoT Edge Devices. Sensors 20, 6104.

Tansaz, S., Baronetto, A., Zhang, R., Derungs, A., and Amft, O. (2019). Printing Wearable Devices in 2D and 3D: An Overview on Mechanical and Electronic Digital Co-design. IEEE Pervasive Computing 18, 38–50.

International cooperations

Prof. GZ Yang, Imperial College London: UK

Prof. D. Kotz, Dartmouth College, Hannover, NH: USA

Prof. K. de Graf, Wageningen University: The Netherlands

Prof. M.A. Spruit, Maastricht University: The Netherlands Prof. L. Chen, De Montfort University, Leicester: UK

Prof. Dr. I. Korhonen, TU Tampere: Finland