Performance Portfolio

Novel Sensor Principles and Sensor Development

Support for Development of Novel Sensor Systems and Sensor Hardware

- Laser beam characterization, Laser power measurement for CW-modulated signals and short pulses
- Test, calibration and verification of navigation sensor elements (IMU, INS, Gyro, Accelerometer, high end inclination sensors) with translational and rotational positioning units to analyze dynamic sensor effects.
- Motion analyze with high speed cameras and non-contact measurement of vibration velocities
- EMC-measuring for compliance assessment
- Certification of hard- and software acc. to TRL5
- Setup Time-of-Flight (ToF) imaging sensors for specific applications
    - Calibration of ToF sensors
    - Medium and long range ToF sensors, high power illumination systems (Laser, LED)
    - Operation with various wavelengths
    - Multi Camera setups (networks)
    - Various light source configurations and modulation schemes
- Electronic design (analog and digital) and verification for new sensor setups
    - FPGA- based and Microcontroller- based sensor systems
    - optical sensors and opto-mechanical sensors
    - Image sensors and multimodal camera configurations including FPGA based Image processing
    - Sensor solutions for navigation and tracking
    - Sensor calibration aspects
    - Low power sensor nodes

Conception and development of radar sensors

- Design and implementation of radar sensors
    - For different bands and waveforms
    - Measurement software development
    - Telemetry system design:
        - Platform navigation
        - Time/Frequency Synchronization
    - Radar sensor calibration

- Versatile consulting activities
    - Advisory expertise in mission planning, ground segment selection, etc.
    - Consulting in antenna design, sensor system conception and platforms

- Characterization of microwave components and subsystems

Control and Medical Applications

- Design of custom stereo cameras for computer assisted surgery
- Research and development in marker design for optical navigation systems
- Design of marker-based rigid bodies for instrument tracking in surgical navigation systems
- Development of a line laser module for a custom laser scanner to be incorporated in an optical 3D localization system

Conception and development of optical and laser based sensors

- Sensors based on spontaneous Raman scattering
  - For fast online gas concentration measurements (e. g. breath-analysis, natural gas, biogas, syngas etc.)
  - Measurement software development and automatization
- Sensors based on coherent anti-Stokes Raman scattering (CARS)
  - For Raman linewidth measurements
  - For spatial and temporal resolved gas temperature and concentration measurements (e. g. in situ combustion diagnostics)
  - Measurement software development
- Sensors based on the laser induced grating technique
  - For the determination of thermophysical properties
  - For spatial and temporal resolved gas temperature and concentration measurements (e.g. combustion diagnostics, fuel/air ratio,)
  - Measurement software development
- Sensors based on chemoluminescence and emission spectroscopy
  - For in situ gas temperature measurements and combustion diagnostics (e.g. online combustion engine diagnostics)
  - Measurement software development
- Two dimensional spray diagnostics
  - Spray visualization and characterization by Mie-scattering and shadowgraphy (e.g. analysis of injection processes)
  - Measurement software development

Wireless sensor networks

- Design, development, and programming of wireless sensor network nodes
- Expertise in, and evaluation of, multi-hop-routing protocols
- Development in WSN-specific tools such as Contiki-OS, Cooja, etc.
- Power analysis for battery-driven wireless sensor network nodes
- Testbed design and analysis

Wearable computing / wearable sensing

- Wearable integration of sensors, particularly inertial sensors and PPG-analysis methods
- Assessment of comfort rating, wearability for new products
- Long-term evaluation of wearable IMU data, gesture recognition, activity detection

- Memory- and energy-efficient recognition strategies for wearables (motif discovery, SoC deployment of classifiers, etc.)

Nanomaterial-based thin-film sensors for mechanical structures

- Development of a graphene-based sensor for structure analysis in the area of structural health monitoring

Conception and characterization of imaging sensors

- Prototypical binocular RGB-D sensor setups
- High performance sensor simulation for
    - AMCW ToF cameras including various sensor effects such as multi-path, motion artefacts etc.
    - Pulse-based ToF cameras including basic concepts such as signal profiles
    - THz cameras

Sensor Information Processing

Real-Time Signal Processing and Sensor Networks

- Embedded Real-Time Signal Processing, sensor data fusion and Image processing (2D/3D)
- Identification and tracking based on sensor network data
- Clustering and classifications algorithms for Sensor Networks (SNs)
- Distributed processing algorithms for SNs
- Behavior sensing and analysis by wearable sensors and environmental sensing data (fixed mounted sensors, moving sensing platforms)
- Navigation and Tracking based on Sensor Network data and Imaging

Acousto Ultrasonics

- Optimization and reliability proof of guided wave structural health monitoring for damage detection in fiber composite structures in aerospace.
- Sensors for damage monitoring of axles in rail vehicles.
- Development of a baseline-free structural diagnostics system based on piezoelectric sensor / actuator array networks.
- Condition monitoring and sensor fault detection of intelligent fiber composite structures.
- Structural health monitoring with surface acoustic waves methods and the construction of a structural health monitoring portable impedance analyzer.

Vibration-based Structural Health Monitoring

- Sparsity-based reconstruction method for simultaneous external force monitoring and structural damage identification.
- Online load identification and operational modal analysis of a floating offshore wind turbine.

- Identification of unknown structural loads from dynamic measurements by using robust observers.
- Integral monitoring and evaluation system for offshore wind turbines (IMO wind).
- Structure diagnostics with ultrasonic waves using piezoelectric sensors and actuators.
- A probabilistic approach for fault detection of railway suspensions.
- A novel full scale roller rig test bench for Structural Health Monitoring concepts of railway vehicles.

Bio-Mechanics

- Patient individual finite element analysis of the human aorta based on real time 3d ultrasound measurements combined with speckle tracking.

Analysis and compensation of an axial drift of heavy axisymmetric symmetrical components

- Axial drift of heavy axisymmetric symmetrical components on roller turning devices, analysis and compensation.

Sensor Signal Processing

- RGB camera data
    - PSF estimation
    - Image sharpening and fusion
- ToF cameras
    - Quantification of depth camera intrinsic errors
    - Correction of intrinsic errors such as motion artefacts
    - Deblurring and superresolution
- THz camera systems
- Synthetic imaging
- Superresolution techniques for imaging beyond the diffraction limit
- Multi- and hyperspectral sensor data (e.g. from confocal Raman microscopy)
- Noise reduction, data compression and feature extraction
- Sensor data preprocessing
    - Radar signal modelling
    - Data Interfaces
- Data processing algorithms:
    - Imaging radar
    - Motion detection and tracking
    - Monostatic real-time processing
    - Interferometric and tomographic processing
    - GPU Processing

Compressive Sensing Reconstruction

- Energy minimization methods and regularization design for model-based image processing and inverse problems
- First-order optimization methods for convex and nonconvex problems; convex relaxation and approximation techniques
- Machine Learning / Deep Learning, e.g. for segmentation and localization tasks

- Hybrid model- and Learning-based algorithm design; incorporating prior knowledge in deep learning
- Linear signal and image reconstruction, e.g. denoising, deblurring/super resolution, compressed sensing
- Nonlinear reconstruction in computer vision, e.g. stereo reconstruction, depth-from-focus, optical flow estimation
- Multiscale decomposition methods
- Convergence analysis of optimization algorithms
- Error-estimates in inverse problems

Control and Medical Applications

- Motion capture and tracking of people, animals or objects
- Image processing for 3D localization applications
- Development of smart microcontroller-based auxiliary tools for computer assisted and navigated surgical interventions
- Research in stereo camera accuracy evaluation and calibration approaches
- Evaluation of measured 3D data for registration with preoperative images

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High Level Information Extraction and System Integration

Design an development of Wired and Wireless sensor networks (SNs, WSNs)

- Embedded Intelligence (edge computing and cloud computing)
- Smart Data
- Embedded Imaging for “Industrie 4.0” applications
- Interaction between real-time level and data analytic-, management-level (communication design in the IoT and “Industrie 4.0”)
- Embedded Intelligence (edge computing and cloud computing)
- Secure operations as an integral part of the high level data processing and communication
- Application specified information extraction

3D Reconstruction of Faces from Images

- Automated Reconstruction of textured 3D face surfaces from single or multiple images, using a 3D Morphable Model of Faces
- Learn common features of human faces from 3D scans, represent them in a vector space of faces
- Adapt to unknown imaging conditions (pose, lighting) in an analysis by synthesis
- Include new imaging conditions, such as complex illumination scenarios, using a Virtual Light Stage approach
- Estimate the shape and texture of occluded regions of faces, based on general, class-specific properties of human faces

- Fully automated framework, using localization of facial features, model fitting, face-specific quality measures and a combination of data from multiple images, if available.

Human Perception

In experiments with human participants, we study the following effects:

- Aftereffects in human face recognition, and their consequences for our understanding of how faces are represented in the human brain
- Human expectation of what a face looks like in profile, given a front view, or what occluded regions look like. The results of these experiments are compared to the predictions of our computational model
- Perceived image similarity, especially with respect to colors. Based on the results from our experiments, we trained a neural network to predict similarity, which is helpful for tasks such as queries in image databases, or for style transfer.

Machine Learning

We have been using different machine learning techniques in the domains of human faces and images. These techniques inlude Support Vector Machines and Convolutional Neural Networks.

- Segmentation and Classification based on CS approaches
- Sparse Scene Representation Models and Dictionary Learning
- Compressed Learning Approaches

Sensor Signal Processing

- Inverse rendering, i.e. extraction of scene lighting and material parameter
- Online range image fusion and scene reconstruction (also on mobile devices) with Tof-based and other depth cameras
- Image fusion with THz camera systems
- Interactive visual analysis of high dimensional data (e.g. multi- and hyperspectral sensor data from confocal Raman microscopy)
- Interactive visual analysis of high dimensional data
- Visual object detection and real-time 3D-environment modelling by sensor fusion
- Design, construction and operation of various autonomous mobile indoor and outdoor robots. Part to part in connection with robot swarms (air robots, multicopter)

Control Applications

- Neural networks, local model networks, fuzzy systems, and other statistical models
    - Black-box and gray-box approaches
    - Knowledge integration
    - Learning nonlinear static and dynamic models from data
    - Dynamics representation in models
    - High-dimensional learning
    - Data-driven selection of relevant inputs
    - Robust online adaptation and learning
- Metamodeling (models of computationally expensive simulations)
- Efficiency optimization with metamodels
- Fault detection and diagnosis via eigenfrequency and mode classification

- Model-based nonlinear control
- Design of experiments
    - Space-filling designs for even data coverage
    - Model-based active learning
    - Automatic calibration for safe process exploration
    - Dynamic excitation signals for learning/testing
- Development of strategies, methods, and algorithms for (hybrid) drivetrains, combustion engines, centrifugal and axial fans, rolling mills, bogies, soft robotics and logistics

Medical Applications

- Contactless registration of surfaces and reference body based navigation with robot guided laser scanner/3D localization system applied in head surgery
- 2D/3D and 3D/3D matching of CT and X-ray-images
- Processing and visualization of point clouds generated by 3D localization systems
- Spine segmentation and diagnosis on routine MRI