Universität Siegen

ZESS

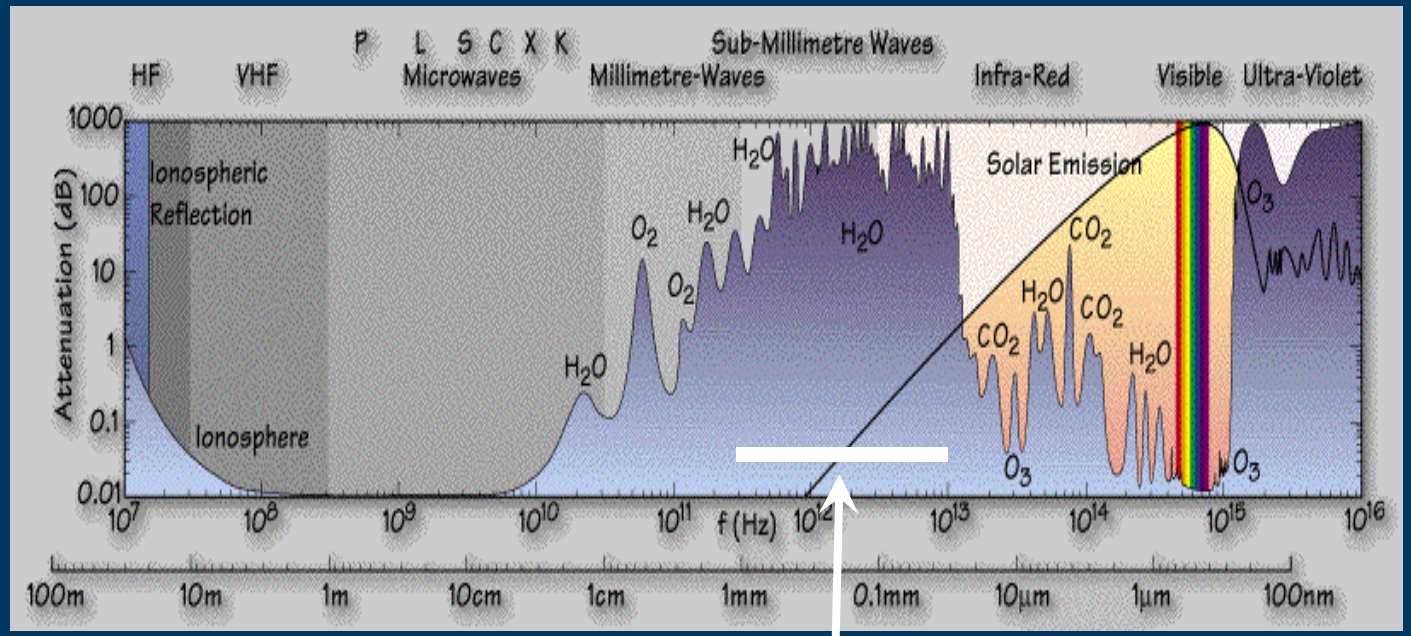
Center for Sensor Systems

Research

High Frequency & Quantum Electronics

Prof Dr Peter Haring Bolívar

The THz Frequency Range

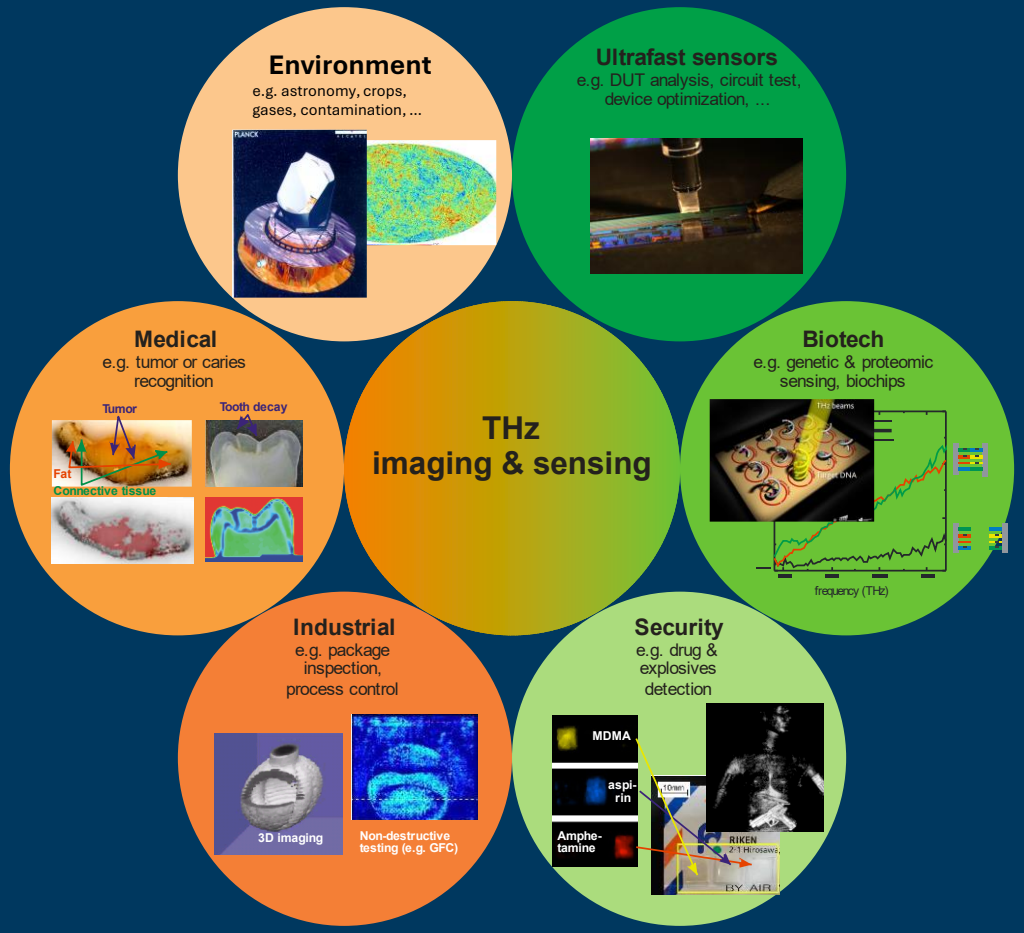


ν = 300 GHz … 10 THz
λ = 1mm … 30µm
k = 10cm^{-1} .. 300cm^{-1}

THz is at the transition from electronics to optics

$$\nabla \times \vec{H} = \vec{j} + \frac{\partial \vec{D}}{\partial t}$$

THz Imaging & Sensing Areas



THz communications
e.g. WAN, WPAN, Chip-to-chip, ...

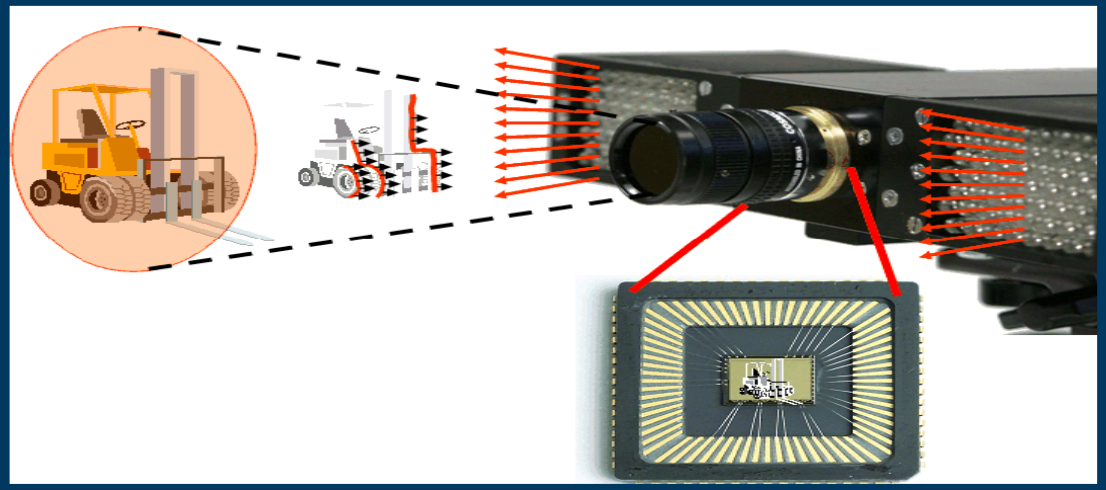
6G

„Emerging“

P. de Maagt, P. Haring Bolivar and C. Mann, Encyclopedia of RF and Microwave Engineering, pp. 5175-5194 (John Wiley & Sons, Inc., 2005) ISBN 0-471-27053-9.

3D Cameras

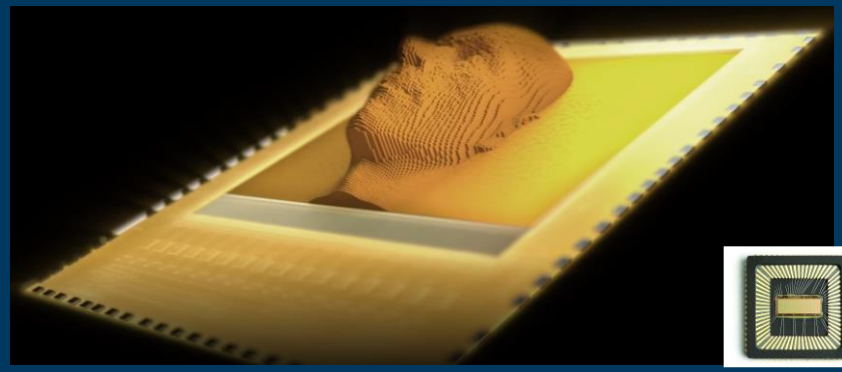
- The AI-infused world is characterised by intelligent technical systems that need to interact reliably with people and each other.
- 3D vision (seeing and recognising) is a crucial prerequisite.

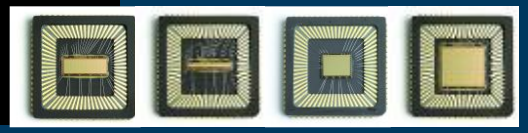


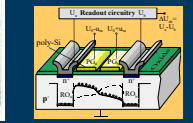
Reliable high resolution 3D-measurements with active optical sensors

3D Camera Spin-offs

- *Real-3D* with Si-integrated Sensors with active illumination (ToF) (Prof. Schwarte)





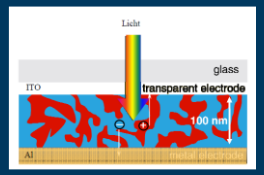


pmd > 100 Staff

infineon Nominated “Zukunftspreis 2002”

Durchbruch durch größere Verbundprojekte, wie z.B. BMBF Projekt LYNKEUS (>1000 Personenmonate) und Industriekonsortia. Eintritt in Massenmärkte gelungen (zB Lenovo, Leica, ...)

- Further Spin-off from BASF research activity (Dr. Thiel, Prof. Haring Bolívar)



trinamiX > 50 Staff

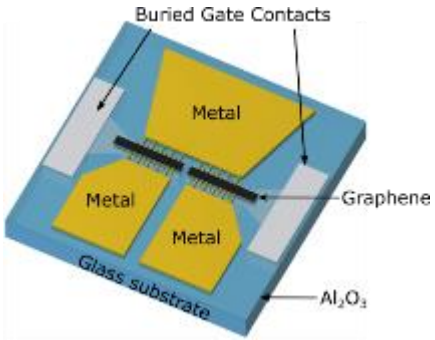
BASF We create chemistry Nominated “AMA Innovation Award 2019”

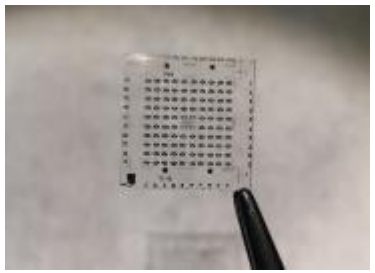
Organische Zelle; Fundamentalbeobachtung und Effekterklärung im Rahmen Industrieprojekt mit BASF/ERT Optik

3D Camera Development

Heterogeneous Integration

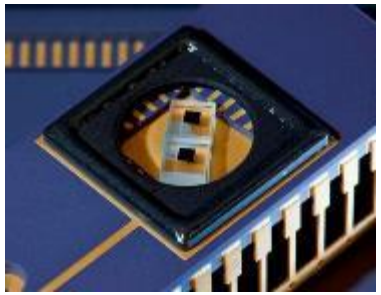
- 2D Materials (Graphen) on Si

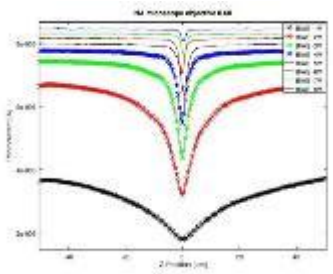




Passive Direct 3D

- Nonlinear. a-Si photodiodes





Cooperation Haring Bolívar, Kolb, Lemme, PMDTec, Charbón, et al.

Computer Graphics

Prof Dr Andreas Kolb

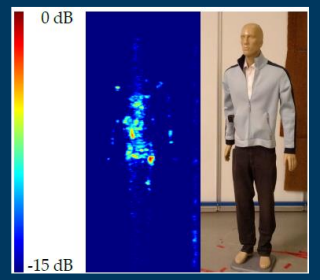
Sensor Simulation

- Various modalities, e.g., color, depth, THz, and multispectral
- Physically based sensor & scene models

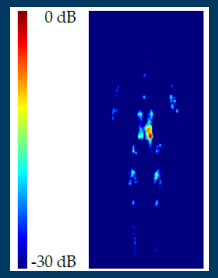
Real Depth Data

Sim. Depth Data

Real THz Data

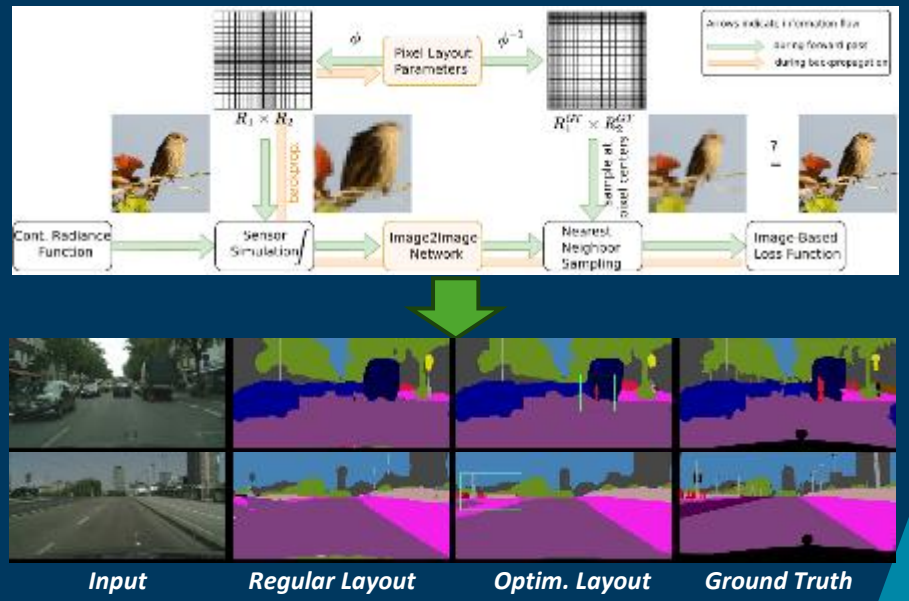


Sim. THz Data



Sensor Optimization

- Variation of sensor parameters, such as pixel layout or color filter
- Joint learning of task and sensor parameters



Model-driven Sensor Data Fusion

- Interactive for high data rates
- Sample tasks: real-time scene or image reconstruction

Low Feature Scene

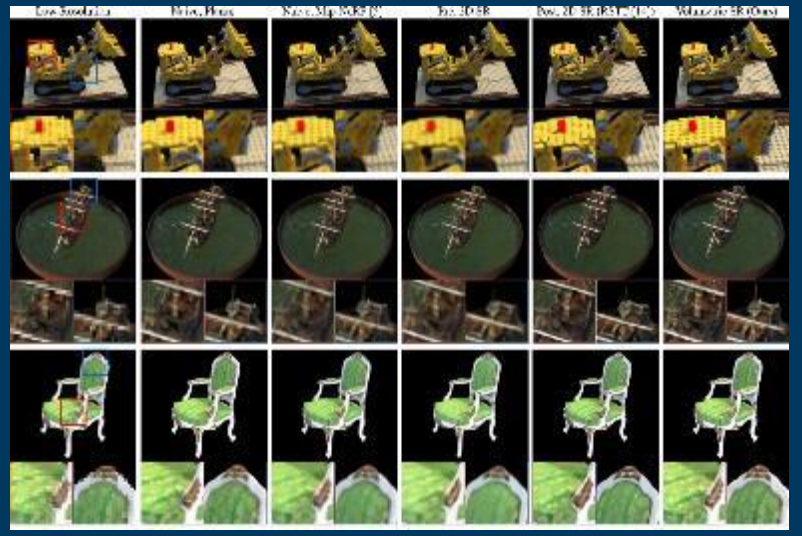
3D reconstruction

Reference offline optimization

Our online2D reconstruction

Data-driven Sensor Data Fusion

- Neural scene representation (NeRF and Gaussian Splatting)
- Sample task: Super-resolution



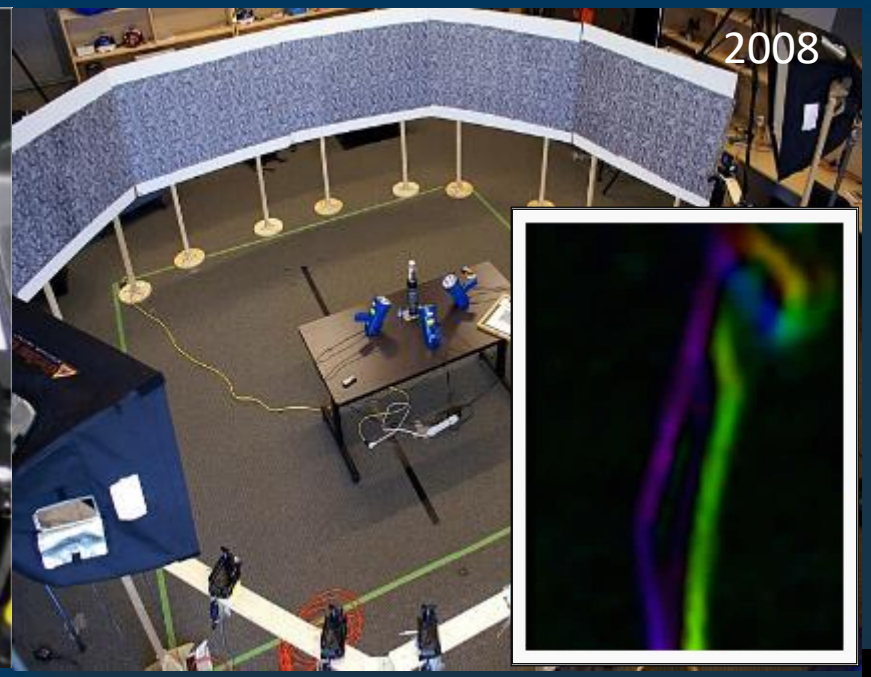
Computational Sensorics & Communications Engineering

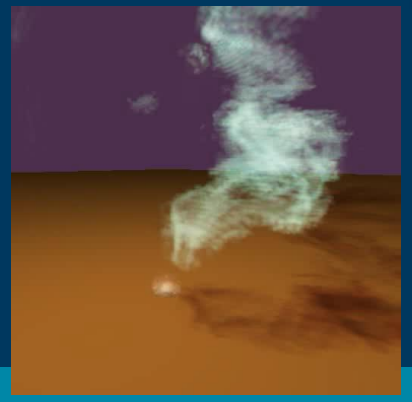
Prof Dr Ivo Ihrke

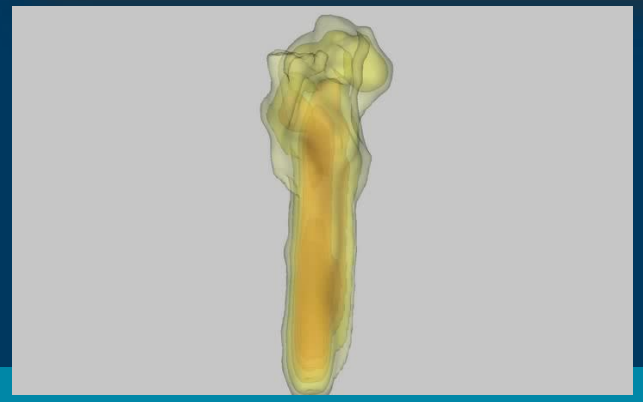
Computer Graphics:
Flame and Smoke Tomography

Engineering Measurements:
3D Refractive Index Tomography

Fluid Velocity Estimation

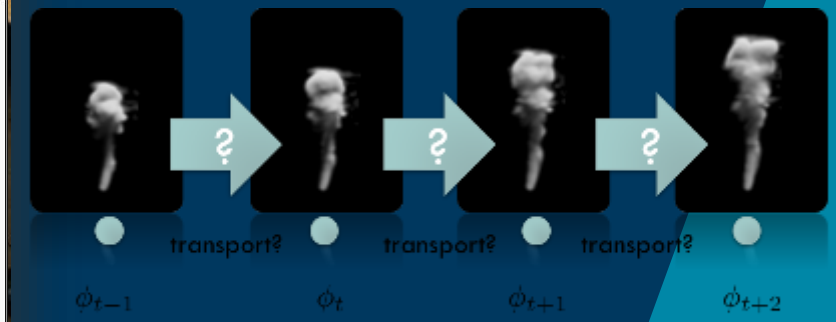






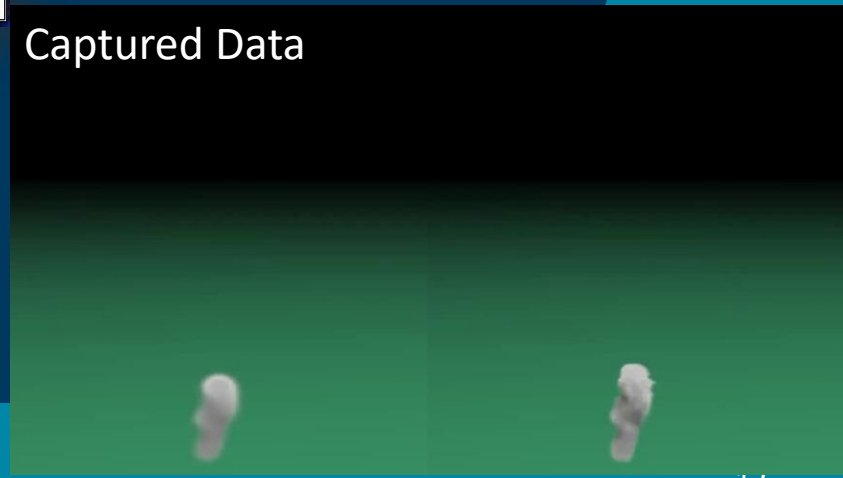
2014

Fluid Velocity Estimation

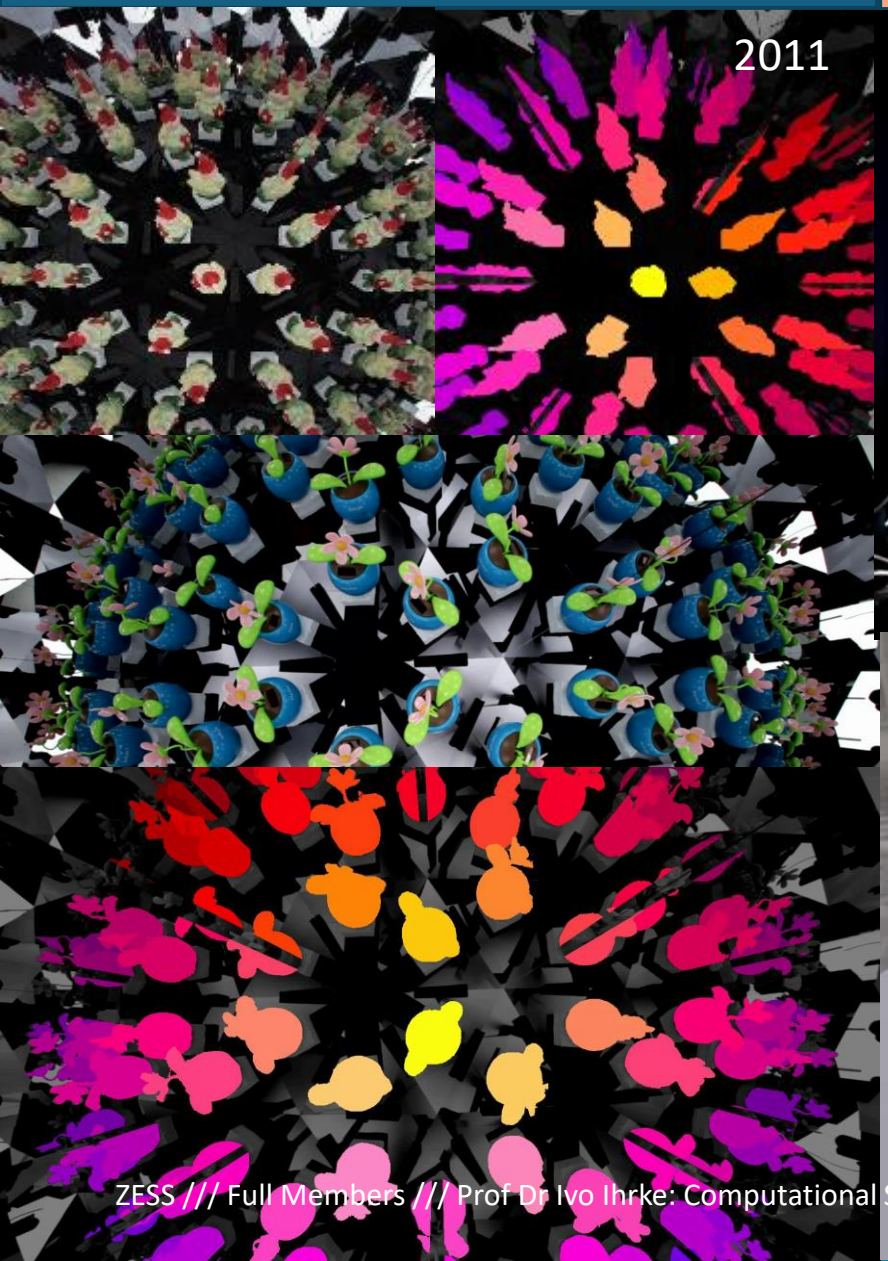


Resim + Turbulence

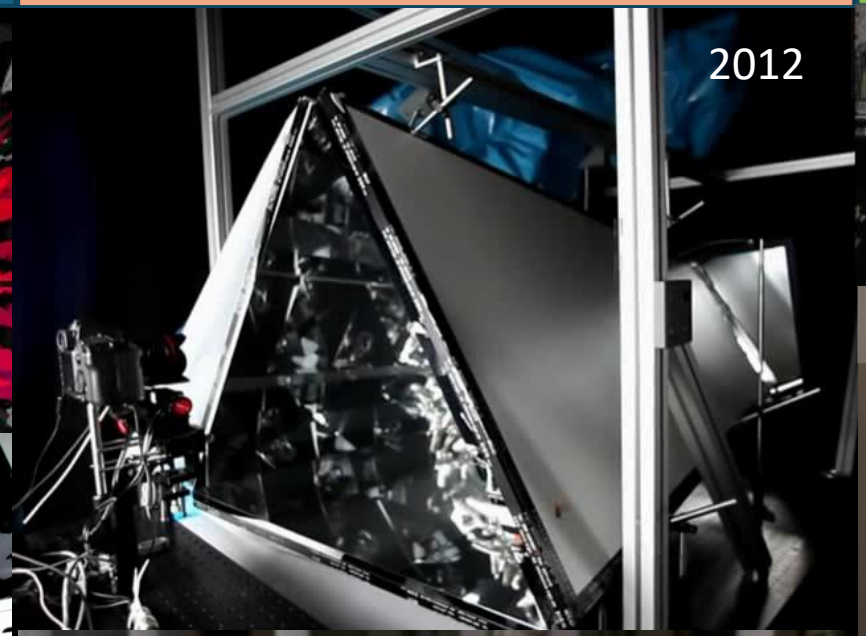
Captured Data

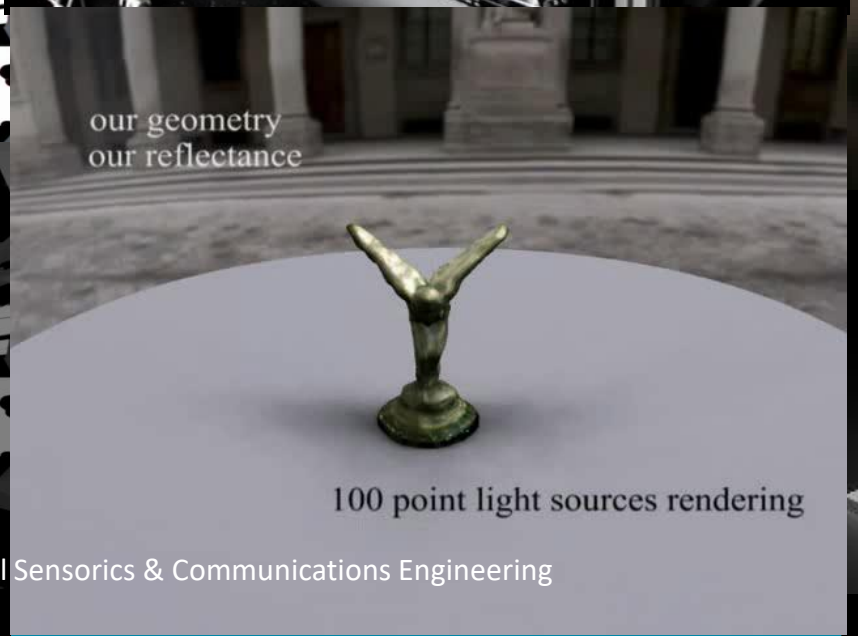


Kaleidoscopic Imaging:
Multiplexing Many Views



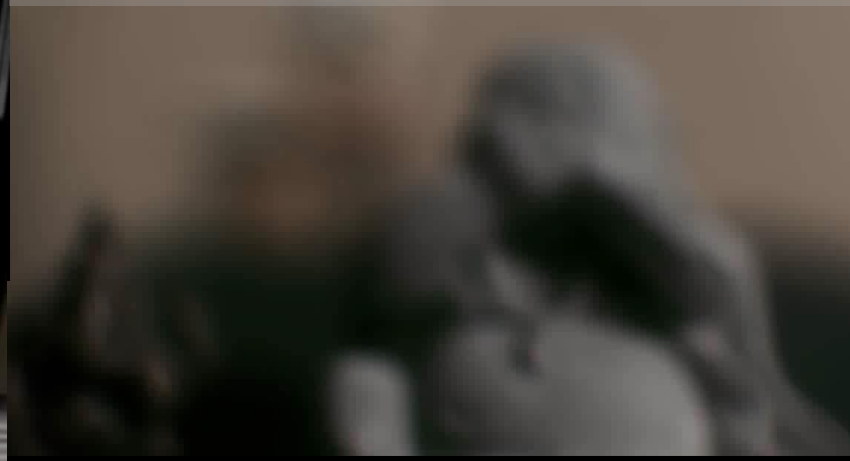
Bidirectional Kaleidoscope:
Simultaneous Geometry and Reflectance





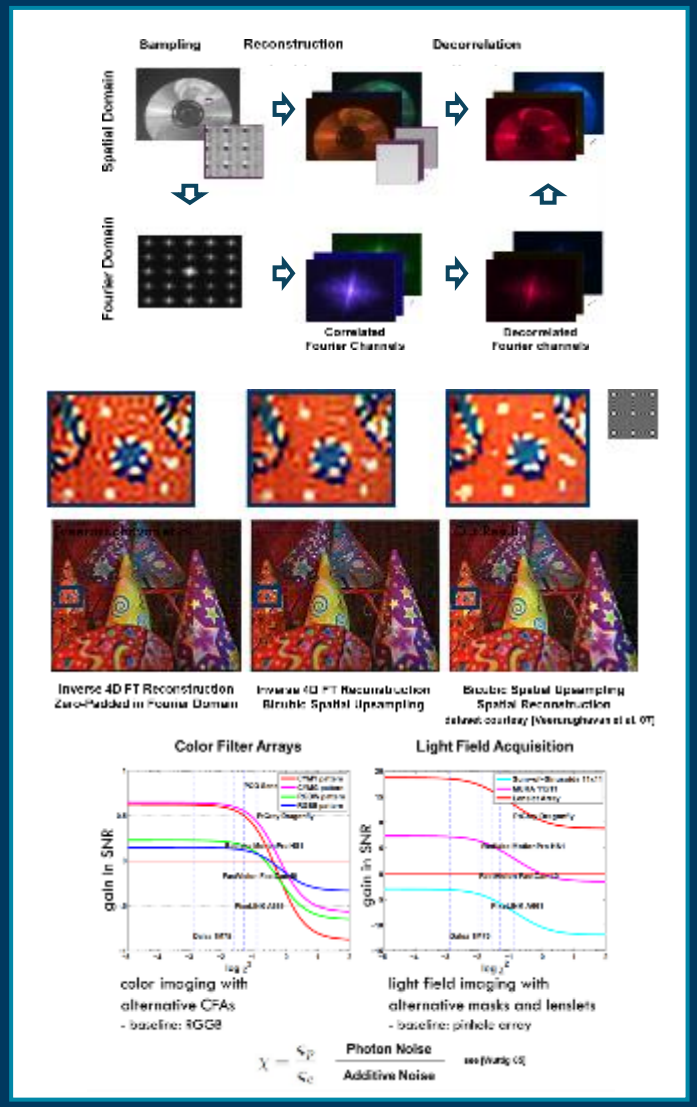
K|Lens
A New Light Field Imaging Architecture

APPLICATION: VIRTUAL F/0.7 REFOCUSSING

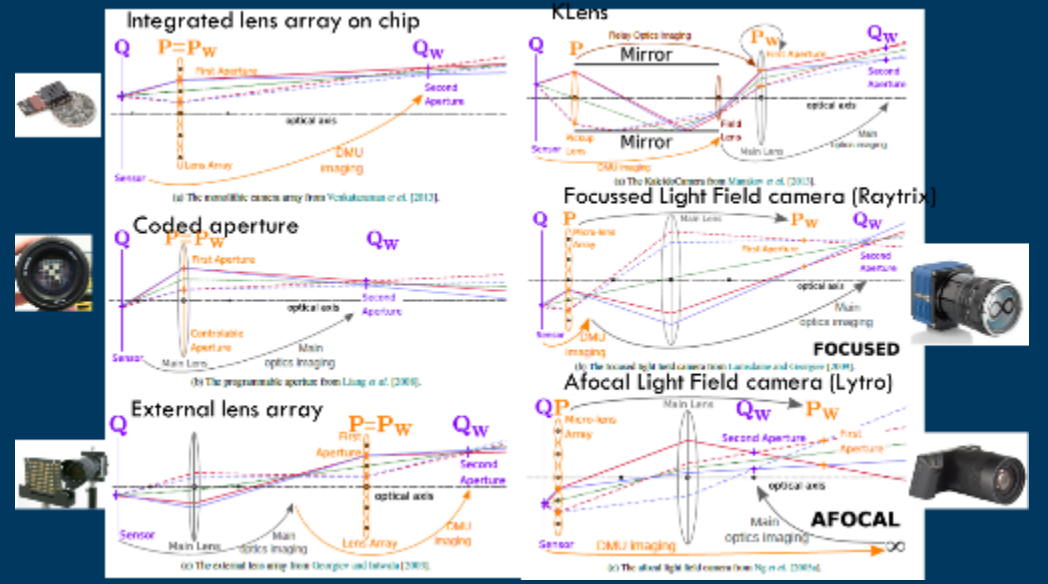


https://www.k-lens-one.com

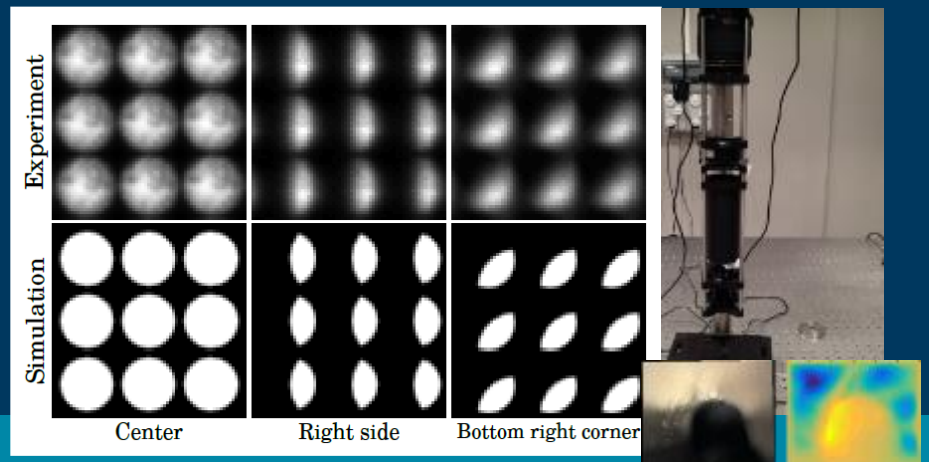
Image Processing
Plenoptic Sampling & Reconstruction



Optical Models
Unifying First-Order Light-Field Theory



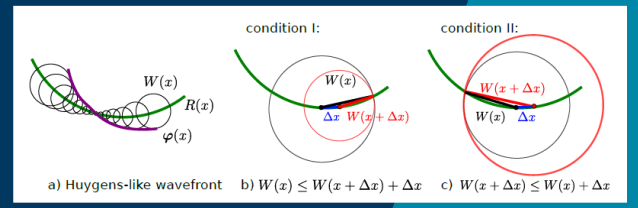
Optical Models
Light Field Radiometry



Optical Models
Aberrations

$$\frac{\partial W}{\partial x} \approx -\frac{\epsilon_x}{r}, \text{ and}$$
$$\frac{\partial W}{\partial y} \approx -\frac{\epsilon_y}{r},$$

Long-standing problem:
This is just an approximation
New: Exact Analytical Solution



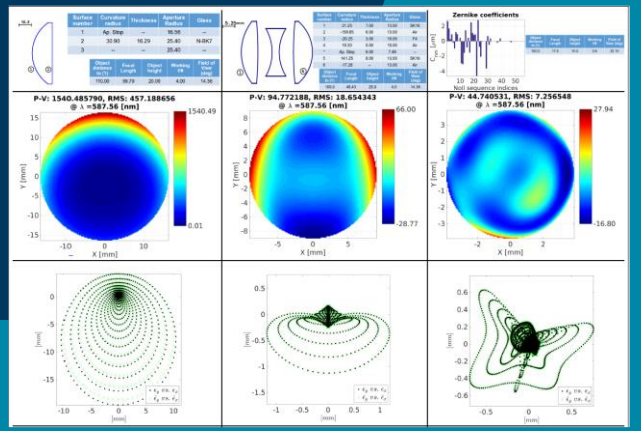


Image Processing
Plenoptic Sampling & Reconstruction

Microscopic Superresolution
Fourier Ptychographic Microscopy

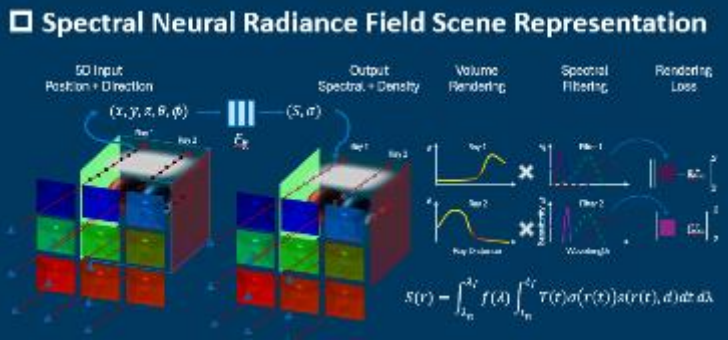
Phase Retrieval & Acousto-fluidics

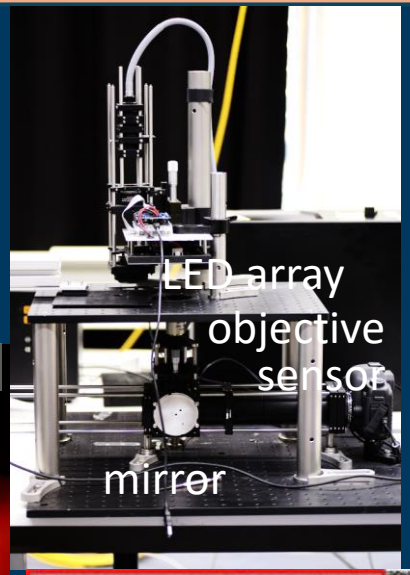
ZESS

Snapshot Plenoptic Imaging

Depth Estimation

Spectral Light Field Imaging

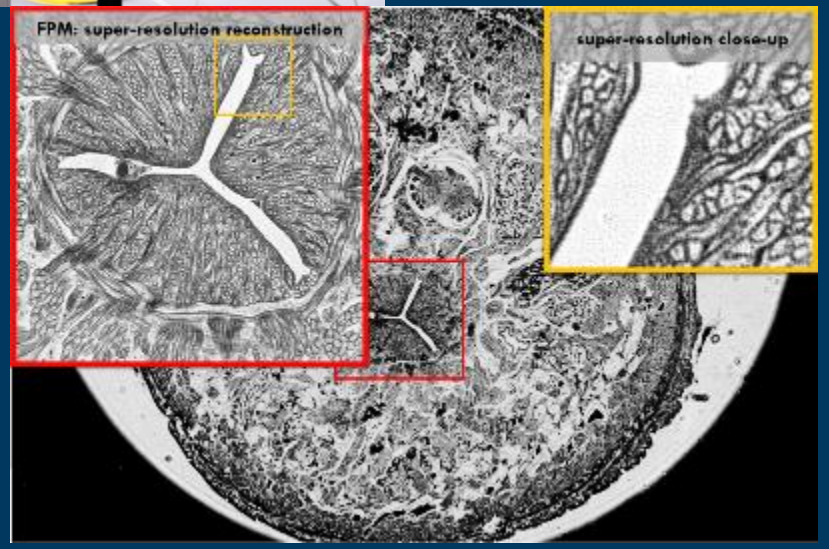




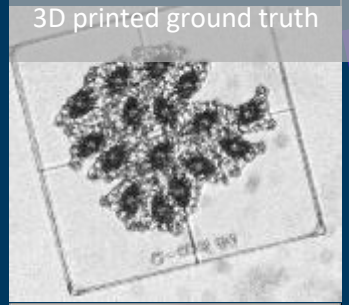
Fourier Ptychographic Microscopy

System Characterization and Calibration

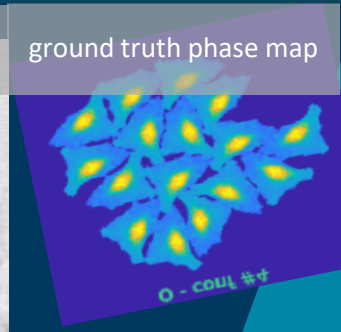
Optical Analysis and Algorithm Development



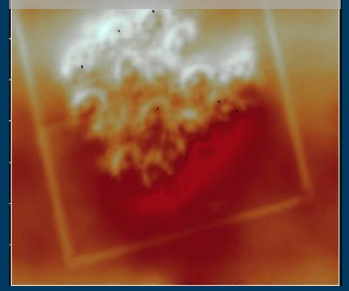
3D printed ground truth



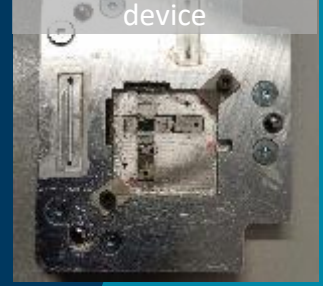
ground truth phase map



captured phase map



acousto-fluidic device



sustained sample rotation

Mechanics & Structural Health Monitoring

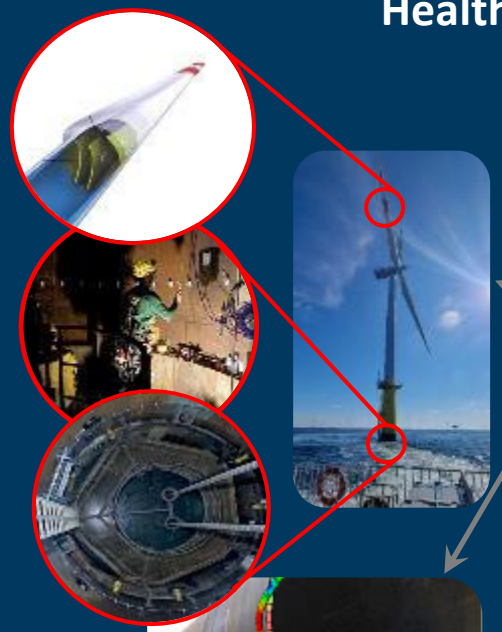
Prof Dr Peter Kraemer

ZESS Co-Speaker & Member of the Board

Condition and Structural Health Monitoring

SHM

SHM of
Rotor blades

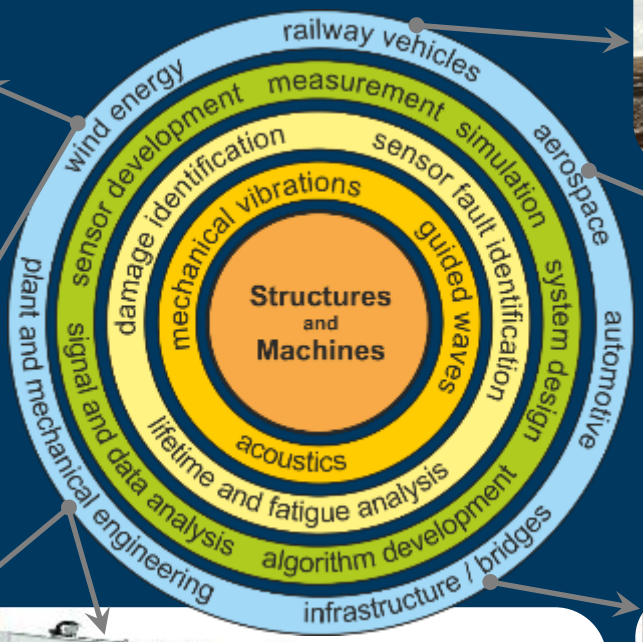


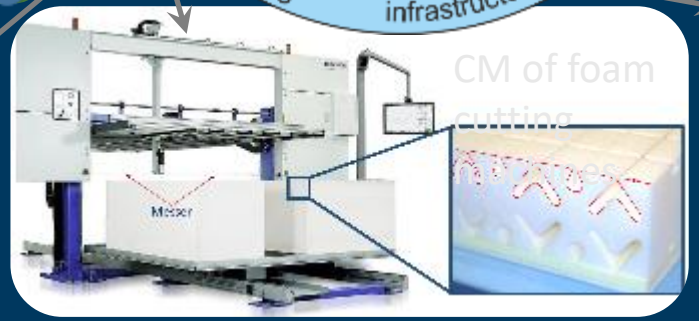
Fleet
Monitoring

SHM of
- Grout
- Foundation
- Tower

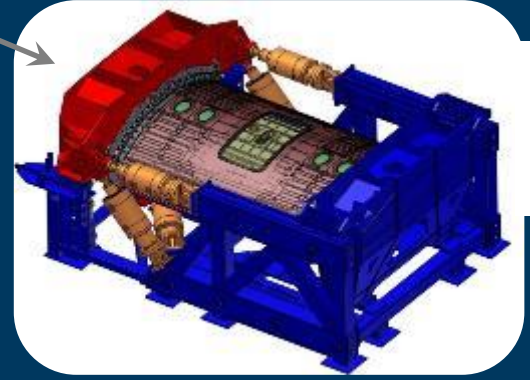
Control engineering for
welding of tower segments

Condition Monitoring
(CM)
of drive trains





Sensors,
automatic fault
detection for rail
vehicles



CM of
aerospace
structures

SHM of rail bridge
components

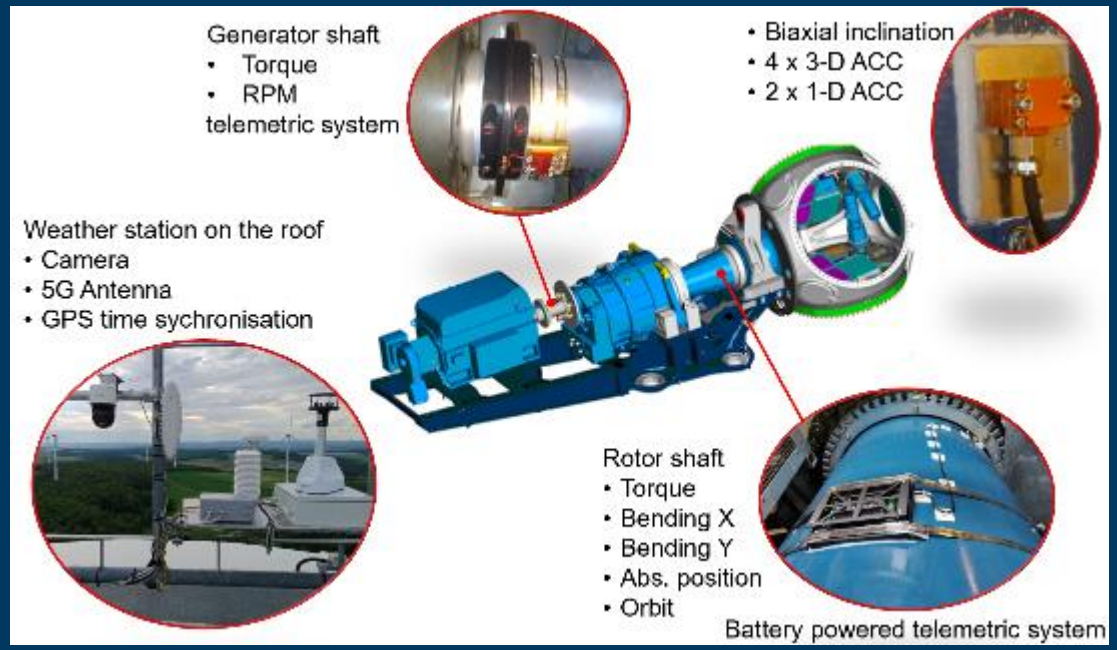
MSHM access to „large test rigs“

Contract between BEA eG and MSHM of University of Siegen

Research on BEA-WEP is allowed for the lifetime of the plant

Tower, blades and drive train are installed with > 100 sensors

Example of drive train installation

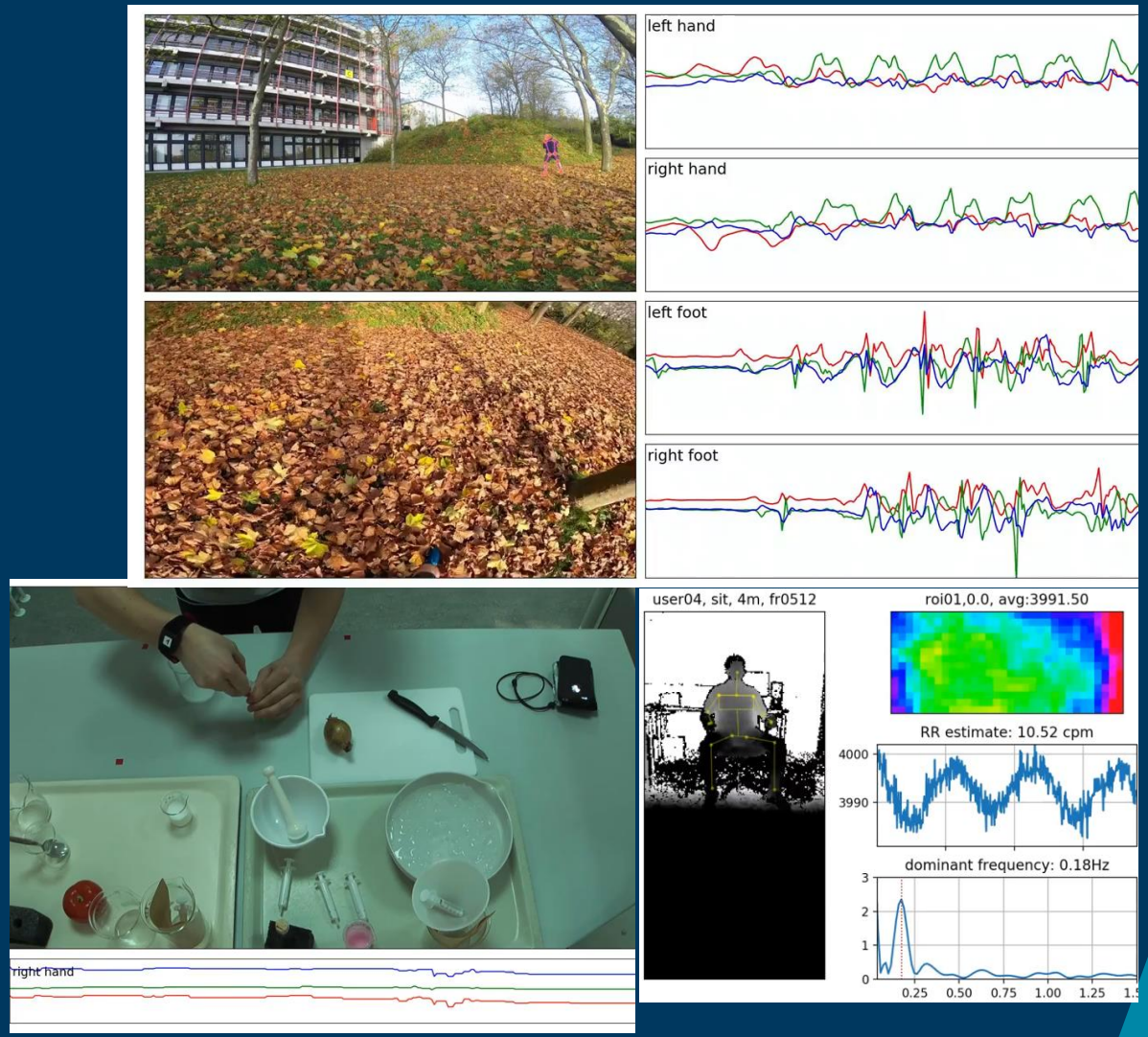


Ubiquitous Computing

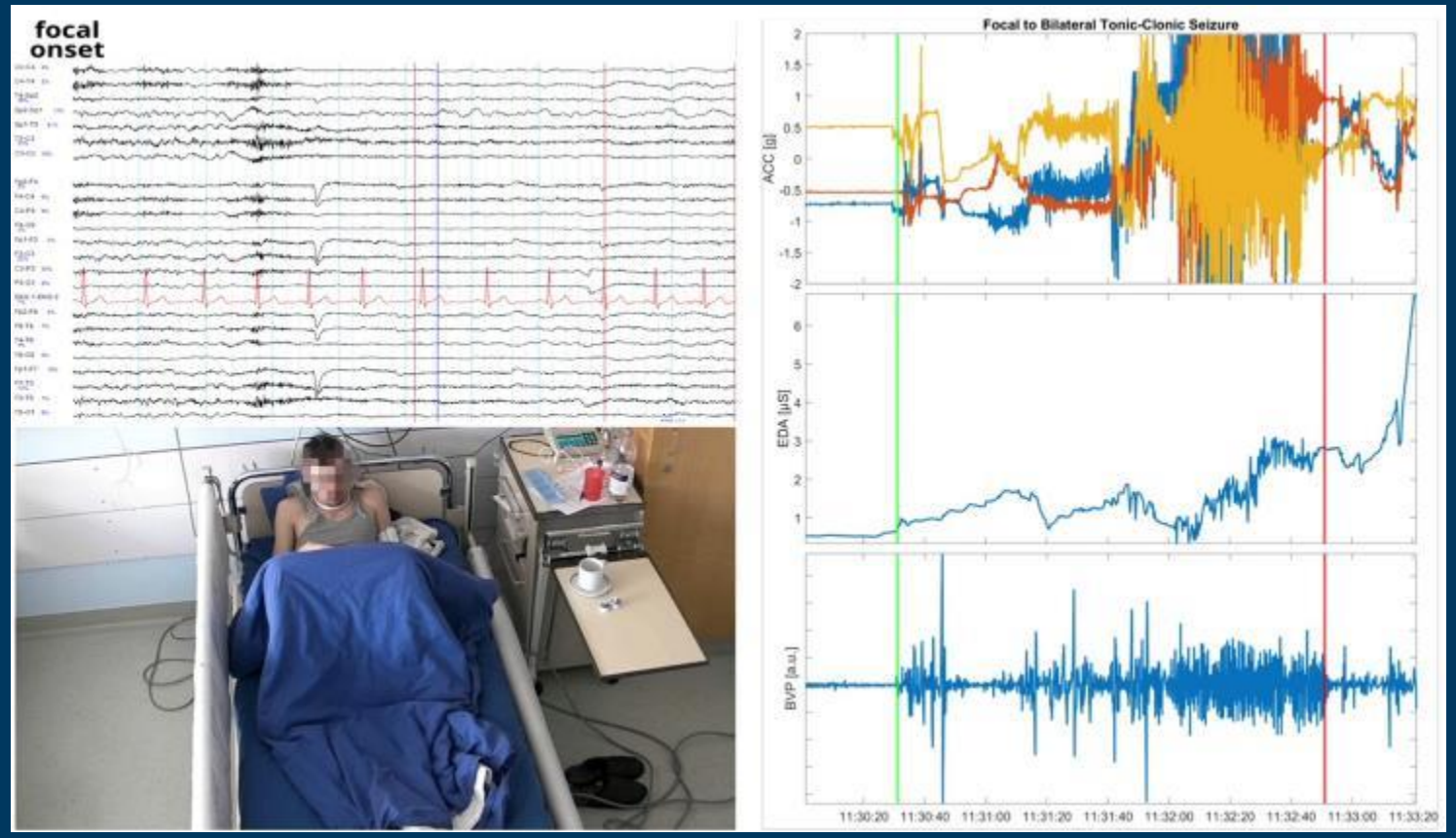
Prof Dr Kristof Van Laerhoven

ZESS Speaker & Member of the Board

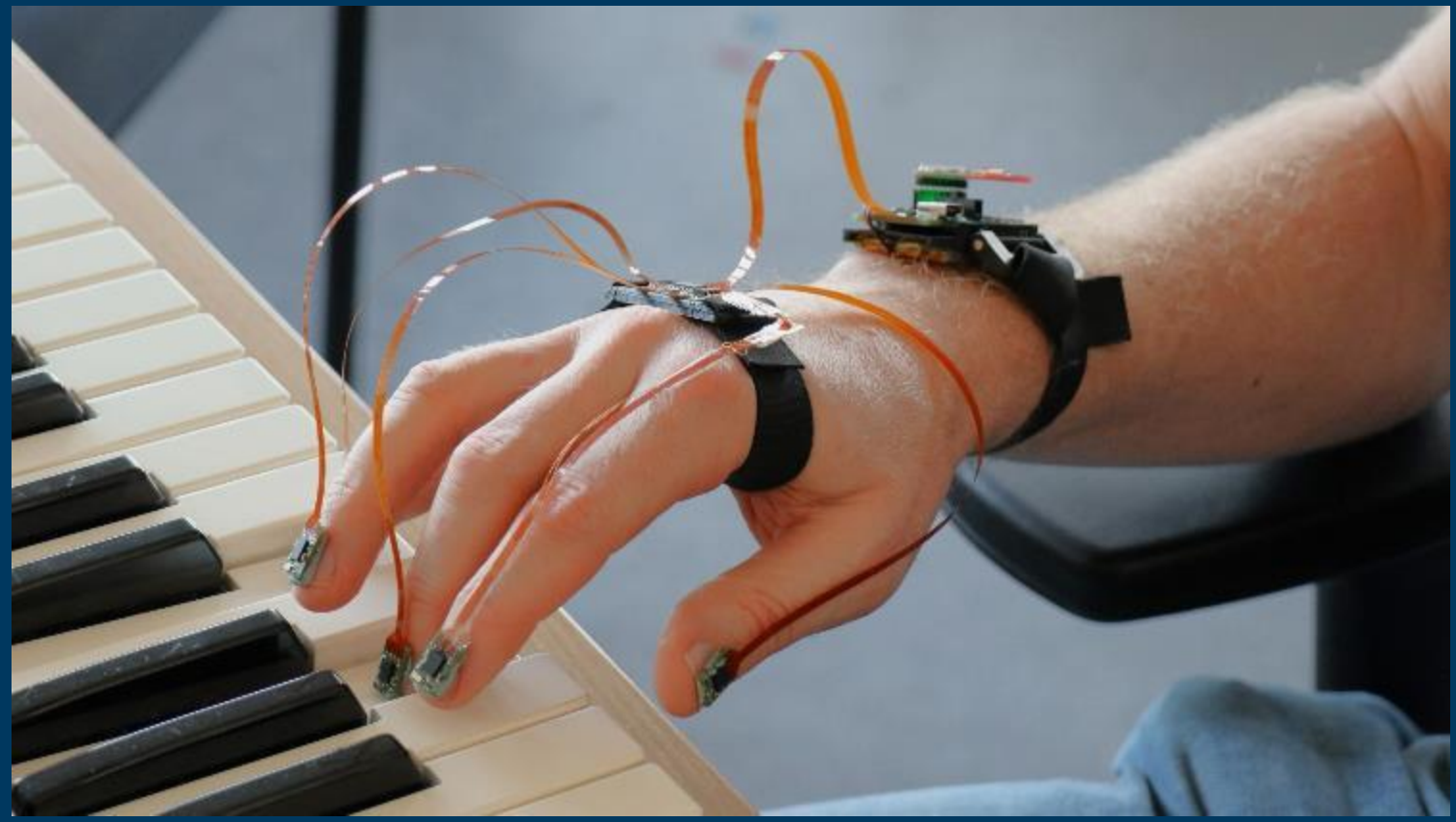
Ubiquitous Computing



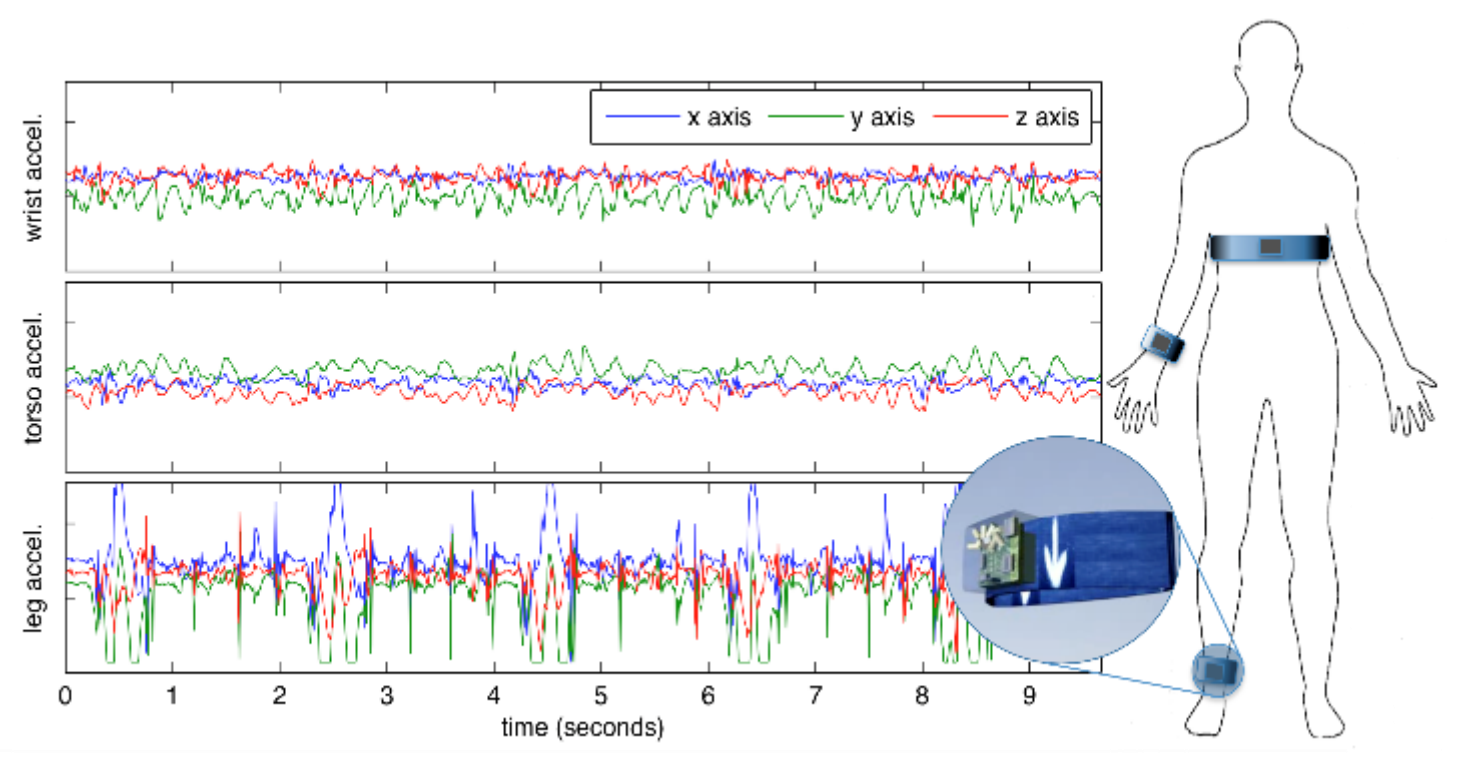
Detecting Epileptic Seizures with Wearable Sensors

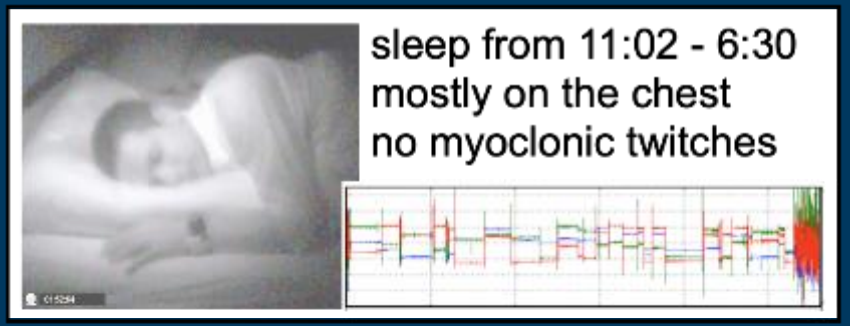


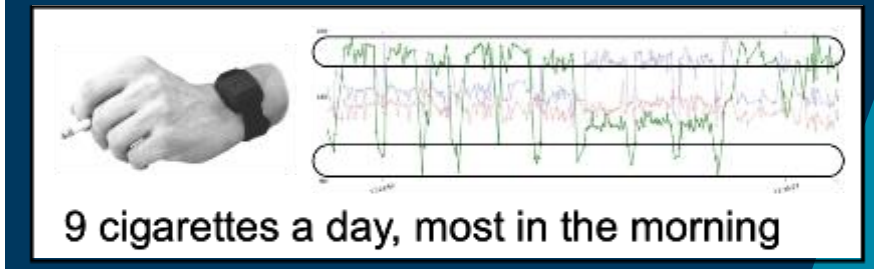
Wearable Sensors for Capturing Hand Articulation



Activity Recognition



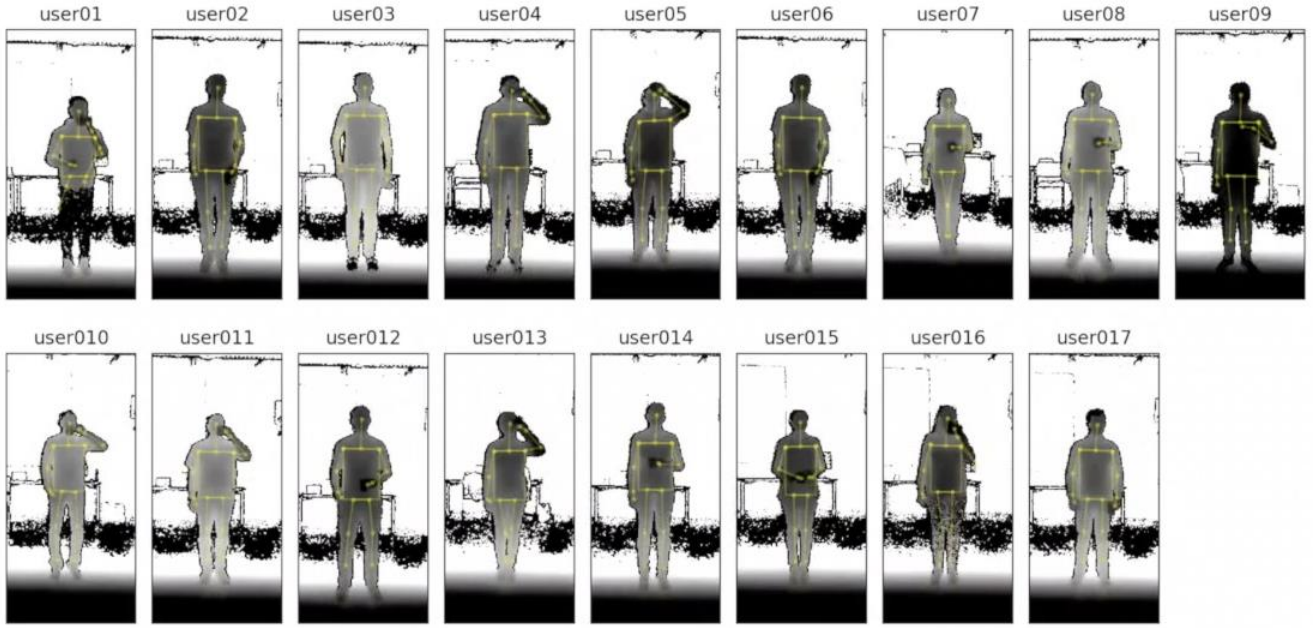




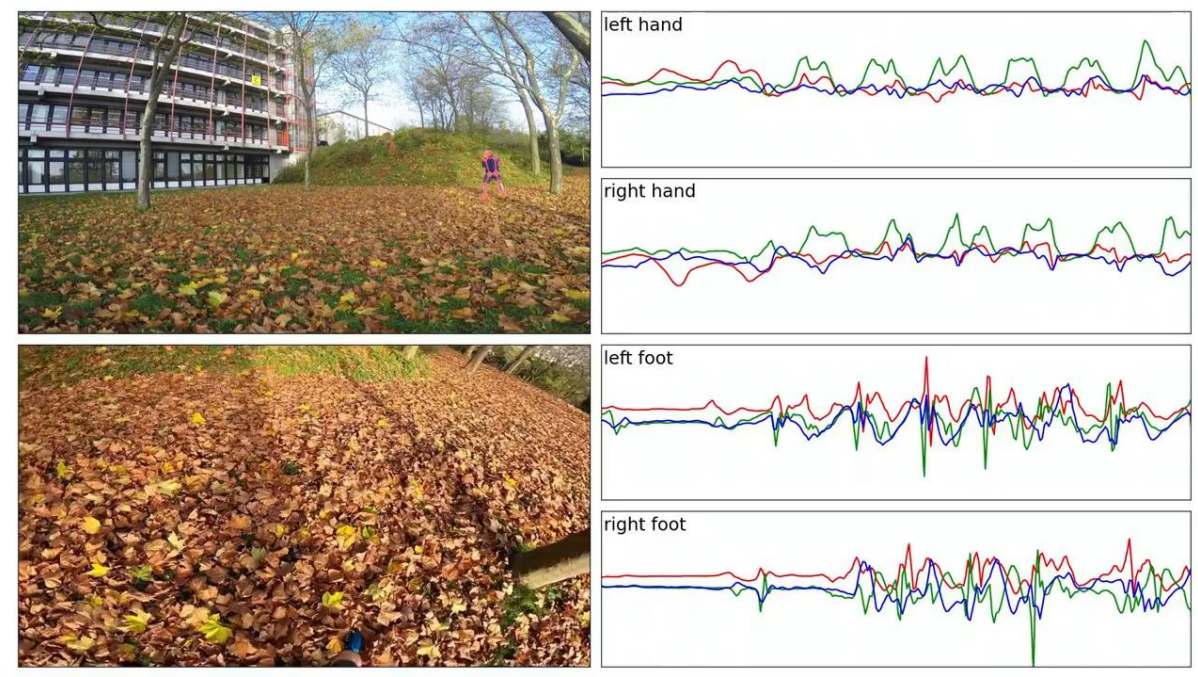
Respiration Monitoring with Depth Cameras

The dataset:

17 participants (age: 22-57, 5 female)



WEAR: An Outdoor Sports Dataset



> 15 hours
615 action segments
10 outdoor locations
4 seasons

18 participants
♂ 10 ♀ 8
28 ± 5 years old

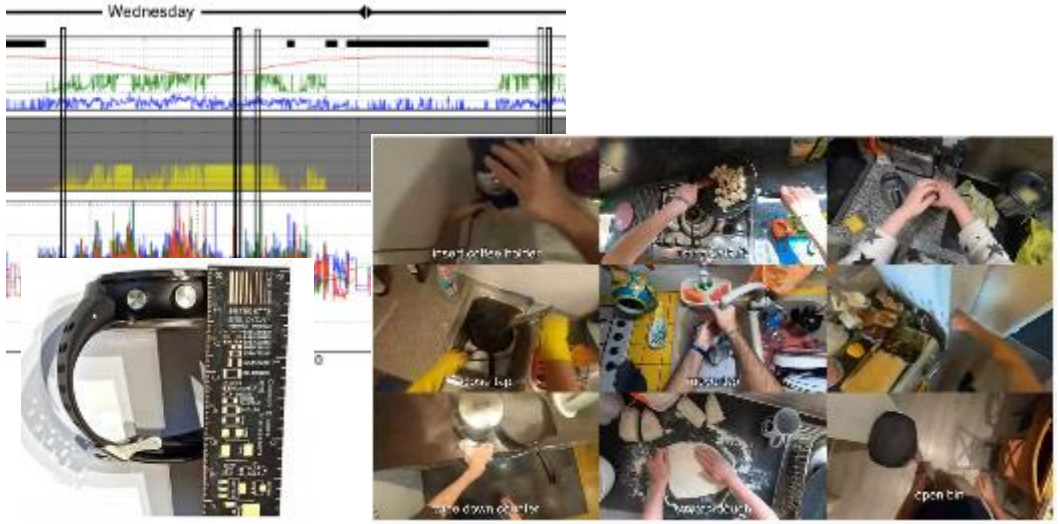
min. 2 sessions
18 workout activities
5 running, 5 stretching &
8 strength

WEAR: An Outdoor Sports Dataset for Wearable and Egocentric Activity Recognition, Marius Bock, Hilde Kuehne, Kristof Van Laerhoven, and Michael Moeller. ACM IMWUT 2024 **https://mariusbock.github.io/wear/**

Computer Vision

Prof Dr Michael Möller

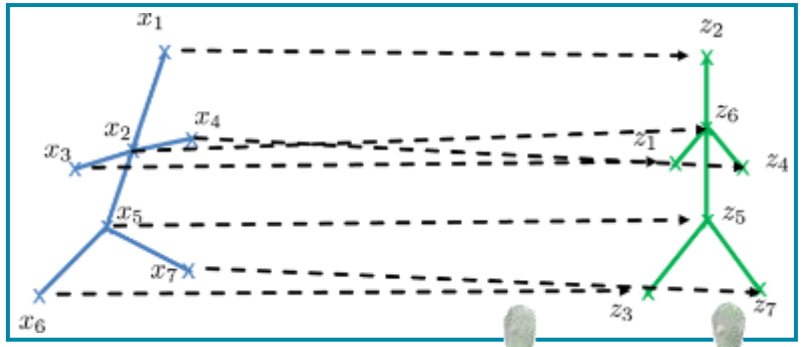
Computer Vision I

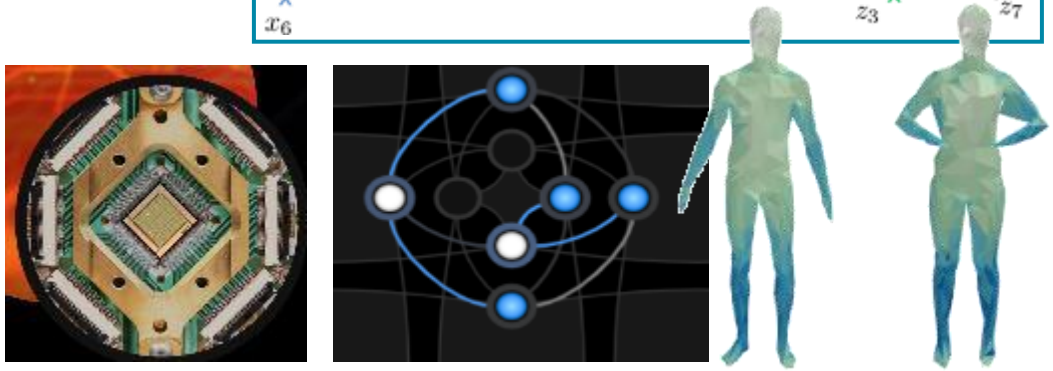


Human activity recognition with visual and body-worn sensor data.

https://shop.espruino.com/banglejs

https://epic-kitchens.github.io/2023



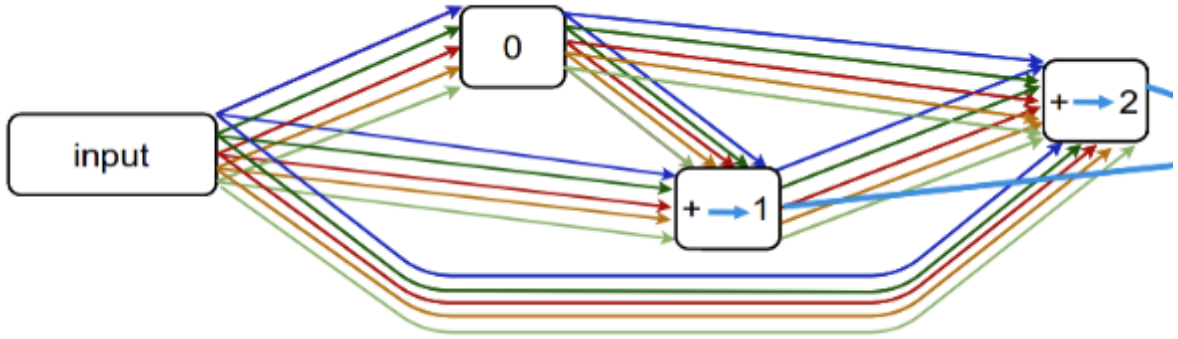


Matching problems and quantum computer Vision

Images taken from D-Wave

Computer Vision II

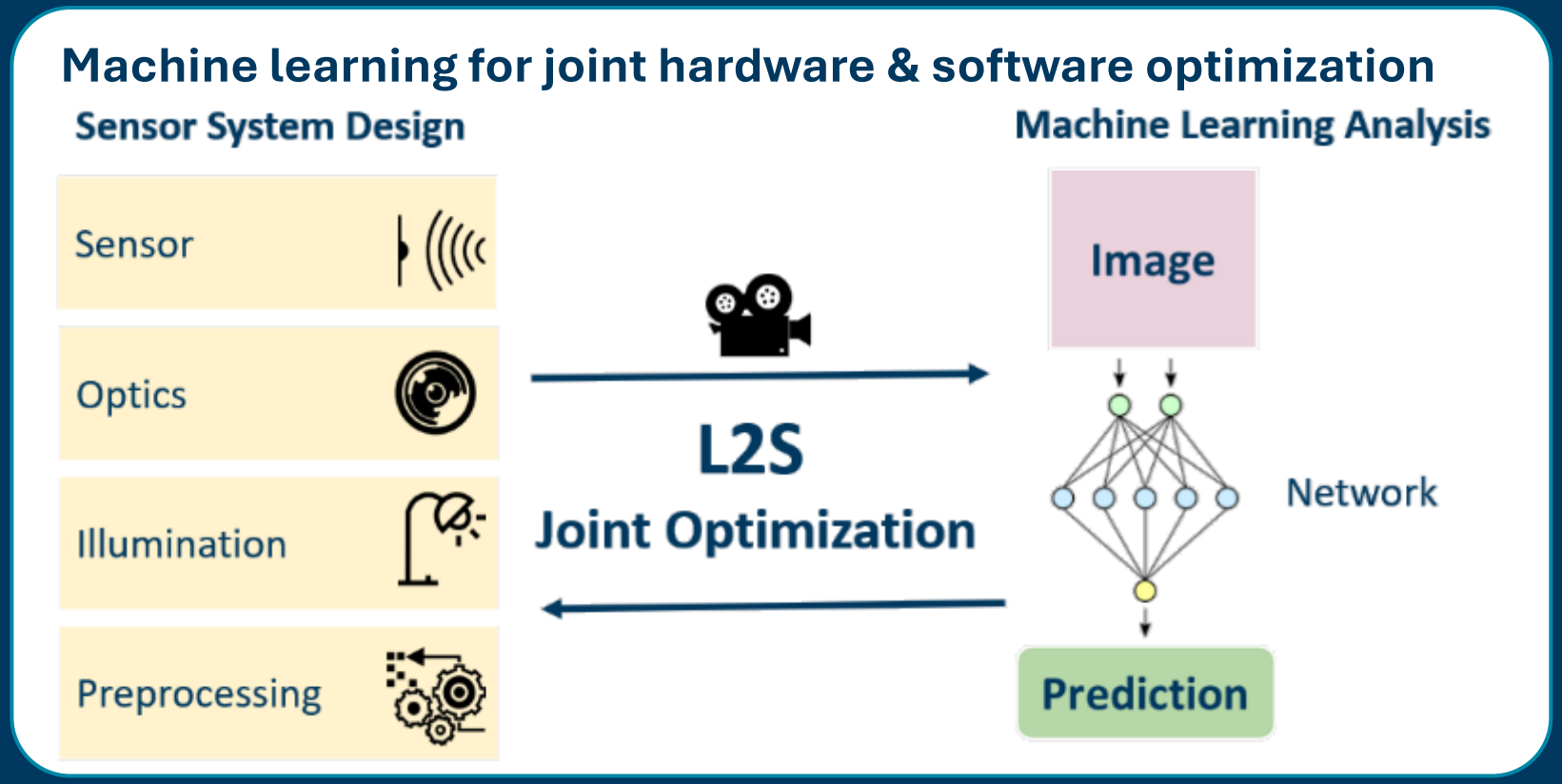
(Robust) Neural Architecture Search



From: *Differentiable Architecture Search,* AutoML Conference 2023 Workshops

Industry:
Sensors & processing for atrial fibrillations

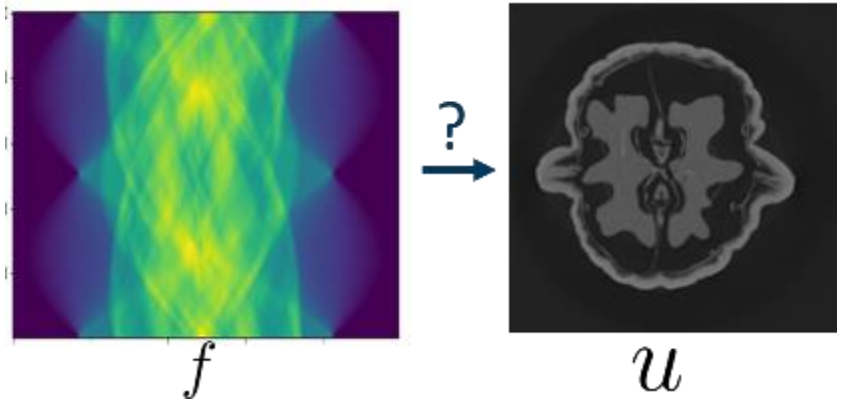
Inverse Problems in Imaging I

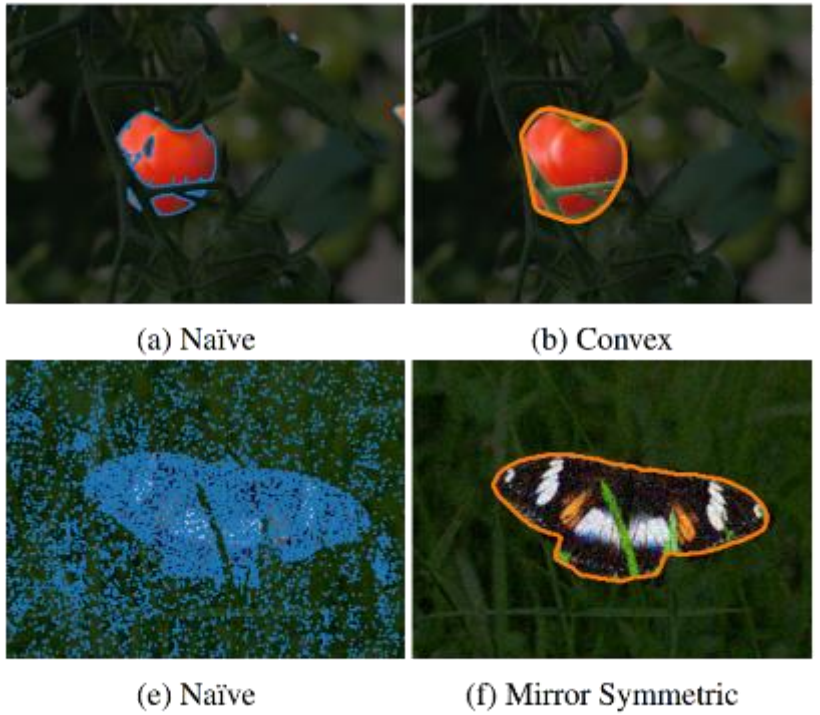


Inverse Problems in Imaging II

Understanding Machine Learning, e.g.

- **Inverse Problems** with provable guarantees
- **Implicit Representations** to constrain neural networks
- **Little training data**; language models





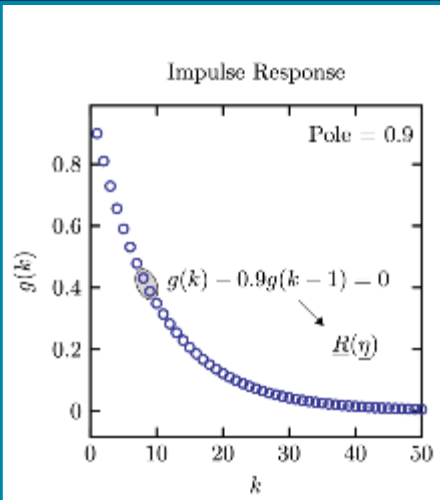
Automatic Control – Mechatronics

Prof Dr Oliver Nelles

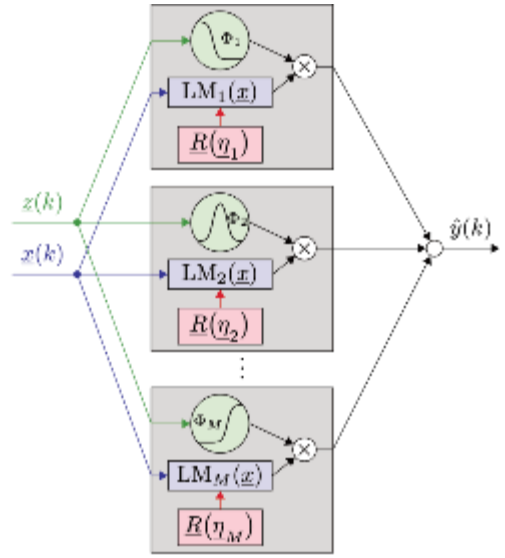
Nonlinear System Identification

Nonlinear Regularized Finite Impulse Response (FIR) Models

- Local Model Network consists of Many Local Linear/Affine Models
- Each Local Model represents an FIR Structure
- Specific Types of Regularization Incorporate Prior Knowledge
- Key Properties
  - inherently stable
  - gray-box
  - very robust w.r.t. model order and dead time
  - least squares estimation



(a) Properties of an impulse response of a first order process which can be used as prior knowledge.

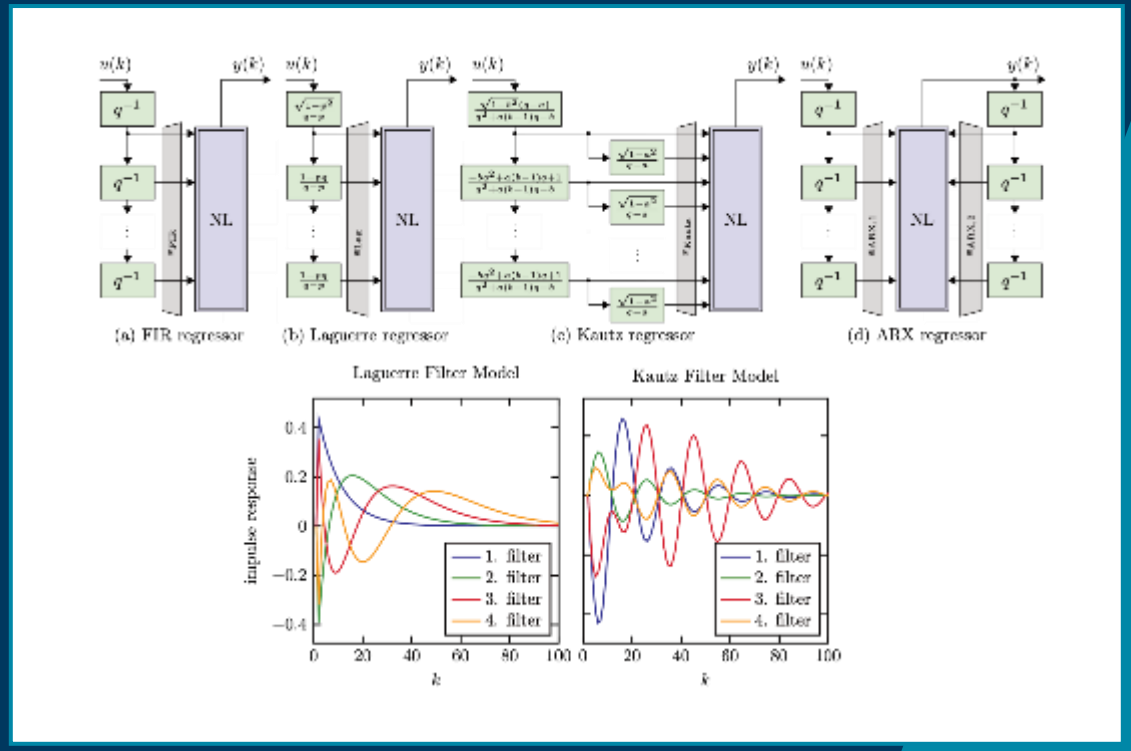


(b) Local model network with linear regularized FIR models (LM_i)

Nonlinear System Identification

Nonlinear Laguerre and Kautz Models

- Structured/Less Flexible Version of Regularized FIR
- Sparser than Regularized FIR
- Laguerre: Asymptotic Processes
- Kautz: Oscillatory Processes



Nonlinear System Identification

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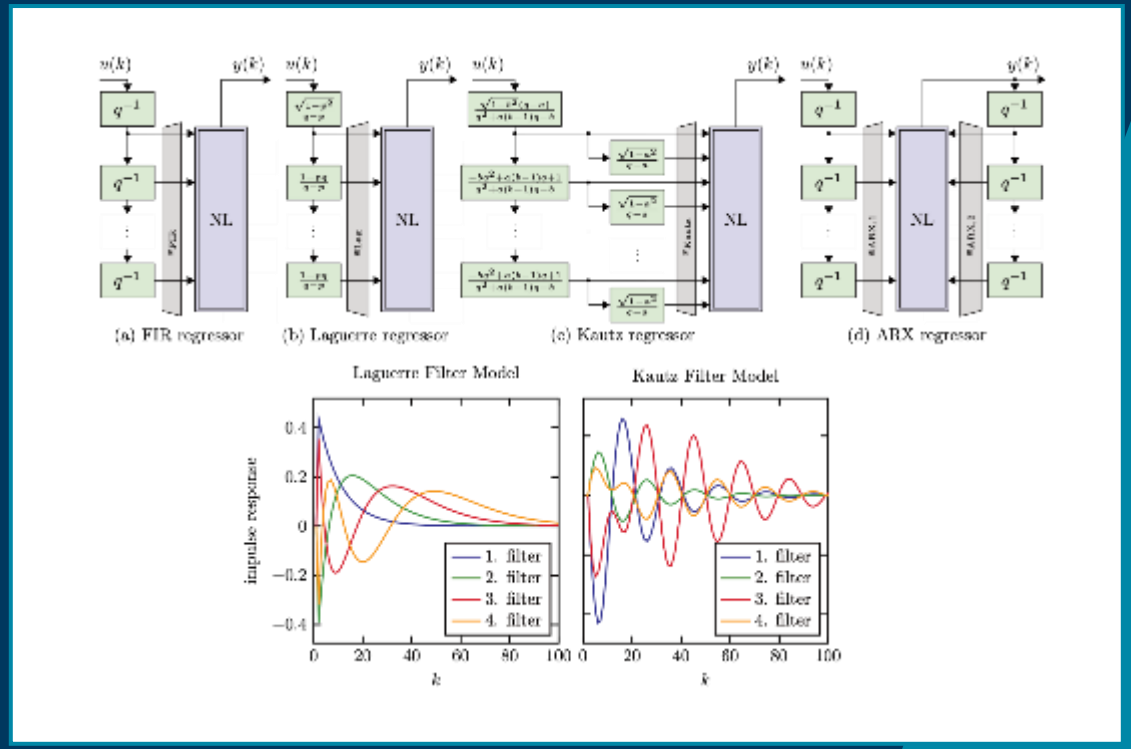
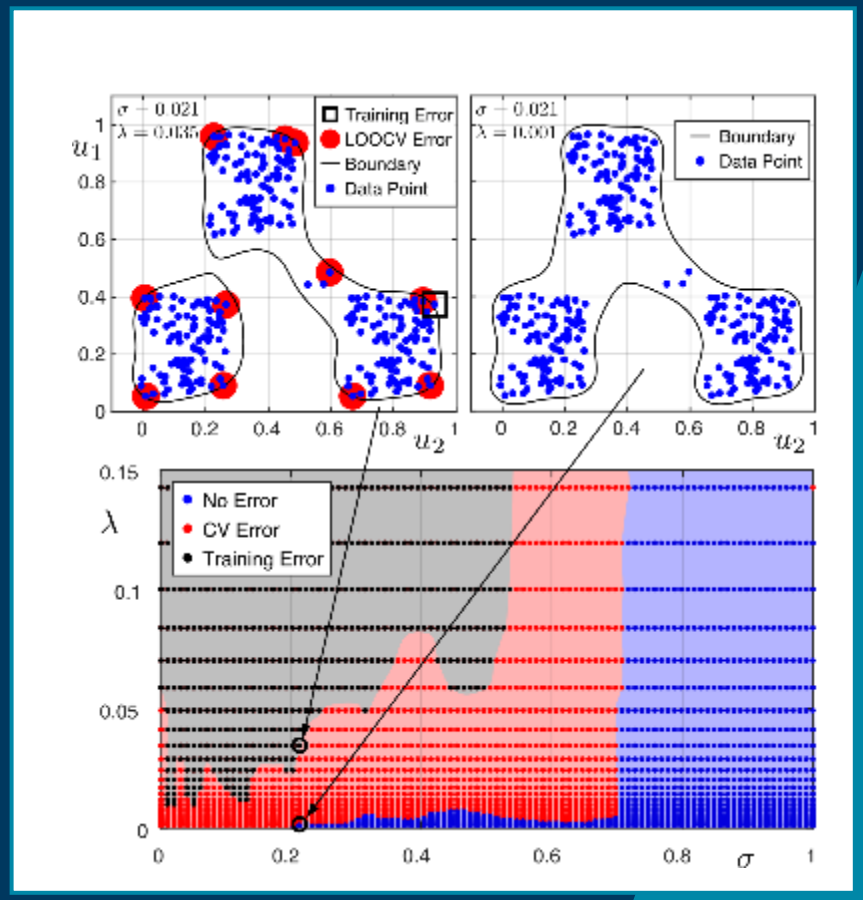


Classification and Diagnosis

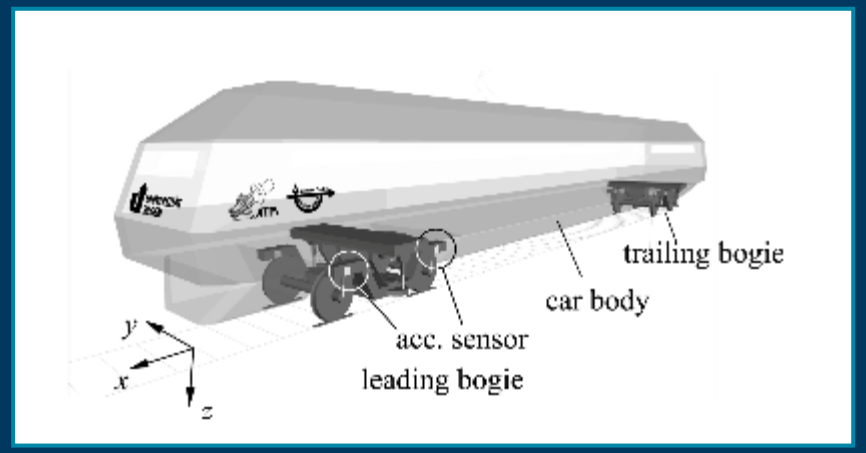
Robust One- and Two-Class Classifiers

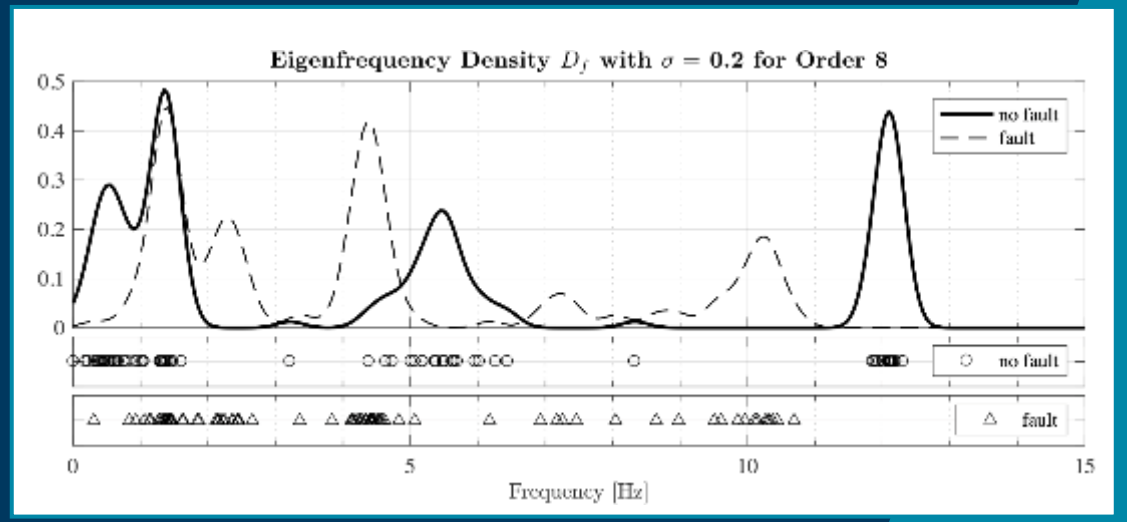
- Robust Classification Boundaries via Zero Leave-One-Out Cross-Validation Errors
- Classifiers based on Least Squares Estimation: LS-SVM or GPs or RBF Networks
- Efficient Computation of Leave-One-Out (LOO) Error
- Hyperparameter Tuning by Optimization of LOO Error
- Hyperparameters: e.g. Length Scale σ and Regularization Strength λ
- Different Strategies for One- and Two-Class Classifiers



Structural Health Monitoring (SHM) Using Probability Density Estimation

- Time Series Subspace Identification → Eigenfrequencies
- Eigenfrequencies for Sequences → Density Estimation
- Density → Fault Diagnosis





Technical Thermodynamics

Prof Dr Thomas Seeger

ZESS Senior Speaker & Member of the Board

Forschungsschwerpunkte

- Verbrennungstechnik
- Turbulente Verbrennung
- Motorische Verbrennung, Brennverfahren
- Lasermesstechnik
- Effiziente Energienutzung
- Adsorptionstechnik
- Wärmeprozesse

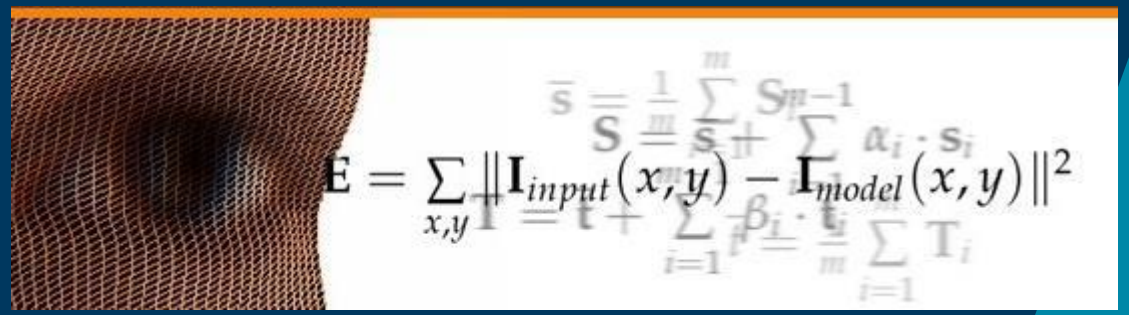
- Optimierung von Strömungs-, Wärme- und Stofftransport
- Methoden der optischen Lasermesstechnik
  - Particle-Image-Velocimetry
  - Planare Laserinduzierte Fluoreszenz
  - Planare Rayleighstreuung
- Computational Fluid Dynamics (CFD)
- Berechnung von Strömung und Optimierung, Reaktion und Wärmetransport

Media Systems

Prof Dr Volker Blanz

Research Focus

- Computer Graphics
- Machine Vision
- Machine Learning
- Human Perception
- Learning-Based Modelling of Objects

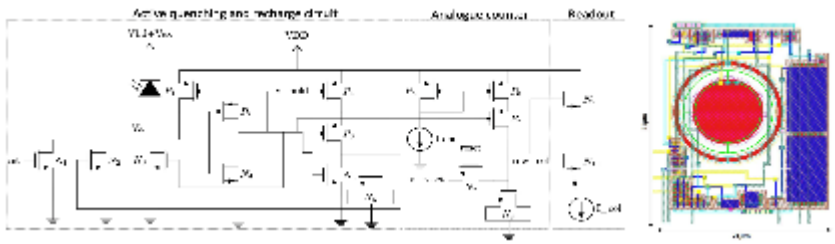


Integrated Analogue Circuits and Image Sensors

Prof Dr Bhaskar Choubey

Skills

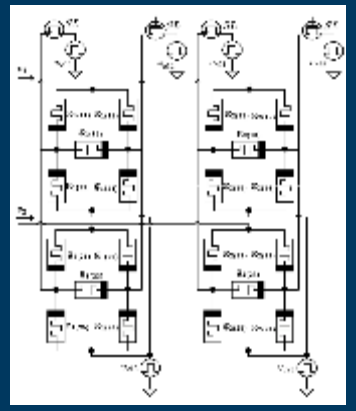
- CMOS Image Sensors
  - Wide dynamic range imaging
  - Single Photon Imaging
- Analogue and mixed signal chip design
  - Neural networks on chip
- Microelectromechanical resonant sensors

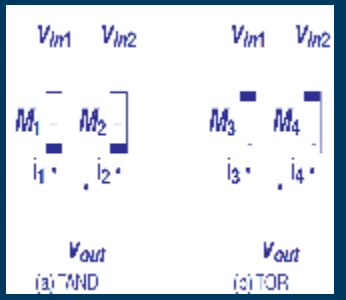


Schematic and layout of the compact SPAD pixel

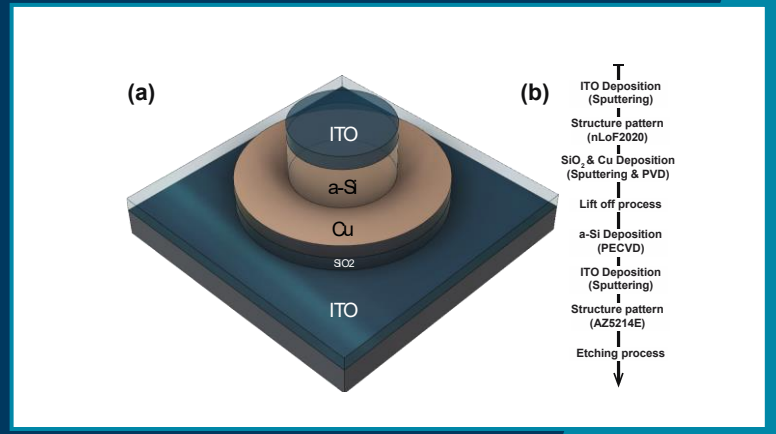
Current Work

- **Memristors and its integration with CMOS Circuits**
  - AI Accelerators
  - Analogue circuits using Memristors
  - Low power intelligent sensors for Edge
- **Intelligent image sensors**
  - New geometries, resolutions and image acquisition pathways
  - Surround view imaging systems
- **Single photon imaging**
  - UV imaging using silicon systems
  - Amorphous silicon and amorphous Germanium detectors
- **Learning in business processes**
  - Liquidity and credit management





The TAND gate and TOR gate

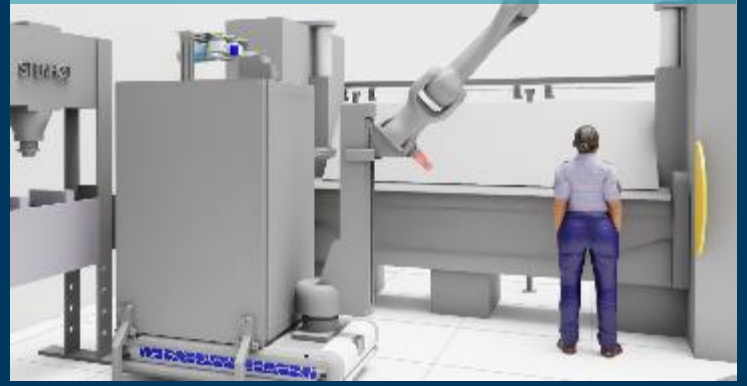


Production Automation and Assembly

Prof Dr Martin Manns

„Montage der Zukunft“

Robotik in der Produktion



HiSMoT

SkaLab 3D FORMING

Montage-Planung

Flex4Res

MOSIM

Additive-Subtraktive Fertigung

smaps Infrastruktur

RoboPutz

Walzist

Numerical Analysis

Prof Dr Thorsten Raasch

Forschungsschwerpunkte

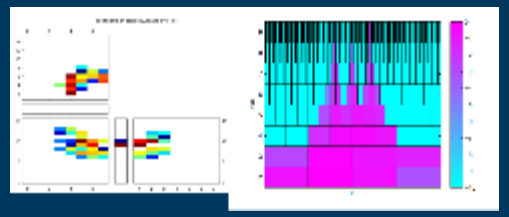
- Analysis numerischer Verfahren, insbes. Stabilität und Konvergenzuntersuchungen
- adaptive Finite Elemente und Wavelet Methoden
- Numerik inverser Probleme, insbes. bei Inverser Wärmeleitung, Parameteridentifizierung, Gebietsoptimierung
- singulär gestörte gewöhnliche und partielle Differentialgleichungen
- Approximationstheorie, Splines

Research Topics

Adaptive Discretization Methods

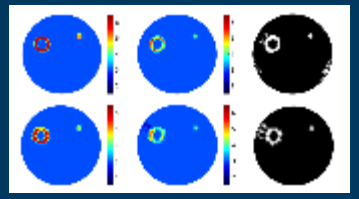
- A posteriori error estimation
- Convergence and complexity analysis
- e.g., adaptive FEM, wavelet and Fourier methods

$$\|u - u_{\Lambda^k}\| \approx ? \;\Rightarrow\; \begin{cases} \Lambda^{k+1} := ? \\ \#\Lambda^{k+1} \approx ? \end{cases}$$



Numerical Solution of Inverse Problems

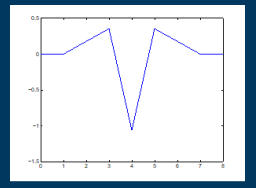
- Variational, Tikhonov-type regularization methods
- Nonsmooth, high-order numerical optimization
- e.g., smooth+nonsmooth functionals, bilevel problems

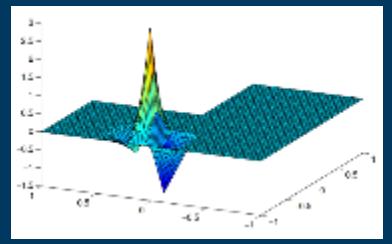


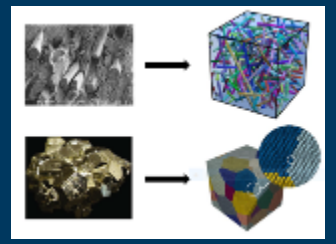
$$x \in \arg\min_{y \in H} f(y) + g(y)$$
$$\Leftrightarrow F(x) := x - \mathrm{prox}_{tg}\left(x - t\nabla f(x)\right) = 0$$

Numerical Fourier and Wavelet Methods

- Wavelet-based solvers for PDEs
- Hybrid schemes with redundant ansatz systems
- e.g., particle-continuum models, hp-FEM, quarklets

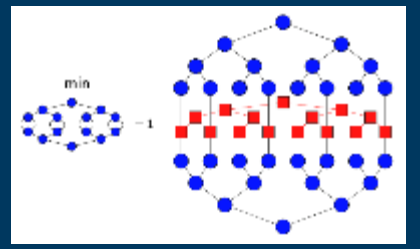


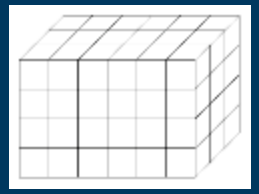




Numerical Multilinear Algebra

- Large-scale, structured eigenvalue problems
- Tensor decomposition
- Tensor eigenvalue problems



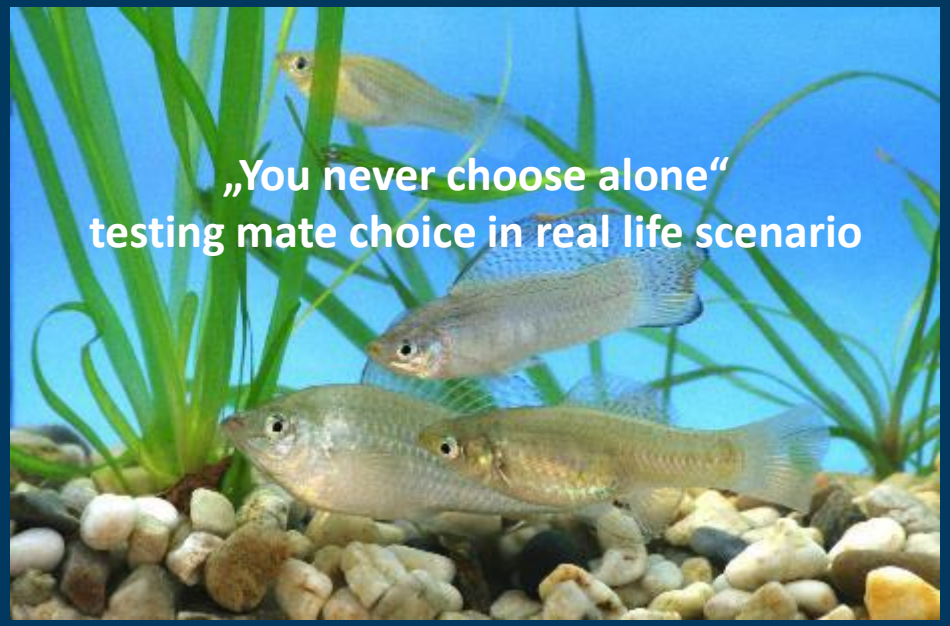


$$\mathcal{T} = \sum_{k=1}^{r} \lambda_k \mathbf{v}_k^{\otimes d}$$

Ecology and Behavioural Biology

Prof Dr Klaudia Witte

Social factors in mate choice



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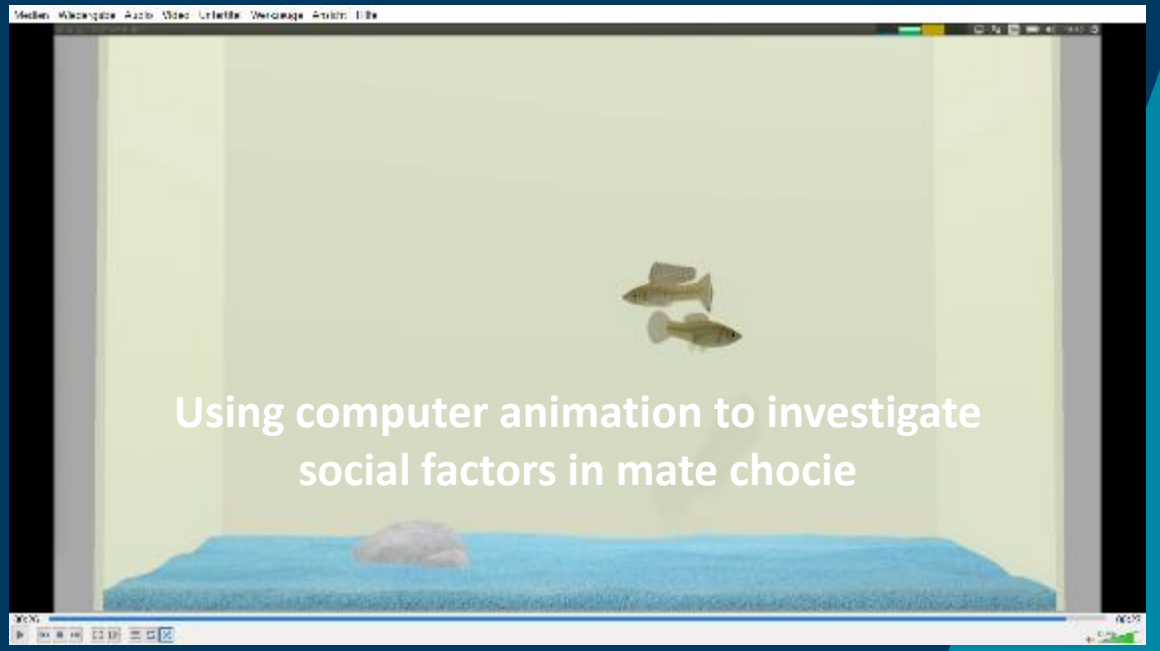
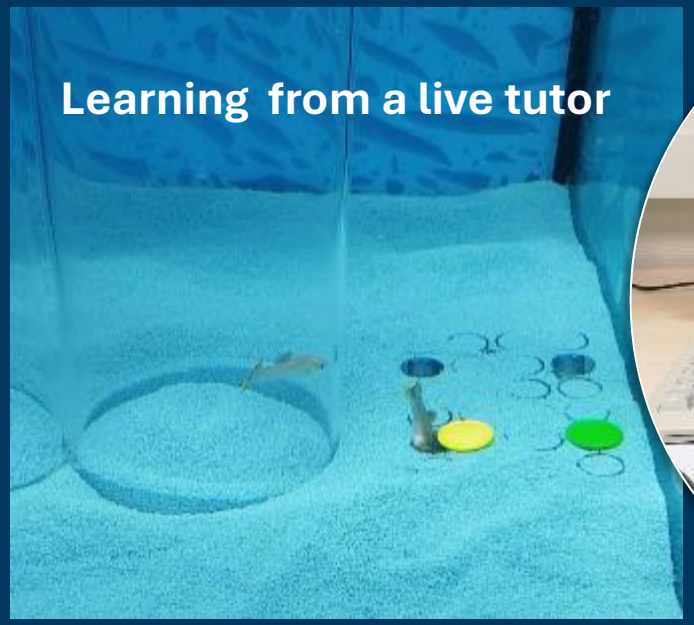
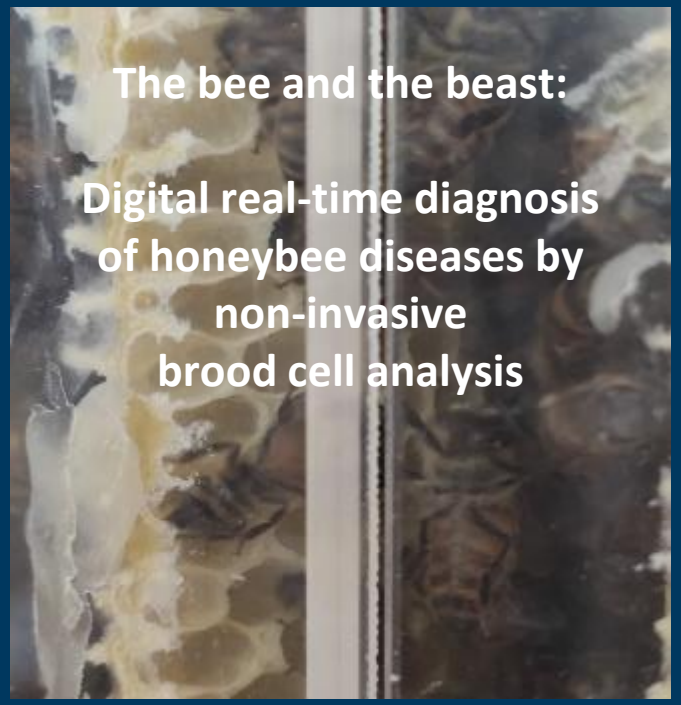


Social learning when foraging



Sensor Innovation to protect honeybees



AI in nature conservation