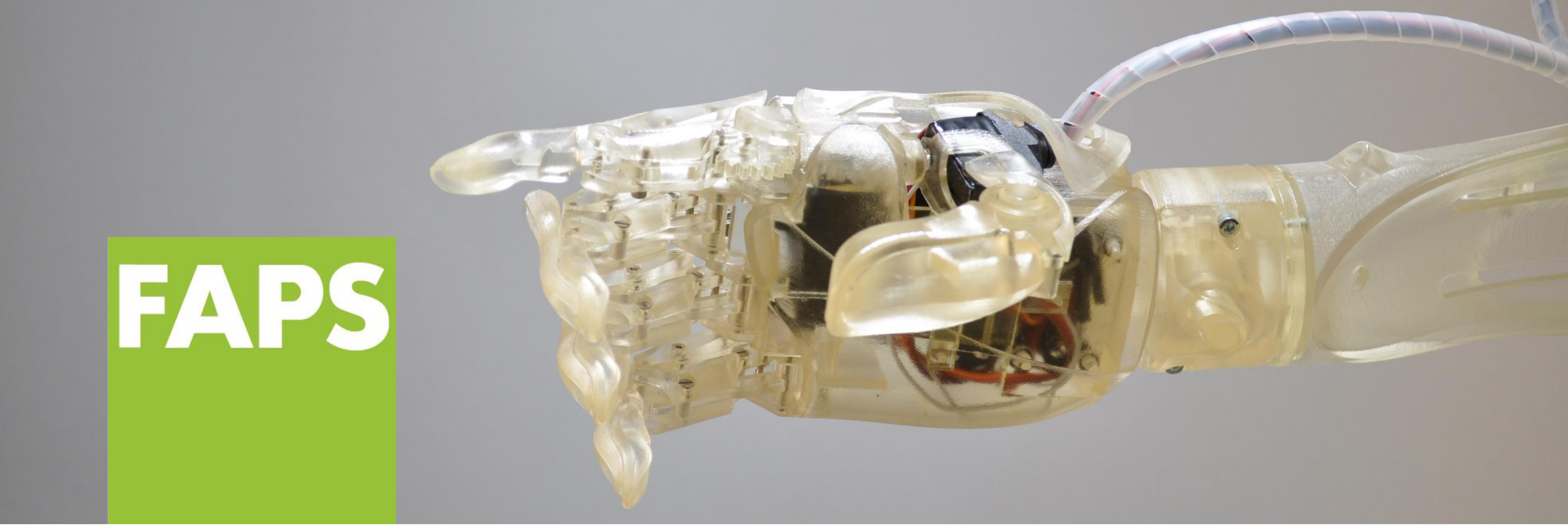


Research Sector Medical Technology

Prof. Dr.-Ing. Jörg Franke

Institute for Factory Automation and Production Systems

Friedrich-Alexander University Erlangen-Nuremberg

Friedrich-Alexander-Universität
Technische Fakultät

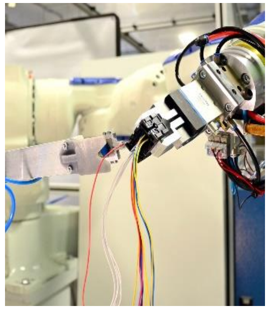
FAPS

The Institute for Factory Automation and Production Systems (FAPS) is researching the production and assembly of mechatronic products.

Electronics Production

Electro-mechanical Engineering

Wiring Systems



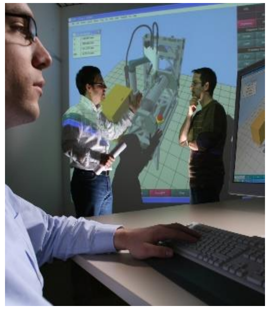
Home Automation

Medical Technology

Robotics

Automated Production Systems

Engineering Systems



Auf AEG Nuremberg

Technical Faculty Erlangen

FAPS

The Institute for Factory Automation and Production Systems (FAPS) is researching the production and assembly of mechatronic products.

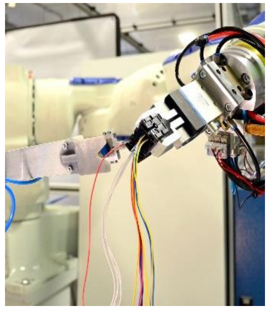
Electronics Production

- Flexible printed circuits
- 3-D MID
- SMT-assembly
- Optoelectronic AVT
- Power electronics
- Quality assurance/ Reliability tests
- Structuring
- Printed electronics
- Additive manufacturing of mechatronics

Electro-mechanical Engineering

- Laser cutting
- Joining laminated core
- Magnet manufacturing, assembly, testing
- Winding technologies
- Impregnating
- Grouting
- Circuitry
- Test technologies
- Additive Manufacturing

Wiring Systems



- New topologies in Wiring systems
- Wire harness CAD
- Assembly and interconnection technologies
- 3D-MID antennas
- Automated assembly of wire harness
- Testing systems
- Assembly of control enclosures

Home Automation

- Home automation
- Energy-management
- Comfort & safety
- Communication and Infotainment
- Decentralized energy production /storage
- Intelligent, efficient heating systems
- Synergy of mobility and smart home

Medical Technology

- (Partly) autonomous assistance systems
- Mechatronic implants
- Automation of medical diagnostics
- Digitalization in medical technology
- Compatible sensors and actuators
- Individualized manufacturing

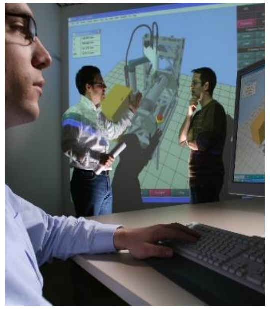
Robotics

- Sensors for detecting the environment and for interaction
- New kinematics and drives
- Safe control architectures
- Learning systems for control, navigation and interaction
- Industrial and service robots
- Personal robots
- Mobile Robots

Automated Production Systems

- Industrial Smart Services
- Service-oriented architectures
- Condition and process monitoring
- Semantic technologies for machine interaction
- Cloud-based platform solutions
- Communication technologies
- Data Analytics and Machine Learning

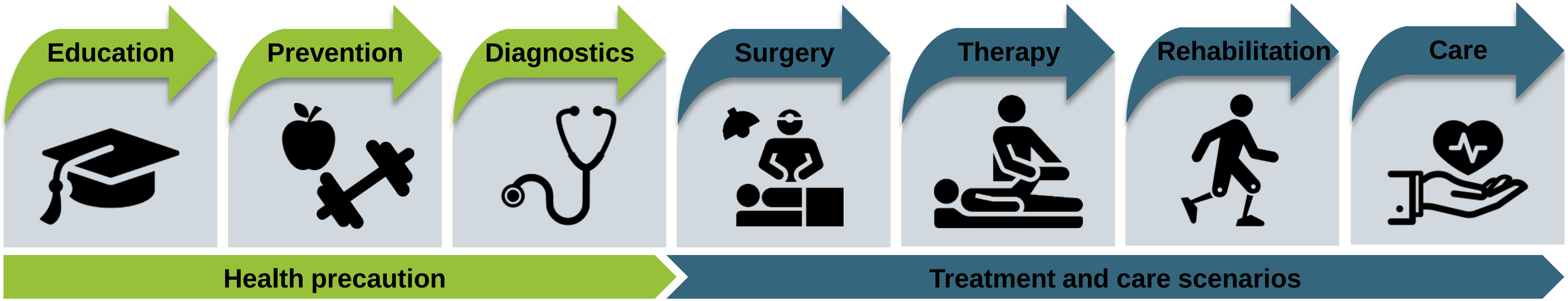
Engineering Systems

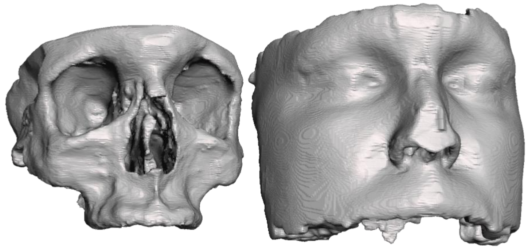


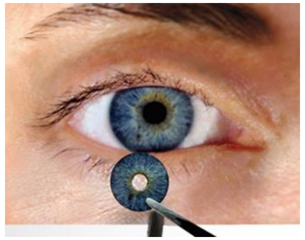
- Integrated Engineering
- Planning of production systems and intralogistics
- Development of digital process chains
- Process automation in engineering
- Engineering of resource-efficient production systems
- Human-Machine-Interaction (VR, AR)

FAPS

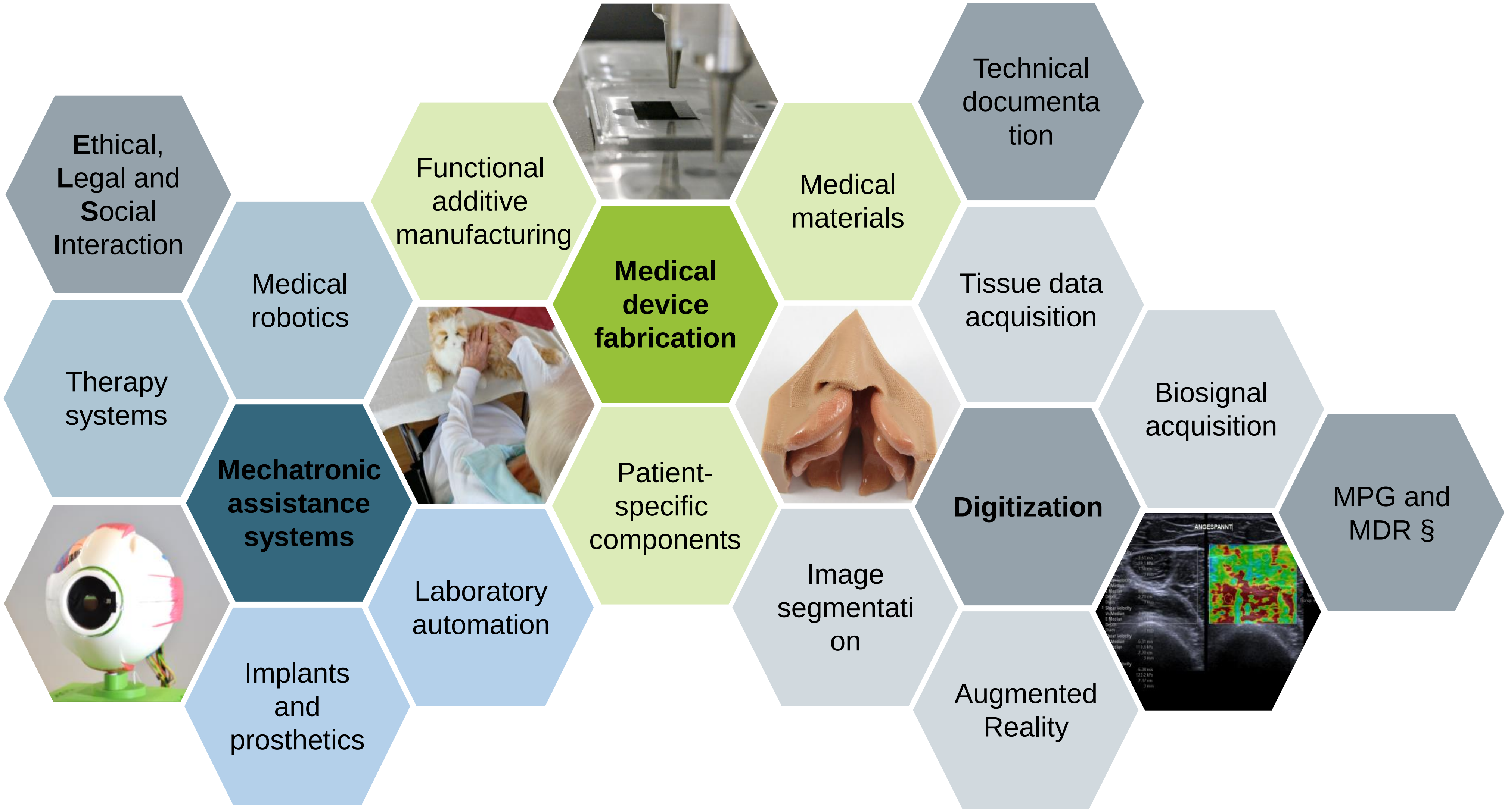
The research sector Medical Technology explores technologies that contribute to human well-being, addressing the entire medical supply chain.







In doing so, we apply the knowledge of automation and mechatronic systems from the industrial environment to the tasks of medical technology.



To increase the visibility and outreach of medical technology at FAPS, we present current research at external events and seminars.

FAPS-Seminar Medical Technology

“New manufacturing strategies in medical technology“

"Mechatronic assistance systems directly on humans"

"Digitization in Medical Technology – Towards the Human Digital Twin".

FAPS Medical Technology at trade fairs

03. - 05.05.2022: Medtec LIVE & T4M, Stuttgart

14. - 17.11.2022: Medica, Düsseldorf

In recent years, a network of different research partnerships in the field of medical technology has been established.

MEDICAL VALLEY
Europäische Metropolregion Nürnberg
SIEMENS Healthineers
ottobock.
ZiMT
ZENTRALINSTITUT FÜR MEDIZINTECHNIK
audEERING™
intelligent Audio Engineering
BAM
PRÄZISIONSFERTIGUNG
SONDERMASCHINENBAU
MATERIALSERVICE
Fraunhofer
IIS
C&S
managing care.
HUMANOPTICS
innovations manufaktur
ASTRUM IT
EARLIEBIRDIE
GESUNDHEITSMANAGEMENT FÜR MÄNNER
YASKAWA
Universitätsklinikum Erlangen
SIOUX
TECHNOLOGIES
HUMBOLDT-UNIVERSITÄT ZU BERLIN
FAU
FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT
infoteam
software
Ostbayerische Technische Hochschule
Amberg-Weiden
VÖLK ORTHOPÄDIE
„Gesundheit von Mensch zu Mensch“
BMAB
Bundesverband für Menschen mit Arm- oder Beinamputation e.V.
Urban & Kemmler
Centrum für technische Orthopädie
reha team Ostbayern
AWO
movi mento
Bewegen. Unterstützen. Entwickeln.
adidas
ANAMOS
WACKER
ACEO

Prosthetic fitting is currently a manual procedure based on the skills and knowledge of the prosthetist.

Current standard for prosthetic fitting

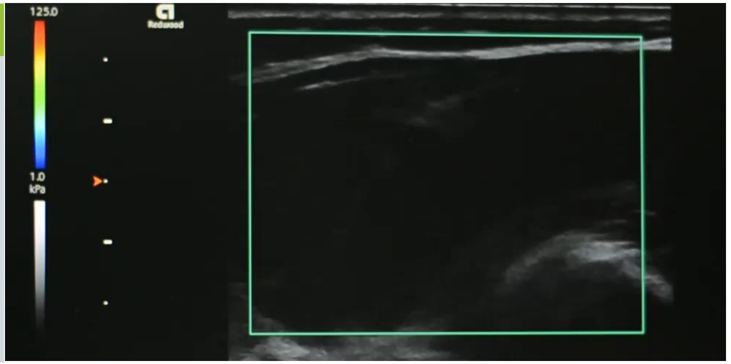
- Physical modeling of a plaster cast based on the manually captured tissue structure
- Difficulty: High dependence on the competence of the orthopedic technician

Quelle: Ottobock

Detection of tissue structure by ultrasound elastography

Shear Wave Elastography (SWE)

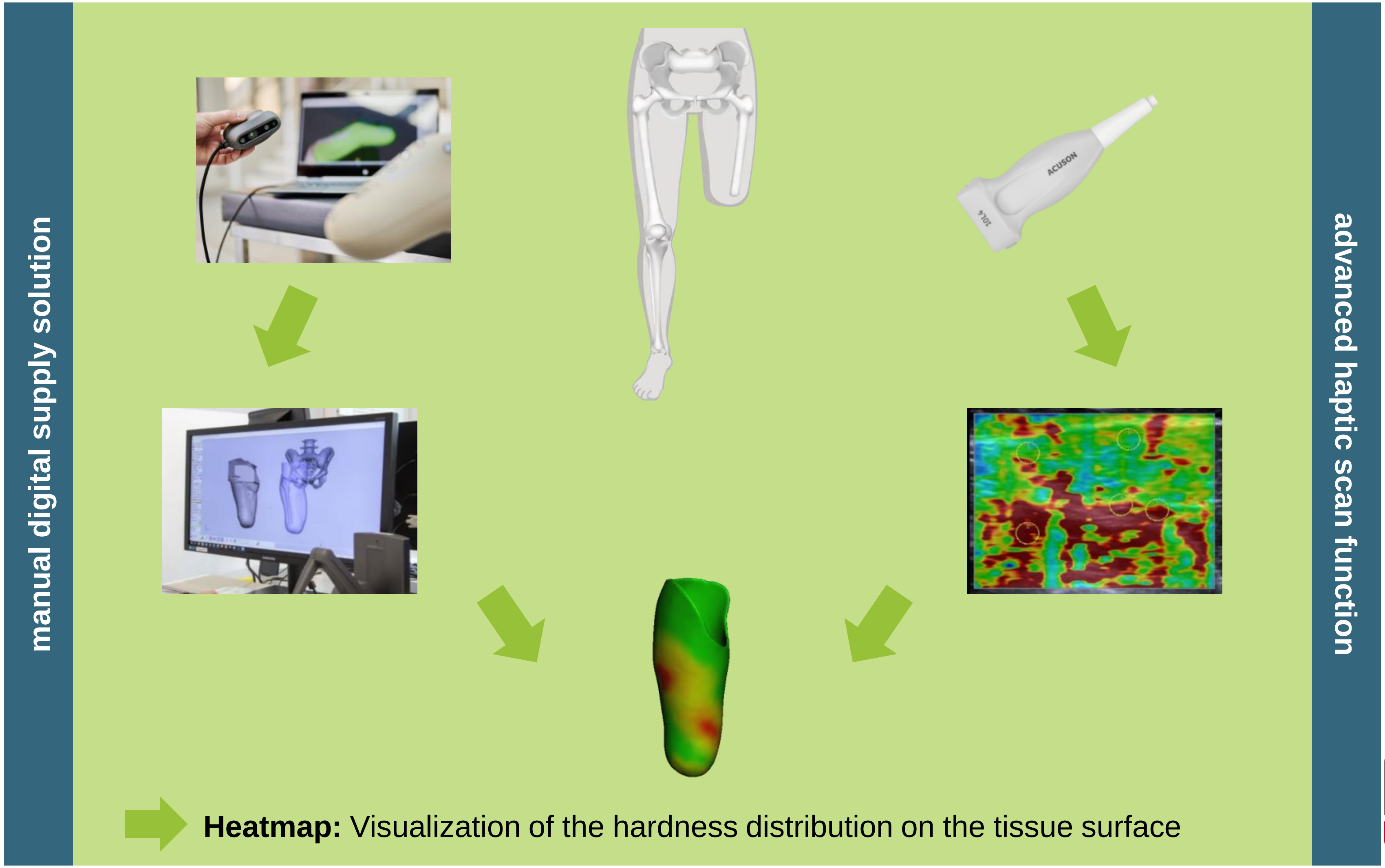
- Measurement of the propagation speed of the shear waves in the tissue
- Quantification of elastic tissue properties (in kPa)



Digitalization of the workflow through the fusion of quantified tissue data with surface data

Objective assessment and consistent prosthetic supply	**Individualized and more efficient patient care**	**Reduced number of revisions and repeated adjustments**

The acquired tissue data is fused with the data from a surface scan to create a holistic information basis for prosthesis fitting.



ottobock.

Ostbayerische Technische Hochschule Amberg-Weiden

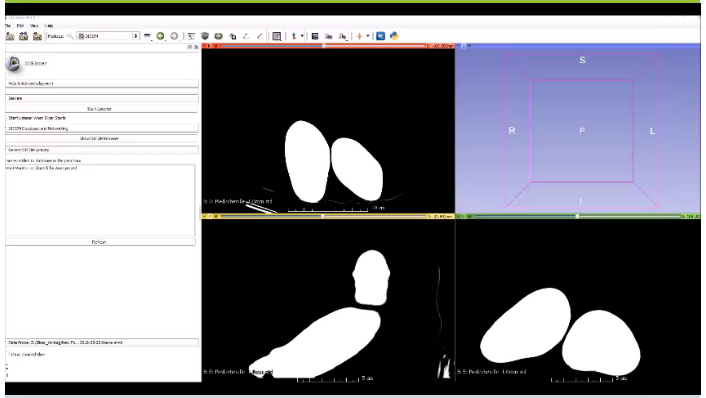
Ergo-Tec

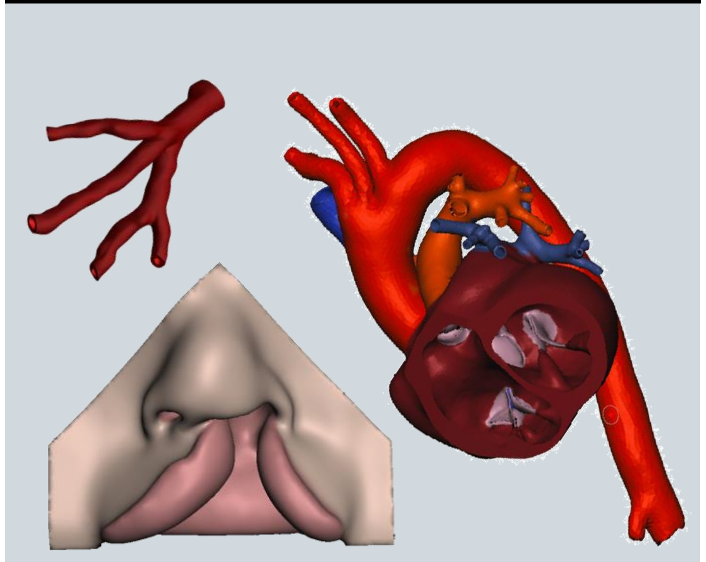
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

FAPS

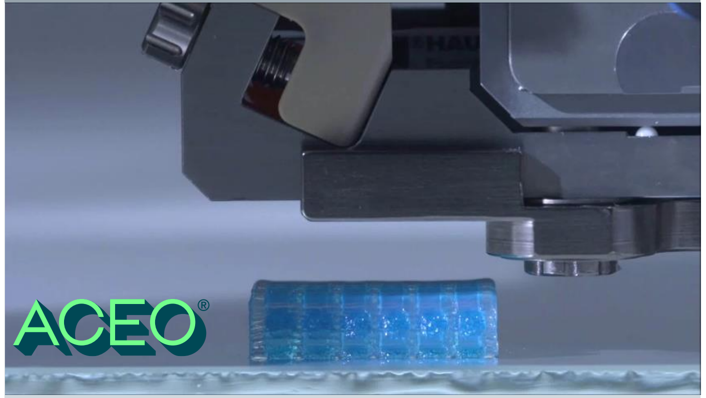
Haptic models of anatomical structures can be used for surgical simulation and should reflect the biological original as closely as possible.

Digital model creation based on CT/MRI data

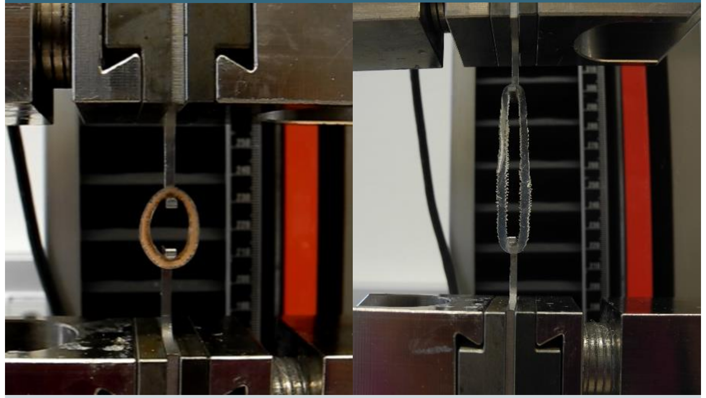




Additive manufacturing from silicone with various properties



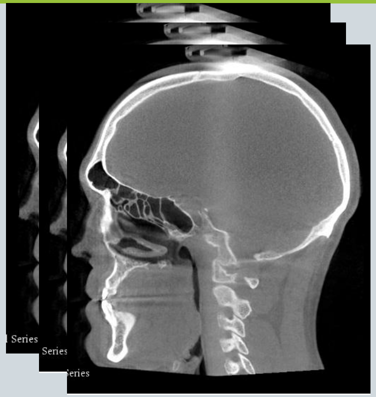
Biomechanical and clinical evaluation of the models



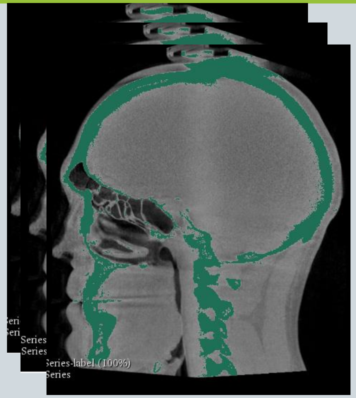
Based on medical image data, digital models can be created via segmentation and then manipulated as desired.

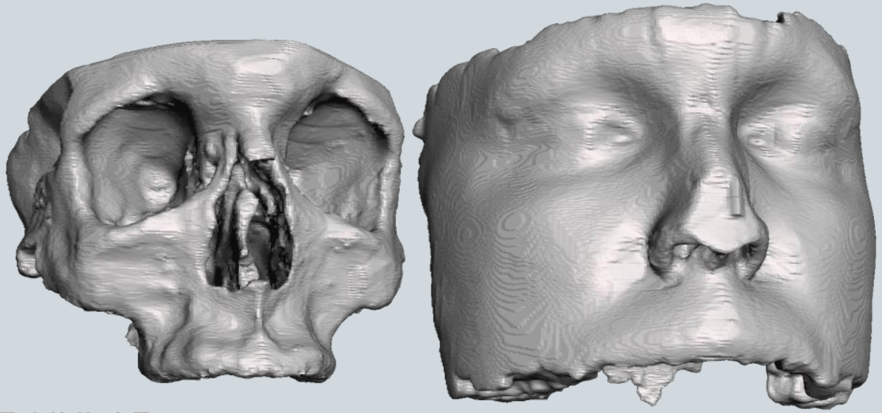
FAPS

Segmentation



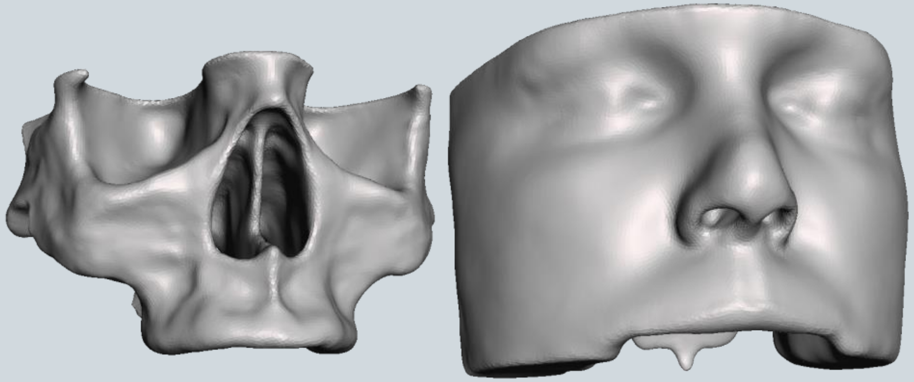
CT-Data

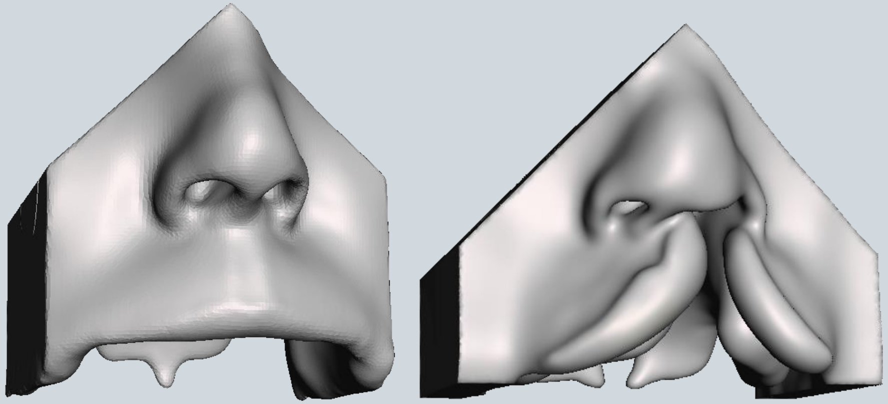




BRAINLAB

Manipulation

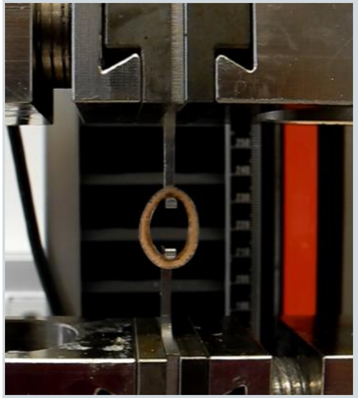




Cleft lip and palate

The biomechanical and clinical evaluation compare the characteristics of the models with the biological originals.

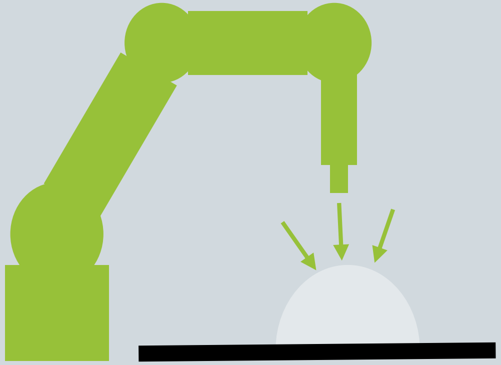
Biomechanical evaluation

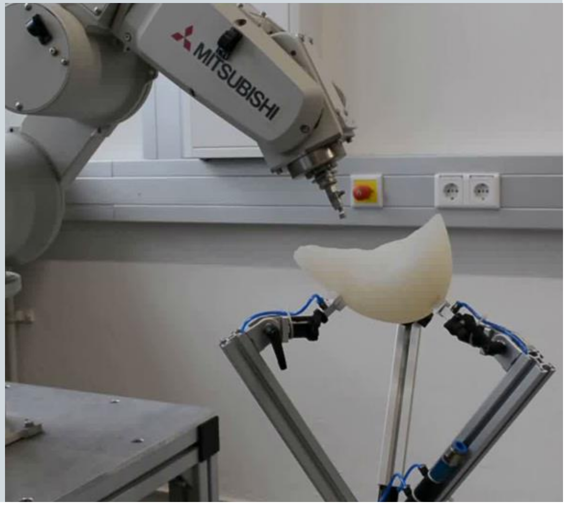


Tensile tests

Source: Optotechnik Zeiss

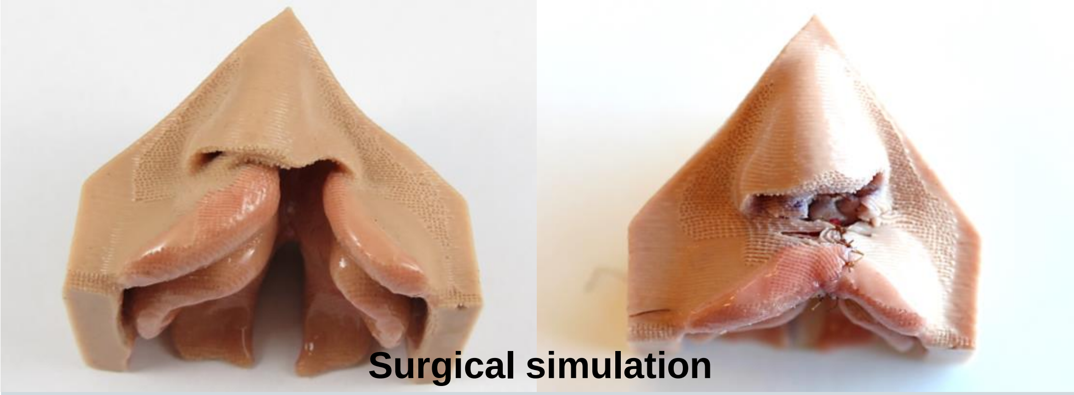
Deformation analysis



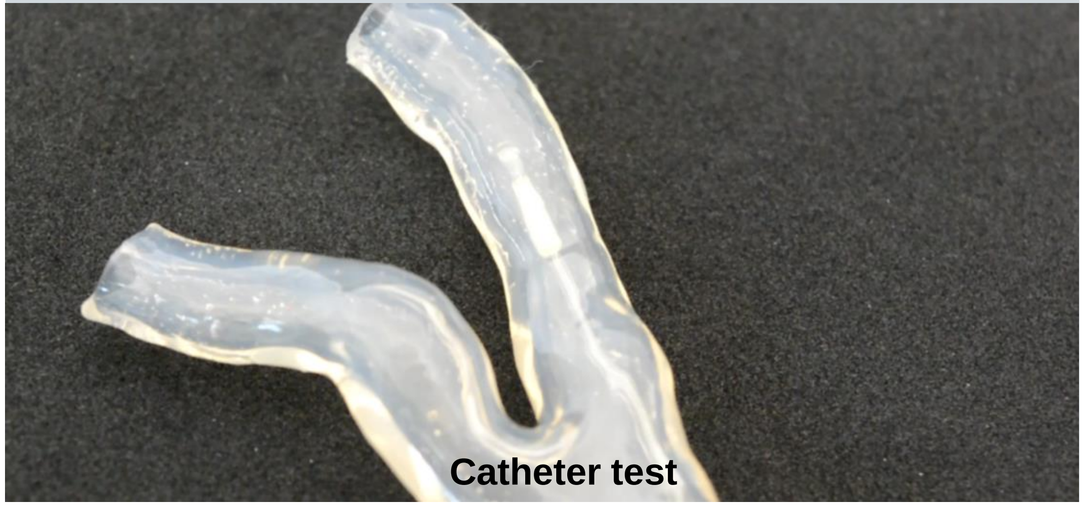


Palpation test bench

Clinical Evaluation



Surgical simulation



Catheter test

Within the ProLAM project, the silicone printing process is optimized by means of both geometry-optimized slicing and dynamic process control.

1 CAD model

2 Slicing

Geometry-optimized

3 Additive Manufacturing

Data acquisition

Parameter tuning

4 Optimized part

Digital process twin

Model of the material deposition mechanism + **Model of the temperature distribution**

Adaptive curing mechanism

- Investigation of different energy input mechanisms
- Optimization of printing parameters

Optimized material deposition

- Investigation of the influence of different printing parameters on the material behavior
- Increase in part accuracy and surface quality

Minimized pre- and post-processing

- Reduction in the number of test prints
- Increase accessibility for inexperienced users

→ **Pre- and in-process optimization**

Project timeline

WP1, 6 months
specification, sensor concept

WP2, 6 months
Sensor integration, data acquisition

WP3, 15 months
modelling, publication

WP4, 18 months
Model based optimization

WP5, 9 months
Project demonstrator, publication

Quelle: innovatiQ.com

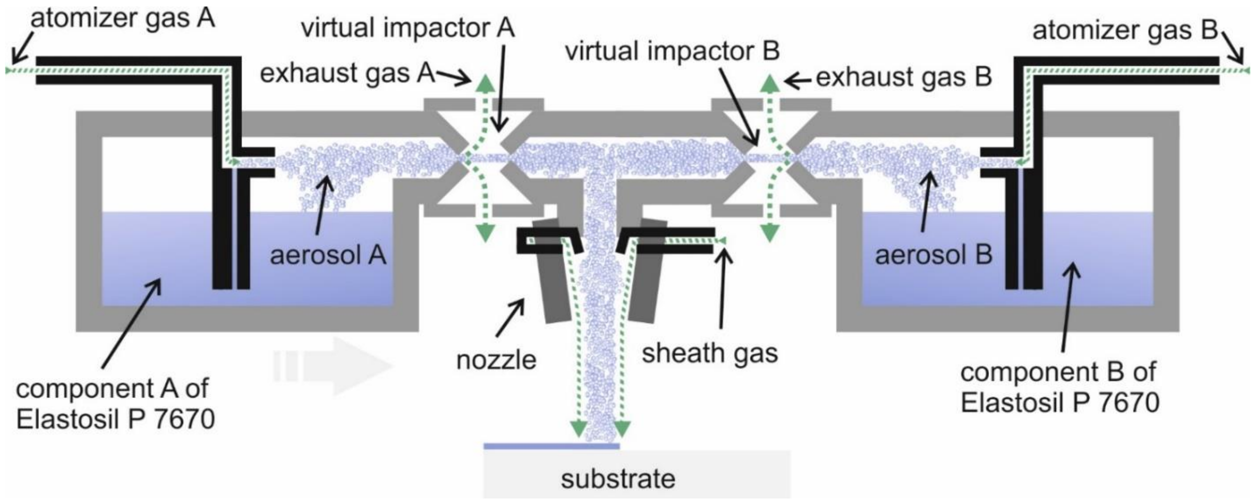
Direct additive manufacturing of silicone components offers advantages for the geometric complexity of the components and duration of the manufacturing process.

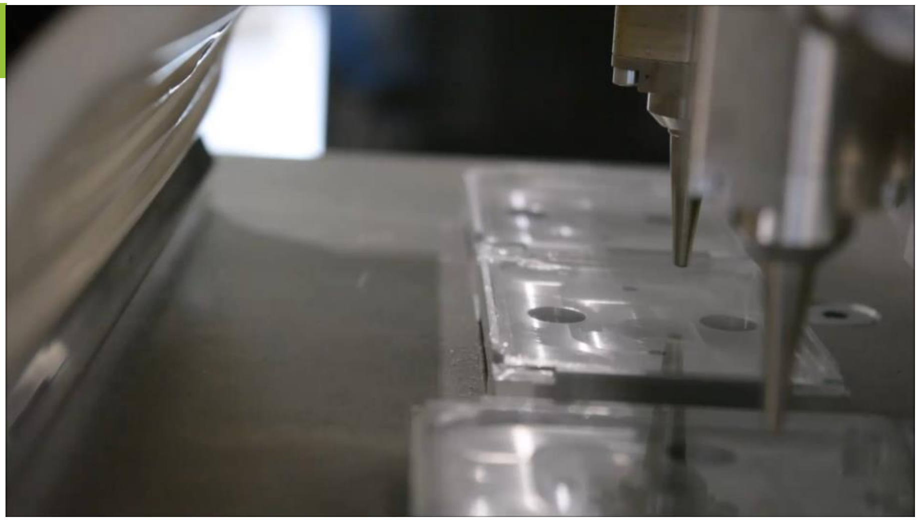
- Production of 2K material systems
- Temperature control and process control by cooling unit
- Use of different materials with different properties
- Modular system as "low cost" approach for different kinematics (e.g. FFF)

- Process adjustment/stabilization
- Expansion of the range of materials
- Use of multiple components and extruders
- Approaches for the production of overhangs
- Dynamic process control towards the desktop printer

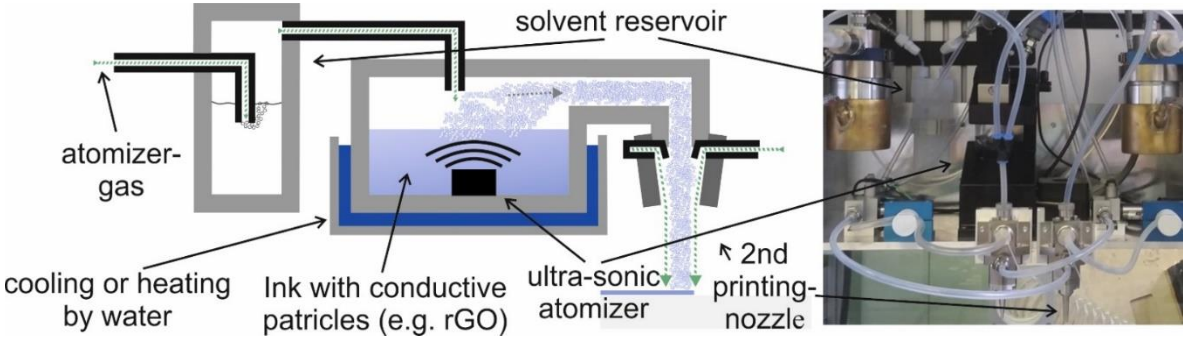
With the ability to print silicone structures and rGO inks in one process, the production of dielectric elastomer actuators for the realization of artificial muscles is possible.

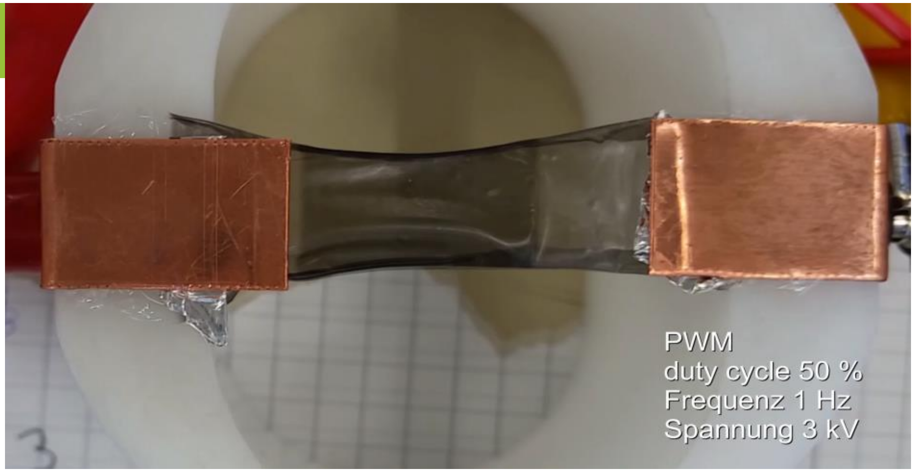
Aerosol jet printing of RTV-2 silicone





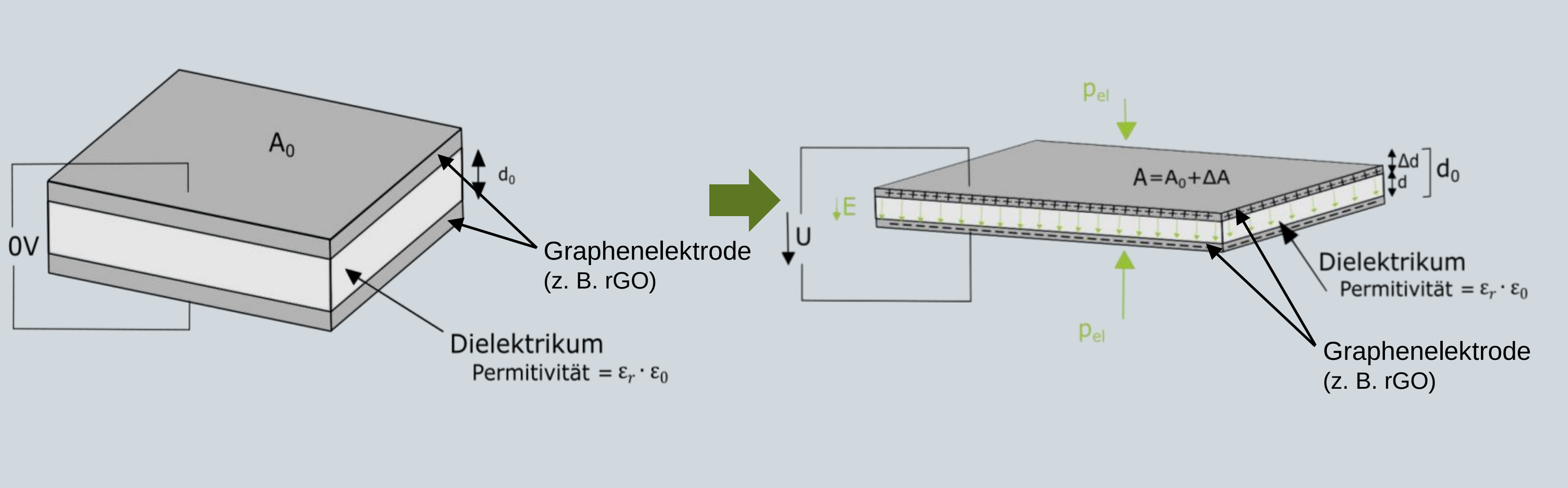
Fabrication of conductive graphene electrodes

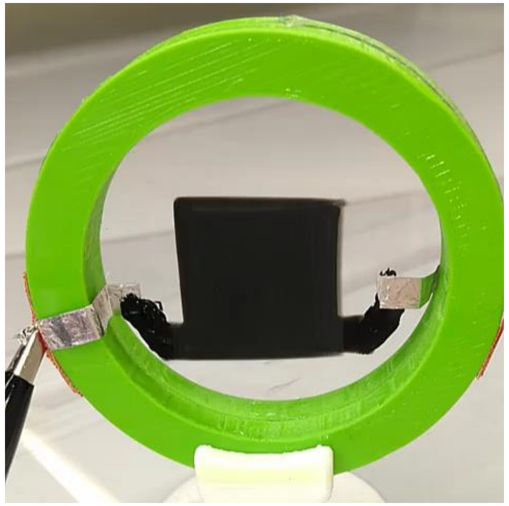




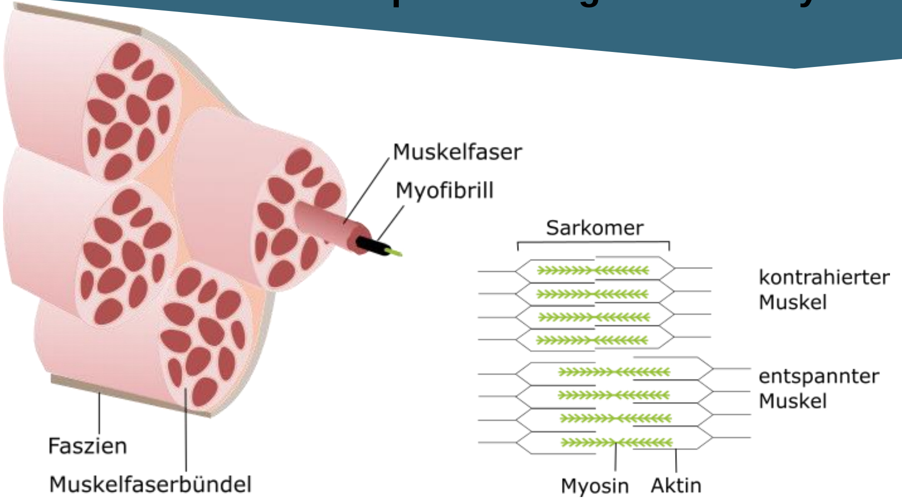
Dielectric elastomer actuators (DEA) are flexible mechatronic systems that are also referred to as "artificial muscles" due to their positive properties.

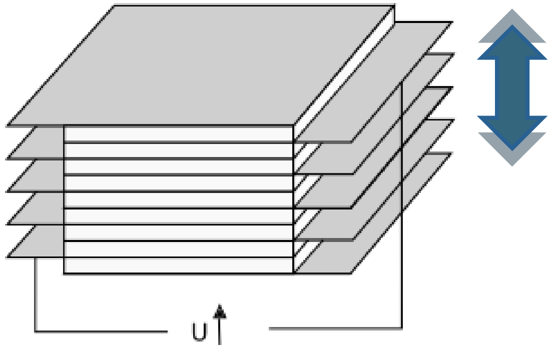
Operating principle of DEA

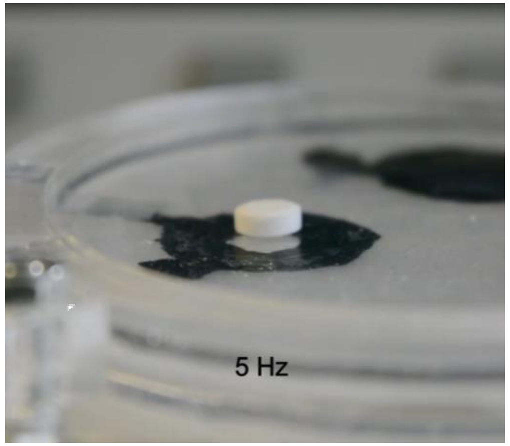




Amplitude magnification by addition of several units







The use of dielectric elastomers opens up new, bionically inspired possibilities in the field of sensors and actuators.

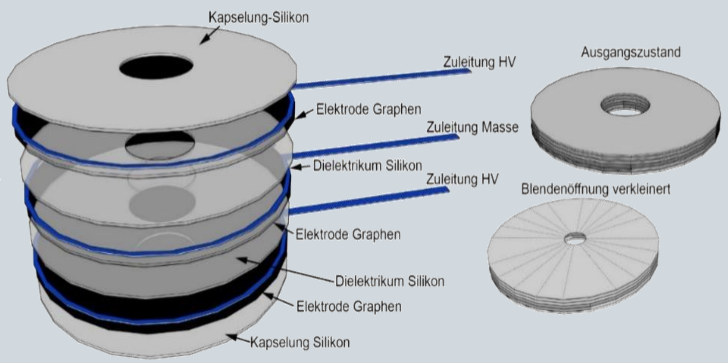
Properties

- Lightweight construction
- Silent operation
- Flexible structure
- Use as sensors & actuators
- Design freedom
- High efficiency

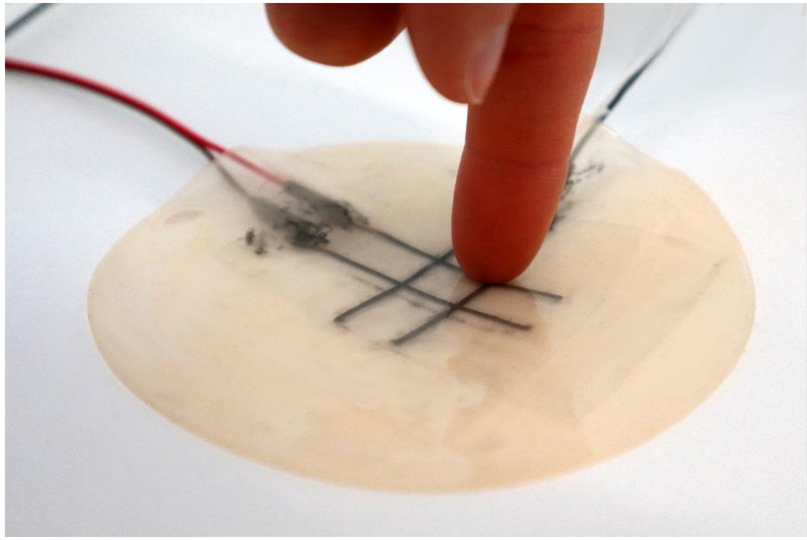
Bionics applications
Realization of technical systems based on nature

Soft actuator technology
Enables bending and stretching

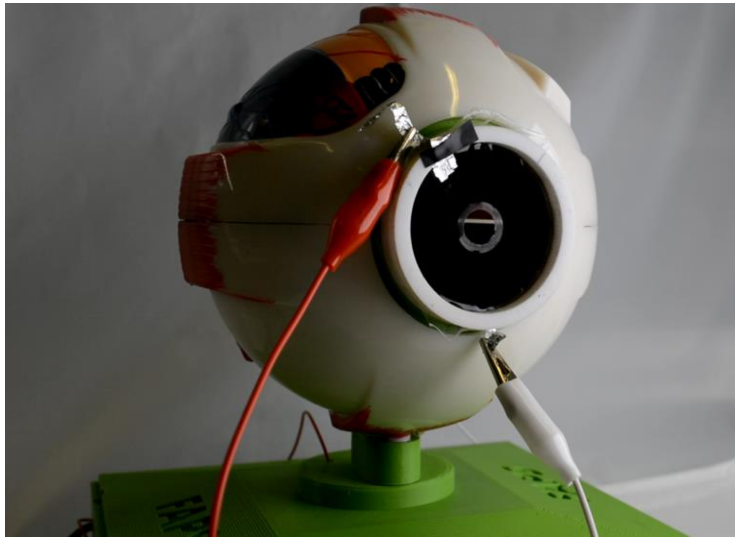
Detection of multiple DoF
Spatially resolved and self-detecting



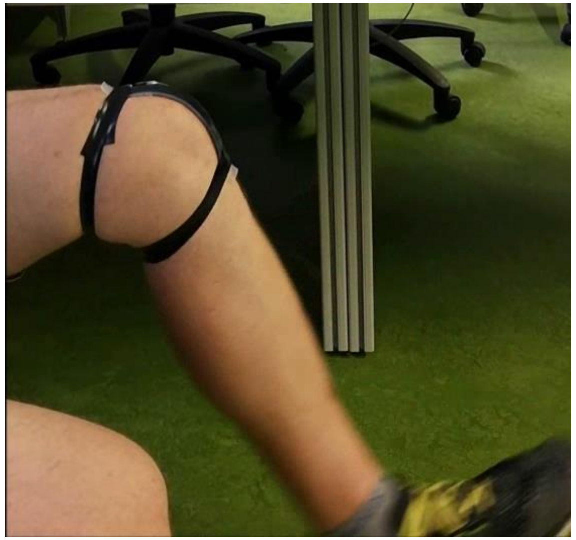
Bionic Application



- Artificial skin as a haptic interface



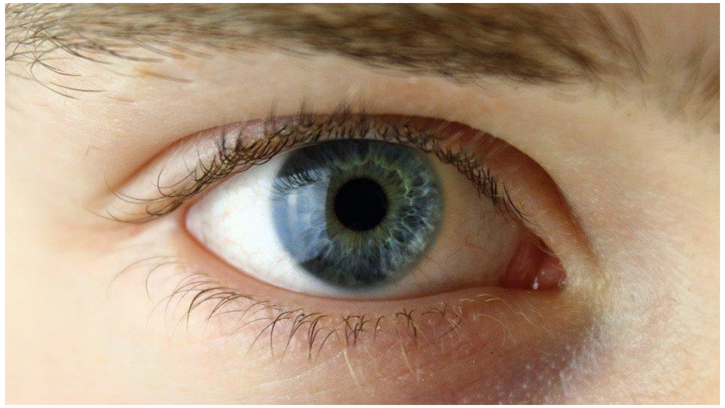
- Functional Iris Demonstrator from the ADAI project



- Application as strain sensor for motion capturing

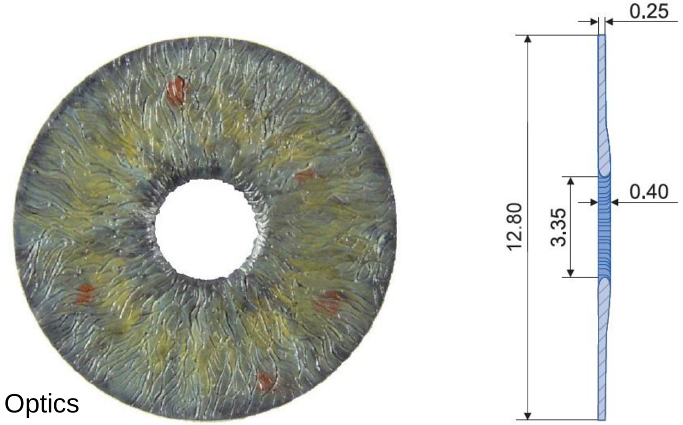
In the ongoing research project ADAI, a DEA-based iris diaphragm for implantation in the human eye is to be realized.

The eye as an point of focus



Until now

Artificial*IRIS* as a cosmetic replacement

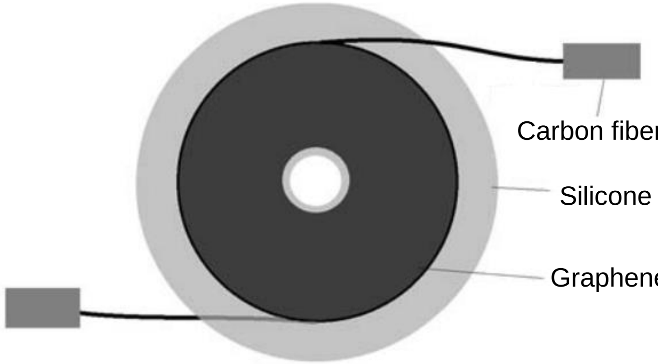


© Human Optics

HUMANOPTICS

Bundesministerium für Wirtschaft und Energie

Realization of pupil response through the aperture function of a DEA-based implant.

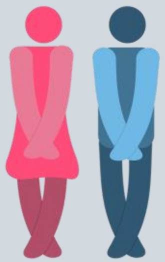


- **Fabrication of multilayer annular actuators using aerosol jet printing.**
- **Safe encapsulation and use of biocompatible materials**
- **Supply voltage >> 1kV**
- **Miniaturized power electronics for system control**
- **External power supply**

In the PARTIS project, research is being conducted into patient-friendly interaction with an artificial intraurethral sphincter.

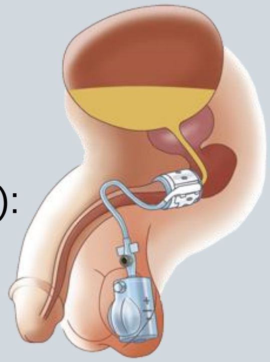
Urinary incontinence - Situation

- Approx. 5 million urinary incontinence patients in Germany alone
- considerable psychological burden and impairment of quality of life
- Increasing problem in medical and socio-economic terms



Problem

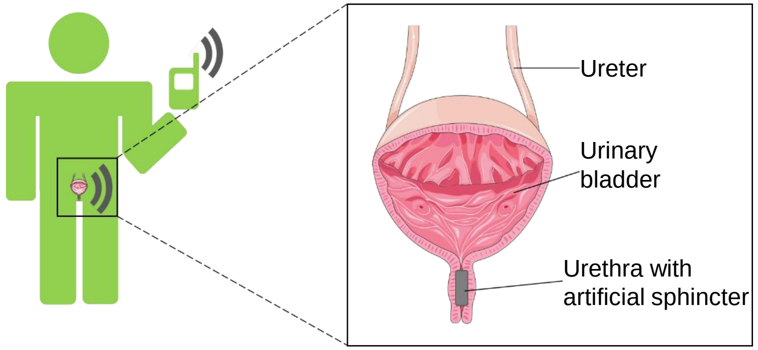
- Therapy methods are gender-specific, have serious disadvantages or do not help to achieve full continence.
- Mechanical, artificial urinary sphincters (AUS):
  - Invasive, multi-cavity interventions with complications
  - Often only applicable to male patients
  - Uncomfortable and indiscreet control by actuating the control pump positioned in the scrotum



Zephyr Surgical Instruments

Objective of the PARTIS project

- Background: Research on a miniaturised, mechatronic sphincter implant since 2016.
- Development of an intuitive and patient-friendly interaction option, as no such therapy system with which the patient interacts themself exists.

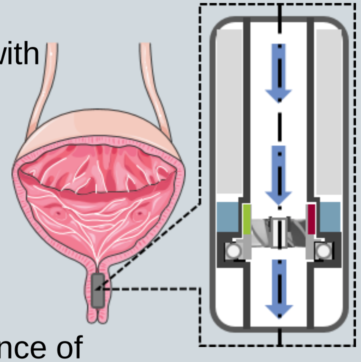


At the FAPS Institute, research is being conducted on various aspects of the mechatronic intraurethral implant in order to develop it holistically.

FAPS

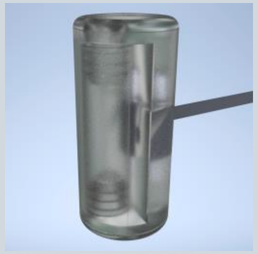
Energy harvesting from the urine flow

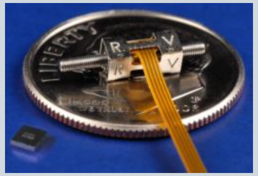
- Micturition: bladder is emptied at 20 - 35 ml/s with intravesical pressure of 25 - 80 cmH_2O
- Energy recovery through turbine-based micro-generator
- Complete integration in the implant to avoid perforation of the urethral tissue
- Prolongation of the implant's lifetime → Avoidance of subsequent surgical interventions to change the energy storage device



Bistable closure mechanism

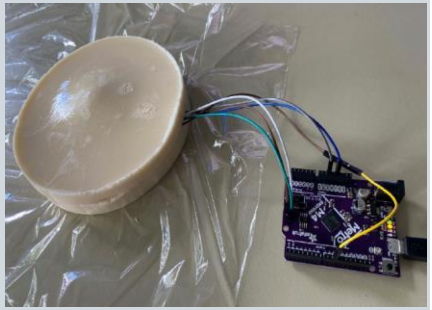
- On-demand release and blocking of the urine flow
- Bistable system to require energy only to change state
- Self-cleaning effect by oscillation of the tubing system to avoid biofilm formation
- Micropiezomotor as actuator





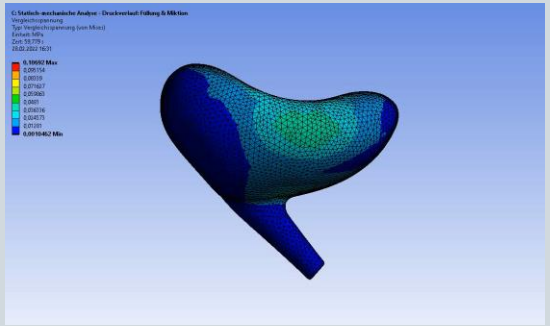
Patient-friendly interaction through 'knocking' signals

- Patient must communicate safely and intuitively with implant to fulfil therapy function
- No need for hand-held device, which can be lost or unavailable
- Research approach: manually generated knocking signals on tissue of the abdomen
- Acquisition of a knocking rhythm with implanted acceleration sensor



Simulation of physiological processes

- Refrain from using animal models in the research process for ethical and practical reasons
- Research using digital twins of the implant → Testing of functional performance even before clinical trials
- Example here: Contraction of the bladder during micturition



A wearable assistance system supports the navigation of visually impaired people through a 3D camera and machine learning.

Assistance system

- Embedded standalone system with 3D stereo cameras and mobile GPU

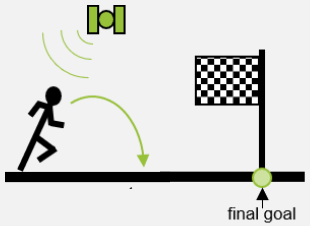
Binary environment segmentation

Path	Obstacles

- Robust and efficient artificial neural networks (encoder-decoders)
- Efficient implementation on embedded GPU

Localization

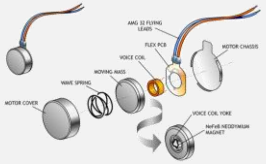
Satellite navigation	Visual odometry



- Robust fusion of mutlimodal localization using Unscented Kalman Filter

Multimodal feedback system

Linear Resonant Actuators	Bone sound headphones

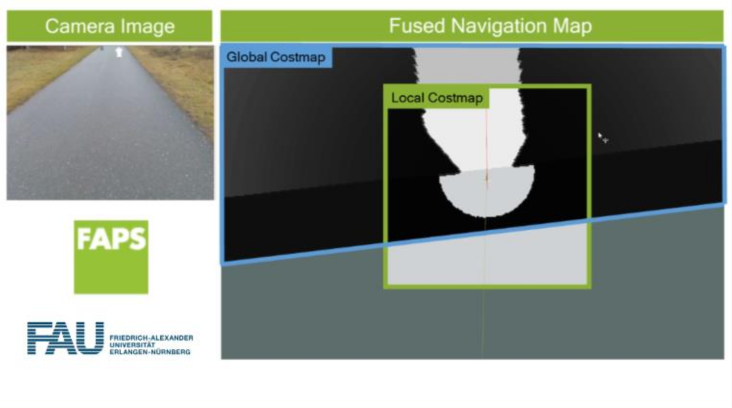


- Local trajectories and warnings are modulated into feedback signals
- Acoustic and/or vibrotactile mediation of the signals

Sources: aftershokz, precision microdrives

Cascaded path planning

- Back-projection of segmented images into hierarchical cost maps
- Orchestration of data processing and path planning via parallel state machines
- Global path planning based on satellite navigation and path trajectories
- Local path planning based on odometry and local environment information



FAPS

A wearable assistance system enables navigation of blind joggers by environment detection using a 3D stereo camera.

Assistance system

3D Stereo Camera

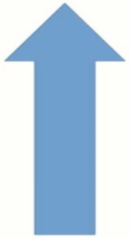
Embedded computing unit

Depth information

Color information

Obstacle map

Route



Virbotactile feedback

Robust obstacle and path course detection

- Ground segmentation and projection of obstacles during dynamic movements of the camera
- Path course detection by means of artificial neural networks

ANWENDUNGSZENTRUM esi

The development of autonomous and intelligent wheelchairs enables novel approaches to support affected persons as well as caregivers and relatives in everyday life.

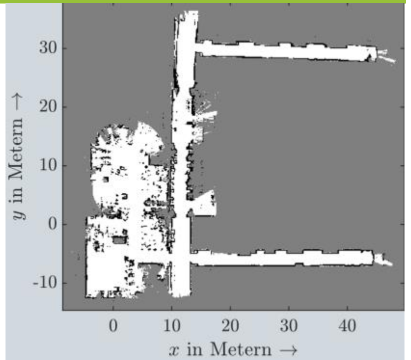
FAPS

- Increasing need for mobility support worldwide
- Reducing the workload of medical staff
- Technologies from related markets (autonomous driving, robotics)
- Improving the mobility of those affected

Sensor-supported localisation	Localisation through odometry and environmental mapping	Identification and movement prediction of a companion

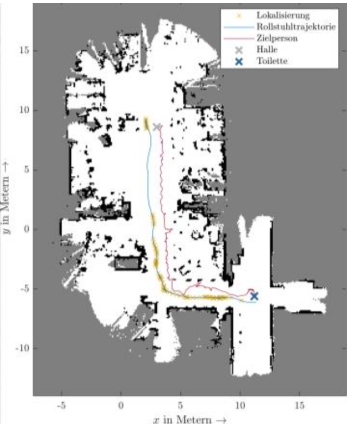
- Use of low-cost sensors (IMU, optical flow sensors, tracking cameras, stereo cameras and laser scanners)
- Open programming environment using the Robot Operating System ROS
- Collision avoidance through mapping of the surroundings
- Partially or fully autonomous navigation
- Socially accepted path planning and movement execution

Autonomous Navigation



Autonomous accompaniment of a person

- Detection of a person using cameras and laser scanner
- Movement prediction of the attendant by interpolation
- Description of the optimal companion position within a map by means of a two-dimensional attractiveness distribution
- Extension of the A* algorithm for solving the two-dimensional optimization problem for finding the optimal companion position



Future Work

- Movement is affected by the low agility of the wheelchair prototype, which can be improved by novel drives
- Improvements in socially accepted navigation, which includes interaction with the environment
- Indoor and outdoor navigation
- Ensuring safety in dangerous situations, e.g. in road traffic

In care and therapy, robotic systems can provide support with various forms of human-robot interaction.

Exoskeletons

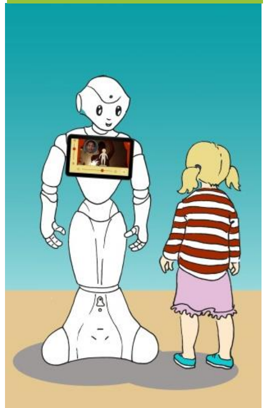
Intelligent care trolleys

Personal care robots

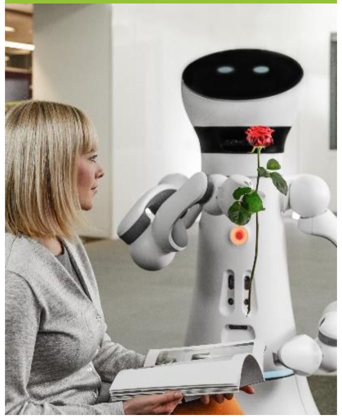
Socio-emotional robots

Prostheses

Therapy robots



Personal assistance



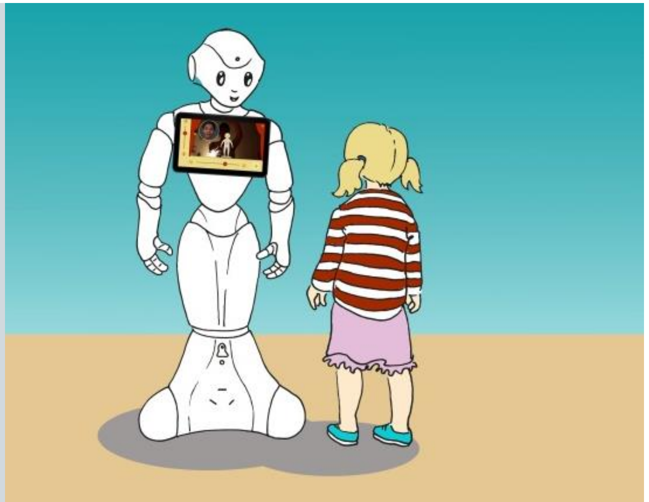
Entertainment

Sources: ReWalk, Open Bionics, Fraunhofer IPA, Riken, LN Online, Fraunhofer IIS, Bibliomed Pflege

Social robots can be used for training socio-emotional skills in children with autism spectrum disorders, thus supporting therapy.

Socially assistive robots for socio-emotional skills training.

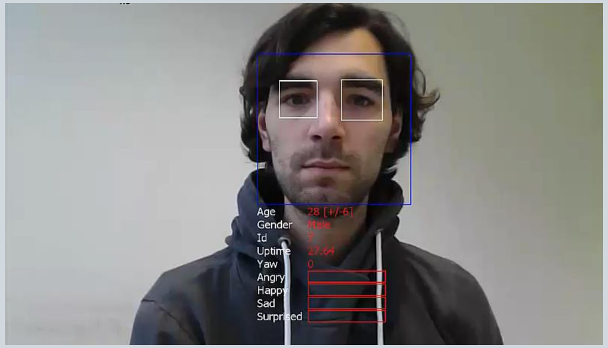
- Interest in humanoid robots among individuals with autism spectrum disorders
  - Limited facial expressions/gestures and predictable responses
  - Generally increased interest in technical topics
- Use of Pepper robot as interaction partner during therapy session
  - Tutor for specific training modules and visualization on tablet
  - Control of robot behavior by therapist
- Use of affective computing to capture emotions and arousal states



Source: Fraunhofer IIS

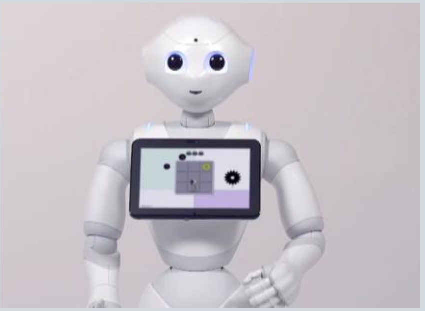
Emotion recognition and mimicry

- Recognition and expression of emotions



Excitation detection and regulation

- Learning game with different difficulty levels and calming exercise if needed

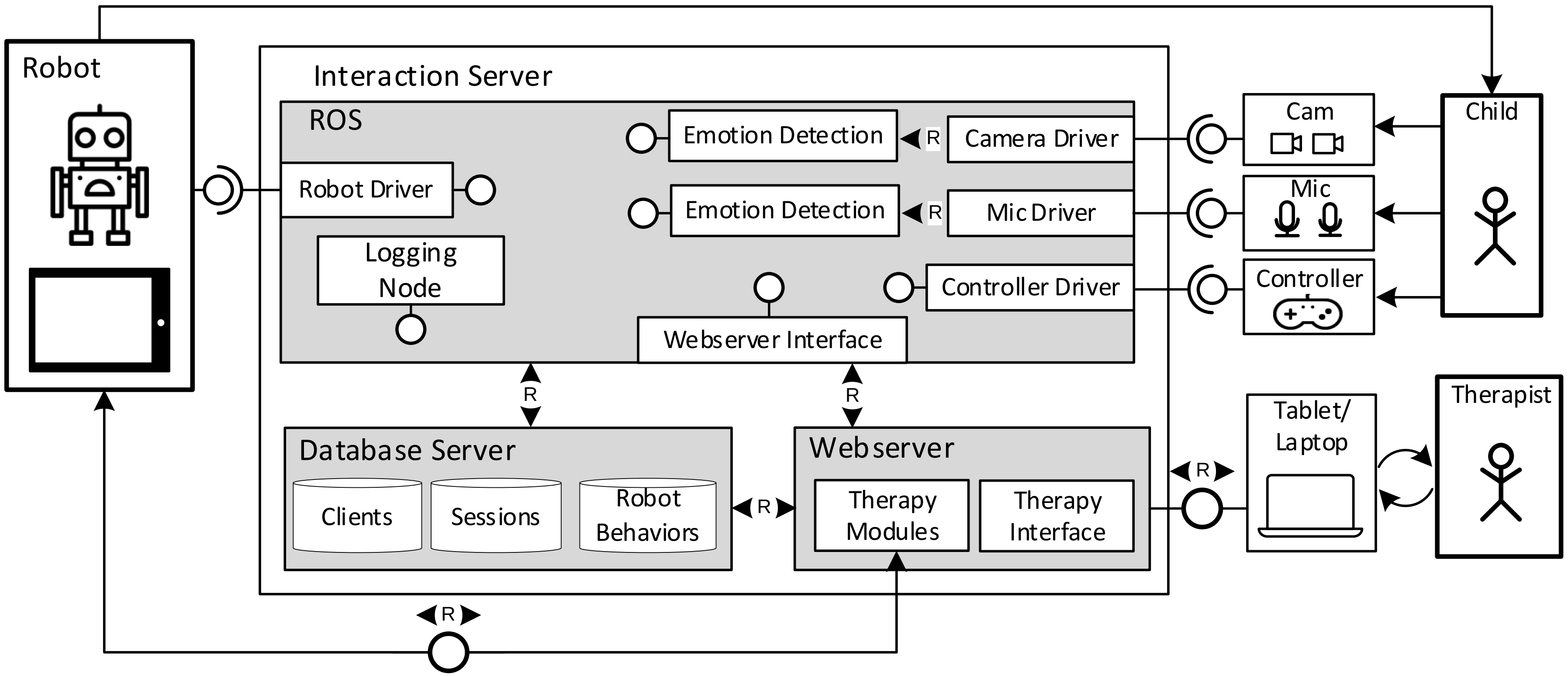


Therapist interface

- Visualization of emotion and pulse recording
- Intuitive and demand-oriented control of therapy content
- Suggestion of robot behavior based on the recorded emotions and arousal states
- Documentation of the course of therapy

FAPS

For the integration of all interaction partners, sensors and software modules, a central interaction server is conceptualized, which provides the corresponding web application.

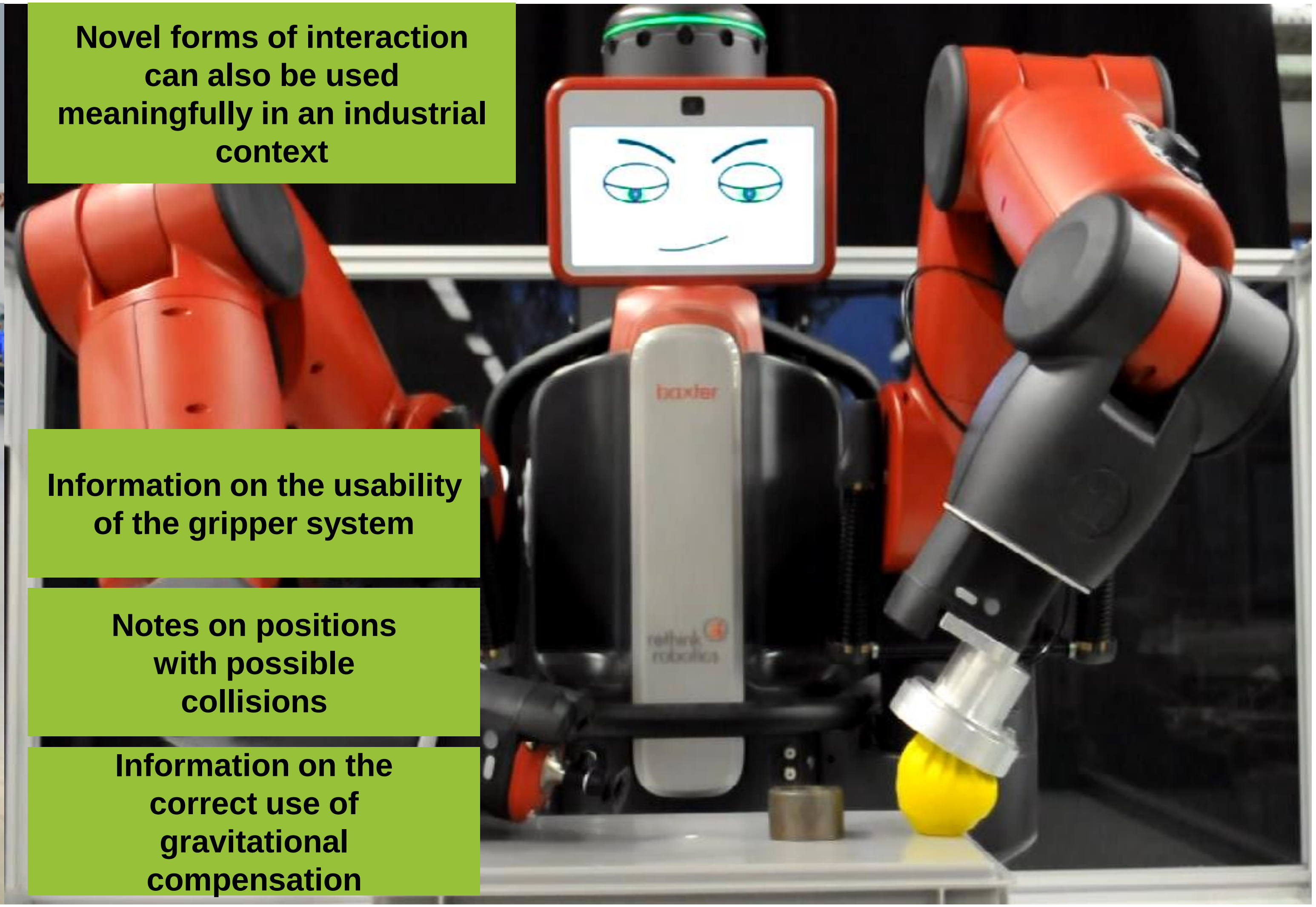


- Interaction server as central instance for integration of sensors and software for the therapy session
- Integration of the Robot Operating System (ROS), database server, web server for therapy interfaces and therapist interface
- Documentation of therapy progress by storing interaction progress and emotion recognition data
- Modular design allows integration of additional sensors, software modules or other robots

Intuitive communication with complex systems facilitates collaboration and creates acceptance.

Multimodal communication via speech, gestures and touch can simplify the use of robotic systems

Novel forms of interaction can also be used meaningfully in an industrial context



Information on the usability of the gripper system

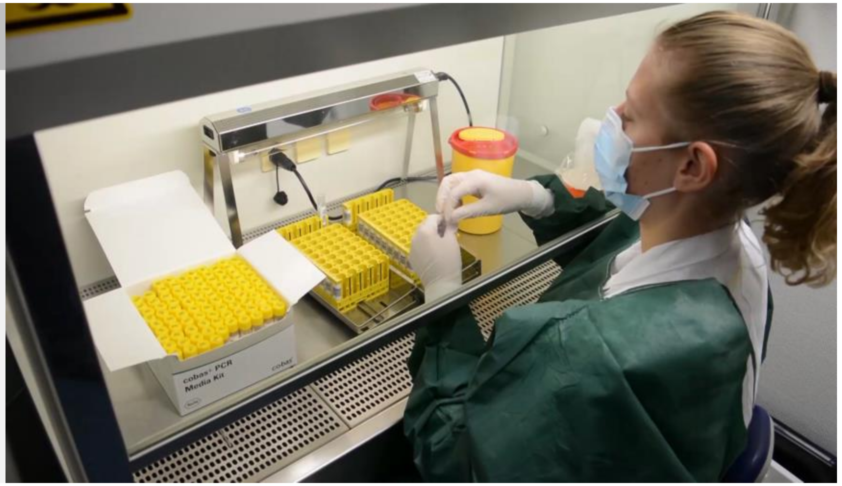
Notes on positions with possible collisions

Information on the correct use of gravitational compensation

The analysis of medical samples is currently still often characterized by manual handling steps for pre- or post-processing and is fraught with various challenges.

Manual handling of medical specimens

- Pre- and post-processing of analytical methods by manual handling steps.
- Potential risk of infection, cross-contamination or contamination
- High hygienic requirements
- Often repetitive activities and insufficient documentation
- Proprietary communication infrastructure



Example: SARS CoV-2 polymerase chain reaction

Sample preparation

- Swabs of the specimen collection are transported in tubes with medium
- Tubes must be manually presorted and optically injected
- Transfer to special transport racks

PCR Analysis

- Fully automated analysis of characteristic viral RNA
- Samples must be manually inserted and removed
- Limitation of maximum throughput

Source: ROCHE cobas

A robot enables sample handling for pre- and post-processing of PCR analysis.

Camera systems

- Localization of the tubes via deep learning
- Camera system for analysis of position and value of barcodes
- Camera and illumination system for detection of swabs and contaminants

7-axis industrial robot

- Implementation of all handling steps by a robot
- Special painting to improve hygiene

Gripper system

- Servo electric gripper
- Additively manufactured multifunction gripper jaws

Communication system

- Communication between robot and PCR system
- Documentation
- GUI for laboratory staff

Project partners

YASKAWA

infoteam software

Universitätsklinikum Erlangen

Prosthetic fitting is currently a manual procedure based on the skills and knowledge of the prosthetist.

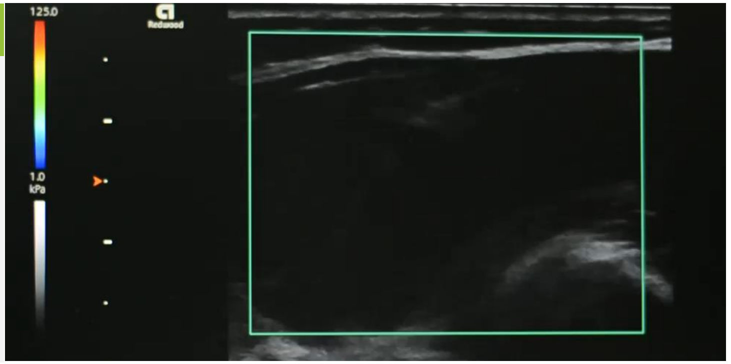
Current standard for prosthetic fitting

- Physical modeling of a plaster cast based on the manually captured tissue structure
- Difficulty: High dependence on the competence of the orthopedic technician

Detection of tissue structure by ultrasound elastography

Shear Wave Elastography (SWE)

- Measurement of the propagation speed of the shear waves in the tissue
- Quantification of elastic tissue properties (in kPa)



Digitalization of the workflow through the fusion of quantified tissue data with surface data

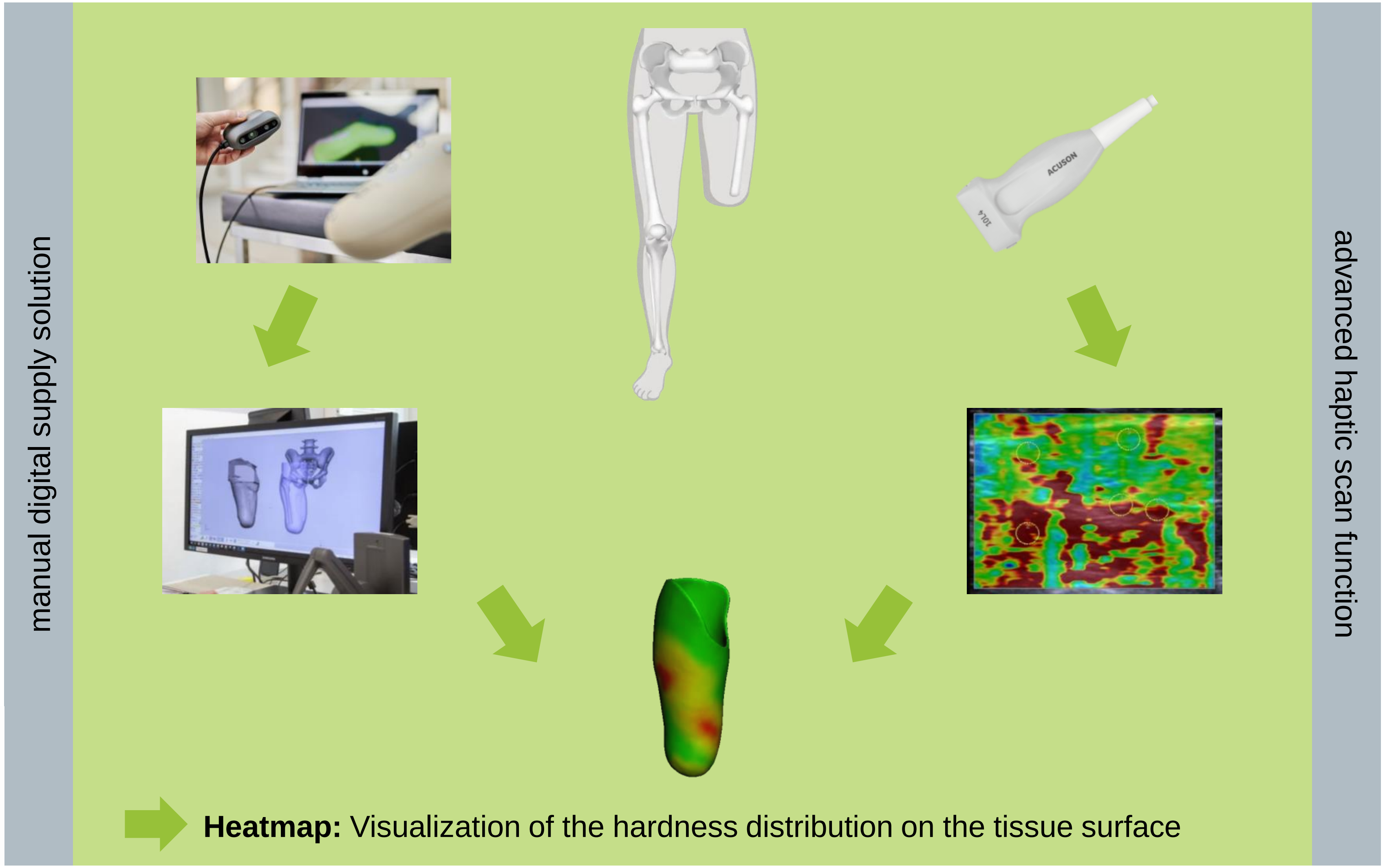
Objective assessment and consistent prosthetic supply

Individualized and more efficient patient care

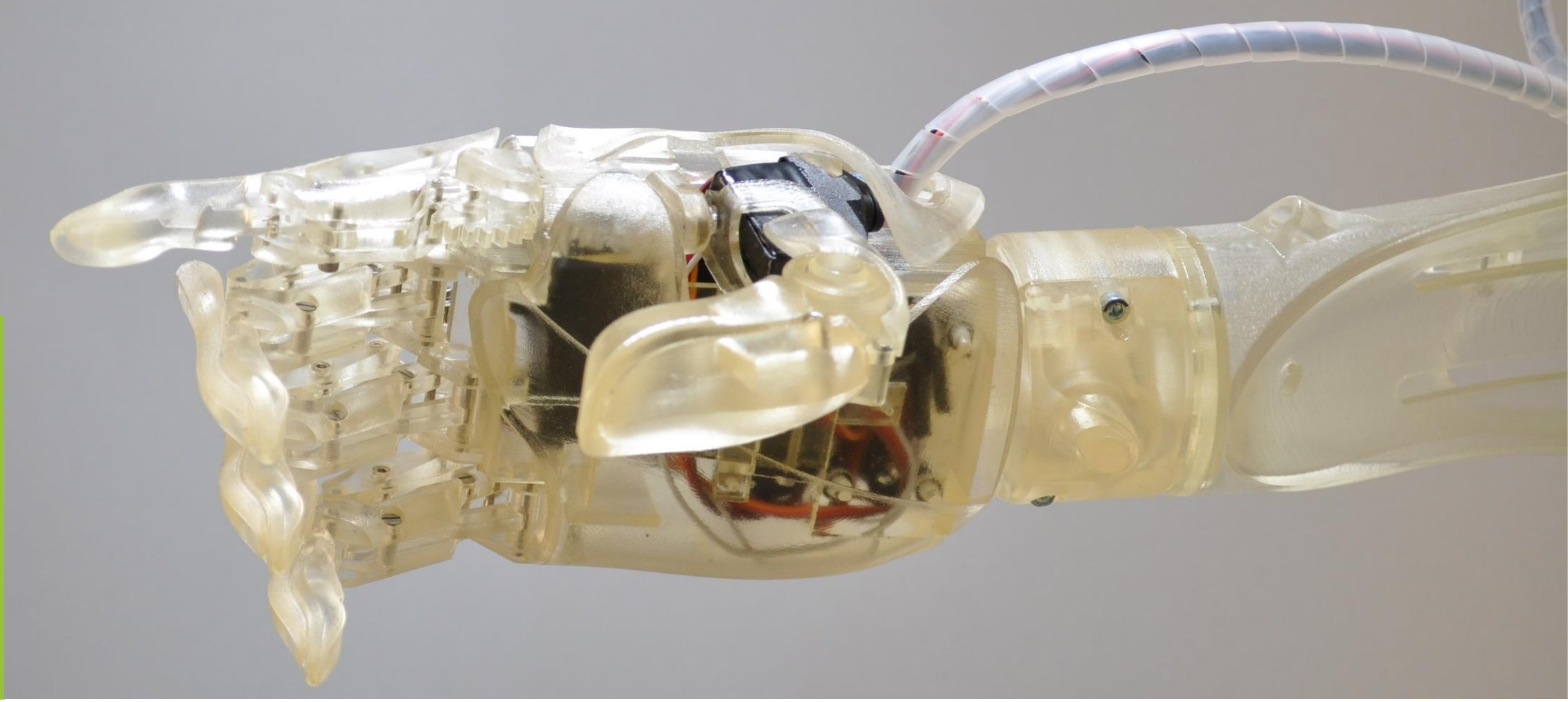
Reduced number of revisions and repeated adjustments

FAPS

The acquired tissue data is fused with the data from a surface scan to create a holistic information basis for prosthesis fitting.



SPONSORED BY THE
Federal Ministry
of Education
and Research



Prof. Dr.-Ing. Jörg Franke

Institute for Factory Automation and Production Systems

Friedrich-Alexander University Erlangen-Nuremberg

FAU
Friedrich-Alexander-Universität
Technische Fakultät

THANK YOU