WORK@MSRM

Robotics Demonstrators and Labs at a Glance

1. Edition

IMPRINT

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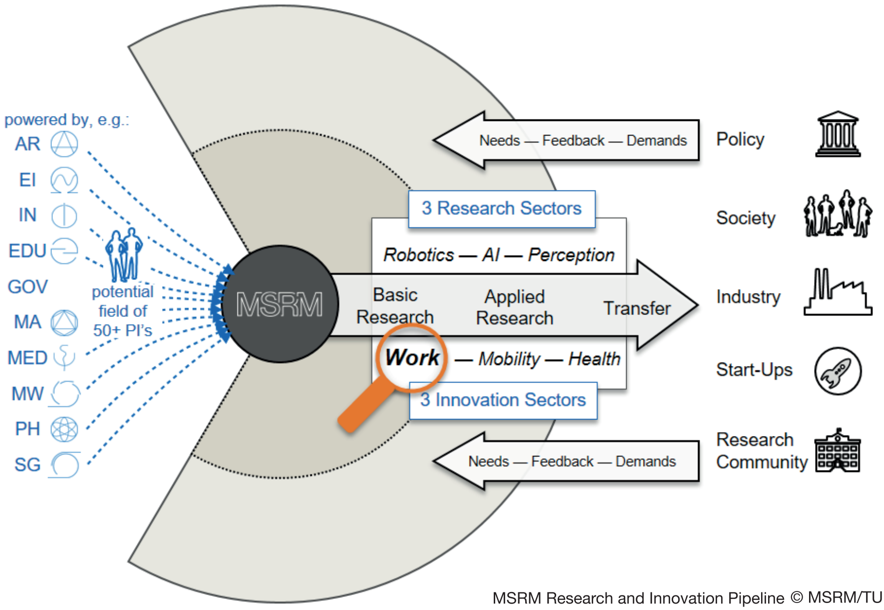
The contents were created with the greatest care by the respective chairs. However, we cannot guarantee the correctness, completeness and actuality of the contents.

A Short Introduction to this Brochure

The Munich School of Robotics and Machine Intelligence (MSRM) and its affiliated Principal Investigators have organised themselves and their research in 6 sectors: 3 “Innovation Sectors“ (Health; Mobility; Work) and 3 “Research Sectors“ (AI; Robotics; Perception) as illustrated below.



MSRM Research and Innovation Pipeline © MSRM/TUM

This brochure is an initiative of the Work@MSRM Innovation Sector and therefore only displays a selection of demonstrators and labs of Work@MSRM (as of January 2020). The shown demonstrators and labs were chosen by the respective chairs/institutes and can be visited upon registration. The goal of this brochure is to serve as a guide across campuses, since the labs and demonstrators of the Work@MSRM members are spread over several TUM locations.

We point out that the brochure does not claim to contain every lab and demonstrator of either TUM or the mentioned departments/chairs.

This is a first, preliminary edition, thus the brochure will be updated constantly in the following editions. If you think you are missing and want your labs and demonstrators to appear in the next brochure, please send an email to: olivia.schmitt-walter@tum.de.

Campus Garching

Department of Mechanical Engineering

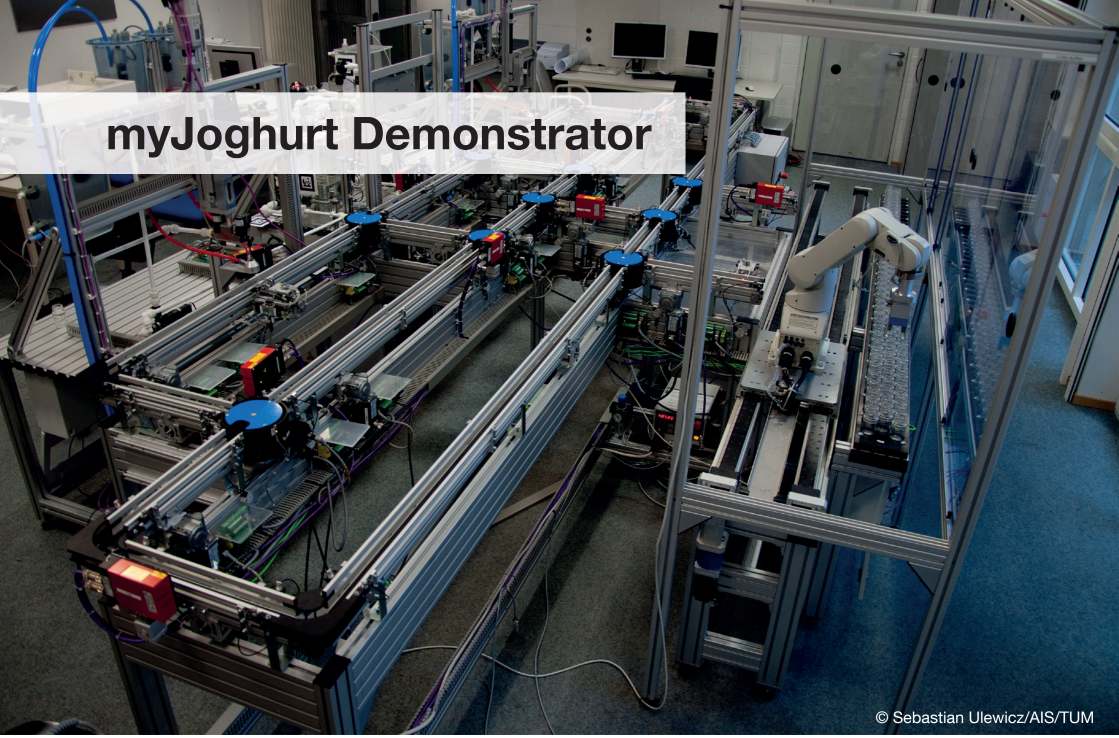
*The locations of the laboratories and demonstrators shown on the map are approximate.

Building 1

Building 3

Building 5

myJoghurt Demonstrator

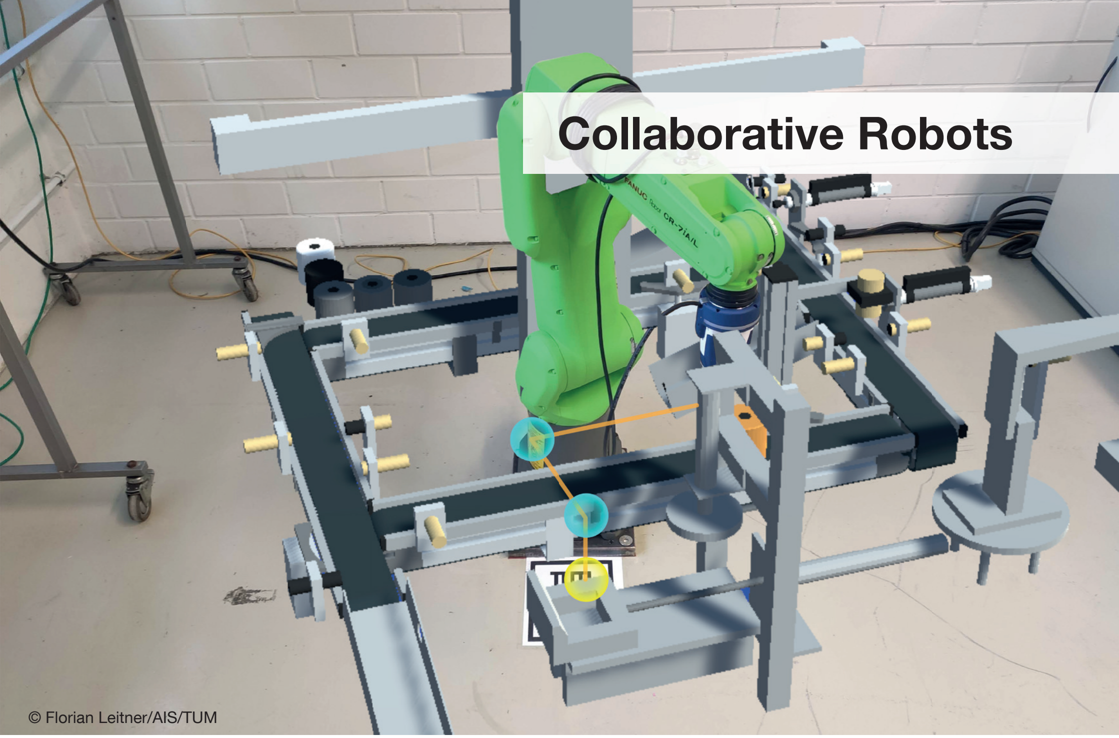


The myJoghurt demonstrator shows the prototypical implementation of an architecture for cyber-physical production systems (CPPS) based on the technology of software agents and has been developed with various German research facilities. Locally separated production systems in myJoghurt are connected across the boundaries of individual corporations and subcontractors – both exemplarily represented by the different research institutes – and are able to realize an optimized, distributed production process. Established communication protocols enable continuous vertical integration of machines on a plant's field-level so that dynamical reconfigurations to current demands and requirements can be made. At the same time, mobile platforms such as robot controllers can be embedded. Further developments of the demonstrator are currently conducted in the TC 5.15 "Multi-Agent-Systems" of the Gesellschaft für Mess- und Automatisierungstechnik (GMA).

Location:
Department of Mechanical Engineering | Institute of Automation and Information Systems (AIS) | Boltzmannstr. 15 | 85748 Garching bei München
Building 1 | Ground Floor | Room MW 0137 | Roomcode 5501.EG.137 | 1 on map

Contact: Secretariat | sekretariat@ais.mw.tum.de

Collaborative Robots

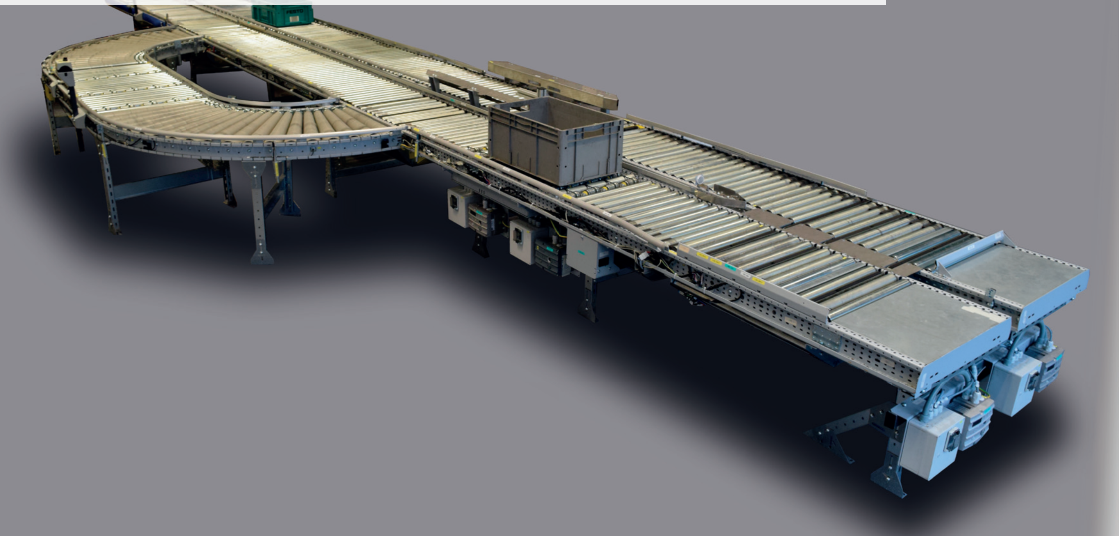


Industrial production lines can no longer be imagined without robots that support the human in processing and assembly or robots that are used in logistics. Modern collaborative robots also facilitate the cooperation between humans and robots significantly. The research at the institute aims to improve communication between robots and humans in their work environment using Augmented Reality (AR). These approaches are demonstrated using a combination of Microsoft‘s HoloLens and a collaborative FANUC robot (CR-7iA/L). The goal is to augment the view of an operator or programmer with additional information to simplify the programming process. The first approach is to support the programmer by a standardized framework to make it easier to generate such AR programs. The second approach focuses on programming industrial robots entirely within an AR environment using hand gestures.

Location:
Department of Mechanical Engineering | Institute of Automation and Information Systems (AIS) | Boltzmannstr. 15 | 85748 Garching bei München
Building 1 | Ground Floor | Room MW 0165b | Roomcode 5501.EG.165B | 2 on map

Contact: Secretariat | sekretariat@ais.mw.tum.de

Self-X Material Flow Demonstrator

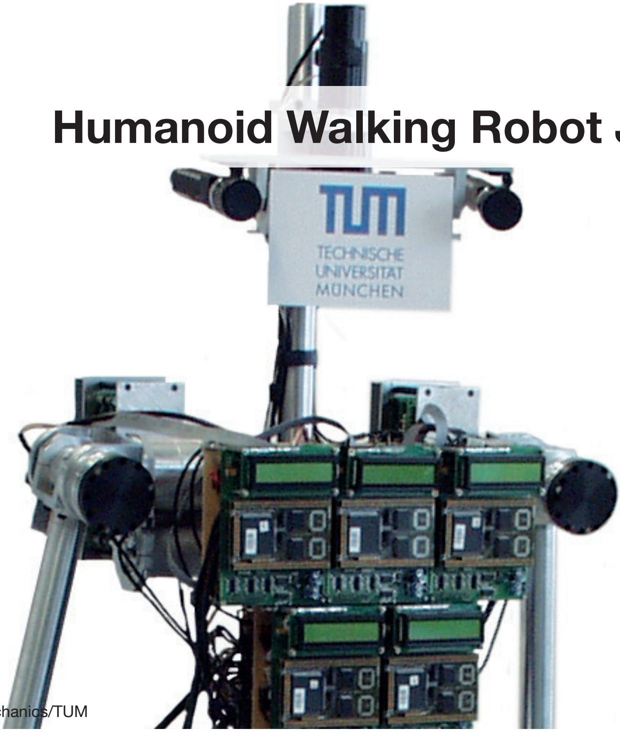


To implement and evaluate different control concepts in the field of intralogistics, the Chair of Automation and Information Systems uses the Self-X Material Flow demonstrator. Automated material flow systems are usually composed of pre-engineered and similar mechanical components, e.g. a certain type of roller conveyor, in order to reduce efforts in early development phases and to obtain a consistent hardware base. With the Self-X Material Flow demonstrator, we want to reflect the modularity of the hardware architecture, which is obtained by the usage of pre-engineered components, into the software to allow a component-wise composition and generation of the software. The segment-wise actuation of the conveyor elements enables a “transported-good-oriented” programming, which means activating only those elements that carry material. In this case, segments can also be subsumed to so called “logistic modules” such as T- or U-units.

Location:
Department of Mechanical Engineering | Institute of Automation and Information Systems (AIS) | Boltzmannstr. 15 | 85748 Garching bei München
Building 1 | Ground Floor | Room MW 0165b | Roomcode 5501.EG.165B | 2 on map

Contact: Secretariat | sekretariat@ais.mw.tum.de

Humanoid Walking Robot JOHNNIE

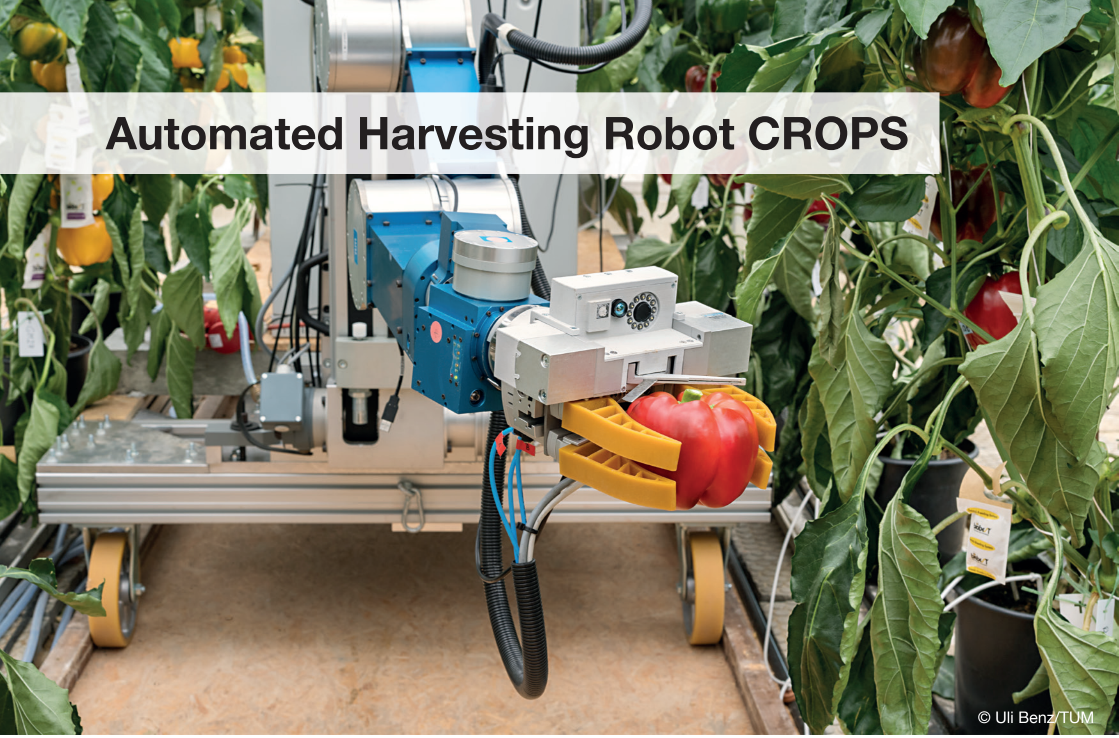


At the end of the sixties, numerous research groups began to investigate biped walking robots. The rapid development of actuators, sensors and computing power makes it possible to realize such highly complex systems today. The humanoid robot JOHNNIE (2003), developed in cooperation of the Chair of Applied Mechanics (Prof. Pfeiffer - Design, Mechanics, Electronics, and Control) and the Chair of Automatic Control Engineering (Prof. Schmidt - Vision System) at TUM, played a pioneering role. The robot consists of over 1,000 individual parts and weighs less than 50kg with a body height of 180cm. 17 driven joints enable a human-like gait as well as a walking speed of up to 2.4km/h. With the vision system, the robot is able to recognize obstacles and bypass them. Its successor, the humanoid LOLA, is the current research platform at the Chair of Applied Mechanics and is used to further improve the robustness and versatility of biped locomotion.

Location:
Department of Mechanical Engineering | Chair of Applied Mechanics (AM) |
Boltzmannstr. 15 | 85748 Garching bei München
Building 1 | 3rd Floor | Foyer | 3 on map

Contact: Prof. Dr. ir. Daniel J. Rixen | robotics@amm.mw.tum.de

Automated Harvesting Robot CROPS



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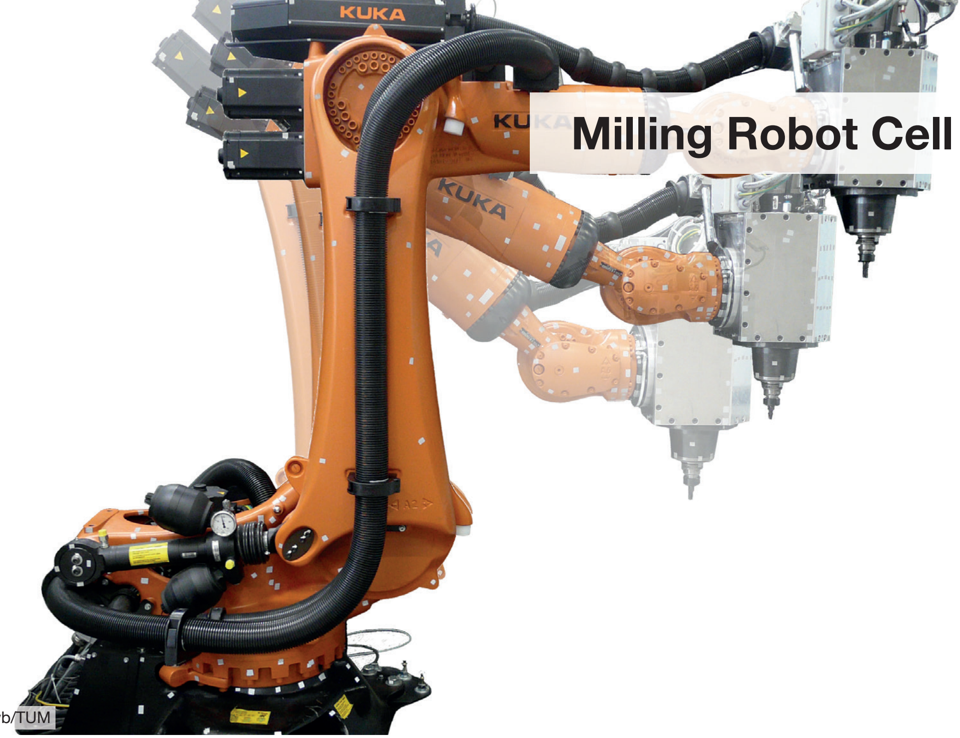
Many site-specific agricultural and forestry tasks such as cultivating, transplanting, spraying, trimming, selective harvesting and transportation, could be performed more efficiently if carried out by robotic systems. However, to date, agriculture and forestry robots are still not available, partly due to the complex and often contradictory, demands for developing such systems. Addressing problems such as continuously changing conditions (e.g. rain and illumination), high variability in both the products (size and shape) and the environment (location and soil properties), the delicate nature of the products, and hostile environmental conditions (e.g. dust, dirt, extreme temperature and humidity) requires advanced sensing, manipulation, and control. The CROPS robot tries to meet these demands by using a modular and configurable design that will keep costs to a minimum by applying a basic configuration to a range of agricultural applications.

Location:
Department of Mechanical Engineering | Chair of Applied Mechanics (AM) |
Boltzmannstr. 15 | 85748 Garching bei München
Building 1 | 3rd Floor | Room MW 3109 | Roomcode 5501.03.109 | 4 on map

Contact: Prof. Dr. ir. Daniel J. Rixen | robotics@amm.mw.tum.de

Milling Robot Cell



The demonstrator consists of a KR240 KUKA Robot with a mounted milling spindle and is used for investigations concerning the stiffness and vibration behavior of the robot during the milling process. The derived information is further used to improve the path planning of the robot offline and online during the milling process to decrease positioning deviations of the spindle during the process and thus enhance component quality. The demonstrator can manufacture complex example components with and without the positioning compensation to prove the value added by this approach. The scientific approaches taken here aim to enable the use of industrial robots in milling components, which is traditionally dominated by highly accurate machining centers. Thereby, the demonstrator is only part of the big test bed of iwb, where many more robots in industrial applications are the core of several research projects.

Location:
Department of Mechanical Engineering | Institute for Machine Tools and Industrial Management (iwb) | Boltzmannstr. 15 | 85748 Garching bei München
Building 3 | Ground Floor | Room MW 0390G | Roomcode 5503.EG.390G | 5 on map

Contact: Maximilian Busch, M.Sc. | maximilian.busch@iwb.mw.tum.de

Lego Assembly Demonstrator

The demonstrator consists of a SCARA-robot with attached force sensors, the robot control, conveyors and work piece fixtures, as well as a GUI. Within this interface, a LEGO brick based product can be designed. The software backend of the demonstrator is capable of automatically deriving the assembly tasks by means of CAD analysis and create the robot code for the assembly steps. Finally, the code can be executed by the robot and the user can receive the assembled bricks. During this assembly process, the robot's force control can be observed, which is crucial to position the bricks accurately on top or next to each other. The demonstrator thus combines smart software with force based control approaches to automate assembly and the attached planning process.

Location:
Department of Mechanical Engineering | Institute for Machine Tools and Industrial Management (iwb) | Boltzmannstr. 15 | 85748 Garching bei München
Building 3 | Ground Floor | Room MW 0390G | Roomcode 5503.EG.390G | 5 on map

Contact: Clemens Gonnermann, M.Sc. | clemens.gonnermann@iwb.mw.tum.de

Ergonomic Robot Behavior

The telepresence system Beam from Suitable Technologies is used to investigate social interactions in Wizard-of-Oz experiments. The kinematic capabilities enable the design and evaluation of movement variations to communicate intent via motion. Gait analysis and the spatial reactions executed by coexisting and cooperating pedestrians can serve as quantitative measures of the fine attunement, needed to solve spatial conflicts in encounters with a robot. A display allows for additional visual feedback. The system has a running time of 7 hours, uses two integrated WiFi antennas for communication and reaches top speeds of approximately 1 m/s. The integrated speakers enable clear and natural sound reproduction. Two HDR cameras provide a wide forward and downward viewing angle to make driving with the beam from an operator desk safe and easy.

Location:
Department of Mechanical Engineering | Chair of Ergonomics (LfE) | Boltzmannstr. 15 | 85748 Garching bei München
Building 3 | 3rd Floor | Room MW 3310M | Roomcode 5503.03.310M | 6 on map

Contact: Jakob Reinhardt, M.Sc. | jakob.reinhardt@tum.de

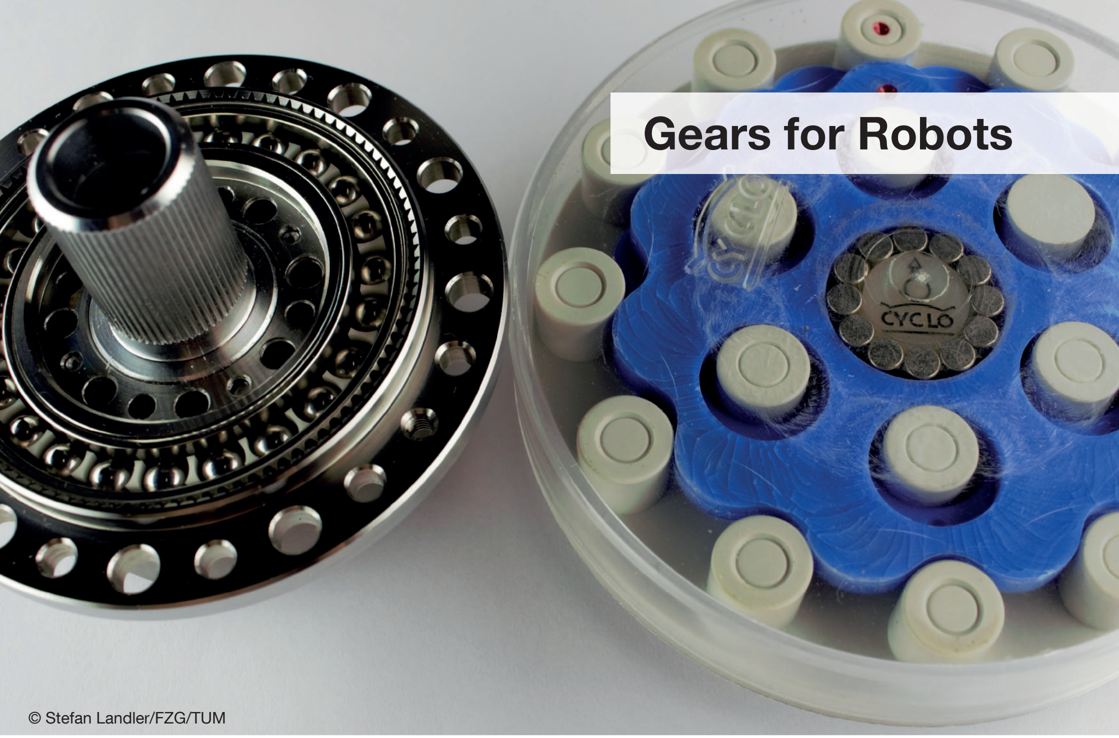
Experience Center Mobile Robotics (ECMR)

© Stefan Titz/fml/TUM

Mobile robots are already playing an important role in logistics processes in almost all sectors of industry today. The “Experience Center Mobile Robotics“ (ECMR) at the Chair for Materials Handling, Material Flow, Logistics (fml) offers a broad insight into state of the art applications of mobile robotics in intralogistics. Demonstrators are categorized in three levels - “Component“, “System“ and “Process“: Examples at component level include AI based object detection in logistics as well as trajectory based human collision avoidance. At system level, the ECMR consists of easily programmable robots for teaching, industry-proven transport systems as well as a self-developed autonomous tugger train. At process level, individual demonstrators are combined and integrated to create a unified system of systems that can autonomously handle increasingly complex logistics tasks, such as autonomous transport processes or robot-supported order picking.

Location:
Department of Mechanical Engineering | Chair of Materials Handling, Material Flow, Logistics (fml) | Boltzmannstr. 15 | 85748 Garching bei München
Building 5 | Ground Floor | Room MW 0590D | Roomcode 5505.EG.590D | 7 on map

Contact: Christopher Mayershofer, M.Sc. | ecmr@fml.mw.tum.de



Gears for Robots

Typical gears for robots are the cycloidal drive and the strain wave gearing (also known as harmonic drive). These two types of gears are shown as standalone assemblies.
The cycloidal drive is made of plastic and includes two cycloidal discs. An eccentric in the middle of the gear drives the discs. The discs engage with the circular pins of the ring gear. The holes in the discs enable the motion of the pins of the output shaft.
The harmonic drive is made of steel and includes a flexible gear rim. A non-circular input shaft deforms the flexible gear rim. The flexible gear rim engages with the rigid ring gear and generates the output movement.
The demonstrators are used for coaxial drive trains for robots in combination with electric motors. Current research is done to increase the efficiency, to introduce parts made of plastic and to examine the comparability of different concepts.

Location:
Department of Mechanical Engineering | Institute of Machine Elements (FZG) |
Boltzmannstr. 15 | 85748 Garching bei München
Building 5 | 2nd Floor | Hallway in front of MW 2511 | Roomcode 5505.02.511 | 8 on map

Contact: Stefan Landler, M.Sc. | landler@fzg.mw.tum.de

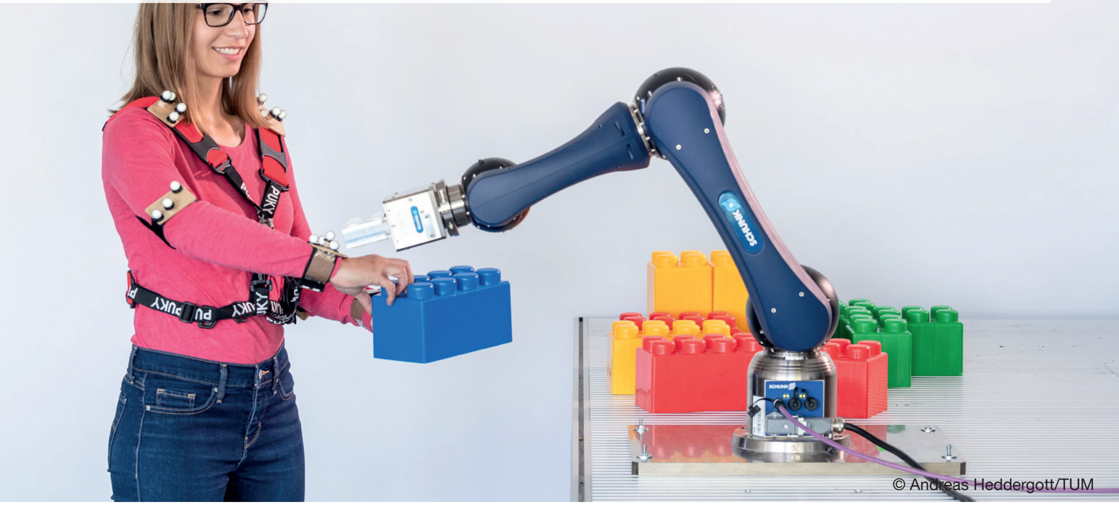
Campus Garching

Department of Informatics

*The locations of the laboratories and demonstrators shown on the map are approximate.

Building 7

Formally Safe and Efficient Human-Robot Coexistence



In this demo, visitors can experience what working is like in close proximity to an industrial robot arm that behaves reliably safe in presence of humans. The key technology are computationally efficient methods that formally verify the safe behavior of robotic systems at runtime. By using human pose recognition (from an installed motion capture system) and the prediction of their reachable sets, we achieve higher productivity at work while retaining the same safety requirements for humans.

Location:
Department of Informatics | Chair of Robotics, Artificial Intelligence, and Real-time Systems | Boltzmannstr. 3 | 85748 Garching bei München
Building 7 | 3rd Floor | Room 011 | Roomcode 5607.03.011 | 1 on map

Contact: Stefan Liu, M.Sc. | stefan.liu@tum.de

Modular Robot

In this demo, visitors can experience the first truly modular industrial robot arm. The key technologies are fully modular and self-contained hardware modules and the self-programming of the robots' control and collision check. After reading kinematic and dynamic data, which is saved on every robot module, a centralized controller is programmed on-the-fly, which enables instant usage of newly assembled or reassembled modular robots.

Location:
Department of Informatics | Chair of Robotics, Artificial Intelligence, and Real-time Systems | Boltzmannstr. 3 | 85748 Garching bei München
Building 7 | 3rd Floor | Room 011 | Roomcode 5607.03.011 | 1 on map

Contact: Paul Maroldt, M.Sc. | paul.maroldt@tum.de

Main Campus Munich

Arcisstraße 21

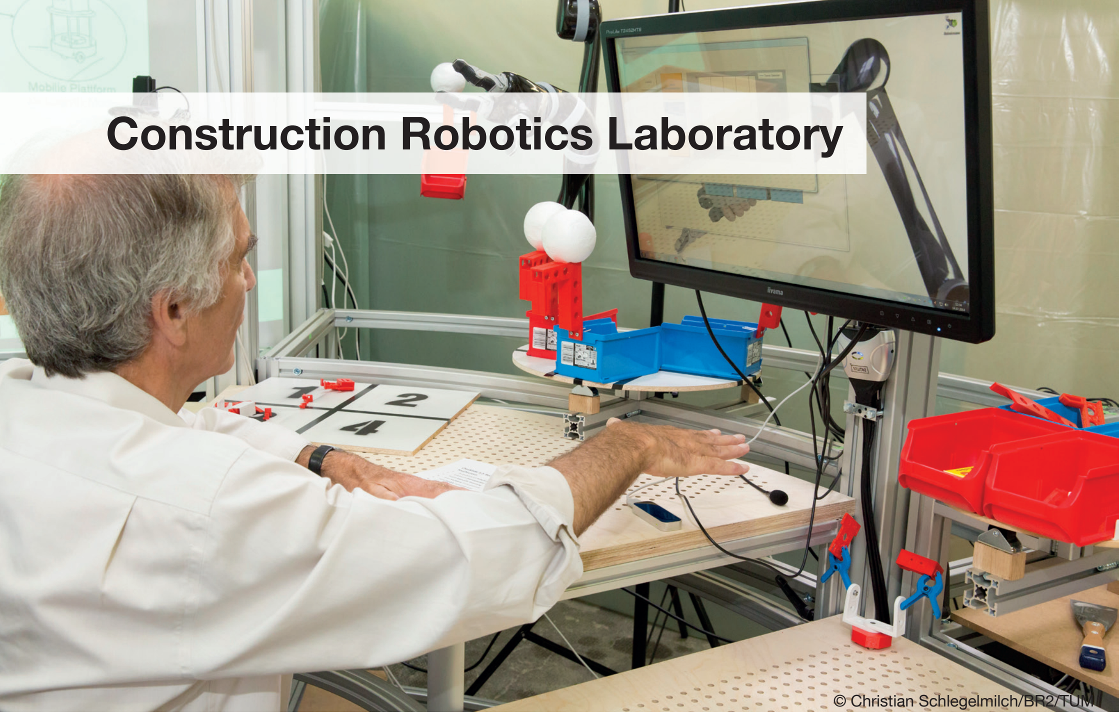
*The locations of the laboratories and demonstrators shown on the map are approximate.

Building 1

Building 4

Building 9

Construction Robotics Laboratory



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The Construction Robotics Laboratory (cum Human-Ambient-Technologies Lab) hosted by the Chair of Building Realization and Robotics is designed as an experimenting laboratory (i.e., an "Incubator"). In the laboratory, students and researchers can experiment with robotic systems and mechatronics in the field of building production and Ambient Assisted Living (AAL). It provides a fully equipped mechatronics workshop and is supervised by the chair staff. The laboratory also deals with applications, strategies and basic philosophies related to the upcoming challenges associated with the integration of advanced technologies (production technology, ICT, microsystems, mechatronics, automation, robotics, personal assistance technology) in daily human living. While in many architectural projects simple design models have the priority, in this laboratory, more complex functional demonstrators or experimental superstructures are implemented.

Location:
Department of Architecture | Chair of Building Realization and Robotics (BR2) | Arcisstr. 21 | 80333 München
Building 1 | 4th Floor | Room 4120 | Roomcode 0501.04.120 | 1 on map

Contact: Prof. Dr.-Ing. Thomas Bock | thomas.bock@br2.ar.tum.de

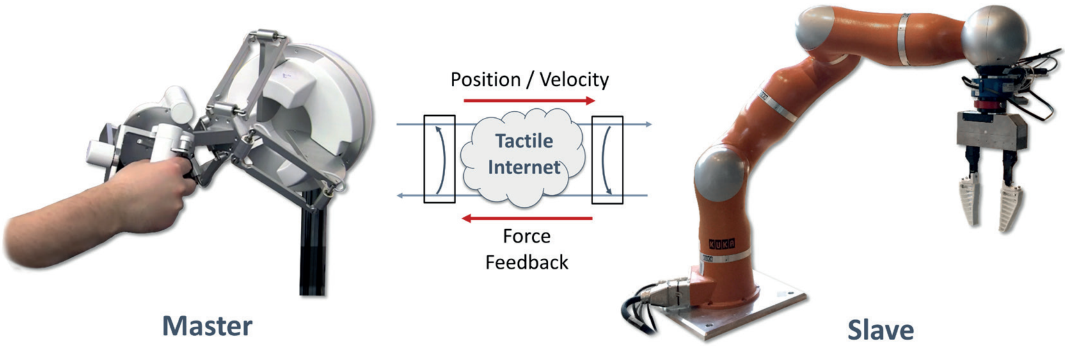
Tactile Computer Mouse

Humans recognize and process different touch-related impressions such as hardness, friction, warmth, micro- and macroscopic roughness in parallel to visual and audible information. The tactile computer mouse (TCM) is a novel haptic output device which aims to virtually render the physical material properties to the user's hand or skin. To model the physical material properties, real materials are scanned with a custom-made recording device ("Texplorer") which relies on a variety of sensors (accelerometer, microphone, FSR, infrared reflective sensor, etc.). The TCM uses voice coil actuators to render high-frequency microscopic roughness feedback, Peltier elements to deliver impressions of thermal conductivity, electromagnets to render friction, and servo motors to display different stiffness levels and macroscopic surface structures. Besides realistic surface recreation or the tactile enhancement of common user interfaces, the TCM can improve the immersion into virtual environments and provide potential touch feedback for online shopping applications ("T-Commerce"). Subsequent versions of the TCM are currently developed at the Chair for Media Technology.

Location:
Department of Electrical and Computer Engineering | Chair of Media Technology (LMT) | Arcisstr. 21 | 80333 München
Building 4 | Ground Floor | Room 0402 | Roomcode 0504.EG.402 | 2 on map

Contact: Matti Strese, M.Sc. | matti.strese@tum.de

Haptic Communication for Stable Bilateral Teleoperation



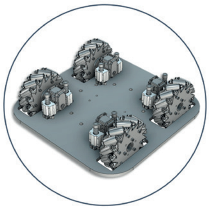
Teleoperation systems with haptic feedback allow users to immerse into a distant environment including the capability to execute and experience physical interaction. Our research aims to ensure an efficient haptic communication for bilateral teleoperation over packet-switched networks, and to realize a stable and transparent remote interaction in the presence of communication unreliabilities (e.g. time delay, packet loss) in challenging real life scenarios. To demonstrate our haptic communication solutions, we use a teleoperation system with a haptic device (Force Dimension omega.6 or sigma.7) as the master controller and a KUKA Lightweight arm as the slave robot. An additional 6 degrees of freedom force/torque sensor at the end-effector of the KUKA arm measures the contact forces and torques. A camera at the slave side provides the real-time video feedback of the remote interaction. Our presented solutions combine haptic data reduction with stability-ensuring control schemes to achieve the best possible system performance under various qualities of service provided by the network.

Location:
Department of Electrical and Computer Engineering | Chair of Media Technology (LMT) | Arcisstr. 21 | 80333 München
Building 9 | 1st Floor | Room 1945 | Roomcode 0509.02.945 | ③ on map

Contact: Dr.-Ing. Xiao Xu | xiao.xu@tum.de

MAVI: A Mobile Robotic Platform for Teleassistance



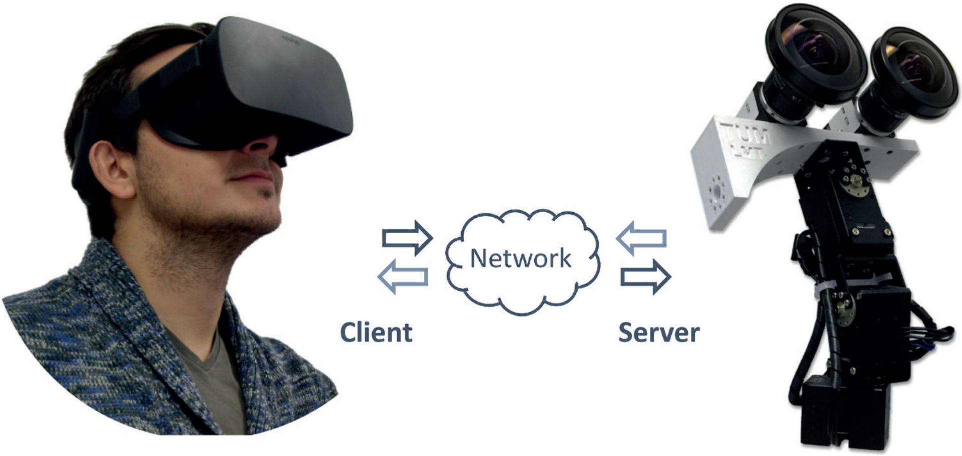



Teleoperated robot assistants are gaining more importance as the need for teleassistance increases, e.g. in the health care system. MAVI is a mobile robotic research platform for indoor teleoperation scenarios with localization, navigation, and semi-autonomous manipulation capabilities. It is designed and implemented at the Chair of Media Technology, constructed mostly from 3D-printed parts making the platform lightweight and low-cost. MAVI has an omnidirectional holonomic locomotion system with four wheels equipped with a suspension system. It possesses a stereo camera system actuated by a pan-tilt-roll unit and provides a low-delay 360° stereoscopic vision for an immersive visual experience. Its manipulator has 7 DoF including 5 cylindrical joints, a parallel gripper and the vertical locomotion of the torso. MAVI possesses a variety of sensors such as inertial measurement unit, 360° laser rangefinder, ultrasonic proximity sensors and force sensors at the joints and wheels. The platform can interact with the remote environment to accomplish teleassistance tasks and has an operation time of 4 to 8 hours depending on the scenario.

Location:
Department of Electrical and Computer Engineering | Chair of Media Technology (LMT) | Arcisstr. 21 | 80333 München
Building 9 | 1st Floor | Room 1963 | Roomcode 0509.02.963 | 4 on map

Contact: Mojtaba Karimi, M.Sc. | mojtaba.karimi@tum.de

Real-time 360° Stereo Telepresence System with Delay Compensation



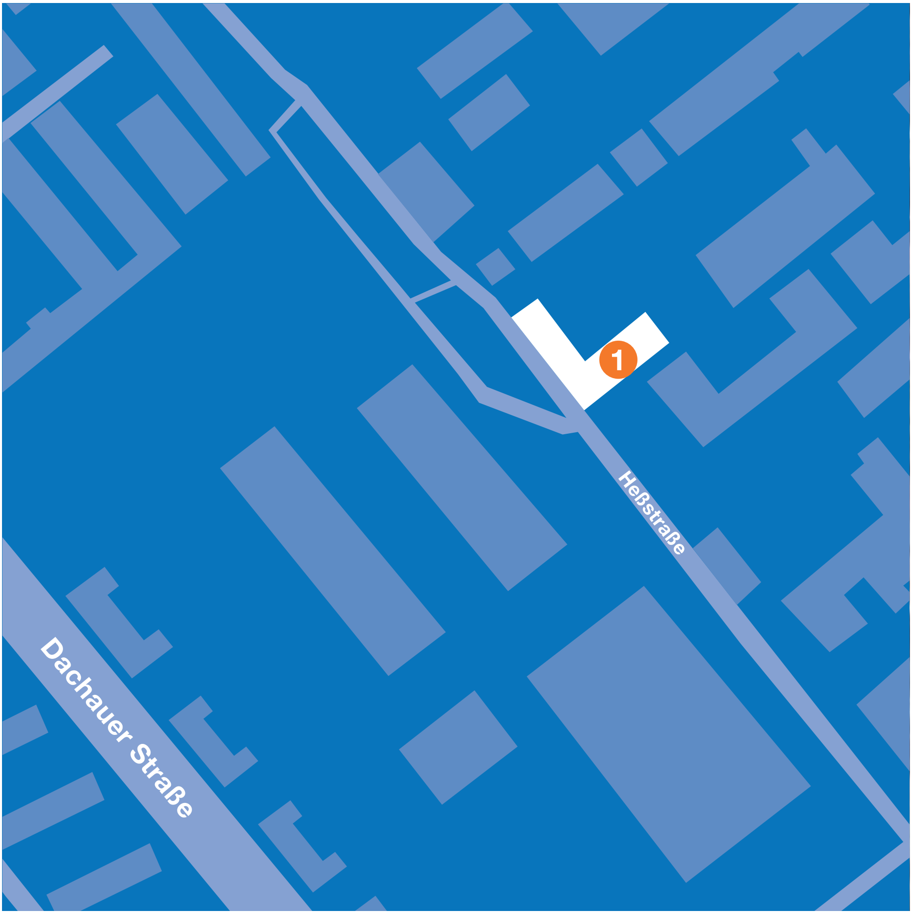
A telepresence system combining 360° stereoscopic video streaming with a head mounted display (HMD) improves the feeling of presence and the task performance, as it allows users to naturally perceive the depth information in every view direction. On the client side of our demonstrator, the user wearing an HMD receives the omnistereoscopic vision of the remote environment, whereas on the server side, a two-camera setup is deployed for stereo vision that is mounted on a 3 DoF actuation unit to mimic the user's head motion in real-time. Since physically unavoidable network delays cause a noticeable lag between the head motion and the visual response, which triggers motion sickness, two delay compensation techniques are deployed. Firstly, a wider visual field than the viewport size of the user is acquired by the cameras and transmitted to the client side. Thereby, instantaneous visual feedback is provided by leveraging the peripheral image content for local delay compensation until the updated image frame arrives. Secondly, the future head orientations of the user are predicted to start the movement of the stereo camera system to the required orientation before the head orientation data arrives at the server side.

Location:
Department of Electrical and Computer Engineering | Chair of Media Technology (LMT) | Arcisstr. 21 | 80333 München
Building 9 | 1st Floor | Room 1963 | Roomcode 0509.02.963 | 4 on map

Contact: Furkan Kaynar, M.Sc. | furkan.kaynar@tum.de

MSRM Core Facilities Munich Schwabing

Heßstraße 134



*The locations of the laboratories and demonstrators shown on the map are approximate.

Heßstraße 134

Robot Collective

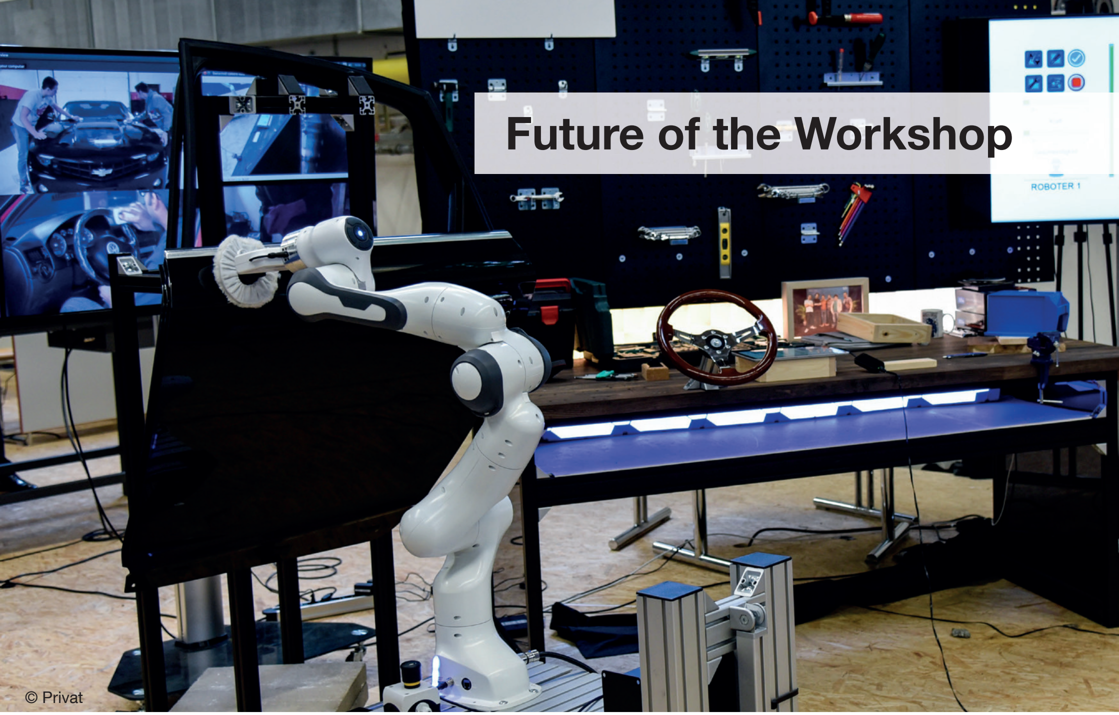
© Nicolas Zunhammer/RSI/TUM

The robot collective is a research platform for various topics such as manipulation learning, collective learning, telepresence, cloud robotics and more. It consists of up to 20 Robots at four to five different locations in Germany and a digital twin in which the physical robots are represented. The main location is at Heßstraße 134. External robots can communicate with the collective and demonstrate its abilities at external locations via the internet. The main showcases are the learning speed-up when using collective learning and telepresence (also 1-to-n telepresence and control of a drone). The collective and its components was mostly developed by the Chair of Robotics Science and Systems Intelligence. Support was given by Vodafone.

Location:
Joint Appointment of the Department of Electrical and Computer Engineering and the Department of Informatics | Chair of Robotics Science and Systems Intelligence (RSI)
Heßstr. 134 | 80797 München | Basement | Hall | 1 on map

Contact: Lars Johannsmeier, M.Sc. | lars.johannsmeier@tum.de

Future of the Workshop



In this demonstration, we present a force-motion control that provides the necessary robustness both for performing tasks and safe direct interactions with the human operator. Additionally, we show a vision system that is able to detect humans and their distance to the robot and affects the robot behavior accordingly – both for safety and for a more convenient observation of the task performance. Another aspect of investigation is the observation and control of energy consumption in the physical and virtual context. The distribution and consumption of energy is directly controlled by taking advantage of an energy-aware control design. The current setup consists of two robots and three typical tasks in an exemplary workshop. A user-interface enables the operator to teach and command the desired tasks in a simple way. In order to apply the same concepts for telepresence scenarios, an additional setup will soon be established.

Location:
Joint Appointment of the Department of Electrical and Computer Engineering and the Department of Informatics | Chair of Robotics Science and Systems Intelligence (RSI)
Heßstr. 134 | 80797 München | Basement | Hall | 1 on map

Contact: Erfan Shahriari, M.Sc. | erfan.shahriari@tum.de

Guest Health@MSRM

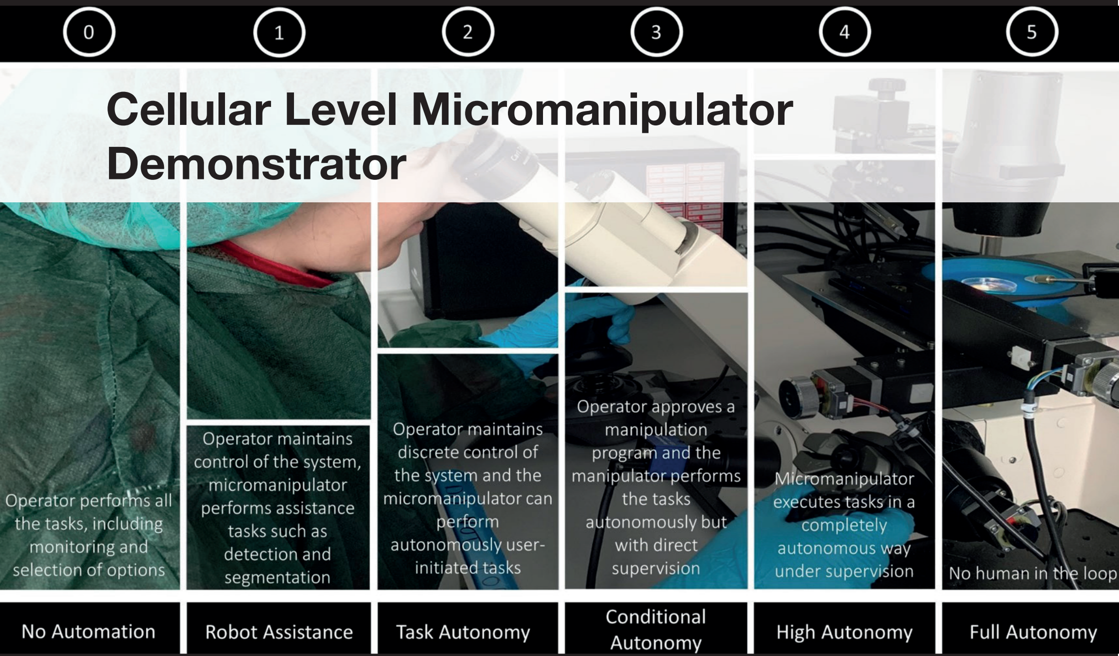
University Hospital - Klinikum rechts der Isar

*The locations of the laboratories and demonstrators shown on the map are approximate.

Building 522

Building 543

Cellular Level Micromanipulator Demonstrator

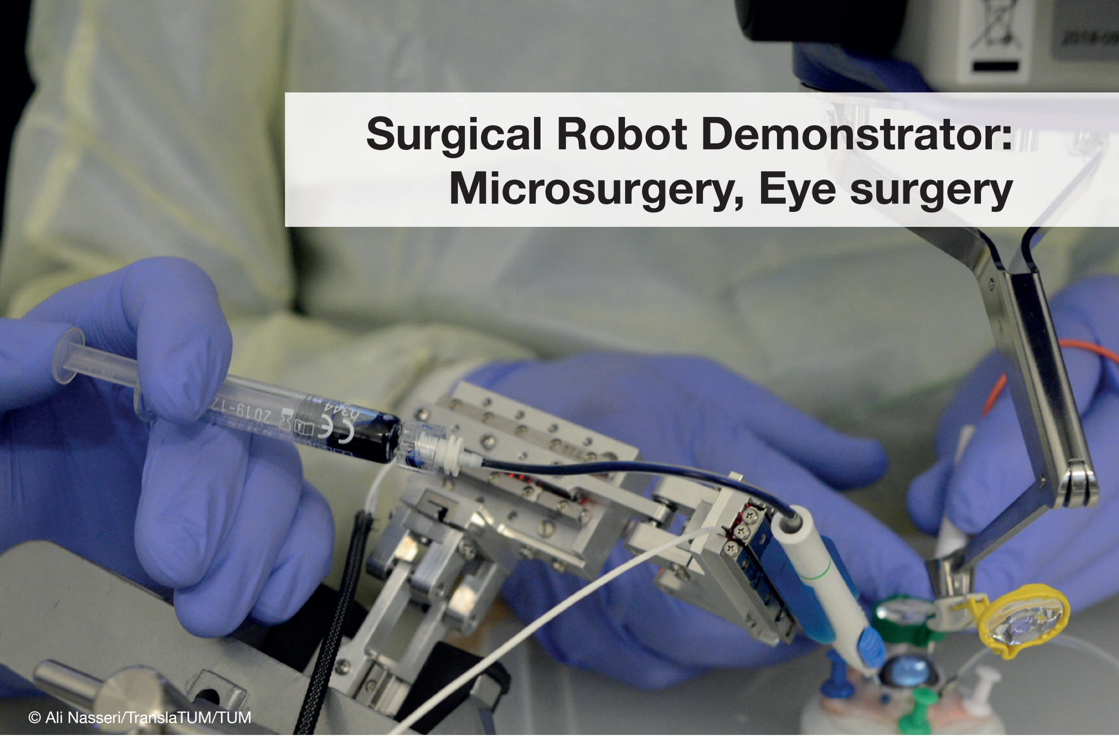


This demonstrator consists of a cellular level micromanipulator, which consists of two arms with sub-micron precision. The setup is used for design and development of machine intelligence algorithms with the purpose of applying image-guided cell micromanipulation. The primary objective of this project is bringing autonomy to cellular level manipulation. Prof. Dr. Nassir Navab and Dr.-Ing. M. Ali Nasseri are leading the project. This platform, which is designed and prototyped by the Japanese company NSK has two arms each with 3 DoF with precision of approx. 5 nanometers. The platform consisting of hardware and software components is able to be used for research and educational purposes in the area of cellular level manipulation, imaging and modeling. Researchers working on this project have direct access to core facilities at TranslaTUM, which are cell culture facilities, cellular imaging systems and many more.

Location:
University Hospital Klinikum rechts der Isar | Center for Translational Cancer Research (TranslaTUM) | Einsteinstr. 25 | 81675 München
Building 522 | 3rd Floor | Room 22.3.45 | 1 on map

Contact: Dr.-Ing. M. Ali Nasseri | ali.nasseri@mri.tum.de

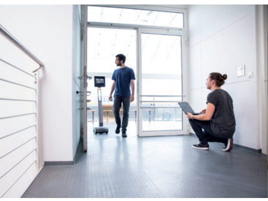
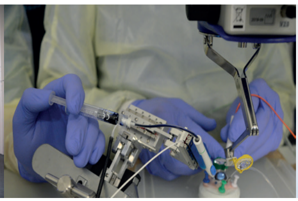
Surgical Robot Demonstrator: Microsurgery, Eye surgery

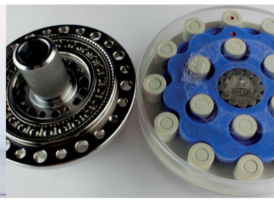


This demonstrator consists of a robotic setup including a user interface and a multi-modal user interface and multimodal imaging platform, which is used for microsurgery and ophthalmic application. The primary objective of this setup is assisting eye surgery to perform precise retinal operation. However, its application can be extended to other microsurgeries. Dr.-Ing. M. Ali Nasseri and Prof. Dr. Dr. Chris P. Lohmann are technical and clinical lead of the project. The project and the demonstrator are a successful example of multidisciplinary and clinical-grade robotic project which is fully designed, developed and prepared for translation at TUM and at the Klinikum rechts der Isar. The setup consists of a hardware and software platform, including a precision surgical micromanipulator with approx. 10 micron precision and 5 DoF; and a software platform that acts as user interface, image processing unit as well as machine intelligence component.

Location:
University Hospital Klinikum rechts der Isar | Department of Ophthalmology |
Precision Surgery Laboratory | Trogerstr. 32 | 81675 München
Building 543 | 3rd Floor | Room 43.4.2 | 2 on map

Contact: Dr.-Ing. M. Ali Nasseri | ali.nasseri@mri.tum.de



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