MIRMI

Munich Institute of Robotics and Machine Intelligence
Integrative Research Institute
Technical University of Munich

TUM

... we are MIRMI

Annual Report 2021
Munich Institute of Robotics and Machine Intelligence

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Foreword

Dear Readers,

Building a strong base for and to-gether with the MIRMI research community in 2021

2021 marks a turning point for MIRMI. With a new name and four new interim locations in Georg-Brauchle-Ring, Garching-Hochbrück and Munich City center MIRMI has put itself on a solid footing organizationally. The Board of Directors started its work early this year, and senior management including the Managing Director, Chief of Science and Chief of Innovation is completed since June 2021. But even more importantly: the MIRMI community is now officially set up, the focus groups started working and we can finally deliver on a 3-year-old promise: we can spread seed funding among the community, and all members finally benefit from the fact that their efforts in the field of robotics and machine intelligence are now recognized twice within TUM - via the mechanism of double counting. We particularly appreciate the patience and persistence of MIRMI Science Board Members who got these initiatives off ground in the course of several meetings with the TUM President Hofmann – the last one being in April 2021.

Officially regsitration of 62 MIRMI members and 24 focus groups

With the approval and start of the integrative research funding MIRMI administration also started to (re-)register our members. As of today, we have 62 members and 24 ideas for focus groups, which are now ready to be kick-started by the MIRMI members, and could get support by the first round of MIRMI seed funds.

Manifold integrative research, teaching and techtransfer initiatives in MIRMI in 2021

In addition to numerous individual highlights and awards – which we try to represent as adequately as possible in our communications despite the extensive size of the community – the MIRMI

community has started and achieved a lot together in this past year. Several research projects funded by BFS, KME, StMWI and BMBF, BIDT, StMWK such as 6G-Life, KI.FABRIK Bayern, munich_i, TUM Venture Lab Robotics/AI, robo.innovate, TUM Campus Gariatronik in Garmisch-Partenkirchen, the One Munich Strategy Forum, AI.HeartCenter... and even more are in preparation for 2022. More information about many of this in the report. A specific officer at TUM ForTe and in the Corporate Communications Center will support the community with setting up and disseminating more of these initiatives.

New MIRMI communication channels and website relaunch in 2021

In order to be able to present MIRMI and most importantly our research properly, we have also upgraded our communications this year: Websites revised for Geriatronics and MIRMI, a monthly newsletter with more than 400 subscribers, a MIRMI-Wiki for members, even a highlight clip (thanks to the Corporate Communications Center of TUM) and much more. And last but not least, this first-ever MIRMI annual report, for which we are looking forward to your suggestions and proposals for improvement in the coming years. It is composed of much of the information that our officially registered MIRMI members (by December 2021) have proactively provided.

MIRMI is its active community and network

As we reflect over this last event- and successful year for MIRMI, we want to thank all those who joined and continuously supported this amazing, still growing community: Those who engaged in their sectors, took over new roles, freely started MIRMI projects and focus groups, who joined and actively contributed to MIRMI offers such as cross-industry collaboration workshops or our strategic partnership with the Imperial College London, and who initiated new teaching and talent initiatives.

Thank you!

Despite another lockdown, at the beginning of this year, we altogether achieved a lot and want to thank all of you and our collaborators for your commitment! We are looking forward to the next year and to see MIRMI become a real community project, a place where we join forces, strive for excellence, cutting-edge research and become a global reference for Robotics and Machine Intelligence.

We wish you a Merry Christmas and a Happy New Year!

The MIRMI Board of Directors

Daniel Rixen, Eckehard Steinbach and Sami Haddadin

Top 11 Milestones of MIRMI in 2021

January
Board of Directors starts work as steering body of MIRMI

April
Science Board presents MIRMI strategy and **incentive model** for integrative research to TUM President Hofmann

April
Intelligent Machine Design Lab (Master course) kicks off the start of the **TUM Venture Lab Robotics/AI** as first education offer

June
munich_i a new 3-day high-tech platform of MIRMI and Messe München offers **an open stage for the MIRMI community** to showcase their research

June
First research project of the MIRMI Lighthouse Initiative **KI.FABRIK Bayern** starts (Sector Work@MIRMI)

July
Research demonstrations at the Pinakothek der Moderne during a visit by Minister Sibler mark the start of the new MIRMI Innovation Sector **Environment@MIRMI**

July
In course of the summer **62 PIs officially register** to be MIRMI members.

August
The BMBF-funded **Research Hub 6G-life** of TUM and TUD starts research to drive future 6G communication networks with a focus on human-machine collaboration

September
Minister Sibler, MdL, visits Geriatronics and promises the **first two positions for the TUM Campus in Ga-Pa**, which will develop from the MIRMI Geriatronics Research Centre
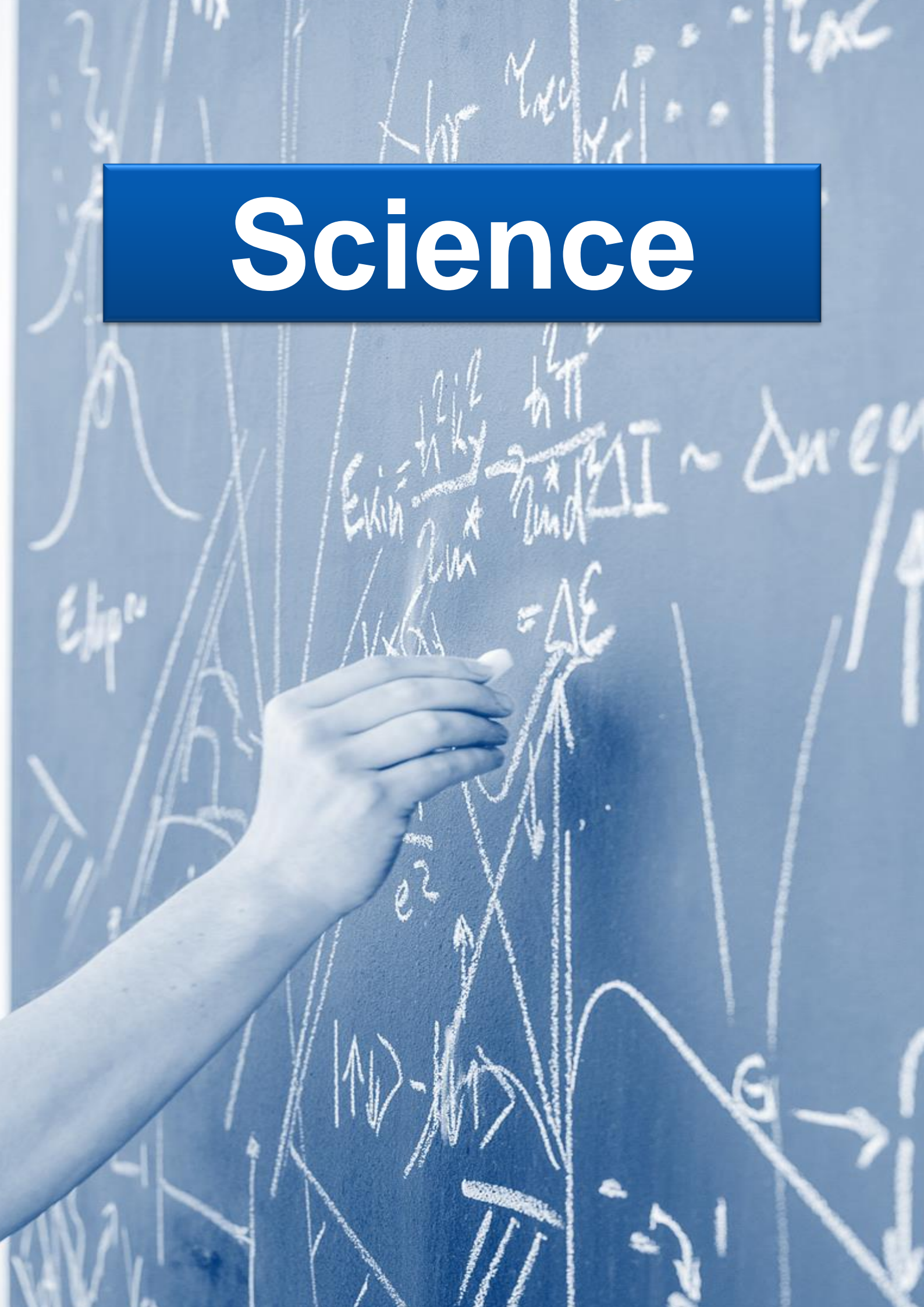
October
Official **renaming** from Munich School of Robotics and Machine Intelligence (MSRM) to Munich Institute of Robotics and Machine Intelligence (**MIRMI**)
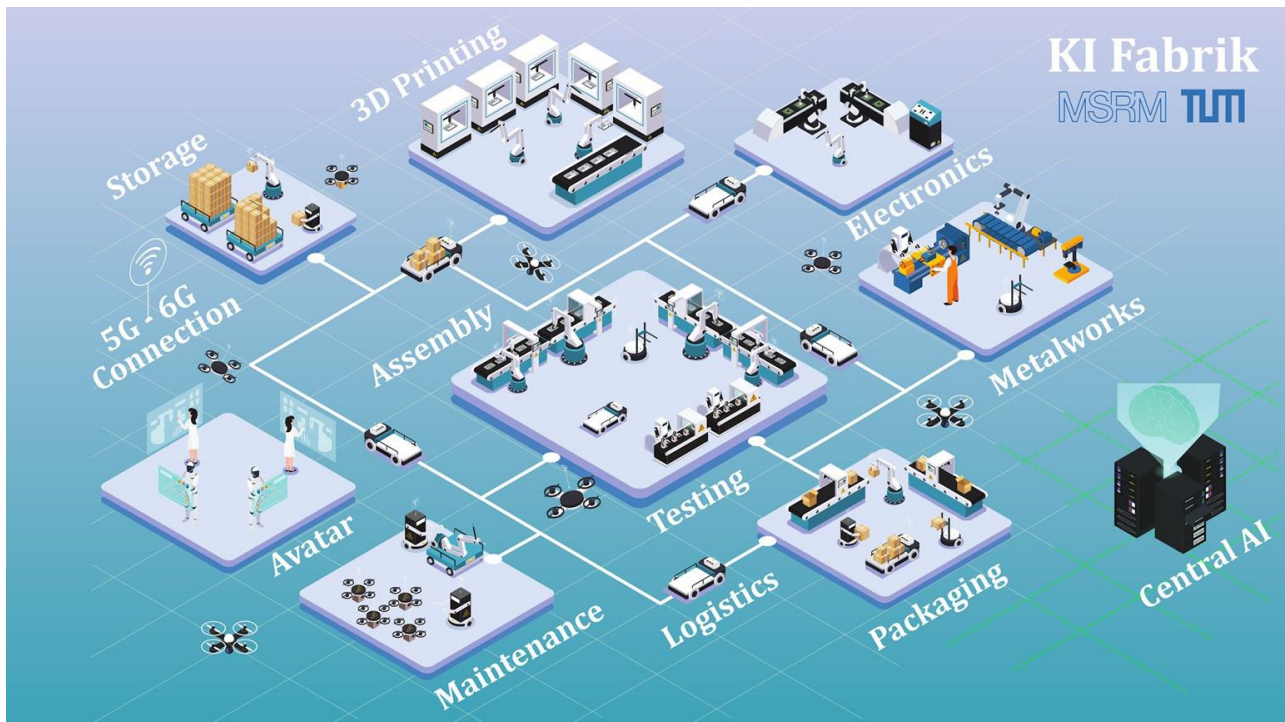
November
MIRMI announces the first call of applications for **MIRMI Seed Funds** (deadline 31 Jan 2022)

Science

The Factory of the Future – Distributed, Connected, Adaptive & AI-driven

First Project in Lighthouse Init. KI.FABRIK (Future of Work)

The innovative idea of the factory of the future - distributed, decentralized cells, connected and controlled via a Central AI
© Utku Culha/Lars Johannsmeier, MIRMI/TUM

On June 15, 2021, the project KI.FABRIK Research and Development officially kicked off, followed by **the public cornerstone ceremony on June 23** with high representatives from politics, economy and academia in the Deutsche Museum in Munich.

In parallel to the ramping up, the consortium agreement was concluded and signed within a few weeks. To get a better insight into the infrastructure and technologies of the consortium partners, mutual visits are planned where the first impression one held at the BMW site in Munich in October. The second one is planned at the TQ Systems site by the beginning of 2022 to support a successful connection of the scientific and economic partners despite the current Covid19 situation. Next to the funded consortium, potential associated partners are planned

and the first bilateral promising meetings have already taken place with for example SAP SE, Schäffler AG and HAWE SE. On the academic side, all chairs of the Technical University of Munich (TUM) have started their activities in the respective work packages and monthly status meetings across all hierarchy levels are set up to synchronize activities within the project but also with the forerunner project KI.FABRIK Infrastructure started earlier this year. Finally, the publication and dissemination strategy for the project is under development in coordination with the academic partners. All activities are reported to and coordinated by a project steering board. Lead use cases (planetary gear and cockpit pre-assembly, quality assurance) were identified until Dec 2021 to promote a common understanding of future research activities, necessary infrastructure and future production technology along

with the initial idea of the factory of the future (see fig. 1). They serve as archetypical use cases for generic approaches showing the potential of self-learning robotics, intention recognition, motion/trajectory planning, teleoperation and digital twin for future production systems. The goal is to achieve a highly flexible, networked production system that is competitive through its reconfiguration abilities and human-machine cooperation.

Therefore, a roadmap for the development and public demonstrators was successfully set up. Further, a holistic and consortium-wide accepted definition of the term digital twin was developed and already externally communicated. Due to the structure of the consortium, different locations will practically contribute to the vision of a distributed but connected factory (see fig. 2) within TUM, the partner sites across Bavaria and Deutsches Museum as the Forum der Zukunft. The latter one will also serve as a prominent and well-known place for the communication of groundbreaking scientific research and developments into the society – in Bavaria, in Germany and worldwide. Solutions being developed in existing networked laboratories across TUM and project partners will be replicated and integrated into the demonstration and research areas at Deutsches Museum.
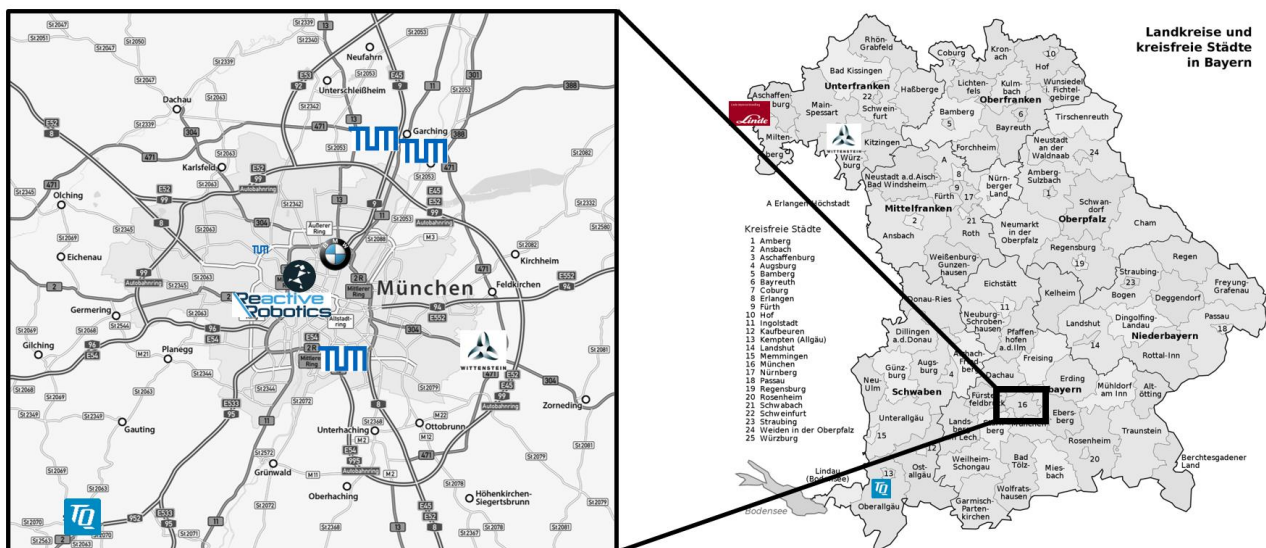
Partner and site locations in Munich and Bavaria (Picture source: Wikipedia)

Coordination "KI.FABRIK Bayern FuE":
- Prof. Bengler

MIRMI PIs Involved in "KI.FABRIK Bayern FuE":
- Prof. Burschka, Prof. Diepold, Prof. Haddadin, Prof. Kellerer, Prof. Knoll, Prof. Steinbach, Prof. Vogel-Heuser

Related Links:
- TUM Press release:
  Cornerstone laid for artificial intelligence-based factory KI.FABRIK

- KI.FABRIK FuE is part of the Innovation Sector Work@MIRMI:
  Work@MIRMI Homepage

MIRMI Lighthouse Initiative Geriatronik

World of Geriatronics!

1. Maintaining independence and social participation by maintaining mobility,
2. Preservation of interpersonal interaction and communication customizable assistance systems and
3. Support and relief of nursing staff in time-consuming or strenuous activities

GARMI robot in rehabilitation activities with humans, and improving autonomy and independence through support on activity of daily living. © Simone Stahl / MIRMI / TUM

MIRMI has launched the "Geriatronics" ("Geriatronik") Lighthouse Initiative as part of the health@MIRMI sector. The concept of "Geriatronics" refers to the use of robotics, mechatronics and information technology, in particular machine intelligence and 3D technology, in geriatrics, gerontology and medical care of the elderly for optimal support and to maintain and improve self-determination in old age. To achieve the greatest possible effectiveness of the Lighthouse Initiative, several funding institutions are to contribute to its implementation via several projects. The goals of the individual projects can in principle be achieved independently of one another, but considerable synergies can be achieved.

This year different projects under the umbrella of Geriatronics received remarkable acknowledgments. The euRobotics TechTransfer Award was presented to the **MobiPar project** for developing a safe and minimalistic control and learning (AI) algorithm, which automatically finds and provides the optimal balance between rigid support and "soft" guidance for any given patient during therapy. This assist-as-needed (AAN)

control strategy is being commercialized in collaboration with the high-tech startup Reactive Robotics and Schön Klinik Bad Aibling, as part of a robotic assistive device called VEMO, used for the early rehabilitation of ICU patients. Additionally, the **ProteCT project** became the winner of the Medical Robotics for Contagious Diseases Challenge of the Hamlyn Symposium on Medical Robotics 2021 in the Design category. The team received a GBP 5,000 prize for developing a Telemedical Diagnostic Framework that enables a modular, robot-based contactless examination. Such telediagnostic solutions ensure the stability of the health system in crises with a high incidence of infections like the global outbreak of COVID-19.

Geriatronics researchers published more than **30 Peer-Reviewed Papers** in 2021 alone. The team conducted user studies for acceptance of a service robot during three activities of daily living tasks with more than 15 subjects. This is the first study of this kind with the Elderly population.

Geriatronics' developments were presented to the general public during several live demonstrations. A Dual Doctor-Patient Twin Paradigm - a novel telemedicine concept through GARMI and Human-Digital-Twin integration was presented at munich_i during the automatica sprint trade fair. Another Demo took place during the Science Summer at the Deutsches Museum. The Geriatronics Research Center welcomed visitors to its facilities in Garmisch-Partenkirchen during the Day of Open Doors in October.

The center was also visited by the Bavarian Minister of Science Bernd Sibler, MdL, the Mayoress of Garmisch-Partenkirchen Elisabeth Koch, and politicians Martin Bachhuber, Alexander Dobrindt and Harald Kühn on September. The Geriatronics research activities made a positive impact on Minister Sibler, MdL, who once again emphasized his support for the new TUM campus and confirmed some first positions to build the new campus of the Technical University of Munich at Bahnhofsareal West in Garmisch-Partenkirchen. On the future campus, research, teaching and care will be closely interlinked. This decision enables Garmisch-Partenkirchen to become a university location.

The Geriatronics project was featured **13 times** in various local and German Media such as Merkur, BR, Süddeutsche Zeitung, Deutschlandfunk, Kreisbote, mpz Digital, GARMISCH-PARTENKIRCHEN & REGION Tagblatt, and the German Platform Lernende Systeme.

Coordination:

- Prof. Haddadin

MIRMI PIs Involved in "Geriatronics" and related projects:

- Prof. Burschka, Prof. Buyx, Prof. Franklin, Prof. Haddadin, Prof. Heckl, Prof. Steinbach, Prof. Walter

Related Links:

- **Geriatronics Website**

Gefördert durch
Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

bidt — Ein Institut der Bayerischen Akademie der Wissenschaften

LONGLEIF GARMISCH-PARTENKIRCHEN

vodafone

Microsoft

DHM – MIRMI Joint Research Center "Zukunft der Medizin – KI-Herzzentrum"

Lighthouse Initiative Digital Heart OR

The German Heart Center Munich (DHM) and the Munich Institute of Robotics and Machine Intelligence (MIRMI) are bundling their expertise in a Lighthouse Initiative funded by the StMWK to establish a center for the future of health in Munich. The joint project (2019 – 2024) is the nucleus of the reference center "AIHeartCenter". Within this Lighthouse Initiative, MIRMI and DHM PIs are jointly developing information technology in the fields of AI-based data analysis and sensor data fusion, robotics, machine learning and VR/AR as well as image fusion for clinical applications in an example-oriented and targeted manner. New systems and procedures are initially established in a research environment and later integrated into clinical processes.

Research team facilitating AI.HeartCenter

An international team of young scientists supports renowned researchers and medical specialists in developing virtual reality and artificial

intelligence for tomorrow's medicine. Since 2021 one additional Postdoc and two more Ph.D. students are working within the medical and technical work packages. The Postdoc started early this year working closely with MIRMI member Prof. Burschka on Interactive Context-Driven Data Fusion. He is also taking over coordinating tasks for all MIRMI PIs and contributes to the Intensive Care Unit research under medical supervision from Prof. Lange. The team is experimenting with inpatient data from the eICU database for diagnosis-based feature selection and is now preparing to include real ICU data. Additionally, two more Ph.D.s are now supporting Prof. Navab's subteam focussing on intraoperative imaging and navigation. Their mock-up room in DHM's research building got completely equipped so that they are ready to work there. One student jointly supervised by Prof. Haddadin and Prof. Ewert from DHM applied for a scholarship and proceeds her research now from Stanford University, working on "An Energy-Consistent 1D Fluid-Structure Interaction Model of a Blood Vessel with a Flow Boundary Condition at the Entrance". Heart Modelling subteam under joint supervision from Prof. Gee (technical) and Prof. Ewert in DHM (medical) also just found a new Ph.D. to continue the research started last year. First papers also from the growing Big Data team are under submission.

On 20 January 2022, research associates and scientists will present DHM and TUM PIs with an overview of the achievements made in all work packages. Together they will discuss project focussed scientific topics, findings, challenges and exchange ideas about additional research and further cooperation based on the running project.

MIRMI-DHM research team (project manager, postdocs and Ph.D. students) © Deutsches Herzzentrum München

Coordination:

- Prof. Lange (DHM), Prof. Navab (MIRMI)

MIRMI PIs involved in "AI. Heart Center"

- Prof. Burschka, Prof. Gee, Prof. Haddadin, Prof. Klinker, Prof. Navab

Related Links:

- DHM-MIRMI Joint Research Center:
  Project Information

Gefördert durch

Bayerisches Staatsministerium für
Wissenschaft und Kunst

BMBF 6G Research Hub 6G-life (TUM/TUD)

© Project Consortium 6G-Life

The expert teams of TUM and TUD succeeded in securing one of the four **German National 6G Research Hubs** funded by the BMBF. With this joint hub the two universities are thus also building on their successful previous collaboration and existing preliminary work such as within the framework of the **CeTI** Cluster of Excellence (Centre for Tactile Internet with Human-in-the-loop). It also goes hand in hand with other TUM 6G projects already funded by the Bavarian state government, such as the **6G Future Lab Bavaria**. Having been started in August 2021, the national 6G Research Hubs are university-based projects for basic research in the field of 6G communications. At the center of 6G-life is research on human-machine collaboration (MMC), as this is the basis for the two main application fields of 6G technology: Industry 4.0 and healthcare.

Coordinators from TUM side (Prof. Boche, Prof. Kellerer) also involved some MIRMI PIs to join the 70 million Euro project in which more than 60 PIs from TUM and TUD will collaborate during the next 4 years.

Coordination (TUM side):
- Prof. Boche, Prof. Kellerer

MIRMI PIs Involved in "6G-Life":
- Prof. Bhatotia, Prof. Haddadin, Prof. Kellerer, Prof. Steinbach, Prof. Steinhorst, Prof. Wilhelm

Related Links:
- Project Website:
  BMBF Research Hub 6G-Life

- TUM Press release:
  Joining forces to shape the 6G future

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Bundesministerium
für Bildung
und Forschung

MIRMI Members in TUM's Strategic Research Programms

One Munich Strategy Forum

As result of an elaborate application process, TUM, LMU and HMGU jointly secured the strategic cooperation project **"ONE MUNICH Strategy Forum HumanCentered Robotics"**. It is funded by the Bavarian StMWK and the Federal Ministry of Education and Research (BMBF) under the Excellence Strategy and coordinated by the LMU-TUM tandem Prof. Kutyniok (LMU) and Prof. Haddadin (TUM/MIRMI) with collaboration of many MIRMI and TUM PIs:

"Through this Strategy Forum the three leading Munich research institutes TUM, LMU and HMGU unite their unique and highly complementary expertise and efforts in the fundamental, theoretical, and applied machine intelligence, system sciences, and translational medicine to address societal health challenges of today and the future. (…) The goal of this project is the fostering of deep and long-term connections between the top research institutes in Munich to create the basic methods, technologies, and systems that allow for the development of the next generation intelligent robotics in the interplay between human embodiment and system agency in trustworthy AI for healthcare, constituting the unification of versatile smart bodies, novel embodied AI algorithms and architectures,

which together are capable of interacting with the physical world intelligently and responsibly."

MIRMI PIs involved in OneMunich:
Prof. Diepold, Prof. Haddadin, Prof. Jacob, Prof. Leutenegger, Prof. Lüth, Prof. Piazza

TUM Innovation Network RISE
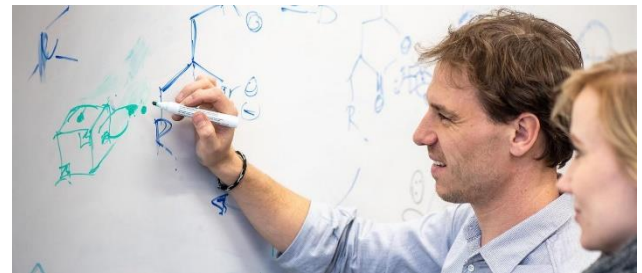
Prof. Job Boekhoven (left), coordinator of the transdisciplinary team of the TUM Innovation Network RISE. © Heddergott / TUM

In the first round of the new TUM funded and TUM internal program for the promotion of interdisciplinary research (**TUM Innovation Networks**), a proposal with the participation of MIRMI PIs Prof. Simmel, Prof. Dietz, Prof. Haddadin, Prof. Lüth could successfully compete among many brilliant ideas and is being funded for 4 years - the TUM Innovation Network **R**obot **I**ntelligence in the **S**ynthesis of Lif**e** (**RISE**):

"How did life emerge? Could it exist elsewhere? Could we even synthesize life – a system that is self-sustaining, self-replicating and evolving? The TUM Innovation Network for Robot Intelligence in the Synthesis of Life (RISE) aims to develop a radically new approach to these centuries-old questions, combining machine learning and robotics with chemical and biophysical experiments."

In Short: Integrative Research Projects

The following project list contains research projects that have been running or started in 2021 and involve more than 2 MIRMI PIs. For reasons of readability, only the MIRMI PIs involved are referred to here (MIRMI members as registered by 16.12.2021). Information on other TUM internal and external project partners and content can be found on the corresponding project pages (hyperlinks).

5G Testbed Bayern mit Schwerpunktanwendung "eHealth" (StMWi)

- MIRMI PIs: Prof. Kellerer, Prof. Steinbach

6G Future Lab Bavaria (StMWi)

- MIRMI PIs: Prof. Boche, Prof. Diepold, Prof. Kellerer, Prof. Steinbach

Adaptive Prozessplanung mittels mobiler Vormontage-Systeme (KME-Mittelstand)

- MIRMI PIs: Prof. Fottner, Prof. Rixen

BMBF Cluster 6G-Life: Digitale Transformation und Souveränität zukünftiger Kommunikationsnetze (BMBF)

- MIRMI PIs: Prof. Bhatotia, Prof. Haddadin, Prof. Kellerer, Prof. Steinbach, Prof. Steinhorst

CeTI - Centre for Tactile Internet with Human-in-the-Loop (EXC 2050)

- MIRMI PIs: Prof. Haddadin, Prof. Steinbach

DHM – MIRMI Joint Research Center "Zukunft der Medizin – KI-Herzzentrum" (AI.HeartCenter) (StMWK):

- MIRMI PIs: Prof. Burschka, Prof. Gee, Prof. Haddadin, Prof. Klinker, Prof. Navab

DSL4RAS: System architecture and modular design of robot-like systems using multidimensional characteristic diagrams (DFG)

- MIRMI PIs: Prof. Stahl, Prof. Vogel-Heuser, Prof. Zimmermann

Exotool (KME-Mittelstand)

- MIRMI PIs: Prof. Bengler, Prof. Zimmermann

Gyro Trainer: Entwicklung einer Simulation menschlicher Bewegungen und Muskelaktivitäten über ein mathematisches Mensch-Modell und des adaptiven Regelungssystems zur Steuerung der Aktorik basierend auf der individuellen Koordinationsfähigkeit des Nutzer (BMWi)

- MIRMI PIs: Prof. Burgkart (MRI), Prof. Haddadin

Human-in-the-Loop Ocean Robotics (IAS Hans Fischer Fellowship)

- MIRMI IAS Fellow: Prof. Takayama
- MIRMI Host: Prof. Haddadin

KI-CP@TUM: TUM KI Competence Program – Professionelle Lerngemeinschaften zur Systematisierung KI-spezifischer Studienangebote an der TUM (BMBF)

- MIRMI PIs: Prof. Diepold, Prof. Haddadin

KI.FABRIK Bayern Forschungs- und Entwicklungsprojekt (StMWi)

- MIRMI PIs: Prof. Bengler, Prof. Diepold, Prof. Haddadin, Prof. Kellerer, Prof. Steinbach

KonMaFS: Consistent Development of Automated Material Flow Systems using a model-based Approach (DFG)

- MIRMI PIs: Prof. Fottner, Prof. Vogel-Heuser

Methad: Toward a MEdical ETHical ADvisor System for Ethical Decisions (IEAI)

- MIRMI PIs: Prof. Buyx, Prof. Diepold

MevoDip: Menschzentrierte Erstellung und Evolution Digitaler Zwillinge in der Prozesstechnik (DFG)

- MIRMI PIs: Prof. Klinker, Prof. Vogel-Heuser

One Munich: Next generation Human-Centered Robotics (StMWK + BMBF)

- MIRMI PIs: Prof. Diepold, Prof. Haddadin, Prof. Jacob, Prof. Leutenegger, Prof. Lüth, Prof. Piazza

OpAI4DNCS: Machine operator-centric parameterization of Artificial Intelligence for tightly coupled, distributed, networked control systems (BFS)

- MIRMI PIs: Prof. Bengler, Prof. Vogel-Heuser

Projekt X: Förderung von Forschung zu Problemen des 3. Lebensalters (StMWi)

- MIRMI PIs from EI: Prof. Burschka, Prof. Franklin, Prof. Haddadin, Prof. Heckl, Prof. Steinbach, Prof. Walter

ProteCT: Protection against the Coronavirus through Robot-Assisted Telemedicine (BMBF)

- MIRMI PIs: Prof. Haddadin, Prof. Wilhelm (MRI)

Responsibe Robotics – AI: Tracing Ethical and Social Aspects of AI-Based Transformations in Healthcare Work and Knowledge Environments (BIDT)

- MIRMI PIs: Prof. Buyx, Prof. Haddadin, Prof. Müller

SafeRoBAY - Sichere MRK-Produktion: Made Dahoam! (StMWi)

- MIRMI PIs: Prof. Burgkart (MRI), Prof. Haddadin

SAINT: Supervised Autonomous Interaction in Unknown Territories (BFS)

- MIRMI PIs: Prof. Rixen, Prof. Walter

SIZA: Sensorintegrierendes Zahnrad (DFG SPP 2305 "Sensorintegrierende Maschinenelemente")

- MIRMI PIs: Prof. Stahl, Prof. Vogel-Heuser

TUM Innovation Network RISE: Robot Intelligence in the Synthesis of Life (TUM)

- MIRMI PIs: Prof. Dietz, Prof. Haddadin, Prof. Lüth, Prof. Simmel

Spotlight on: MIRMI PIs in TUM News

A stage for individual achievements of MIRMI PIs

In coordination and cooperation with the Corporate Communications Center and the MIRMI officer there, the medium- to long-term goal is to place MIRMI and its PIs once a month in the national daily press. Measures to promote this in 2021 included the public press workshop that took place in the run-up to munich_i. Professors Bengler, Haddadin, Lienkamp, Rixen and Wall took part, presenting their research to around a dozen press representatives from ORF, RTL, Süddeutsche Zeitung. Deutschlandradio, VDI nachrichten, and the Bayerischer Rundfunk.

Furthermore TUM Corporate Communications Center has set up an **"Artificial Intelligence" section** on the TUM central webpage. Within the CCC, this page is now maintained by a specific officer acting as an interface to the MIRMI community, bundling and presenting research(ers) to be adopted by the national and international media. Through the **MIRMI newsletter** and the **"news" section** on the MIRMI homepage, these are further disseminated to the specialist community. Some press releases published in this and other sections are listed below (chronolog).

- Prof. Bock: **Cable robot builds and renovates facades** (05.01.21)
- Prof. Lienkamp: **M Cube future cluster wins federal funding** (03.02.21)
- Prof. Steinbach: **New early warning system for self-driving cars** (30.03.21)
- Prof. Haddadin: **Robots could safeguard people from pain** (05.05.21)
- Prof. Kellerer: **Joining forces to shape the 6G future** (29.06.21)
- Prof. Haddadin: **In the Pinakothek der Moderne: KI.ROBOTIK.DESIGN** (14.07.2021)
- Prof. Dietz: **The virus trap** (15.07.21)
- Prof. Knoll:**"The road of the future is digital"** (08.10.21)
- Prof. Chen: **Dr. Markus Söder praises cutting-edge research 'Made in Bavaria'** (11.10.21)
- Prof. Lienkamp: **TUM wins the Indy Autonomous Challenge** (24.10.21)
- Prof. Ntziachristos: **Deep insights in skin imaging** (13.12.21)

Robo.Innovate: The New Robotics and AI Incubator Launched at MIRMI

Angsa Robotics – a team supported by robo.innovate and one of their prototypes (Co-Founders: Lukas Wiesmeier, Philippo Rabast, Bilal Tariq and Karl Schulz, from left) © Angsa Robotics

In November 2021 robo.innovate a new tech incubator for advanced Bavarian start-ups in the field of robotics and AI was launched. It is a new project initiated by and located at the Munich Institute of Robotics and Machine Intelligence (MIRMI/TUM). The project is closely aligned with the activities of the **TUM Venture Labs Robotics/AI**, which started end of 2020 and **opened to the public with the opening of the Munich Urban Colab in April 2021**.

robo.innovate is funded by "Gründerland Bayern" and the Bavarian Ministry of Economic Affairs, Energy and Technology. As a nucleus in Munich, robo.innovate is intended to become the hub for robotics and AI visionaries for the whole of Bavaria and potentially beyond.

The project is promoting and supporting teams as well as entrepreneurs to build up and scale their idea to be able to set up their venture successfully.

robo.innovate already supports several teams, including e.g. Angsa Robotics (autonomous trash picking robot), CargoKite (flexible maritime logistics), Devanthro (anthropometric, i.e. humanlike robodies) and Olive Robotics (modular robotic components for easy prototyping education).

In addition to supporting in the pre-foundation phase, robo.innovate offers domain-specific education with new courses like the **Intelligent Machine Design Lab** (I.MDL, started 2021) or Intelligent Machine Design Programming Lab (I.MPL, starting 2022), where TUM master students have the chance to uniquely experience intelligent robotics and AI to broaden their expertise.

All activities are flanked by an experienced network of industry partners, mentorship- and coaching programs. Adding domain-specific offerings robo.innovate thereby enriches the startup ecosystem together with Unternehmer-TUM and MakerSpace at the Munich Urban Colab. Moreover, it aspires to bring together robotics enthusiasts and experts all over Bavaria.

Starting 2022, teams have the chance to pitch their ideas and become part of robo.innovate.

Contact and further information:
Daniel Straimer, Managing Director robo.inno-vate, **daniel.straimer@tum.de**

Cross-Industry Collaboration Workshops

Member companies of the MIRMI Industry Advisory Board and MIRMI members identify topics of joint research interest across industries in an online workshop.
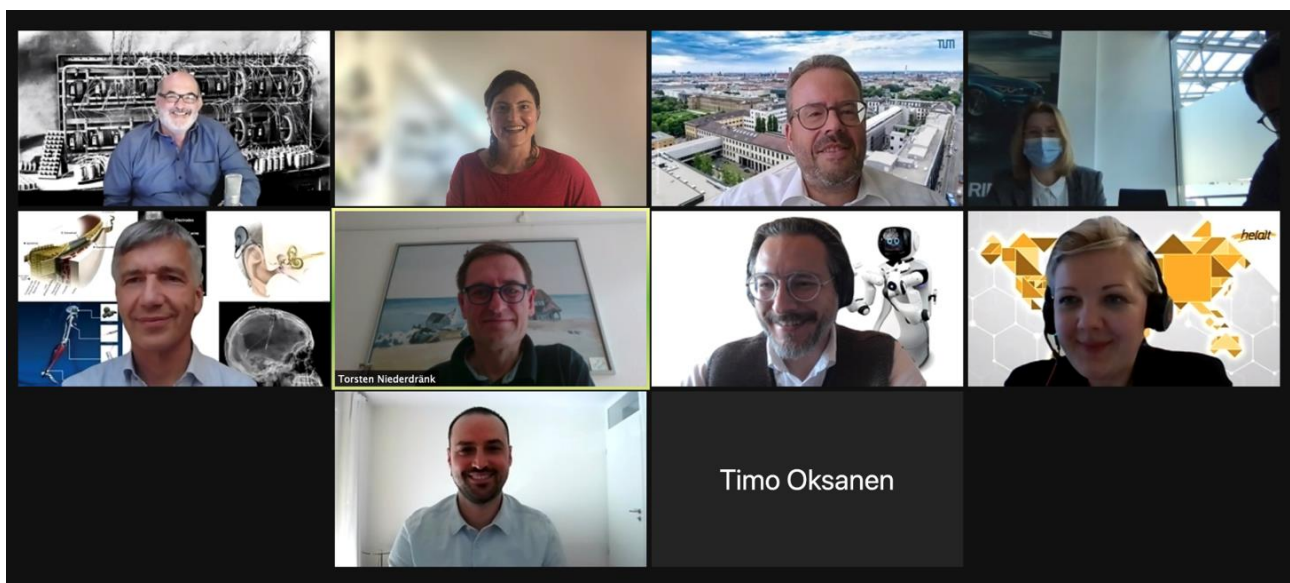
The participants of the Cross-Industry Collaboration Workshop organized by MIRMI in April 2021. From left to right and top to bottom: Prof. Klaus Diepold, Dr. Maria Danninger, Prof. Eckehard Steinbach, Ms. Carolin Richter (BMW AG), Dr. Peter Lehnert (BMW AG), Prof. Werner Hemmert, Dr. Torsten Niederdränk (Siemens Healthineers AG), Prof. Sami Haddadin, Dr. Corina Apachite (Continental AG), Kristian Dencovski (Siemens Healthineers AG), Prof. Timo Oksanen. Also participating, but not in the picture: Prof. Klaus Bengler. © MIRMI / TUM

The goal of the cross-industry collaboration workshop held in April 2021 was to identify topics in which both the Munich Institute of Robotics and Machine Intelligence and industry companies have a broad common interest and, if possible, to agree on specific research projects where MIRMI and industry can join forces in the future. 5 MIRMI PIs and 5 industry representatives from BMW AG, Siemens Healthineers and Continental AG participated in the workshop.

In the discussions of past (semi-annual) Industry Advisory Board meetings, several topics of common interest to both the MIRMI sectors and of member companies had emerged. These topics

and discussions were followed up in the online workshop:

1. Factory of the Future and Future of Work;
2. Autonomous drone teams for inspection, mapping and exploration of infrastructure and the environment;
3. Federated learning in autonomous vehicles (land, air, water) and health systems;
4. Agricultural Robotics;
5. Certification, benchmarking, and standards for machine intelligence systems;
6. Trustworthy Human-Robot Systems.

The results and lessons learned from this workshop were presented at the Industry Advisory Board meeting on May 3, 2021. A series of face-to-face Deep Dive workshops to follow up on the topics with most interest (factory of the future, federated learning, certification and reference systems) could not yet take place.

In Short: Industry Liaison Activities

In addition to the major milestones in this work area, there are of course many other activities in which MIRMI works to build a durable and stable network in the industry for the benefit of research at MIRMI. Activities here range from interaction with MIRMI's own Industry Advisory Board passing through presentations at industry associations to engagement in networks with strong industry participation. Some of these activities are listed below.

MIRMI Industry Advisory Board Meetings

From left to right: Barbara Bergmeier (Airbus DS), Michele Melchiorre BMW Group) and Prof. Wörner (acatech) join the IAB as new members.

The 12 high-level representatives from major technology companies in the **MIRMI Industry Advisory Board** continuously advise the Integrative Research Center as critical friends. In the bi-annual meetings (mostly in spring and fall of each year), the board receives insights into the research work and highlights of MIRMI and in return advises the MIRMI Board of Directors and the Sector Leads on the development and future strategic direction of the institute - especially concerning topics with industrial relevance. At the meetings, the MIRMI community (from Ph.D. student to professor) has the opportunity - if desired - to present their ideas or other relevant topics to the industry experts and to engage them as champions for their project. At this year's meetings in May and October 2021, which took place on the main focus of the discussions was the sector strategy of the AI@MIRMI research sector, as well as the Lighthouse Initiatives Geriatronics and AI.FABRIK. Furthermore, it was discussed how the IAB can contribute to MIRMI initiatives for startup support (TUM VL Robotics/AI), education (I.MDL), joint research projects (results of joint cross-industry collaboration workshops), or in the context of joint challenge competitions.

The following company representatives have retired from the IAB in 2021 due to retirement and personnel changes:
- Prof. Dieter Spath (acatech),
- Dirk Hoke (Airbus DS),
- Dr. Gerd Schuster (BMW Group)

In their succession, we are pleased to welcome the following high-profile members to the IAB:

- Prof. Jan Wörner (President - acatech),
- Barbara Bergmeier (Executive Vice President, Head of Operations and Member of the Executive Committee - Airbus DS),
- Michele Melchiorre (Senior Vice President Production System, Technical Planning, Tool Shop, Plant Construction - BMW Group)

We thank all IAB members for their continuous and valuable contribution to the development of MIRMI.

MIRMI joins the etami network

Etami is a cooperation network to explore the potential of a standardization and a certification process concerning **e**thical and **t**rustworthy **a**rtificial and **m**achine **i**ntelligence (**etami**). It is coordinated by the VW AG, Prof. Patrick van der Smagt. MIRMI joined the network in fall 2021 to collaboratively work on further scientific and technical research relating to the topic of ethics in the application of artificial intelligence. Besides several scientific partners (e.g. TU Berlin, DFKI, TU Leuven), many large technology companies such as VW AG, Deutsche Telekom, Siemens AG, ABB AG or Deutsche Bahn AG are part of the network:

"The goal of the alliance is to suggest a public standard or framework for ethics in AI, as well as suggestions and piloting of certification of such standard or framework."

An extension of the cooperation in the network until 30.09.2022, which originally lasts until 31.12.2021, is currently being evaluated.

Invitations to present MIRMI at different industry associations

As in the previous year, several members were invited to present MIRMI at various industry association events and also scientific conference formats. Together with the Corporate Communications Center, Professor Cremers (**"Bitkom AI Research Network"**) and Professor Haddadin (**Big-Data.AI Summit 2021**; **#BAS21**) were each independently invited to speak at **Bitkom** and also presented MIRMI on this occasion. In addition the Board of Directors also presented MIRMI, its research, and potential collaboration opportunities at **ZVEI, bayme vbm F+E Kongress, FamilienunternehmerTUM and other occasions**. Further appointments with renowned industry associations are already under planning for 2022.

Workshop with Continental on Agricultural Robotics

During one of the MIRMI Industry Advisory Board meetings in 2020, the idea emerged to get more strongly involved in Agricultural Robotics, also about the new (and at that point still to be established) Environment@MIRMI sector. Following that discussion, **Dr. Corina Apachiţe** (Continental Teves AG & Co. OHG, Artificial Intelligence, Holistic Engineering and Technologies, Automotive Technologies) offered to organize a virtual meeting and brainstorm on possible collaborations and projects with PIs from MIRMI. Topics included AI, Trajectory Planning, Machine Learning, Vehicles, Manipulators. To prepare this, MIRMI member Prof. Rixen organized a short internal and informal "Coffee Chat" with some MIRMI PIs via spatialchat, to get an overview of the different interests and expertise that MIRMI could bring in. It was discussed that collaboration in this field would be a first good step to explore the potential of Machine Intelligence and Robotics for this societal challenge "Future of Environment" where the full potential

of new technologies still needs to be fully exploited.

Some of the agricultural systems were introduced during the workshop with Continental Teves. Top: Harvesting robot "CROPS", © Chair AMM/TUM; bottom: Continental robots "Contadino" and "Corriere LM", © Continental AG

The workshop with Continental finally brought together 7 MIRMI researchers and 4 researchers from Continental at the end of January. Among other things, Continental presented its robot Contadino (Agricultural Robot) and other current systems, e.g. in the last-mile delivery robot "Corriere LM". The workshop helped to cascade the interaction inside Continental and TUM/MIRMI from management to researcher/project level In the end, more areas for potential collaboration were identified and individual mutual follow-up appointments were agreed upon.

__The following MIRMI PIs participated in the workshop with Continental:__
Prof. Althoff, Prof. Bengler, Prof. Burschka, Prof. Fottner, Prof. Haddadin, Prof. Oksanen, Hr. Prexl (Prof. Walter), Prof. Rixen.

Bundling of cooperation requests from the private sector

Since the collaboration requests from companies in the Munich metropolitan region grow stronger from month to month, MIRMI intends to create a low-threshold and uncomplicated point of contact to MIRMI. This is why MIRMI Chief of Innovation and the Officer for Industry Relations and Internal Affairs have been working together with the TUM central departments in 2021 to design an industry relations program that offers precisely this form of easy entry point, where MIRMI researchers and companies specifically interested in Robotics and Machine Intelligence can get in direct touch. The ideation phase with TUM central has not yet been completed, but among the interested companies that can imagine collaborating with MIRMI in the future and in different contexts are e.g., Intel, THK, SAP, Oerlikon, Schaeffler, Robert Bosch GmbH, Bosch Siemens Hausgeräte, Google X, Huawei Technologies Duesseldorf GmbH, Hyperganic Technologies AG, IBM Deutschland GmbH, Infineon Technologies, Nokia Solutions and Networks GmbH & Co. KG, Oerlikon AM GmbH, SAP SE, Texas Instruments Germany GmbH or Microsoft Deutschland and Vodafone GmbH.

Interested PIs are invited to contact the MIRMI Officer for Industry Relations and Internal Affairs, __Mrs. Olivia Schmitt-Walter,__ if they want to be involved in any of these potential collaborations or are already in contact and cooperation with one of the above mentioned companies.

Community

munich_i: A New High-Tech Platform for the MIRMI Community

automatica *sprint* and munich_i successfully premiered together from 22-24 June 2021 in a digital format. munich_i is a joint initiative of Messe München, automatica and the Munich Institute of Robotics and Machine Intelligence (MIRMI) of the Technical University of Munich (TUM). Bavarian Prime Minister Dr. Markus Söder, MdL, was the patron of munich_i. The new high-tech platform for Munich is a combination of 4 integrated parts: Hightech Summit, AI.Society special exhibition area, Robothon® – The Grand Challenge and Robot driver's license.
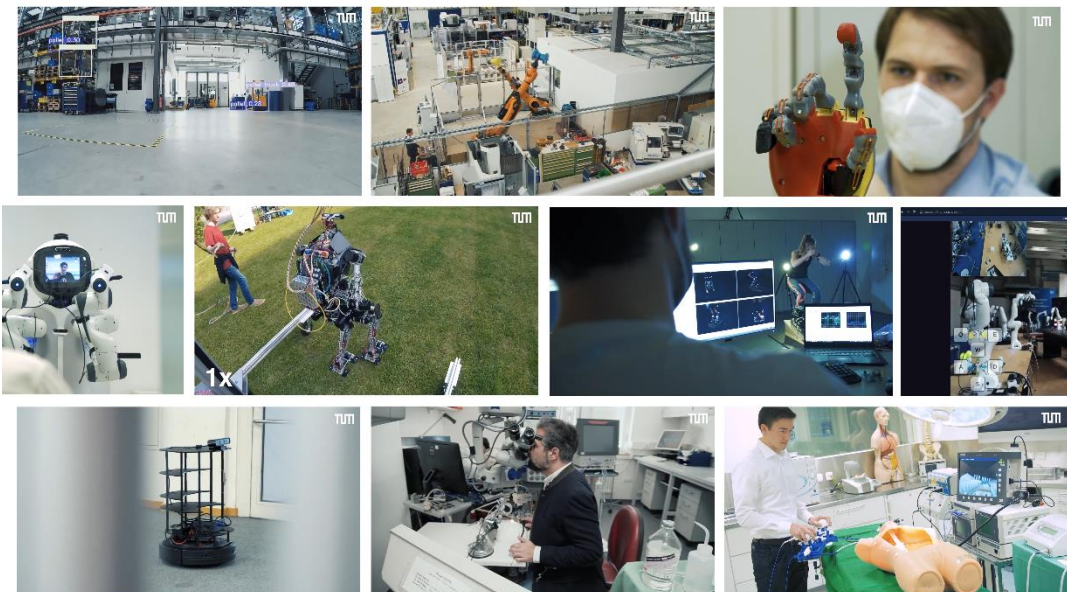

3,500 participants from the robotics and automation industry with a record attendance of approx. 1,400 participants were at the munich_i Hightech Summit.

Dr. Reinhard Ploss (CEO, Infineon Technologies AG) with Session Chair Prof. Ruth Müller starting the first Session "Assisting the human" (from left). © Messe München.

During the munich_i **Hightech Summit**: 1,400 people followed the speeches of 23 world-renowned research and industry representatives such as Dr. Reinhard Ploss (Infineon Technologies), Prof. Oussama Khatib (Stanford University), Prof. Carme Torras (Institut de Robòtica i Informàtica Industrial), Prof. Dieter Fox (University of Washington), Prof. Yoshihiko Nakamura (University of Tokyo) and Gurdeep Singh Pall (Microsoft Corp).

Along a journey through the future of work, health and mobility, 30 teams from MIRMI/TUM and award-winning start-ups from the greater Munich area, as well as other renowned partners demonstrated their research projects and showcases in **AI.Society.** The digital "Live Sessions of AI.Society" were visited with an average of 110 participants per presentation.

AI.Society showcased 19 TUM project demos from 13 TUM Chairs, 7 start-up demos and 2 partner project demos.

Overview of some of the demos presented at the digital AI.Society special exhibition area © MIRMI / TUM

In **Robothon® – The Grand Challenge**, a competition for robotics enthusiasts from academic and professional fields, more than 10 international teams tried to solve an automation task: **The disassembly and sorting of electronic waste.** All teams were evaluated based on their robot platforms' autonomous performance via their live presentation to the Grand Jury. The Jury was so pleased by their presentations that the prize money was spontaneously raised to a sum of 23,000 €. The winners of the Robothon® 2021 Grand Challenge were announced during a live studio recording at the **automatica sprint Hightech Summit**.

SAVE THE DATE: The Grand Challenge is entering the second phase. Robothon® will take place digitally again from 29 April to 25 May, 2022!

4 winning teams at the Robothon® Award Ceremony and total prize money of 23,000 € sponsored by Huawei, Franka Emika and Prof. Hirzinger.

Left picture: The Members of the Robothon Grand Jury Prof. Patrick van der Smagt, Prof. Tamim Asfour and Prof. Gerd Hirzinger evaluate and decide on the winners, moderated by Technical Leader of the Robothon®, Peter So (second from right). Right picture: The 4 winning teams at the Award Ceremony Robothon®: *Team RAND-E (Cairo, Egypt), Team Ewas (Milano, Italy)*, *Team RoboPig (Würzburg-Schweinfurt, Germany), Team RoboTHIx (Ingolstadt, Germany)* © Messe München

Following up on this success, munich_i, the platform for driving forward responsible and human-centered technological development, will continue to be part of the next automatica trade fair in June 2022 in Munich.

Spotlight on: Activities of MIRMI Sectors

Artificial Intelligence@MIRMI
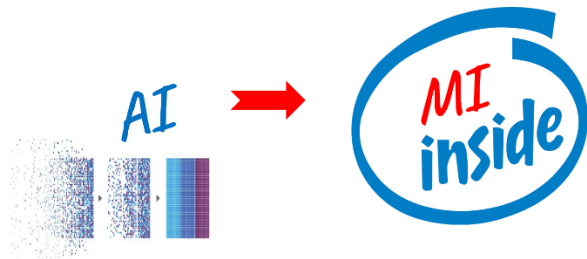
AI@MIRMI in a nutshell © Prof. Diepold, Prof. Hirche

In the IAB Meeting Spring/Summer 2021, AI@MIRMI presented its sector strategy, closing the round of sector strategies presented to the Board. "MI inside" was the thread, which the sector leaders Prof. Diepold and Prof. Hirche used to present their ideas for the development of the sector, as well as the contribution of AI to solving major societal challenges. The mission of the sector is to drive AI for Physical Systems (Embodied Intelligence) and make AI tangible. Along the way, they also demonstrated how intersectoral multiplication between research in different MIRMI sectors (e.g. AI and Environment) can advance the common cause. The IAB reacted with great interest to the strategy and pointed towards the compatibility of the ideas to their own initiatives.

Environment@MIRMI

2021 also marked the start of a new Innovation Sector. Compared to the "Research Sectors", the MIRMI "Innovation Sectors" are more usage-driven and dedicated to the deployment of robotics and machine intelligence to solve the grand societal challenges of our time. Since one of these challenges is, of course, environmental and climate protection, a group of members around Prof. Chen and Prof. Oksnanen has formed that wants to drive this area forward in MIRMI. The kick-off to the sector, whose leaders are appointed at the end of 2021, took place dur-

ing a **joint demonstration booth** on the occasion of a visit by Bavarian Science Minister Sibler, MdL: the first demo combined the research activities of Prof. Chen, Prof. Haddadin, Prof. Oksanen, and showed how machine intelligence can be used in agriculture and environmental monitoring. Remote-controlled drones from the air supported technology on the ground. The second demonstrator showed the research work on autonomous drones of Prof. Stefan Leutenegger, formerly from Imperial College London (ICL), and Prof. Markus Ryll, recently brought to Munich from MIT.


From left to right Prof. Oksanen, Prof. Chen, F. Dietrich, Prof. Ryll, Prof. Haddadin, Prof. Leutenegger, in the MIRMI Demo Booth around the new sector "Future of Environment - Reducing Environmental Pollution with Intelligent Robot Networks" at Die Neue Sammlung - The Design Museum. © Robert Haas

Work@MIRMI

Following a good tradition, the PIs of the Work@MIRMI sector met again in 2021 (as in previous years) for an General Assembly organized by Sector Lead Prof. Vogel-Heuser. From these General Assemblies, as well as from a joint Summer School, ideas for several now **successfully funded projects of the sector** had emerged in the past. In addition to brief status reports from the sector's Focus Groups and running projects, it was also discussed how the doctoral network within the sector could be strengthened in the future.

Partnership: Imperial College London
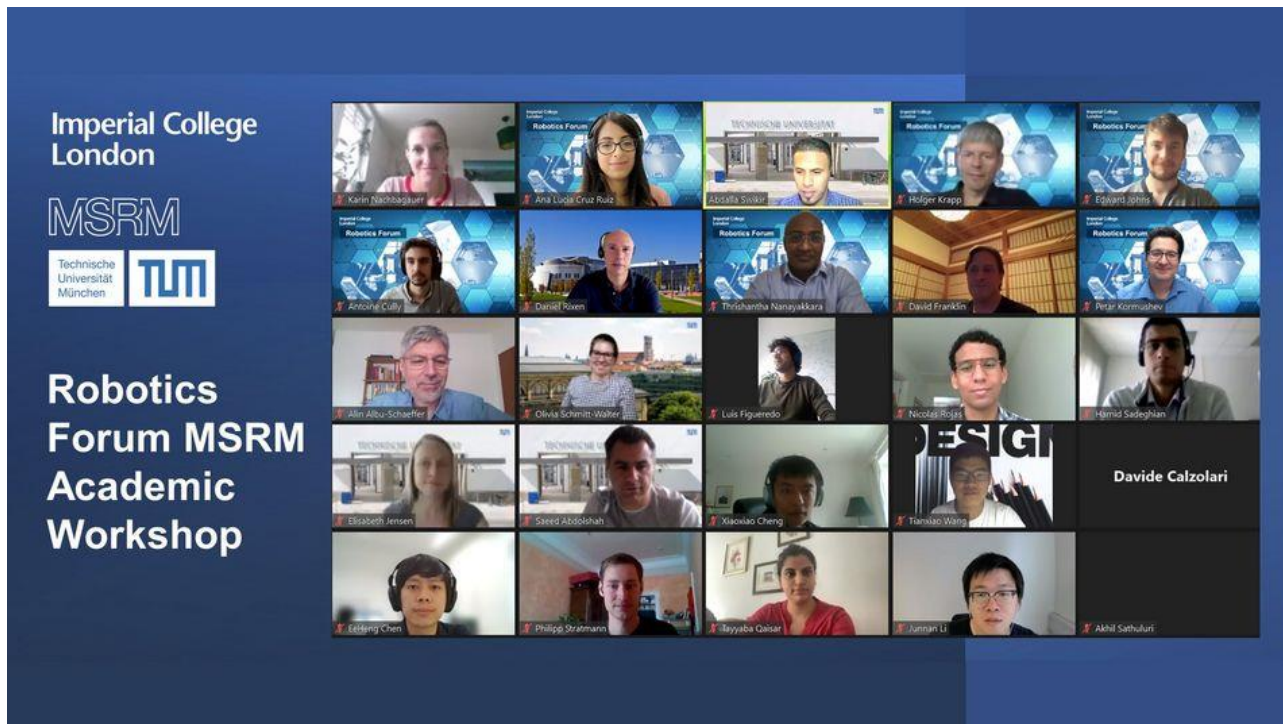
Some of the participants of MIRMI/TUM and Robotics Forum/ICL during workshop day 3, which brought together researchers interested in the topic area "Locomotion (& Infrastructures, Transport, Construction)". ©MIRMI / TUM

After a one-year delay due to corona, the strategic online workshop (see the **program of the workshop here**) to strengthen the partnership between two of the leading European robotics research centers took place. It was funded and incentivized by the TUM Global Incentive Fund and facilitated by MIRMI admin and researchers.

In the week of 28 June to 2 July, the joint Academic Workshop of MIRMI and ICL brought together a total of 95 participants. From Principal Investigators to Ph.D. students, the 4 workshop days were open to everyone. While the 10-minute short presentations on days 1-4 were mainly aimed at getting to know each other and exchanging information on the research areas "Home Robotics", "Hospital Robotics", "Perception & Interaction" and "Locomotion", day 5 focused on the set-up of strategic initiatives like joint proposals for EU calls or networking activities for Ph.D. students. In addition to many individual cooperation interests between the PIs the

preparation of a joint summer school in October 2021 was agreed and started.

A particular noteworthy result of the workshop is, that a consortium of MIRMI PIs, ICL PIs and IIT PIs submitted a joint proposal for a Doctoral Network in "Medical Robotics" within the framework of the Marie Skłodowska-Curie Actions of the EU (**MSCA-DN**). The proposal is currently under review. A notification about the results is expected in April 2022. From TUM side, all PIs involved in this proposal are also members of MIRMI: Prof. C. Piazza, Prof. S. Haddadin and Prof. J. Hermsdörfer.

Active contributions in the workshop came from 11 MIRMI members:
Prof. Albu-Schäffer, Prof. Burschka, Prof. Franklin, Prof. Haddadin, Prof. Hirche, Dr. Nachbagauer, Dr. Nasseri, Prof. Navab, Prof. Rixen, Prof. Steinbach, Prof. Wilhelm

The Bavarian AI Council: MIRMI's Gateway to AI Policy in Bavaria

Constitutional meeting of the Bavarian AI Council on 22 December 2020 also involved Minister of State Bernd Sibler, MdL (Ministry of Science and Arts), Minister of State Judith Gerlach, MdL (State Ministry of Digital Affairs) and Minister of State Hubert Aiwanger, MdL (State Ministry for Economic Affairs, Regional Development and Energy). © Bayerischer KI-Rat.

The Bavarian State Government has appointed the **Bavarian AI Council ("Bayerischer KI-Rat")**, an independent advisory board of 21 top-class experts from universities, non-university research and industry to establish and bring forward the State of Bavaria as Europe's leading hotspot in AI. The Council supports the expansion of the AI-Network Bavaria and provides important impulses for politics in the areas of Robotics, Data Science, Mobility and Health.

Prof. Haddadin was appointed **Chairman of the AI Council**. The dual position of Sami Haddadin as Chairman of the AI Council and Acting Director of MIRMI provides the MIRMI community with a direct line into this committee and thus into the AI policy of the Free State of Bavaria. Prof. Alena Buyx, Chairperson of the German Ethics Council and Director of the TUM Institute of History and Ethics in Medicine, is also a member of the Bavarian Council. Additionally, MIRMI member Prof. Alin Albu-Schäffer is part of the council as Director of the Institute for Robotics and Mechatronics at the German Aerospace Center (DLR).

"Bavaria offers excellent conditions for the field of artificial intelligence - from strong Munich institutions like the Munich School of Robotics and Machine Intelligence to new networks like the collaboration for resource-aware AI applications with TUM and the universities of Bayreuth and Eichstätt-Ingolstadt. With the new AI Council, we can make the Bavarian lighthouse for AI research, transfer and application shine even brighter internationally..."

Judith Gerlach, MdL
(State Minister of Digital Affairs)

In its first year of operation, the Bavarian AI Council attracted and recruited seven additional internationally recognized experts in the field of AI as Global Members and advisors of the Bavarian AI Council. A key milestone was also, when the Council handed over a project study about the necessity of an International AI Science and Community Center in Bavaria to politics as a strategic component of the high-tech agenda. During the **Onsite-Kickoff Event** of the Council on 15 September 2021 in Kloster Speinshart the AI Council discussed and recommended the monastery with attached venues in the east of Bavaria as suitable location for this potential AI community center.

Members, leadership and guests of the Bavarian AI Council together with the fathers of the Monastery Speinshart in the Oberpfalz (Bavaria, Germany) during the "Onsite-Kickoff" Event of the Bavarian AI Council. Bavarian State Minister for Digital Affairs Judith Gerlach, MdL (front center right), Bavarian State Minister of Science and the Arts, Bernd Sibler, MdL (front center left), and State Secretary for the Ministry of Economic Affairs, Regional Development and Energy Roland Weigert (back center), were also present - as well as the Council´s Honorary Member, Prof. Hirzinger, the first in world to send a remotely controlled robot into space (experiment ROTEX) in 1992. ©Kerstin Wegmann.

Furthermore, the Council initiated project groups and taskforces to give advice and push forward topics such as the "AI Act" of the European Commission. On request of politics, the Bavarian AI Council also deals with pressing societal issues such as "Environment and Sustainability" and the role AI should play in it in the future.

The AI Council builds on the tradition of research and innovation in Bavaria to grow the AI ecosystem, develop high-end technologies for the benefit of humans and set up future standards in AI internationally by attracting talents, key technologies and investments to Bavaria.

The leadership of the Bavarian AI Council T. Hahn (front left) and S. Haddadin (front right) hand over the project study about a potential international AI Center in Bavaria for science and community to (from left to right middle): Bavarian State Minister for Digital Affairs Judith Gerlach, MdL, Bavarian State Minister of Science and the Arts, Bernd Sibler, MdL, and State Secretary for the Ministry of Economic Affairs, Regional Development and Energy Roland Weigert, MdL. In the background from left to right: Father Adrian of the Kloster Speinshart, Tobias Reiß, representative of the Bavarian Parliament, District Administrator Andreas Meier, and Speinshart Mayor, Albert Nickl. ©StMWi/E. Neureuther

Members Bayerischer KI-Rat (see brochure)

Universities
- Prof. Sami Haddadin, Chair
- Prof. Elisabeth André
- Prof. Alena Buyx
- Prof. Eric Hilgendorf
- Prof. Dirk Jacob
- Prof. Ute Schmid
- Prof. Thomas Seidl

Non-university research
- Prof. Fabian J. Theis, Co-Chair
- Prof. Alin Albu-Schäffer
- Prof. Claudia Eckert
- Prof. Dietmar Harhoff, Ph.D.
- Prof. Dieter Kranzlmüller
- Prof. Alexander Martin
- Apl. Prof. Dr. habil. Mario Trapp

Private sector
- Thomas Hahn, Co-Chair
- Dr. Anna Bauer-Mehren
- Dr. Wieland Holfelder
- Andrea Martin
- Dr. Felix Reinshagen
- Prof. Patrick van der Smagt
- Dr. Michael Würtenberger

In Short: Further Political Network Activities

MIRMI researchers presenting recent development of "Garmi" to Minister of State Bernd Sibler, MdL (right) Martin Bachhuber, MdL, Alexander Dobrindt, MdB, Harald Kühn, MdL, and Elisabeth Koch, Mayoress of Garmisch-Partenkirchen in the Geriatronics Research Center. ©Simone Stahl / MIRMI / TUM

Minister of Economic Affairs of the Dutch province of Noord-Brabant, Martijn van Gruijthuijsen (center), together with various delegates and MIRMI representatives at the Robot Collective Lab on September 29. 2021 at Heßstraße 134, Munich. © Dayana Ramirez / MIRMI / TUM

MIRMI researchers presented the latest developments for the humanoid robot assistant "Garmi" to the Bavarian Minister of Science Bernd Sibler, MdL, the Mayoress of Garmisch-Partenkirchen Elisabeth Koch, and politicians Martin Bachhuber, Alexander Dobrindt and Harald Kühn on September 14. 2021 at the **Geriatronics Research Center** in the alpine town of Garmisch-Partenkirchen.

"It is impressive what has happened since my last visit a year and six weeks ago"

Bavarian Science Minister
Bernd Sibler, MdL

The Geriatronics research activities made a positive impact on Minister Sibler, MdL, who once again emphasized his support for the new TUM campus and confirmed some first positions to build the new campus of the Technical University of Munich at Bahnhofsareal West in Garmish-Partenkirchen. On the future campus, research, teaching and care will be closely interlinked. This decision enables Garmisch-Partenkirchen to become a university location.

A few days later, **the Delegation of the Minister of Economic Affairs for the Dutch province of Noord-Brabant** visited MIRMI in Munich. During the meeting, participants identified common interests and potential cooperation topics.

Our guests got an overview of MIRMI's Lighthouse Initiatives such as Geriatonics and KI.FABRIK as well as TUM activities to promote ventures in robotics and AI in Bavaria via UnternehmerTUM. The Dutch delegation presented their initiatives related to smart technologies, education using AI, Augmented Reality, software clusters, Digital Twins, advanced manufacturing logistics, among other digitalization advancements. The presentations were followed by a guided lab tour.

Participants found that both institutions are intensively promoting the translation of research ideas into real applications and business opportunities. Interests are specially aligned in regards to smart manufacturing, where projects like the Dutch **Digital Factory of the Future** and the Bavarian **KI.FABRIK** could strengthen the role of both regions to face key societal challenges via digitalization.

Spotlight on: MIRMI PIs Awards and Honours in 2021

Research awards and honors

The "TUM Autonomous Motorsport" team, led by **Prof. Dr-Ing. Markus Lienkamp**, won the Indy Autonomous Challenge. Their AI-controlled race car made the fastest time in Indianapolis with an average speed of 218 kilometers per hour. That won the young researchers first place and a cash prize of one million US dollars.

The prestigious ERC Advanced Grants were granted to **Prof. Hendrik Dietz** and **Prof. Wolfgang A. Wall**. In his project named GENESHUTTLE, Prof. Dietz aims at building virus-like objects from synthetic DNA. With the BREATHE project, Prof. Wall aims to develop unprecedented comprehensive computational models of the respiratory system.

Prof. Eckehard Steinbach received the IEEE Tactile Internet Technical Committee (TI TC) technical contributions award for his distinguished contributions to the Haptic Codecs, which is an essential part of the Tactile Internet. He is also actively contributing to and chairing the IEEE P1918.1.1 group on Haptics Codecs.

Prof. Nassir Navab was honored with the prestigious MICCAI Enduring Impact Award (EIA) 2021, the award recognizes senior researchers whose work made an enduring impact in the areas of medical image computing and computer-assisted interventions.

Prof. Dirk Wilhelm and the project ProteCT team became the winners of the Medical Robotics for Contagious Diseases Challenge of the Hamlyn Symposium on Medical Robotics 2021 in the Design category. They developed a Telemedical Diagnostic Framework that enables a modular, robot-based contactless examination. Such telediagnostic solutions ensure the stability of the health system in crises with a high incidence of infections like the global outbreak of COVID-19. The winning team received a GBP 5,000 prize.

The euRobotics TechTransfer Award was granted to **Prof. Sami Haddadin** and partners. They developed a safe and minimalistic control and learning (AI) algorithm, which automatically finds and provides the optimal balance between rigid support and "soft" guidance for any given patient during therapy. This assist-as-needed (AAN) control strategy is being commercialized in collaboration with the high-tech startup Reactive Robotics and Schön Klinik Bad Aibling, as part of a robotic assistive device called VEMO, used for the early rehabilitation of ICU patients.

The interdisciplinary research group of **Prof. Werner Hemmert** received the Medical Valley Award with the project „Objective Hearing Screening". Researchers aim to reduce the cost of common hearing test probes to facilitate nationwide hearing screenings for newborns worldwide for the early detection of hearing impairments. The award-winning concept is granted pre-seed funding of up to € 250,000 for two years.

Memberships, Fellows, Committees

The scientific achievements of our researchers are also recognized through their membership in specialized organizations. This year several new memberships were conferred.

Prof. Birgit Vogel-Heuser was appointed Co-Chair of IEEE Robotics and Automation Society Technical Committee for Digital Manufacturing and Human-Centered Automation. She was honored with the Distinguished Lecturer of IEEE

Robotics and Automation Society Technical Committee for Digital Manufacturing and Human-Centered-Automation. And she became a Representative of the faculty of mechanical engineering (Technical University of Munich) in the German "Fakultätentag" of mechanical and process engineering, association of all mechanical and process engineering faculties at German universities since 2021.

acatech – the German Academy of Science and Engineering – elected **Prof. med. Alena Buyx** and **Prof. Alin Albu-Schäffer** to their ranks.

Prof. Nassir Navab was elected as an IEEE Fellow. **Prof. Gerhard Rigoll** became a fellow of the Asia-Pacific Artificial Intelligence Association (AAIA), and **Prof. Sami Haddadin** was elected Leopoldina Member.

TUM awards and additional honors

Medical ethicist **Prof. Alena Buyx** was presented the Heinz Maier-Leibnitz Medal, TUM's highest honor. The Medal honored the outstanding achievements by Buyx in providing scientifically well-founded information and consultation to the public and policymakers as Chair of the German Ethics Council. Her exemplary commitment to social cohesion during the Corona crisis was acknowledged by the Deutsche Nationalstiftung with the German National Award 2021.

The TUM Sustainability Award was presented to **Prof. Johannes Fottner** and Prof. Magnus Fröhling for establishing the CirculaTUM network and their research on the circular economy. The TUM Faculty of Mechanical Engineering recognized the good teaching performed by **Prof. Karsten Stahl** with the Golden Teaching Award 2021. The TUM Start-up Mentor of Excellence Award 2021 went to **Prof. Klaus Diepold**. The award honors the extraordinary commitment to promoting talent at the university and to transferring cutting-edge technology from research into innovative marketable products.

Education

MIRMI-ICL Summer School for Ph.D. Students
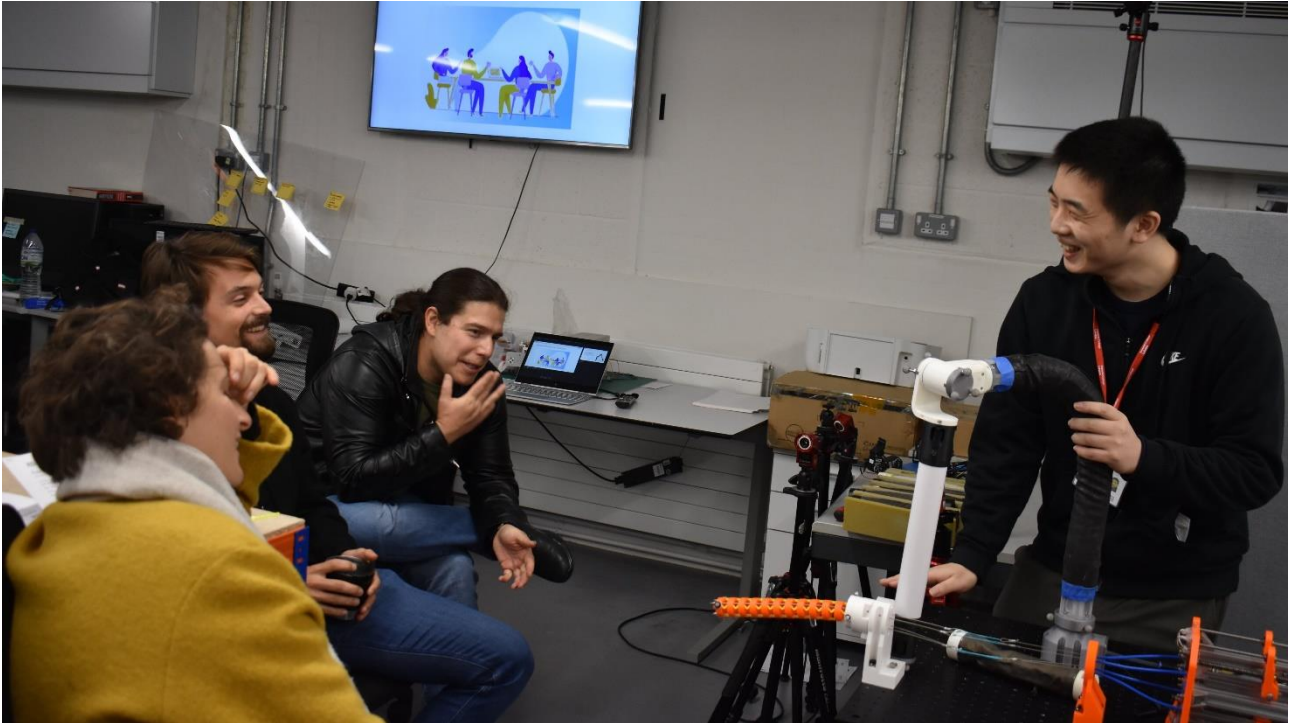
Researchers from TUM and Imperial College London (ICL) got an overview of the research carried out by various chairs at both institutions on the subject of "Embodied Perception for Real-Time Action", worked on solutions to robotics challenges, visited colleagues' laboratories, and strengthened their research network. © Nicolas_Reds / ICL

Between 11 – 13 October 2021 Ph.D. students from MIRMI related chairs participated in a **Summer School on "Embodied Perception for Real-Time Action"** which was organized between MIRMI and its pendant at Imperial College London, the Robotics Forum. Originally planned for 2020, the Summer School had to be postponed to 2021 for corona reasons, but now even took place in hybrid form. The Robotics Forum-MIRMI 4 day summer school hosted doctoral researchers and professors from the Technical University of Munich (TUM) and Imperial College London (ICL) in parallel in London and in Munich. The theme of the summer school evolved all around the topic of Embodied Perception of Real-time Action in the context of Robotics research. From day 1 on the participating Ph.D. students were actively engaging in the summer school: student pitches on their research project, hands-on activities led by PIs and visits to the participating TUM and ICL labs – all of it online and on-site.

With the participation of 10 Professors, 2 post-docs, and more than 25 Doctoral researchers from both institutes, several research directions were heavily discussed, and various collaboration ideas were proposed. In particular, some doctoral researchers agreed to join forces working to implement new sensor concepts and to communicate this in a joint publication. Additionally, a monthly journal club was decided to be established in which researchers from Robotics Forum and MIRMI will discuss important scientific achievements in the field of robotics. Moreover, both institutes agreed to establish a program for student exchange to enhance the collaboration between TUM and ICL.

MIRMI PIs & teams actively contributing to the summer school with ICL:
Prof. Franklin, Prof. Haddadin, Prof. Navab, Prof. Piazza, Prof. Rixen, Prof. Ryll, Prof. Vogel-Heuser.

Fostering the Next Generation of Tech-Entrepreneurs in Robotics and AI

Courses by MIRMI: Intelligent Machine Design Lab and Intelligent Machine Programming Lab

With the I.MDL and the I.MPL, two new courses are coming to TUM in 2021 and 2022 that originate from MIRMI and are aimed at TUM students interested in founding a company in the fields of robotics and AI. Both courses are offered as an educational component of the **TUM Venture Lab Robotics/AI**, which is under the academic direction of the two MIRMI PIs Prof. Haddadin and Prof. Steinbach.

Intelligent Machine Design Lab (I.MDL)

The I.MDL started in April 2021 and is part of a multi-semester master course series, which aims to enable TUM master's students to develop and build complex and intelligent mechatronic robot systems with high social and economic relevance. I.MDL is offered to students from a wide range of disciplines and majors e.g., electrical engineering, mechanical engineering, mechatronics, and computer science. Content and complexity are incrementally increasing with

each semester - starting with mechatronics basics and ending with product development in a startup context. They learn to develop product ideas independently and to transfer them step by step into near-series product prototypes. After completing the module series, students are able to evolve complex mechatronic system projects. Particular focus is placed on the development of multi-disciplinary design and integration skills and their use in an interdisciplinary team. Accordingly, I.MDL is a hot spot for a new generation of innovative engineers and computer scientists ("the modern technologists").

The I.MDL course was designed by MIRMI researchers in close exchange with and following the role model of Stanford's Smart Product Design Lab. It is powered by MIRMI research associates and is located in the recently opened **Munich Urban Colab Space**, Munich's new innovation and start-up center. In its first semester, 21 participants finished the I.MDL courses.
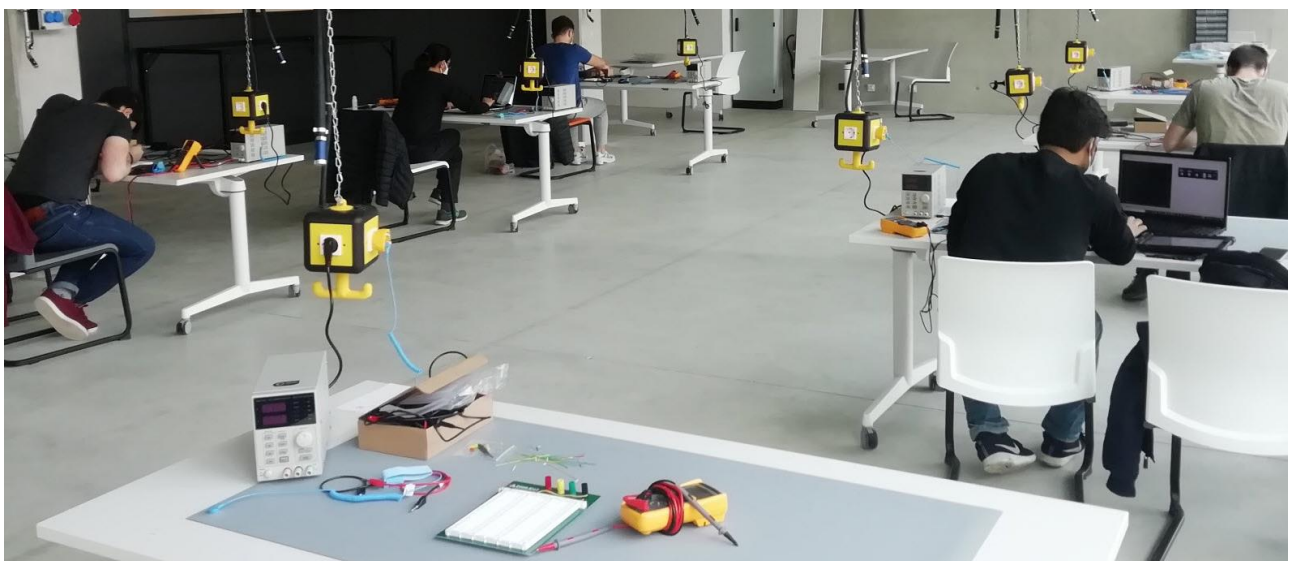
The first cohort during an I.MDL course in the Munich Urban Colab in Munich City Center. © MIRMI / TUM

Since the training at the I.MDL takes place close to industry and with the latest technologies, technology companies are invited to be supporters and content partners of the I.MDL for the future-oriented training of engineers and computer scientists, among other things with the help of donations in kind or money or as lecturers. The first partners are already supporting the training at the I.MDL by providing components and tutorials.

Intelligent Machine Programming Lab
In addition to the I.MDL, which focuses on the development and construction of complex mechatronic hardware components and robot systems, a dedicated development lab for robot apps, the so-called Intelligent Machine Programming Lab (I.MPL), will be set up. The main focus of IMPL is to give participants (mainly, startup founders) the opportunity to learn how to program robots and how to find solutions for given specific tasks. This in its turn, will offer the chance for founders to build up increasingly important competencies in the field of deep tech. It is offered as part of an innovation curriculum from 2022. Founders who are accepted into the robo.innovate incubator can learn how to program robots and create solutions using automated processes on the basis of concrete "challenges". In addition, IMPL will be offered as a regular course for TUM-MS students.

AI Competence Program for Non-Technical Fields (KI-CP @ TUM)

Inspired by the need to involve all of our society in the development of AI systems and by the pandemic teaching/learning situation with their digital learning content, the project TUM AI Competence Program (CP) "Professional learning communities for the systematization of AI-specific courses at TUM" was launched at TUM in December 2021. It will receive 1.9 million Euros funding over four years (BMBF, Bund-Länder-Förderprogramm „KI in der Hochschulbildung"). The interdisciplinary project, which is coordinated by Prof. Nerdel and involves some MIRMI PIs, aims to adapt new and existing AI modules to primarily non-technical courses and to work on transferable structures for the assembly of educational offers. AI-CP@TUM builds on existing expertise in the field of AI at TUM by bringing together AI experts from the technical and natural science, as well as from social science departments to form interdisciplinary Professional Learning Communities (PLC) for the development of new modules.

Remote Machine Intelligence Lab (RMI-L)

One of the proposed teaching modules includes a lab and a training location. *The Remote Machine Intelligence Lab (RMI-L)* teaches students the challenges of remote operation in combination with AI. This is achieved through the merger of expertise of several professorships for a lecture series in which the current research of MI aspects are covered, including communication, regulation, and telepresence under the influence of latencies, machine learning, AI, and shared autonomy. Each lecture is accompanied by an example of a real system application, in the areas of health, work, mobility, and the environment. The training location – *Remote Machine Intelligence Experience Center for Training & Education (RMI-EC)* – is set up under the umbrella of the KI.FABRIK. It is a remotely accessible center, equipped with state-of-the-art robot technology with the purpose of research, teaching, and applied machine intelligence.

In addition, the project ties in with the Plug-In Initiative at TUM and existing experience in this area among the lectures involved in the AI certificate. The Plug-In Initiative offers disciplinary or transdisciplinary modules for particularly motivated students who want to deal in depth with the essential elements of a discipline that is foreign to them and/or with challenges in cross-disciplinary fields in an extracurricular program.

The new modules created in the context of the project described here are to be perpetuated TUM-wide in the form of an AI certificate, building on the experience gained with the TUM Skills Excellence Program.

The following Chairs and Institutes are contributing:
Prof. Nerdel (coordination), Prof. Günnemann, Prof. Althoff, Prof. Diepold, Prof. Haddadin, Prof. Heckmann, Munich Institute of Robotics and Machine Intelligence (MIRMI), Munich Data Science Institute (MDSI), TUM-DigiLLab at the TUM School of Social Sciences and Technology.

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Work in Progress: MIRMI Educational Offers

In 2021 the Educations sector leads of MIRMI have been discussing and conceptualizing future MIRMI educational offers within TUM.

MIRMI Graduate Program
MIRMI is setting up a Graduate Program to be approved by the respective Graduate Centers of the schools/Faculties that will allow Ph.D.s to follow a Robotic and MI specific program for partial fulfillment of the Graduate School requirement.

The program will include advanced courses and other formats for Ph.D.s to network and build an active community around topics related to MIRMI.

MIRMI Master
MIRMI is also considering defining an innovative international master program complementary to the existing study programs at TUM in the field of robotics and machine intelligence

In Short: MIRMI's Activities in Promoting STEM Education in Different Target Groups

Once again in 2021, MIRMI and its researchers have been involved in promoting STEM education to various target groups beyond the boundaries of the university.

Encouraging women to take up a digital profession in the future at the BayFid Kick-Off for Batch 3

Back in 2020, we hosted the first cohort of the women's talent programme **BayFiD** (Bayerns Frauen in Digitalberufen) during a visit at MIRMI for a deep dive sessions on AI, robotics and tech. During demos, we gave an insight into exemplary research work at MIRMI. Afterwards, the participants also exchanged ideas with our scientists and the Chief of Innovation about career paths in and outside of the economy.In 2021, MIRMI supported the initiative for the promotion of women in digital professions through Prof. Haddadin as a patron and speaker at the **kickoff event for batch 3** under the motto "Artificial Intelligence - the technology of the future".

The first BayFiD cohort on a visit to MIRMI in 2020 ©StMD

Students from the Foundation Bayerische Elite Akademie visit MIRMI

Students from the **Bayerische EliteAkademie** visited two MSRM labs located at Heßstraße 134 in Munich. They learned about embodied AI and discussed with experienced researchers the opportunities that human-centered robotics and AI can open to their future career paths.

Fellows of the Bayerische EliteAkademie during their visit at MIRMI. © Dayana Ramirez / MIRMI

Jugend Forscht Munich West 2021 takes place from March 3.–4. online event

The commitment of some MIRMI researchers to promoting STEM education among school children that began in 2020, when MIRMI hosted the regional **"Jugend forscht" competition** in Heßstraße, was continued - albeit on a smaller scale - in 2021. MIRMI researchers provided support as advisory partner in terms of content and with Prof. Haddadin as a speaker during the regional competition "Jugend forscht" (Munich West).