Munich School of Robotics and Machine Intelligence – **The Gentle Robot**

Picture credit: Astrid Eckert/TUM; Graphics: ediundsepp

Link
www.msrm.tum.de/rsi/lehrstuhl-fuer-robotik-und-systemintelligenz

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A robot hand can be that gentle: Unlike most industrial robots, from whose power you have to protect the human being, Haddadin's robots can even gently shave a test person.

How do we define the essence of human intelligence? And how can we transfer it to robots and other intelligent machines? These are just two of the questions that drive Prof. Sami Haddadin at the Munich School of Robotics and Machine Intelligence. Drawing on new theories and methods, he and his team are developing robots with a smart sense of "touch", leading to self-learning, networked robot assistants designed for real-world tasks.

Kurzfassung

Kollektiv lernende Roboter

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Maschinelle Intelligenz soll Roboter feinfühlig und intelligent machen, wie es der Mensch ist. Die Maschinen werden künftig auch in der realen Welt mit Menschen in Kontakt treten und müssen daher nicht nur intuitiv zu bedienen, sondern auch sicher sein.

Die TUM will diese Entwicklung maßgeblich mitgestalten. Mit der Gründung der Munich School of Robotics and Machine Intelligence (MSRM) beschreitet sie neue Wege, um maschinelle Assistenten reaktionsfähiger und „schlauer“ zu machen.

Direktor des neu gegründeten Instituts ist Professor Sami Haddadin, einer der bedeutendsten Wissenschaftler auf dem Gebiet der Robotik und Systemintelligenz. TUM-Präsident Wolfgang A. Herrmann hat den Topwissenschaftler nach München geholt und damit die Eliteuniversität Stanford und das MIT in Massachusetts ausgestochen.

Haddadins aktuelles Vorzeigeprojekt sind durch kollektives maschinelles Lernen kooperierende Roboter, die binnen kürzester Zeit und bei geringstem Rechenbedarf nahezu verzögerungsfrei neue Fertigkeiten erlernen. Der Prüfstein bei diesem Forschungsprojekt ist eine Schlüssel-Schloss-Einheit: Ein Roboter lernt, Schlüssel in verschiedene Schlüssellöcher zu stecken und das Schloss zu öffnen – eine für einen erwachsenen Menschen geradezu triviale, für eine Maschine aber höchst komplexe Handlung. Das gelernte Wissen können über die kollektive Künstliche Intelligenz andere Roboter weiter nutzen.

Für Haddadin hat die Robotik sehr viel damit zu tun, wie der Mensch funktioniert. In seinen Robotern sieht er eine Art „Testbed“, um die Grundprinzipien intelligenten Verhaltens zu studieren und den menschlichen Bauplan in seinen Robotern technisch-systemisch nachzubilden. Auf diese Weise können Roboter auch viel besser mit Menschen in Kontakt treten.

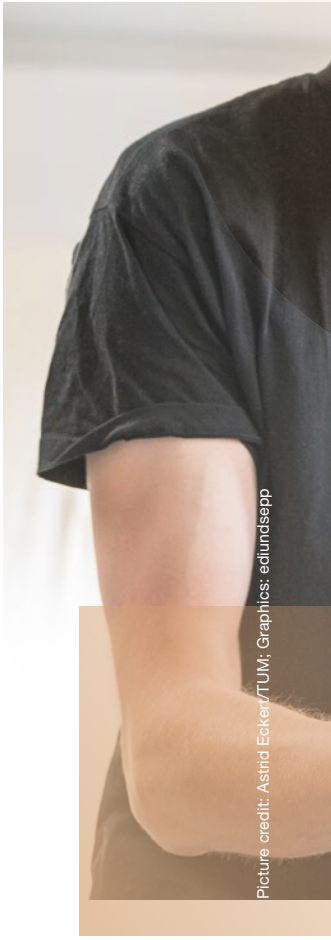
Drei gesellschaftlich relevante Themen bilden aktuell die praktischen Forschungsschwerpunkte: In der „Zukunft der Gesundheit“ geht es um die Unterstützung älterer Menschen durch Robotik und Künstliche Intelligenz, in der „Zukunft der Arbeit“ stehen kollektiv lernende und sichere Roboterassistenten im Mittelpunkt, und in der „Zukunft der Mobilität“ sollen autonome Teams von Transportsystemen entwickelt werden. Begleitet wird Haddadins Forschung von ethischen Diskursen. □

54

professors work on robotics related topics at TUM

280

million euros will be provided by the Bavarian State Government for the Artificial Machine Intelligence Competence Network by 2023



Alexander Tödtheide (left), here in a discussion with Prof. Sami Haddadin, develops a prosthetic hand with artificial muscles.

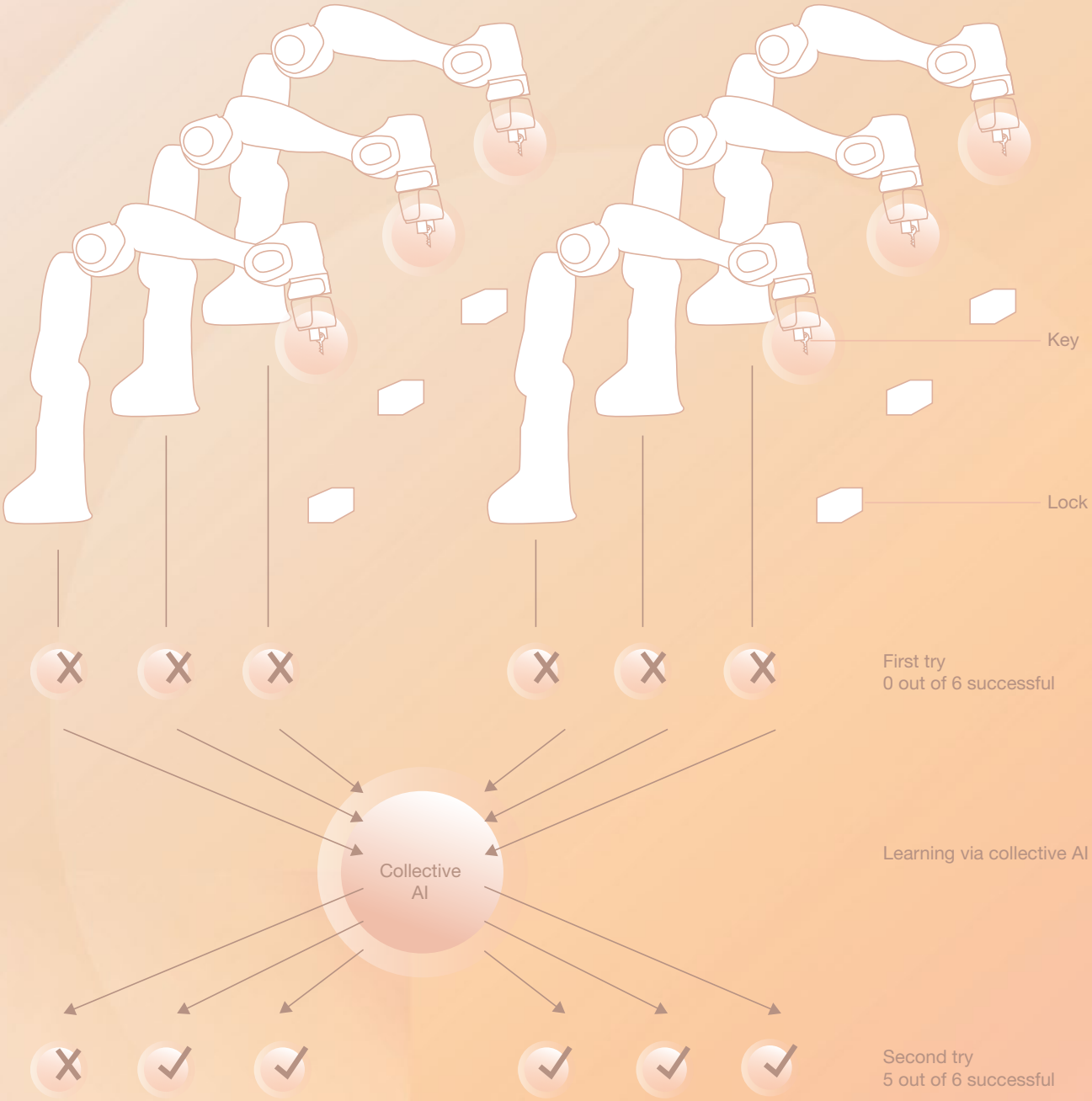
Picture credit: Astrid Eckert/TUM; Graphics: ediundsepp

Robots and intelligent machines are set to transform the way we live and work over the coming years. On the one hand, machines will be as capable of learning as humans. On the other hand, however, we need to draw clear lines between technical systems and their human archetype. As machines evolve, they will increasingly collaborate with people – so safe, intuitive interaction is a must.

TUM is set to play a key role in shaping the evolution of human-robot interaction and has strengthened its position by welcoming Prof. Sami Haddadin – one of the most prominent scientists in the field of robotics and systems intelligence – to its ranks.

Since April 2018, the 38-year-old researcher has been Director of the newly founded Munich School of Robotics and Machine Intelligence (MSRM), located in the former buildings of the paper technology research institute PTS in the Schwabing district of Munich. MSRM aims to explore new ways of making robots and other machines smarter, building on the latest artificial intelligence developments and further pushing the boundaries.

TUM President Wolfgang Herrmann was instrumental in attracting the robotics luminary to Munich – thus outpitching elite institutions such as Stanford University and Massachusetts Institute of Technology. This was a major coup for TUM, since Haddadin's research into human-robot interaction is generally considered to be groundbreaking. His work opens up a completely new perspective on the way robots are designed and built, how they learn and how they are programmed. ▷



Collective learning: A robot learns how to insert keys into various keyholes to open a lock. Then the robot can pass its knowledge on to its "colleagues" via the collective AI. They have access to the increasing pool of knowledge that all machines have fed into.

Prof. Haddadin's current flagship project involves robots cooperating through collective machine learning, enabling them to acquire new skills almost instantly and with minimal computing power. Proof-of-concept at the heart of this research project is a lock and key: A robot learns to insert keys into various keyholes to open the lock. For an adult human, this would be a straightforward task, but it is a highly complex operation for a machine.

Picture credit: Astrid Eckert/TUM; Graphics: ediundsepp

Machines that can "sense"

Inserting a key into a lock requires a sophisticated degree of sensory skill – and equipping robots with this capability is anything but simple. To enable the robotic hand to move with similar dexterity to a human hand, Prof. Haddadin created a completely new mechanism, inspired by human motor skills. "This level of sensitivity brings us to the limits of what is technically feasible for machines today," he confirms. "Children only develop this level of sensory-motor ability when they are three or four years old. If you use other robots for this challenge, they will damage either the lock or the key. You could call us the creators of robotic fine motor skills."

The dexterous sense of touch is considered a central tool in robotics – it is essentially the interface between the robot's mind and its surroundings. And it was more or less the hand that brought Sami Haddadin to his current field of research. "In my very pre-student days, robots were still fairly crude machines – and I wasn't particularly interested," he recalls. "However, even before the end of the nineties, I saw something that really caught my attention at the Hanover trade fair: a robotic hand. I was fascinated by the notion that science had created a technical system inspired by the human hand that actually came very close – as I thought at the time – to the human model." This connection between man and machine led Haddadin work on biological systems from an early stage.

Robot collectives learn like toddlers

These tactile sensory skills are only a means to an end, however. The real highlight of the project is the fact that the robot can pass lessons learned on to other robots; its peers have access to the collective pool of knowledge that all of the machines have fed into. "Not only can robots pick up and pass on this knowledge, they can also put it to constructive use – with the result that learning is suddenly massively accelerated through networking-based avalanching effects," Haddadin explains.

And he is already looking beyond the simple lock-and-key proof-of-concept. Convinced that the current system can be built out, he plans, for instance, to expand the use case to bimanual scenarios and develop new hands that have additional capabilities based on better insights into human building principles and sensory-motor abilities. ▷

Torque sensors in the joints in combination with an artificial central nervous system allow the robot to feel how it has to position the key correctly.

Haddadin's ultimate vision is a global network of interconnected robots. "A few thousand networked robots will be able to pick up the skills of a small child within a blink of an eye – no need for complex big data algorithms running on supercomputers and eating up massive computing power over years. Instead, the systems intelligence in the innovative AI algorithms is all the robots need to learn the skills in just a few steps, like humans do. I see almost infinite possibilities in these technologies. It is then up to us humans to use them properly and responsibly for the benefit of society."

Learning through creation

For Haddadin, robotics has a lot to do with the way that human-embodied intelligence works. "Understanding the basic principles of human intelligence is actually what drives me," he reveals. Just as Newton's laws or Maxwell's equations offer universal explanations of the physical world, Haddadin also sees basic principles in intelligent systems, which work in the background to determine systemic behavior. One such basic principle lies in the answer to the question of how the human hand reaches for an object. This influences the design of both robots and intelligent learning algorithms. As a result, operating the robots becomes child's play and requires no programming knowledge whatsoever. To teach the robot something, you need only demonstrate what you want it to do. The machine then learns from this and can independently apply the acquired knowledge to other challenges – a skill that conventional industrial robots do not possess.

Prof. Haddadin's work is not limited to any one particular type of intelligence – intelligent systems might be artificial, biological or hybrid. He views his robots as a type of testbed for studying the basic principles of intelligent behavior and simulating the human blueprint at a technical/systemic level. "Learning through creation" is his motto. If human-inspired artificial systems are able to approximate the performance of biological systems, this is at least an indication that we have understood something essential about humans themselves. So, for Haddadin, artificial systems are also attempts to explain intelligence in humans or other biological systems – explanations that previously eluded us.

"You could call us the creators of robotic fine motor skills"

Sami Haddadin

The theoretical background of his work is not an end in itself, however. Rather, these fundamental insights into machine intelligence provide the platform for Haddadin's research projects. "Findings from basic research should flow into practical applications with the ability to let society at large benefit," he declares, outlining his plans. Together with colleagues, industry partners and startups, he aims to test and implement his developments in everyday use cases.

At TUM, there are now over fifty professors focused on machine intelligence across a variety of disciplines – computer scientists, mechatronics specialists and mechanical engineers, medics and physicists. The idea of MSRM is to create an open-minded, creative space for all of them to collaborate with the robotics researchers. The scientists also work closely with industry here, with members of the MSRM Industrial Advisory Board including leaders and board members from Siemens, BMW, IBM, Airbus and other enterprises.

MSRM has currently defined three research strands with a specific innovation focus. "The future of health" explores for example the use of robotics and artificial intelligence to support elderly people. "The future of work" focuses on collective learning by safe robotic assistants. And "The future of mobility" seeks to develop teams of autonomous mobile systems for inspection and maintenance.

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Robotic assistants to help senior citizens

The first of these topics will be tackled at a geriatronics center now being set up in the nearby town of Garmisch-Partenkirchen. In this MSRM satellite, researchers will develop robotic assistants to enable independent living for the elderly. Currently, the most important project in this area is the two-armed robotic assistant, GARMI. This system is intended to help elderly people with everyday activities such as getting up, making food and clearing the table. Doctors may also connect with the assistant to establish a remote diagnosis, take ultrasound images or prescribe medication, for example.

Another project in this field involves smart rehabilitation robots. Here, specially developed robots for people recovering from strokes or operations reach out and guide them in such a way that these patients learn to carry out various tasks again and gradually regain motor control. Here, too, Haddadin's basic premise applies: "You need to understand humans to purposefully interact with them."

Haddadin is well aware that his research inevitably raises legal and ethical questions. "We need to communicate extensively and make sure we understand what people want, what they don't want, what is useful and what is not – as well as what will and won't be accepted." ▷

Since April 2018, the 38-year-old Prof. Sami Haddadin – one of the most prominent scientists in the field of robotics and systems intelligence – has been Director of the newly founded Munich School of Robotics and Machine Intelligence (MSRM).

To engage in this debate alongside colleagues in ethics, philosophy and the social sciences, Haddadin is participating in the German federal parliament's dedicated study commission and in the European Commission's high-level Artificial Intelligence expert group. He is also in dialog with legal experts to understand the possible legal framework around robotics and AI research.

Despite all the reservations humans may have about robots, "We needn't be afraid," counsels Haddadin. In the future, intelligent machines will relieve people of tedious and dangerous work, nursing staff will be free to devote more time to their patients, and workers can replace monotonous activities with valuable ones. People's work evolves with progress – and the important thing is to set the right course. "I think fear has always been the worst of all advisers – perhaps even the most dangerous." ■

Klaus Manhart

Prof. Sami Haddadin

Robotics researcher with a raft of scientific awards

Prof. Sami Haddadin studied electrical engineering and computer science at TUM, and technology management at the Center for Digital Technology and Management (CDTM) – a joint TUM and LMU institute. Besides pursuing his doctorate at RWTH Aachen University, he began his research career at the German Aerospace Center (DLR), then becoming full professor at the Gottfried Wilhelm Leibniz Universität Hannover in 2014. Among many other accolades, he received the Early Career Award from the IEEE Robotics and Automation Society and the Alfried Krupp Award in recognition of his research. Together with his brother Simon Haddadin and his colleague Sven Parusel, he also received the German President's Award for Innovation in Science and Technology (Deutscher Zukunftspreis) in 2017. In 2019, the German Research Foundation (DFG) awarded Sami Haddadin the Gottfried Wilhelm Leibniz Prize for his pioneering robotics research. As Founding Director of the MSRM, Haddadin has attracted an excellent team of scientists from the fields of robotics and artificial intelligence.

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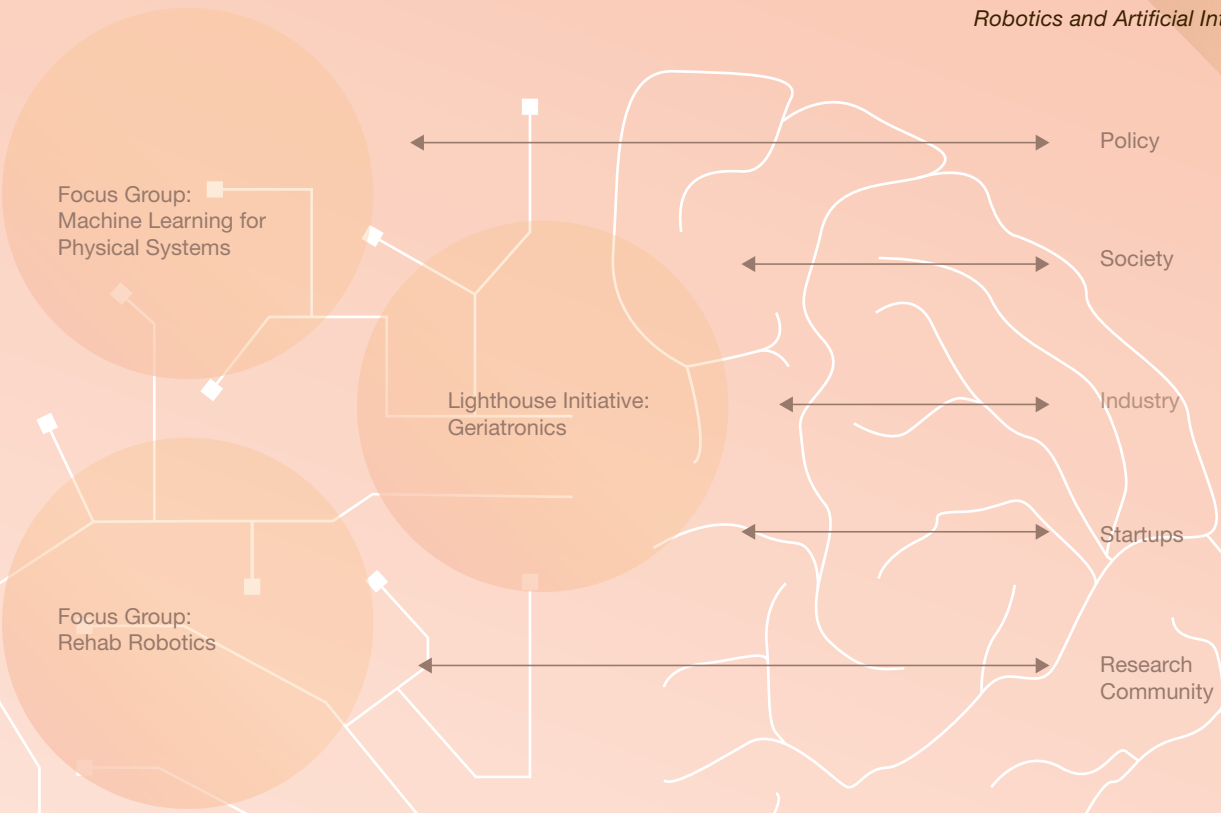

Munich School
of Robotics and Machine Intelligence

MSRM

The Munich School of Robotics and Machine Intelligence (MSRM) was founded in April 2018. Its purpose is to research the fundamentals of robotics, perception and artificial intelligence in order to develop innovative and sustainable technological solutions for key challenges of our time.

The school benefits from an ideal environment in Munich: 54 professors are working on robot-related topics at TUM. Prof. Haddadin wants to create a collaborative environment for the already world-class research and teaching going on at one of Europe's leading universities and to become the catalyst for this key technology far beyond the metropolitan Munich area. Close collaboration with institutions in the areas of philosophy, ethics and law also serve to ensure responsible technology development and subsequent integration into society.