MAX PLANCK INSTITUTE
FOR INTELLIGENT SYSTEMS

HIGHLIGHTS

Max Planck Institute for Intelligent Systems
Stuttgart & Tübingen

Highlights
2019 edition

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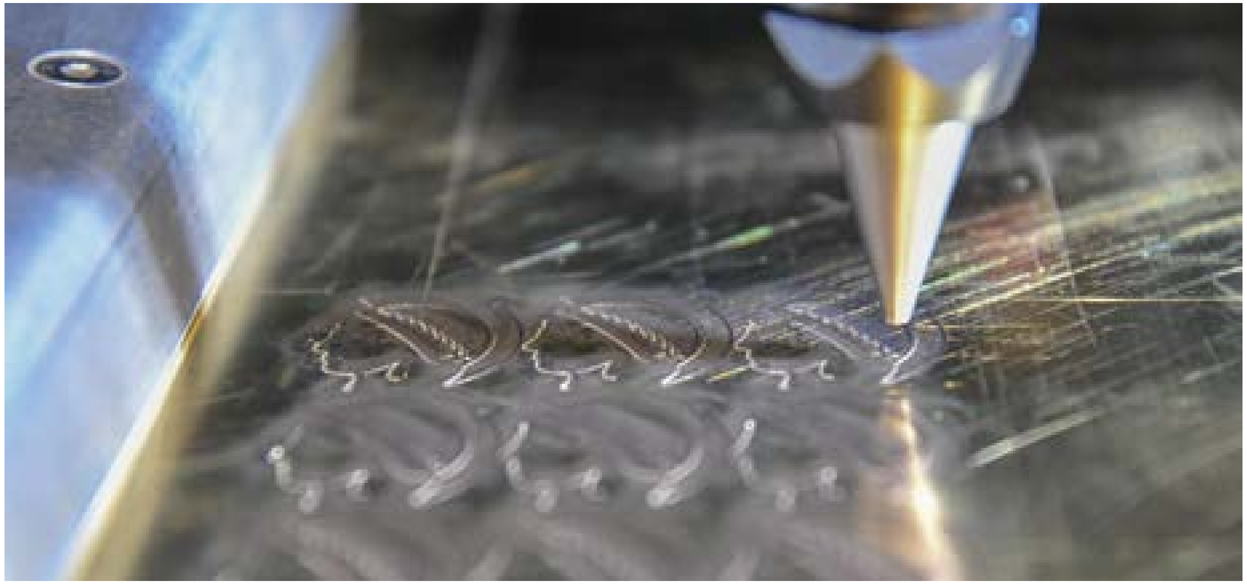
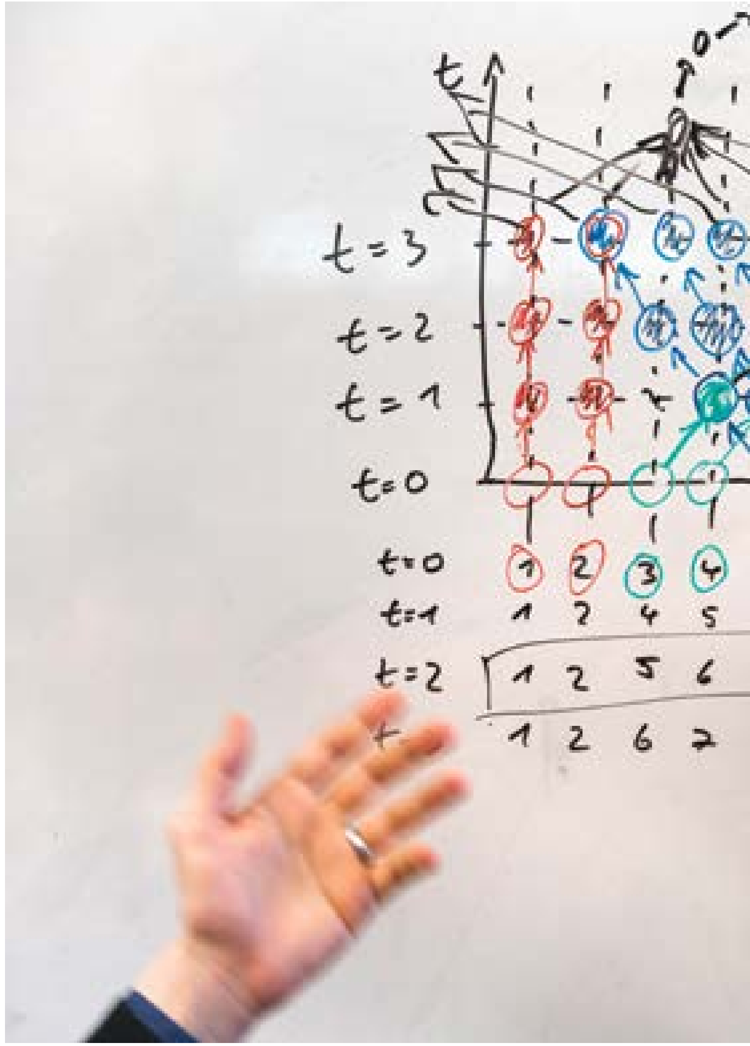
Max Planck Institute for Intelligent Systems

Mission

In the future, artificially intelligent systems will substantially change the way we live, work, and communicate. Intelligent systems will become increasingly important in all spheres of life – as virtual systems on the Internet, or as cyber-physical systems in the real world. Artificial intelligence (AI) will be used for autonomous driving, as well as to diagnose and fight diseases, or to carry out emergency operations that are too dangerous for humans. This is just the beginning.

Researchers at the Max Planck Institute for Intelligent Systems (MPI-IS) strive to understand the principles of perception, action, and learning which underlie intelligent systems that successfully interact with complex environments. In addition to gaining a scientific understanding of natural intelligent systems, the institute's researchers aim to use such insights to design artificially intelligent systems that could benefit humanity in the future. With campuses in Tübingen and Stuttgart, the MPI-IS combines theory, software, and hardware expertise in a single interdisciplinary center. This combination enables the pursuit of pioneering research in a broad range of connected topics within the thriving research field of intelligent systems.





Mission

A researcher captures the motion of hands during real-life interactions and uses the data to calculate a 3D model on his computer.

A 3D print of a robot leg and one that is powered by two electro motors. Complex bioinspired spring structures simplify the control of locomotion.

At a glimpse:

Our Stuttgart site concentrates on physical realizations of intelligent systems, with departments in the broad fields of mobile micro-robots and haptics, and with research groups that emphasize smaller scales, biological inspiration, and control.

Our Tübingen site focuses on computational aspects of intelligence, with departments in the broad fields of computer vision and machine learning. It is also home to research groups that address theory, algorithms, and robotics.

The Max Planck Institute for Intelligent Systems is growing steadily. The majority of our staff (approx. 600 people) are scientists and doctoral students. They come from more than 30 countries.

The Stuttgart site is also home to two departments from the former Max Planck Institute for Metals Research. One department focuses on modern magnetic systems, while the other is dedicated to theory of inhomogeneous condensed matter.

The Stuttgart – Tübingen Region becomes a Hotspot for Artificial Intelligence

CyberValley

This Pepper robot that interacts with its environment is capable of multitasking: the robot perceives its environment, acts accordingly, and calculates its next action. This complex interaction is routine for humans. For a robot, however, this orchestrated behavior is very difficult and requires a lot of computing power.

Cyber Valley is one of Europe's largest research consortiums in the field of AI, which is widely regarded as one of the most important and disruptive technologies of the 21st century. Together, partners from science, industry, and society have established a unique ecosystem that enables an active exchange. This combination of strengths has made the Stuttgart/Tübingen region a hotspot for world-class AI research.

Ten new research groups and ten new university chairs are at the core of Cyber Valley. Their research focuses on machine learning, robotics, and computer vision. Nine research groups and university chairs are already up and running. The remaining positions are gradually being filled. The scientists are performing world-class basic research with state-of-the-art equipment. They come to the region from the world's best universities and research institutions to advance their research in this ecosystem, which testifies to Cyber Valley's growing global popularity.

Baden-Württemberg Fraunhofer MAX PLANCK GESELLSCHAFT Universität Stuttgart EBERHARD KARLS UNIVERSITÄT TÜBINGEN

amazon BMW BOSCH Technik fürs Leben DAIMLER automotive engineering iav ZF PORSCHE

The robot Apollo tries to learn how to balance a rod. Using a camera system, the humanoid robot scans its surroundings 200 times per second, thus generating a 3D image of its surroundings and learning from what it sees. It then calculates how to move to balance the rod as perfectly as possible.

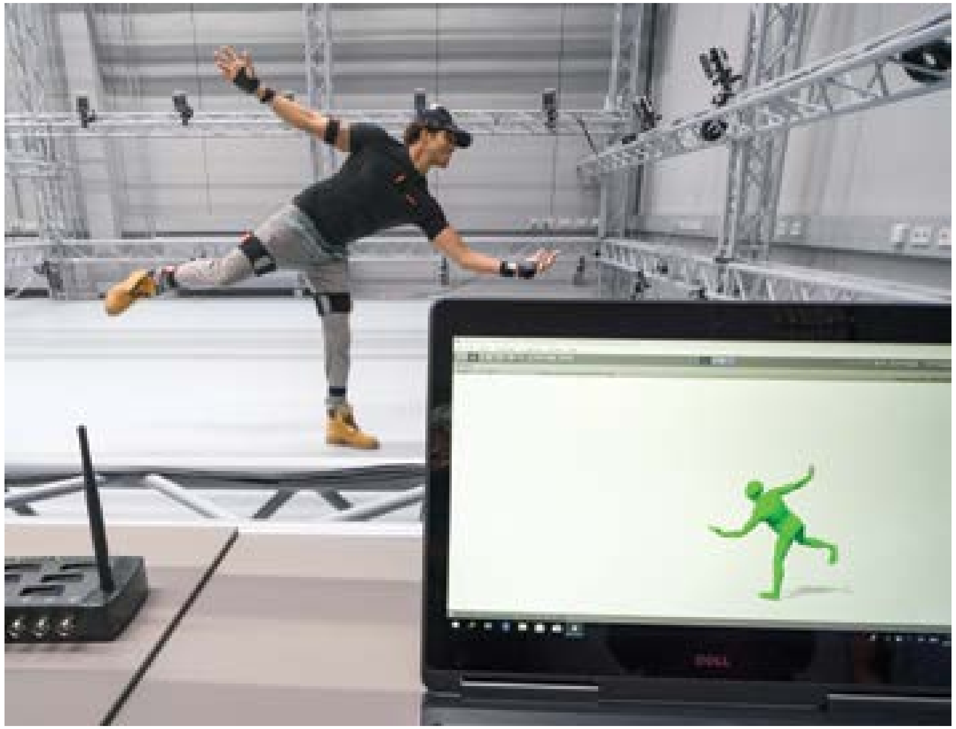
Training up-and-coming scientists within the Cyber Valley ecosystem is one of the research consortium's top priorities. To this end, the International Max Planck Research School for Intelligent Systems (IMPRS-IS) was founded in 2017.

Another central goal is to provide a fertile ground for start-ups. After all, when it comes to the development of intelligent systems, the path from basic research to commercialization is often very short. Start-ups that originate in the research environment are the engines of this development. The aim is to combine top-class research with entrepreneurial spirit to promote spin-offs and technology transfer.

Two researchers observes the 3D avatar" to "Two researchers observe the 3D avatar.

https://cyber-valley.de/

Human-like organ models are developed to test new medical instruments, provide quantitative evaluation on surgical performance and offer useful feedback for surgeons to improve surgical skills.



Sixty-six cameras record the person's movement, down to the last detail and millimeter. Of these, 22 record colour images, while the remaining 44 record black and white. Each camera captures 60 shots per second, for a total of 237,600 pictures per minute.

Public Advisory Board:

Cyber Valley is also committed to social responsibility, which includes ensuring that research is transparent. Holding public outreach events on AI-related topics at regular intervals has helped raise awareness about Cyber Valley's activities. For instance, Cyber Valley researchers have taken part in panel discussions, given lectures to members of the general public, and participated in science slams and digital summits.

With the Public Advisory Board (PAB), Cyber Valley has established an independent committee to advise researchers about the ethical and social implications of research projects. Europe's largest research cooperation in the field of AI has thus created an additional element of transparency.

The PAB's role is to review project proposals from Cyber Valley research groups prior to approval by the Cyber Valley Research Fund Board. It will also contribute to the development of an ethical and social model for AI research.

The PAB members come from different areas of science and society and thus represent a broad spectrum of relevant disciplines and backgrounds.

BMBF Competence Center for Artificial Intelligence and Machine Learning, known as the "Tübingen AI Center":

Tübingen is one of four locations in Germany where the Federal Ministry of Education and Research (BMBF) pools science projects in the field of artificial intelligence.

In 2018, the MPI-IS and the University of Tübingen opened the the Tübingen AI Center, a joint competence center for artificial intelligence and machine learning.

The Center is home to research groups from the University of Tübingen and the MPI-IS. Together, they are working on the further development of robust learning systems. The Center also conducts research on AI and ethics, with a focus on the possible misuse of artificial intelligence. For instance, a junior research group is developing solutions for the protection of sensitive data.

The center is funded by the German Federal Ministry of Education and Research, which recently announced that the center's initial funding of 6.6 million euros would be doubled by 2022.

Federal Education Minister Anja Karliczek (third from the left) and Baden-Württemberg's Science Minister Theresia Bauer (middle) try out the research conducted at the Tübingen AI Center.

The President of the University of Tübingen, Professor Bernd Engler, presents Federal Education Minister Anja Karliczek with a DeepArt print of her portrait.

Clusters of Excellence

Researchers at the "Integrative Computational Design and Construction for Architecture" Cluster of Excellence are developing new methods for a comprehensive modernization of construction.

Clusters of Excellence enable German university locations to enhance their international visibility and ensure competitive research and training facilities. In turn, these clusters promote networking and cooperation between institutions.

In the 2018 funding round, the MPI-IS was involved in four proposals, all of which were selected as Clusters of Excellence:

Clusters of Excellence at the University of Stuttgart with MPI-IS involvement:

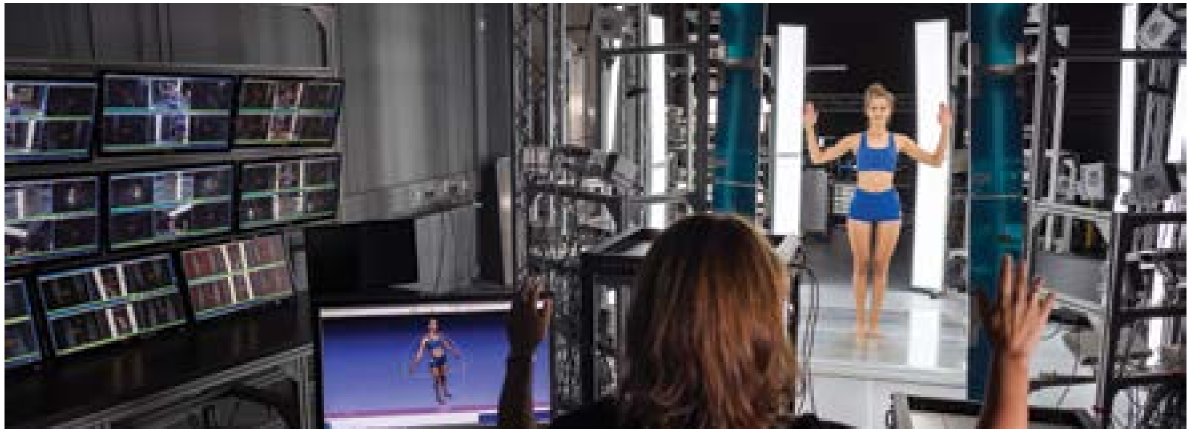
Integrative Computational Design and Construction for Architecture
Data-Integrated Simulation Science

Clusters of Excellence at the University of Tübingen with MPI-IS involvement:

Machine Learning: New Perspectives for Science
Image-Guided and Functionally Instructed Tumor Therapies (iFIT)

Professor Hendrik Lensch of the University of Tübingen is seated in front of a light stage, where he is conducting various computer graphics experiments. The hyperspectral light stage allows for precise acquisition of a reflectance field for a given scene by illuminating it from about 200 directions with a controlled spectrum, capturing HDR photographs and accurate 3D scans from almost any perspective.

Ecosystem for AI



Beyond Cyber Valley's core activities, the AI ecosystem in the Stuttgart/Tübingen region has seen rapid growth, making it a global hotspot for AI research. In the course of this development...

... the University of Tübingen has become the first German university to offer a master's program in machine learning, which was kicked off in September 2019.

... the Universities of Stuttgart and Tübingen have established new university chairs in the fields of machine learning, robotics, virtual and augmented reality, and computer vision.

... Bosch and Amazon, both of which are Cyber Valley partners, have established or expanded their research centers in Tübingen. Bosch plans to invest 100 million euros to build an AI campus that will be home to 700 AI researchers by 2022. In turn, Amazon plans to expand its research staff to more than 100 in the coming years.

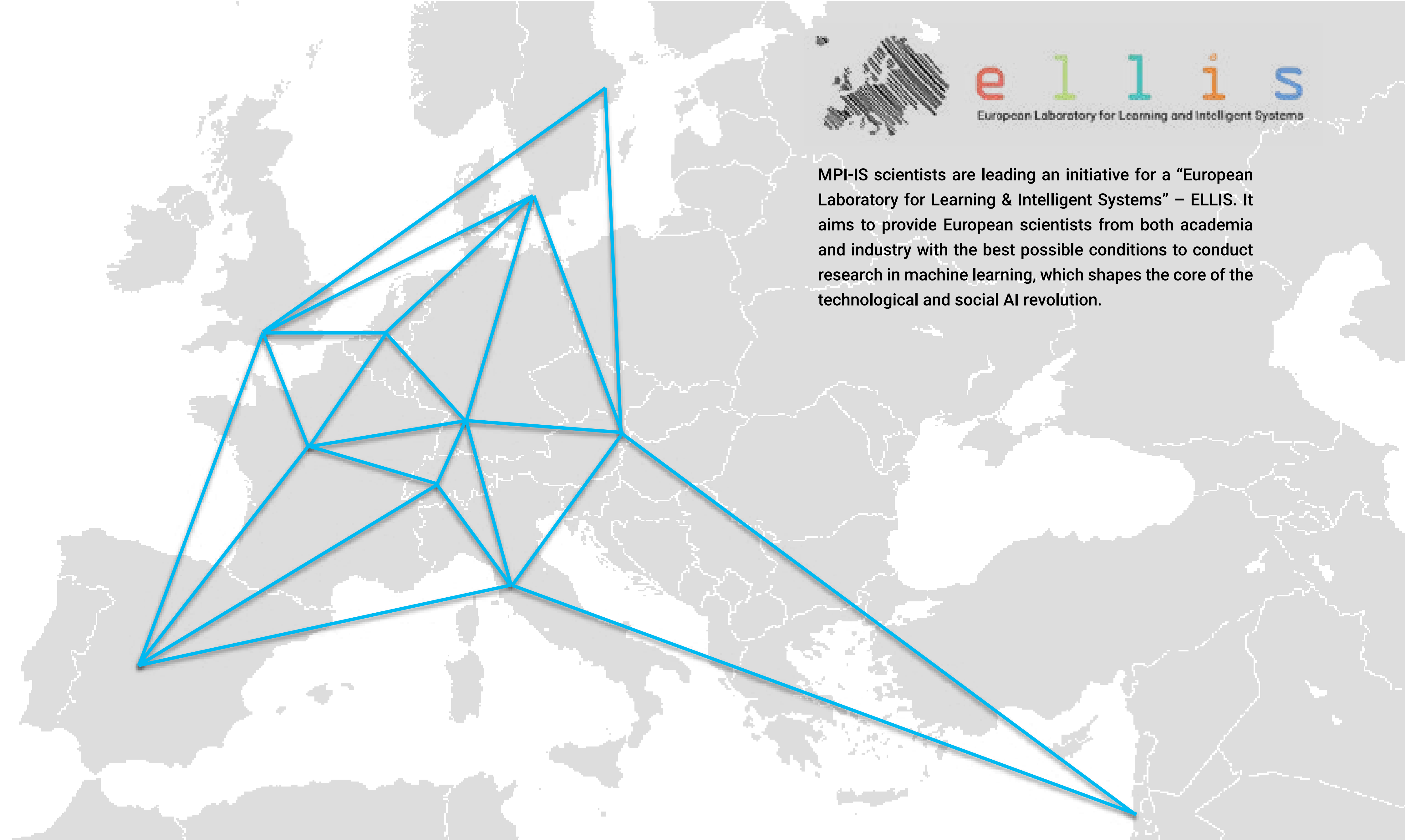
... Bosch has also established two "Industry on Campus" professorships, with which the company has made industry experts part of the Cyber Valley research and teaching community.

... the Max Planck Institute for Biological Cybernetics in Tübingen has undergone a process of scientific reorientation.

...the "Bundeswettbewerb KI" (BWKI), a national competition that invites German high school students to develop AI applications, has been launched.

... the University of Tübingen has opened a new AI research building that will serve as the heart of a new university AI campus in the direct vicinity of the Tübingen Max Planck Campus.

European Laboratory for Learning & Intelligent Systems



ellis European Laboratory for Learning and Intelligent Systems

MPI-IS scientists are leading an initiative for a “European Laboratory for Learning & Intelligent Systems” – ELLIS. It aims to provide European scientists from both academia and industry with the best possible conditions to conduct research in machine learning, which shapes the core of the technological and social AI revolution.

ELLIS aims at enabling Europe to play an important role in the current scientific and social AI revolution by attracting outstanding machine learning scientists and providing them with the means to generate scientific, economic, and societal innovation. Its goal is also to become a top employer in the field of machine learning and a state-of-the-art training and education location by encouraging top scientists to collaborate with basic researchers from industry. This will create a breeding ground for start-ups and technology transfer, which will in turn promote economic development and improve people's lives.

The scientists taking part in the ELLIS initiative demand a significant increase in investment for research infrastructure and the establishment of interconnected ELLIS locations throughout Europe.

In a first step, eleven ELLIS Programmes were launched in 2019. All programs are directed by two to three outstanding European scientists, who head a team of around 15 promising researchers.

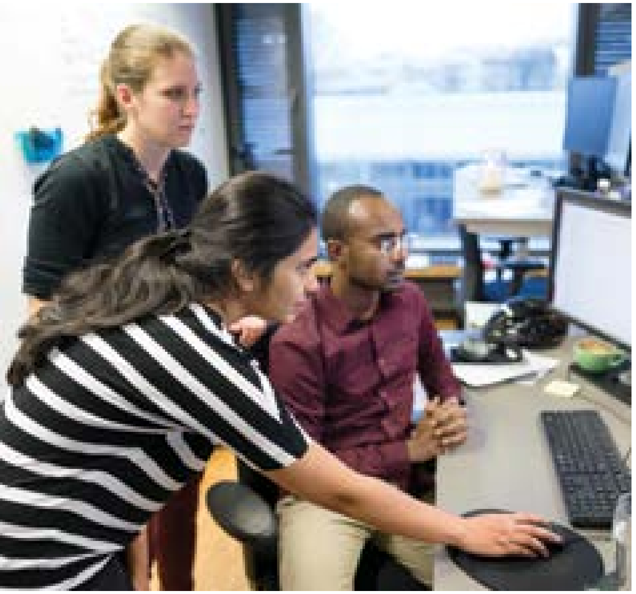
In April 2019, Baden-Württemberg's Minister-President Winfried Kretschmann and Science Minister Theresia Bauer hosted Europe's leading scientists in the field of machine learning at Stuttgart's Neues Schloss.

Professor Bernhard Schölkopf, one of the world's leading machine learning experts, initiated ELLIS.

An ELLIS doctoral programme is also planned, which will aim to attract talented young scientists from around the world and a broad range of disciplines to Europe. The development of a broad and interdisciplinary talent pool will be crucial for the future of European AI research.

Fostering Young Researchers

Fostering Young Researchers



The Max Planck Institute for Intelligent Systems is fully committed to educating and promoting the next generation of scientists. The institute actively fosters young researchers by providing an interdisciplinary education in the field of intelligent systems and offering state-of-the-art research opportunities. Doctoral students from all over the world play a key role in our research activities, and about half the scientists at MPI-IS are currently at the doctoral level.

In addition to individual doctoral scholarships, many Ph.D. students at MPI-IS are participating in one of the unique graduate programs that the institute has set up with partner universities. Established in 2017 in partnership with the Universities of Stuttgart and Tübingen, the International Max Planck Research School for Intelligent Systems (IMPRS-IS) is the institute's main doctoral program, and a key element of the Cyber Valley initiative. In addition, the institute runs joint doctoral programs with university partners abroad: the Max Planck ETH Center for Learning Systems with ETH Zurich, Switzerland, the Cambridge-Tübingen Machine Learning Program with the University of Cambridge, UK, and a joint Ph.D. program in cooperation with Carnegie Mellon University in Pittsburgh, USA.

Thanks to this targeted support, the number of junior scientists and guest researchers has increased significantly in recent years, to approximately 140.

Fostering Young Researchers

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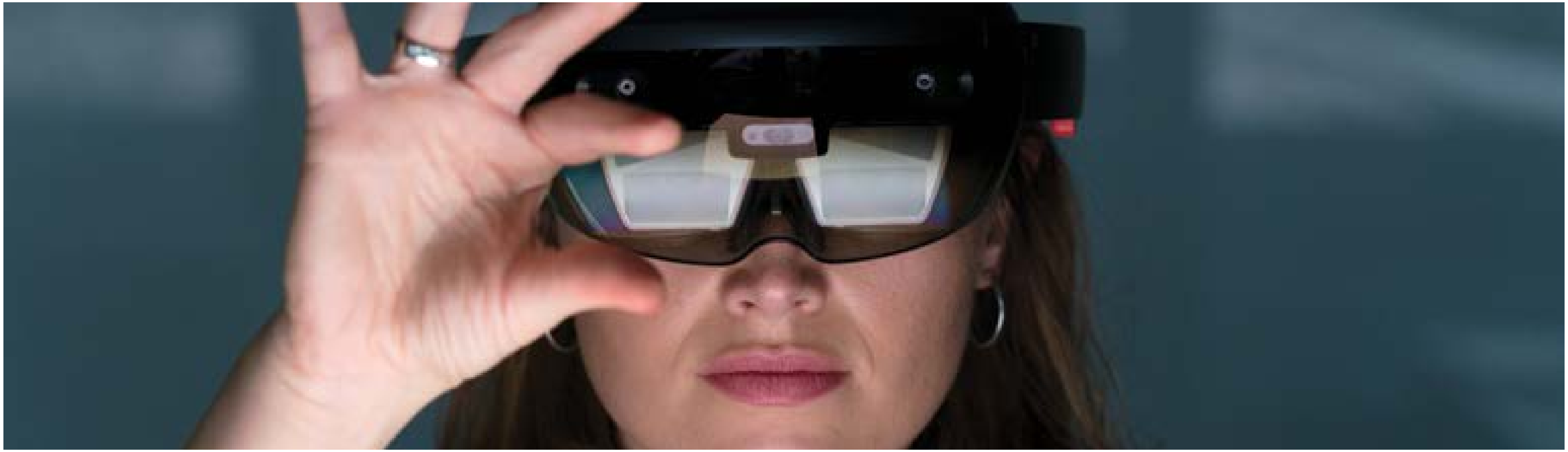
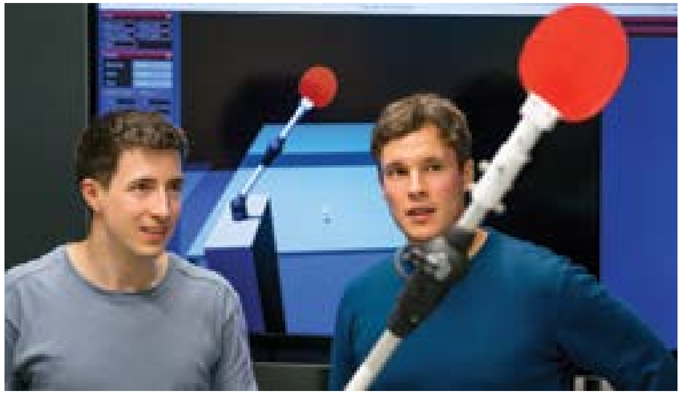




International Max Planck Research School for Intelligent Systems

An IMPRS-IS Ph.D. student presents a poster about his research.

The International Max Planck Research School for Intelligent Systems is the institute's main doctoral program. It was founded in early 2017 and is a key element of the Cyber Valley initiative. Partners are the MPI for Intelligent Systems, the University of Tübingen, and the University of Stuttgart. Together, they count 38 IMPRS-IS faculty members and nine associated faculty members.

IMPRS-IS is the first structured doctoral program of its kind in Germany. In just two years, over 100 talented junior researchers have started their doctoral projects.

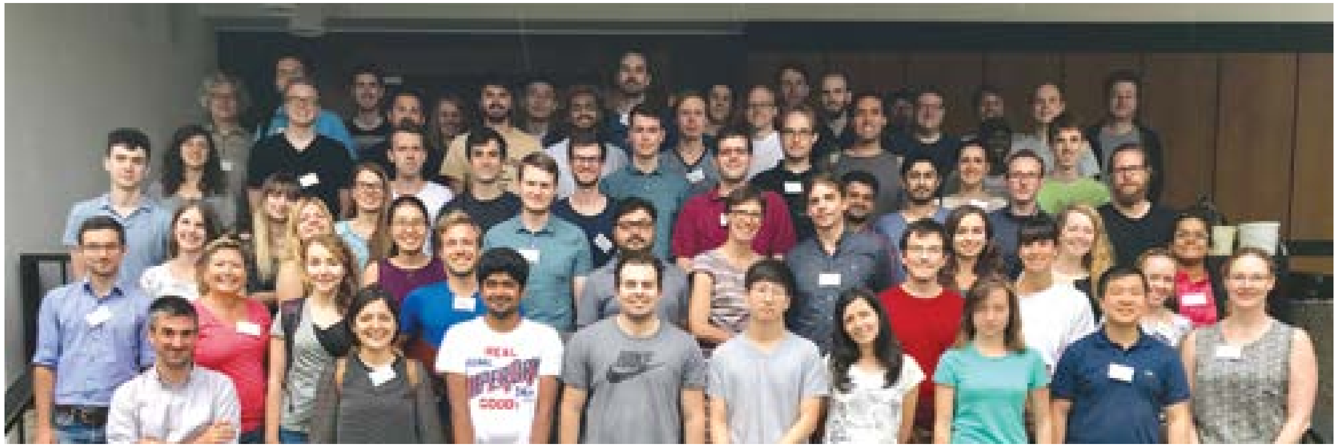
https://imprs.is.mpg.de/

Max Planck Institute for Intelligent Systems

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Universität Stuttgart

impr-is



The exchange between doctoral students is important and is actively promoted with events such as IMPRS-IS boot camps.

Facts and Figures:

More than 1,300 applicants to date.

210 students from more than 23 countries have been invited to interviews.

There are currently 109 Ph.D. students enrolled in the IMPRS-IS program, which has an acceptance rate of approximately 8.4 percent.

Max Planck ETH Center for Learning Systems

The Max Planck ETH Center for Learning Systems is the first joint doctoral program between ETH Zurich and the Max Planck Society. It is well on its way to becoming one of the strongest European centers for modern AI research.

Since the Center for Learning Systems was founded in 2015, 112 Ph.D. students and postdocs have been accepted to the program as Fellows or Associates.

At present, 50 directors, professors, and research group leaders are active as members or associated members of the Max Planck ETH Center for Learning Systems.

The Max Planck Society and ETH have agreed to extend funding for the Center for Learning Systems until 2025. Together, both institutions are contributing a total of ten million euros until 2025.

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ETH zürich

Max Planck ETH Center for Learning Systems

The ETH Zurich campus in Switzerland.

Opening ceremony (from left to right): Christine Schraner Burgener (Swiss Ambassador to Germany at the time), Professor Lino Guzella (President ETH Zürich at the time), Professor Martin Stratmann (President Max Planck Society), Theresia Bauer (Science Minister of Baden-Württemberg), Professor Bernhard Schölkopf (MPI for Intelligent Systems and Co-Director of the CLS), Professor Thomas Hofmann (ETH Zürich, Co-Director of the CLS).

A group of CLS students during a retreat.

A Max Planck ETH Center for Learning Systems retreat took place from October 15-17, 2018, on Reichenau Island, on the Swiss/German border.

Cambridge-Tübingen Machine Learning Program

UNIVERSITY OF CAMBRIDGE

Max Planck Institute for Intelligent Systems

The Cambridge-Tübingen Machine Learning Program was launched in 2014 by the Empirical Inference Department, which is led by Professor Bernhard Schölkopf, and the Machine Learning Group of the University of Cambridge. Both are among the world-leading centers of research in machine learning.

The program is collaborative, meaning that scientists at both institutions jointly supervise a small group of top doctoral students. Each year, about three Ph.D. fellows are jointly selected via a symposium. There are currently ten Ph.D. students enrolled in the program. They will spend at least one year at each institution, and benefit from the excellent research environment that both institutions provide. Successful graduates will receive their doctoral degrees from the University of Cambridge.

Carnegie Mellon-MPI-IS Ph.D. Program

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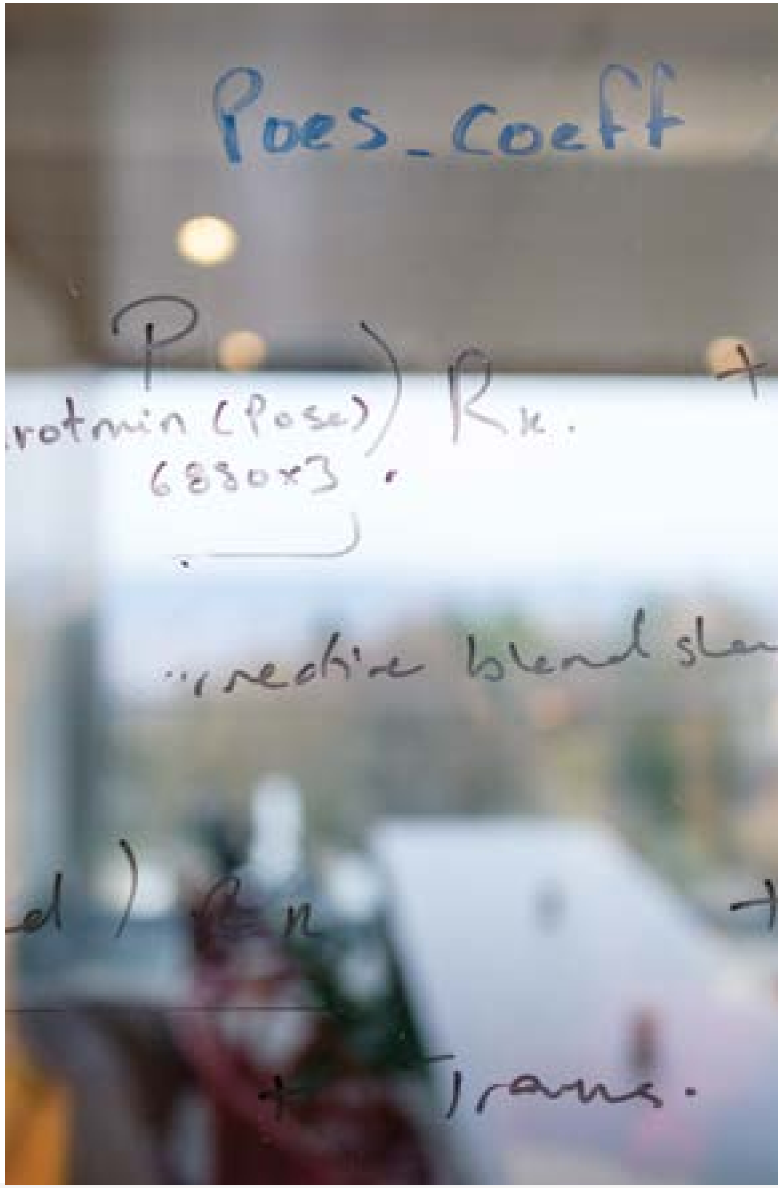
Carnegie Mellon University (CMU) and the MPI-IS established a new joint Ph.D. program in 2018. CMU in Pittsburgh, USA, is one of the world's leading universities in the field of intelligent systems and robotics. The program was initiated by Dr. Metin Sitti, Director of the Physical Intelligence Department at the MPI-IS. Before joining MPI-IS, he spent twelve years as a professor in the Department of Mechanical Engineering and the Robotics Institute at CMU.

For the most promising Ph.D. students interested in robotics, the program is an opportunity to benefit from the strong and unique research environments that both CMU and MPI-IS offer. Two Ph.D. students are currently enrolled in the program. They first spend 1.5 to two years conducting their research with a professor at CMU. They then continue under the supervision of a director or group leader at the MPI-IS for at least another two years. Successful graduates will receive their Ph.D. degree from CMU.

Carnegie Mellon University

Max Planck Institute for Intelligent Systems



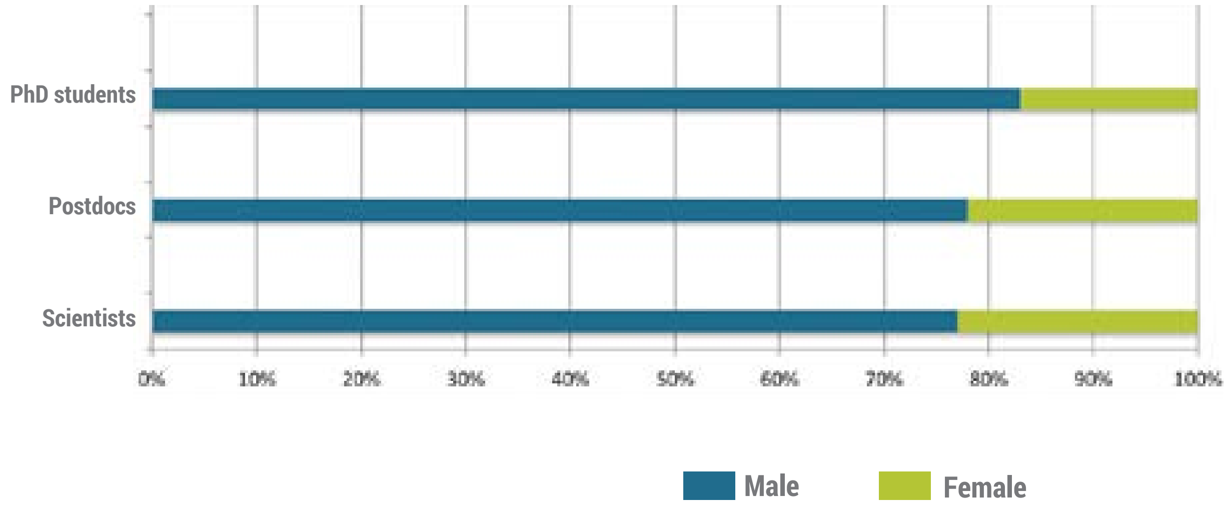
More about MPI-IS

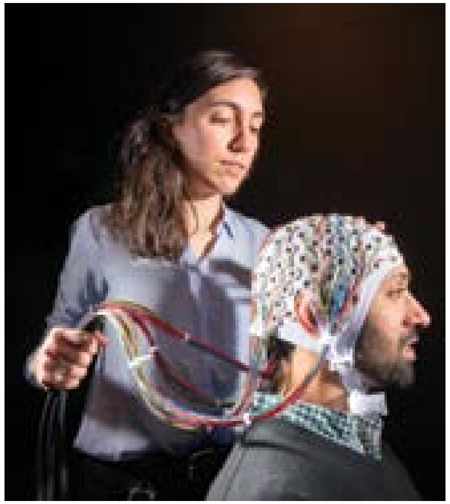
Women in Science

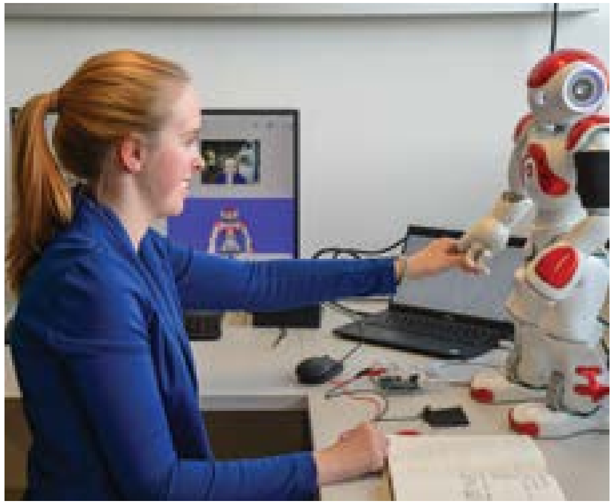
In the course of the last year, the number of women in leadership roles has increased at the MPI-IS. With Catherina De Bacco's appointment as Cyber Valley Research Group Leader in September 2018, and Isabel Valera's appointment as Group Leader in July 2019, the share of women at the group leader level increased over the previous year. The current share of female group leaders at the MPI-IS stands at 28.6% (4 of 14).

The percentage of female postdocs stood at 22%, whereas the percentage of female Ph.D. students stood at 17% as of August 2019.

The institute aims to increase the share of female scientists at all levels, and it is continuously working to achieve this goal.







Women in Science

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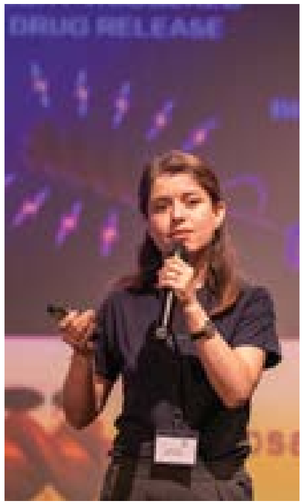
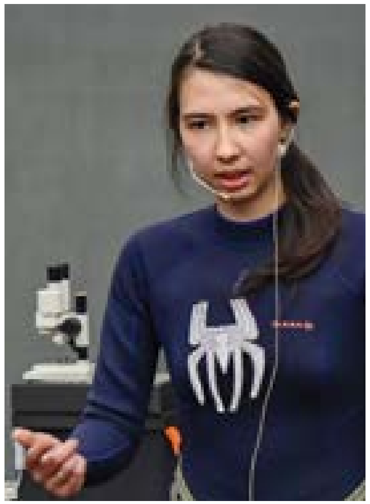
The Athena Group was founded in the fall of 2017 at the MPI-IS Stuttgart site. The new initiative aims to serve as a networking and support platform for women in science, technology, engineering, mathematics, robotics, intelligent systems, and related fields. In the fall of 2018, an Athena Group chapter was established at the Tübingen site of MPI-IS.

At informal Athena Group meetings that are held on a regular basis, female scientists at the MPI-IS can exchange experiences about their career paths, benefit from a supportive community, and work together on addressing relevant issues.

The Athena Group launched a special seminar series that features successful female scientists who discuss both their scientific contribution and personal experiences in their respective fields of research. Additionally, the Stuttgart branch of the Athena Group created a mentor/mentee program to provide more personal support to interested individuals. All female doctoral students are particularly encouraged to join this program. Thirteen women (five postdocs and eight Ph.D. students) are presently participating, and more are expected to join each year.

In February 2019, the Stuttgart Athena Group celebrated the International Day of Women and Girls in Science.





https://www.is.mpg.de/athena-group

Appointments

MPI-IS scientists are regularly appointed to professorships at renowned universities and colleges. A high number of appointments is considered to reflect the quality of research and training carried out at the institute.

Dr. Siyu Tang, a postdoc in the Perceiving Systems Department, will take on a tenure-track assistant professorship at ETH Zurich in early 2020.

Professor Marc Toussaint began his five-year tenure as a Max Planck Fellow at the MPI-IS on November 1, 2018. He is supervising a small research group at the institute's Stuttgart site. Toussaint is a full professor of computer science at the University of Stuttgart, where he has led the Machine Learning and Robotics Lab since 2012. He is one of 57 current Max Planck Fellows worldwide.

Appointments 2018-2019 (selection):

Morteza Amjadi (PI Dept.), Assistant Professor at Heriot Watt University, Edinburgh, Scotland
Michael J. Black (PS Dept.), Adjunct Professor of Computer Science at Brown University, Providence, Rhode Island, USA
Kristen Kozielski (PI Dept.), Tenure-Track Assistant Professor at Karlsruhe Institute of Technology
Byung Wook Park (PI Dept.), Assistant Professor at Youngstown State University, Ohio, USA
Gunhyuk Park (HI Dept.), Assistant Professor at GIST, Gwangju, South Korea
Jonas Peters (EI Dept.), Associate Professor at the University of Copenhagen, Denmark
Bernhard Schölkopf (EI Dept.), Affiliated Professor at ETH Zurich, Switzerland
Dhruv Singh (MNMS Group), Assistant Professor at the Indian Institute of Technology, Delhi, India
Siyu Tang (PS Dept.), Tenure-track Assistant Professor at ETH Zurich, Switzerland
Marc Toussaint appointed Max Planck Fellow at MPI-IS
Matthew Woodward (PI Dept.), Assistant Professor at Tufts University, Boston, USA

Awards & Acknowledgments

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Professor Bernhard Schölkopf (middle) is awarded the Körber European Science Prize 2019 by Professor Martin Stratmann, the President of the Max Planck Society (left), and Dr. Lothar Dittmer, the Chairman of the Executive Board of the Körber Foundation.

Professor Laura Na Liu, independent group leader at the Max Planck Institute for Intelligent Systems.

Dr. Metin Sitti, Director of the Physical Intelligent Department.

Bernhard Schölkopf: recipient of the 2019 Körber European Science Prize
Bernhard Schölkopf: recipient of the 2018 State of Baden-Württemberg's State Prize for Basic Research
Metin Sitti: recipient of the 2019 ERC Advanced Grant (SoMMoR)
Andreas Geiger: recipient of the 2019 ERC Starting Grant

Hannah-Noa Barad: recipient of the 2018 two-year Minerva Fellowship
Dominik Baumann, Sebastian Trimpe et al.: winners of the 2019 ACM/IEEE International Conference for Cyber-physical Systems (ICCPS) Best Paper Award
Jeannette Bohg: winner of the 2019 IEEE/RAS early career award
Xiaoyang Duan: recipient of the 2018 Chinese Government Award for Outstanding Students Abroad, in recognition of his excellent Ph.D. thesis
Philipp Hennig: named one of 2018 Germany's "40 under 40" in the Science and Society category
Wenqi Hu, Guo Zhan Lum, and Metin Sitti: recipient of Design & Elektronik Magazine's Innovator of the Year Award in the Medical Devices category
Francesco Locatello, Stefan Bauer, Bernhard Schölkopf et al.: winners of the 2019 ICML Best Paper Award
Laura Na Liu: recipient of the 2018 Rudolf-Kaiser prize
Laura Na Liu: recipient of the 2018 Kavli Foundation Early Career Award
Laura Na Liu: winner of the 2019 European Materials Research Society's EU-40 Materials Prize
Laura Na Liu: winner of the 2019 Adolph Lomb Medal
Michel Perrot, Ulrike von Luxburg: winners of the 2019 Distinguished Paper Award at IJCAI
Jan Peters et al.: winners of the 2018 Best Paper Award at the International Conference on Advances in Systems Testing and Validation Lifecycle
Jan Peters: elected 2019 IEEE Fellow
Ziyu Ren, Tianlu Wang, Wenqi Hu, and Metin Sitti: recipient of the Best Paper Award at the 2019 Robotics Science & Systems Conference
Ludovic Righetti: recipient of the 2018 Google Faculty Research Award
Bernhard Schölkopf: recipient of the 2018 Hector Science Award
Bernhard Schölkopf: honored as one of 2019's leading minds in German AI research
Hamed Shahsavan: recipient of the Canadian NSERC Postdoctoral Fellowship
Metin Sitti: recipient of the 2018 Rahmi Koç Medal of Science, in Turkey, which is given to one world-wide pioneering scientist of Turkish origin each year

Public Relations

Press Highlights:

The institute's scientists were featured in several media reports, and requests to interview MPI-IS researchers continued to increase. At the same time, the institute's PR team also handled press work for Cyber Valley, Europe's largest research consortium in the field of artificial intelligence. Here, too, it was evident that public interest in AI research has continued unabated: in response to both positive and critical voices, Cyber Valley scientists participated in several public outreach events and welcomed a number of visitor groups and delegations. In addition, many reports about the institute's research and scientists appeared in the local, national, and international press.

A selection of MPI-IS and Cyber Valley press clippings and events (in German):

Auf eine Goldader gestoßen
Maschinelles Lernen: Österreichs grüner Staatspräsident und Baden-Württembergs grüner Ministerpräsident besuchten gestern den Max-Planck-Campus
30.11.2018, Schwäbisches Tagblatt

Wir wollen Künstliche Intelligenz, die sich nicht täuschen lässt
Im Gespräch: Professor Bernhard Schölkopf vom Max-Planck-Institut für Intelligente Systeme und Bosch-Geschäftsführer Michael Bolle
05.12.2018, FAZ

Silicon Valley auf Schwäbisch
Mit drei Milliarden Euro will die Bundesregierung die Erforschung der künstlichen Intelligenz fördern. In der Grünen-Hochburg Tübingen sind sie dabei schon ziemlich weit – auch mit Amazons Hilfe
05.01.2019, Stern

Wie der Elefant ein Schwan wird
Science Notes: Im Tübinger Schlachthaus präsentierten vier junge Wissenschaftler ihre Forschungen zu Maschinellem Lernen und Künstlicher Intelligenz
20.01.2019, Schwäbisches Tagblatt

An den Schnittstellen sind wir noch in der Steinzeit
Neuroroboter stehen zwischen Mensch und Maschine: Ihre Zeit ist erst angebrochen, moralische Fragen stellen sich aber schon massiv
03.04.2019, FAZ
Vortragsreihe „Das Gehirn der Zukunft"

Müssen Porsche-Fahrer künftig ins Reservat?
Experten haben bei einer Diskussion am Stuttgarter Max-Planck-Institut für Intelligente Systeme vor zu hohen Erwartungen an automatisierte Fahrzeuge gewarnt. Die Technik könnte lange Zeit auf Autobahnen beschränkt sein.
15.05.2019, Stuttgarter Zeitung
Vortragsreihe „Das Gehirn der Zukunft"

Pionier der Künstlichen Intelligenz ausgezeichnet
Informatik: Der Tübinger Bernhard Schölkopf erhält den Körber-Preis.
28.06.2019, Stuttgarter Zeitung

Wie Miniroboter durch den Körper reisen
Innovationen: An der Uni Stuttgart forscht Tian Qiu an der Hightechmedizin der Zukunft. Seit Juli leitet der junge Wissenschaftler eine neue Arbeitsgruppe, die winzige Roboter für neue Therapien entwickelt. Ein Besuch im Labor.
30.07.2019, Stuttgarter Zeitung

TV / Radio
National reports on the Körber Prize award ceremony on September 13, 2019.
ZDF heute journal, ARD Tagesthemen, 3Sat nano, NDR Nachrichten Hamburg

Public Events and Visits (selection):

September 14, 2018: Max Planck Day with an “AI and Society” symposium
September 15, 2018: Open Day at the MPI-IS
November 9, 2018: AICon, organized by Bosch and Cyber Valley, Renningen
November 29, 2018: Austrian President Dr. Alexander Van der Bellen and Baden-Württemberg’s Minister-President Winfried Kretschmann visit Cyber Valley at the MPI-IS in Tübingen
March 2019 to October 2019: “The Brain of the Future” lecture series in collaboration with the Hertie Foundation
April 15, 2019: Baden-Württemberg’s Minister of Economic Affairs, Dr. Nicole Hoffmeister-Kraut visits the MPI-IS and Cyber Valley
May 2, 2019: Federal State Secretary Björn Böhning visits the MPI-IS and Cyber Valley
May 17, 2019: High-ranking AI delegation from France visits Cyber Valley
May 24, 2019: Tübinger Fenster für Forschung (TÜFFF) at the University of Tübingen
June 17, 2019: High-ranking Canadian delegation visits Cyber Valley in Tübingen
June 20, 2019: Federal Minister of Education and Research Anja Karliczek visits Cyber Valley
July 5, 2019: MPI-IS Summer Colloquium in Stuttgart
July 15, 2019: Federal State Secretary Thomas Bareiß visits the MPI-IS and Cyber Valley
August 1, 2019: State Minister Theresa Schopper and Dr. Florian Stegmann, Head of the State Chancellery, visit the MPI-IS and Cyber Valley

In cooperation with Cyber Valley, the Bosch Center for Artificial Intelligence (BCAI) held the first Bosch AICon conference in Renningen in November 2018, bringing together leaders in academic and corporate AI research.

In November 2018, the Austrian Federal President Dr. Alexander Van der Bellen visited Cyber Valley with Baden-Württemberg’s Minister-President Winfried Kretschmann.

The Hertie Foundation and Cyber Valley organized a series of four lectures on topics related to AI, neural networks, and autonomous systems, each followed by a panel discussion with visionaries from science and business.

Public Relations

Young pupils were given a tour of the institute on Girls' Day.

Dr. Nicole Hoffmeister-Kraut, Baden-Württemberg's Minister for Economic Affairs, Labour and Housing, visited the institute in April.

Numerous visitor groups came to the institute in 2019.

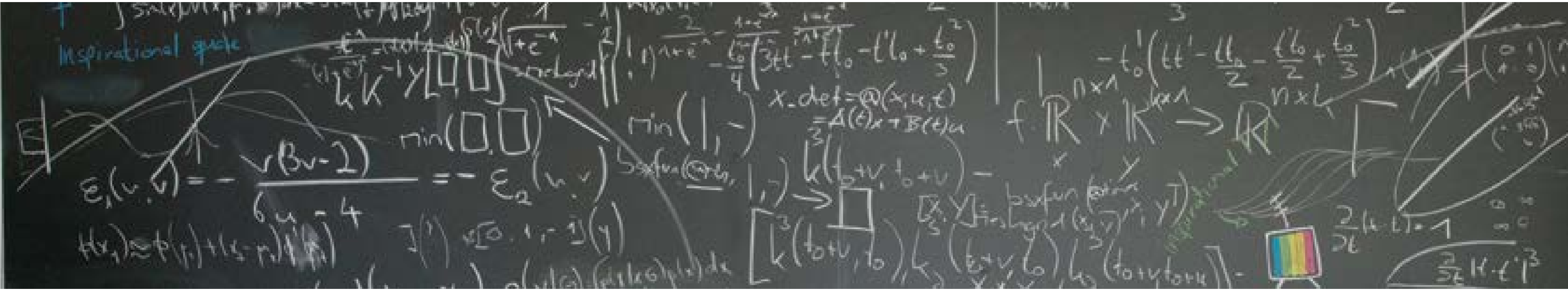
Visitors

Student Interns and Visitors:

In addition to their research, MPI-IS scientists are committed to making a contribution to society through internships, presentations, and demos for visitor groups of all kinds.

In 2018, 82 interns visited our institute as part of their studies and vocational training. From January 2019 to July 2019, 76 interns completed an internship at MPI-IS.

Visitor groups include members of the general public, politicians, and industry representatives. This past year, a growing number of delegations came to the MPI-IS from different countries, among them Great Britain, France, and Canada.



Research Highlights from the Departments

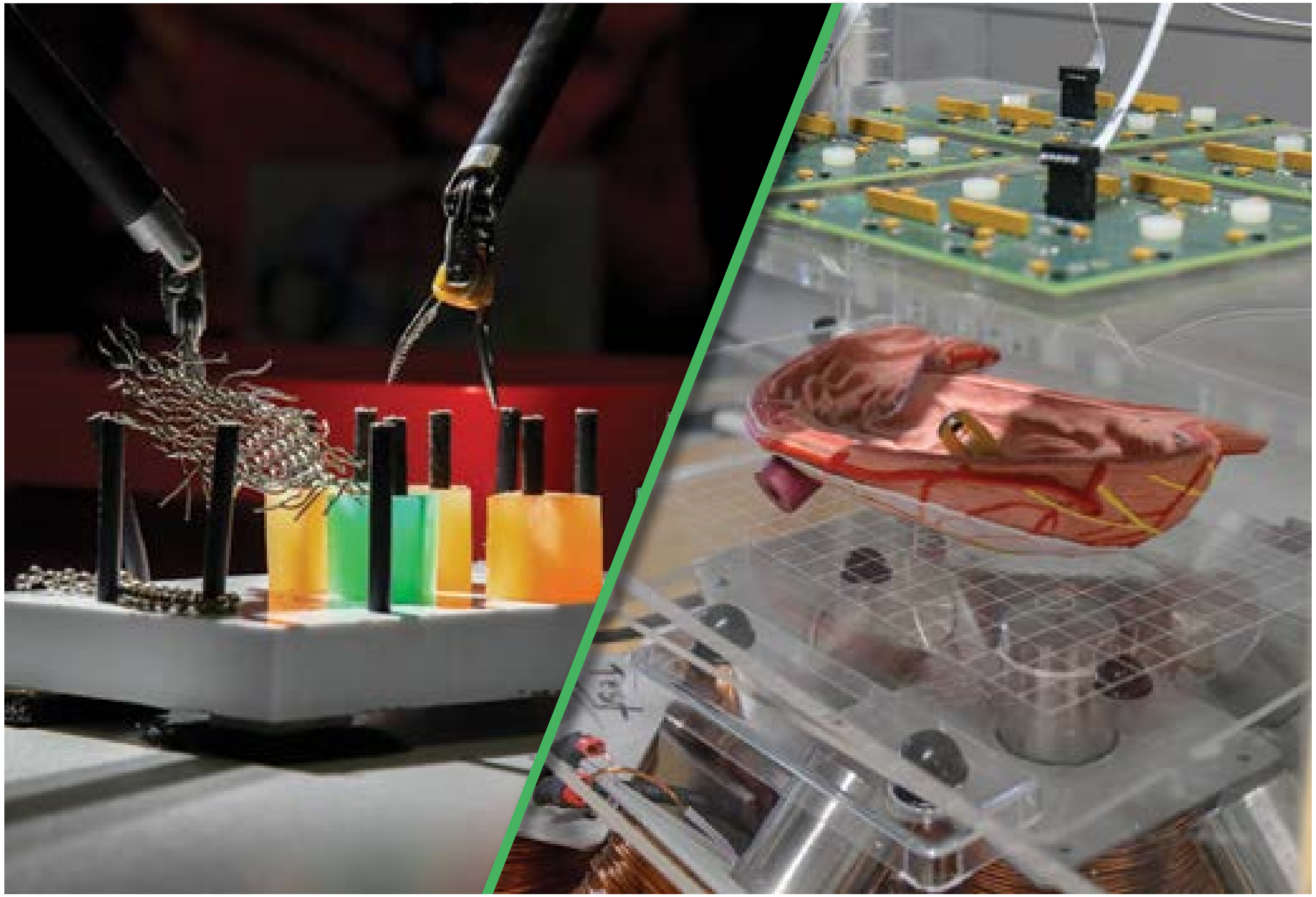
Departments

Our institute currently has six departments, two of which are affiliated with the former metals research orientation. In the future, the MPI-IS will have four departments at each of its locations in Stuttgart and Tübingen, for a total of eight.

Each department is headed by one director. Once a department has been established, it comprises between 30 and 60 members.

In most cases, doctoral students make up the majority of the department's staff, and postdocs are the second largest group. Department staff also includes technical personnel and administrative experts.

Most departments maintain laboratories, many of which have special large-scale equipment, research instruments and, in some cases, field stations.



A robot-assisted surgical system is equipped with haptic feedback and is thus extended to create a sense of touch.

Researchers magnetically steer a capsule robot through a 3D model of a stomach.

Departments

Empirical Inference

Professor Bernhard Schölkopf

Haptic Intelligence

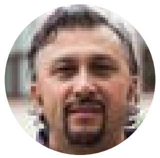
Katherine J. Kuchenbecker, Ph.D.

Modern Magnetic Systems

Professor Gisela Schütz

Perceiving Systems

Dr. Michael J. Black

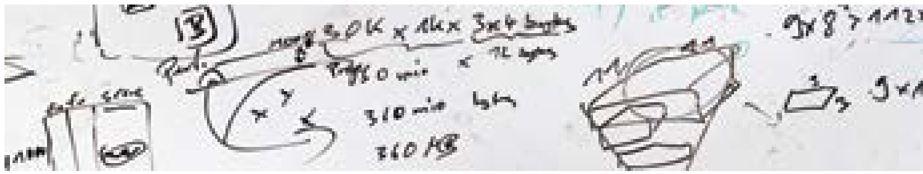


Physical Intelligence

Dr. Metin Sitti

Theory of Inhomogeneous Condensed Matter

Professor Siegfried Dietrich



Empirical Inference

Professor Bernhard Schölkopf

The members of the Empirical Inference department are dedicated to machine learning and causal inference. They develop algorithms that independently recognize regularities in data and draw conclusions from them. The researchers' primary goal is to understand how living beings and artificial systems recognize structures in order to act in the world. They aim to contribute to the application of theoretical methods of machine learning, for instance in medicine or astronomy.

Using machine learning, computers can quickly recognize structures in large amounts of data that a human being would not find, as the data often have complex structures and influencing variables that change. To interpret the data, the department's researchers are developing new statistical methods and algorithms that can "learn" from known relationships in data sets and then analyze unknown data.

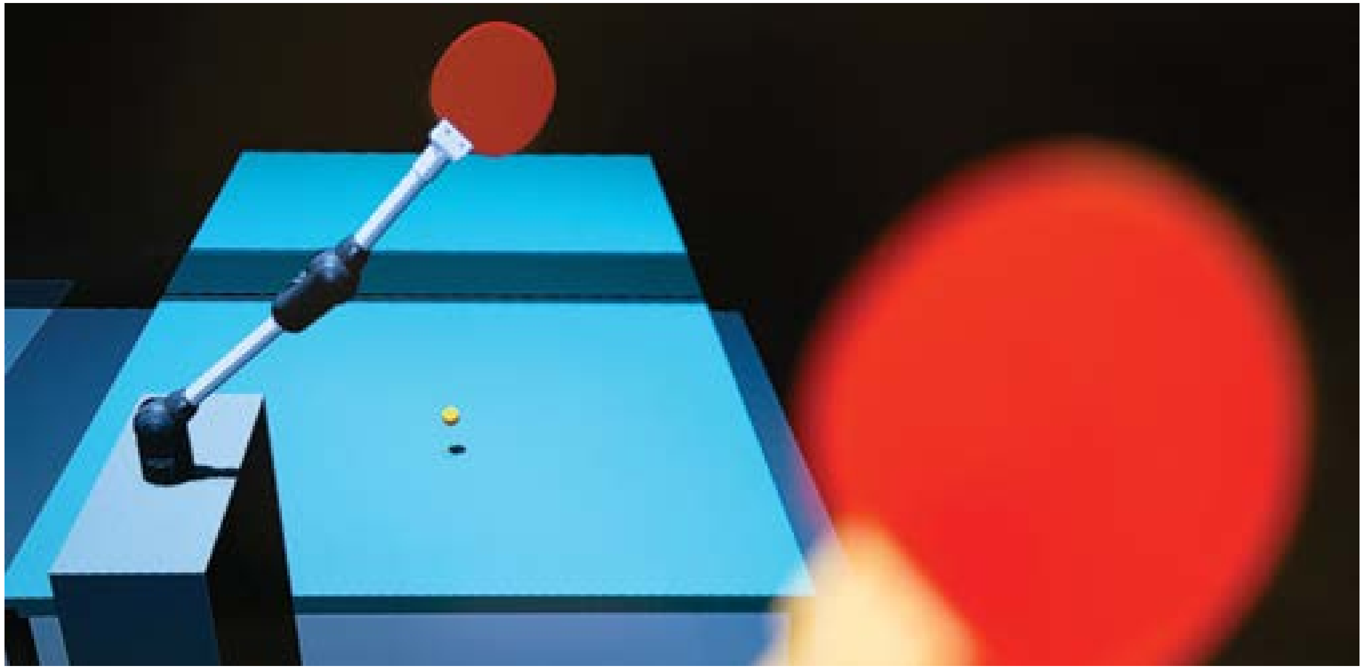
Causal inference is concerned with finding correlations between cause and effect from statistical data. This enables computers to gain insight into the underlying mechanisms of the data and to predict the effects of external influences. This means, for example, that AI systems can become significantly less prone to error.

The department works with empirical data from various sources, from biological measurements (e.g. from neuroscience) to astronomical recordings. The department's researchers conduct theoretical, algorithmic, and experimental research to find answers to questions relating to empirical inference.

The department's research highlights include:

A Table-Tennis Playing Muscle Robot:

While human beings can easily learn sports like table tennis, doing so is much more difficult for robots. The task is challenging in many ways: the dynamics of the game are unpredictable. Perceiving the situation and acting accordingly occurs within a very limited timeframe. While humans use their muscles to play, the robot is equipped with pneumatic muscles, artificial high-tech muscles that resemble human muscles. The department's researchers succeeded in constructing a robot that can generate very fast movements and execute them safely. The robot first learned to play a ball in simulation. After a few hours, it succeeded in playing a real ball in a certain direction, as well as smashing it to the other side of the table.



Personalized Brain Stimulation for Motor Rehabilitation:

With the help of healthy volunteers who try to burst as many balloons as possible within a short time in computer games, a team of researchers measures the brain activity associated with arm movement and collects the corresponding data. Based on this, the scientists develop methods that allow them to analyze the data and identify individual brain patterns. In this way, they build predictive models from the data that show where and how the motor cortex - the area of the cerebral cortex in the brain that controls movement - of a specific sick subject should be stimulated to facilitate his or her movement.

Fair algorithms:

In the future, computers will increasingly be used in decision-making processes that affect people. Such decisions are based on certain variables, such as a loan applicant's financial history or previous professional experience in the selection of job applicants. The department's researchers are looking at how algorithms can be fair, responsible, and transparent when making decisions with huge amounts of data.

Developing fair algorithms is very challenging. Every instance of discrimination resulting from a decision made with a system comprising large amounts of data is different, and must first be analyzed. This is the only way to find out where and how data is collected, where the system may draw wrong conclusions, and how the problem can be described in a mathematical formula. The more machine learning processes are used in different realms of society, the more important it becomes that they are fair.

Haptic Intelligence

Katherine J. Kuchenbecker, Ph.D.

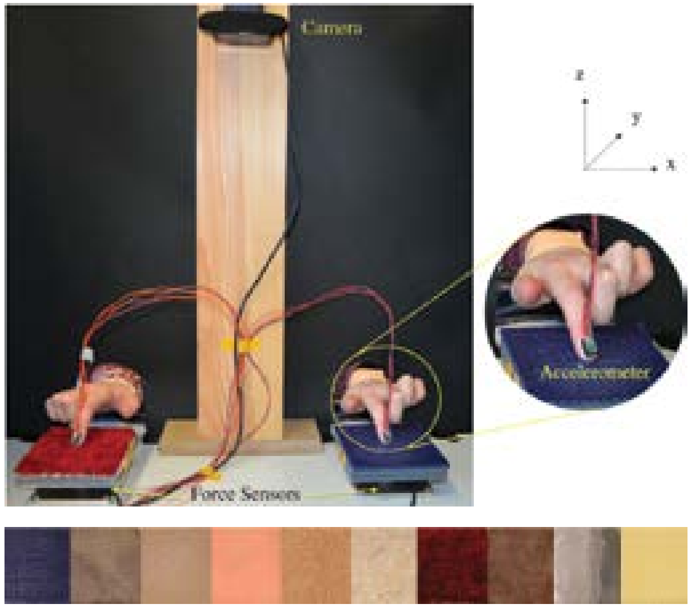
The Haptic Intelligence department aims to advance the scientific understanding of haptic interaction while simultaneously inventing human-computer and human-robot systems that take advantage of the unique capabilities of the sense of touch. The department pursues this goal by undertaking research in four main fields:

- understanding tactile contact during physical interactions by both humans and robots,
- creating and characterizing haptic interface technology,
- advancing and evaluating teleoperation interfaces, and
- designing contact-based human-robot interaction systems.

The department's research highlights include:

Tactile Contacts:

Scientists do not yet understand the mechanisms that underpin haptic perception, action, and learning as well as they understand the same processes for vision and hearing. The department's researchers thus focus a portion of their energy on understanding the phenomenon of tactile contact, wherein a human or robot interacts with a physical object while feeling the resulting cutaneous and kinesthetic sensations. Yasemin Vardar, one of the department's postdocs, recently compared how humans visually and haptically perceive real surfaces. Until now, vision has often been thought to dominate between the senses. With a carefully selected experimental set-up, Vardar and her collaborators were able to demonstrate that people perceive real surfaces quite similarly through vision and touch. Furthermore, these perceptual judgments correspond well to the key haptic properties of the surfaces, namely their friction, hardness, and roughness.



The experimental setup that Vardar, Wallraven, and Kuchenbecker used to capture physical interaction signals while participants touched pairs of surfaces drawn from the depicted set of ten diverse real materials.

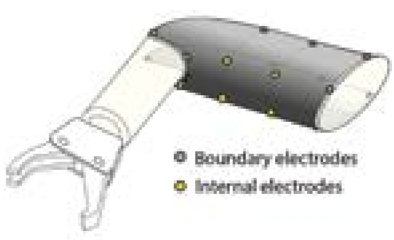
Haptic Interfaces:

Haptic interfaces are mechatronic systems with which people interact physically. They give users the illusion of touching things that are actually in another place (in a distant environment) or that do not really exist (in a virtual environment). A team led by postdoc Hasti Seifi initiated the Haptipedia project to help people understand the rich variety of such devices. Specifically, Haptipedia provides an online taxonomy, database, and visualization of haptic interfaces that have already been developed. The researchers analyzed more than 2000 publications and gathered input from more than 100 people. By combining all this data, Haptipedia has made it possible to accelerate the development of haptic interfaces and facilitate the use of haptic feedback for interaction designers. The platform is publicly accessible at haptipedia.org.

MAX PLANCK GESELLSCHAFT

Teleoperation Interfaces:

By remotely controlling a robot, people today can perform tasks without being in the same place. For example, the robot can be on the other side of the room, deep in the ocean, or orbiting above Earth's surface. The remote-controlled robot's job is to represent the user's actions in the remote environment. The user sends these commands and receives multimodal feedback via a teleoperation interface. One of the department's research teams is working to advance medical teleoperation systems that are already in use. The robot's contact interactions generate 3D acceleration data that can provide realistic haptic feedback to the user. For simplicity, this feedback is typically generated with a uniaxial vibration actuator. One of the department's postdocs, Gunhyuk Park, analyzed how existing approaches usually reduce 3D acceleration data to one-dimensional signals. By testing the algorithms against one another objectively and subjectively, Park and his team showed for the first time that the chosen approach has a substantial impact on the perceived quality of the resulting waveform. In addition, the team developed new quantitative signal quality metrics that correlate with human perception.

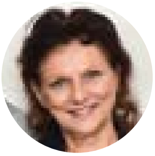


The large-scale fabric-based tactile sensor invented by Lee, Park, Kim, and Kuchenbecker. Highly conductive fabric patches and conductive thread electrodes distributed across a low conductivity fabric sheet enable real-time localization of multiple contact points.

All members of the Haptic Intelligence Department in July 2019, including our director, department assistant, research scientist, seven postdocs, nine Ph.D. students, four master's thesis students, a visiting professor, two visiting Ph.D. students, six interns, and four technical staff members.

Human-Robot Interaction:

In robotics, major opportunities exist for helping humans in their everyday lives. However, since everyday environments are unstructured and constantly changing, new approaches are needed to ensure that robots can be used as successfully at home or in hospitals as they are in factories. To enable the completion of useful tasks, one research team is dedicated to the field of physical human-robot interaction. However, most robots do not have haptic sensors, as commercially available tactile sensors are usually expensive and limited in size, robustness, sensitivity and/or reliability. In an effort led by postdoc Hyosang Lee and visiting Ph.D. student Kyungseo Park, the department is working to create tactile sensors that can be easily manufactured to cover all exposed surfaces of a robot and provide useful information about physical contact. The research team makes these sensors from layers of fabric that have different conductivity levels. They reconstruct the contact map using very fast pairwise electrical measurements and mathematical methods from electrical resistance tomography (ERT). The resulting tactile sensors have the potential to be low cost, reliable, sensitive, fast, and accurate. Future generations of robots can thus have a sense of touch.



Modern Magnetic Systems

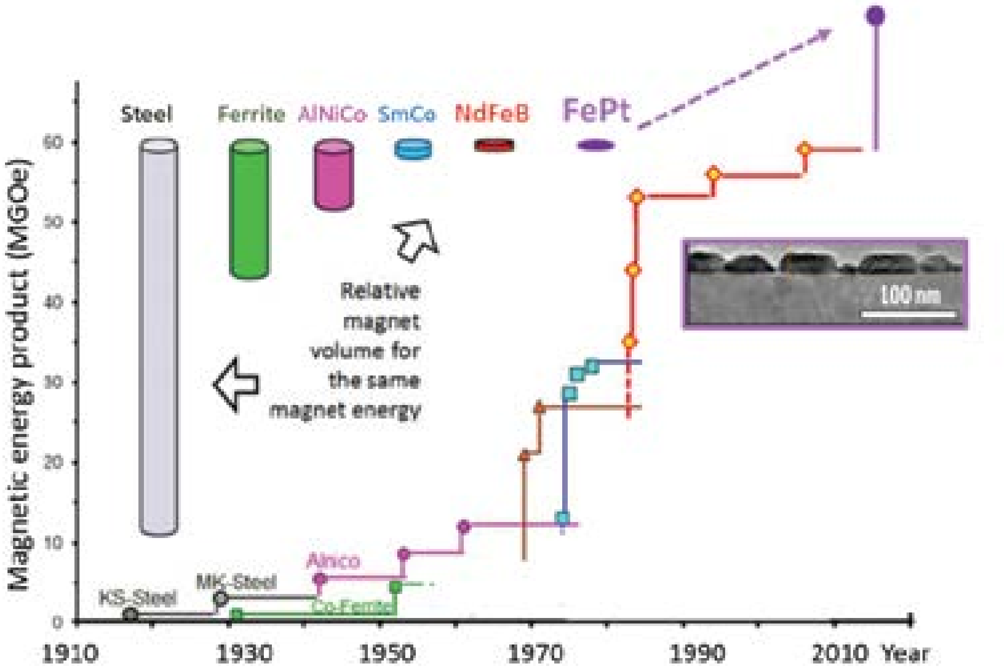
Professor Gisela Schütz

The research of the Modern Magnetic Systems department is dedicated to exploring nano magnetic structures, developing nano and micro sized novel devices, and understanding their spin dynamics. Hereby, the application and the steady improvement of X-ray-based imaging techniques play an essential role. By utilizing advanced nanoprinting techniques, the department's researchers developed novel plastic X-ray lenses with nanometer-sized features and excellent focusing capabilities. For this and other projects, the team uses the X-ray microscope MAXYMUS, located at BESSY II, an 80 meter-wide synchrotron radiation source at the Helmholtz Center Berlin, through which even the smallest structures can be made more visible. Another research focus is the development of novel supermagnets at the nano- to micrometer-scale, which far exceed the performance of conventional magnets.

The department's research highlights include:

New supermagnets:

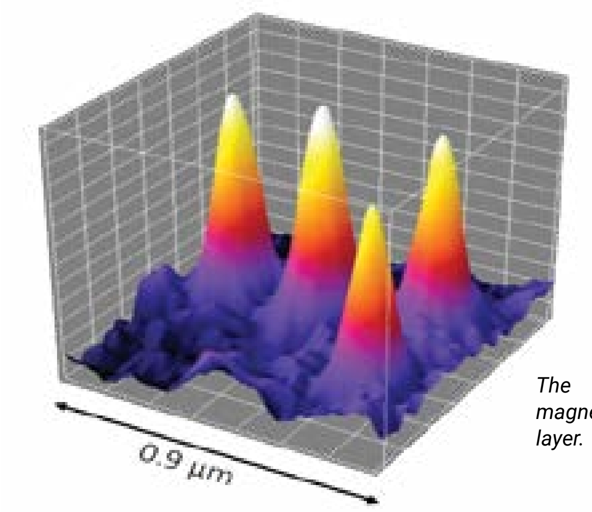
Gisela Schütz and her team have successfully increased the energy of solids and developed a new magnet based on iron and platinum (FePt), which is about 30% stronger than neodymium (Nd) magnets. The latter was discovered in 1984 and has since been considered the strongest commercially available permanent magnet. The new supermagnet could one day be integrated into micro-sized sensors, motors, and generators. The team is currently working on compacting the materials, and on new plastic bonded and nano printed high-performance magnetic structures. In the future, these could potentially also be used for micro robots.



The increase in the magnetic energies of different materials 110 years ago until now. The iron–platinum (FePt) nano particles have the highest magnetic energy per volume ever observed.

Skyrmions become visible for the first time:

Skyrmions are three-dimensional structures that occur in magnetic materials. They are topologically protected, meaning that their shape cannot be changed and their three-dimensional structure is less than one-hundred nanometers in size. Until now, it was not possible to make the structure of Skyrmions visible. With the high-resolution X-ray microscope MAXYMUS at the storage ring BESSY II, the researchers were able to map the three-dimensional structure of Skyrmions for the first time.
Understanding these magnetic structures is particularly important for the development and future manufacture of spintronic storage devices – the highly-efficient data storage systems of the future. Storing information in Skyrmions is considered less susceptible to interference. But to be able to use Skyrmions as data storage devices, one must first understand their structure.

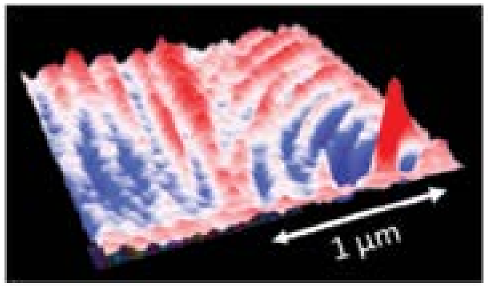


The magnetization distribution of magnetic skyrmions in a thin metallic layer.

The formation and propagation of spin waves visible for the first time:

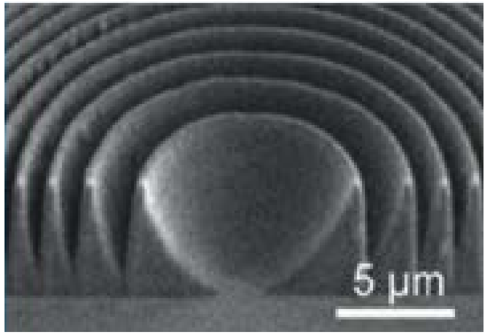
Magnonics is a new field in materials science and information technology that addresses magnetic phenomena in crystals. The main focus here are spin waves, the magnetic counterparts of electromagnetic waves, with wave lengths about 10 times larger. With the X-ray microscope MAXYMUS, the team is the only one to date that can directly visualize the creation and propagation of the spin wave in space and time.

Snapshot of spinwaves excited by microwaves in the edge region of a magnetic platelet.



Novel polymer lenses for X-ray microscopes:

X-ray microscopes are fascinating imaging tools. They combine nanometer size resolution with a large penetration depth, with which buried features become visible. However, the focusing of X-rays requires expensive optical devices. A collaboration between the Modern Magnetic Systems and Physical Intelligence departments led to the invention of a new, fast, and less expensive 3D-nanoprinting method for making Kinoforms – converging lenses that are able to efficiently focus X-rays.



An X-ray lense with nanometer-sized features and excellent focusing capabilities. By using an advanced 3D printing technique, a single lens can be manufactured in under a minute from polymeric materials with extremely favorable X-ray optical properties.

Perceiving Systems

Dr. Michael J. Black

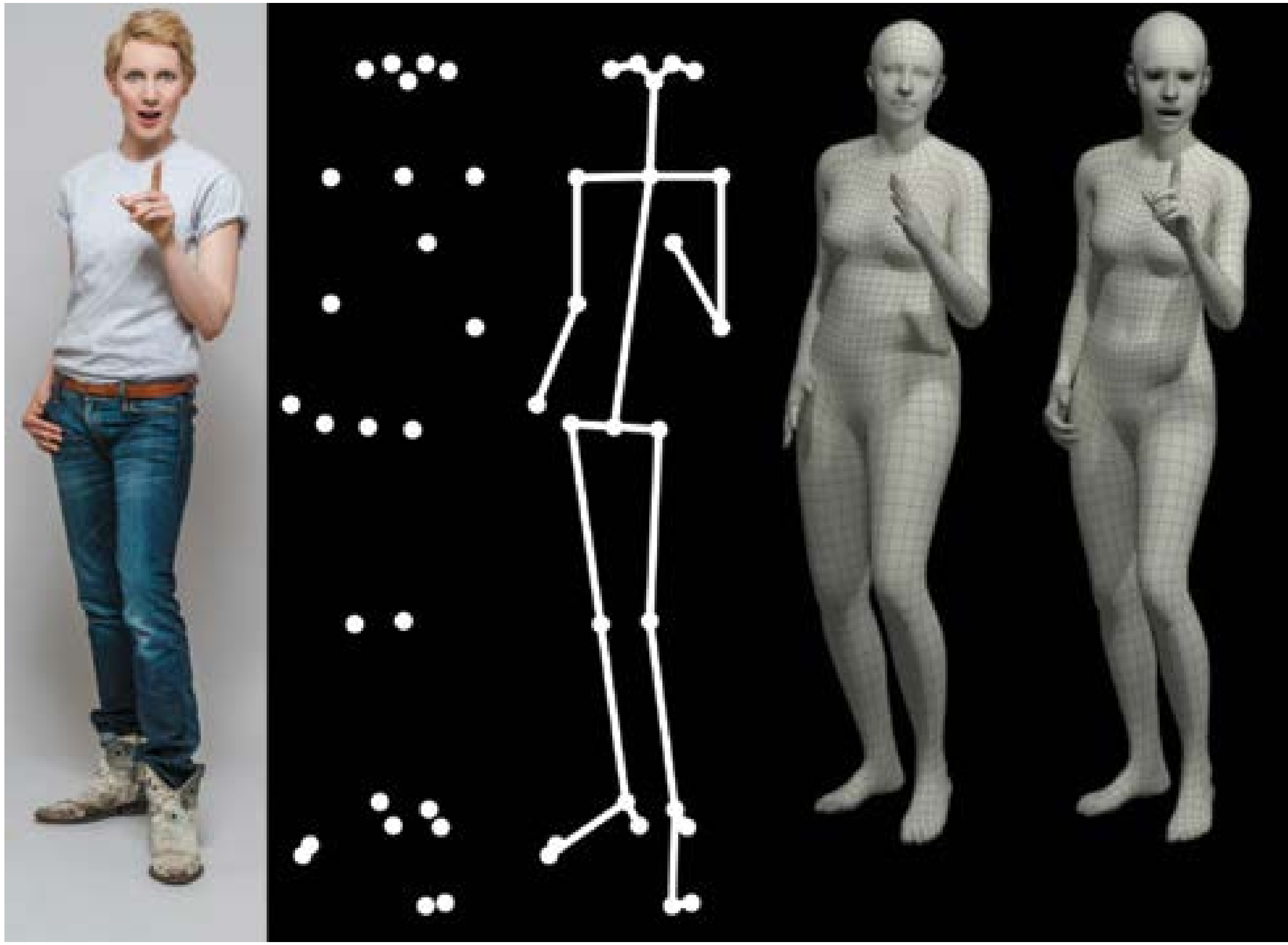
Learning to be a Digital Human:

The Perceiving Systems department combines computer vision, machine learning, and computer graphics to train computers to understand humans and their behavior in images and video. Our unique approach begins with learning compact parametric models of 3D human shape and motion. We use these to extract and analyze human behavior in the context of 3D scenes. The department has approximately 45 staff and students and additional affiliated researchers. It operates unique 4D scanning facilities that produce highly accurate and detailed 3D meshes of the body, face, hands, and feet at 60 frames per second. The department also employs wearable motion capture suits, flying robots, and camera-based systems to record human movement.

The department's research highlights include:

Expressive body models:

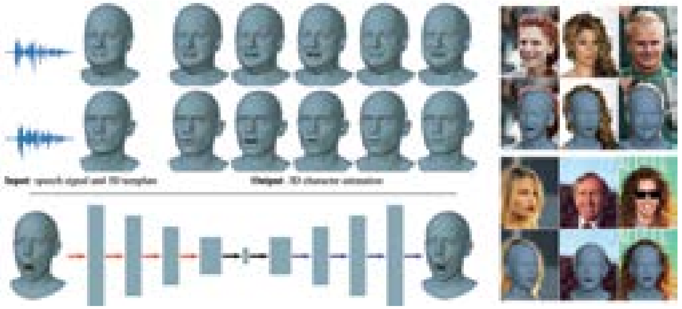
Humans use their bodies to communicate and to manipulate the world. This involves using our 3D bodies to interact with the 3D world. Consequently, the department focuses on modeling 3D body shape as a triangulated mesh, which enables reasoning about human-object contact. Objects cannot be interpenetrated and they cannot interpenetrate people. Body shape also provides information about a person's health, age, fitness, and clothing size. To facilitate the analysis of human (inter)actions and emotions, the department created a new 3D human model from thousands of 3D and 4D scans with fully articulated hands and an expressive face. We have developed state-of-the-art methods for extracting these models from images and video. This is a step towards automatic human understanding.



Creation of realistic virtual avatars from single images by learning a model of the body that includes expressive faces and hands through the estimation of the model parameters from an image.

Faces:

Face shape and motion are important for human communication. To train computers to better understand us, we learn detailed 3D models of human face shape and motion. We then train computer vision algorithms to extract these models from images and video. Over the last year, we pioneered several new technologies to model and analyze faces. CoMA is a neural network model that learns a non-linear representation of a face using spectral convolutions. CoMA provides a new approach for learning convolutional models in 3D meshes. VOCA is an audio-driven 4D facial animation model that takes any speech signal as input and then realistically animates adult faces. Finally, RingNet learns to compute 3D face shape from a single image without any explicit 3D supervision.



Extraction of detailed facial motion and expression from images by learning models of faces and their expressions from 4D scans and training neural networks to estimate 3D faces from images.

Hands and Objects:

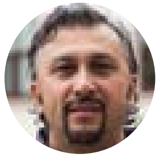
Hands are important to humans for signaling, communication, and interacting with the physical world. Estimating hand-object manipulation is thus essential for interpreting and imitating human actions. Despite recent progress towards reconstruction of hand poses and object shapes in isolation, reconstructing hands and objects during manipulation remains challenging due to significant occlusions of both the hand and object. To address this, we developed an end-to-end learnable model that exploits a novel contact loss, favoring physically plausible hand-object constellations. The network estimates 3D hand shape and pose together with 3D object shape from a single image.

Reconstruction of realistic hand and object interactions by learning a model that estimates hand pose and shape together with object shape by enforcing physical constraints.

Medical and Health:

The department's medical and health-related projects exploit the fact that bodies and health are often intertwined. By collaborating with medical doctors and psychologists, the department's researchers established how anorexia nervosa patients perceive their bodies using models and VR technologies, such as the virtual caliper. Body shape also relates to various diseases, including diabetes and cardiovascular disease. The department's models provide a non-invasive approach to help determine the risk for such diseases using visible body shape. We have also developed methods to estimate the shape and motion of infants and are using this for the early detection of cerebral palsy and the detection of underweight babies.

Relating 3D body shape to human health through the application of our 3D body models in the study of eating disorders, adipose tissue measurement, and social science.



Physical Intelligence

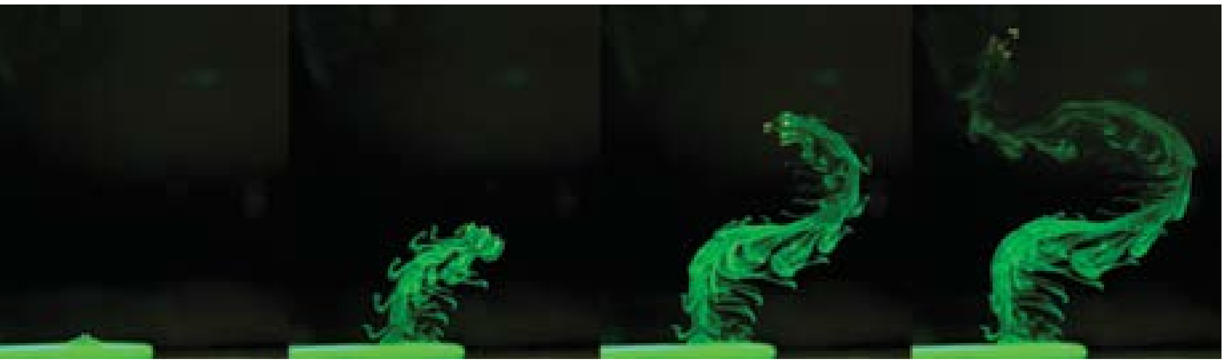
Dr. Metin Sitti

When developing small-scale mobile robots made of smart and soft materials, the Physical Intelligence team looks to nature for inspiration. The built-in physical intelligence of biological systems serves as a model for micro- and milli-machines. Due to their small size, the intelligence of such robots is mainly rooted in their physical design, the material used, and their ability to adapt and self-organize – rather than in their inherently limited computation, actuation, powering, perception, and control capabilities. The team focuses on medical applications of these novel small-scale robotic systems to revolutionize the healthcare technologies of the future by enabling unprecedented minimally invasive medical interventions inside the human body.

The department's research highlights include:

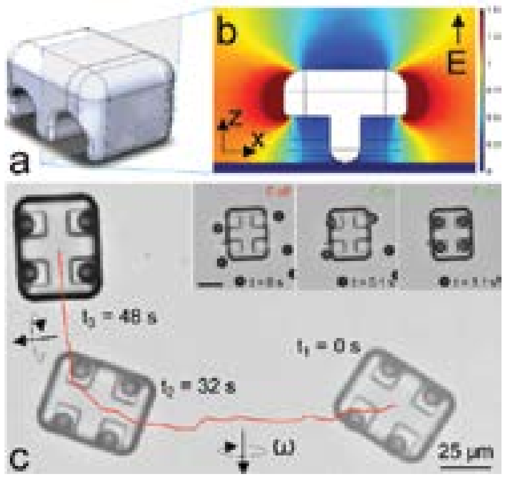
A Jellyfish-Inspired Robot:

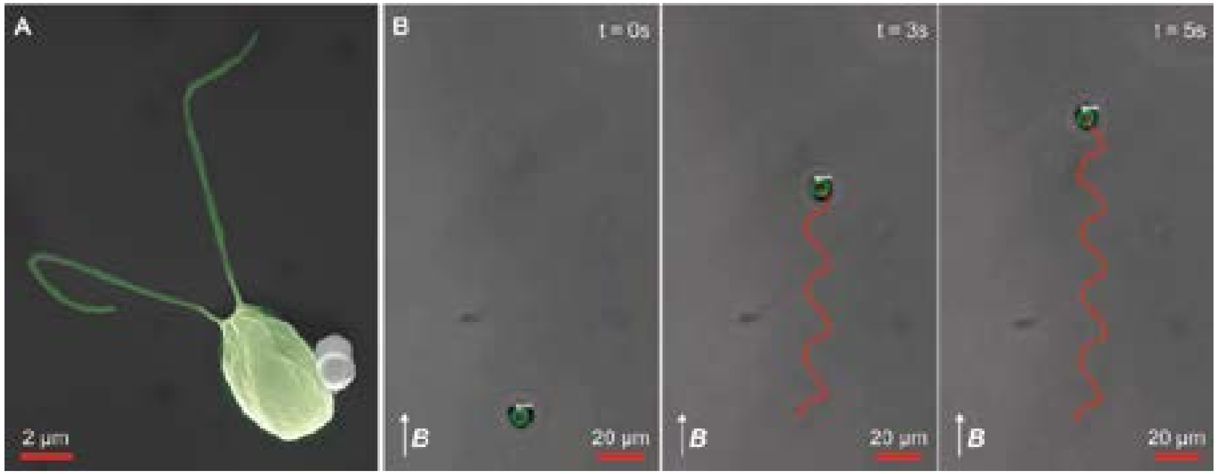
Jellyfish are fascinating animals. They consist almost exclusively of water and have a peculiar physique. The cnidarians play an important role in the marine ecosystem, as they whirl up water and create currents. Some of the department's researchers were fascinated by how they did this. They took nature as their role model and built Jellyfishbot – a robot that looks and moves like a real baby jellyfish. The tiny construct is only five millimeters in diameter. Like its natural counterpart, it has an umbrella-shaped bell and tentacles. The researchers embedded magnetic particles in the multi-unit, soft lobes. This enabled them to control Jellyfishbot from the outside when it was exposed to an external oscillating magnetic field. The scientists succeeded in making the robot's soft body float upwards in a snake-like movement, like a real jellyfish. The scientists believe that their research could be used for a broad range of applications. For instance, these tiny robots could one day explore the marine ecosystem.



Micromachines that Assemble Themselves:

Building a robot with many different components is a highly complex task, especially when it is only a few micrometers in size. In their research on self-assembling micromachines, scientists in the department made use of magnetic particles that assemble themselves under rotating magnetic fields. At the same time, they used components that combined with each other through chemical reactions. The researchers were thus able to construct not just one, but many differently shaped machines just a few micrometers in size. Their findings demonstrate that programmable self-assembly of micromachines is possible solely through the design and structure of the individual components, in combination with dielectrophoretic forces that form around the individual parts under the influence of an electric field.





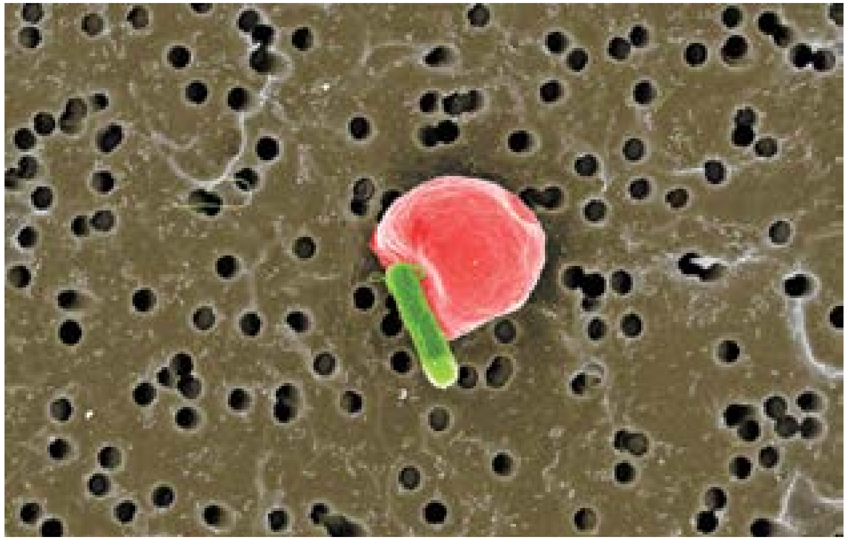
Microalga-Powered Microswimmers:

Another sub-team researched biohybrid microswimmers powered by a freshwater green alga. Scientists investigated the small object's swimming behavior in the presence of a uniform magnetic field, and tested swimming activities under different conditions. The possible use of microswimmers as a vehicle for transporting drugs is promising in the minimally-invasive treatment of illnesses and diseases. A machine that can transport therapeutics to places in the body that are otherwise difficult to access could one day substantially change therapeutic approaches.

Red Blood Cell-Driven Microswimmers:

The same idea is behind an untethered biohybrid microswimmer that can transport and deliver cargo encapsulated in a red blood cell, while an attached bacterium – one of nature's most efficient swimmers – propels it forward. The researchers selected a red blood cell as a main component, as it has a high load-bearing capacity and can easily adapt its form. As a result, it can squeeze through capillaries half its size with ease. Combined with the drive dynamics of bacteria – the mircoswimmer's motor – it can transport cargo even through narrow capillaries that are half its size.

The researchers encapsulated a cancer drug and iron nanoparticles in the red blood cell, enabling them to magnetically control the microswimmer from the outside. Once it has reached its destination, for example a cancer cell, the tumor's acidic environment attacks the membrane of the red blood cell, making it brittle and releasing the cancer drug onto the cancer cell's doorstep. Once this task has been fulfilled, the researchers can make the microswimmer decompose by heating it with infrared light.



Theory of Inhomogeneous Condensed Matter

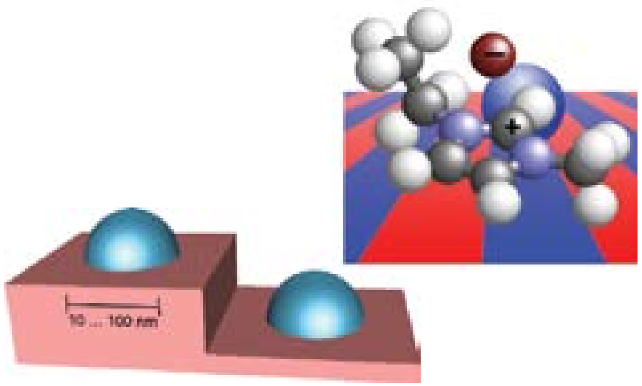
Professor Siegfried Dietrich

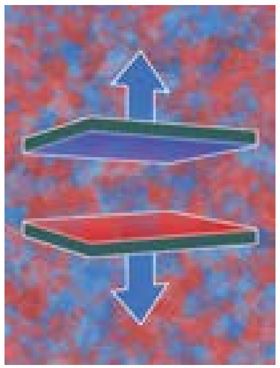
Scientific Mission:

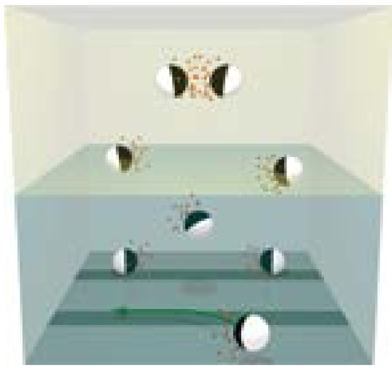
The research goal of the department Theory of Inhomogeneous Condensed Matter at the Max Planck Institute for Intelligent Systems as well as of the Chair for Theoretical Physics in personal union at the University of Stuttgart is directed towards relating macroscopic properties of condensed matter to the collective behavior of the underlying microscopic degrees of freedom. Based on statistical physics, the research focuses on systems that are inhomogeneous on mesoscopic length scales, encompassing interfaces as well as anisotropy and disorder. These systems exhibit a wealth of phenomena and can generate states of condensed matter which do not form in bulk materials, offering perspectives for useful applications. Specifically, the following research areas are under investigation:

- wetting phenomena and capillary forces
- critical phenomena and collective dynamics
- active matter
- soft matter at interfaces and complex fluids.

Although these research areas distinctly differ from each other, there is also significant overlap between them, which binds them together under the general theme of inhomogeneous condensed matter: wetting phenomena play a role in all these research areas. Dynamics and active matter account for a large share of the department's work. Phase transitions, including critical phenomena, play an important role for all listed research areas.





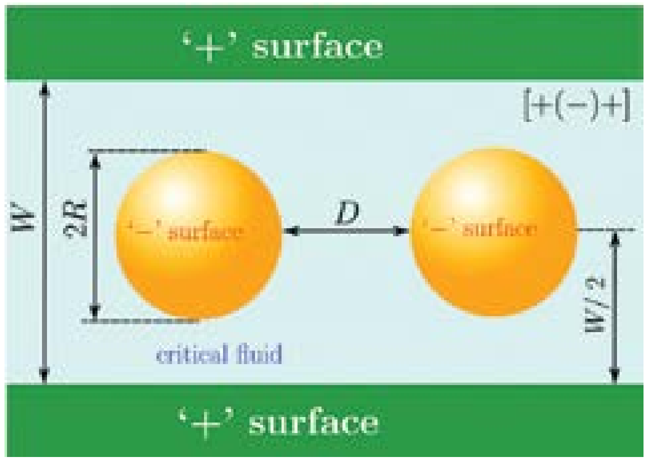


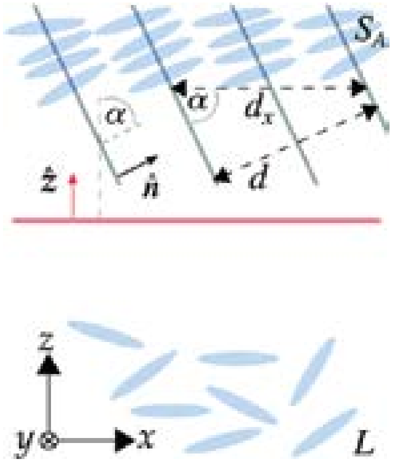
The department's research highlights include:

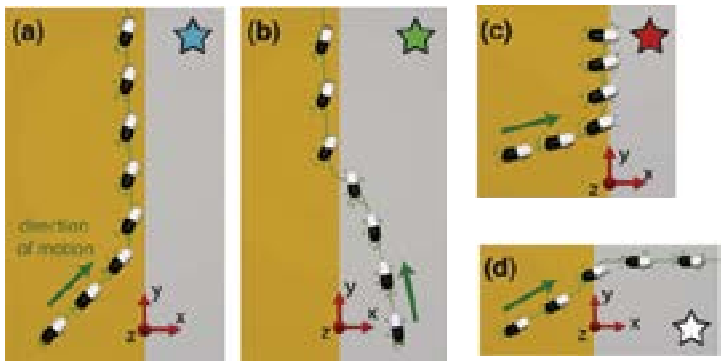
- The researchers in the department investigate the interplay between various physical interactions on mesoscopic length scales. For microparticles, so-called colloids, which are immersed in a liquid between two interfaces, the mutual interactions, due to van-der-Waals and critical Casimir forces, can be tuned at will from attractive to repulsive by adjusting the temperature of the liquid or by adapting the surface properties. These phenomena offer perspectives for many useful applications, because they allow one to manipulate a plenty of these particles at the same time, which is not possible with conventional methods. For instance, it can be used to prevent flocculation in colloidal suspensions, as well as, for handling, feeding, trapping, and fixing microparticles in solution.

- Liquid crystals are composed of molecules, the structure of which leads to direction-dependent (anisotropic) macroscopic physical properties of this type of material and they are used in many conventional flat-panel displays. In the department, researchers study so-called ionic liquid crystals, the molecules of which additionally carry charges. This combination of direction-dependent interactions of the liquid-crystal molecules on one hand, and the interactions of the charges on the other hand, gives rise to complex material properties of ionic liquid crystals, combining those of liquid crystals and ionic liquids. By using methods of statistical physics, researchers of the department analyze and characterize the interfaces which are formed between different states of matter of the ionic liquid crystal.

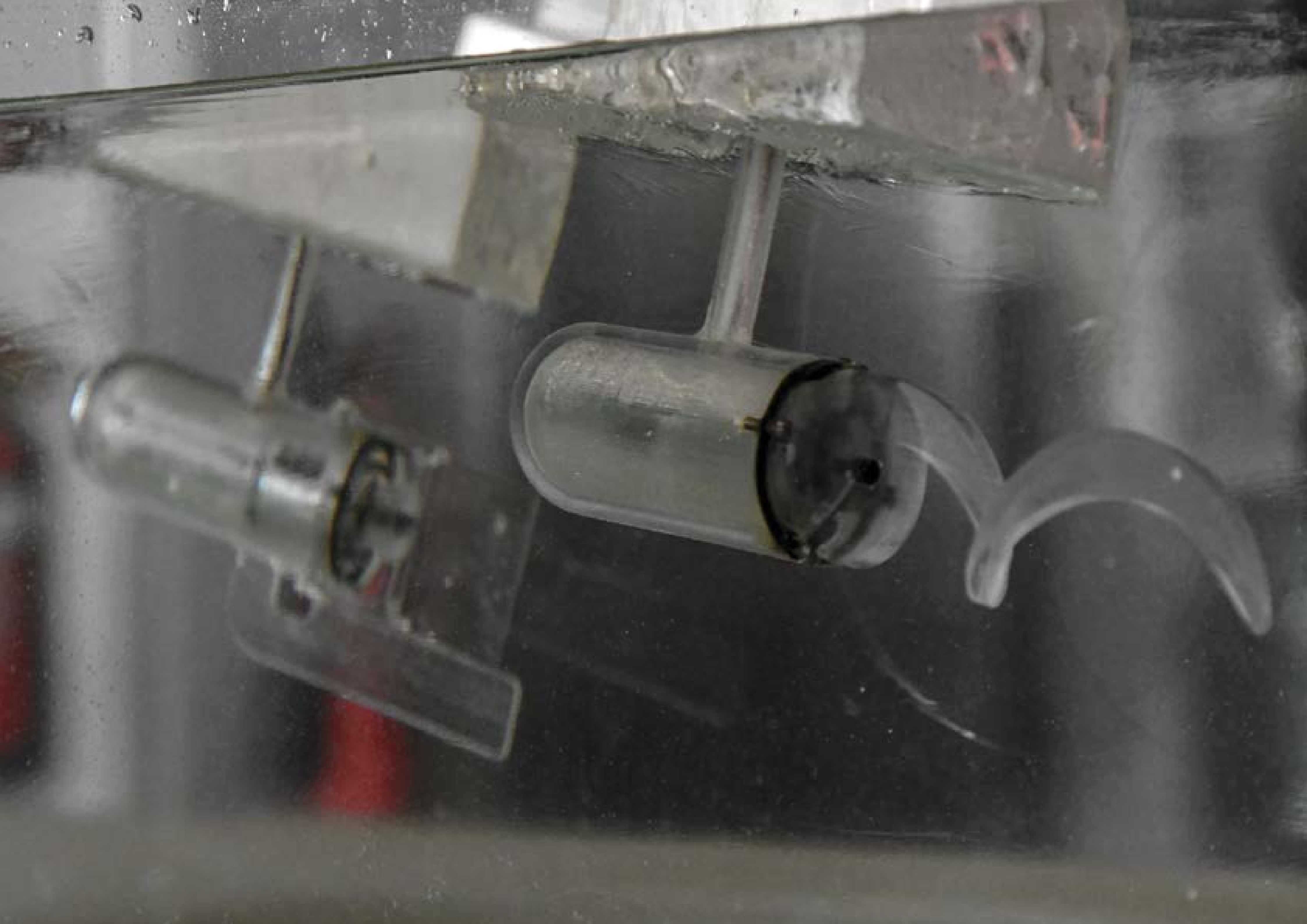
- Microparticles exhibiting distinct chemical properties on the two sides of their surface are called Janus particles, referring to the two-faced ancient roman god. If so-called chemically active Janus particles are immersed in a solution, they can show self-induced motion, due to chemical reactions, occurring at their surfaces. They usually sediment in the vicinity of a confining wall and move along the wall. The research in the department has shown that via suitable chemical-patterning of the confining wall the motion of spherical or rod-shaped Janus particles can be steered or the mircroparticles can even be trapped. These are new ways of controlling the motion of active matter.







Research Highlights from the Research Groups



Research Groups

The Max Planck Institute for Intelligent Systems currently hosts 14 research groups in a broad range of research fields. Within the MPG, our institute is among those with the highest number of research groups. The group leaders are outstanding young scientists with extensive experience as researchers.

Group leaders receive research funding for several years to employ doctoral students, postdocs, and other staff. During this time, they work with group members to advance their own research topics and establish their reputation within the research community. The group leader position is often the stepping stone to a professorship.

However, some of our group leaders are already professors. For instance, the Max Planck Fellow Program promotes cooperation between outstanding university professors and Max Planck Society researchers. The appointment of university professors as Max Planck Fellows is limited to a five-year period and includes the supervision of a small working group at a Max Planck Institute.

Other research groups headed by professors are primarily financed by the European Union, for instance with ERC Starting Grants. Other sources of funding include the institute's budget, the Max Planck Society, and the Cyber Valley budget.

Autonomous Learning

Max Planck Research Group - Dr. Georg Martius

Autonomous Vision

Max Planck Research Group - Professor Andreas Geiger

Dynamic Locomotion

Max Planck Research Group - Dr. Alexander Badri-Spröwitz

Embodied Vision

Cyber Valley Max Planck Research Group - Dr. Jörg Stückler

Intelligent Control Systems

Cyber Valley Max Planck Research Group - Dr. Sebastian Trimpe

Locomotion in Biorobotic and Somatic Systems

Cyber Valley Max Planck Research Group - Dr. Ardian Jusufi

Micro, Nano, and Molecular Systems

Max Planck Research Group - Professor Peer Fischer

Research Groups

MAX PLANCK GESELLSCHAFT

Movement Generation and Control

ERC Group - Professor Ludovic Righetti

Physical Reasoning and Manipulation

Max Planck Fellow Group - Professor Marc Toussaint

Physics for Inference and Optimization

Cyber Valley Research Group - Dr. Caterina De Bacco

Probabilistic Learning

Max Planck Research Group - Dr. Isabel Valera

Rationality Enhancement

Cyber Valley Max Planck Research Group - Dr. Falk Lieder

Smart Nanoplasmonics

ERC Group - Professor Laura Na Liu

Statistical Learning Theory

Max Planck Fellow Group - Professor Ulrike von Luxburg

A bird's eye view of the Max Planck Campus in Stuttgart.

The new MPI for Intelligent Systems in Tübingen seen from above.

Autonomous Learning

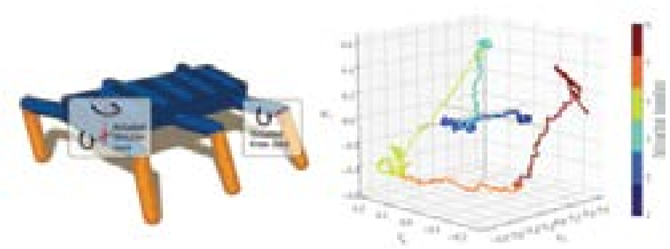
Max Planck Research Group - Dr. Georg Martius

The Autonomous Learning group's mission is to make robots learn in a way that is similar to early childhood development. Learning directly from interacting with their environment can potentially enable them to act in a complex and constantly changing world, which they cannot be programmed to do.

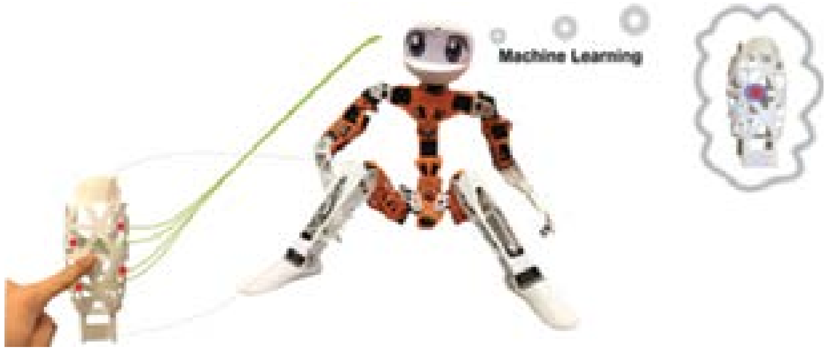
The group's research highlights include:

Self-Determined Exploration of Behaviors:

With a hexapod robot that has no prior knowledge of its body or the environment, the researchers study how sensorimotor coordination can emerge based on simple mechanisms. The scientists focus on a self-organized search for potentially useful behaviors. Martius and his team have developed a basic method that systematically explores many movement patterns fitting to the body in its environment. In this way, the robot can learn to locomote in many different ways relatively quickly, within half an hour of interaction time.



A hexapod robot (left) learns to locomote. After 30 minutes, it can move at different speeds and in different directions, and it can transition between behaviors (right).



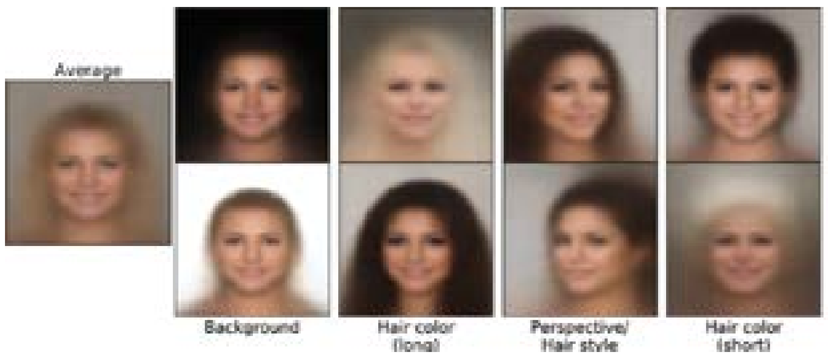
New limp (left) of Poppy robot (middle) is equipped with several deformation sensors. Machine learning makes it possible to infer force amplitude and location in a precise manner.

Representation Learning:

For a robot that learns autonomously, making generalizations based on individual observations can be important. The researchers study this using the example of faces: finding common factors explaining most of the differences between faces, such as gender or hair color. Variational Autoencoders, a common machine learning method, can do this to an astonishing extent. However, until now it wasn't clear why. Martius and his research team recently found a mathematical explanation. The group hopes to utilize this knowledge for further advances in general data analysis.

An Efficient Sense of Touch:

So far, robots have a very limited sense of touch. Moreover, most sensing systems that enable robots to detect touch are bulky, fragile, and expensive. In this project, the researchers developed an efficient method that is robust and sufficiently precise to measure haptic forces on the surface of 3D robot limbs. The trick is to use a few sensors on the insides of robots' limbs that measure deformation and learn which sensor patterns correspond to which forces on the body. Doing this is possible thanks to advanced machine learning methods, which detect the sensor patterns of external simulation. These methods reduce the number of sensors required to give robots a sense of touch.



The representation of the average face (left) along with pairs of images where each one learned generating factor is varied.

Autonomous Vision

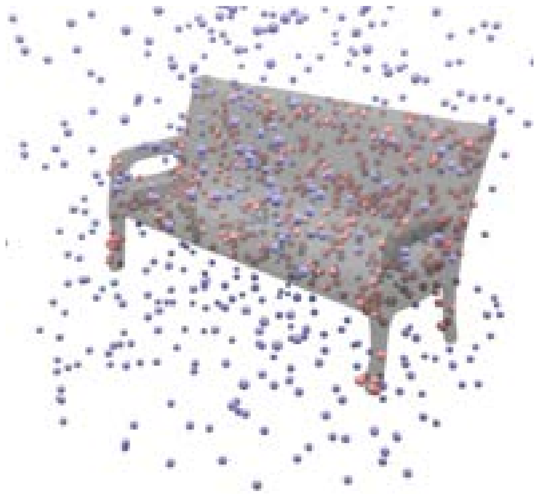
Max Planck Research Group - Professor Andreas Geiger

The Autonomous Vision research group, which is based at the Max Planck Institute for Intelligent Systems in Tübingen and the University of Tübingen, addresses questions related to robustness as well as methods that enable high-capacity models (such as deep neuronal networks) to learn with a small amount of data. More specifically, the group's research focuses on robust perception for autonomous agents, especially autonomous vehicles. Research activities range from sensor-based perception (3D reconstruction, motion estimation, object recognition) and holistic scene interpretation (3D lane and intersection estimation), to sensor engine control approaches.

The group's research highlights include:

Learning 3D Reconstruction in Function Space:

Existing approaches for learning to reconstruct 3D shapes from 2D images are limited to coarse 3D geometry or specific domains, as they lack a compact, memory-efficient 3D representation. The Autonomous Vision research group develops novel representations that facilitate the learning problem in 3D space. The group's models make it possible to infer 3D shapes at very high resolution from various inputs, including two-dimensional images and sparse 3D point clouds.

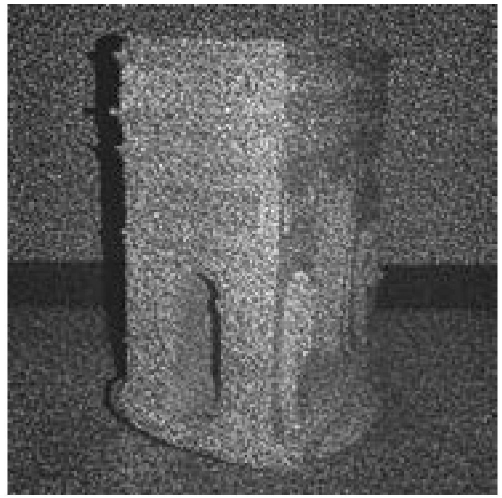


3D Shape Abstraction:

Abstracting complex 3D shapes, which means describing them on the basis of a few parameters, has been a long-standing goal in computer vision. The group's researchers develop learning-based solutions to this problem and demonstrate that representations based on "superquadratic" shapes can describe 3D scenes in an expressive and compact manner. These new models can be applied in a broad range of object categories (including humans) and decompose complex shapes automatically.

Unsupervised Active Depth Estimation:

The researchers investigate techniques for depth estimation using monocular structured-light cameras, which comprise one video camera and one laser projector. Their ultimate goal is to capture geometry and materials with very fine details. Such detailed information about the distance and shape of surrounding objects is indispensable in enabling agents such as autonomous vehicles to successfully operate within their environment.



Dynamic Locomotion

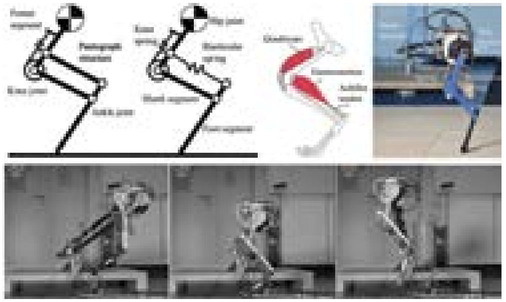
Max Planck Research Group - Dr. Alexander Badri-Spröwitz

Animals not only run dynamically, efficiently, and elegantly, they also quickly adapt to new terrain while moving on it. Their locomotion is a carefully orchestrated interplay of muscles and tendons that has been optimized over the course of evolution. Alexander Badri-Spröwitz and his team use robots and simulations to understand animals and their movements. They investigate why an animal activates a muscle, what forces enable the animal to move or why not all muscles and tendons are the same. The researchers take inspiration from animals to build robot models. With robots, researchers can directly test the function of the individual parts. Their findings could help to improve walking robots, prostheses or exoskeleton technologies – external support structures for the body.

The group's research highlights include:

A three-segmented robotic leg inspired by nature:

The anatomy of four-legged mammals is surprisingly similar; the hind legs of many mammals have three leg segments and several digit joints. The leg segments are connected by mono- and biarticular muscles and tendons that act like springs. Monoarticular muscles span over one joint, while biarticular muscles span over two joints. The function and benefit of muscles extending over two joints has not been sufficiently researched. Why did such muscles develop in the course of evolution? To understand their function during locomotion, the researchers designed and tested a three-segmented robotic leg equipped with mono- and biarticular springs: inspired by nature.



The morphology of animal legs can be transferred and tested on biologically inspired robot legs. The researchers show the advantageous properties of muscles and tendons that span several joints.

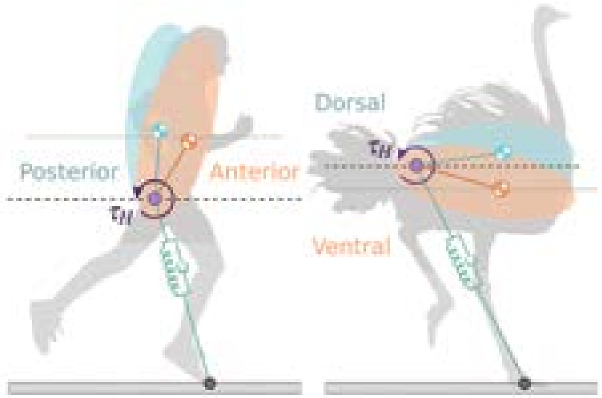
They tested both the mono- and biarticular spring-tendon configurations. Their experiments show how the biarticular springs and tendons convert energy effectively into forward speed. A biarticular spring acts as an energy-to-power converter: it stores energy during the impact phase, and releases the energy into forward speed and leg extension force during the propulsion phase.

A leg equipped with mono- and biarticular springs and tendons stores energy better, compared with a leg equipped only with monoarticular springs. It was surprising to discover that a robot with biarticular muscles and tendons is even more energy efficient than a comparable animal. In addition, the scientists showed how the robot leg can walk without the need for a sensor that precisely measures its environment. Equipped with both spring configurations, it locomotes in a self-contained manner.

Positioning of the virtual target point:

The research group also works with simulations, complementing research with robot hardware. One team investigated the gait of bipeds exploiting natural dynamics. Special attention was paid to hip muscles, which move the leg and stabilize the upper body.

The researchers investigated this motion sequence by creating a spring-loaded inverted pendulum model that includes a trunk. The forces that are generated by the hip joint are pooled in a "virtual target point"; both in human and birdlike torso morphologies. The scientists were able to replicate the trunk posture of human- and bird-like morphologies. Virtual targets for both trunk postures can be placed below, into, or above the center of mass. The research showed how re-positioning the virtual target altered hip torque profiles and energy expenditure.



Humans and birds are excellent two-legged runners. The virtual target point makes it possible to create various gait patterns for both trunk morphologies, while trading between hip peak torques and energy expenditure.

Embodied Vision

Cyber Valley Max Planck Research Group - Dr. Jörg Stückler

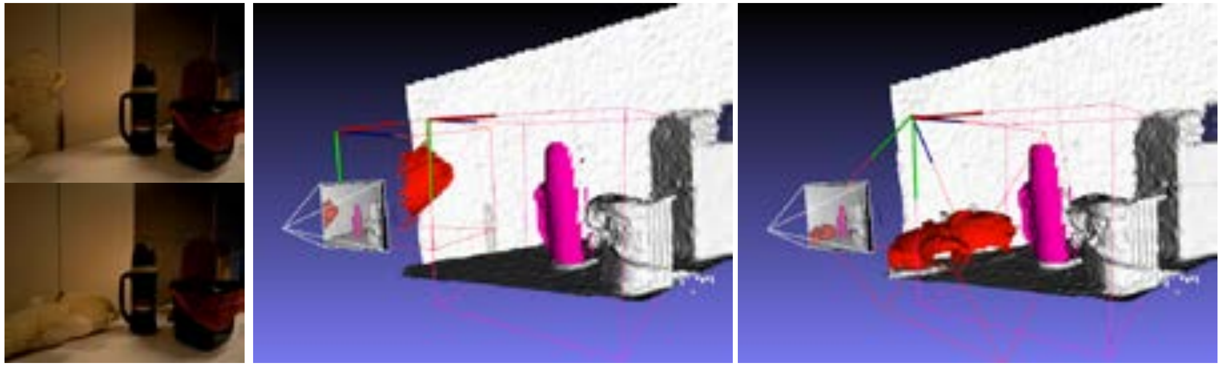
Intelligent systems such as robots need the ability to learn and adapt to their environment. The Embodied Vision research group investigates novel methods that make it possible to understand dynamic 3D scenes. Such knowledge is required for artificial intelligent systems to solve complex tasks such as autonomous navigation or object manipulation.

Most common approaches that enable robots to carry out specific tasks are based on different components for perception and control. In contrast, the group's researchers develop holistic methods that allow robots to learn how to interact with the environment and perform tasks. To do this, the robots should learn to draw on the sensor data of cameras and touch sensors to develop a model of their surroundings that is related to their task. They should also learn to predict the immediate effects of their actions. In turn, the knowledge they acquire from the model could enable robots to choose their actions themselves.

The group's research highlights include:

Dynamic scene reconstruction:

Approaches that track moving objects and reconstruct their shape in 3D have great potential for applications in robotics and augmented reality. The majority of approaches for scene reconstruction only reconstruct the static part of the environment and estimate the camera pose towards it. While many methods filter dynamic objects from the measurements, these objects in the scene are important when an agent interacts with them. For this reason, their 3D shape and motion needs to be estimated as well.



The approach detects objects and estimates their motion and shape in 3D space from depth camera images.

The group developed a novel probabilistic method that detects objects in images and estimates their motion and shape in 3D space. In the experimental example, a plastic bucket and a thermos flask stand next to each other on a table. A teddy bear is added from the left. The algorithm needs to estimate which pixels in the images belong to the various objects. The method concurrently learns 3D maps of the objects and estimates their motion from measurements. A major novelty of the method lies in the probabilistic approach, which decides on the association of pixels to objects and also handles occlusions. As a result, the method achieves more accurate and robust scene reconstruction than previous state-of-the-art methods.

Intelligent Control Systems

Cyber Valley Max Planck Research Group - Dr. Sebastian Trimpe

CyberValley

The Intelligent Control Systems (ICS) group focuses on fundamental questions of future intelligent systems, which will be able to autonomously interact with their environment by perceiving the world, acting according to a goal, and learning from both. For instance, the group's researchers investigate how a machine can independently learn new tasks from data reliably, safely, and efficiently. They also look at how collectives of several intelligent systems can carry out a task together – such as several robots coordinating their motion or autonomous vehicles driving in a convoy. It all comes down to sophisticated decision-making and learning algorithms, which are essentially the intelligent system's brain.

Starting with mathematical problem descriptions and analysis, the team develops new algorithms and methods that can be applied in many different future systems. Going beyond models and simulations, the team validates its research in laboratory experiments, for instance on a humanoid robot learning to balance a stick in its hand, or multiple dynamical systems coordinating their motion over large-scale wireless networks. They also implement their algorithms outside the lab with Cyber Valley industry partners.

Research at the ICS group is interdisciplinary and spans engineering, computer science, mathematics, and machine learning. The main research directions are currently learning-based control, distributed and networked systems, and resource-efficient algorithms.

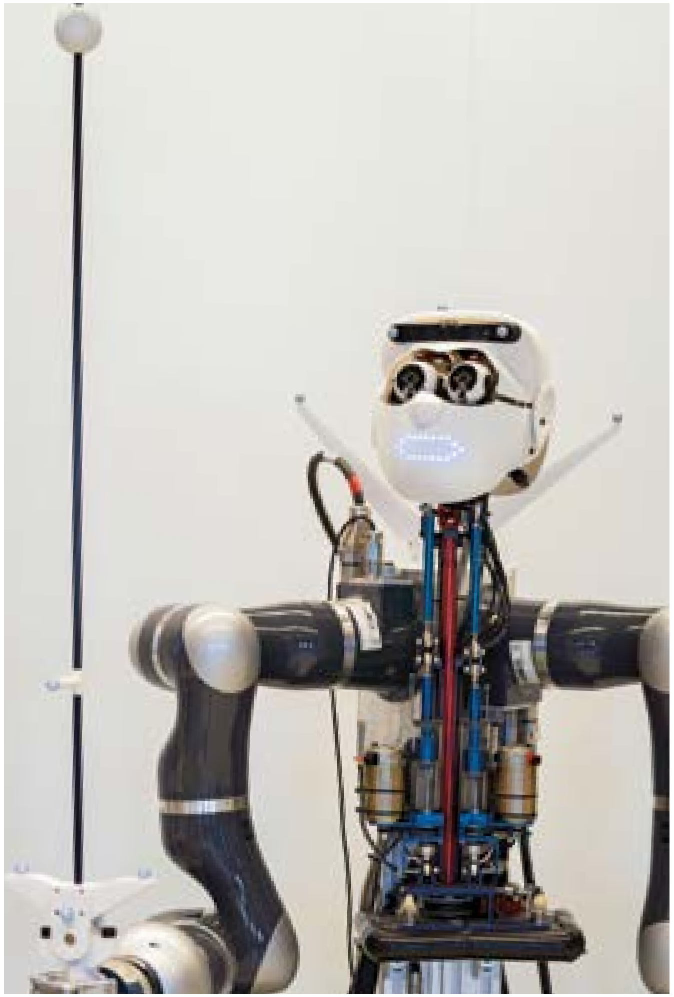
The group's research highlights include:

Feedback control goes wireless:

The ICS group has pushed the limits of what is possible in distributed control over several systems that exchange information with each other via wireless networks, whereby each agent relies on the information of the others for its own decision-making. One example could be a smart production process with many mobile robots. The publication "Feedback Control goes Wireless" was a joint research project with TU Dresden and ETH Zurich.

Control of complex systems:

Sebastian Trimpe has established strong connections with the University of Stuttgart, in particular with the Institute for Systems Theory and Automatic Control, which is headed by Professor Frank Allgöwer. In one project, the scientists are developing a novel approach to the high-performance and safe control of complex systems such as humanoid and collaborative robots. In their recent work, they combine modern optimization-based control with deep learning. The focus is on performance, simplicity, practicality, and most importantly on safety. Safety must be guaranteed even while a disturbance occurs in an uncertain situation, or when data is inaccurate. In robotics, this is known as "robustness".



Locomotion in Biorobotic and Somatic Systems

Cyber Valley Max Planck Research Group - Dr. Ardian Jusufi

Led by Ardian Jusufi, the scientists of the independent Cyber Valley “Locomotion in Biorobotic and Somatic Systems” research group investigates animals’ locomotion and physical structure, as perfected by nature. The researchers then apply their biological findings to the development of life-like robots. Their research is at the interface between engineering and biology – a relatively new and promising field.

Soft robotics is one of the group’s fields of research. While most of today’s robots are still made of hard, rigid components, soft robotics aims to incorporate flexible, malleable components into synthetic systems. To this end, scientists draw upon the morphological intelligence that is found in the body structure of mammals, insects or reptiles which allows them to move efficiently and robustly. Based on these natural design principles, they develop robots that can walk, run, or swim like their animal counterparts. Of particular interest are the interactions of stronger or stiffer tissues with softer or more flexible ones; animal locomotion is a perfectly coordinated action of all materials. By incorporating morphological intelligence into swimming or climbing robots, Jusufi and his team are confident that such machines can cope better with complex environments and overcome obstacles more easily.

However, the scientists’ motivation goes even further; when building such robots, the researchers gain insights into the animal, how its locomotion is adapted to its terrain, and they can answer questions as to why evolution has produced certain structures. Ultimately, the scientists aim to gain a deeper understanding of both animals and machines simultaneously.

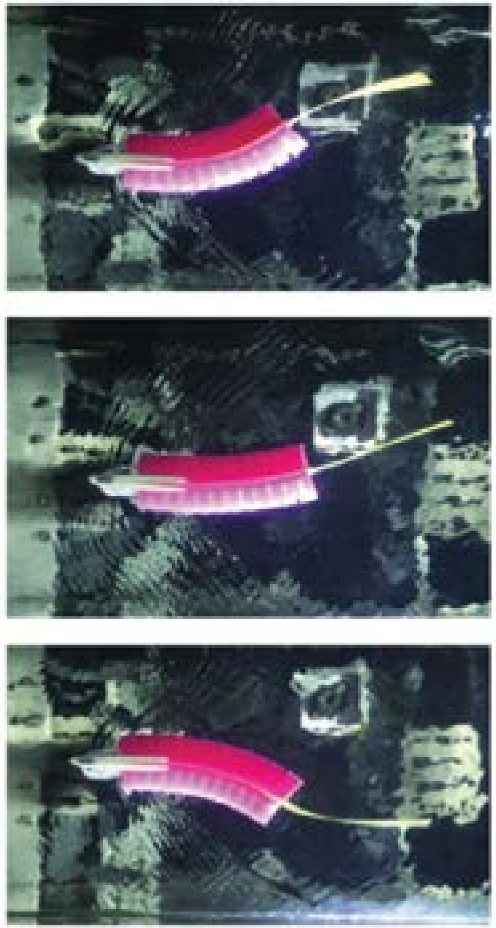
The group’s research highlights include:

Geckos that run over water:

Jusufi and his colleagues have shown how geckos can run over water with little loss in speed compared to running on land. In an experiment, they let a gecko run from one side of a water tank to the other. With the help of high-speed cameras, they were able to observe exactly what techniques a gecko uses, and estimate the forces generated. The researchers discovered that surface tension is essential. But even without surface tension, geckos can walk on water by hitting the surface with their feet – a kind of paddle movement of the legs. The leg strokes create air cushions under the feet that help prevent the gecko’s body from submerging. The reptiles also use their smooth, water-repellent (superhydrophobic) skin to glide over the surface – a process similar to aquaplaning. Finally, they also use their tail to push the water back like an alligator. This creates a forward force as well as buoyancy, and stabilizes the animal. If geckos use all these mechanisms at the same time, they can move on the water surface with amazing speed.

Soft sensors in a soft robotic fish:

Building on the findings on how geckos are able to run over water, the researchers have developed a soft robot made of silicone, inspired by a fish. Like its natural model, it moves forward in a wave-like pattern. The robotic fish must be able to bend easily and so the material used is important. The scientists used silicone structures actuated by compressed air. These actuators were attached to each side of a flexible plate. The stiffness of all components is comparable to that of a fish body. Next, the researchers attached hyper-elastic soft sensors embedded with liquid metal to the robot fish’s body. These sensors can measure the curvature, as the electrical conductivity of the liquid metal decreases proportionally to the stretching of the silicone structure as the robot bends. Being able to measure when a fish bends its caudal fin while swimming helps researchers build even more sophisticated swimming robots.



Our development of soft robotic undulatory swimming capabilities continues apace. Image credit: Jusufi et al. 2017.

Micro, Nano, and Molecular Systems

Max Planck Research Group - Professor Peer Fischer

Headed by Professor Peer Fischer, the independent Max Planck Research Group “Micro, Nano and Molecular Systems” investigates the physical and chemical properties of active matter, develops unique nanofabrication methods, and builds nanorobotic systems that are smaller than a human cell. For example, the group is working on microswimmers, nanomotors driven by chemical reactions, and nanopropellers that can move through biological tissue. Such “nanobots” hold great potential in applications such as the minimally invasive medical technology of the future. The group has also developed a state-of-the-art vapor deposition technique with which it can produce hundreds of billions of nanostructures quickly and with high precision. Moreover, the group has invented the acoustic hologram, with which ultrasound waves can be formed three-dimensionally and the most precise ultrasound fields to date can be generated.

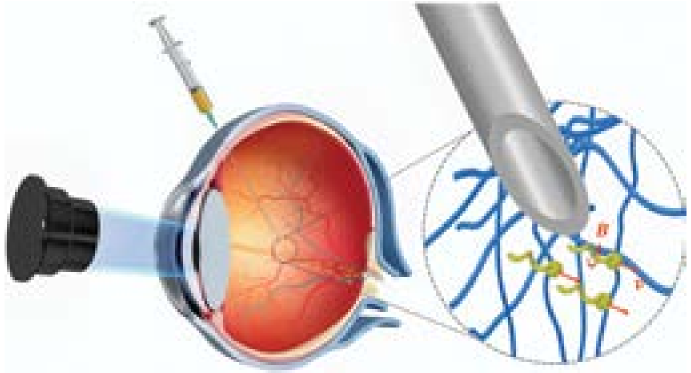
The group’s research highlights include:

Biomedical application of nanopropellers:

The research group develops propeller-shaped nanorobots, the world’s first system capable of piercing dense tissue as it occurs inside the eyeball. The researchers applied a non-stick coating to the tiny propellers. These are only 500 nanometers wide, and are thus about 40 times smaller than a human cell; so small that they fit through the narrow molecular matrix of the gel-like substance in the vitreous of the eye. The propeller’s coating is modelled on the carnivorous pitcher plant (Nepenthes). The combination of helical structure, size, and slippery coating allows the nanopropellers to move relatively unhindered through an eye without getting stuck or damaging the surrounding tissue structures. The research team has thus come significantly closer to the vision of one day using nanopropellers as a means of transport for therapeutics.

Acoustic holograms:

The invention of an acoustic hologram that has made modelling sound waves three-dimensionally possible is another of the research group’s highlights, which was published in Nature. The scientists were able to produce sound images that were significantly more detailed than what was previously possible. Small particles can be moved and arranged with ultrasound so that an object can be formed. The scientists were also able to show that their ultrasonic fields can be used to produce entire objects “in one shot”. The findings are important for ultrasound diagnostics in medicine. With the acoustic hologram, for example, it is possible to transport ultrasound waves more efficiently through the cranial wall and focus them more precisely inside the brain.

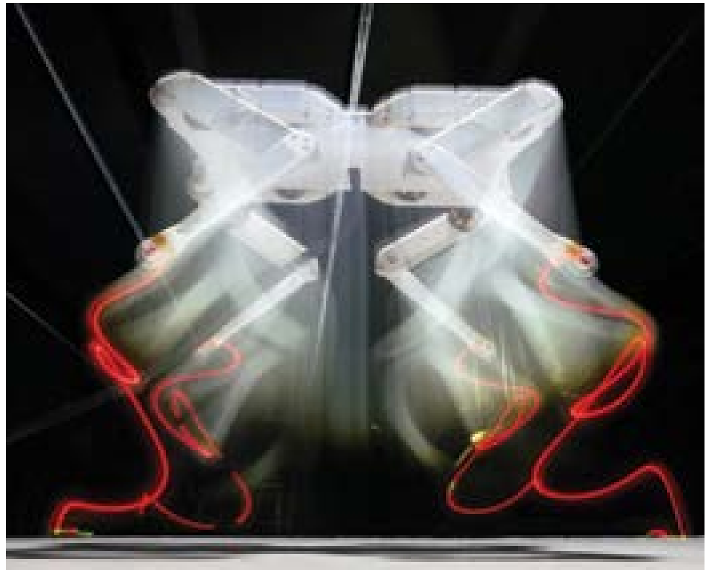


Nanopropellers are magnetically propelled through an eye.

With the help of the acoustic hologram, the ultrasonic pressure is shaped in such a way that particles arrange themselves to form Picasso’s Dove of Peace.

Movement Generation and Control

ERC Group - Professor Ludovic Righetti

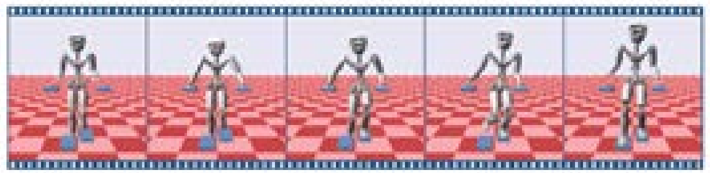


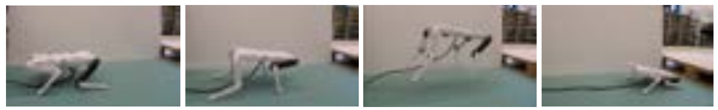
Complex action sequences, such as running on uneven terrain, are relatively easy for adults, but still present great challenges for robots. Led by Dr. Ludovic Righetti, The Motion Generation and Control research group investigates algorithmic principles that allow humanoid robots to perform complex motion sequences, such as lifting a cushion while simultaneously grasping an object underneath it. The research aims to develop basic principles of movement and manipulation that robots need to adapt to unknown variables and changing environments, and thus act efficiently and autonomously.

In order to be reliable and safe, robots must be able to react quickly to unpredictable events. The research group's scientists have developed an algorithm that can calculate optimal movements in less than a second – making it the fastest to date. This has made it possible to develop novel methods for robotics that make physical contact between robots and their environment significantly more stable.

In cooperation with the MPI-IS "Dynamic Locomotion" research group, Righetti's team created the world's lightest force-controlled four-legged robot. This robot's movement is very dynamic, which makes it an ideal platform for evaluating new control and learning algorithms. With this four-legged animal, researchers can test the capabilities of their motion planning algorithm for walking and jumping tasks. These movements are very robust to external disturbances, even when the robot is pushed or the ground moves.

The research team is also investigating how robots can learn from previous experiences, both positive and negative. In collaboration with other research teams, the Motion Generation and Control group has developed a new exploration strategy based on machine learning methods. This strategy makes it possible to generalize and optimize movements toward unknown objects or accessible places.





Quadruped robot Solo (top) and example of humanoid movements computed with the group's algorithm (bottom)

Physical Reasoning and Manipulation

Max Planck Fellow Group - Professor Marc Toussaint

Professor Marc Toussaint began his five-year tenure as a Max Planck Fellow at the Stuttgart site of the MPI-IS in November 2018. Toussaint is a Full Professor of Computer Science at the University of Stuttgart, where he has led the Machine Learning and Robotics Lab since 2012. He named his group at the MPI-IS "Physical Reasoning and Manipulation Lab".

Toussaint conducts research at the interfaces between artificial intelligence, robotics, and machine learning. His research interests include the ways in which robots can manipulate their physical environment to learn. For instance, he has built an experimental setup with two robotic arms that can interact with objects on a tabletop. Manipulating objects comes easily to a human, but the logic behind such actions is currently beyond what robots are capable of.

Toussaint is also working on a project that aims to demonstrate that a robot can solve problems geometrically and physically. He wants to be able to program a robot with a sense of what Toussaint refers to as "intuitive physics". He is working on programming algorithms that enable the robot to imagine what could physically happen. For instance, in the future a scientist could ask a robot how to best build a treehouse in a forest. The robot would give the researcher several ideas about what material to use, possible shapes for the treehouse, which tree could best be used, and how the house could ultimately be built. The robot would have an innate creativity and a basic understanding of physical processes. Toussaint is working on developing the algorithms that could enable robots to be creative.

Physics for Inference and Optimization

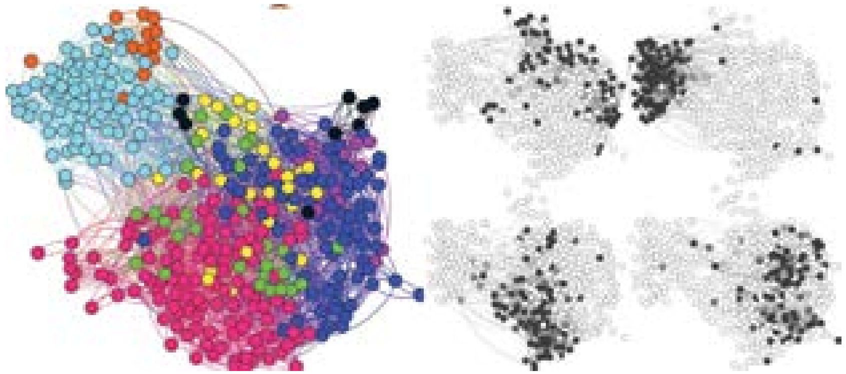
Cyber Valley Max Planck Research Group - Dr. Caterina De Bacco

CyberValley

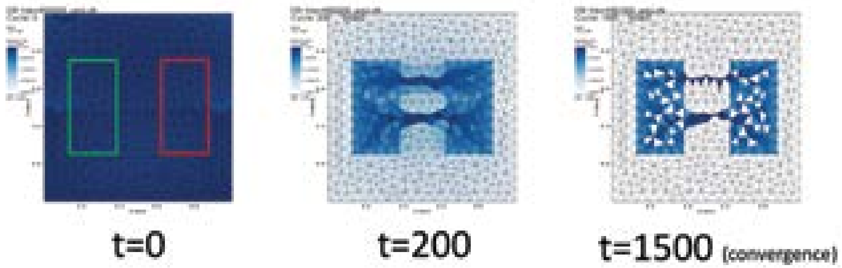
The Physics for Inference and Optimization Group's research focuses on understanding relations between the microscopic and macroscopic properties of complex large-scale interacting systems, such as networks. In cooperation with experts from other disciplines, De Bacco and her team develop models and algorithms based on principles of statistical physics. This knowledge could be used, for instance, to modify the interactions of a network's individual constituents and thus to optimize its overall properties.

One of the group's research interests is routing optimization. By collecting data on individual drivers and the vehicles in their immediate surroundings, researchers can draw conclusions on the behavioral patterns of this small group, and use these to make a generalization about all driving behaviors. In other words, they zoom in on part of the whole, closely observe behavioral patterns, and project their findings onto the big picture. Such knowledge can be used to calculate the best possible individual routes for all drivers by optimizing traffic management, even if this may mean a longer distance for the individual. In a collaboration with the Mathematics Department at the University of Padova, De Bacco's group developed an efficient algorithm capable of deriving optimal general solutions for many routing problems.

De Bacco and her team also focus on investigating inference problems on networks. Inference aims to estimate the parameters of a model that is believed to have generated certain data. De Bacco investigates, for example, how likely it is that members of a social network will interact with one another. In this research area, for instance, she and her group recently developed a model that serves to estimate a node's measure of importance in a network (known as eigenvector centrality) from a graph sample. This measure is particularly relevant when retrieving the information for the whole network is not feasible, as is the case with social networks.



Example of multilayer network community detection results (left). Colors denote values of node attributes (right); grey-colored nodes denote communities inferred by the algorithm.



Example of optimal routing topologies in an unconstrained space.

Probabilistic Learning

Max Planck Research Group - Dr. Isabel Valera

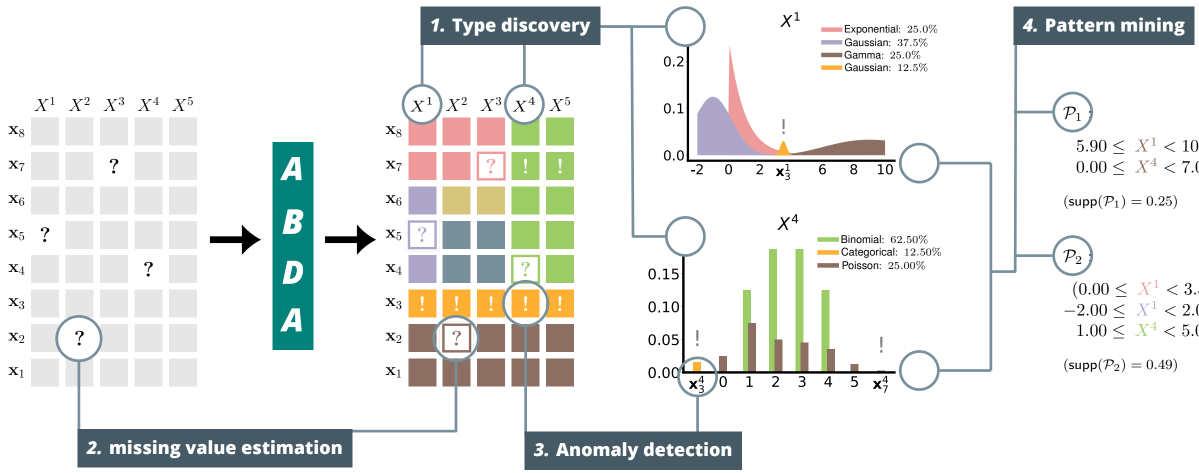
The Probabilistic Learning Group, which was affiliated to the Empirical Inference Department during the reporting period, was established as an independent research group from July 1, 2019. It is led by Dr. Isabel Valera.

Valera and her group focus on developing machine learning methods that are flexible, robust, and fair. Flexible means they are capable of modeling complex real-world data, which are often heterogeneous in nature and collected over time. Secondly, the group's research aims to improve the robustness of algorithms. An algorithm is considered robust when it is able to point out "what it does not know". This means that, in addition to making predictions, it also expresses how probable they are. The group's research findings have given rise to new methods and software applications for automatic data pre-processing.

In addition, Valera and her team are researching ways to make algorithms that are part of important decision-making processes fairer. To this end, the scientists have worked on translating legal definitions of fairness into a mathematical formula. Valera and her team are thus designing new algorithms that are both accurate and fair, and which can be quantified with the support of observational data.

The group's researchers have already achieved significant results in the field of fairness and machine learning. Topics of the group's publications have included approaches to improving the performance and fairness of human decision making, as well as an efficient learning procedure to transform an original (unfair) classifier into a fair one.

The group's research can be applied in a broad range of fields, from medicine and psychiatry to fields that are socially relevant. Valera's research thus pays close attention to the ethical challenges of decisions that are supported by algorithms and could have far-reaching consequences for the people concerned. These issues play a major role in areas such as hiring or loan approval processes.

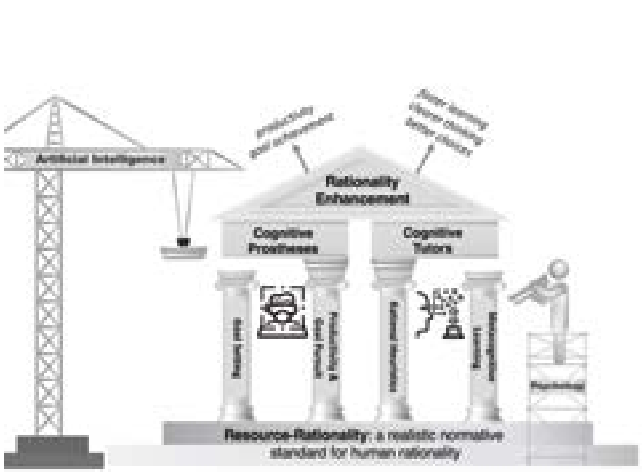


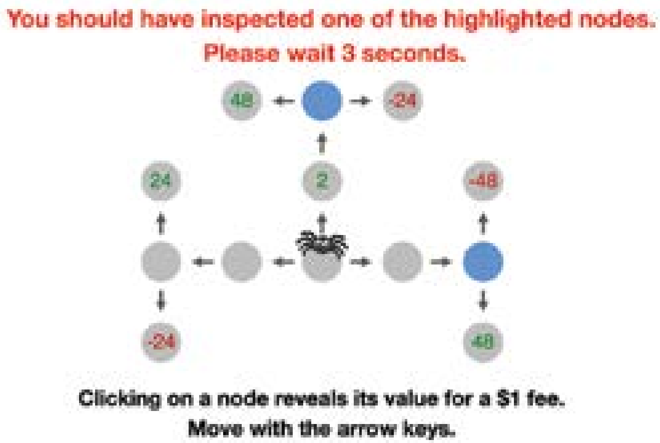
Visualization of Automatic Bayesian Density Analysis (ABDA): ABDA performs automatic pre-processing of tabular datasets comprising samples from mixed continuous and discrete features, and potentially containing missing values and outliers.

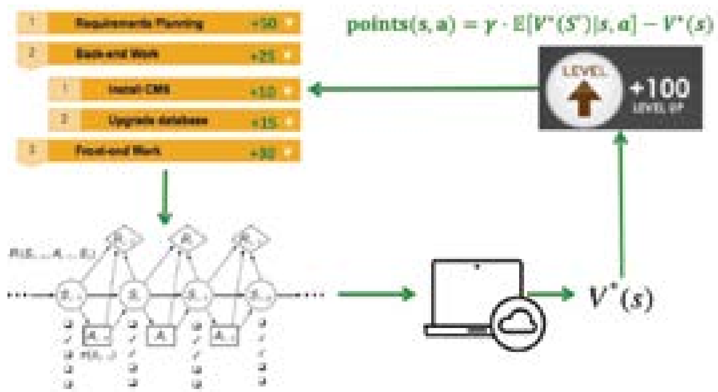
Rationality Enhancement

Cyber Valley Max Planck Research Group - Dr. Falk Lieder

CyberValley







Rationality Enhancement Overview:

The Max Planck Research Group for Rationality Enhancement aims to develop a scientific foundation and intelligent technologies that enable people to become more effective. To this end, its research focuses on cognitive growth, goal setting, and goal achievement. The group elucidates the underlying mechanisms and investigates how they can be promoted, supported, and improved. If it succeeds, the group's findings will revolutionize self-improvement, personal development, psychiatry and psychotherapy, brain training, and education.

CognitiveTutor:

To improve human decision making, the Rationality Enhancement Group investigates how people learn to decide. The researchers have leveraged the resulting insights to develop an intelligent tutor that teaches people effective long-term decision-making strategies. It does this with a brain training game that provides optimal feedback on the ways in which people make decisions.

Optimal Gamification:

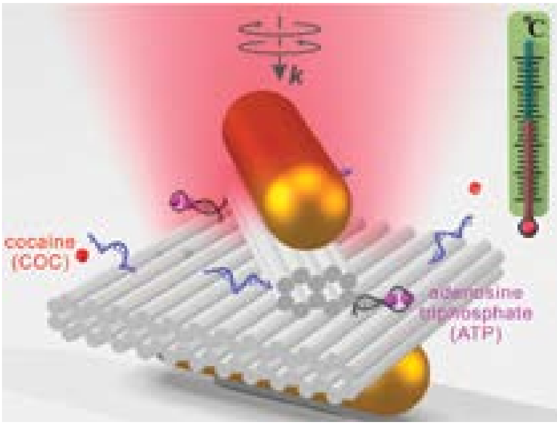
In a complementary line of work, the group is developing a to-do list gamification app that combines insights from psychology with methods from artificial intelligence. The app helps people overcome procrastination and prioritize their most important tasks.

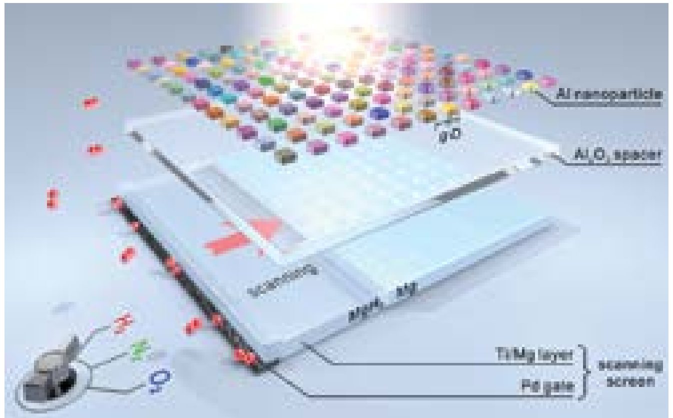
Smart Nanoplasmonics

ERC Group - Professor Laura Na Liu

If light interacts with metal nanostructures, free electrons start to vibrate and plasmons are formed. Researchers from the “Smart Nanoplasmonics” group apply such plasmons to probe chemical reactions and tiny structural changes of bio-molecules. To achieve this aim, complex metal nanostructures are built and, in some instances, decorated with molecules or DNA segments. Moreover, the researchers designed nanostructures featuring shiny colors. Such structures could be applied in future color displays.

The group’s research highlights include:





The Art of Folding on the Nanometer Scale:

Similarly to origami – the art of folding paper into objects – the researchers fold flabby DNA strands, and can thus create tiny bundles of “DNA origami” that are nanometers in size. In their most recent study, the researchers successfully modified DNA-origami structures and configurated them with metal nanoparticles. By adding organic molecules or changing the temperature, the scientists can both observe and control structural changes in these DNA bundles.

Plasmonic color displays :

Depending on their size, shape, and material, metal nanostructures can appear as shiny and colorful objects. The researchers created tiny images based on such nanostructures. Moreover, they employed phase-change materials instead of classical metals to generate dynamic images. As a result, they were able to create plasmonic micro color displays as small as the diameter of a single hair.

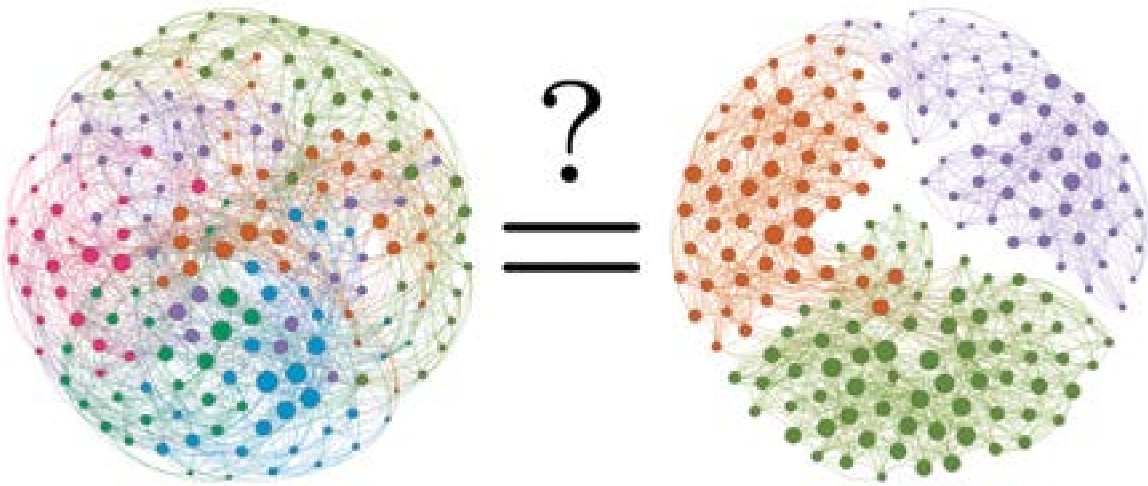
Secure encryption based on meta-surface:

If one arranges nanostructures in certain patterns on surfaces, completely new light phenomena can be observed that are not otherwise found in nature. The researches from the “Smart Nanoplasmonics group” took advantage of such meta-surfaces and generated optical holograms. Using phase-change materials instead of common metals, the scientists encoded several holograms in a single meta-surface. Such holograms could be applied in secure information encryption, for instance.

Statistical Learning Theory

Max Planck Fellow Group - Professor Ulrike von Luxburg

The goal of statistical learning theory is to provide a solid mathematical basis for machine learning algorithms and to analyze their behavior. The scientists of the Max Planck Fellow Group aim to assess whether the results achieved by machine learning algorithms are trustworthy, whether the algorithms work or not, or how complex they are in terms of data required or computation time needed.

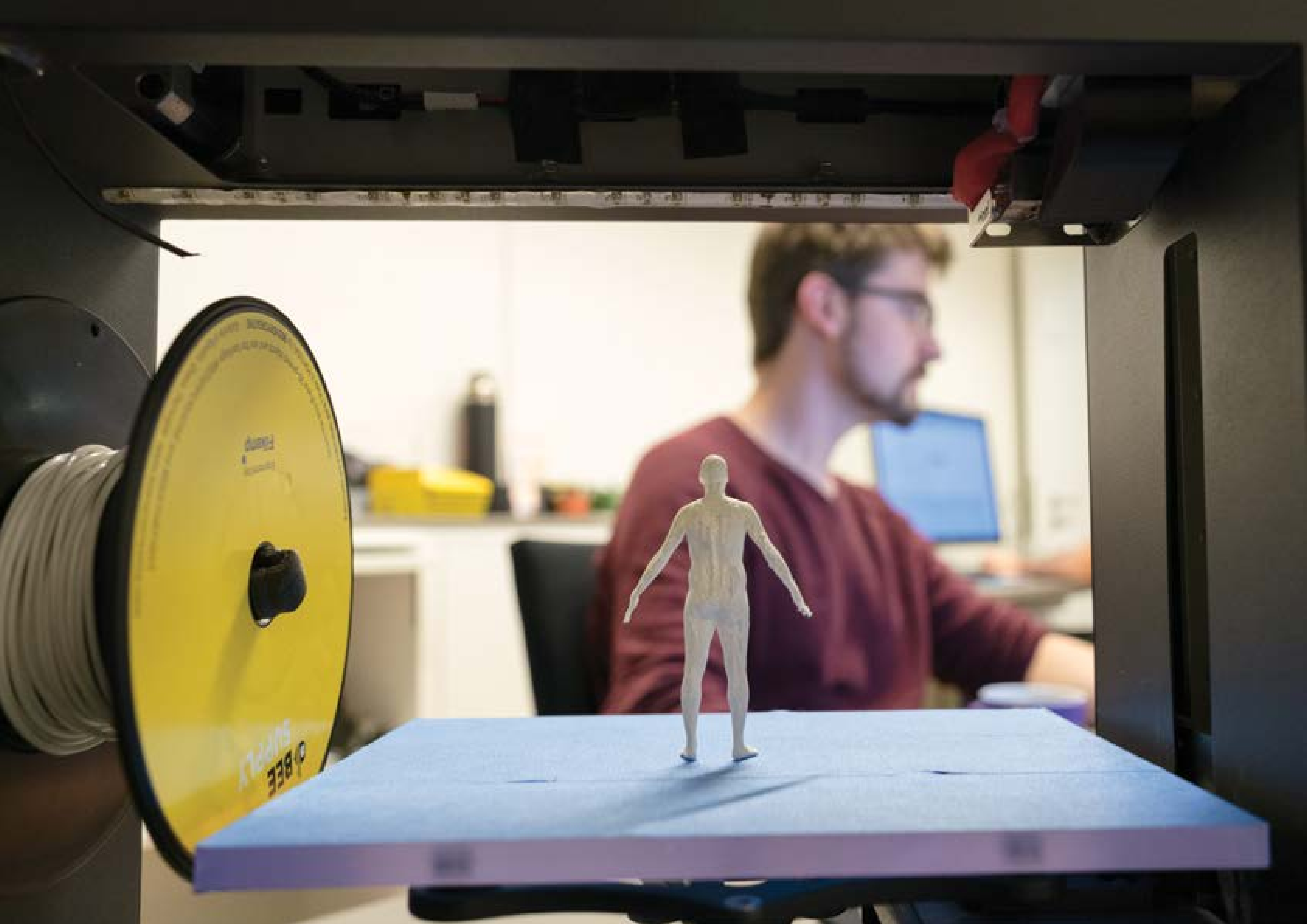


The group's researchers focus on the area of comparison-based machine learning, which is a subfield of machine learning. The researchers consider a particular scenario where the input to a machine learning algorithm can be collected in a human-friendly way. They consider a setting where the input to a machine learning algorithm is not given in terms of similarity values ("On a scale from 0 to 1, the similarity between image A and image B is 0.8"), but rather in terms of distance comparisons ("Image A is more similar to image B than to image C"). Many studies in psychology show that, for people, such qualitative comparisons are much easier to provide than quantitative similarity scores.

Statistical learning theory in Alzheimer's research:

This group also conducts research in the area of statistics on complex networks. Such networks are used in many fields of applied research. For example, physicians are investigating whether the brain structures of healthy individuals are different from those of Alzheimer's patients. The network describes the interactions between nerve cells in the brain. Physicians have hypothesized that Alzheimer's disease is associated with too many "false" connections between nerve cells in the brain. Now, they would like to confirm or reject this hypothesis on the basis of data. To obtain data, they measure the structure of nerve cells in the brains of Alzheimer's patients. This results in a "network" comprising nerve cells that are connected to other nerve cells. Of course, this network looks different from patient to patient. The scientists do the same for a control group of people who do not suffer from Alzheimer's disease. The data generated in these experiments are many "brain networks" of both healthy and diseased individuals. These data are too complicated to be analyzed by conventional methods; machine learning is needed.

This is where the Max Planck Fellow Group comes in. The question is whether the "brain networks" of Alzheimer's patients systematically differs from those of other test subjects. In their quest to find answers, the group has developed a series of statistical tests that can be applied in such situations. These tests are based on methods from the field of statistics and machine learning. They are a good example of how machine learning can be used to support or reject scientific hypotheses from other fields of application.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