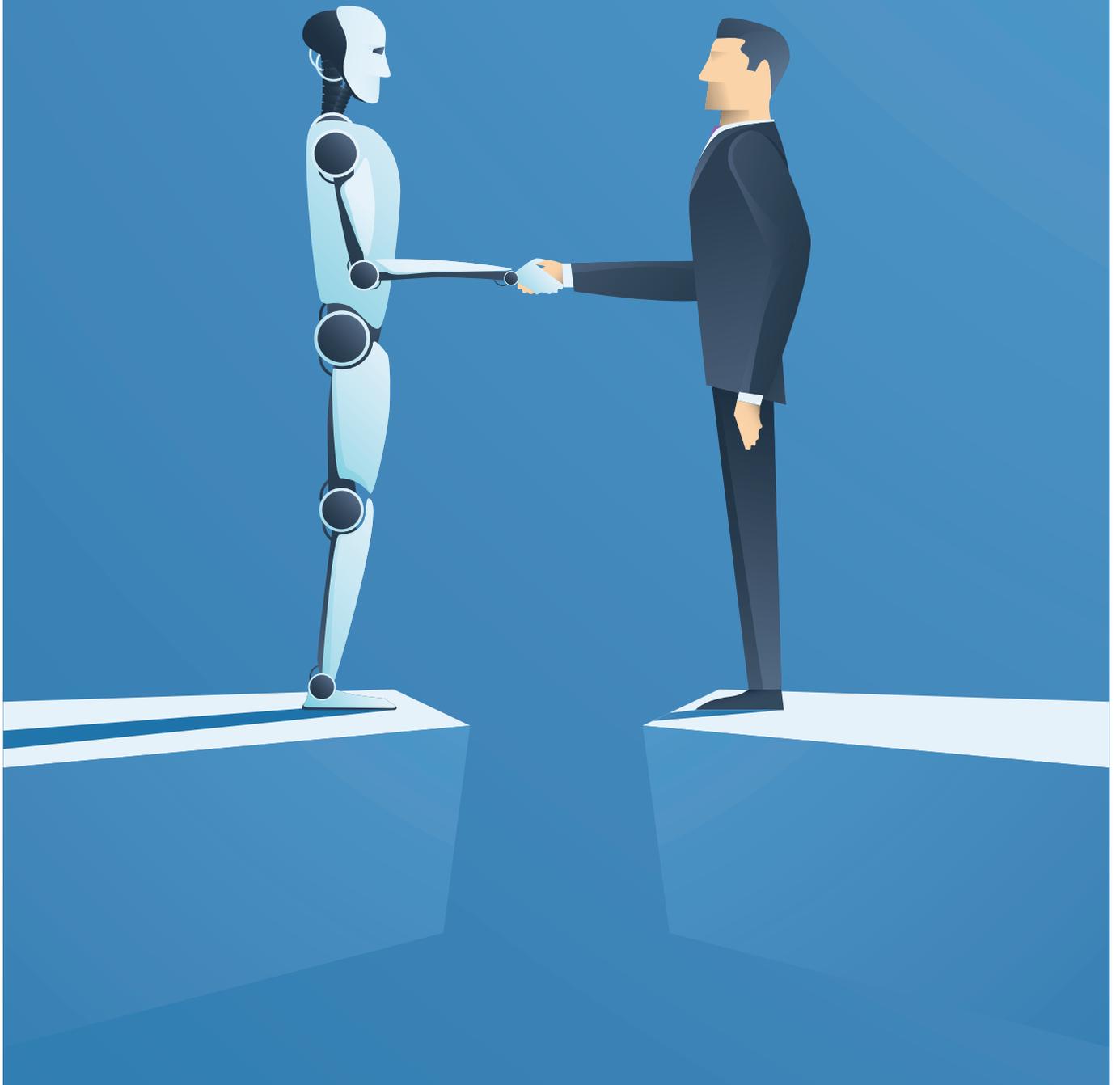


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# Sustainability and Trust for Artificial Intelligence Technologies



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This strategic paper highlights selected research initiatives and success stories of technology transfer in the domain of artificial intelligence that have been driven by researchers in North Rhine-Westphalia (NRW). It was inspired by a round table on Artificial Intelligence (AI) initiated by the Ministry of Culture and Science (MKW) of NRW.

## Dear reader,

artificial intelligence (AI) currently counts as one of the grand challenges that face our societies. At the same time, it is an enormous opportunity brought by the digitalization. AI is characterised by a lot of heterogeneous technologies and developments. Beyond the technological dimension, there is also a need to discuss the social, ethical and legal aspects of how we want to use the tool AI.



With this in mind, North Rhine-Westphalia, as well as the Federal Government and the European Union, is working for a human-centred AI. Under its AI initiative, the State Government gives targeted support to research, technology transfer and sustainable implementation with regard to a trustworthy AI system. As a holistic concept 'AI made in NRW' rests on three pillars, 'Excellence in research and education', 'Success in Business' and 'Ethics in implementation'.

The variety and diversity in science, business and society as well as the outstanding expertise in the core area of AI offer ideal conditions to help shape the development of reliable AI in Europe.

This brochure gives an overview of the extensive activities of North Rhine-Westphalia in the field of AI – from outstanding basic research to creative start-up firms. As one of the leading centres of AI, North Rhine-Westphalia possesses excellent competence in the centrally linked areas of cyber security, logistics and cognitive interaction. In addition to research on cutting-edge developments interdisciplinary research teams are working on innovative research transfer of new AI technologies into the economy as well as the potential of AI in solving important social challenges such as the energy transition or health.

I wish you some inspiring insights into North Rhine-Westphalia's various research priorities and would like to thank the authors of this brochure, who present AI in and from North Rhine-Westphalia in this brochure both exemplary and well-founded.

**Isabel Pfeiffer-Poensgen**

Minister for Culture and Science of the State of North Rhine-Westphalia

## Integrated focal projects in NRW

NRW's strong expertise in AI and its leadership in important fields such as AI for logistics, AI and cybersecurity, sustainable industrial transfer, AI for intelligent technical systems, trustworthy and human-compatible AI, and AI's impact on society are illustrated by several larger research initiatives which bundle competencies within the federal state and implement holistic approaches to achieve trustworthy AI.

### ML2R

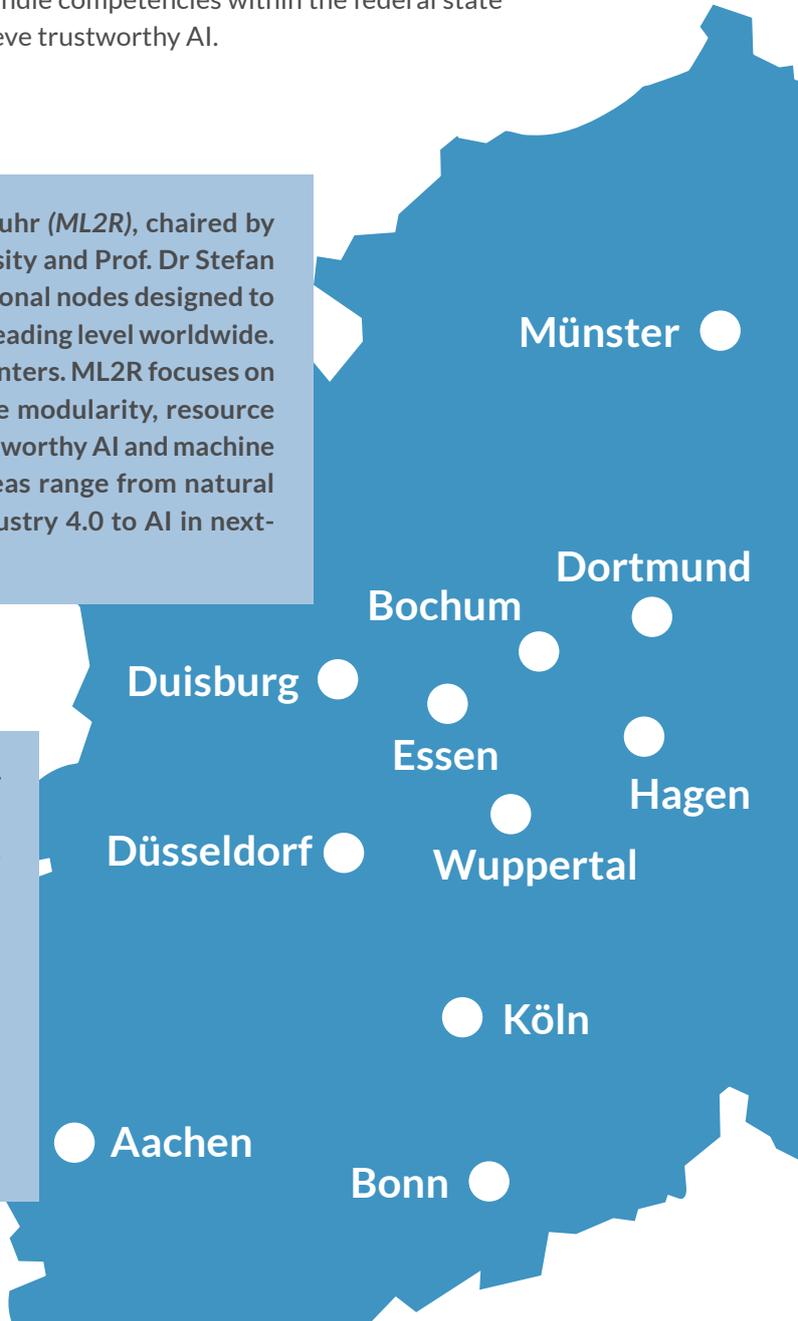
The Competence Center Machine Learning Rhine-Ruhr (ML2R), chaired by Prof. Dr Katharina Morik from TU Dortmund University and Prof. Dr Stefan Wrobel from the University of Bonn, is one of six national nodes designed to bring the development of AI and ML in Germany to a leading level worldwide. Prof. Morik coordinates the network of German AI centers. ML2R focuses on cutting-edge research in machine learning to enable modularity, resource efficiency, explainability, knowledge integration, trustworthy AI and machine learning on quantum computers. Its application areas range from natural language question answering, astrophysics, and Industry 4.0 to AI in next-generation intelligent logistics.

### CAIS

The research agenda of the *Center for Advanced Internet Studies* (CAIS) with the Ruhr University Bochum, the University of Duisburg-Essen, Heinrich Heine University Düsseldorf, the University of Münster, and the Grimme-Institute (Marl) as its partners focuses on the risks and opportunities of digital transformation for our society. CAIS is chaired by Prof. Dr Michael Baumann from the University of Düsseldorf. It offers room for interdisciplinary research projects as well as possibilities to interact with representatives from society, research, industry, media and politics.

### KI.NRW

KI.NRW is a networking initiative in the field of artificial intelligence for the federal state of NRW, which is coordinated by Fraunhofer IAIS in Sankt Augustin (chaired by Prof. Dr Stefan Wrobel). It is integrating several flagship projects, one of them being the certification of AI, and reaching out to important activities on the European level such as AI4EU – A European AI On-Demand Platform and Ecosystem. The main concern of KI.NRW is to bundle and strengthen competencies in the field of AI and to closely interlink science and industry.





## Data-NInJA

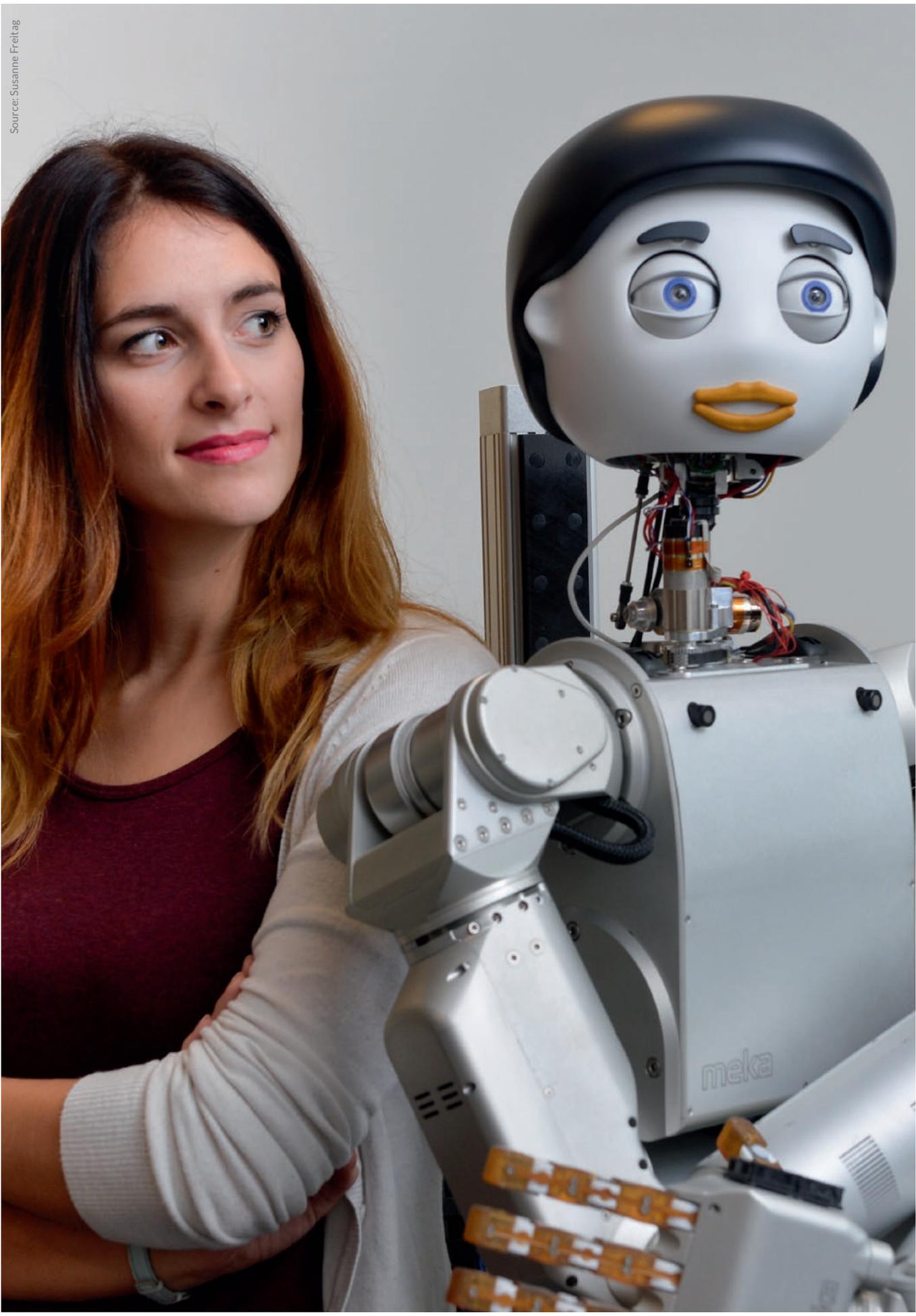
In the newly established research training group 'Trustworthy AI for Seamless Problem Solving: Next Generation Intelligence Joins Robust Data Analysis (*Data-NInJA*)' chaired by Prof. Dr Barbara Hammer from Bielefeld University, research teams from NRW's universities and universities of applied sciences focus on novel solutions for core AI methodologies so that they become robust, easier to integrate, transparent and safe for practical applications.

## NERD.NRW

The Research Training Group *NERD.NRW* (North Rhine-Westphalian Experts on Research in Digitalization) chaired by Prof. Dr Jörg Schwenk and Prof. Dr Thorsten Holz from the Ruhr University Bochum funds researchers in information technology (IT) security at universities and universities of applied sciences in North Rhine-Westphalia, with the aim of promoting research in the area of Human Centered Systems Security.

## NRW – Digital Society

The Research Training Group '*NRW – Digital Society*' chaired by Prof. Dr Caja Thimm from the University of Bonn aims for a multi-perspective view on questions of strengthening and securing democracy in the context of the digitalization of society, thereby integrating research teams from NRW's universities and universities of applied sciences.



Source: Susanne Freitag

## AI research in NRW

As a key technology of digital change, AI is of central importance for the economy, science and society: intelligent components improve the quality and efficiency of existing processes along the entire value chain and open up new markets. AI technologies support solutions for our main societal problems, for example through intelligent mobility concepts or computer-supported drug development. AI applications such as intelligent language assistants or machine translation are omnipresent in society. In order to make this development safe, sustainable and for the benefit of humankind, a wide range of technological and societal challenges have to be met. The digital strategy of North Rhine-Westphalia is guided by the triad of *“excellence in research and education”*, *“success in business”* and *“ethics in implementation”*. With its rich ecosystem, NRW ideally reflects the heterogeneous demands placed on AI and can draw on the expertise of renowned scientists, outstanding flagship projects and a strong industry and start-up scene. Research topics range from concepts to enable AI as a service, privacy, security and the explainability of trustworthy AI models, the development of next-generation AI-driven logistics, to cognitive compatibility and societal implications.

AI constitutes an important focus in NRW’s research landscape, with currently 50 research institutes and 23 transfer centres listed on NRW’s AI map. NRW is home to a number of AI pioneers, including Frank Rosenblatt Awardee Hans-Paul Schwefel, one of the inventors of evolutionary strategies, Leibniz awardee Helge Ritter, who built novel interdisciplinary bridges between robotics and cognition, and GI-Fellow Katharina Morik, who introduced hardware considerations into machine learning theory. Language processing technologies from Hermann Ney’s group helped make today’s automatic speech recognition and natural language processing viable, as was acknowledged by a Google Focused Research Award in 2018. Staying true to these roots, current AI research projects in NRW focus on developing multifaceted and interdisciplinary solutions to AI challenges: they combine the power of deep learning and the need for flexible online and edge computing, they marry the physical demands on robotics with the requirements of human cognition, and they span the bridge from powerful symbolic argumentations to noise-robust sub-symbolic embedding technologies.

NRW has close links with European partners and is collaborating in initiatives such as AI4EU—a European AI on demand platform and ecosystem. A dedicated French-German AI initiative is spearheaded by AI expert Katharina Morik from TU Dortmund University and Bertrand Braunschweig from INRIA, the French National Institute for Research in Computer Science and Automation. This abundance of expertise is the ideal prerequisite for integrating crucial components which facilitate explanations and safety guarantees of AI models to meet the fundamental demands of a sustainable AI. Transcending the boundaries of merely technical domains to sociology, psychology, and law, AI researchers in NRW help to shape data privacy, social acceptance, and legislation to meet the challenges of future AI.

NRW has always placed strong emphasis on the translation of fundamental AI research into practical innovative applications. This leads to novel insight as well as economic revenue, and NRW is host to innovative AI start-ups such as RapidMiner and DeepL. NRW's small and medium-sized enterprises (SMEs), major companies, and hidden champions have joined forces on their way towards digital transformation in rich networks such as the leading-edge cluster "it's OWL", the cooperation network "KI-MAP", and digital hubs spread all over NRW. By focusing on specific services which are tailored to the needs of local SMEs as well as European standards, NRW's industrial AI services offer sustainable solutions for the future challenges of Europe's next-generation digitalized industry.



## From hardware-specific machine learning to industrial digital transformation

In a market research report by Fortune Business Insights™ published in July 2020, the global AI market size was valued at USD 27.23 billion in 2019, and it is projected to reach USD 266.92 billion by 2027. Among other factors, this development is driven by the growing adoption of the Internet of Things (IoT) and the proliferation of cloud-based applications across manufacturing, healthcare, retail, financial technologies, and the growing sophistication of cyber-attacks. Besides big internet companies, AI start-ups, specialized SMEs, and major enterprises are increasingly integrating AI technologies into their portfolio, whereby AI hardware, software, and services share the overall market value. AI has enabled industries to increase quality and revenue of production, to implement novel efficient maintenance-concepts, to realize flexible personalized services, and to bring innovative AI to industrial logistics. Yet, with these advents arise quite a number of challenges: there is a need for machine learning algorithms which can be employed in distributed hardware and embedded devices; there is a quest for infrastructure which enables test data for advanced ML algorithms to be shared without violating data sovereignty and non-disclosure requirements; standards are needed which can guarantee the quality and sustainability of AI components in industrial solutions also in the long term. Further intelligent concepts are required which enable the early adoption and transfer of modern AI research to industrial partners.

NRW provides a particularly rich eco-system which translates knowledge gained from innovative AI research to its multifaceted industrial landscape. It hosts leading AI start-ups as well as major industrial players who enrich their teams with dedicated AI experts, often working closely together with partners from universities and universities of applied sciences. Researchers from NRW are among the early adopters of decentralized decision propagation and the energy efficient realization of intelligence at the edge. IoT plays a crucial role in NRW's production systems and logistic centres, and it is spearheaded by world-leading research centres such as Dortmund's logistics campus, Aachen's excellence cluster Internet of Production, or the leading edge cluster it's OWL. Here, researchers also look into novel hardware solutions such as quantum computing, and the Jülich supercomputers JUWELS and JURECA are currently among the most powerful ones in the world. NRW researchers are pioneering algorithmic developments so that AI solutions can enable emerging technologies which respect privacy and security requirements. Being host to strong industrial networks and public-private partnerships, NRW also puts a strong focus on the challenge of designing future industry and work environments for the benefit of humankind.

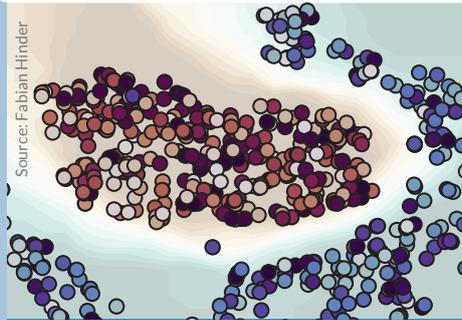


Source: Susame Freitag

Bielefeld University's anthropomorphic robot head Flobi.

The NRW Forschungskolleg "Design of flexible working environments—human-centred use of Cyber-Physical Systems in Industry 4.0" enables researchers from the fields of psychology, sociology, pedagogy, electrical engineering, mathematics, mechanical engineering, economics and computer science from the Universities of Paderborn and Bielefeld to combine their expertise for the development of human-centred cyber-physical devices, spanning technical aspects with human cognition.

KI-LiveS is an AI lab for distributed and embedded systems coordinated by the University of Duisburg-Essen (funded by BMBF) focussing on the development and testing of differentiable self-adaptive and resource-efficient data analysis technologies, which also incorporate domain-specific ontologies.

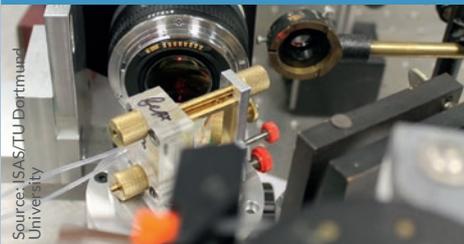


Source: Fabian Hinder

Results of a novel drift detection technology developed by Bielefeld University's ML group

How to offer AI as a service? A crucial component is the question of how to realize machine learning paradigms which allow sustainable life-long model adaptation. AI experts from Bielefeld and Paderborn have joined forces to address this challenge in the research project *EML4U* (funded by BMBF, the Federal Ministry of Education and Research) based on explainable machine learning technologies.

In 2011, the collaborative research centre *SFB 876 Providing information through analysis under resource constraints* at TU Dortmund University started to investigate sound guarantees for distributed, parallel, streaming machine learning algorithms on computing architectures ranging from ultra-low power devices to GPU clusters. The 13 projects and an integrated graduate school have now been accepted by the German Research Foundation for the third phase.



Source: ISAS/TU Dortmund University

A Plasmon Assisted Microscopy of Nano-sized Objects has been developed by researchers from TU Dortmund University and the Leibniz Institute for Analytical Sciences (ISAS).

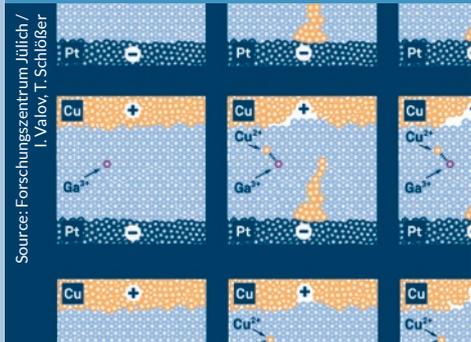


Source: Susanne Freitag

*RapidMiner*, an easy to use end-to-end prediction system for self-optimizing machine learning pipelines—a spinoff from TU Dortmund University—was placed by Gartner in the leader quadrant for Data Science and Machine Learning Platforms for the seventh year in a row in 2020.

The *EURO-BLOCK* project chaired by Fraunhofer IML is building up the European Blockchain Institute in Dortmund. The application of blockchain technology for the IoT allows AI to participate in smart contracting thus further expanding the reach of those algorithms to impact the real world.

The Jülich Research Centre and RWTH Aachen University have initiated an international hub dedicated to innovative technologies and concepts for memristive circuits to overcome the limitations of current computer architectures, especially for AI applications, and to gain a deep insight into novel computational paradigms and advanced brain functions.



More than 180 companies, research institutes, and business-related organizations in the region East Westphalia-Lippe (OWL) have joined forces in the leading-edge cluster it's OWL (Intelligent Technical Systems OWL) to boost the intelligent industrial digital transformation. Innovative concepts pursued within the cluster range from the innovative integration of digital twins up to self-optimization in industry.

*Bielefeld University's robot AMiRo offers AI technologies as edge-computing service*

With two start-ups among the winners of the competition "Digital start-up of the year" in 2019, *Physec* and *Rips*, Bochum is an outstanding region as regards intelligent technologies for cybersecurity.

RWTH Aachen University's excellence cluster *Internet of Production* uses various forms of machine learning (e.g. process mining) to create "digital shadows of production processes" thus providing the core for Industry 4.0.

*The Vision of the Internet of Production IoP: The World becomes a Lab*



## From robotics challenges to cognitive compatibility

While industrial robotics automates production on a large scale, there is an increasing need for flexible systems, agile fabrication, and the safe collaboration of humans and machines. Autonomous robots enable new services such as self-driving cars or household assistants, and autonomous robot swarms can efficiently manage decentralized tasks such as those prevalent in logistics. Yet, robots face increasingly demanding environments, where not only physical limitations have to be dealt with. Hardware and software design need to cope with unexpected situations, changes in the environment and new demands of the human partners. Further, increasingly complex systems cause yet unprecedented computational challenges. In this context, recent sensing and machine learning research yielded breakthroughs in visual perception, with miniaturized high-resolution cameras and pattern recognition capabilities surpassing human ones in some areas. Further, complex learning scenarios have been mastered by deep reinforcement learning, and intelligent localization and mapping empower the navigation capabilities of self-driving cars, unmanned vehicles, and drones. Besides merely technical demands, bio-inspired robots and cognitive systems can understand and mimic human cognition, emotion, and empathy. Nevertheless, several challenges lie ahead, with toddlers still surpassing robots in tasks such as object manipulation—and doing so without access to complex physics engines or high-performance computing.

Robotics research in NRW spans the full spectrum of industrial robotics and autonomous systems, over distributed edge computing and AI in large-scale logistics, up to humanoid robotics and human-machine collaboration. Researchers from NRW have been among the first to appreciate the impact of adaptation and cognition on innovative robotic design suitable for human-robot interaction. Robot teams from NRW have frequently scored first places in international challenges such as RoboCup. Future mobility concepts such as autonomous e-buses for public transport, which also come with an intelligent communication system and adaptive services, are being explored for NRW's streets. Further, the federal state is host to one of the world's leading research centres for logistics, where AI is key to robustly coordinating distributed autonomous robots and realizing new intralogistics technologies. In addition to their great economic impact, mobile robot systems will play a vital role in civil emergency response, and computer vision and robotics are about to transform crucial application domains including crop farming and medicine, as explored in leading-edge research projects by experts in NRW. Here, in aiming for a sustainable integration of AI solutions into science and society, one of NRW's specialities is the inter- and transdisciplinarity with which these challenges are addressed.

Source: Cluster of Excellence  
PhenoRob



Researchers from the University of Bonn and Forschungszentrum Jülich join forces in the Cluster of Excellence *PhenoRob*. Their objective is to achieve sustainable crop production with limited resources by optimizing breeding and farming management using new technologies.

*Intelligent drones to support sustainable crop production in University of Bonn's Cluster of Excellence PhenoRob.*

NRW is where the EU's largest logistics research institute is located at Fraunhofer IML and TU Dortmund University, including over 1000 sqm covered with a high performance, real-time motion capturing system, which is home to the *LoadRunner*<sup>®</sup>, a novel class of logistics automation, and the *AI Arena* — a living lab for swarm robotics.



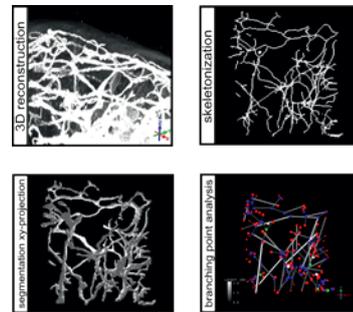
Source: TU Dortmund University

Research center 'Innovation Lab Hybrid Services in Logistics' at TU Dortmund University

Computer vision is key to scene understanding for mobile robotics. Prof. Dr Bastian Leibe from RWTH Aachen University is investigating deep learning for dynamic 3D visual scene understanding under the ERC grant *DeeViSe*.

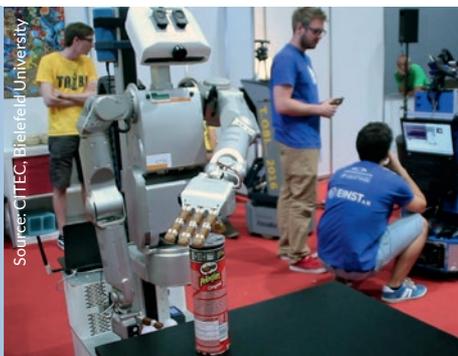
Computer vision and deep learning are about to revolutionize experimental research in other disciplines, such as biomedical imaging, as demonstrated e.g. by AI researchers from the University of Münster. They use image analysis to support the automation of experimentation in cell biology.

Source: F. Kiefer and X. Jiang, WWU Münster



Structural analysis of microscopic images

Within the *German Rescue Robotic Center (DRZ)*, chaired by Dortmund's fire brigade, researchers from Dortmund, Bonn, and Gelsenkirchen — among others explore how mobile robot systems can best support civil emergency response.



Source: CTTEC, Bielefeld University

Bielefeld University's RoboCup Team ToBi at work

Several teams from NRW have scored first places in the prestigious RoboCup competition: NimbRo from the University of Bonn won the AdultSize soccer Humanoid league, the ToBi Team from Bielefeld University won RoboCup@Home, the b-it-bots team of the University of Applied Sciences Bonn-Rhein-Sieg won the RoboCup@Work league, and Carologistics from RWTH Aachen University won the RoboCup Logistics League.

Source: Susanne Freitag



Bielefeld University's Center for Cognitive Interaction Technology, *CITEC*, and its transfer-oriented Research Institute for Cognition and Robotics (*CoR-Lab*) host projects which range from bio-inspired design up to social robotics and human-centred behaviour. For example, Bielefeld's walking robot HECTOR combines compliant joint drives, a great number of sensors, and a biologically inspired decentralized reactive control concept. In other projects, the focus is on how to induce human trust in personalized assistive systems.

*Bielefeld University's walking robot HECTOR*

*Intelligent future mobility* is about much more than self-driving cars: the a-Bus Iserlohn—New Mobility Lab enables South Westphalia University of Applied Sciences and the local public transport operators to put e-buses onto a 1.5 km test drive to provide customers with an autonomous service. The *SELE* (Silicon Economy Logistics Ecosystem) project located in Dortmund focuses on building up an all-embracing business to business platform economy for transportation systems, which realizes in particular federated and sovereign data exchange. In Bergisch.Smart, AI is being investigated as an enabler of future mobility in the triangle spanned by the cities Wuppertal, Remscheid, and Solingen.

Quite a few scientific fiction fantasies can become reality with the increasing availability of intelligent prostheses and *wearables*, which can help to restore functionality and support everyday healthcare such as for instance early warning systems for epileptic patients, as investigated by researchers from the University of Siegen, or transfer learning for robust prosthesis control as investigated by researchers from Bielefeld University.

Source: ML Group, Bielefeld University



*Transfer learning technologies developed at Bielefeld University enable a rapid recalibration of cuff electrodes for hand prosthesis*

## From structure processing to natural language understanding

The research challenge of how to bridge high-level symbolic representations and robust sub-symbolic signal processing has lost none of its relevance since it first appeared in the early days of AI. This question is crucial for understanding and leveraging how the human brain represents semantics, logic, and reasoning, and it is at the heart of the endeavour to explain (especially black-box) models of machine learning in human-understandable form. Moreover, it is of uttermost relevance for the intelligent processing of rich ubiquitous modalities such as natural language. In the last few years, breathtaking advances in natural language processing by deep networks and other approaches to machine learning have led to services which are about to transform our interaction with technological devices: understanding spoken language, machine translation, and natural question answering have reached such a level of quality that talking to computers is no longer a painstaking activity but helpful and enjoyable. Large parts of these successes are based on novel technologies which process knowledge graphs and language in differentiable form—demonstrating the power of harnessing both sub-symbolic and symbolic representations for structure processing and language understanding.

Some of the world's recognized experts in the field of language processing come from NRW. Further, researchers from NRW were among the first to substantiate structure embedding technologies by mathematical insight, and several research projects work towards a better delivery of these technologies on a large scale. A number of successful start-ups are based on a specialization of this basic technology to meet the actual needs of customers. The interaction of low-level data signals and high-level semantics represents a duality which is relevant far beyond the language domain: NRW researchers have developed process mining techniques to automatically learn higher-level process models from raw event data. These techniques can be used to predict and improve performance and compliance problems in a wide variety of operational processes (logistics, production, administration, finance, etc.). The question as to how semantics emerges from raw signals constitutes a fascinating challenge even in computational neuroscience. Since this problem is in general ill-posed, solutions crucially depend on the identification of overarching principles such as the slowness of semantic features. This way, NRW researchers contribute cutting-edge solutions for the challenge of how best to explore synergies of connectionist systems and symbolic reasoning.

Source: Susanne Freitag

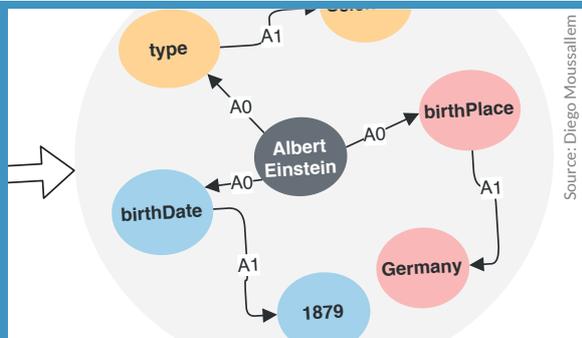


The priority programme Robust Argumentation Machines (RATIO) of the German Research Foundation, coordinated at Bielefeld University, aims at the development of AI technologies which can uncover complex lines of argumentation from digital sources instead of mere facts.

*Bielefeld researchers are investigating how the robot Nao can help children learn a language.*

The Bielefeld start-up Semalytix leverages AI and data story telling for patient-focused product development in the pharmaceutical industry. By uncovering real-world evidence from patient reports, Semalytix technology contributes to the delivery of innovative drugs and therapies addressing real-world patient needs. Semalytix was recognized as one of Germany's 10 most innovative start-ups by Forbes in 2018.

The translation services of *DeepL*, a start-up located in Cologne, won the 2020 Webby Award for Best Practices in the category Apps, Mobile & Voice. Its intelligent training protocols and high-quality data selection led to a machine translation service, which can compete with internet giants.

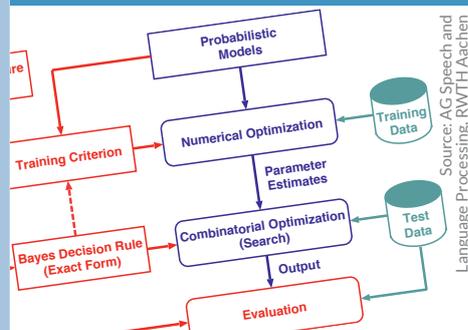


Source: Diego Mousallem

The Innovative Training Network *KnowGraphs*, coordinated by researchers from Paderborn University, aims at making knowledge graphs accessible to companies and users at scale that makes them a key enabler for a number of increasingly popular technologies including Web search, question answering, conversational AIs and personal assistants.

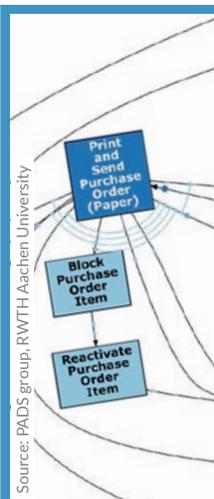
Reification to efficiently process linked data

Advancing sequence-to-sequence classification for automatic speech recognition and machine translation beyond the state of the art is one of the the main goals in the ERC Advanced Grant *SEQCLAS*, awarded to Prof. Dr Hermann Ney from RWTH Aachen University.



Source: AG Speech and Language Processing, RWTH Aachen

Processing pipeline for state-of-the-art language processing models



Source: PADS group, RWTH Aachen University

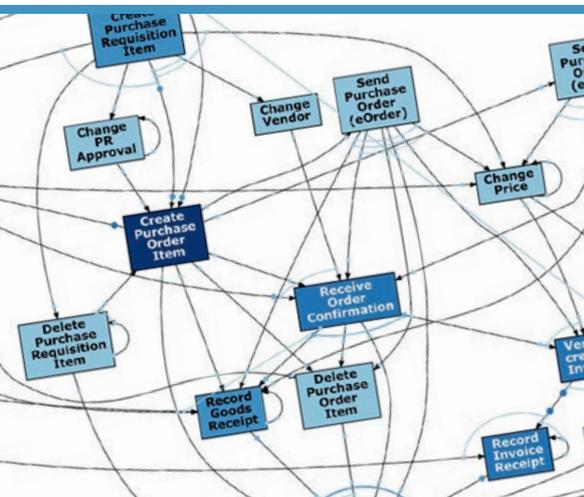
Including researchers from the Universities of Bonn, Paderborn, and Fraunhofer IAIS, the semantic analytics stack (SANSa) has been developed as a big data engine for the scalable processing of large-scale linked RDF data with facilities for semantic data representation, querying, inference, and analytics.

distribution,  $d_i = P(S_i | \text{tree})$   
 $\sum_i p_i = 1$ ; then the unluckiness function  $L(\mathbf{x}, J) = \dots$   
 leads to a bound  
 $P(\mathbf{x} \mid |\hat{d}_m(f, h_m(f, \mathbf{x}), \mathbf{x}) - d_P(f, h_m(f, \mathbf{x}))| \leq \epsilon) \geq 1 -$   
 $\frac{8 \lg(1/\delta)}{m} + \sqrt{\frac{16}{m} \left( 2 \lg\left(\frac{1}{\delta}\right) \ln m + (3+i) \ln 2 + \ln \dots \right)}$   
 Source: Barbara Hammer  
 $\dots \ln(4em/\alpha))$  and  $\alpha > 0$ .

Both, the first *mathematical substantiation* of structure processing neural networks as well as recent links of graph embeddings to the Weisfeiler-Leman graph isomorphism heuristic come from researchers from NRW, more specifically Bielefeld University and RWTH Aachen University.

*An early result, proving the generalization ability of structure processing recursive network*

How can we extract meaningful entities from raw signals without relying on prior knowledge? AI experts from Ruhr University Bochum turned the principle of slowness into an efficient algorithmic scheme to extract *Slow Features* from given data, with applications ranging from dimensionality reduction to self-localization in robotics.



The godfather of *Process Mining*, Alexander-von-Humboldt professor Wil van der Aalst at RWTH Aachen University, helps to bridge the gap between traditional model-based process analysis and data-centric methods.

*Process model generated from log files by process mining technologies*

## Trustworthy AI in a changing society

As a key enabler of future digital industry, potential game-changer for experimentation and discovery in science, and prevalent technology in everyday services such as internet search and human-machine communication, AI has an enormous economic impact. Moreover, AI is involved in the solutions of humans' grand challenges, examples being AI-based environment-friendly mobility concepts, augmentation of human capabilities by intelligent assistive systems in an ageing society, or support in developing medical therapies or vaccines. Yet, the very nature of AI technologies includes a number of novel threats which need to be addressed for trustworthy AI: machine learning models often act as black boxes and can show unexpected behaviour where human and machine perception differ considerably. Since models are trained on real-life data, there is the risk that models allow unauthorized access to sensitive information contained in the data and a violation of privacy. In addition, data biases, which are caused by spurious correlations in the data rather than causalities, can be mirrored in ML models, making model behaviour systematically inferior for specific individuals or (e.g. ethnic) groups. Further, the ubiquity of AI in virtually every aspect of life has an enormous impact on the way in which we as a society communicate, decide, and interact. Opportunities as offered by AI will irreversibly change working environments and the changes will deeply challenge policy and legislation. Hence novel concepts on how to guarantee security, safety, privacy, and fairness of AI and how to create AI systems which support humans rather than incapacitating them are of uttermost importance.

NRW has put a strong focus on trustworthy AI, and quite a few projects make AI available for the benefit of humankind. Examples include the quest for AI technologies which support the transformation of Germany's energy system, those which improve healthcare logistics to avoid shortages occurring in the global Covid19 crises, or those which make AI resources, data, and software available to support discoveries in science. Further, interdisciplinary teams work towards sustainable solutions and the cognitive compatibility of human and AI: NRW researchers are among the first to establish testable criteria for trustworthy AI technologies in an interdisciplinary team. Solutions which can guarantee the privacy and security of AI technologies often rely on a combination of advanced machine learning and novel mathematical concepts, such as those developed in NRW's cybersecurity hub in Bochum. Legal, ethical, and societal implications of AI solutions are the topic of several projects such as those pursued in NRW's Center for Advanced Internet Studies as well as other research projects. Based on such interdisciplinary endeavours, the sustainability of AI solutions is pursued as one of NRW's priorities.

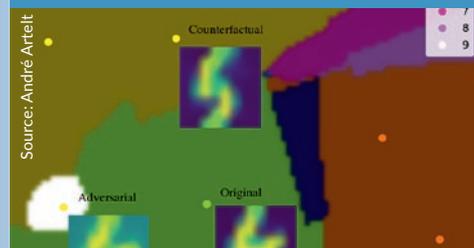


Source: Simon Bierwald

The Cluster of Excellence Cyber Security in the Age of Large-Scale Adversaries, CAsA, in Bochum, the *Center for Cybersecurity Bonn*, and the newly established *Max Planck Institute for Security and Privacy* constitute one of the world-leading hubs in cybersecurity, with machine learning solutions for security as well as secure ML being one of its focal points.

An interdisciplinary research team is developing a test catalogue within the framework of the KI.NRW competence platform, hosted at Fraunhofer IAIS, with the participation of the BSI, Germany's federal office for security in information technology. This enables the expert and neutral assessment of AI. The aim is to ensure technical reliability and the responsible use of the technology by means of *certification for AI*. AI experts from the competence platform ML2R contribute crucial research input.

In the *IMPACT* project chaired by a research team from the University of Duisburg-Essen and funded by the Volkswagen Foundation, experts from machine learning, social interaction, sociology, law, and ethics, have joined forces to investigate the behavioural and societal implications of intelligent speech assistants prevalent in today's households.



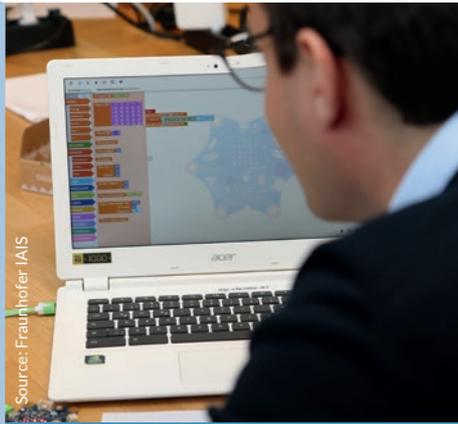
DeepView visualization of an adversarial example versus a counterfactual explanation.



A glimpse at Germany's bioinformatics de.NBI cloud infrastructure hosted at Bielefeld University

Data and compute resources constitute a crucial component to making AI accessible in applications, as is the case with data analysis in the life sciences. *Cloud services for Germany's bioinformatics infrastructure network de.NBI* are hosted at Bielefeld University to support integrative analysis for the entire life sciences community in Germany and the efficient use of data in research and application, currently supporting Germany-wide research to fight Covid-19.

The Center for Advanced Internet Studies, *CAIS*, is host to interdisciplinary projects which assess the impact of AI on our society. These cover diverse topics such as the challenges and risks of AI in state administration, public perception and misconceptions of AI, and design opportunities of AI legislation.



Source: Fraunhofer IAIS

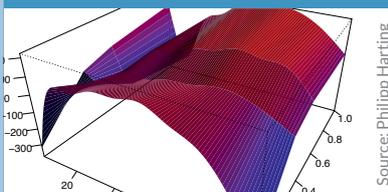
Open Roberta developed at Fraunhofer IAIS supports vocational education and training.

Education constitutes a crucial facet in rapidly emerging areas such as AI. There are a number of dedicated training programmes for industrial partners which are embedded in large-scale projects spread over NRW, such as Digital in NRW or ITS.ML, and also an increasing number of dedicated study programmes at all levels in NRW's universities and universities of applied sciences. *Open Roberta* developed at Fraunhofer IAIS focuses on educating the next-generation of AI experts. The Roberta team is also expanding the initiative to include vocational education and training.

*Corona.KEX.net* is a digital platform in Aachen's Invention Center which supports the acquisition and distribution of medical products in short supply due to increasing demand such as that caused by the Covid'19 crises.

Two spin-offs of RWTH Aachen University aim at transforming our energy system: *Gridhound* — a spin-off of the university and the E.ON Energy Research Center which offers the innovative cost-efficient monitoring of highly fluctuating power distribution networks; *EnergyCortex*, a spin-off offering cloud-solutions to enable the efficient control and optimization of the energy-consumption of industrial customers.

The Innovative Training Network Economic Policy in Complex Environments (*EPOC*), coordinated by Bielefeld University, focuses on the development of intelligent analysis technologies to help decision-makers in complex settings and to facilitate economic decision making in application areas of importance such as climate change.



Source: Philipp Harting

Effects of policy variation computed by Bielefeld University's macroeconomic simulation model *Eurace@Unibi*

On its way to truly personalized medicine, the *University Hospital Essen* is the first one in Germany with a dedicated Institute for AI in medicine, the AI Futurelab.

## AI researchers in NRW

NRW's AI experts are too many to be named. In addition to the chairs of NRW's integrated focal projects in AI, the following map shows some researchers from the 2020 6th edition of Top Scientists Ranking for Computer Science & Electronics, whose research focus is dedicated to developing and understanding core AI methodology—and we expect this number to grow as new researchers join the field.



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