Honda Research Institute **EU**

Innovation through Science

Welcome
Honda Research Institute Europe

Innovation through Science

At HRI-EU, our products are ideas – ideas that lead to Innovations. Science without Innovation neglects opportunities. Innovation without Science remains shallow and superficial. Innovation through Science is the HRI-EU philosophy. It keeps us focused on our role in Honda and in the society at large.

In 2003, when the Honda Research Institutes were founded in Japan, in the United States and in Europe, our central focus was research into Computational Intelligence, Optimization and Robotics. More than a decade later Artificial Intelligence is seen as the next big tech thing. We couldn't agree more.

Intelligent systems will shape our future in many ways, ranging from autonomous and accident-free driving to personal robots and from smart design and manufacturing to the efficient use of resources. We envision intelligent systems to work among us, for us and with us. This is why we call it Cooperative Intelligence.

The ideas and concepts our researchers introduce on the next pages are the basis for achieving Cooperative Intelligence.

We hope to spark some interest in you and we encourage you to get in touch with us. After all, progress in Artificial Intelligence will affect us all.

Please enjoy!

Bernhard Sendhoff

Andreas Richter

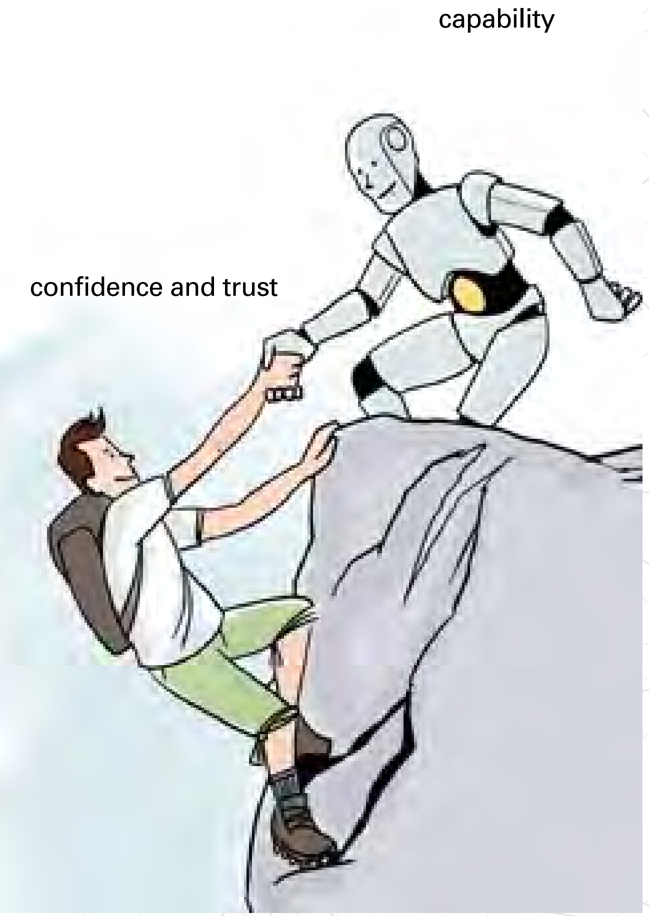
Manabu Ozawa

Artificial Intelligence is the ability to use optimally limited resources – including time – to achieve goals in complex environments

Based on the definition of intelligence by R. Kurzweil. *The age of spiritual machines: When computers exceed human intelligence. Penguin, 2000.*

Cooperative Intelligence is Artificial Intelligence embedded in a Social Context

Cooperative Intelligence is the ability to optimally use limited resources to achieve goals in complex environments ***together with others.*** Where Artificial Intelligence focuses on the capability, Cooperative Intelligence ensures confidence and trust when interacting with artificial systems. The interaction will advance the user in many ways. Even if the system is able to perform a task autonomously, cooperation can be desirable. In order to have ***confidence*** or even ***trust*** in the system, the user needs to understand its state and intention. However, the interaction can also take place for the benefit of the system, e.g., to cope with restricted functionality and robustness or to use interaction to teach and advance the system.



Cooperative Intelligence

Cooperative Intelligence enables us to build up a relationship of confidence and trust with artificial systems, enhances our capabilities, allows us to share our experiences and strengthens our role in society

Empower	Experience	Empathy
Together we do it better	We grow together	I know how you feel

Cooperative Driving

Cooperative Engineering

Cooperative Manufacturing

Cooperative Life Assist

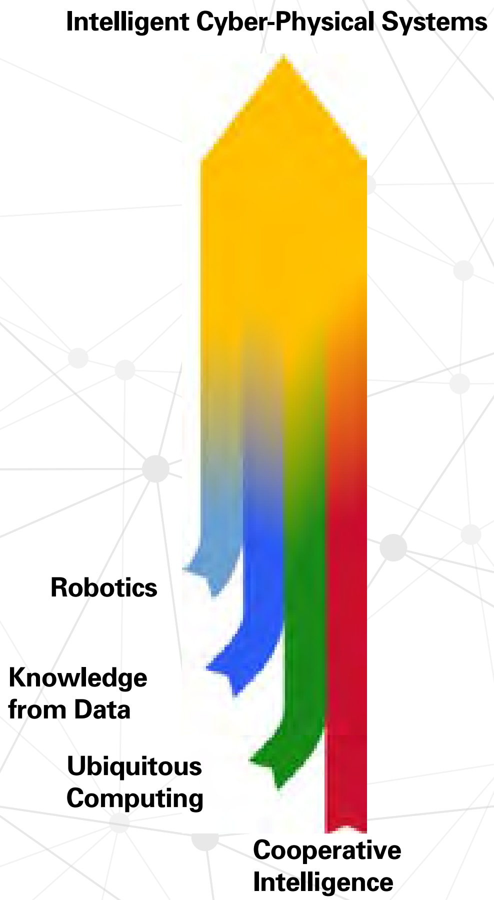
Intelligent Cyber-Physical Systems (ICPS)

Transition towards an Intelligent Cyber-Physical Society

We are envisioning a growing entanglement of different technological streams: Cooperative Intelligence, Data-Driven Knowledge Generation, Robotics, and Ubiquitous Computing (or Internet of Things). This inspired us to develop the concept of Intelligent Cyber-Physical Systems (ICPS).

ICPS will have the form of different embodiments that are optimally adapted to accompanying and supporting us in our daily life: As a life assist, ICPS will share our hobbies and duties. With smart clothing, the system will coach us in sports and even allow us to experience the movement of masters by replaying their movement with our body. In manufacturing, ICPS will perform heavy work together with us, enabling efficient, relaxed, and joyful working.

So what is ICPS? Is it a robot, a wearable device, or a car? No, it is a well orchestrated connecting of all these applications into one system, centered around us humans. This system will not only act as one. It will also transform collected data into personalized knowledge about us, ensuring Privacy by Design. ICPS will share our **experiences**, **empower** us just as we need it, and act **empathically**.



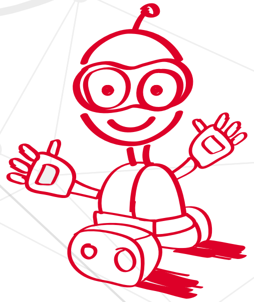
Empower
Together we do it better

Experience
We grow together

Empathy
I know how you feel

People at HRI-EU
from Student to Researcher

"Hi,
I am David. I am a student from TU Darmstadt and work on improving the Relational Local Dynamic Map concept and map representation. During my studies at HRI-EU, I get to know the scientific day to day life and meet many great people!"



"HRI-EU is a multi-cultural Science Think Tank for Honda, researching technologies of tomorrow!

As a student, you can tip your toe into the water of research, experience a challenging scientific community and start your scientific career leading to a PhD."

"Hello,
I am Moritz, working towards my PhD in a cooperation project with TU Darmstadt. My research topic is about improving Human Robot Cooperation with the target to develop a causal understanding for the human to enable a more intuitive and human like interaction."

M. Bühler and T. Weisswange, "Online inference of human belief for cooperative robots", 2018 IEEE IROS, 2018.

"Hi, I am Sneha. I am working in the EU Horizon2020 ECOLE project for my PhD in collaboration with the University of Birmingham. Working at HRI-EU, gives me the opportunity to learn from other researchers and to carry out research independently. My research interests include Deep Learning for learning based constraints and multi-criteria optimization."

"From there you can grow as a scientific expert in your field and work at the intersection of research and visionary application for Honda. Do you want to look beyond the existing with us?"

"Hello,
my name is Michael.
I am a chief scientist, and I like robots that interact with humans. Working at the intersection of company and academic research is a fascinating and challenging mission for me."

M. Gienger, et al., "Human-Robot Cooperative Object Manipulation with Contact Changes." 2018 IEEE IROS, 2018.

"Hi,
I am Martina. As a senior scientist, my goal is to make machine learning work in challenging real-world applications. Apart from my scientific work at HRI-EU, I enjoy the opportunity to work with people from various disciplines and cultures."

M. Hasenjäger and H. Wersing, "Personalization in Advanced Driver Assistance Systems and Autonomous Vehicles: A Review", 2017 IEEE ITSC, 2017.

"Hi,
I am Tobias. As a principal scientist, I develop simulation tools and optimization algorithms to support the transition to an emission-free mobility. My research tries to identify and overcome the challenges of future energy systems including e-mobility."

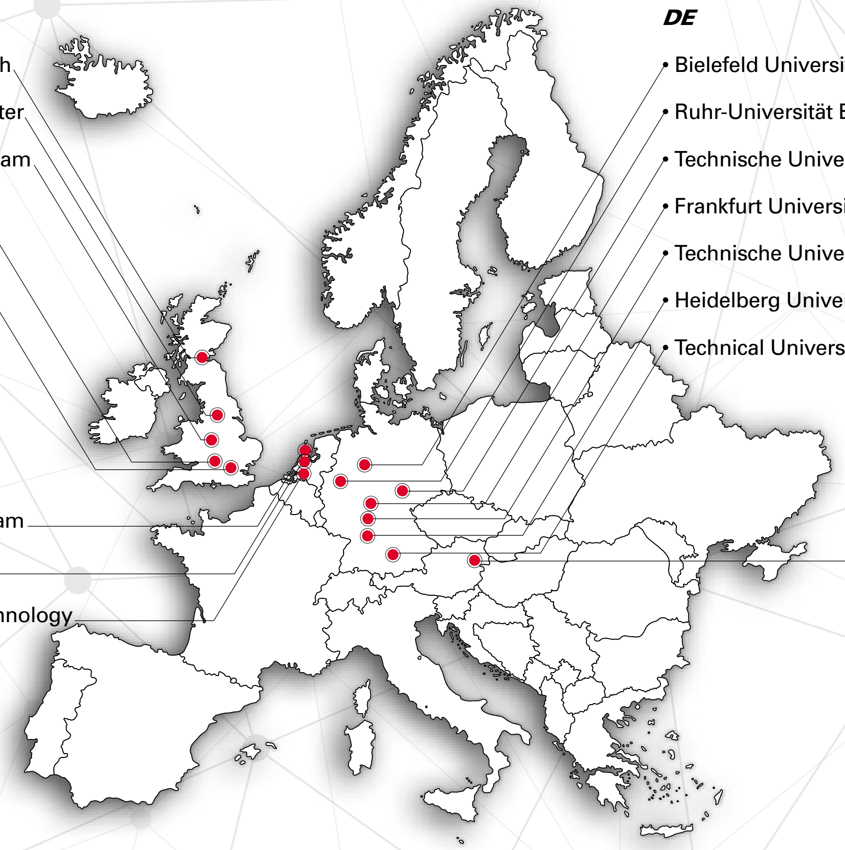
T. Rodemann, "A Many-Objective Configuration Optimization for Building Energy Management", 2018 IEEE WCCI, 2018.

GB

- University of Edinburgh
- University of Manchester
- University of Birmingham
- University of Oxford
- University of Surrey (located in Guildford)

NL

- University of Amsterdam
- Leiden University
- Delft University of Technology

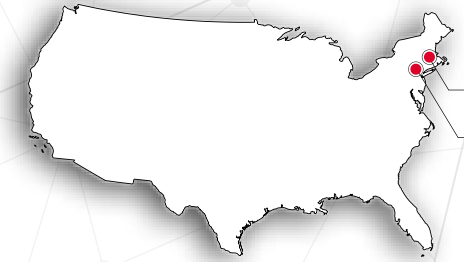


DE

- Bielefeld University
- Ruhr-Universität Bochum
- Technische Universität Illmenau
- Frankfurt University of Applied Sciences
- Technische Universität Darmstadt
- Heidelberg University
- Technical University of Munich

AT

- University of Vienna



USA

- Boston University
- New York University

JP

- Tokyo Institute of Technology

HRI-EU European Graduate Network
Partnership in Science

The HRI-EU European Graduate Network (EGN) is our initiative for all graduate students supported by the Honda Research Institute Europe. It also includes associates who pursue a PhD degree together with their work at our institute.

The EGN shall foster the spirit of togetherness among the students, strengthen our advisory role and create a network that lasts beyond their time at our institute.

Most students in the EGN are supported by Partnership in Science projects with universities and academic institutes, facilitating open research and discussion.

Joining our partner's and HRI-EU's scientific expertise advances our understanding of intelligent systems. HRI-EU also contributes to scientific programmes and open source software development.

In this way, we join in educating the next generation of researchers in their local communities providing a global perspective.

HRI-EU European Graduate Network Symposium 2018

Research Topics
at HRI-EU

Perception & Knowledge Representation
understand the environment

Risk & Planning
foresee the criticality of situations and structure the next actions

Group Leader
Julian Eggert

Decision Making
evaluate alternatives

Data Analytics
discover patterns in big data

System Optimization
enhance system capabilities

Group Leader
Markus Olhofer

Group Leader
Heiko Wersing

Learning
acquire new knowledge and skills

Personalization & HMI
adapt to user expectations

Ethics in Artificial Intelligence
be socially compliant

Prediction
understand what might happen next

Group Leader
Christian Goerick

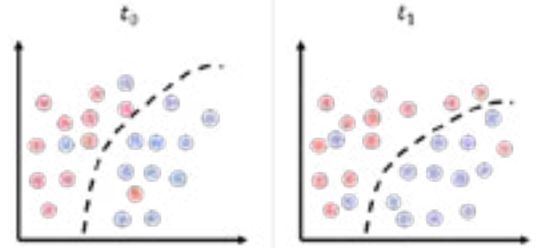
Cooperative Behavior
achieve tasks together

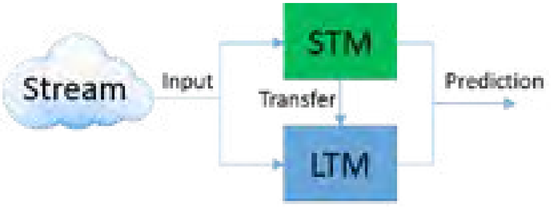
System Architecture
decompose a system

Memory Models for Non-Stationary Environments

The capability to deal with change is essential, considering the fact that the world is constantly evolving. Old knowledge may become obsolete or even wrong, contradicting the current beliefs. In these dynamic conditions, algorithms clearly need to capture the current situation and then continuously adapt in order to track changes. In particular, they require a mechanism to decide whether past knowledge is still valid.

We propose the Self-Adjusting Memory (SAM), a new architecture to integrate past and current knowledge in an innovative way. It is based on interlinking the short-term memory (STM) and the long-term memory (LTM). While the STM contains the current concept, the LTM accumulates the information of all past concepts. A consistency between both memories is continuously maintained by selectively filtering contradicting instances. Past knowledge is compressed whenever the upper memory bound is reached. This leads to to an adaptive level of abstraction, making SAM well suited for lifelong learning scenarios like smart home, intelligent life assist or mobility applications.

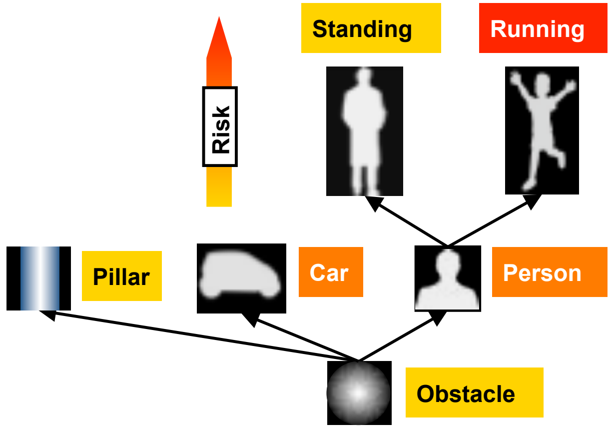


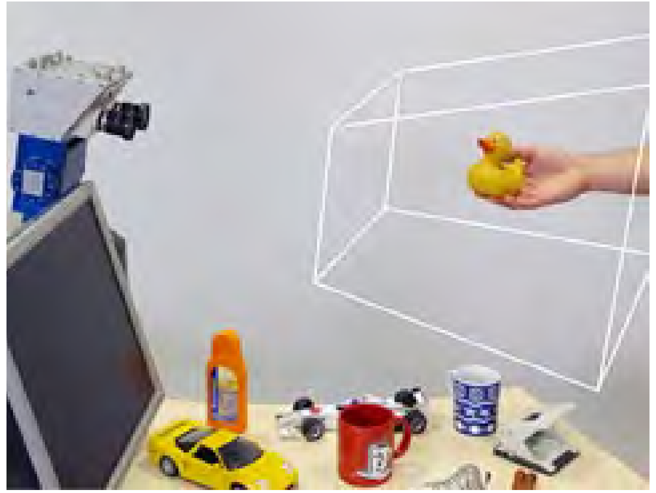


For more information:

V. Losing, B. Hammer, H. Wersing, "Tackling Heterogeneous Concept Drift with the Self Adjusting Memory (SAM)", Knowledge and Information Systems, 2018

Learning is one of the key features of intelligence: The capability of using prior experience to adapt intelligent behavior to novel situations. This requires some form of memory that may be divided into short-term and long-term memory. The stored information can be used to adapt and synthesize representations, acquire new skills and change values or preferences. This flexibility widens the scope of intelligent systems going beyond the boundaries of fully pre-programmed solutions.





Incremental learning is characterized by the capability to perform experience-based adaptation from a continuous stream of incoming data. Thus, it facilitates an immediate feedback between a learning system, its user(s) and its environment. HRI-EU develops new approaches for the key challenge of incremental learning systems: finding a good compromise between stability and plasticity of the learned representations. Incremental learning is a prerequisite for personalized assistance systems and HRI-EU's Collaborative Intelligence vision.

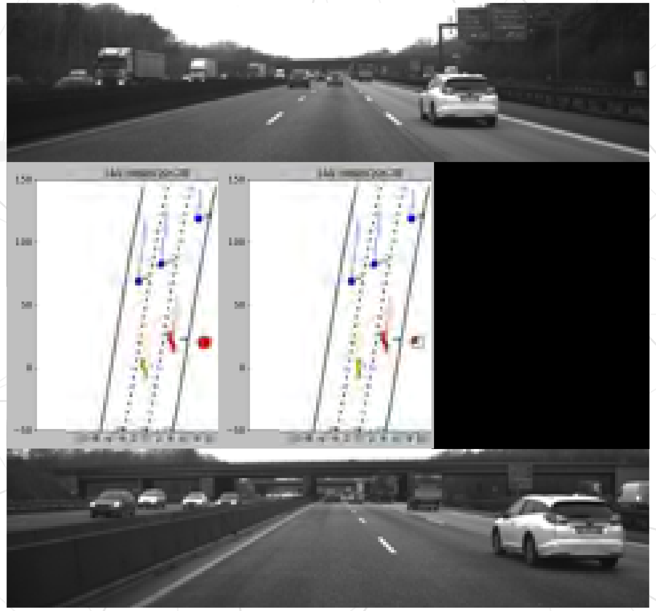
Prediction of Highway Lane Changes

Predicting the lane change intentions of other traffic participants is an important challenge for autonomous driving and driver assistance systems. In this research, a physical prediction is combined with a context-based prediction and the ego-vehicle's behavior influence.

The physical prediction uses observations of recent lateral vehicle positions and compares them to models of typical lane change trajectories. The resulting prediction is highly accurate, but only capable of predicting behaviors once they started.

The context-based prediction is based on cognitive models comprising the influence of the driving context on the lane change intention. It evaluates relations between the target and its context vehicles to estimate a future lane change. For example, a driver tends to change lane when approaching a slower vehicle with a sufficient gap on the next lane. This provides a lane change prediction before any physical movement can be observed.

Given a probability for a behavior of the ego-vehicle, the influence of its decision on the prediction is inferred. The combined method allows to make foresighted behavior decisions that robustly factor in future changes in the driving situation.



Different predictions depending on own behavior choice

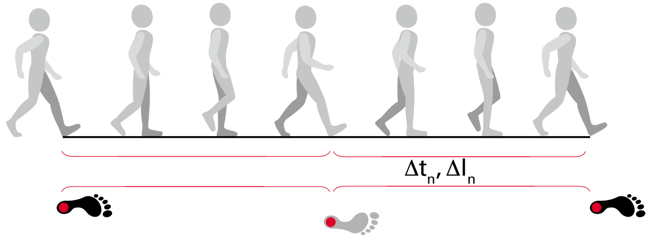
For more information:

T. Weisswange, et al., "intelligent Traffic Flow Assist: Optimized Highway Driving Using Conditional Behavior Prediction", IEEE Intelligent Transportation Systems Magazine, 2019

Research Focus
Prediction

Prediction is the estimation of how the future will evolve. It can be as diverse as a human's motion, the weather or the next action performed by a human co-worker. While most of us have experienced the uncertainty in predicting the weather, the later example is qualitatively different. Humans have the freedom to choose their next step or behavior and it depends on preferences, experiences or context. In a similar way, machines are trained to decide based on a target function.

In a system, intentions of all participants – human or machine, decision maker or bystander – have to be predicted correctly.



Heel strike prediction of a human walking

At HRI-EU, we decompose the prediction task into a variety of different sequences, each following a certain qualitative pattern of assumptions and constraints. These sequences can merge and diverge depending on the continuous perception and new information of the environment. If a decision is required, sequences are combined which take into account their different levels of reliability. An illustrative example is the combination of context-based and physical prediction outlined on the previous page.

Research Focus
Personalization & Human-Machine-Interaction (HMI)

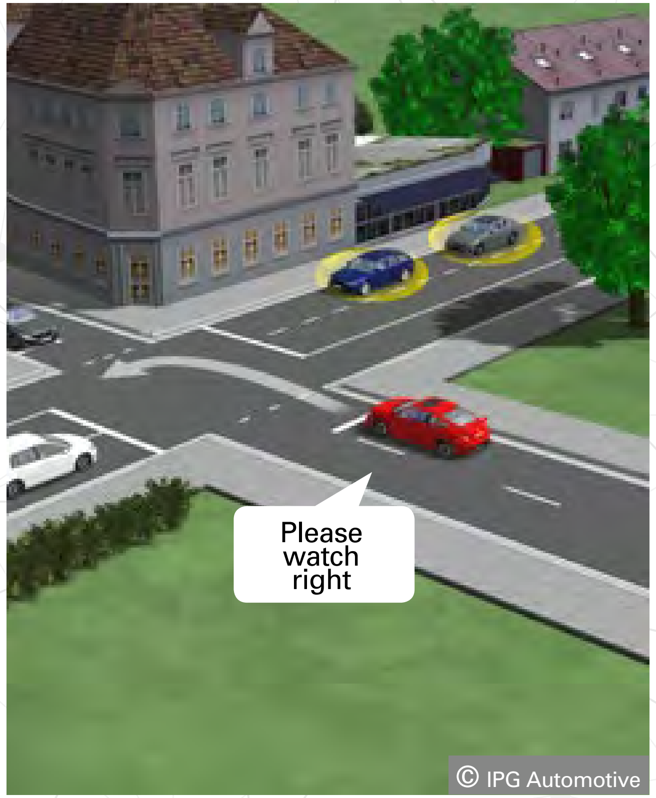
Assistance on Demand

The Assistance on Demand concept offers a highly personalized and context-based approach by delivering assistance only when the driver actively asks for it. Using a speech interface enables the driver to keep his visual attention on the driving task.

The concept was first evaluated in a simulator study, implemented as a left-turn assistant for urban traffic situations. When approaching a complex intersection, the driver may ask the assistant system to "watch right". The system then detects traffic participants approaching from the right and informs the driver about potential gaps or changes in the situation. Relying on the system's information, the driver can visually concentrate on the other directions, only checking the right side before entering the intersection.

In a follow-up study, the system's recommendations were personalized to the individual drivers according to their preference for the gap size. In both cases, the system was very well received by the drivers, in particular when it included the personalization.

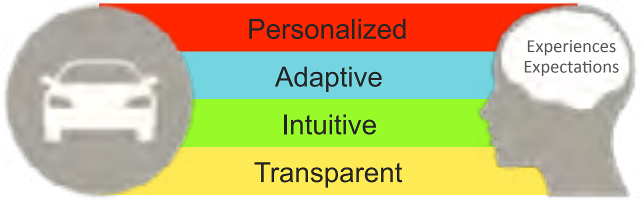
To proof the online capabilities, the system has been implemented on a prototype vehicle and tested in real-world traffic situations.



For more information:

D. Orth, et. al, "Benefits of Personalization in the Context of a Speech-Based Left-Turn Assistant", ACM International Conference on Automotive User Interfaces and Interactive Vehicular Applications, 2017

Personalization is the user-specific adaptation of a system towards individual user capability, experience and preference. It can be based on assigning the user to one of a number of pre-specified categories or clusters. More flexible models of personalization may require larger sets of individual user data to allow a robust estimation of the user's properties and preferences. Personalizing the interface can make the interaction more intuitive or comfortable, i.e. better respecting the experiences and preferences of a user.



Human-Machine-Interaction (HMI) with intelligent assistant systems poses great challenges for the mutual understanding of goals, capabilities and mental models of interaction partners.

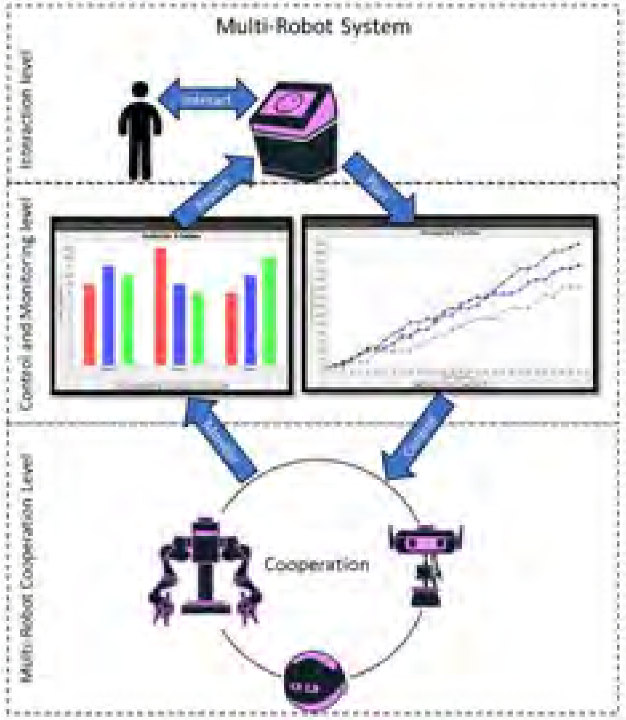
With HRI-EU's incremental learning approaches, user-centered system adaptations are researched and developed aiming at a mutual understanding of learning progress and concepts. The result is trust between machine and user – a core value of HRI-EU.

Cooperative Multi-Robot Systems Architecture Modeling and Simulation

A Multi-Robot System (MRS) is an Intelligent Cyber-Physical System, in which robots cooperate to fulfill a human's needs.

In modelling the MRS, a proposed system architecture can be simulated and its performance measured prior to implementation. The challenge is to consider many dependent and dynamically changing behaviors due to the current status of the overall system.

To demonstrate the modelling approach, a general purpose MRS case study was created. A system architecture with several components is proposed to enable the robots interaction and planning according to their current, individual capabilities when triggered by a human's task. Each component is modeled as an activity diagram to precisely represent the behaviors of the component. The components' behaviors and interaction are then simulated in a software agent environment called Java Agent DEvelopment (JADE). By defining a number of quantitative measurements, obtained from the simulation in JADE, the performance of the proposed architecture is analyzed. This allows a comparison to other architectures and an online observation of the overall system's performance.



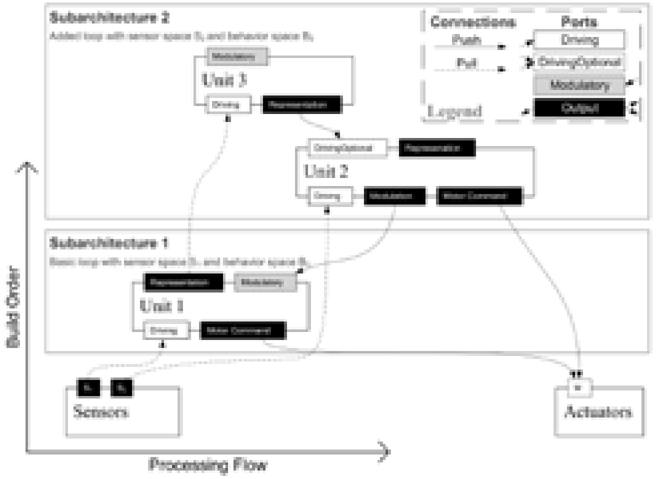
For more information:

A. Sadik, C. Goerick, M. Mühlig, "Modeling and Simulation of a Multi-Robot System Architecture", International Conference on Mechatronics, Robotics & System Engineering, 2019

Research Focus
System Architecture

A System Architecture describes the interplay and relations of a number of elements that together create a defined output. It allows, e.g., for easy analysis, control of dependencies and computational timing requirements. In particular, for systems consisting of modules of different types or origins.

The theoretical analysis of System Architectures is important for constructing increasingly complex systems. It becomes mandatory for the design of general architectures, as required, e.g., for building autonomous systems.



The most prominent questions when researching System Architectures are:

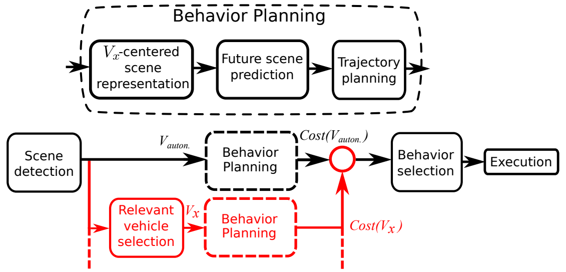
- Can general beneficial decompositions be found that facilitate incremental composition with respect to functions, stability, testability, maintainability, re-usability and even certifiability?
- Can we find a series of abstractions for perceptions and behaviors that allow researchers to focus on their specific challenge without the necessity to consider all technological dependencies in detail?
- Can we provide scientific models that guarantee specific requirements by means of the design process rather than by tedious testing and validation?

Applied Distributive Justice for Autonomous Driving

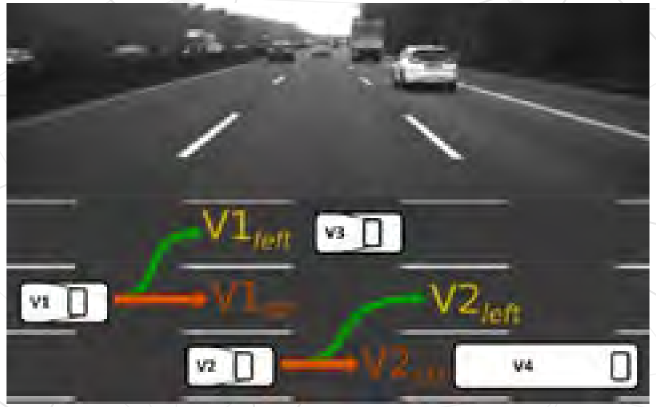
With Autonomous Vehicles (AVs), a new kind of traffic participant with Artificial Intelligence enters the shared public space. Taking ethical principles in any driving situation into consideration is highly relevant as every driving decision impacts the behavior option space of others. In our research, we propose to add a distributive justice model as framework for the AV's decision process. This enables the future vehicle to operate ethically towards other traffic participants.

The developed AV behavioral architecture understands itself as being part of a system with the other traffic participants. It systematically takes into account the perspective of all traffic participants – others and its own. When predicting the driving options, the AV also considers the impact on each other. Based on safety, utility and comfort needs, each behavior option gets a calculated cost assigned. The behavior planning module compares all available options and decides on an action according to a just distribution of the costs over the whole system.

The addition of a distributive justice model aims to make road usage for human drivers and autonomous vehicles in a shared space a just experience.



Behavior planning module



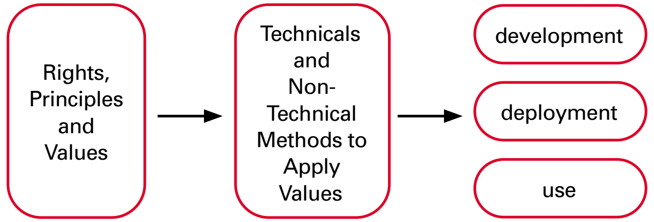
Considering the driving options of all vehicles

For more information:

M. Dietrich and T. Weisswange, "Distributive Justice as an Ethical Principle for Autonomous Vehicle Behavior Beyond Hazard Scenarios", Ethics and Information Technology, 2019

The approach of Cooperative Intelligence considers ethical Artificial Intelligence as a prerequisite for confidence and trust between human and machine. While most of the current research on ethics and technology concentrates on applying the ethical principle of preventing harm, at HRI-EU we focus on the aspects of fairness, mutual respect and explainability.

Integrating ethical principles into Artificial Intelligence reasoning, gives the autonomous machine a human-like value framework for Decision Making and



HRI-EU develops Privacy by Design concepts to preserve privacy for future personal data-driven Artificial Intelligence applications like assistance robotics. User interfaces which provide meaningful explanations of Artificial Intelligence behavior are conceptualised and tested in smart home environments. Autonomous vehicles are advanced by fairness considerations during selection and execution of behavior.

The user perceives these resulting systems to act more naturally and understandably – a human-centered Artificial Intelligence.

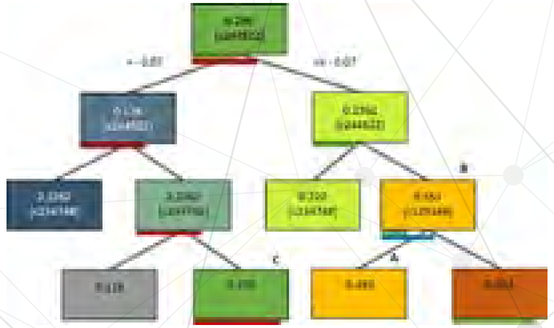
Research Focus
Data Analytics

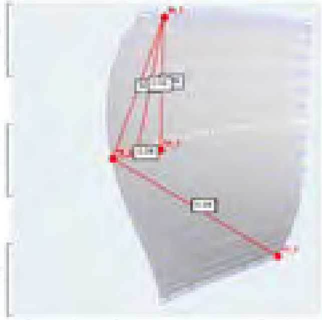
Data Analysis for Industrial and Engineering Design Data

Modern engineering development cycles are driven by CAE methods and the computational analysis of digital simulation models, leading to an ever increasing availability of complex, large-scale data sets. To handle this complexity, data-driven approaches from machine learning and artificial intelligence are explored to provide novel insights into engineering processes.

We place special emphasis on the integration of shape and structural information by deploying and researching machine learning techniques for processing of engineering data, in particular 3D designs. For dependency analysis, nonlinear multivariate methods are deployed, providing additional insights into simulation results. Interaction graphs are created to illustrate these newly found interrelations between spatially decoupled surface areas.

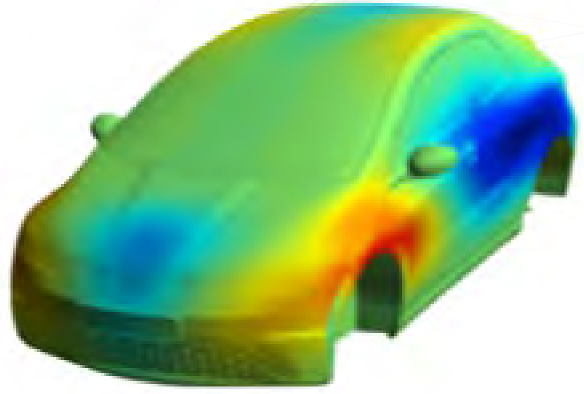
The ability and analysis of relating surface and shape information to performance indices, assists the engineer in the exploration of the design space and significantly reduces development time.

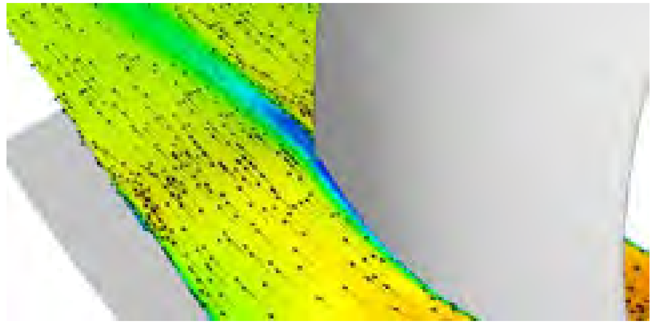


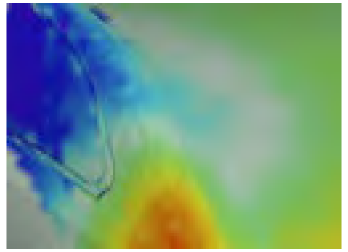


The intensive use of computational tools like Computational Fluid Dynamics and Finite Element Methods in development, test, manufacturing, and service has resulted in a tremendous increase of data that is managed in an engineering context.

The integration and combined analysis of data from multiple disciplines resulting from cyber physical systems potentially allows for a drastic increase in efficiency and quality during the overall product lifecycle.







Flow field simulation

In order to optimally utilize this data, algorithms are developed which are able to autonomously identify on the one hand system states, operation patterns and eventual unexpected system behavior. On the other hand to identify and explain system behavior and interaction with the environment to improve and to innovate the system during current and future design phases.

Complex dependencies are not necessarily obvious during the design phase, especially for interacting systems in a dynamic environment. In Data Analytics, a diverse set of methods from statistics and computational intelligence is applied to enrich the knowledge about the system and its interaction with the environment including the user, to maintain and to improve the systems.

Research Focus
System Optimization

Cooperative Charging of Electric Vehicles

With a strong increase in the number of battery electric and plug-in hybrid vehicles, smart charging approaches are needed to reduce the negative impact of electric mobility on the stable operation of the power grid to reduce social costs as well as environmental impacts.

Our cooperative approach enables the driver of an EV (Electric Vehicle) to choose their preferred charging conditions. The decision incentives provided in form of dynamic charging price offers, reward choices that are beneficial to the electric grid and the charging operator. For instance, a longer charging duration results in a lower electricity price for the driver and more flexibility in the charging process for the operator.

This dynamical determination of optimal price offer and charging profiles combines mixed integer linear programming with evolutionary multi-objective optimization. Additional constraints like price fairness can be added into the price finding optimization, creating a smart energy service system in which driver, energy provider and mobility provider are engaged.

This approach enables the utilisation of machine learning and optimization to develop and test robust energy management systems.

The new Honda EV: Honda e

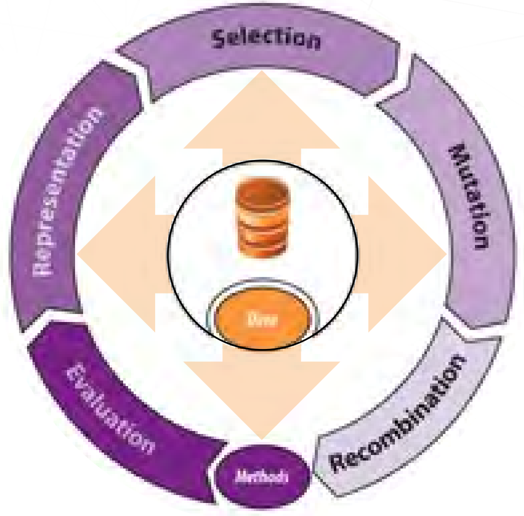
Charging station at Honda R&D facility in Offenbach

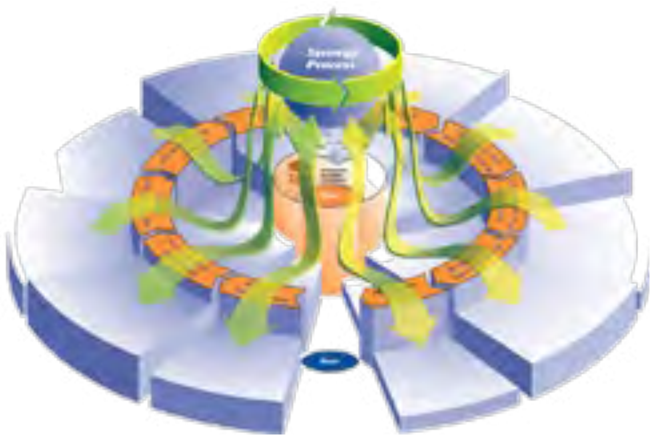
For more information:

S. Limmer and T. Rodemann, "Peak Load Reduction through Dynamic Pricing for Electric Vehicle Charging", International Journal of Electrical Power & Energy Systems, 2019

System Optimization is the adaptation of an existing system with a fitting parametrization according to a previously determined optimal system structure. The optimal spatio-temporal decomposition into subsystems, their patterns of interaction and the propagation of uncertainties are central questions. Like in Systems- and Requirements-Engineering, optimization has to be holistic.

System Optimization can add profound value to a variety of applications like interdisciplinary engineering design, the high connectivity of large scale economic models or the multi-scale complexity of intelligent systems.





At HRI-EU, we approach System Optimization with stochastic optimization methods inspired by biological evolution. Biological evolution is "situated design" or "optimization in-vivo". This means that the design and operation process are occurring concurrently in the same environment. In our research, we focus on Many Objective and Many Disciplinary Optimization tasks. For system characteristics, we explore Robustness as inherent property and Evolvability, enabling systems to continuously evolve.

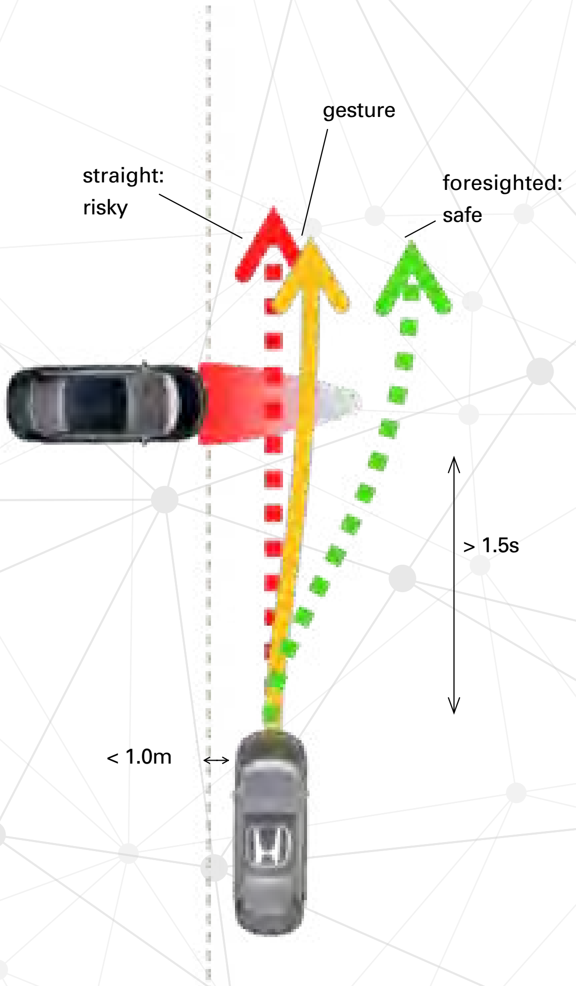
Research Focus
Cooperative Behavior

Cooperative Driving

A concrete instance of Cooperative Driving is the “CarGesture”. Human drivers use “gestures” frequently to communicate their intentions. For example: approaching a zebra crossing and braking already far away from the crossing conveys the intention to let a waiting pedestrian pass this crossing.

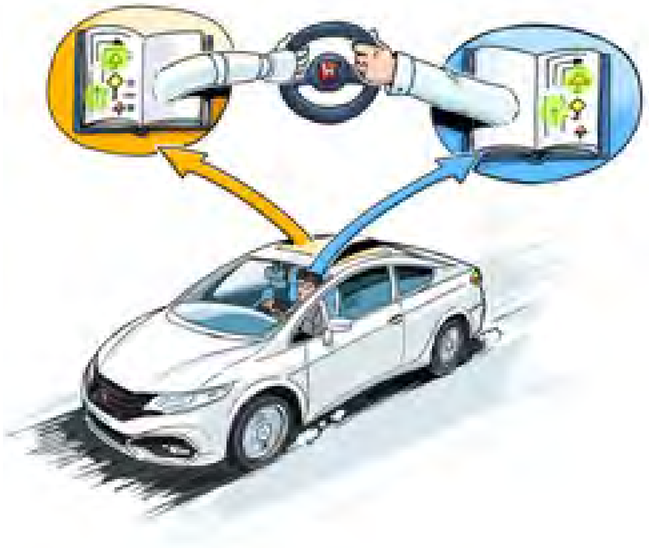
Imagine the car predicts a potentially hazardous situation and communicates this by indicating a de-escalating trajectory with a gentle steering wheel impulse, a CarGesture. The gesture should be clearly noticeable for the driver but will not be sufficient for avoiding the hazard by itself. In this way, the driver is informed early with a beneficial behavior bias. The driver then has the full spectrum of choices to either follow this recommendation, initiate an even less hazardous trajectory or to reject the recommendation by staying on the chosen trajectory for a reason unknown to the vehicle. A scientific user study has shown that people accept CarGestures due to their non-invasiveness and their action-proposing nature.

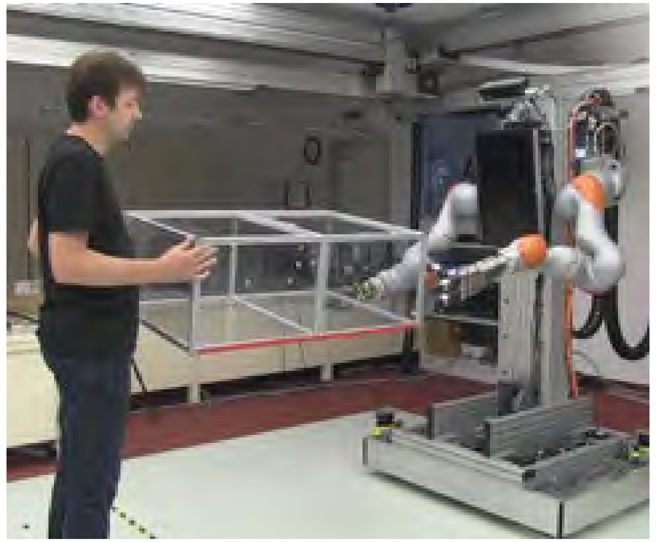
In the future, we expect autonomous vehicles to employ such kind of gestures in mixed traffic with human drivers in order to convey their intentions in a human legible way.



The foundation of Cooperative Behavior is a shared goal between machine and human partner. For a successful, long-term cooperation, the arising relation needs to be fostered and it is crucial to generate mutual understanding. Reaching the goal together is accompanied then by a feeling of accomplishment and joy.

HRI-EU researches Cooperative Behavior generation, answering the question what a system‘s actions should be. Considering the aspects above, this goes beyond a simple task achievement.





Two applications for Cooperative Behavior are mobility and robotics.

In mobility, it is a challenge to guide the drivers proactively without supervision. The goal is to empower and not to replace the driver. Cooperative vehicles maximize the joy together with the driver and other traffic participants.

In robotics, the physical component of achieving something together is much stronger. Manipulating objects jointly by the robot and its human partner should primarily generate a feeling of accomplishment, which is central to cooperative robotics.

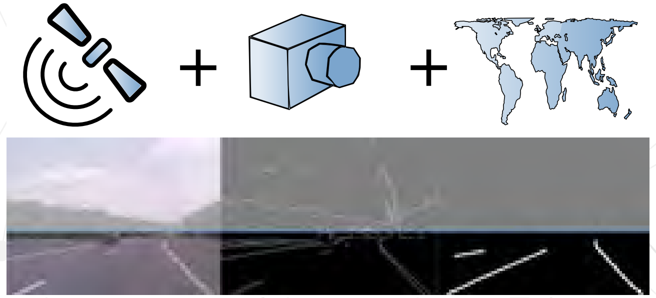
Research Focus
Perception & Knowledge Representation

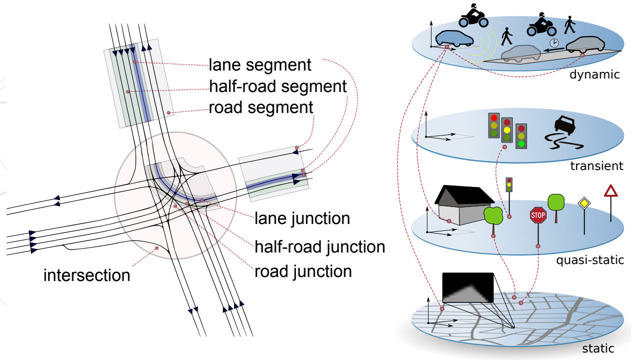
Sensor Fusion for Localization

Localization on maps at lane-level accuracy is a key capability for future autonomous driving systems. It enables intelligent vehicles to better understand their environment, to predict future trajectories of other traffic participants and allows for an improved evaluation of behavior options.

For the localization, data from several sensors has to be integrated to provide a more complete and coherent view of the environment. Information has to be fused from different types of sensors, and multimodal sensor measurements have to be combined with other available information about the environment, e.g., from spatial plausibility considerations or map data.

In this work, camera-based road views are combined with satellite-based positioning information and infrastructure geometry data from maps. This leads to a more accurate map-relative localization of traffic participants, supporting the overall driving situation analysis. A beneficial side-effect of our approach is the alignment of the sensor (e.g. the front camera view) with environment data which allows for the accurate 2D and 3D visualization of map related information. Augmented reality (AR) possibilities are also explored as a key.


Sensor fusion for camera-to-map alignment



Environment representation including map data

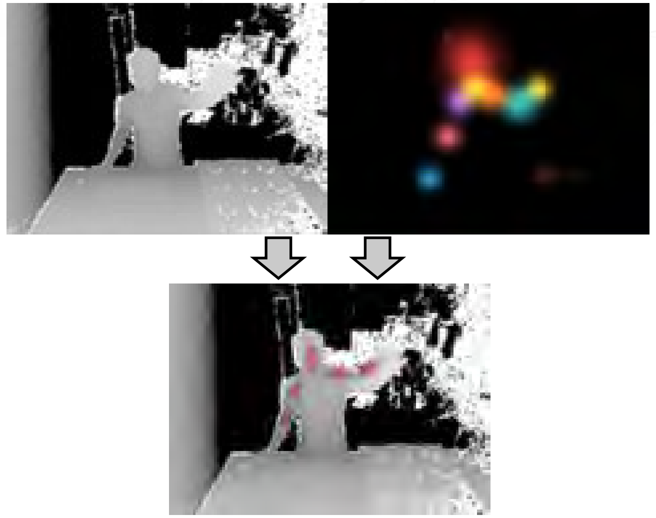
For more information:

B. Flade, M. Nieto, G. Isasmendi, J. Eggert, "Lane Detection Based Camera to Map Alignment Using Open-Source Map Data", IEEE Conference on Intelligent Transportation Systems, 2018

Perception is a system's ability to receive and evaluate useful information about its environment. It comprises manifold capabilities such as detection, recognition, tracking and state estimation based on sensory measurements.

Together with a structured Knowledge Representation in which the percepts can be stored, enriched and combined into a world model, perception forms the grounding point for all higher-level cognitive capabilities. These include learning, prediction, situation analysis, behavior planning or even abstract thinking.

Graph-based Knowledge Representation


Human pose estimation

The Knowledge Representation also comprises knowledge about the environment, the situational context and the behavioral goals of involved agents.

HRI-EU researches multi-sensor fusion and spatio-temporal integration to improve the confidence and reliability of perceptions. Incremental Knowledge Representations are developed to connect perception with a system's broader knowledge, including common-sense human knowledge.

The acquired knowledge combined with the grounded percepts, form the basis for real-world behavior planning and reasoning.

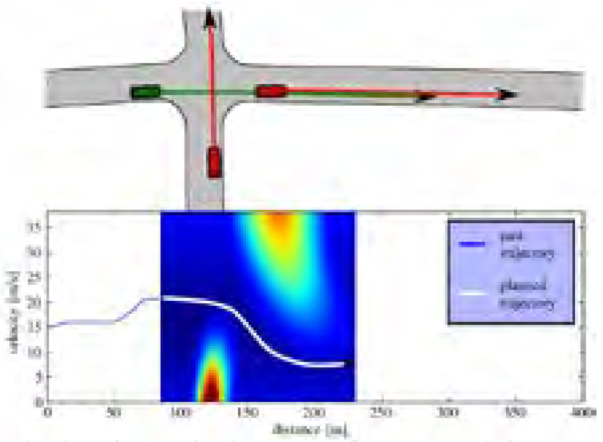
Driving Support using Predictive Risk Maps

A key attribute of intelligent mobility systems is the capability to smoothly find safe trajectories in highly dynamic environments. This involves the evaluation of own behavior alternatives in the context of the anticipated scene dynamics, e.g., the predicted evolution of the other traffic participants.

The associated risk with a behavior alternative can be represented in so-called “risk-maps”, which quantify risk as a function of prediction time and ego-behavior. Two factors influence the behavior planning: (1) the risk associated with a determined behavior and (2) the resulting utility/gain in terms of mobility goals and comfort constraints.

The optimal behavior is a trade-off between risk, utility and comfort given by a path through the risk map which avoids the peaks of high risk.

Furthermore, the risk map representation can be used as a model to predict the intended behavior of others, and to detect whether they follow a risk-minimizing strategy. Risk estimation technologies are also the basis for future "guardian" type driving assistance systems aiming to enhance safety by recommending and supporting low risk driving strategies. They constitute a core ingredient towards concretizing the vision of zero accident, zero fatality mobility systems.



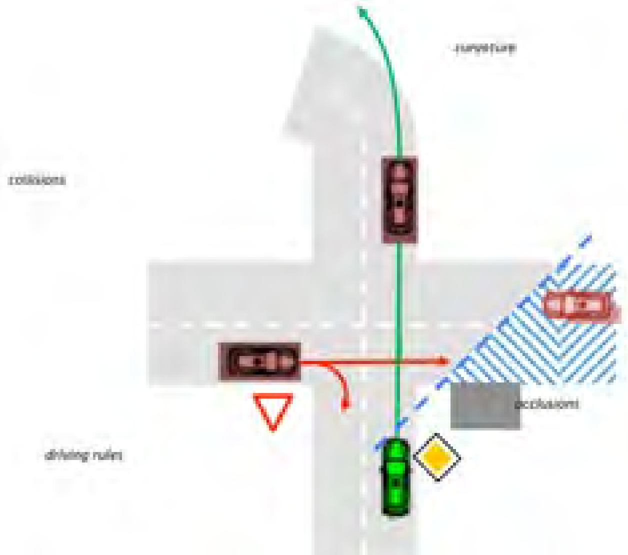
Risk maps for behavior planning


Trajectory planning including occlusion risks

For more information:

T. Puphal, M. Probst and J. Eggert, “Probabilistic Uncertainty-Aware Risk Spot Detector for Naturalistic Driving”, IEEE Transactions on Intelligent Vehicles, 2019

Planning complex maneuvers in real environments usually implies taking risks. For humans, these risks are qualitatively related to utility, comfort and social norms based on experiences and observations. In comparison, Artificial Intelligence systems can quantify risks based on a variety of parameters and influences. The result is a range of choices, each one having a calculated risk assigned. Complex planning supported by intelligent systems is therefore able to identify beneficial trajectories in the trade-off between utility and risk under the premise of machine ethics, e.g., for the use in autonomous driving or robot motion.



Risk and planning topics adress questions like:

- How do we move smoothly through a crowded airport hall?
- How do we plan an overtaking maneuver on a busy highway?

A major challenge when estimating risks is the uncertainty related to the prediction of future events due to the unknown future behavior of others.

HRI-EU’s research focuses on quantitative risk models for the evaluation of different prototypical behavior alternatives. A risk map then serves to identify the spots of highest risks, which we use for near-optimal behavior planning.

Innovation
Quantifying Rider Skill and Posture

Motorcycle safety is essential for the future of riding. Honda has been pioneering motorcycle safety systems from the first disc brake in 1969 up to the latest airbag and C-ABS systems. In recent years, the focus is more and more shifting towards the rider and rider skills.

Online analysis and quantification of riding skills allow to improve rider education by precise individual feedback and engage potentially safety relevant systems such as stability control or future emergency braking systems.

HRI-EU developed a machine-learning based algorithm that is trained with everyday riding data. It automatically understands riding maneuvers such as riding straights or preparing, going through and exiting curves.

In cooperation with Honda R&D Europe (Deutschland) GmbH

The algorithm analyzes how precise each of the rider's turns and corners are and how stable the motorcycle is during these maneuvers. Notably, all this is under typical riding conditions on popular weekend routes and riding appropriately in a safe manner. By testing with a number of riders from beginners, intermediates, experts as well as professional test riders and even racing champions, we found that we can reliably classify rider skill from a ride of about 50km. The algorithm is also able to find riding inconsistencies and can measure how smoothly each curve was handled.

We are currently investigating the usefulness of this technology for rider education, first for the Honda internal education of professional test riders and possibly for general driving schools in the future.

We are also researching ways to extend these results by measuring the rider's body posture and, e.g., handle grip strength and body stiffness as well as eye movements with respect to the road and other vehicles using gaze tracking glasses in combination with cameras and convolutional network based object recognition. By this, we want to advance the understanding of the human rider and make Honda motorcycles safer and more adaptable to individual skill and behavior.

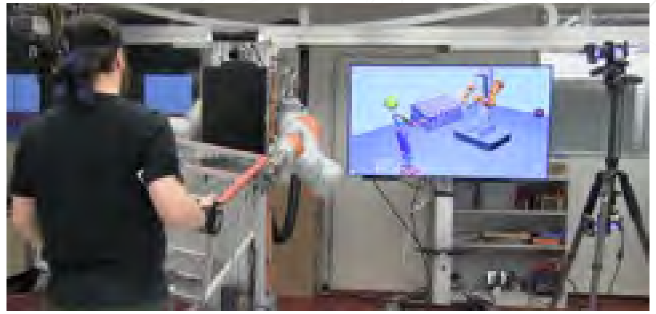
Innovation
Ergonomics for Robots

There is consensus in academia and industry that physical human-robot interaction technology has a large potential for future robotics applications.

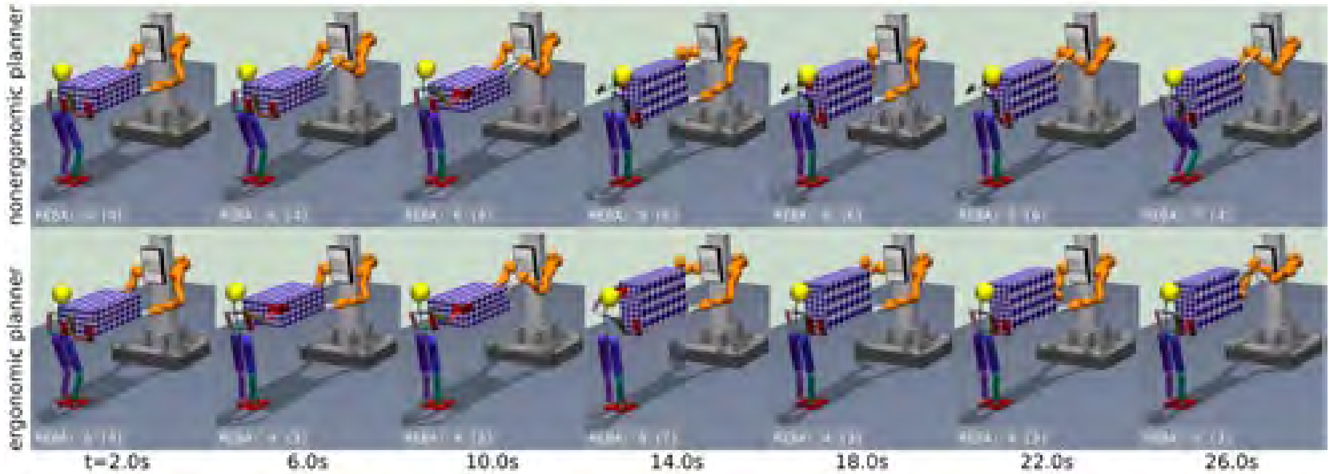
Our research targets the modelling of human motion and behavior within interaction tasks. One aspect is ergonomics. Based on online automated assessments using motion capture systems, we apply algorithms to learn ergonomics prediction models of humans. These allow to predict the near-future ergonomics state of the human in a given situation.

Integrating ergonomical considerations can organize robot behavior in an intuitive way and minimize the ergonomics impact on humans.

Such models are building blocks for the development of novel human-robot collaboration strategies.



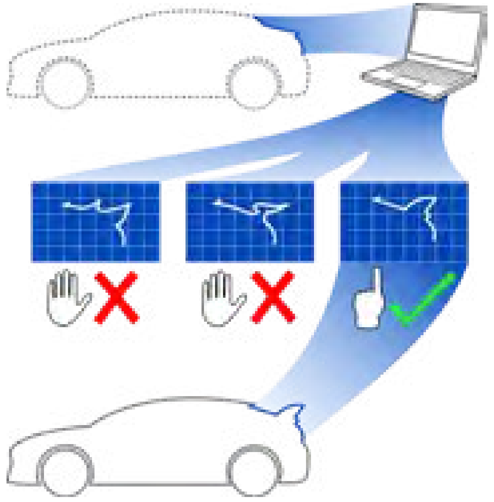
HRI-EU research results demonstrate technologies that allow for personalized production training on the job, as well as ergonomics-aware human-machine cooperation, and a continuous monitoring of the human's health condition. Such novel, collaborative systems can improve the human's working conditions at Honda production sites in the future, and increase the joy of working with collaborative robots.



Innovation
Cooperative Engineering

There is a trend for a holistic perspective in engineering optimization based upon knowledge generation from large heterogeneous data sets, machine learning and search algorithms. New types of human user interaction enable a learning-driven adaptation of the system to not only come up with co-created innovative solutions but also to allow the system to innovate itself online.

At HRI-EU, we research on key components like efficient representations ranging from traditional CAE methods and shape morphing techniques for reasonable shape variations to modern geometric deep learning approaches for building compact encodings in an unsupervised fashion.



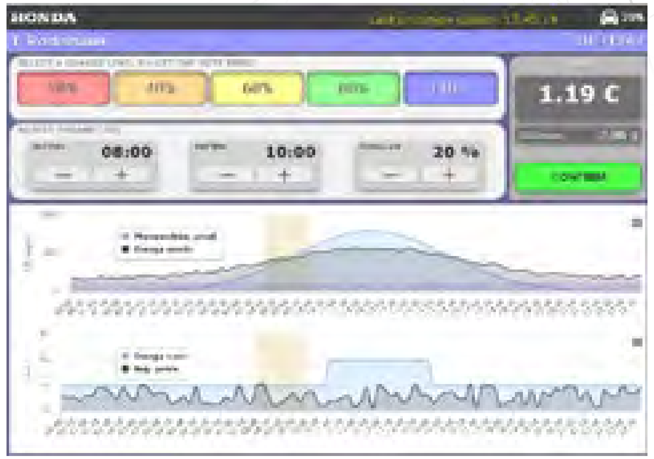
Style transfer research

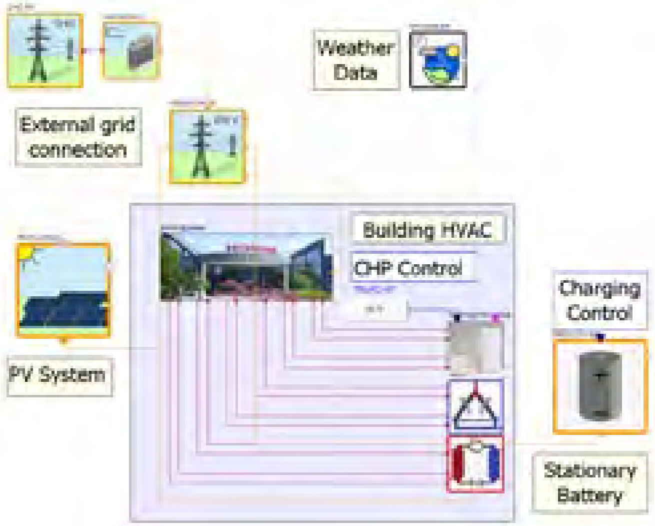
Machine learning allows us to capture the essence from data sets and build models for fast optimization circles in complex industrial applications, leading to the first notion of experience transfer. In addition, human user interaction recorded as process knowledge builds upon the engineer's engagement in the current task for extracting user preferences and self-adapting the optimization system. This bridges the gap from a pure support system to a partnering system in a shared Decision Making environment. This second notion of experience utilization follows the idea of generating a co-creative environment for a cooperative workforce to strive for innovative solutions.

Innovation
Energy Management

Energy Management describes the control of energy production, storage and consumption in complex and often heterogeneous systems in order to increase the overall efficiency. It is a key component to reduce energy costs and greenhouse gas emissions.

A recent challenge is an integrated Energy Management for buildings and e-mobility (electric or fuel-cell vehicles), where cars can be used to balance energy flows. The main goal is finding the balance between the drivers' flexibility and the building inhabitants' comfort demands.





Smart company digital twin

At HRI-EU, simulation models of cars and buildings are employed, so called Digital Twins. This approach allows us to develop and test robust energy management systems in different scenarios under a variety of conditions.

A wide range of control architectures, from simple rule-based approaches to model predictive control (MPC) are explored. Using adversarial and many objective optimization algorithms, the robustness and performance of controller solutions are investigated and increased.

Studied scenarios and applications range from smart home charging solutions to public charging station operations and small smart company premises.

Selected Publications

S. Limmer and T. Rodemann, "Peak Load Reduction through Dynamic Pricing for Electric Vehicle Charging", International Journal of Electrical Power & Energy Systems, 2019

Q. Liu, Y. Jin, M. Heiderich and T. Rodemann, "Adaptation of Reference Vectors for Evolutionary Many-objective Optimization of Problems with Irregular Pareto Fronts", Proceedings of IEEE Conference on Evolutionary Computation, 2019

N. Dommaraju, M. Bujny, S. Menzel, M.Olhofer, F. Duddeck, "Identifying Topological Prototypes using Deep Point Cloud Autoencoder Networks", IEEE International Conference on Data Mining, 2019

E. Raponi, M. Bujny, M. Olhofer, N. Aulig, S. Boria and F. Duddeck, "Kriging-Assisted Topology Optimization of Crash Structures", Computer Methods in Applied Mechanics and Engineering, 2019

G. Yu, Y. Jin and M. Olhofer, "Benchmark Problems and Performance Indicators for Search of Knee Points in Multi-objective Optimization", IEEE Transactions on Cybernetics, 2019

R. Cheng, M. N. Omidvar , A. H. Gandomi, B. Sendhoff, S. Menzel, X. Yao, "Solving Incremental Optimization Problems via Cooperative Coevolution", IEEE Transactions on Evolutionary Computation, 2018

T. Weisswange, S. Rebhan, B. Bolder, N. Steinhardt, F. Joublin, J. Schmüdderich, C. Goerick, "intelligent Traffic Flow Assist: Optimized Highway Driving Using Conditional Behavior Prediction", IEEE Intelligent Transportation Systems Magazine, 2019

C. Maag, N. Schneider, T. Lübbeke, T. Weisswange, C. Goerick, "Car Gestures – Advisory Warning Using Additional Steering Wheel Angles", Accident Analysis & Prevention, 2015

A. Hayashi, D. Ruiken, C. Goerick, T. Hasegawa, "Online adaptation of uncertain models using neural network priors and partially observable planning", International Conference on Robotics and Automation, 2019

F. Muratore, F. Treede, M. Gienger, J. Peters, "Domain Randomization for Simulation-Based Policy Optimization with Transferability Assessment", Conference on Robot Learning, 2018

M. Bühler and T. Weisswange, "Online inference of human belief for cooperative robots", IEEE/RSJ International Conference on Intelligent Robots and Systems, 2018

S. Manschitz, M. Gienger, J. Kober, J. Peters, "Mixture of Attractors: A novel Movement Primitive Representation for Learning Motor Skills from Demonstrations", IEEE Robotics and Automation Letters, 2018

N. Schömig, M. Heckmann, H. Wersing, C. Maag, A. Neukum, "“Please watch right” – Evaluation of a speech-based on-demand assistance system for urban intersections", Transportation Research F: traffic psychology and behaviour, 2018

M. Dietrich and T. Weisswange, "Distributive Justice as an Ethical Principle for Autonomous Vehicle Behavior Beyond Hazard Scenarios", Ethics and Information Technology, 2019

S. Hasler, J. Kreger, U. Bauer-Wersing, "Interactive Incremental Online Learning of Objects Onboard of a Cooperative Autonomous Mobile Robot", International Conference on Neural Information Processing, 2018

M. Hasenjäger and H. Wersing, "Personalization in Advanced Driver Assistance Systems and Autonomous Vehicles: A Review", 2017 IEEE20th International Conference on Intelligent Transportation Systems (ITSC), 2017

B. Metka, U. Bauer-Wersing, M. Franzius, "Bio-inspired visual self-localization in real world scenarios using Slow Feature Analysis", PLOS ONE, 2018

V. Losing, B. Hammer, H. Wersing, "KNN classifier with self adjusting memory for heterogenous concept drift", IEEE International Conference on Data Mining, 2016

Wang, C., "A Framework of the Non-critical Spontaneous Intervention in Highly Automated Driving Scenarios", 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, 2019

F. Damerow, T. Puphal, B. Flade, Y. Li, J. Eggert, "Intersection Warning System for Occlusion Risks using Local Dynamic Maps ", Intelligent Transportation Systems Magazine, 2018

J. Eggert, J. Deigmöller, L. Fischer and A. Richter, "Memory Nets: Knowledge Representation for Intelligent Agent Operations in Real World", International Conference on Knowledge Engineering and Ontology Development, 2019

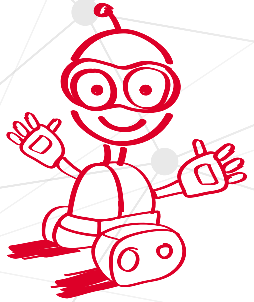
T. Puphal, M. Probst and J. Eggert, "Probabilistic Uncertainty-Aware Risk Spot Detector for Naturalistic Driving", IEEE Transactions on Intelligent Vehicles, 2019

B. Flade, A. Koppert, G. Ve'lez Isasmendi, M. Nieto, A. Das, D. Be'taille, O. Otaegui, J. Eggert, "Low-Cost Lane-level self-localization using filtered GNSS and Camera to Map Alignment", IEEE Intelligent Transportation Systems Magazine, 2019

J. Eggert, "Risk estimation for Driving Support and Behavior Planning in Intelligent Vehicles", Automatisierungstechnik, 2018

D. Shannon, F. Murphy, M. Mullins, J. Eggert, "Applying Crash Data to Injury Claims - An Investigation of Determinant Factors in Severe Motor Vehicle Accidents", Accident Analysis & Prevention, 2018

J. Deigmöller, N. Einecke, O. Fuchs, and H. Janssen, "Road surface scanning using stereo cameras for motor-cycles", 13th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications, 2018



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