

# Mission & vision

**EIASI**

EINDHOVEN  
AI SYSTEMS  
INSTITUTE

**TU/e**

EINDHOVEN AI SYSTEMS INSTITUTE



## INTRODUCTION

Current and future developments in data science and artificial intelligence are expected to create major breakthroughs in the role that engineering systems play in our society. The impact of these breakthroughs will be present in many domains, such as smart robots and manufacturing systems, autonomous cars, and individualized health-care and monitoring systems, and will lead to system capabilities that are beyond our current imagination. The ubiquitous availability of data, and the smart analysis and on-line processing of this data, will allow the development of intelligent systems that are capable of learning to perform complex diagnostic and decision-making tasks, with a high level of autonomy and in harmony with humans involved.

Artificial Intelligence (AI) refers to the capability of computer systems and algorithms to analyze data and, on the basis of the resulting 'understanding' of it, to provide advice or take decisions with some degree of autonomy. As most progress in human civilization to date has been the product of intelligence, extending or augmenting human intelligence through artificial intelligence has the potential to yield enormous benefits.

We realize that AI developments are likely to have transformational societal effects which are, to an extent, difficult to predict. Despite our enthusiasm for the possibilities offered by AI, we will also need to make sure that our work will be beneficial to society and the environment at large. Thus, the main challenges in

artificial intelligence are of a socio-technical nature. In addition to state-of-the-art computer science and engineering, this requires expertise in psychology, ethics, technology assessment and value-sensitive design.

Over recent years, artificial Intelligence has made rapid progress in a host of new applications, predominantly in situations of handling consumer (database/internet) data. This success forms the basis for a second wave of applications that are cyber-physical in nature and positioned in the domain of engineering systems. This second wave will be driven primarily by industrial players. One essential difference between these two waves is that the latter deals with applying AI algorithms to sensor data from complex physical systems.

This is an area where advanced high-tech engineering systems meet artificial intelligence. In-depth domain knowledge will be needed to be combined with AI to develop intelligent machines that meet required domain-specific performance and safety standards. Moreover, to date, artificial intelligence has mostly been used for the purpose of diagnostics and predictive analytics in off-line situations.

The new wave of AI will include autonomous systems capable of learning and real-time (on-line) adaptive decision-making in uncertain, changing environments, in which humans and machines will co-exist and collaborate.

## MISSION AND MAJOR CHALLENGES

The long-term goal of AI-based innovation in EAI is the design of intelligent engineering systems that sense on-line their multimodal environment, learn and understand it, and reason about which action to take to achieve specified goals.

**EAI AIMS TO DEVELOP  
AI-TECHNOLOGY FOR  
REAL-TIME AUTONOMOUS  
DECISION-MAKING IN  
ENGINEERING SYSTEMS THAT  
INTERACT WITH HUMANS.**

By focusing on engineering systems, the effect of AI technology will take place in the real (physical) world, and generally in the presence and with the involvement of humans. Decision-making needs to be interpreted as any operational action for diagnosis, monitoring and analysis, as well as control, task performance and optimization of systems behavior.

In the scope of this Mission, we see the following major challenges:

### **1. Merging model-driven and data-driven approaches as a basis for learning**

The learning of system behavior as well as that of optimal strategies/decision-making will need to be based on heterogeneous data as well as constitutive model information from science domains (e.g. physics). AI for engineering systems will need to integrate and balance the effective use of these resources. In addition, it should actively maintain models of systems behavior and optimal strategies, as well as provide learning strategies.

### **2. Decision-making under uncertainty in complex engineering systems**

Due to

- increasing complexity and heterogeneity of engineering systems,
- increasing interconnectivity of cyber-physical networked systems,
- systems increasingly operating in the open world, interacting with humans and other technology,
- safety-critical operations requiring guaranteed performance in decision-making.

AI algorithms will need to operate robustly with certified performance, provide reasoning mechanisms for decision-making under uncertainty, and handle the complexity of current and future engineering systems while continuously adapting to heterogeneous data from multiple sources.

### 3. Develop systems with long-term benefit for society and the environment

'Responsible AI' cannot not just do what is technically possible and legally permitted - it must take into account the known ethical issues, and be prepared for the unknown ones. So, for example:

- Our systems respect the right to privacy and to data ownership; they are not used to deceive or manipulate users,
- Our decision systems are fair and allow users transparent access to why and how the system makes its decisions. We develop methods to explain and audit AI systems,
- Our systems are safe to use in the workplace, in public spaces and at home,
- Our systems are environmentally sustainable, in fact beneficial to the natural environment.

This is how societal acceptance and long-term benefit are assured.

### 4. Hardware and software architectures

- Hardware for AI: computational hardware and communication technology to efficiently support (embedded) AI computations; sensing and actuation technology to connect to the real world,
- Algorithm engineering: implementations and architectures for efficient AI algorithms.

Innovative hardware and software architectures, as well as new sensing and actuation technology, will enable the development and implementation of AI algorithms in real-life engineering systems.

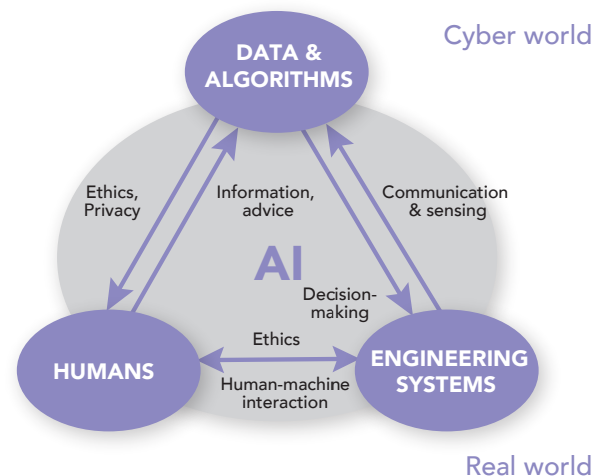
### 5. Connecting and linking data sources

The abundance of data often comes from different sources and locations. To be able to connect, link and implement data in a safe and secure manner, even if distributed approaches are used to access the data, presents ethical, legal, software and hardware challenges.

The creation of data platforms with appropriate software and protocols that allow easy communication between other platforms and systems (from different organizations) is necessary to be able to test and implement AI solutions, in particular in an application domain like health. It also contributes to processes that makes it possible to collect the data needed to derive fair and unbiased results and decisions.

These major challenges will require expertise and contributions from different scientific disciplines. An integrated system view on AI will be developed in a multidisciplinary institute, with key contributions from three key domains:

- Data & Algorithms,
- Humans and Ethics,
- Engineering Systems.



The research performed in the institute will typically be directed towards the lower TRL levels: 1-5/6, ranging from basic technology research to technology development.



# CONNECTING THE CYBER AND REAL WORLD WITH 3 KEY DOMAINS

## 1. Data and algorithms

AI-based algorithms rely on huge amounts of data. Collecting, handling and processing data, represented as design, modeling and learning are at the heart of current AI. Model-driven techniques use data to accurately fit pre-designed models; data-driven techniques construct models from (huge amounts of) data, but are difficult to fathom.

Current AI methodologies are specialized, focusing on particular problems and on “best decisions” or “best strategy” using these data modalities in diverse application contexts, but with little actual perception and understanding of the world. Data-driven modeling and learning techniques in engineering systems are adopting and developing AI and machine-learning approaches to arrive at interpretable models.

### Key Research Aims are:

- Combining and integrating model-driven and data-driven techniques,
- System thinking, systemic techniques as opposed to local and point solutions,
- Adaptive and reflexive systems, capable of continuously optimizing behavior over time and adapting to changing operational conditions – autonomy and agent-based control,
- Continuous evaluation of the trustworthiness of data and algorithms and consequences of decisions,
- The engineering of AI systems: defining and recognizing patterns and solutions, creating subsystems that can be integrated in open world systems. Robustness of algorithms, decision-making, causal inferences and distributed learning are key features,
- Further improvements in algorithms: e.g. multiple tasks, requiring less data, distribution in computational implementations.

## 2. Humans and Human-centered AI

Where in the past our tools have been primarily passive extensions of ourselves, we are now moving to an era where we, as humans, will be working with toolsets as active, intelligent partners. It will require us to rethink and redesign the relationships and the interfaces we have with and to the intelligent technology that we use in our daily lives. This urges us to focus our efforts on the development of human-centered AI, that is, AI that connects to humans, helps and learns from humans, and collaborates with humans in a meaningful way, combining the advantages of AI with those of humans. Even perfectly functioning AI is useless if humans are not willing or able to integrate it in their daily lives and ways of working.

### Key Research Challenges are:

- Optimal human-machine co-adaptation and collaboration, from required organizational processes to individual human-machine interfaces,
- Understanding and mitigating the impact on humans of AI risks, limitations, unintended effects, and errors in relation to (frequently flawed) human behavior,

- AI that is trustworthy and transparent to humans, taking decisions and making recommendations that are robust, fair, explainable and contestable, and designing AI for justifiable levels of trust – based on the ethical behavior of the system,
- Socially, emotionally and morally intelligent machines, able to understand human language, emotions, intentions, values and behaviors, and to interact with sophistication and nuance with humans and their broader value systems.

## 3. Engineering Systems

On the one hand, **future engineering systems** will be highly complex and characterized by large-scale interconnections of dynamic components that will be multi-physics, heterogeneous and where either physical connections or communication links interconnect the different system components. On the other hand, we want to make these interconnected systems more intelligent in order to support autonomous operation in complex environments that include humans. Exemplary drivers to such goals are automated vehicles (cars, drones and ships), automated robotics for manufacturing, construction, agriculture, care & cure, logistics, and Digital Twinning (e.g., for preventive maintenance) to support the transition to Industry 4.0.

### Key Research Aims are:

- Robustly coping with complexity and uncertainty:* due to 1) increasing complexity of engineering systems, 2) increasing interconnectivity of cyber-physical engineering and 3) systems increasingly operating in the open world interacting with humans and other technology under limited sensory information and a dynamically changing environment,
- Meeting requirements for guaranteed performance and safety,* which cannot currently be provided by AI techniques and require an integrated systems approach. Such an integrated approach should be based on innovative synergies between novel learning methods and prior model information,
- Making AI transparent and explainable:* this is currently not provided by AI techniques (e.g., pixel-to-torque control in automated cars) and it is required to systematically interpret, back-trace and analyze causes and effects of achieved behavior with a clear interpretation in the respective engineering context. This requires a fusion of model-based and AI methods to develop systemic design schemes and standardize AI structures for engineering problems,
- The development of dedicated hardware for AI:* computational hardware and communication technology to efficiently support (embedded) AI computations; sensing and actuation technology to connect to the real world,
- Dedicated software engineering for AI:* implementations and architectures for efficient AI algorithms.



## KEY TU/E STRENGTHS

Key and unique strengths of TU/e that are essential in taking on these challenges:

- a. Synergy between the three key domains of Data Science & AI, Engineering Systems and Humans to enable taking on the challenges of developing AI for engineering systems that interact with humans,
- b. Synergy between model-based engineering and system thinking, on the one hand, and AI, on the other hand, to support agile system design for complex engineering systems of the future,
- c. Synergy between systems and control engineering, on the one hand, and AI, on the other hand, to develop next-generation real-time decision-making strategies that guarantee high performance and safety of autonomous systems in complex open world scenarios that include humans and other technology. Here, an integrated systems approach involving sensing, communication, computation, data analytics and AI, hardware design and control is needed,
- d. Unique multidisciplinary collaboration and world-leading expertise regarding the Human Factor in AI whereby the focus is on human-AI interaction design, trustworthy and transparent AI, quality of AI decision-making, human-AI collaboration, organizational embedding of AI, and ethics of AI,
- e. Our embedding in the Brainport region, with a focus on research and technological development in a number of industrial fields: high-tech, healthcare, smart mobility, etc. Combining AI-assisted engineering with the technological challenges in these sectors is a rich breeding ground for AI-based technologies of the future.

## KEY APPLICATION AREAS

There will be an initial focus on three target technology domains, with listed potential benefits:

### 1. High-tech systems and robotics

- a. Guaranteed machine performance under uncertain and changing conditions of operation,
- b. Autonomous machine operation and smart human-operator support,
- c. Multi-agent robotics,
- d. Machine health management and/or predictive maintenance,
- e. Digital twinning for a responsive design cycle and manufacturing process.

### 2. Health applications

- a. Improved and explainable diagnostics capabilities,
- b. Personalized and wearable health systems with monitoring, health risk detection, and adaptation capabilities,
- c. Causal and systemic understanding of individual states of health,
- d. Preventive health management,
- e. Process optimization in health care systems.

### 3. Smart mobility

- a. Vision, sensor fusion and world modeling for automated driving,
- b. Data analytics for high-definition maps for automated driving,
- c. Data analytics for effective and easy-to-use multi-modal transportation systems,
- d. Data-analytics to minimize the environmental footprint of transportation,
- e. 'Data driven control systems for smart charging, V2G management and local storage and production systems.

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# AI FOR THE REAL WORLD

## INTERESTED TO LEARN MORE?

Or to discuss any other AI challenge?  
Let's talk! Contact us at [eaisi@tue.nl](mailto:eaisi@tue.nl)

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