Main focus and Intended Learning Outcomes (ILOs) per Track

Track 1. High-tech Systems and Robotics

Short description

AI is a multidisciplinary field combining methods from computer science, information technology, systems and control and life and social sciences with important implication in the high-tech sector and in robotics. The design, development and integration of AI tools play a key role in virtually all engineering aspects in this sector and require that tools for autonomous decision making and certifying the robust performance of machines in uncertain environments are understood and expanded. This implies a strong focus on control, automated decision making and process optimization. Also, questions on operator support for maintenance of high-tech equipment, the detection and identification of failures, safety and optimized performance, material design, and the discovery of material properties are of key importance to the engineering of high-tech systems and robotics.

Specific AI aspects

Specific AI aspects in the high-tech engineering and robotics area include the combined data- and first principle modeling tools, that yield the basis for process optimization, design, and control of systems. It includes performance enhancement and optimization of processes, data acquisition and analysis for failure prediction, maintenance scheduling, service, support and calibration. Furthermore, it is recognized that for engineering applications in this sector, data by itself is less relevant than the data-human-machine integration. The enhancing and complementing of human decision making in processes is therefore a specific AI related aspect in this track.

ILOs

1. Students are competent in applying and integrating AI tools to enhance perception, planning, monitoring and autonomous decision making for high-tech and robotic systems in order to certify performance and reliable operation of engineered systems or devices in the high-tech and robotic sectors.
2. Students are aware that decision making systems need to operate in real-time, with high levels of reliability, performance and safety, and that these systems can be held accountable for malfunctioning, failures and safety or security critical situations.
3. Students have identifiable domain knowledge in the interdisciplinary field where high-tech and robotic systems are used, developed and applied.

Domain-specific knowledge

Main focus

- Mechanical (heat, fluid, material, motion), Electrical (components, electronics, energy, communication, signal processing), Physics (fluids, bio soft matter, fusion, plasma engineering, rheology), Systems and Control.

AI in Engineered Systems

Main focus

- Main focus of AI in engineered high-tech and robotic systems include sensor and actuator technology, the use of AI in system design and manufacturing, optimal control, communication technology, hardware architectures and computing, AI on devices.

Data cultivation

Main focus

- acquiring and processing data: analysis, processing, mining, interpretation, system excitation, probing, active data generation, active fusion and linking of data and measurements, measurement and data-processing algorithm design, data quality, standardization, cleaning of data, treating "imbalanced data".

Learning and intelligence

Main focus

- data-based learning and decision-making: merging model-based and data-based methods for learning, optimal decision making and control in uncertain environments; verification and performance certification in safety critical situations; modeling and complexity management in cyberphysical systems; supervised, unsupervised, distributed, reinforcement, machine, deep learning, neural networks; human interfacing.

Track 2. Mobility

Short description

The area of mobility is one of the core research themes at TU/e and covers many automotive aspects including

- Assistive and automated driving
- Sensor fusion, vision, interpretation
- Safety, security, reliability, verified and certified performance in uncertain, chaotic or safety critical situations
- Behavioral analysis
- Infrastructural design and transportation networks
- V2X communication and management
- Electrification, energy management
- Mobility systems

Specific AI aspects

- behavioral analysis (sentiment, emotion, influencing)
- linked data in autonomous driving
- pattern recognition, object recognition, visualization, real-time data analysis
- assistive devices for driving, automated decisions
- network resources, communication and computation
- multi-agent modeling
- travel demand data

ILOs

1. Students are competent in developing, applying and integrating AI tools to enhance perception, planning, monitoring and both assistive and autonomous decision making in vehicles, in order to analyze performance, reliability and safety. They are competent in leveraging AI tools for the design and operation of transportation networks and infrastructure.
2. Students are aware that AI tools can be held accountable for safety critical and possibly life-threatening situations and have to operate in relation to human users.
3. Students have identifiable domain knowledge in the interdisciplinary and multi-level field of mobility, where energy management, behavioral analysis, communication, computation need to result in safe and reliable vehicles, and in mobility systems that are efficient and sustainable, whilst also fostering justice and wellbeing.

Domain-specific knowledge

Main focus

- Mechanical (motion, heat, materials), Electrical (power electronics, electromagnetism, components, electronics, energy, communication, signal processing), Systems and Control, Environmental (urban flow, people flow, traffic)

AI in Engineered Systems

- *Main focus*
  Main focus of AI in motion systems include sensor and actuator technology, the use of AI in assistive devices for driving, automated decision making, electrification and energy management, communication and design in the relation between infrastructure and vehicles, network resources and communication protocols, computation, imaging, pattern recognition, behavioral analysis. Network flow optimization. Co-design optimization.
- Specific course items are model based controller synthesis, sensor and actuator development, advanced powertrain design and decision support in transportation and logistics.

Data cultivation

Main focus

- Data fusion, image and pattern recognition. Semantic data interpretation in vision-based data. Data justice.
- Specific course items are data fusion, image and pattern recognition, semantic data interpretation in vision-based data, and on human interaction and high-level learning.

Learning and intelligence

Main focus

- Merging model-based and data-based methods for learning. Optimal decision making and control in uncertain environments.

- Verification and performance certification in safety critical situations. Modeling and complexity management in cyber-physical systems. Supervised, unsupervised, distributed, reinforcement, machine, deep learning, neural networks. Human interfacing.

Track 3. Healthcare

Short description
The area of health is one of the core research themes at TU/e and covers diagnostic processes, the monitoring through digital, mobile and wireless technologies, assistive devices or assistive augmentation as they occur in hearing, speech, mobility, cognitive aids, rehabilitation. But also cognitive aspects, human-AI interaction and actuation, medication, self-organizing mechanisms.

Specific AI aspects

- Reliability and robustness
- Explainability & interpretability (saliency mappings, clinical decision models, uncertainty modeling)
- Data efficiency
- AI architectures (for e.g. image analysis, drug discovery, automatic reporting)
- Privacy & ethics (legal knowledge, data acquisition protocols)

ILOs

1. Students are competent in the use of AI tools in health-related applications and are aware of ethical and regulatory considerations of these tools in clinical and general health-care applications.
2. Students are aware of legal and ethical aspects related to the acquisition, storage and use of data in health-care systems.
3. Students have identifiable domain knowledge in the interdisciplinary field of healthcare where human aspects are combined with technical aspects to develop safe and reliable systems for diagnosis, monitoring, treatment and treatment planning in healthcare.

Domain-specific knowledge

Main focus

- Because of the strong interdisciplinary character of the topic the choice is decided on the basis of suggestions from the graduation group.

AI in Engineered Systems

Main focus

- Medical imaging fundamentals (MRI, Ultrasound)
- Monitoring and healthcare
- Healthcare management

Data cultivation

- Data collection and preparation

Learning and intelligence

Main focus

- AI architectures, foundation models and deep learning
- Human-AI interaction

Track 4. Smart Cities and Energy Systems

Short description

The track "Smart Cities and Energy Systems" covers intelligent and optimized buildings (Ambient Intelligence, data-driven buildings, smart building monitoring and control, IoT-enabled automation), AI-driven Digital Twins for building- and urban decision making, smart mobility (smart transportation and intelligent traffic management, autonomous vehicles), intelligent energy systems (renewable energy generation, load forecasting, electricity markets and power system optimization) and smart human-environment interaction (smart infrastructure, multi-agent systems, inhabitants).

Specific AI aspects

- Buildings: AI-driven monitoring and control of Heating, Ventilation and Air Conditioning, lighting, energy management and acoustics systems, robotic construction, generative design, decision support systems, data-driven smart buildings
- Vehicles: automation and high-tech robotics in construction and manufacturing, autonomous mobility
- Citizens: Indoor Environmental Comfort optimization, Ambient Intelligence, smart safety and security, urban flow monitoring of people, goods and traffic
- Energy Systems: learning and forecasting demand, energy consumption scheduling based on pricing, integrating electricity markets with power system generation, enhancing stability of distributed energy systems

ILOs

1. Students are competent in the use of AI tools to enhance the design, construction, quality, comfort or facilities in buildings, in autonomous vehicles, in urban decision making involving the flow of traffic, people and goods, or for control and optimization of energy systems, including renewable generation and electricity markets.
2. Students are aware of ethical aspects related to the acquisition, storage and use of data in autonomous vehicles, buildings, energy systems, and urban decision making and that systems can be held accountable for malfunctioning, failures, safety, privacy and security critical situations.
3. Students have identifiable domain knowledge in the interdisciplinary field of transport and logistics, design and manufacturing, and cognitive aspects in engineering.

Domain-specific knowledge

Main focus

- Building Information Modelling and intelligent buildings
- (Micro)Traffic simulations and Innovative mobility services (MaaS, Sharing services)
- Smart urban systems
- Intelligent energy systems, smart grid applications and electricity markets

AI in Engineered Systems

Main focus

- Robotics and building automation (smart buildings)
- Image processing, sensors, and system safety
- Smart Human-Environment interaction and Human – System interaction
- Control and operation of future energy systems

Data cultivation

Main focus

- Building Information Modeling and Geographic Information Systems
- Advanced information processing in city and data fusion
- Human - environment interaction in urban engineering domain

Learning and intelligence

Main focus

- Building Performance and Energy Systems Simulation
- Data fusion and sensing in Autonomous Vehicles

Track 5. Science and Discovery

Short description

This track covers foundational aspects of artificial intelligence in connection with its emerging role in fundamental and engineering sciences. The track aims to educate students in the quickly growing role that artificial intelligence plays in scientific discovery. Specific themes in this track are:

- Merging model-driven and data-driven approaches in learning
- Trustworthy data integration
- AI in Fluids, bio soft matter,
- AI in Materials design and materials discovery
- AI for Energy (e.g. fusion)
- AI for design and decision making for complex engineering systems
- AI for Model discovery and Metrology
- Physics-informed machine learning

ILOs

1. Students are competent in contributing to the use or development of artificial intelligence for scientific discovery and metrology.
2. Students are aware of ethical implications of scientific discoveries and potential limitations of Artificial Intelligence as a discovery tool.
3. Students have identifiable knowledge for enabling novel applications of AI or have proven skills for broadening the accessibility of AI towards different applications or application domains.

Domain-specific knowledge

Main focus

- Physics (fluids, bio soft matter, fusion, plasma engineering, rheology), Mechanical (heat, fluids), Systems and control.

AI in Engineered Systems

Main focus

- Discovery, metrology, modeling and simulation.

Data cultivation

Main focus

- Model simplification and surrogate modeling. Data collection and algorithmic design.

Learning and intelligence

Main focus

- Modeling and complexity management in cyberphysical systems; supervised, unsupervised, distributed, reinforcement, machine, deep learning, neural networks; human interfacing. Embedding of structural knowledge and symmetry. Verification and performance certification in safety critical situations.

Track 6. Manufacturing Systems

Short description

Manufacturing forms the backbone of the Dutch economy. The Fourth Industrial Revolution (Industry 4.0-5.0) is transforming this sector through unprecedented advances in digitalization, automation, and networking technologies, creating significant opportunities for smarter manufacturing. Through the integration of AI tools, smart manufacturing systems enable automated decision-making in manufacturing operations and supply chains, manufacturing logistics, multi-agent systems for scheduling, digital twins and cyber-physical production systems, human-robot interaction in manufacturing and warehousing.

ILOs

1. Students are competent in the use of AI tools in the modeling, design, analysis and control of manufacturing systems and material handling systems operating in dynamic and stochastic environments.
2. Students are aware that AI tools in manufacturing systems can be held accountable for malfunctioning, failures and safety or security critical situations and have to operate in relation to human users.
3. Students have identifiable knowledge on the interdisciplinary domain of manufacturing systems where logistics, data collection and analysis, stochastic modeling, control technology, maintenance and failure detection, isolation and prediction are combined.

Domain-specific knowledge

Main focus

- Fundamental knowledge on traditional and modern manufacturing processes. Digitalization in manufacturing.

AI in Engineered Systems

Main focus

- The use of AI in the design, analysis and control of manufacturing systems and material handling systems for manufacturing logistics

Data cultivation

Main focus

- Manufacturing systems equipped with sensors generate huge amounts of data (both on processes and products) in a smart factory. The collection and analysis of such data is the main focus. Building stochastic simulation models and using it for manufacturing analytics by using input data with end-to-end traceability.

Learning and intelligence

Main focus

- Sequential decision making under uncertainty, where machine learning models play a role in representing uncertainty.
- AI algorithms for making (real-time) decisions in a factory with human planners/operators in the loop.