PROFESSORSHIP

Computer Vision & Data science

I'M A.I.

IMage Processing and
Artificial **I**ntelligence

NHL STENDEN
university of applied sciences

Introduction

Computer vision revolves around the visual perception of the world through the use of image processing algorithms. Typically, the goal is to automatically analyze properties of objects in a wide variety of contexts. This enabling technology has many applications: disease and insect classification in agriculture, bacterial colony counting in water samples, optically measuring blood flow during surgery, recognizing polymer types using hyper-spectral camera technology, detecting anomalies in x-ray images, analyzing behavior of traffic to improve safety, which are just a few examples of the exciting applications the professorship Computer Vision & Data Science (CV&DS) worked on.

Recent advancements in artificial intelligence (AI) show that learning from data achieves groundbreaking results on almost all applications, particularly in notoriously difficult fields like computer vision, natural language processing and audio processing. The main ingredients needed for the successful application of AI are models, data, human resources and a lot of computing power.

RESEARCH ASSIGNMENT

The professorship CV&DS is at the forefront of applied research in its field. With over two decades of experience in helping companies integrate image processing and AI into their organizations, we continue to follow our main mission:

"To share and broaden the collective knowledge on Artificial Intelligence and Computer Vision through cutting-edge applied research by solving real-life challenges in a team of students, teacher-researchers and companies."

Innovative education

The professorship Computer Vision & Data Science implements the Design Based Education (DBE) educational concept. Students, teacher-researchers and companies work together on real-life projects in a complex and international context. This creates an inspiring environment which promotes intrinsic motivation and thereby achieves added value for all stakeholders. The roles are tuned to optimize learning for everyone, while at the same time be goal-oriented so that the outcome of a project is of real value.

The **student** learns about artificial intelligence, computer vision and machine learning in the practical and theoretical professional context. Both minor and master students from several disciplines work together in project teams to dive into the challenge which was posed by the companies.

The **company** gains access to cutting-edge knowledge and gains insight on how artificial intelligence, computer vision and machine learning perform in their own practical business context. A research team of AI experts and students forms a durable professional relation with the companies to successfully apply AI.

The **researcher** uses and expands their expertise and works in the central role of the project leader and expert. In the diverse and engaging context of real-life projects they connect research, education and companies and are responsible tangible and valuable results for the project.

For this well-balanced triangle of roles is important to achieve research, educational and company goals. These roles strengthen in such a way that the collaborative result is more than the sum of its parts.

Research focus

A strong trend in computer science that extends to the field of artificial intelligence is Moore's law, which states that the number of transistors in a microchip doubles every two years. From this it can be inferred that the cost for computing power decreases and, because current AI advancements rely heavily on the available processing power this causes AI to rapidly advance with it.

Since the inception of computing, this trend has caused a shift in how we approach practical problems. Where in the past, technical solutions were sought in logically defining solutions by programming and rule-based systems, nowadays, the problems are described in the form of annotated data and exemplar images or written natural language from which the AI system learns or on which the AI acts.

Through extreme amounts of data and seemingly abundant computing resources, foundation models have emerged that are able to generally solve long standing problems like image segmentation, tracking and chatting. These models can only be trained using large investments in, mainly, the electricity bill. This important energy resource is not infinitely available, we need either Moore's law to cut the overall cost of AI or think of more clever solutions.

Because, in AI, a solution to a practical problem is defined by the data, the Achilles heel remains the quality of the data. The higher the quality of the data, the more effectively the model can be trained. Similarly, following a proven problem-solving strategy, defining sub-tasks makes finding a solution for a problem easier. This means that cleverly combining several models makes the whole system less dependent on large amounts of data. Some sub-tasks can, for example, be easily solved by the existing pre-trained models, while others remain too problem specific and require further fine-tuning.

This data-centric strategy has proven invaluable to solve practical applications using AI and computer vision. While the most straightforward solution might be to ever increase data and computing power, for real-life applications this might not be feasible. Taking x-ray images of humans requires low dosages, harmful insects like the green-peach-aphid are rare, windmill-blades are hard to reach, seasonal products like fruits are not available most of the time. In most of these applications there is an inherent data shortage that needs to be addressed.

The research focus will be on developing strategies for optimally using the available data to solve specific real-life tasks either in a model-centric or a data-centric approach. On one hand there is the effect of the data itself: quality of the images and annotations, availability of images and annotations, distribution of the classes or missing and unknown classes. On the other hand, there is the architecture of the models themselves: how do models handle missing data for anomalous classes, how can models be trained with bad quality data or small data, how can automatically selecting appropriate images help in improving overall performance.

Apart from the established strategies like data-augmentation and fine-tuning to create models using relatively small amounts of data, a new and exciting research direction is the combination of model-centric and data-centric approaches. This revolves around using synthetic images when there is not enough real data available. This is a research topic which involves creating visually convincing digital twins of processes, either using pre-trained deep learning models, 3d graphics or a combination of both. This can be seen as an extension of data-augmentation and requires handling the interplay between big-data, small-data and models as well as clever solutions for combining and adapting general models for specific tasks.

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Research lines

The professorship focusses on three main research topics: artificial intelligence, computer vision and vision systems, both where there is data-abundance and for applications which have to deal with data-shortage.

ARTIFICIAL INTELLIGENCE

Deep learning is at the core of the current AI revolution and represents the main research focus of the professorship. How can common practical tasks like quality control, defect classification, disease detection, object recognition and segmentation be automated using deep learning? This includes research into the development of the following tasks:

- **Anomaly detection** research focusses on applications when there are only negative samples available, and examples of positive samples are missing. This can be used to detect anomalies, unknown damage and other deviations from normal situations.
- **Synthetic data** research focusses on generating digital twins using pre-trained generative models which are fine-tuned to generate data from a few exemplary images, text prompts or 3d graphics.
- **Few-shot and zero shot** research focusses on handling situations when there are only a few images per class available or even for situations where there are no images available.
- **Explainable AI** aims to give feedback on where the models were basing their decisions on. This research focusses on how to prevent the model from overtraining on small amounts of data and has broader applications in signaling bias and alleviate the black-box nature of AI.

Further research lines focus on improving data quality the use of sophisticated image acquisition set-ups and automated image-data mining and image querying strategies.

COMPUTER VISION

Computer vision represents research into the main data modality that the professorship focusses on: image and video data. This includes the research and development in traditional computer vision algorithms and imaging:

- **Image acquisition** research focusses on how to optimally collect image data using state-of-the-art equipment. This encompasses choice of illumination, lasers, lenses, optical filters and cameras for high resolution and high-speed imaging using area scan, line scan or mosaic sensors.
- **Hyper-spectral and multi-spectral** are advanced image acquisition methods to collect image data in a broad range of visual spectra with narrow spectral bands. This has applications in detecting and recognizing materials using Short Wave Infrared (SWIR) or to measure heat sources using Long Wave Infrared (LWIR).
- **Pattern recognition** includes research into the application of traditional machine vision and machine learning algorithms where pure deep-learning solutions struggle. Applications include 3d geometry using multi-camera set-ups, key-point detection and sub-millimeter measurement.

VISION SYSTEMS PROTOTYPING

In all applied research projects one of the most important outcomes is the prototype. This is a technical working system that shows the performance of the solution. This represents the final pinnacle of all research efforts and revolves around the following steps:

- **Prototype** it is the tangible demonstration of the work. This represents the main deliverable to the stakeholders. It includes all software and hardware components needed to reproduce experiments and is a strong base to continue to the next steps.
- **Software and optimization** is needed after successfully demonstrating performance of an algorithm in the prototypical phase. This step focusses on optimizing the solution for the practical application. This includes: algorithm optimization, mixed-precision and other model optimizations like pruning.
- **(Robot) integration** requires a well-designed interface between the vision system and the high level system. In our research we use either custom designed software interfaces for integrating the research or use existing platforms like Robotic Operating System (ROS).
- **Smart data** is the process of turning raw data into information. In research this involves cleaning and validating the data, performing visual and statistical analysis, applying algorithms and models, and leveraging advanced technologies to extract relevant information to provide insight.

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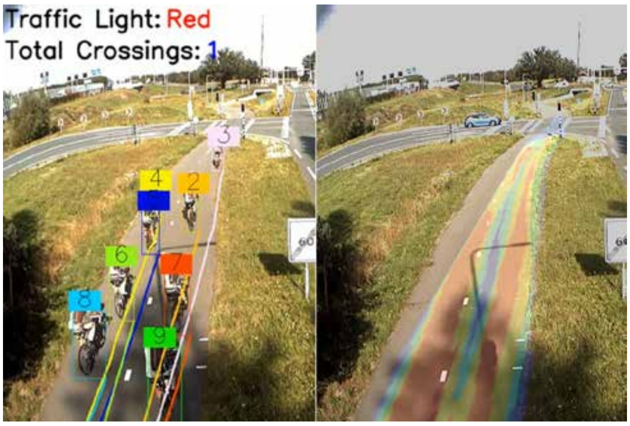
Cutting-edge projects

A few example projects showcase the activities of the professorship. They are closely chosen to showcase the research focus and the research lines.

Smart Traffic Analys and Traffic Safety (STATS)



Goal:	Use AI to automatically detect behavior of traffic participants. This information serves to improve decision making to optimize traffic safety.
Main challenge:	How to leverage AI to take measurements such as, position and speed, and transform this into high-level traffic behavior.
Result:	A demonstrator which uses AI to track an detect red-light crossing of bicycles. A network of public institutions and companies to define and execute future research projects in the STATS space.
Future:	Development of follow-up project to improve traffic safety.

Few shot ship corrosion detection

Goal:	Detect the corrosion of metal in ships.
Main challenge:	The large variation in the visual appearance of corrosion combined with the availability of only a few example images requires advanced few shot models.
Result:	A few-shot model that recognized ship corrosion from only a few training images.
Future:	Apply the few-shot approach to other context in which only a limited amount of image data is available.

Contraband anomaly detection

Goal:	Detect contraband in x-ray images.
Main challenge:	Contraband shape and features are not known in advance and there is limited data available. To limit the hazardous x-ray exposure the data has a low signal-to-noise ratio.
Result:	An anomaly detection AI model to detect previously unseen contraband.
Future:	Further improvement of the anomaly detection algorithms and investigate this performance in other applications.

Potato-Y virus detection using XAI

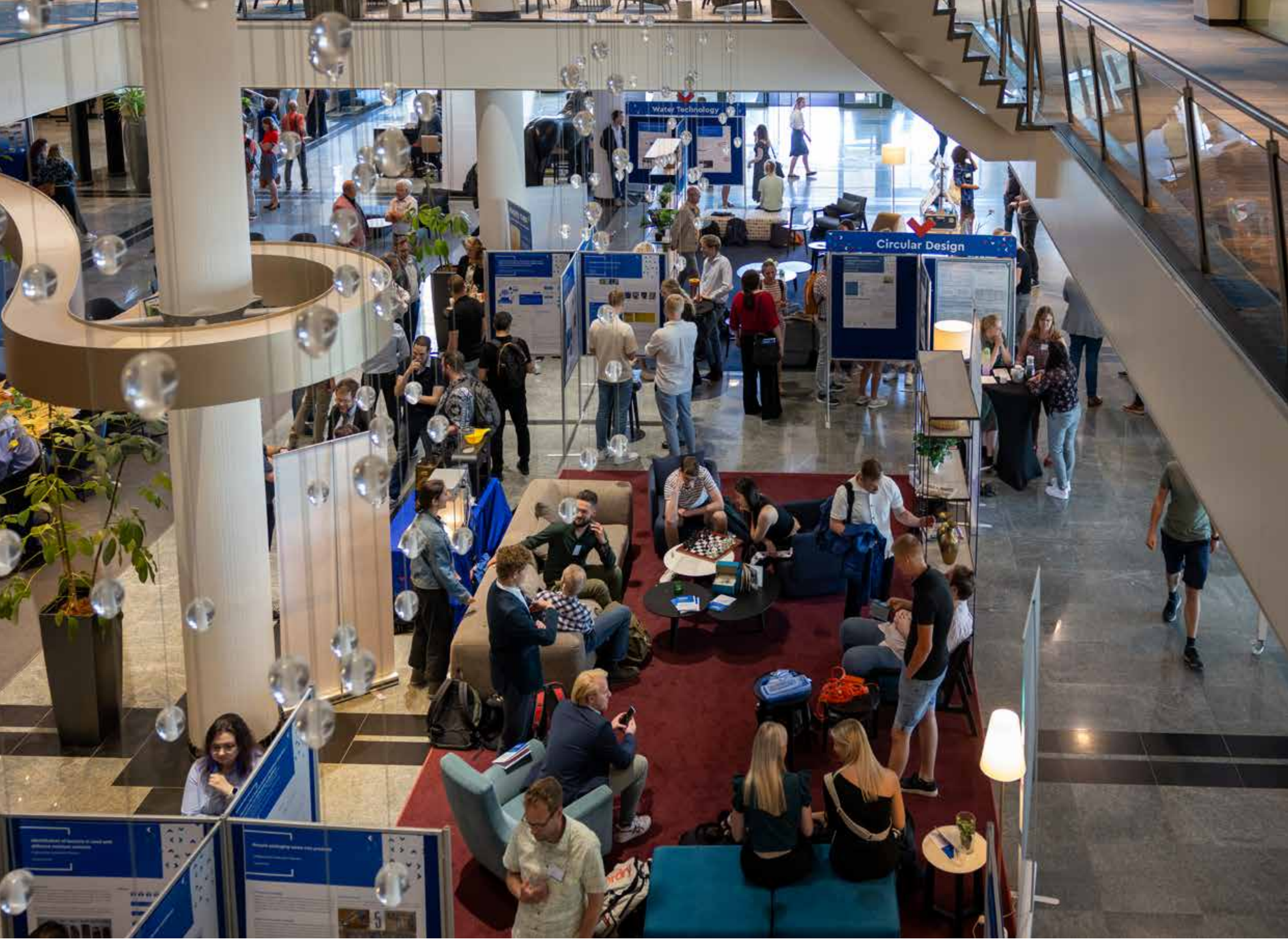
Goal:	Detect the potato-Y virus infection using AI.
Main challenge:	The limited availability of image data of diseased potato plants combined with the subtle visual distinction of diseased and non-diseased plants.
Result:	An AI model that detects the potato-Y virus from images and an explainable AI output that shows which input-pixels caused the decision.
Future:	Integration of advanced XAI to improve debugging of models that are prone to overfitting due to small datasets.

Apple detection using synthetic data

Goal:	Detect and measure apples in orchards.
Main challenge:	There is a limited amount of image data available due to the apple being a seasonal product.
Result:	A model that generates realistic images of apples on which the AI detection models is trained. The model is trained on synthetic images and shows impressive real-image accuracy.
Future:	Use more sophisticated models to generate visually convincing image data to reduce the need for expensive real-life data collection.

Real-time Aphid detection

Goal:	Detect aphids in real-time.
Main challenge:	The small size of the insect and the large variety of insects the extreme class-imbalance.
Result:	A vision system set-up that creates sharp images of flying aphids in real-time.
Future:	Improving the detection models and extend to the detection of other small and harmful insects.



AI for everyone

IMage Processing and **A**rtificial **I**ntelligence (IMAI) is the new organizational umbrella for bringing AI technology and AI applications together. It is built from the strong and established base of computer vision & data science. In IMAI the four main components contribute to the ambition of making AI available to everyone:

The **IMAI Research Community** is where cutting-edge applied research is performed. Here students, teachers, researchers and companies work together in a DBE-atelier to solve real-life challenges with AI technology.

The **IMAI Learning Community** brings together companies, students, researchers and teachers to learn about the exciting possibilities of AI. There is room for every level and discipline ranging from AI 101s to AI deep dives as well as thematic sessions on various application domains and technological domains.

The **IMAI Business Community** brings together companies and networks who want to collaborate on shared challenges within AI. This is where new networks are born and established consortia inspire with results they already achieved.

The **IMAI Store** is the physical location where interested parties can get inspired about the possibilities of AI and bring their own data to brainstorm and get advice from experts.

"AI technology is revolutionizing a myriad of applications in ways that were once inconceivable. What was deemed impossible just a few short years ago is now accessible to everyone. In the future, AI will be the driving force for innovation in almost every domain."

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