Research Project for the Research Master Data Science

Project title: 1 Data-driven churn prevention and customer-specific sales optimization at Stadtwerke Bielefeld

Project overview

Number of Students	1
Project Type	Project with external partners
Project Owner	
Project Context	The project takes place in close cooperation with the Stadtwerke Bielefeld Group. Contact persons from the areas of business development, IT and data protection are available. The database includes data from four companies in the Group with a fivedigit number of customers, whose opt-ins allows a data-driven evaluation. Workstation and a regular presence in Bielefeld are planned.

Abstract

The Stadtwerke Bielefeld Group is confronted with high customer churn in the energy market. The aim of the project is to develop a data science model to predict churn and derive customer-specific sales measures. The students analyze existing data, develop a predictive model and support the integration into the sales processes for sustainable customer retention.

Short description

The energy industry is undergoing profound change: following the liberalization of the markets, customers are increasingly aware of the steadily growing market offering, as a result of which the industry is characterized by increasing competition and rising demands for sustainability and customer orientation. The Stadtwerke Bielefeld Group, consisting of the energy, heating, water, telecommunications, mobility and public baths divisions, is facing intense price competition and growing customer churn, particularly in the energy sector. This churn leads to a loss of sales and makes long-term planning more difficult.

The project addresses this challenge by using existing customer data from four divisions to develop data-driven models to reduce churn. If necessary, data can also be obtained from external service providers to check their contribution to more meaningful models. The aim is to better understand churn motives and patterns as well as the characteristics of churners and to create a predictive model that identifies customers at risk of churning at an early stage. In addition, customer-specific measures for customer retention and sales optimization are to be derived together with the sales department. This can lead to further practical questions that can be decisively supported with the help of the data model.

The solution offers considerable added value for the company and the Bielefeld location: targeted preventative measures can reduce customer churn, stabilize sales and thus enable a municipal company to continue investing in the region in the long term. At the same time, the project enables a data-based, personalized customer approach that sustainably improves customer satisfaction and loyalty. The project thus makes a key contribution to the digitalization and future viability of municipal utility companies in a dynamic market environment.

Task definition

- Review and evaluation of the existing data situation and identification of data gaps
- Analysis and characterization of churn customers and the structure of their supplier change behavior
- Development and validation of a predictive churn model
- Derivation and testing of measures for churn reduction and customer-specific sales optimization
- Support with the integration of the model into operational systems and processes

Reference to the topic of data science

The project deals with central data science disciplines:

- Data exploration and preparation
- Feature engineering
- Classification and predictive modeling (e.g. random forest, XGBoost, logistic regression)
- Model interpretability (Explainable AI)
- Integration of models into operational systems (e.g. CRM)
- Evaluation of measures (A/B testing, impact analysis)

Available resources

- Customer data (with opt-in) from four companies in the Stadtwerke Group (5-digit number)
- Contact persons from sales, IT and data protection

Project plan

First Semester: Preparation of a research exposé, familiarization with and evaluation of the data situation, derivation of measures to optimize data quality, coordination with the departments, first simple statistical analyses

Second Semester: Literature research on churn prediction and customer-specific sales management, preparation of an overview paper, preparation of a proof of concept

Third Semester: development and validation of the churn model, first quantitative results, publication of a paper

Fourth Semester: Master's thesis including final integration of the model into the processes and final colloquium

Necessary competencies

Mandatory:

- Good knowledge of German
- Willingness to familiarize yourself with the company's processes, including assessing the project's evaluation procedures together with data protection and ensuring their compliance

Optional:

- Experience with data science projects in companies
- Experience in working with a business warehouse desirable (e.g. SAP BW)
- Experience with CRM systems, ideally SAP C4C desirable
- Knowledge of the energy industry

Acquirable competencies

- Application and evaluation of modern data science methods in practice
- Development and operationalization of predictive models
- Interdisciplinary collaboration with experts in the field
- Presentation and communication of analysis results
- Experience in dealing with sensitive customer data and data protection

Research project for the Research Master Data Science

Project title: 2 Learning digital twins

Project overview

Number of students	1-3
Project Type	Project with external partners
Project Owner	Prof. Dr.-Ing. Christian Schwede
Project Context	Project in cooperation with the **Fraunhofer Institute for Software and Systems Engineering** (ISST) in Dortmund and in the context of the **Center for Applied Data Science** (CfADS) and **the Institute for Data Science Solutions** (IDaS); employment as a student assistant at Fraunhofer is possible

Abstract

The aim of the project is to learn simulation-based digital twins for planning and controlling production and logistics environments from IoT data. It builds on and extends the open source framework OFacT developed by HSBI and Fraunhofer ISST. The data comes from Fraunhofer customer projects and the CfADS IoT Factory. In addition to process mining methods, generative models such as large language models (LLMs) are also used.

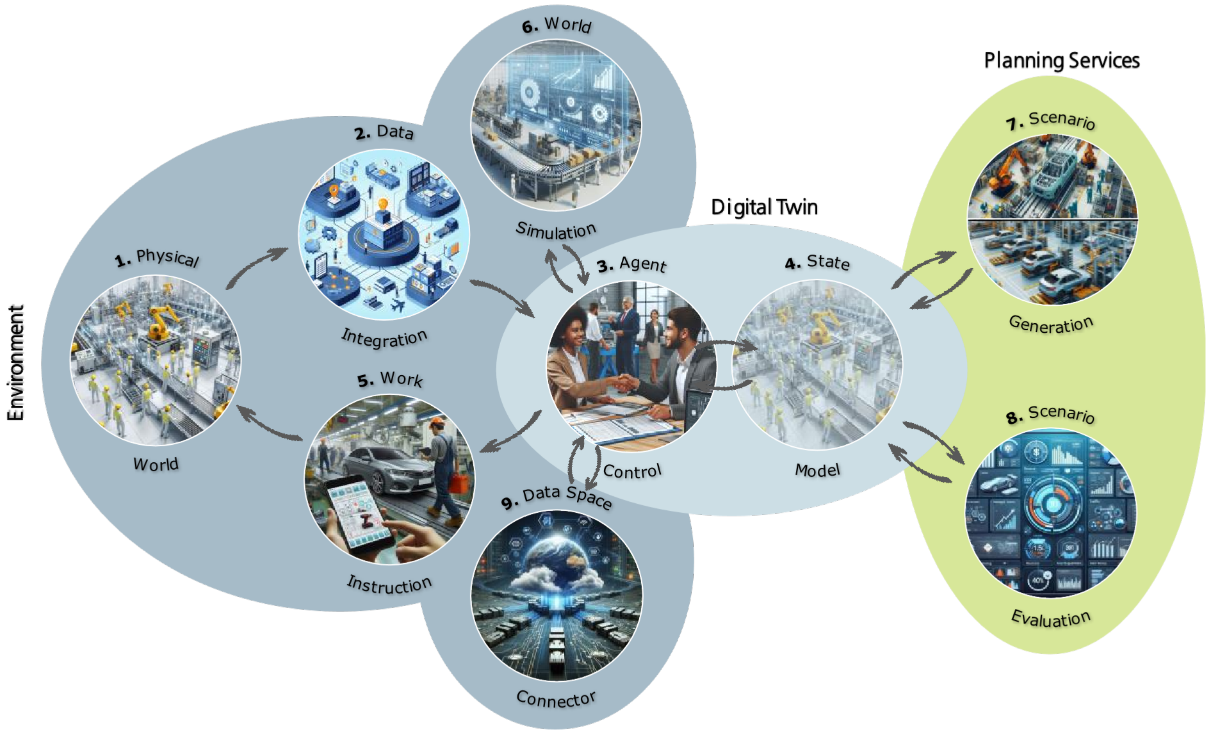
Short description

Digital twins are the key to the optimal design, planning and control of production and logistics environments. These software frameworks allow access to a constantly updated digital image of the system, enable the optimization and simulation of scenarios in this virtual environment and communicate changes directly back to the store floor by means of work instructions. In this way, decisions can be evaluated and optimized in all phases of the system's life cycle before they are made. Both long-term changes to the system and reactions to short-term disruptions can be optimally implemented. The potential for companies is estimated to be very high (forecast market volume of USD

10 billion in 2028[1]). Fraunhofer ISST and HSBI have created the open source framework OFact (Open Factory Twin), which allows small and medium-sized companies in particular to digitize their production systems.

OFacT
Open Factory Twin

OFacT is based on a standardized state model that can be used to map any discrete material flow system. Any data interfaces can be addressed via the data integration module. The system is controlled by a multi-agent system so that control rules can be mapped and changed in a highly flexible manner and separately from the state model. The agents also control the material flow system by means of work instructions.



As an environment, the framework can draw on a simulated reality to evaluate scenarios, for example. Planning services allow the creation and optimization of alternative courses of action and a dashboard allows evaluation based on standard key figures.

[1] Bain & Company: Global Machinery & Equipment Report 2024

An important hurdle in the implementation of digital twins in small and medium-sized companies is the cost of manual modeling by experts. These costs are incurred not only during the creation, but also during regular updates. The aim of this project is therefore to learn digital twins from company data.

Task definition

In the project, the student should use methods from the field of machine learning to learn OFacT models based on data from production environments. The IoT data or event logs from the store floor of companies often already contain a lot of the graded information. Data from existing industrial projects from Fraunhofer ISST or the IoT Factory on the Gütersloh campus can be used. In addition to process mining methods, regression and classification methods, e.g. based on deep neural networks, will be used. It will also be investigated to what extent parts of the models can also be created with current Large Language Models (LLM). For this purpose, it may be useful to use Retrival-Augmented Generation (RAG) to provide the LLM with domain-specific information.

Reference to the topic of data science

The regression and classification methods used, as well as LLM and RAG, are part of the Research Master's course and core areas of Data Science.

Available resources

- Data is provided via Fraunhofer ISST and the IoT Factory
- The open source framework OFacT is being developed at HSBI and is available
- Hardware for machine learning is available via the Data Science Lab, CfADS and the AI computing cluster yourAI at HSBI

Project plan

First semester: Preparation of a research exposé as an examination. Familiarization with the task and the OFacT framework.

Second semester: Literature research on the generation of models using machine learning methods, in particular LLMs and RAG. Review of data sets and application of first simple methods of process mining and existing language models. Preparation of a paper that gives an overview of the research area is an examination achievement.

Third semester: Practical implementation of your own solution and generation of an OFacT model for a specific application. Publication of a paper with the first results is an examination achievement.

Fourth semester: Master's thesis and colloquium. Final evaluation by comparing different methods.

Necessary competencies

Mandatory:

- Programming skills (e.g. Python) Optional:

- Experience with machine learning
- Experience with LLMs

Acquirable competencies

- Development and use of digital twins

- Generation of models using LLMs and RAGs
- Publication of scientific papers at international conferences
- Competencies in working in a team - Open source development

Research Project for the Research Master Data Science

Project title: 3 Intelligent Information Retrieval for Clinical Documents

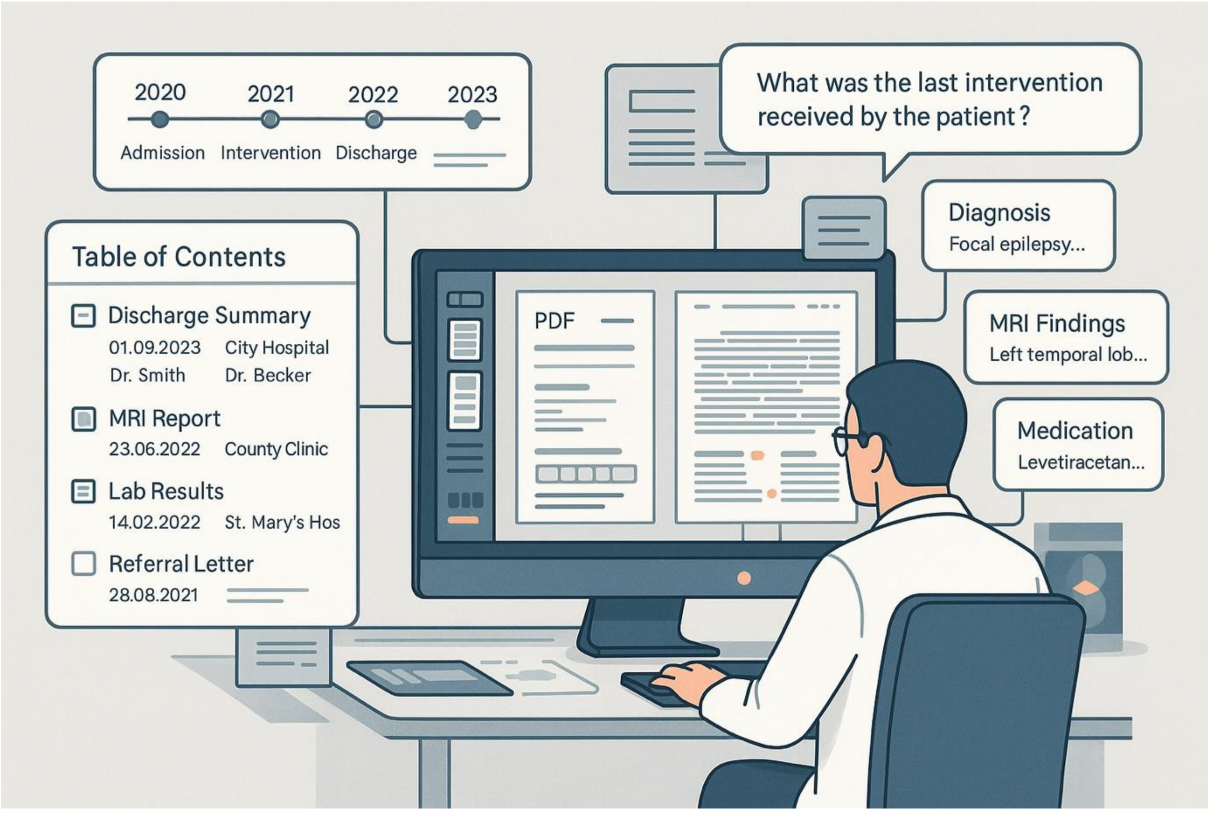


Figure 1 - Illustration of the intelligent sysetm able to organise and visualise information for browsing, as well as enable natural language questions from doctors.

Project overview

Number of Students	1-2
Project Type	project with external partner
Project Owner	Prof. Dr.-Ing. Wolfram Schenck, Dr. Med. Thomas Cloppenborg (Mara Hospital), Dr.-Ing. Marcos Baez, Dr. rer. nat. Christoph Ostrau
Project Context	Close collaboration with the Mara Hospital in Bielefeld is required for the project. There is potential for students to be employed at the hospital.

Abstract

Doctors often work with long, unstructured PDFs collections containing a patient's medical history, which makes identifying relevant information difficult. This process is time-consuming and errorprone, and is further hindered by poor scan quality or missing structure. Advances in document intelligence and large language models now enable automated segmentation, metadata extraction and semantic search, supporting the efficient exploration of documents. Due to the sensitivity of the data, a tailored, on premise solution is required.

Short description

Doctors and case managers in the epilepsy and pre-surgical wards rely on large, unstructured PDF collections to access each patient's medical history. Our observations in a partner hospital show that these documents—discharge letters, referral notes, MRI reports, EEG results, laboratory findings—are often merged into a single, lengthy file without internal structure or search support. Browsing them to find relevant information is slow, demanding, and error-prone, especially when documents are duplicated or of poor scan quality. It also forces them to often manually organize or print them, in order to make sense of the information, adding to the time they spend reviewing the documents.

Preliminary assessments indicate opportunities for a system that could **automatically organize and understand patient document histories**, providing both a structured entry point and intelligent ways to explore the content. For example, before admitting a patient, the doctor needs a quick sense of: *"What is the patient's history, what documents do we have, and what information is missing?"* Such a system should also enable semantic searches and the formulation of questions over documents, supporting efficient navigation rather than manual review (see Figure 1 for an illustration).

Because of the *sensitive nature of hospital data*, solutions in this context require their processing to occur **locally** within the institution's infrastructure. This calls for the use of **open-source** and **onpremise** solutions, carefully **tailored** to the clinical and technical context of the hospital.

Task definition

The goal of this project is to design and implement a prototype and local AI pipeline capable of organizing, analyzing, and enabling exploration of patient document histories in German (bundled PDFs). The solution focuses on supporting information browsing and exploration rather than structured summarization, offering an intelligent "map" of a patient's medical history. Thus, the system should be able to:

- **Segment and classify** the bundled PDF into individual documents.
- **Detect the type** of each document (e.g., discharge letter, MRI report, lab result, referral).
- **Extract and normalize metadata** such as date, hospital, city, doctor name, and department.
- **Construct a chronological timeline** summarizing the sequence of events and admissions.
- **Generate a Table of Contents** (ToC) with clickable links to each document section.
- **Enable semantic search** and question answering (RAG) over the document corpus for interactive exploration.

Reference to the topic of data science

The project addresses core data science themes through the processing and transformation of unstructured medical PDFs. It involves data preprocessing, OCR, and segmenting long documents into meaningful units, followed by fine-tuning and evaluating models for document classification and metadata extraction. The work culminates in building a retrieval and exploration pipeline, including semantic search or RAG—that integrates multiple AI components into a coherent

Available Resources

- Anonymized Data of the partnering hospital
- Access to the yourAI cluster for heavy loads like fine-tuning
- Edge AI devices like the Nvidia Jetson Orin Nx

- Contact to clinicians for requirements, evaluation and feedback

Project plan

First Semester - Understanding the problem. Conduct a literature search on document intelligence, clinical text mining, and medical information extraction. Analyze hospital document structure, typical document types, and available metadata to understand feasibility, define the scope and guide the design of a annotation schema. This contributes to the research exposé.

Second Semester - Build the data foundation and test baselines. Design and refine an annotation schema based on insights from semester one. Create an annotated dataset of patient document bundles. In parallel, prototype baseline models for PDF preprocessing, document segmentation, and metadata extraction to assess feasibility and refine annotation guidelines. Establish evaluation metrics and an initial benchmark to guide later fine-tuning.

Third Semester - Build the actual system. Fine-tune transformer-based models using the curated hospital dataset. Integrate the resulting components into a unified pipeline capable of generating a structured table of contents and a chronological patient timeline. Implement a RAG to enable naturallanguage querying over the document set. Summarize findings in a scientific paper.

Fourth Semester - Evaluation: Evaluate the prototype with clinicians in simulated browsing tasks to assess its impact on information access, efficiency, navigability, and user satisfaction. Improve the system based on feedback and error analysis. Document the final outcomes in the master's thesis and present results in the colloquium.

Necessary Competencies

Mandatory: Programming experience (ideally in python)

Acquirable Competencies

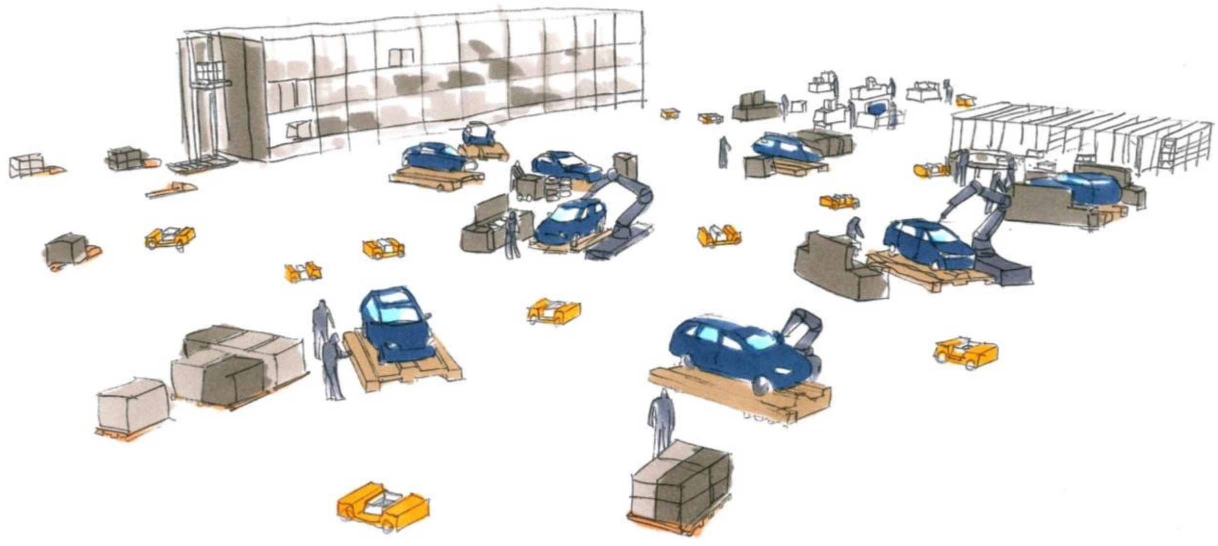
The student will gain experience in employing the following technologies:

- **Document Intelligence**: PDF preprocessing, OCR, layout-aware text extraction
- **NLP / LLMs**: Transformer-based models for document-type classification, metadata extraction; semantic search and RAG using local models and fine-tuning
- **Backend Development**: Python-based pipelines (FastAPI, LangChain or equivalent libraries) for integrating multiple AI components
- **Evaluation & Benchmarking**: Establishing baselines, designing evaluation metrics, and comparing model performance across tasks
- **Integration**: Mock APIs or MCP-based interfaces simulating clinical system integration (e.g., iMedOne)
- **Annotation Tools**: Label Studio for creating ground-truth datasets and refining annotation schemas

Furthermore, the student will work in an interdisciplinary context and gain experience developing tools for the medical domain.

Research project proposal for the Research Master Data Science

Project title: 4 AI for highly flexible, multi-variant mass production



Project overview

Number of students	1
Project Type	Project with external partners
Project Owner	Prof. Dr. Christian Schwede
Project Context	Project in cooperation with the **Fraunhofer Institute for Software and Systems Engineering (ISST)** in Dortmund and in the context of the **Center for Applied Data Science (CfADS)** and the **Institute for Data Science Solutions (IDaS)**; employment as a student assistant at Fraunhofer is possible;

Abstract

The constant individualization of products poses challenges not only for German automotive production, forcing a complete rethink of production organization. Away from clocked flow production towards decentralized matrix production systems. Here, swarms of autonomous robots coordinate the value creation processes and adapt flexibly to the current situation. While the basic idea of the concept is clearly outlined, there are still many open research questions in detail, particularly concerning the behavior of the individual robots. This is where the project comes in and explores different AI strategies in a virtual testbed.

Short description

In matrix production, production is coordinated decentrally by software agents in a multi-agent system (MAS). The resource agents negotiate with the order agent, for example, about the provision of valueadded processes that are necessary for the realization of the order. The freedom of the sequence of production steps is only limited by the technical properties of the product. In this way, the entire system can adapt flexibly to unplanned incidents, such as a delivery bottleneck or a machine breakdown. While the concept was initially met with rejection and scepticism in the automotive industry, intensive efforts have been made in recent years to research and promote its operationalization. In principle, there are still many unanswered questions regarding its efficient use that need to be researched.

The open source OFacT (Open Factory Twin) software framework has been developed by the HSBI research group in cooperation with the Fraunhofer ISST in Dortmund for several years. Among other things, this tool allows highly flexible matrix production to be modeled using agent-based simulation and various strategies and design variants to be dynamically evaluated. The framework can also be used as a digital twin and can be connected directly to production via sensor data streams and used to control operational processes.

Task definition

The student has the opportunity to work on one of the following topics in order to explore the possibilities and limitations of matrix production and to contribute new solution concepts to the realization of the state of the art.

Agent control for decentralized production

One of the most crucial open questions is the optimal control of the agents. In particular, the synchronization of material flows with the main product is a decisive factor in preventing waiting times and maintaining flexibility at the same time. The development and implementation of efficient control strategies for the MAS is the core task here, which includes the question of whether and to what extent planning and reservations should be made in the future. Methods of optimization, search and planning algorithms from AI or reinforcement learning can be used here.

Layout design and optimization

Even if the term matrix production implies a grid-like arrangement of the production stations, the question of the optimal arrangement of the various elements of matrix production (stations, storage locations for parts, loading stations for transport vehicles, parking spaces for intermediate buffering of car bodies, etc.) has not yet been finally decided. Optimization algorithms, which are used in combination with simulation as an evaluation method, must be developed here in order to determine the optimal layout for a specific production setup. The question of how strongly the optimum layout depends on the specific order mix is relevant and could imply the need for regular re-planning of the layout.

Routing and congestion analysis

The formation of traffic jams in front of the production stations or on the various routes is a central aspect of the efficiency of the overall system. For this purpose, the simulation environment must be expanded to include a route planning element that also recognizes temporary route conflicts. AI search algorithms from the area of route finding must be implemented and various strategies tested. Finally, existing control strategies and layouts must be examined and evaluated against the background of congestion in the system.

Acceleration of negotiations by means of reinforcement learning

A weak point of multi-agent systems is the amount of communication that arises from the decentralized negotiations between the agents. Negotiation strategies need to be examined, implemented and compared and, in particular, unnecessary communication needs to be avoided. Reinforcement learning can be used to recognize when requests from agents are not expedient and can therefore be avoided in advance.

Agent-based value creation networks

The integration of logistical processes from the value creation network around production is another open topic. In addition to the development of suitable supply and disposal strategies, which must meet the needs of flexible matrix production, the visionary question of whether decentralized, autonomous value creation can also be extended beyond the factory boundaries should be answered. To this end, the agents must negotiate contracts with suppliers and service providers on the basis of money as a means of payment. The corresponding negotiation algorithms and scenarios must be implemented and evaluated.

Reference to the topic of data science

Software agents and multi-agent systems, search algorithms and reinforcement learning are core areas of AI and are addressed in various courses of the research master's program.

Available resources

- The modeling framework OFacT is provided by HSBI and Fraunhofer ISST
- Industry-related scenarios of individual bicycle production exist to validate the developments
- Scenarios from industrial customers of ISST and the IoT Factory in Gütersloh also exist for evaluating individual processes
- Hardware for more complex machine learning is available via the Data Science Lab or the CfADS of the

Project plan

First semester: Formulation of the research proposal, familiarization with the OFacT environment, selection of the topic.

Second semester: Modeling of an initial scenario, research on relevant work in the subject area and preparation of a report on the state of the art.

Third semester: Implementation and evaluation of initial procedures, evaluation of initial results based on the scenario, writing a paper for an (inter)national conference.

Fourth semester: Development of further procedures and optimization of the overall approach, evaluation of the quality and evaluation of the results in the Master's thesis

Necessary competencies

Mandatory:

- Programming skills (ideally in Python)

Optional:

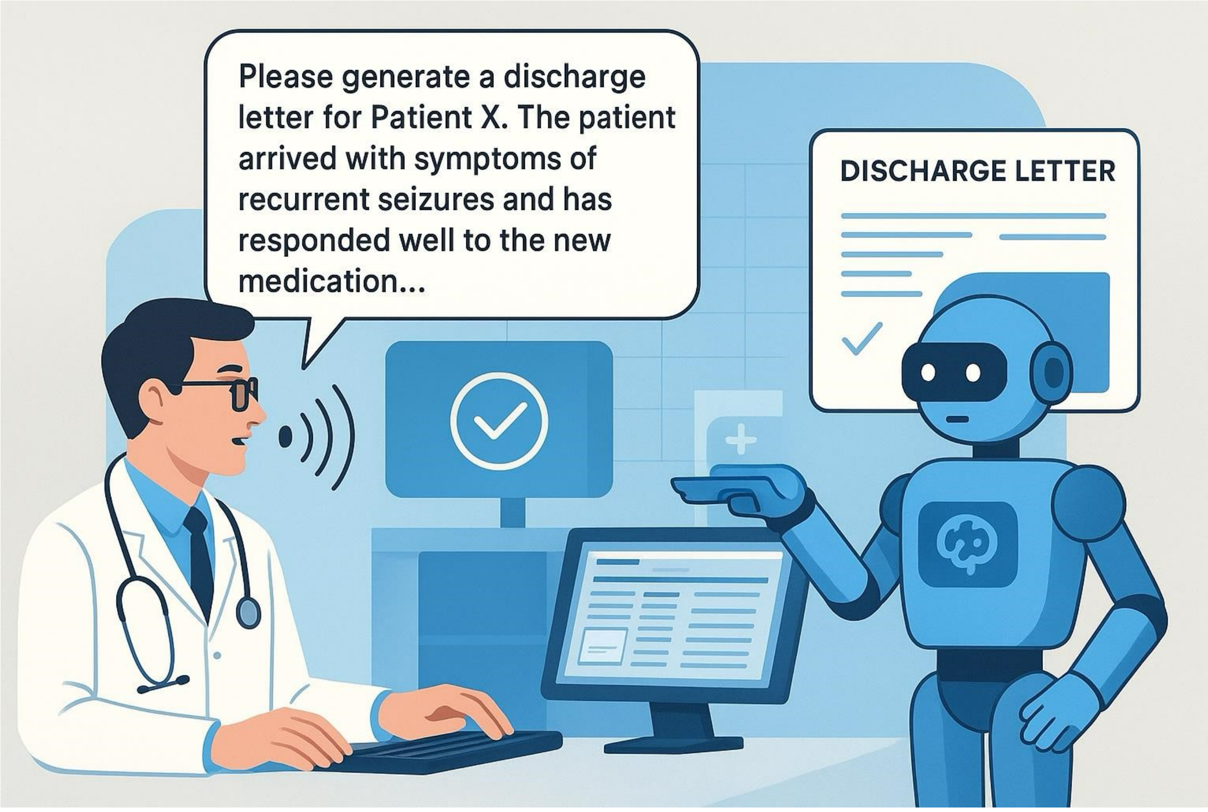
- Experience with agent systems
- Experience with simulation and optimization
- Background knowledge of production logistics and production systems
- Experience with the implementation of reinforcement learning / ML methods

Acquirable competencies

- Use of reinforcement learning methods
- Development and evaluation of MAS
- Development of intelligent agents
- Working with agent simulations
- Planning of production and logistics systems, in particular market production systems and Industry 4.0

Research Project for the Research Master Data Science

Project title: 5 AI Assistant for Medical Task Delegation: From Doctor Dictations to Intelligent System Actions



Project overview

Number of Students	1-2
Project Type	project with external partner
Project Owner	Prof. Dr.-Ing. Wolfram Schenck, Dr. Med. Thomas Cloppenborg (Mara Hospital), Dr.Ing. Marcos Baez, Dr. rer. nat. Christoph Ostrau
Project Context	Close collaboration with the Mara Hospital in Bielefeld is required for the project. Therefore, there is potential for students to be employed at the hospital.

Abstract

In medical contexts, doctors record audio dictations that are transcribed by typing professionals, who then create reports, discharge letters, and perform data entry tasks. However, this process is manual, error-prone and time-consuming. Advancements in speech recognition and large language models

enable dictations to be interpreted to extract intent and automate actions. Given the sensitivity of hospital data, such systems must be operated locally using open-source, on-premises solutions adapted to clinical requirements.

Short description

In epilepsy and pre-surgical wards, doctors often **delegate transcription and data-entry tasks** to typists through audio dictations. Typists listen, interpret, and manually act on these recordings—entering data into the Health Information System (HIS), formatting discharge letters, or generating reports. For example, a doctor might dictate a 10min audio: "*Please generate a discharge letter for Patient X. The patient arrived with symptoms of recurrent seizures and has responded well to the new medication…".* This process is time-consuming, prone to errors and misinterpretation, and requires manual orchestration across several medical systems. Doctors report frequent interruptions and high cognitive load, while typists face unclear recordings and inconsistent dictation styles.

Recent advances in **speech understanding** and l**arge language models (LLMs)** make it possible to envision an **AI assistant** that listens to a doctor's dictation, understands the intent, and executes or orchestrate system actions—much like a human typist. Thus, for the earlier example, the system would recognize the task as a **document generation** request, **extract** the relevant patient information, prepare a **summary of intended actions** for the doctor's approval, and then **automate** the corresponding steps through a Model Context Protocol (**MCP**)-based orchestration layer.

Because of the **sensitive** nature of hospital data, all AI processing must occur **locally** within the institution's infrastructure. This calls for the use of open-source and on-premises solutions, carefully tailored to the clinical and technical context of the hospital.

Task definition

The goal of this project is to design and prototype an AI assistant to reduce the documentation burden, improve consistency, and streamline interactions across hospital systems. The assistant should be able to

- Process German audio recordings from doctors.
- Identifyi and structure intended tasks, such as entering data into medical information systems or the generation of medical documents
- Preview actions, being as transparent as possible, as it would be acting on sensitive medical data: All actions must be confirmed by a doctor or typist
- Use MCP to orchestrate system interactions (mock or real APIs) safely and modularly

Reference to the topic of data science

The project covers various aspects related to data science. It begins with data preprocessing and the analysis and extraction of information from audio and written resources. It then moves on to finetuning models for a given task and creating a pipeline that interconnects different AI tools.

Available Resources

- Anonymized Data of the partnering hospital
- Access to the yourAI cluster for heavy loads like fine-tuning
- Edge AI devices like the Nvidia Jetson Orin Nx
- Contact to clinicians for requirements, evaluation and feedback

Project plan

First Semester: Review literature on AI-assisted clinical documentation and the automated analysis of doctor dictations to identify common task types. This contributes to the research exposé.

Second Semester: Write a literature review about AI-assisted clinical documentation. Test speech recognition systems (e.g., Whisper) for transcription and LLM or Natural Language Processing models for intent extraction and task generation.

Third Semester: Fine-tune models for the given tasks, integrate models into a single prototype application. Summarize findings in a scientific paper.

Fourth Semester: Evaluate the prototype in (simulated) clinical tasks with clinicians to assess its impact on relevant performance metrics. Improve the system based on feedback. Document outcomes as master's thesis and present results in a colloquium.

Necessary Competencies

Mandatory: Programming experience (ideally in python)

Optional: Experience in the usage of MCP systems

Acquirable Competencies

The student will gain experience in employing the following technologies:

- Speech Recognition
- NLP / LLM, local models with fine-tuning
- Backend: Python (FastAPI, LangChain)
- Integration: Mock APIs simulating deployed health systems or real systems in test environment
- Annotation Tools: Label Studio

Furthermore, the student will work in an interdisciplinary context and gain experience developing tools for the medical domain.

Research Project for the Research Master Data Science

Project title: 6 Machine learning for detecting anomalies and prediction of interactions based on movement information in a smart home environment

Project overview

Number of Students	1
Project Type	Project with external partners
Project Owner	Prof. Dr.-Ing. Thorsten Jungeblut
Project Context	Project in cooperation with **KogniHome - Technikunterstützes Wohnen für Menschen e.V.** in Bielefeld; Data sets and hardware resources are provided; Employment as a research assistant is possible; There is the possibility of close cooperation with members of KogniHome e.V., including Bethel, Steinel, Hettich, HUM Systems, C&S GmbH and many more.

Abstract

The aim of the project is the co-development of a system that uses AI methods to learn the usage behavior of the residents of a smart home in order to subsequently provide suitable recommendations for action or, if anomalies are detected, to initiate appropriate measures. The scientific challenge of the project is the application and evaluation of machine learning methods for learning interaction patterns based on the data provided by minimal-sensor technology, as well as the prediction of future interaction and anomaly detection.

Short description

Digitalization is penetrating more and more areas of life, and the associated networking of diverse components in our daily environment is leading to a situation in which constantly higher demands are being placed on everyday technology. Systems need to become smarter, automated and autonomous.

Ideally, technology will anticipate the needs of people and they will no longer need to make corrections. Needs-based human-technology interaction requires the intelligent technical system (ITS) to adapt to the context of use and not the other way round. A requirement for intuitive interaction is therefore first and foremost the reliable recognition of the context of use, i.e. where the user is located and what action they are currently performing. Knowledge of regularly occurring interaction patterns enables the ITS to predict future interactions and predictively control assistance functions. Imaging sensor technology (e.g. cameras, high-resolution time-of-flight sensors) enables powerful recognition of the context of the action through person, object, gesture or even facial recognition, but brings with it the problem of collecting personal data. This may be undesirable for data protection reasons, particularly in private domestic environments, but also in office buildings or production facilities. Minimal sensors, such as motion or presence detectors, do not directly generate personal data, but only record selective information about the presence of people or objects in a spatially restricted area. For comprehensive detection of the context of use, the combination of many simple sensors promises sufficient detection of the context of use while at the same time preserving privacy. If more complex sensor technology is required for an assistance function (e.g. for voice or gesture recognition), it only needs to be activated (and only then) if the use of the assistance system is at least foreseeable. However, the continuous recording of the context of use also makes it possible to learn regular patterns of behavior. The ITS can derive expected future interactions from these learnt action patterns and make recommendations for the activation of assistance functions or prepare them (predictive control). In addition, deviations from the potential control state (anomalies) can also be recognized and responded to appropriately; the derivation of recommendations for action by the ITS can be rulebased in the simplest implementation (e.g. "If the motion detector in the hallway is activated, then the light should be switched on"). In systems with many sensors, however, this is very complex, cannot be flexibly customized and is difficult to scale to growing environments. In addition, different sensors provide different abstract information (e.g. local movement (PIR, ultrasound) or movement across several rooms (HF/microwaves), binary "on/off" or distances) or even more complex information from camera-based systems (e.g. number of recognized people/pets/objects (robot vacuum cleaner/transport platform)). It is therefore necessary to abstract the various pieces of information, anonymize them if necessary and use them in a holistic approach to learn the context of use, estimate future interaction and detect anomalies. The scientific challenge of the project is therefore the application and evaluation of machine learning methods for learning interaction patterns based on the data provided by the minimal-sensor technology, as well as the prediction of future interaction and anomaly detection.

Task definition

In this project, the student will co-develop an ITS that uses machine learning methods to learn the usage behavior of the residents of a smart home in order to subsequently provide suitable recommendations for action based on the real-time data or, if anomalies are detected, to initiate suitable measures. The development of the concrete application scenario, together with the KogniHome e.V. team, is part of the project. To illustrate this, the following scenario is described: "Sabine (74) gets up every morning between 7 and 8 a.m., goes to the toilet and then makes herself a coffee". Three activities can be recognized in this action sequence: Getting up, going to the toilet, making coffee. Each of these activities can now lead to recommended actions or anomalies. For example, the ITS could prepare for going to the toilet with suitable lighting or switch on the coffee machine. At the same time, the ITS monitors the activities and recognizes deviations from the usual behavior. For example, if Sabine falls on the way to the toilet and does not get up again on her own, the ITS should recognize this and, for example, call the emergency services or the nursing home.

Reference to the topic of data science

The evaluation and application of AI/ML methods for condition monitoring and prediction are a core topic of data science and are covered, for example, in the modules "Data Mining & Machine Learning" and "Artificial Intelligence". The recording of high-resolution measurement data (e.g. consumption data) from many sensors in complex living environments highly demands on the organization and processing of the data. This is the core of the "Big Data Architectures" module.

Available Resources

- Information required to create the scenario (system description, logistical processes, relevant key figures) is provided by KogniHome e.V.
- Access to the research apartment of KogniHome e.V.
- Extensive test data sets are available via the KogniHome e.V. research apartment - The contact person at KogniHome e.V. will be available for the duration of the project
- Required materials will be provided by KogniHome e.V.
- Hardware for the more complex machine learning is available via the Data Science Lab, CfADS and the AI computing cluster yourAI at HSBI.

Project plan

First semester: Preparation of a research exposé as examination performance. Familiarization with the concepts and structures (IoT software, smart home protocols, interfaces, etc.) of the KogniHome e.V. research apartment.

Second semester: Creation of the system concept for anomaly detection for predictive control of assistance systems. Research on relevant work in the field of the use of AI methods for learning event sequences and for anomaly detection. Preparation of a paper that provides an overview of the respective research area as an examination performance.

Third semester: Practical implementation of various machine learning methods in the field of unsupervised and (semi-)supervised learning to optimize automated interaction between humans and machines, as well as their evaluation.

Fourth semester: Master's thesis and colloquium. Final evaluation by comparing the implemented strategies. Preparation of a paper with initial quantitative results as an examination.

Necessary Competencies

Mandatory:

- Programming skills (especially Python)
- Experience with the version control system "git"

Optional:

- Experience in electronics development
- Experience in the field of smart home technologies/IoT devices
- Programming of microcontrollers

Acquirable Competencies

- Artificial intelligence methods for problem solving

- Sensor-based information processing

- Predictive assistance and anomaly detection (transferability to industrial processes)

- Expertise in working in a team

Research Project for the Research Master Data Science

Project title: 7 Efficient Execution of Object Detection Algorithm on Edge Devices

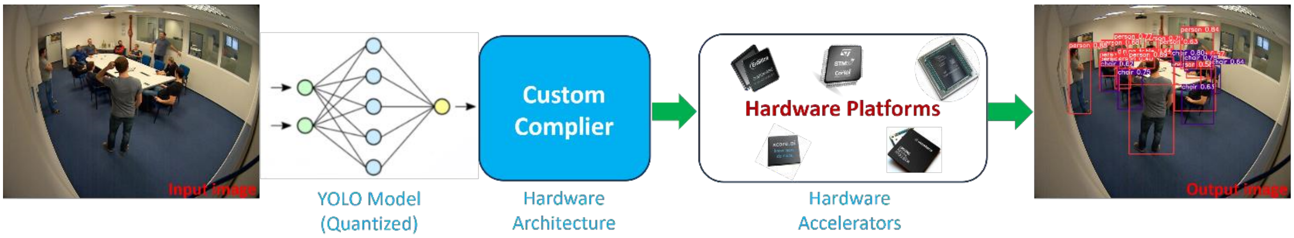


Figure 1: Efficient mapping of YOLO-Vx model on edge devices

Project Overview

Number of Students	1
Project Type	Study project in collaboration with an external partner
Project Owner	Prof. Dr.-Ing. habil. Thorsten Jungeblut Dr.-Ing. Qazi Arbab Ahmed
Project Context	**CareTech OWL** transfer project in collaboration with an external partner, **Steinel GmbH**, as part of the CareTech OWL research project. Parallel employment as a student research assistant (WHK) is possible.

Abstract

The artificial intelligence (AI) paradigm has replaced a handful of traditional computer vision techniques to intelligently predict the correct output of a complex system under tight constraints and varying conditions. However, many AI algorithms require huge amounts of hardware resources due to their massive computational requirements. The main task of this project is the development of a framework for the efficient implementation of object detection algorithms on highly resourceconstrained hardware architectures (low-end FPGAs, embedded microcontrollers). Based on the framework, automated methods for exploring the design space of suitable combinations of object detection algorithms and hardware in terms of HW/AI-co-design will be explored. In particular, industrial applications with high latency requirements are targeted, such as real-time human presence detection.

Short description

For the efficient execution of AI algorithms, techniques such as federated learning (FL) and cognitive edge computing (CEC) have already shifted the load of training and inference of neural networks from the cloud to the edge. The partitioning of the execution of the application has a significant impact on the performance and resource efficiency of the overall system. For example, a distinction can be made here between fundamentally different approaches of decentralized feature extraction as close as possible to the sensor with subsequent fusion versus central processing in the cloud. The first approach requires powerful edge hardware for preprocessing and potentially offers advantages for high realtime requirements. The second approach places higher demands on the communication infrastructure but potentially enables the execution of more complex networks. The main goal of this project is therefore to explore automated methods for exploring the design space of suitable combinations of AI-based objection detection methods and resource-constrained hardware in terms of HW/AI codesign.

In the area of efficient execution of AI procedures on embedded systems (cognitive edge computing), great progress has been made in the past. At all levels of the different processing concepts (cloud, fog, edge, very edge) in the production chain, a variety of potential hardware architectures and AI accelerators can be found, which differ in the available system resources (e.g., performance or power consumption). Examples of relevant hardware architectures are embedded microcontrollers with integrated AI acceleration, embedded GPUs/FPGAs, dedicated AI hardware accelerators, or high-end GPUs/FPGAs from the HPC domain.

We consider the complete processing chain, starting with the pre-processing close to the sensor (very edge), by connecting the groups of sensors and their information in the edge, via local decentralized cloud instances (fog), to the central station of all relevant information (cloud). At each level in the processing chain, individual approaches exist to locally optimize the resource efficiency of AI methods, for example, by reducing numerical precision (e.g., from 32 to 16, or 8 bits) to enable more efficient execution on specialized hardware or to minimize local storage space. The goal of this project is to determine an optimal combination of hardware and object detection algorithms (e.g., YOLO) as part of a holistic design space exploration close to the sensor.

Task definition

In this project, students will develop a framework for the efficient execution of AI-based object detection algorithms on resource-constrained edge devices. In order to support the sustainable use of the developed methods and frameworks by the industrial partner, universally applicable models and automated design tools are to be made available in this project in the form of a standard development toolkit. The first main challenge is the compression of the latest object detection algorithm (e.g., YOLO) to reduce the model size, yet with acceptable accuracy, using AI approximation techniques. The next challenge is to develop resource-efficient techniques (inference compiler) to map the compressed model to a suitable hardware platform e.g., low-end FPGAs or embedded (AI-) microcontrollers, considering the resource utilization in terms of area, power/energy, and latency/throughput, as demonstrated in Figure 1.

Reference to the topic of data science

The evaluation and application of AI/ML methods in the field of "machine vision", e.g., the use of CNNs in object classification, are a core topic of data science and are dealt with, for example, in the modules "Data Mining & Machine Learning" and "Artificial Intelligence". AI-supported image processing places high demands on the organization and processing of data at all levels of IoT processing concepts (edge/fog/cloud). This is the core of the module "Big Data Architectures". The consideration of the entire system process from the imaging sensor to the cloud requires a holistic view of the complete data science process, which is covered in the module "Data Science".

Available Resources

Ensuring the availability of data, computing resources, hardware, application experts

- Information required to create the scenario (system description, interfaces, documentation, relevant key figures, etc.) is provided by the resource person

- Steinel GmbH provides extensive test data sets from real production environments
- The Steinel GmbH contact person will be available for the duration of the project
- The components required for the prototype development as well as other required materials will be provided by the Steinel GmbH
- Hardware for the more complex machine learning is available via the Data Science Lab, the CfADS, and the AI computing cluster, yourAI, at Bielefeld University of Applied Sciences

Project Plan

First semester: Preparation of a research exposé as an examination. Familiarization with the concept of AI-based object detection algorithms, in particular, YOLO, R-CNN, image recognition, neural network approximation techniques, hardware platforms, and design flow tools.

Second semester: Creation of the system concept for design space exploration of cognitive edge computing architectures. Research on relevant work in the field of AI-based object detection algorithms and model compression in the above-mentioned context. Preparation of a paper that gives an overview of the respective research area, as an examination.

Third semester: Development of a first demonstrator and proof-of-concept for hardware acceleration for human presence detector (HPD) using, for example, YOLO-V7. Comparison of the developed framework with a classic implementation.

Fourth semester: Master's thesis and colloquium. Implementation and comparison of different combinations of AI-based object detection algorithms and hardware accelerators. Systematic evaluation and exploration of the efficiency of the developed framework. Final evaluation by comparing the implemented strategies with the state-of-the-art methods. Preparation of a paper with the first quantitative results as an examination.

Necessary Competencies

Mandatory:

- Expertise in Python, Pytorch
- Good knowledge of C++

Optional:

- Experience with hardware design flow tools
- Programming of microcontrollers/FPGAs
- Basic knowledge of HDL (Verilog, VHDL)
- Experience with IoT devices
- Experience with the version control system "git"

Acquirable Competencies

- Resource-efficient information processing at edge (embedded microcontrollers, FPGAs) in line with the IoT processing concept
- Sensor-related information processing
- AI/ML-based object detection methods
- Leveraging embedded hardware to accelerate AI/ML processes

Research Project for the Research Master Data Science

Project title: 8 Hardware-AI Codesign for Efficient Execution of Neural Networks

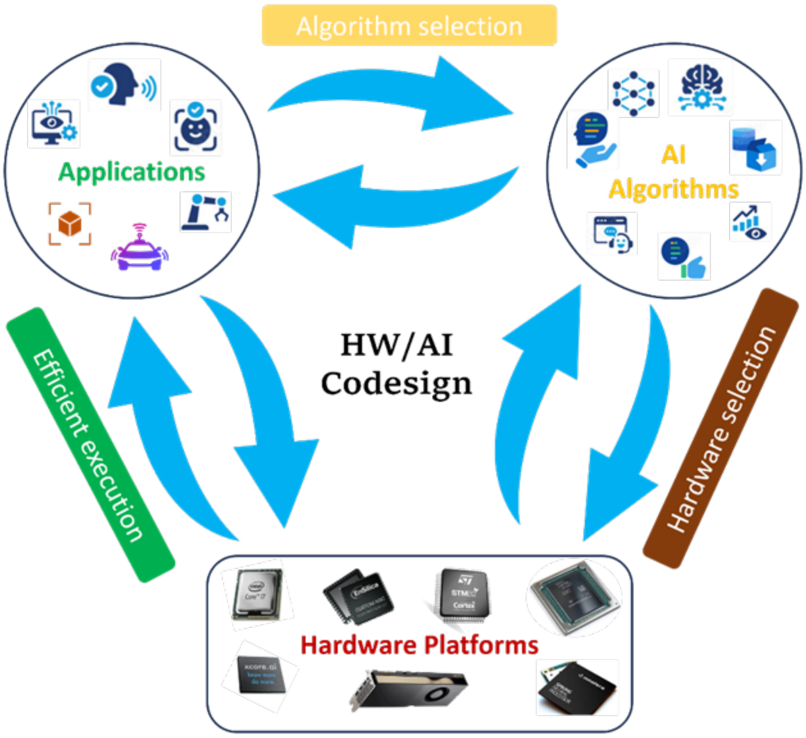


Figure 1: Design space exploration for Hardware-AI codesign

Project Overview

Number of Students	1
Project Type	Study project in collaboration with an external partner
Project Owner	Prof. Dr.-Ing. habil. Thorsten Jungeblut, Dr.-Ing. Qazi Arbab Ahmed
Project Context	**CareTech OWL** transfer project in collaboration with external partner, **Steinel GmbH**, as part of the CareTech OWL research project. Parallel employment as a student research assistant (WHK) is possible.

Abstract

The artificial intelligence (AI) paradigm has replaced a handful of traditional computer vision techniques to intelligently predict the correct output of a complex system under tight constraints and varying conditions. However, many AI algorithms require huge amounts of hardware resources due to their massive computational requirements. The goal of this project is the development of a framework for the efficient implementation of AI and ML algorithms on highly resource-constrained hardware architectures. Based on the framework, automated methods for exploring the design space of suitable

combinations of AI algorithms and hardware in terms of HW/AI-co-design will be explored. In particular, industrial applications with high latency requirements are targeted. Not only the entire chain as a linear process from model training to inference will be taken into account, but also the impact of the choice of possible hardware configurations on the original model development.

Short description

For the efficient execution of AI algorithms, techniques such as federated learning (FL) and cognitive edge computing (CEC) have already shifted the load of training and inference of neural networks from the cloud to the edge. The partitioning of the execution of the application has a significant impact on the performance and resource efficiency of the overall system. For example, a distinction can be made here between fundamentally different approaches of decentralized feature extraction as close as possible to the sensor with subsequent fusion versus central processing in the cloud. The first approach requires powerful edge hardware for preprocessing and potentially offers advantages for high realtime requirements. The second approach places higher demands on the communication infrastructure but potentially enables the execution of more complex networks. The main goal of this project is therefore to explore automated methods for exploring the design space of suitable combinations of AI methods and resource-constrained hardware in terms of HW/AI codesign.

In the area of efficient execution of AI procedures on embedded systems (cognitive edge computing), great progress has been made in the past. At all levels of the different processing concepts (cloud, fog, edge, very edge) in the production chain, a variety of potential hardware architectures and AI accelerators can be found, which differ in the available system resources (e.g., performance or power consumption). Examples of relevant hardware architectures are embedded microcontrollers with integrated AI acceleration, embedded GPUs/FPGAs, dedicated AI hardware accelerators, or high-end GPUs/FPGAs from the HPC domain.

We consider the complete processing chain, starting with the pre-processing close to the sensor (very edge), by connecting the groups of sensors and their information in the edge, via local decentralized cloud instances (fog), to the central station of all relevant information (cloud). At each level in the processing chain, individual approaches exist to locally optimize the resource efficiency of AI processes, for example, by reducing numerical precision (e.g., from 32 to 16, or 8 bits) to enable more efficient execution on specialized hardware or to minimize local storage space. The goal is to determine an optimal combination of hardware and software (i.e., AI algorithm) as part of a holistic design space exploration at all processing levels.

Task definition

In this project, students will develop an automated toolkit for design space exploration that can support the user in HW/AI codesign. In order to support the sustainable use of the developed methods and frameworks by the industrial partner, universally applicable models and automated design tools are to be made available in this project in the form of a development toolkit, which abstracts from the concrete use cases and make it possible to obtain recommendations for an optimal combination of AI methods and suitable (edge) hardware architecture based on a future application scenario. The goal is to provide the user with preliminary models and automated design tools that enable recommendations for a combination of AI methods and suitable (edge) hardware architecture based on a given application scenario and evaluation measures.

Figure 1 illustrates the general concept of design space exploration of hardware-AI codesign. The first main challenge is the compression/optimization of the neural network to reduce the size, yet with acceptable accuracy, using AI approximation techniques. The next challenge is to develop resourceefficient techniques to map the compressed (AI) model to a suitable hardware platform, such as GPUs, CPUs, ASICs, and FPGAs, considering the resource utilization in terms of area, power/energy, and latency/throughput.

Reference to the topic of data science

The evaluation and application of AI/ML methods in the field of "machine vision", e.g., the use of CNNs in object classification, are a core topic of data science and are dealt with, for example, in the modules "Data Mining & Machine Learning" and "Artificial Intelligence". AI-supported image processing places high demands on the organization and processing of data at all levels of IoT processing concepts (edge/fog/cloud). This is the core of the module "Big Data Architectures". The consideration of the entire system process from the imaging sensor to the cloud requires a holistic view of the complete data science process, which is covered in the module "Data Science".

Available Resources

Ensuring the availability of data, computing resources, hardware, application experts

- Information required to create the scenario (system description, interfaces, documentation, relevant key figures, etc.) is provided by the resource person
- Steinel GmbH provides extensive test data sets from real production environments
- The Steinel GmbH contact person will be available for the duration of the project
- The components required for the prototype development as well as other required materials will be provided by the Steinel GmbH
- Hardware for the more complex machine learning is available via the Data Science Lab, the CfADS, and the AI computing cluster, yourAI, at Bielefeld University of Applied Sciences

Project Plan

First semester: Preparation of a research exposé as an examination. Familiarization with the concept of AI algorithms (CNN, DNN), in particular, object detection and image recognition, hardware platforms, and design flow tools used.

Second semester: Creation of the system concept for design space exploration of cognitive edge computing architectures. Research on relevant work in the field of the use of AI/ML methods for data processing and model compression in the above-mentioned context. Preparation of a paper that gives an overview of the respective research area, as an examination.

Third semester: Development of a first demonstrator and proof-of-concept for hardware acceleration of relevant application. Comparison of an AI process with a classic implementation.

Fourth semester: Master's thesis and colloquium. Implementation and comparison of different combinations of AI/ML methods and hardware accelerators. Systematic evaluation and exploration of the efficiency of the combinations. Comparison of different processing concepts (embedded AI, edge, cloud). Final evaluation by comparing the implemented strategies. Preparation of a paper with the first quantitative results as an examination.

Necessary Competencies

Mandatory:

- Expertise in Python, Pytorch
- Good knowledge of C++

Optional:

- Experience with hardware design flow tools
- Programming of microcontrollers/FPGAs
- Basic knowledge of HDL (Verilog, VHDL)
- Experience with IoT devices
- Experience with the version control system "git"

Acquirable Competencies

- Resource-efficient information processing at the various levels (edge, fog, cloud) in line with the IoT processing concept
- Sensor-related information processing
- AI/ML methods
- Leveraging embedded hardware to accelerate AI/ML processes

Research Project for the Research Master Data Science

Project title: 9 Cognitive Edge Computing for AI/ML-based Surface Inspection

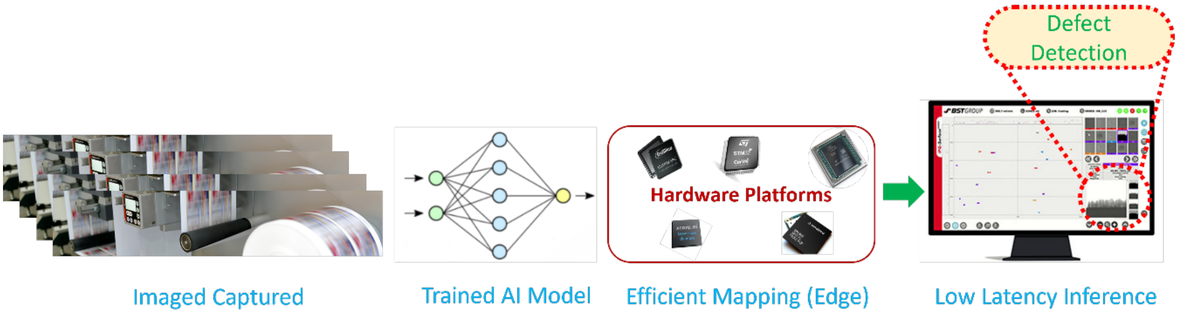


Figure 1: Efficient surface inspection using AI on edge

Project Overview

Number of Students	1
Project Type	Study project in collaboration with an external partner
Project Owner	Prof. Dr.-Ing. habil. Thorsten Jungeblut Dr.-Ing. Qazi Arbab Ahmed
Project Context	**CareTech OWL** transfer project in collaboration with an external partner, **BST Group**, as part of the CareTech OWL research project. The partner company **BST Group** provides extensive test data sets as well as a prototype hardware setup. Parallel employment as a student research assistant (WHK) is possible. The BST Group is very interested in the recruitment and long-term employment of junior staff.

Abstract

The artificial intelligence (AI) paradigm has replaced a handful of traditional computer vision techniques to intelligently predict the correct output of a complex system under tight constraints and varying conditions. The aim of the project is the design space exploration of AI/ML hardware accelerators in surface inspection. The focus is not only on learning the models on HPC systems but also on efficient execution (inference) on embedded hardware. The result of the design space exploration is the partitioning of the application, i.e. which AI methods can be evaluated on the sensor, which procedures can be accelerated via edge hardware (e.g. embedded GPU/FPGA), and which require powerful HPC hardware in the cloud.

Short description

Developments in the field of intelligent technical systems (ITS) are currently leading to a radical change in the entire value chain of industrial production. The increasing performance of information processing offers many new possibilities for the application area of industrial image processing, where humans and machines have so far reached their limits. In particular, the use of machine learning processes and artificial intelligence methods promises previously unknown possibilities, for example in object classification or visual quality control. Since around 2010, significant progress has been made with deep neural networks (DNN) and convolutional neural networks (CNN).

However, the performance of established AI/ML methods has so far mostly been based on the use of powerful decentralized computing resources (high-performance computing) in the cloud. The user is dependent on these powerful resources not only for learning the models but also for their execution (inference). However, the requirements arising in the field of industrial image processing deviate from the issues addressed by large providers of AI expertise due to high demands on low latency, real-time capability, or data locality. Issues such as maintainability, certifiability, or privacy also make it difficult to use popular models such as DNNs or CNNs in the cloud.

Nevertheless, great progress has also been made in the past in the area of efficient execution of AI/ML processes on embedded systems (**cognitive edge computing**). Suitable hardware accelerators can be found at all levels of the different processing concepts in networked production (edge/fog/cloud computing), which aim to achieve a suitable compromise between system resources such as required performance (e.g. classification accuracy), power consumption/energy requirements or data throughput/latency. Examples of relevant hardware architectures are embedded microcontrollers, embedded GPUs, embedded FPGAs, or dedicated AI hardware accelerators.

The BST Group develops systems for surface inspection (e.g., for battery cell production) that can reliably and immediately detect typical defects in the manufacturing process (e.g., coating discontinuities). BST systems can be perfectly adapted to a wide range of applications, due to their modular design. Image capture and defect detection can take place in real-time. The systems can be used on uniform, textured, and printed surfaces. The immediate and automatic detection and display of even the smallest defects and deviations enables the process to be adapted quickly and reliably to avoid rejects. The system consists of several optical sensors whose sensor data is suitably fused. The use of machine learning methods promises higher performance in defect detection and optimization of the entire process. However, with web speeds of several hundred meters per second, very high demands are required on the throughput and latency of the AI/ML processes used. Figure 1 shows the overview of the proposed methodology.

Task definition

The aim of the project is the design space exploration of AI/ML hardware accelerators for use in surface inspection. The focus is not only on learning the models of HPC systems but also on efficient execution (inference). Consideration of the entire system architecture, from intelligent sensors to edge gateways for local data pre-processing through to the cloud infrastructure, places high demands on the mapping of the AI network model to the hardware. The choice of target architecture, in turn, influences the choice and training of models. This results in an iterative cycle (model-to-inference-to-model), which includes both the selection of a suitable AI algorithm and the determination of the (hyper)parameters of the model. This approach of holistic design space exploration can also be referred to as HW/KI codesign, based on the established term HW/SW co-design. The design space exploration should consider numerous design goals, such as classification accuracy, latency, or resource requirements of the hardware. The result of the design space exploration is the partitioning of the application, i.e. which AI algorithm can be evaluated directly on the sensor (e.g. through dimension reduction or feature extraction), which algorithm can be accelerated via edge hardware (e.g. embedded GPU/FPGA or dedicated TPU accelerators) and which require powerful HPC hardware in the cloud.

Reference to the topic of data science

The evaluation and application of AI/ML methods in the field of "machine vision", e.g., the use of CNNs in object classification, are a core topic of data science and are dealt with, for example, in the modules "Data Mining & Machine Learning" and "Artificial Intelligence". AI-supported image processing places high demands on the organization and processing of data at all levels of IoT processing concepts (edge/fog/cloud). This is the core of the module "Big Data Architectures". The consideration of the entire system process from the imaging sensor to the cloud requires a holistic view of the complete data science process, which is covered in the module "Data Science".

Available Resources

Ensuring the availability of data, computing resources, hardware, application experts

- Information required to create the scenario (system description, interfaces, documentation, relevant key figures, etc.) is provided by the BST Group
- The BST Group provides extensive test data sets from real production environments
- The BST Group contact person will be available for the duration of the project
- The components required for the prototype development as well as other required materials will be provided by the BST Group
- Hardware for the more complex machine learning is available via the Data Science Lab, the CfADS, and the AI computing cluster, yourAI, at Bielefeld University of Applied Sciences

Project Plan

First semester: Preparation of a research exposé as an examination. Familiarization with the concept of BST's surface inspection systems, and the interfaces of the intelligent sensors provided.

Second semester: Creation of the system concept for design space exploration of cognitive edge computing architectures. Research on relevant work in the field of the use of AI/ML algorithms for sensor data processing in the above-mentioned context. Preparation of a paper that gives an overview of the respective field of research as an examination achievement.

Third semester: Development of a first demonstrator and proof-of-concept for hardware acceleration of an application for surface inspection of BST. Comparison of an AI-based inspection with a classic implementation.

Fourth semester: Master's thesis and colloquium. Implementation and comparison of different combinations of AI/ML methods and hardware accelerators. Systematic evaluation and exploration of the efficiency of the combinations. Comparison of different processing concepts (embedded AI, edge, cloud). Final evaluation by comparing the implemented strategies. Preparation of a paper with the first quantitative results as an examination achievement.

Necessary Competencies

Mandatory:

- Expertise in Python, Pytorch
- Good knowledge of C++

Optional:

- Basic knowledge of HDL (Verilog, VHDL)
- Experience with hardware design flow tools
- Programming of microcontrollers/FPGAs
- Experience with IoT devices

Acquirable Competencies

- Resource-efficient information processing at edge (embedded microcontrollers, FPGAs) in line with the IoT processing concept
- Sensor-related information processing
- AI/ML-based object detection methods
- Leveraging embedded hardware to accelerate AI/ML processes

Research Project for the Research Master Data Science

Project title: 10 Helios 2 - Predicting solar radiation from cloud images for improved integration of solar energy into the power grid

Subproject: Data mining for cloud detection and classification for energy yield forecasts

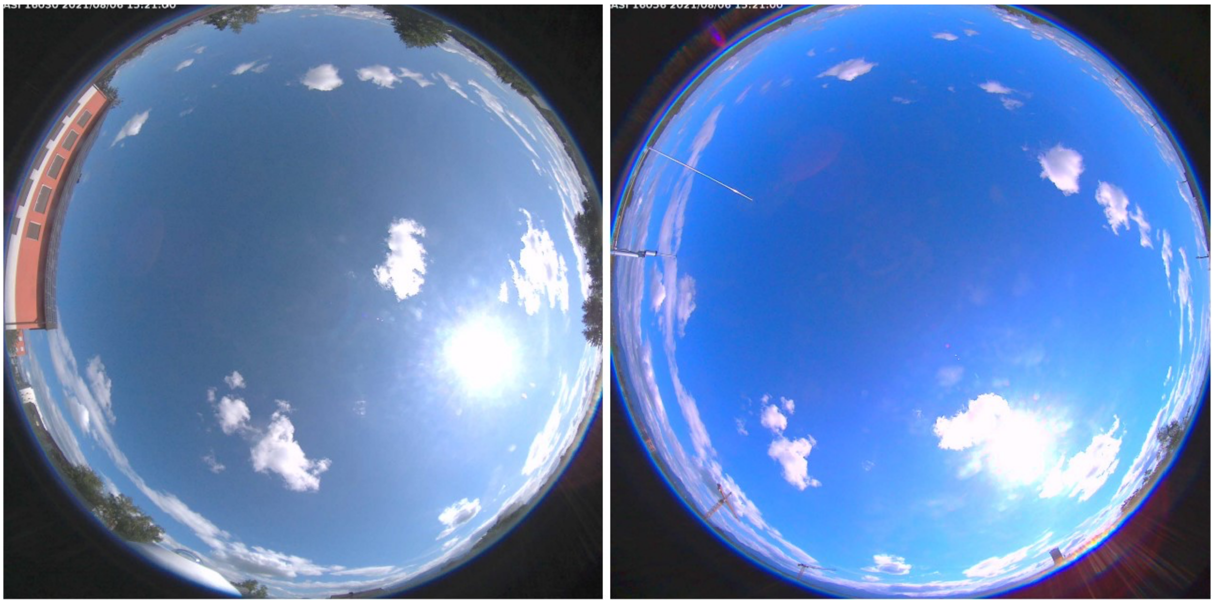


Figure: ALL-Sky-Images

Projektübersicht

Starting Semester	WS 2025/26
Type	DBU - funded project follow-up to Helios with external partners (duration until December 28)
Project responsibility	Prof. Dr.-Ing. Grit Behrens
Project context	The subproject "Data Mining for Cloud Detection and Classification for Energy Yield Forecasts" is located in the Solar Computing Lab on the Minden campus and is led by Prof. Behrens. The team also includes a research associate at the project partner's Solar Energy Systems Laboratory at the Rosenheim University of Applied Sciences, led by Prof. Mike Zehner. A position as a research associate is possible (subject to final funding approval).

Abstract

In this project, all-sky images are analyzed using, among other things, convolutional neural networks and deep learning methods in order to forecast solar irradiation on photovoltaic fields and the expected yields.

Short description

Fluctuations and peaks in solar radiation are significantly influenced by cloud formations. This volatility has a significant impact on the performance of photovoltaic (PV) systems. To predict the input of PV systems into the power grid as accurately as possible, a temporally and spatially high-resolution forecast of solar radiation is required. All-Sky Imagers (ASI) play a key role in this. It is particularly important to be able to detect and track cloud formations in ASI images from multiple cameras distributed across large PV fields, and to evaluate and classify them according to various criteria.

Task

The student is expected to segment and track clouds in ASI images using deep learning methods (e.g. CNN), classify them using clustering methods (e.g. kmeans), and forecast the energy yields for the next 5-15 minutes as precisely as possible based on a temporally and spatially high-resolution forecast of solar irradiation and a digital twin of the PV field using RNN (possibly LSTM, BiLSTM).

Relation on Data Science

Methods of deep learning, clustering, and time-series-based forecasting and simulation with digital twins are core topics of data science and are covered in the research master's courses.

Data- and Hardware Ressources

Two ASI(AllSkyImgager)-cameras and meteorological sensors are installed at the Rosenheim Technology Center for Energy and Buildings, recording images and data since August 2021. The available data set will continue to be continuously expanded every 20 seconds, with one image per camera in parallel. Furthermore, two cloud cameras from WeMatics will be installed on PV fields belonging to the Rosenheim municipal utility company during the course of the project, providing additional consumption data and electricity sales revenue. From the previous research project, Helios 1, image data from three SkyCams, cloud profiles from a lidar, and radiation measurements from the meteocontrol research field covering two years (2024-2026) are available. Computing resources are available in the Solar Computing Lab in the form of a well-equipped machine learning server.

Project plan

1st Semester: Collect all data sources from sensors, available APIs (e.g., openmeteo), and ASI images. Consolidate the dataset and analyze the data. Detect clouds and track cloud objects using multiple ASI cameras. Prepare the research proposal. Optionally, prepare and submit a paper for a work-in-progress submission at a national workshop (e.g., the GI AI & Sustainability working group).

2nd Semester: Optimizing cloud detection performance. Creating prototypes for cloud classes. Creating a first labled learning dataset for cloud types and initial classification results. The final exam will include preparing and submitting a paper to a national conference (e.g., the Annual Photovoltaic Symposium) that provides an overview of the respective research area.

3rd Semester: Consolidation of the dataset with measured yield data and simulated yield data from the PV system's digital twin (utilizing data from project partners). Creation of solar irradiation forecasts and PV yield forecasts. Creation and submission of a paper with presentation at an international conference (e.g., EUPVSEC or ENVIROINFO).

4th Semester: Master's thesis and colloquium with research questions related to the state of research achieved in the joint project.

Eligibility criteria

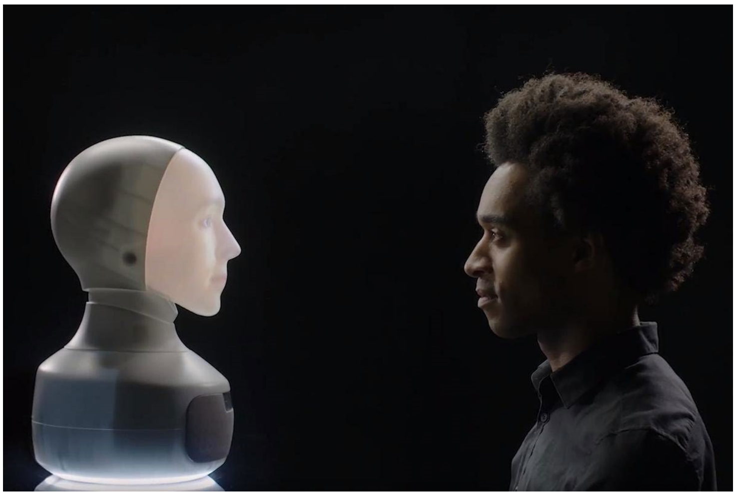
Mandatory: Python programming skills, experience with machine learning and computer vision.
Optional: Knowledge of photovoltaics and energy meteorology.

Acquirable Skills

Use of state-of-the-art machine learning technologies on image and sensor data (such as SkyGPT) in technical applications. Specialized knowledge in the fields of energy meteorology, photovoltaics, and solar computing. Independent scientific work in collaborative projects with companies and research laboratories.

Research project for the Research Master Data Science

Project title: 11 Human-robot interaction: design, implementation and use of a humanoid robot as an individual conversation partner



Project overview

Number of students	1 to 2
Kind	Study project
Project responsibility	Prof. Dr. Thomas Süße and Dr. Maria Kobert
Project context	Possible employment as a student assistant depends on available financial resources. Cooperation with companies is also conceivable.

Abstract

The interaction between humans and social humanoid robots is central in current and future human-machine interaction. Social robots are able to communicate with people in a human-like way - by speaking, listening, showing emotions and maintaining eye contact. For example, they can be used to serve customers, provide companionship, train employees or teach a language. An example scenario with the Furhat robot, that is also available on campus Gütersloh is shown in this video:

https://www.youtube.com/watch?v=3lEQDf9Cv4s

Despite the many possible applications, the development and use of these promising technologies presents new challenges in terms of the fit and compatibility between the needs and requirements of users and humanoid robots. One challenge lies in configuring the robots in terms of speech, facial expressions and gestures so that they meet the individual needs of the users. This is where this project comes in. The overarching goal is to configure the humanoid robot Furhat, which is already available to the Department of Engineering and Mathematics at the Gütersloh campus, so that it can interact appropriately with humans in practical application scenarios to be defined. Furhat shall first be enabled to communicate and collaborate with people in a specific practical

scenario. The practical scenario will be defined together with the project supervisors. In addition, machine learning will be used to ensure that the robot learns from interactions with its human conversation partners and remembers their language, facial expressions, gestures, preferences and conversation content. Furhat should thus "develop its skills" and be perceived as an accepted, pleasant and helpful conversation partner by its human counterparts. Alongside the technical development of Furhat, the interactions between the humans and Furhat will also be examined from a human perspective. An experimental setting will be set up to investigate specific variants of configurations with regard to Furhat's "appearance" (in particular facial expressions, language, appearance) and their effect on the human counterpart.

Brief description

At present, the importance of interaction between humans and social robots is constantly increasing. The use of social robots is becoming increasingly widespread in the healthcare sector, in education, in hotels and restaurants, in shopping malls, in industry and at home. Possible fields of application include informing and activating older people, providing support in care-related services, supporting children and young people, e.g. with autistic conditions, supervising homework and generally imparting knowledge in the education and training sector, or receiving and accompanying visitors to companies, organizations or shopping centers. Despite the many potentials of the usage of these robots, there are also numerous challenges associated with their use. For example, initial studies with humans have shown a low level of acceptance of robots among people. In order to increase acceptance, a key challenge is to configure the robots in terms of speech, facial expressions, gestures and appearance in such a way that they meet the needs of the users. This is the overarching goal of this project. A learning algorithm is to be developed that enables Furhat to remember the characteristics of the human conversation partners and adapt to them.

The main research question of the project is: How can Furhat get to know people and remember them?

To this end, the social humanoid robot head Furhat, which was developed and is marketed by the Swedish company Furhat Robotics, will be used. Furhat is a robotic head without limbs with a face projected onto the inside, where the external appearance such as skin color, eyebrow position and make-up is adjustable. The Furhat robot thus realizes soft facial features and can participate directly in a conversation through natural movements such as shaking and nodding its head. Expressive characters are created with modern speech recognition, an advanced conversation system and automated lip synchronization.

Initially, the Furhat is available to students as a raw version. The first step is to configure it using a practical scenario (use case) and make it capable to interact with humans. In the second step, regular interactions with humans are to be carried out, e.g. weekly meetings. With the help of machine learning, Furhat should be made capable of building up a conversation history in the course of the joint meetings and thus remember past conversations with certain people. To this end, a learning algorithm is to be developed that will enable Furhat to remember and recall the language, facial expressions, gestures, preferences and content of conversations with the person in question. Furhat should therefore develop the ability, as a "conversation partner" for people, to link to information and results of past conversations and continue them. This can be done using a practical scenario (use case) in which a joint task between humans and Furhat is to be solved over several meetings. In addition, the human-robot interaction is examined from a human perspective with the help of interviews and observations.

Task

1. The raw version of the humanoid robot head Furhat has to be configured and made capable of interaction on the basis of a practical scenario (use case).
2. A learning algorithm has to be developed that enables Furhat to remember its human counterpart, his/her language, facial expressions, gestures, preferences and conversation content during regular interactions in the course of the use case developed under 1.
3. With the help of interviews with participating humans and observations of the interactions that take place, the human-robot interaction is examined from a human perspective.

Reference to the topic of data science

A machine learning algorithm will be developed.

Available resources

The Furhat robot head and the software required to program the robot are made available to the students.

Project plan

First semester: Preparation of a research exposé is an examination requirement.

Second semester: Preparation of a paper that provides an overview of the respective research area is an examination requirement.

Third semester: Preparation of a paper with initial quantitative results is an examination requirement.

Fourth semester: Master's thesis and colloquium

Suitability criteria

Mandatory: Programming skills, preferably in Python

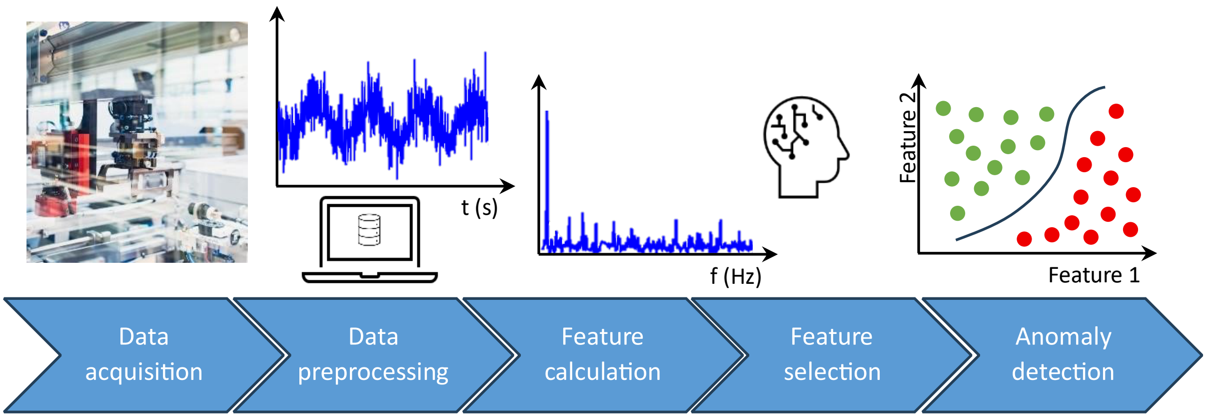
Optional: Knowledge of conducting social science studies (e.g. conducting interviews)

Acquirable skills

- Testing a humanoid robot
- Artificial intelligence methods for problem solving
- Human-robot interaction

Research Project for the Research Master Data Science

Project title: 12 Systematic Data and Feature Engineering for AI-Based Condition Monitoring in Industrial Automation



Project overview

Number of Students	1
Project Type	Master student project
Project Owner	Dr.-Ing. Annika Junker Prof. Dr.-Ing Wolfram Schenck Dr.-Ing. Heiko Stichweh (Lenze)
Project Context	Project within the Center for Applied Data Science Gütersloh (CfADS) with the external partner Lenze in Groß Berkel

Abstract

This Master student project focuses on developing AI-driven methods for machine condition monitoring using data from frequency inverters, eliminating the need for additional sensors. Conducted in close collaboration with Lenze and embedded within the Center for Applied Data Science Gütersloh (CfADS), the project aims to develop innovative, physics-informed data processing and AI techniques for predictive maintenance.

Short description

The increasing digitalization in industrial environments and the rise of Industry 4.0 have created new opportunities for automated machine condition monitoring. Instead of adding costly sensors, modern drive systems already provide rich operational data. Lenze's advanced frequency inverters deliver highquality signals that can be leveraged for sensorless monitoring, reducing hardware costs and simplifying integration. Combined with AI-based anomaly detection, this approach can significantly improve machine availability, reduce downtime, and optimize maintenance strategies. This research project aims to develop a physics-informed AI system for anomaly detection in storage and retrieval machines, using only inverter data. Key objectives include:

- Extracting time- and frequency-domain features with drivetrain knowledge.
- Preprocessing and segmenting data for comparable motion patterns.
- Building robust ML models for reliable anomaly detection.
- Development of robust machine learning models for reliable anomaly detection based on representative training datasets.

The expected outcome is a scalable solution for predictive maintenance in industrial automation.

Task definition

The objective of this research project is to design, implement, and critically evaluate a robust data and feature processing pipeline for AI-supported condition monitoring systems. The methods are designed to work with various machines and applications. The following work packages are planned:

Data Preprocessing and Feature Engineering: The student will systematically prepare operational data collected from frequency inverters, ensuring reliable performance across diverse operational motions, such as acceleration, constant speed, and deceleration. Preprocessing steps should guarantee that the resulting dataset allows for meaningful comparison and supports transfer to similar systems.

Feature Selection and Construction: Both data-driven features (e.g., statistical measures, time-series characteristics, and patterns learned directly from data) and physics-informed features (e.g., metrics derived from drivetrain models, domain knowledge, or physical laws) should be considered. Domain knowledge is to be explicitly integrated in the construction of physics-motivated features, leveraging expertise in drive technology and system dynamics.

Model Development and Robustness: Develop and train machine learning models for anomaly detection using the engineered feature sets. Robustness must be validated by applying the trained models to data from an additional, comparable machine. The student should ensure that both feature processing and model performance are transferable, not narrowly tailored to a single device or set of operating conditions. To avoid overfitting and improve model generalization, feature reduction techniques such as principal component analysis should be implemented, efficiently selecting the most relevant features for anomaly detection.

Comparative Analysis: The student will conduct a critical comparison between data-driven and physics-informed features, discussing their respective strengths and limitations. This includes:

- Assessing performance and robustness of models built on each approach
- Evaluating transferability to new machines or operational scenarios
- Considering factors such as interpretability, computational requirements, and resilience to changing system conditions

Documentation and Critical Reflection: The methodology, selection of algorithms, and all major decisions must be thoroughly documented. The student is expected to provide a reasoned discussion of the results, limitations, and practical implications, particularly with respect to the transferability and reliability of the developed system.

Reference to the topic of data science

This project addresses key aspects of data science, including data processing, particularly the preprocessing of raw data, and the targeted computation and selection of relevant features for subsequent AI-based condition monitoring. In addition, approaches from physics-informed machine learning will be explored, as the integration of physical domain knowledge into the machine learning pipeline represents an exciting and forward-looking research field.

Available Resources

- **Data access:** Availability of realistic operational data from modern frequency inverters across different machine types and applications. This data forms the basis for developing and training anomaly detection methods.

- **Expert support**: Guidance from specialists in automation and drive technology and data science available to advise on data interpretation, modeling, and implementation questions.

Project plan

First Semester:

- Conduct a literature review on condition monitoring and physics-informed machine learning.
- Familiarize with the operation of automation systems using frequency inverters.
- Perform data exploration and preprocessing for an exemplary system. - Write a research exposé summarizing the findings.

Second Semester:

- Implement the calculation and selection of relevant features from both data-driven and physically motivated domains for the exemplary system of the first semester.
- Develop and evaluate a machine learning model to identify abnormal machine states.
- Write a paper of a literature review as the mandatory artefact.

Third Semester:

- Test the transferability of the developed model to at least two other systems: assess to what extent the model can be applied to comparable, yet previously unseen installations.
- Identify features critical for model quality reducing complexity and improving generalizability.
- Write a scientific paper with first results as a mandatory artifact.
- Define specific research questions to be addressed within the scope of the Master thesis.

Fourth Semester:

- Master thesis and colloquium.

Necessary Competencies

Mandatory:

- Bachelor’s degree in an engineering-related field.
- Interest in both data-driven and physically motivated modeling.
- Experience with the implementation of machine learning methods with Python.
- Strong passion for exploring complex technical challenges in depth.

Acquirable Competencies

- Application of machine learning methods to real industrially relevant problems.
- Application of physics-informed machine learning, which is a particularly exciting and forwardlooking research field.