TKH AI Master Thesis Project Proposals 2024

TKH group is a leading technology company with a focus on creating innovative and client-centric technology systems in high-growth markets. The TKH AI hub is a new initiative from the TKH group that focuses on solving complex AI challenges for around 60 companies within the TKH group. As a student, you will work together with our AI engineers to research cutting-edge solutions that make a real-world impact.

TKH AI will give you the chance to gain valuable experience and skills in artificial intelligence while working on exciting projects. While we have the following project proposals / research directions available for master theses, we are also open to hearing your innovative ideas. You must be enrolled in an educational program to apply for these projects. Besides master's thesis projects, we also have openings for part-time student workers available.
If any of these options sound interesting to you, please send us an email **(recruitment@tkh.ai)** with your CV attached. We look forward to hearing from you!

Computer Vision

Many of our projects involve the use of cutting-edge computer vision techniques, with different objectives (i.e. anomaly detection or classification) and in different settings.

1. Reasoning with Technical Drawings / Figures

TKH has a lot of companies that operate with manuals containing technical figures. While parsing through these manuals for automated solutions, there is often trouble parsing through technical figures and interpreting them. In these technical figures, one can typically find artefacts such as lines, dimensions, annotations, symbols, and scales. There have been a few works already trying to infer the information expressed in technical figures, however the scope has been limited (and out-of-context for us) and the focus has been more on extracting text than extracting knowledge [1-4].
For our use, we would like to have a pipeline through which the information can be extracted from these technical figures and can be used with an LLM to improve reasoning capabilities.
This project's objective, in essence, is to investigate feasible methods to improve interpretation of technical figures typically present in manuals.

[1] Haar, C., Kim, H., Koberg, L.: AI-Based Engineering and Production Drawing Information Extraction. In: Kim, KY., Monplaisir, L., Rickli, J. (eds) Flexible Automation and Intelligent Manufacturing: The Human-Data-Technology Nexus (2023)
[2] Al-Wesabi, Tariq & Bach, Andreas & Schönfelder, Phillip & Staka, Inri & König, Markus: Extracting Information from Old and Scanned Engineering Drawings of Existing Buildings for the Creation of Digital Building Models. 10.1007/978-3-031-35399-4_14 (2023)
[3] Scheibel, B., Mangler, J., Rinderle-Ma, S.: Extraction of dimension requirements from engineering drawings for supporting quality control in production processes. Comput. Ind. 129, 103442 (2021)
[4] Elyan, E., Jamieson, L., Ali-Gombe, A.: Deep learning for symbols detection and classification in engineering drawings. Neural Netw. 129, 91–102 (2020)

Expectations:

- Self-motivated, eager to innovate and make a change to existing algorithms
- Affinity with Python and one of the deep learning libraries (Pytorch, Tensorflow, etc.)
- Affinity with the latest computer vision techniques and some knowledge of natural language processing.

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2. Sign Language Recognition

Sign language is a vital form of communication for millions of people worldwide, but it remains inaccessible to many who do not understand it. Developing accurate and efficient sign language recognition systems can help bridge this communication gap, enabling seamless interaction between sign language users and non-users.
In this project, you will contribute to developing a sign language recognition (SLR) system capable of identifying and interpreting sign language gestures from video input. Several works address only word level recognition of sign language (isolated sign language recognition). Meanwhile the latest methods are focused on continuous sign language recognition (CSLR), which is a more challenging problem as it involves the reconstruction of full sentences [1].

Your contributions will include implementing cutting-edge sign language recognition techniques and researching how to establish a seamless pipeline to translate the extracted words into a conversational format using large language models (LLM). We are specifically interested in researching the possibilities of using visual embeddings in text models for sign language translation [2].

Expectations:

- Affinity with video processing techniques, such as background subtraction, pose estimation, optical flow and video processing frameworks such as OpenCV.
- Affinity with working with text models.
- Eager to contribute to society by developing innovative and accessible technologies

[1] Papastratis, Ilias, et al. "Artificial intelligence technologies for sign language." *Sensors* 21.17 (2021): 5843.
[2] Uthus, Dave, Garrett Tanzer, and Manfred Georg. "Youtube-asl: A large-scale, open-domain american sign language-english parallel corpus." *Advances in Neural Information Processing Systems* 36 (2024)

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3. MVTec Data Benchmark Improvement

The MVTec dataset [1] is commonly used for industrial inspection and object detection applications, serving as a crucial benchmark for evaluating machine learning algorithms' performance, particularly in quality control tasks. This project offers several possibilities:

- Data-centric AI: Analyze the dataset's quality, focusing on improving data integrity and relevance to enhance machine learning model performance.
- State-of-the-art (SOTA) Algorithm Development: Design and implement a SOTA algorithm that surpasses the current performance or accuracy benchmarks.
- Anomaly Localization and Segmentation: Besides Image-wise anomaly detection, improve existing algorithms' ability to accurately localize and segment anomalies in industrial scenes.

[1] Bergmann, Paul, et al. "MVTec AD--A comprehensive real-world dataset for unsupervised anomaly detection." *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*. 2019.

Expectations:

- Self-motivated, eager to innovate and make a change to existing algorithms
- Affinity with Python and one of the deep learning libraries (Pytorch, Tensorflow, etc.)
- Affinity with the latest computer vision techniques and data processing.

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4. Standard Model Customization for Computer Vision Applications

Open-source computer vision repositories offer a wealth of opportunities for tailoring models to specific customer requirements. However, modifying these models can often be a complex and time-consuming task. This project aims to develop algorithms that assist in personalizing existing computer vision models for various applications, optimized for implementation in vision cameras from several relevant manufacturers in TKH group. By standardizing this personalization process, we can facilitate experimentation and model switching, allowing customers to efficiently switch between models and improve solutions powered by TKH AI.

Your work will include:

- Development of algorithms to streamline the customization of existing computer vision models for specific customer requirements.
- Optimizing the implementation in vision cameras from LMI, TKH Vision, Chromasens, and other relevant manufacturers within the TKH group.
- Evaluating the performance and efficiency of the customized models and propose improvements to enhance their effectiveness.

Expectations

1. Strong programming skills in Python and experience with deep learning libraries, such as TensorFlow or PyTorch, for implementing and customizing computer vision models.
2. Eagerness to contribute to the development of efficient and accessible computer vision solutions for industry implementations

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Large Language Models

With the advent of large language models (LLM) many companies would like to have an internal chatbot such that functionality for private chat is enabled and confidential information is not exposed to external entities (such as OpenAI in case of ChatGPT). For this reason, amongst many others, we have an internal chat platform called ChatTKH which contains multiple chat modules with different functionalities. There are several research directions that we would like to explore to prospectively increase the performance of our current offerings and to pave the path for adding new functionalities:

1. Hierarchical Social Learning in LLMs

LLMs have recently been co-opted to perform a wide array of tasks, including coding to develop software. While a singular LLM does not perform favorably at making intermediate decisions, it would be interesting to see how multiple LLMs with varying levels of ability perform collaboratively in a hierarchical set-up. This project's objective would be to evaluate multiple such set-ups of LLMs conversing with each other to collaboratively reach a solution. This solution could be any application depending on the interest of the researcher. For TKH AI, we plan to test this technique to build plans/roadmaps for software applications if the method shows good prospects. These LLMs would be playing different roles introducing hierarchy within their social dynamics (such as Lead Developer, Senior Developer, Associate Developer, etc. in the case of software development and planning). It would be interesting to compare this performance with the baselines of the singular models, and the models collaborating with each other in a non-hierarchical set-up.

[1] https://research.google/blog/social-learning-collaborative-learning-with-large-language-models/

Expectations:

- Self-motivated, eager to innovate and make a change to existing algorithms
- Affinity with Python and one of the deep learning libraries (Pytorch, Tensorflow, etc.)
- Affinity with LLMs and prompt-tuning.

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2. Using Interpretability Tools to Develop Writing Assistants

Different writing styles or phrasing can impact the reader's perception. For example, the way a company conveys its news can directly affect its stock price or the way a job vacancy is advertised can influence the number of applicants. This project aims to develop a writing assistant that uses interpretability tools [1] to highlight the most impactful words based on a chosen attribute. The attributes can be selected based on the student's interests and can range from sentiment, financial sentiment [2], toxicity and others [3]. Additionally, the student will investigate controlled text generation methods [4, 5] with the goal of integrating an LLM to increase/decrease the prominence of the selected attribute. In this way, users will be able to manually or through LLMs tailor their text, achieving the desired impact.

[1] Sundararajan, Mukund, Ankur Taly, and Qiqi Yan. "Axiomatic attribution for deep networks." *International conference on machine learning*. PMLR, 2017.
[2] Araci, Dogu. "Finbert: Financial sentiment analysis with pre-trained language models." *arXiv preprint arXiv:1908.10063*(2019).
[3] Devlin, Jacob et al. "BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding." *North American Chapter of the Association for Computational Linguistics* (2019).
[4] Keskar, Nitish Shirish, et al. "Ctrl: A conditional transformer language model for controllable generation." *arXiv preprint arXiv:1909.05858* (2019).

[5] Khattab, Omar, et al. "Dspy: Compiling declarative language model calls into self-improving pipelines." *arXiv preprint arXiv:2310.03714* (2023).

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3. Knowledge Graph Creation and Curation with LLMs in the Loop

As all companies withing TKH Group continue to closely collaborate, it becomes increasingly important to have a centralized and organized repository of knowledge that can be easily accessed and analyzed. A knowledge graph is a powerful tool for achieving this goal, as it can represent complex relationships between different entities and concepts in a structured and queryable format. In this project, we aim to create and curate an enterprise knowledge graph for TKH Group, by mining relevant triplets from various sources such as documents, websites, and APIs, with the help of LLMs.

The objective of this project is to develop a system (through researching and evaluating different methods) that can automatically extract and curate relevant triples (i.e., subject-predicate-object relations) from various textual sources, using LLMs, and use them to build and maintain a knowledge graph for TKH Group. The system should be able to handle large volumes of data, be scalable, and provide high-precision and recall results.

Expectations:

- Strong background in natural language processing, machine learning, knowledge representation and reasoning
- Proficiency in Python
- Bonus: familiarity with knowledge graph construction and maintenance tools (e.g., Neo4j, Apache Jena, Microsoft Graph API)

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4. Knowing When to Retrieve & Act

In our chat system, we are working on enabling users to chat with their own documents, which requires the ability to automatically retrieve and process information from various sources. However, existing agents often lack the ability to accurately determine when to retrieve information and from which sources, leading to inefficiencies and missed opportunities. In this project, we aim to investigate the state-of-the-art of multi-chain agents, i.e., agents that can determine when to retrieve information from documents (and from which documents), and/or from APIs.

The objective of this project is to conduct a comprehensive review of the state-of-the-art of multi-chain agents, and to identify potential directions for future research. The project will focus on the following aspects:

- Understanding the current state of the art in multi-chain agents, including their architecture, algorithms, and applications.
- Identifying the strengths and limitations of existing multi-chain agents, and highlighting potential areas for improvement.
- Exploring the use of advanced machine learning techniques to improve the decision-making capabilities of multi-chain agents.
- Evaluating the performance of multi-chain agents in various scenarios and comparing them to traditional information retrieval methods.

Expectations:

- Affinity with knowledge retrieval, natural language processing, and machine learning
- Proficiency in Python and one or more deep learning libraries (e.g., PyTorch, TensorFlow)
- Familiarity with reinforcement learning and multi-agent systems
- Strong analytical and problem-solving skills

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5. Chat with Tabular Data (in LLM)

In the past, dealing with tabular data typically required the creation of SQL queries to retrieve information. With the help of LLMs it is possible to engage in interactive conversations with the data, without needing to manipulate the data themselves. You will investigate conversational queries and try to understand the chain of thought behind conversational responses. You are encouraged to work in a set-up which tries to infer the knowledge from tabular data. It may also be interesting to look into the works that synthesize tabular data (such as [1]) and consider adversarial approaches.

[1] Solatorio, Aivin V., and Olivier Dupriez. "Realtabformer: Generating realistic relational and tabular data using transformers." arXiv preprint arXiv:2302.02041 (2023). https://github.com/worldbank/REaLTabFormer.

Expectations:

- Self-motivated, eager to innovate and make a change to existing algorithms
- Affinity with Python and one of the deep learning libraries (Pytorch, Tensorflow, etc.)
- Affinity with working with LLMs.

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