

ABEL05 - Audiovisual Speech Processing and Recognition

Academic: Abel, Andrew

Last updated: 2025-01-13 11:33:39

Project is suitable for 2 students

Speech recognition with lipreading is the process of using visual information (i.e. recordings of a speakers face) to recognise and generate text. Feature extraction can be used to extract detailed audio and visual information, and Gabor based methods have been developed which have been used for speech recognition [1]. These are a form of edge detector and allow us to extract detailed mouth information, such as height, width and area of a speaker's mouth [2]. Using these techniques, we have successfully extracted features and produced good lipreading results. In this project, we will focus on improving our initial speech recognition systems. These are mainly research based projects and all include machine learning. These include:

- (i) Speech Segmentation for Real Data Processing. As part of a real time speech processing system, there is a requirement to break speech data up into individual words so that it can be processed. The student will investigate and implement a speech segmentation algorithm.
- (ii) Subtitle Generator Application. We are currently developing an application that will generate subtitles from video files. The aim of this project will be to improve an initial application and is more focused on software development.
- (iii) Speech recognition with LLMs. We wish to evaluate audio speech recognition using commercial LLMs. We will run experiments with Open AI and evaluate with several datasets.
- (iv) Noisy audio and visual data. For speech recognition, most testing takes place with clean data, we wish to generate noisy audio data by adding noise to speech, and also experiment with different types of visual noise.

[1] Zhang, Xuejie, et al. "Visual Speech Recognition with Lightweight Psychologically Motivated Gabor Features." Entropy 22.12 (2020): 1367.

[2] Xu, Yan, Yuexuan Li, and Andrew Abel. "Gabor based lipreading with a new audiovisual mandarin corpus." International Conference on Brain Inspired Cognitive Systems. Springer, Cham, 2019.

ABEL06 - Machine Learning for Emotion Recognition and Explainable AI

Academic: Abel, Andrew

Last updated: 2025-01-13 11:33:39

Project is suitable for 4 students

Emotion recognition from facial expressions is an established field of research, and in recent years, this has been expanded on by using video data and machine learning, in particular a combination of convolution neural networks (CNNs) and recurrent neural networks (RNNs), can be used to estimate emotions and map them in the emotional space [1]. There are a number of features that can be used for emotion recognition, including pose, psychological measures, and facial features. This is a more research focused project that will build on existing emotion recognition work and develop new ideas. Several individual projects are possible:

- (i) Emotion recognition using transformer based end-to-end methods. The student will investigate the literature, identify state of the art research, and use a deep learning model to generate results, which will be fully analysed.
- (ii) Emotion recognition using individual features, such as eye and mouth movements. This has the benefit of being explainable and lightweight. This will involve some image processing and then machine learning. Existing models and features are available and will be built upon.
- (iii) Facial Expression Visualisation. Facial expressions associated with the upper face, in particular the eyes, are extremely useful in emotion recognition. We aim to develop quick and lightweight facial features that can be used to generate and visualise fast information, including tracking blinking, nodding, smiling, and other cues. This is more of a software development project than the others.
- (iv) Explainable AI. We have a collaborative project with the Zero Hunger Lab at Tilburg University, and we are investigating the trustworthiness of machine learning networks. This project will focus on machine learning for image processing, and demonstrating what the network is learning.

[1] M. Ayoub, H. Zhang and A. Abel, "Continuous Valence-Arousal Space Prediction and Recognition Based on Feature Fusion," 2024 IEEE International Conference on Industrial Technology (ICIT), Bristol, United Kingdom, 2024, pp. 1-6, doi: 10.1109/ICIT58233.2024.10540915.

ABEL07 - Model Railway Design and Management

Academic: Abel, Andrew

Last updated: 2025-01-13 11:33:39

Project is suitable for 2 students

Railway planning and driving is a challenging issue. Given the limited number of lines, different routes, and requirements for real time responses, it can be very difficult to successfully model driverless trains. With regard to model railways, it is also challenging to design suitable and interesting track layouts. This project proposes to develop an automated model railway system with a practical implementation using wooden railways and electronic trains. We currently have a functioning basic train set, and this project aims to improve upon the initial system. There are two projects available:

(i) Track layout design. Using Agent based programming and machine learning to design optimal track layouts given an input of track pieces and desired criteria. The output of this should include track visualisation and an application, but this is primarily an AI based project, building on preliminary work.

(ii) Virtual train system modelling. The ultimate aim is to develop a real representation of a train system that will automatically handle variable conditions and plan its own routes. To do this, we need a system that will allow for parameters to be modelled and adjusted such as number of stations, passenger loads, and unexpected events. This will improve on an initial program and is primarily a software development project, with the aim being to make the existing project suitable for use as a teaching resource.

Prerequisites: This would best suit a student who has taken CS823 or CS814

ANDE01 - Large Language Model Textbooks

Academic: Anderson, Damien

Last updated: 2025-01-13 11:33:39

Project is suitable for 2 students

Large Language Models (LLMs) such as ChatGPT are good at producing human level text and conversation. This makes for an engaging experience and has in recent years led to a boom in Artificial Intelligence (AI) interest and investment. How can these tools be used to improve the educational process? Can trust be built into such systems that educators could rely on them to provide accurate information?

This project aims to research the effectiveness of LLMs as educational tools, by training a LLM on a specific textbook and evaluating its effectiveness and engagement for human learners.

Students will be expected to complete the following as part of this project:

1. Identify a topic, or textbook, that would be appropriate for experimentation (Including obtaining any required permission for using it for this work).
2. Build a LLM trained on this textbook that can answer questions relating to the content and engage the user in further study.
3. Evaluate the level of understanding of users of the chosen topic.

MSc Project students will be expected to explore multimodal implementations such as a video game interface or a VR environment. This project is also suitable for students taking MSc Advanced Computer Science with AI.

ANDE02 - Good Parent AI

Academic: Anderson, Damien

Last updated: 2025-01-13 11:33:39

Project is suitable for 5 students

When teaching a game to a new or inexperienced player, a more veteran player will take the approach of providing an appropriate level of challenge for the current skill level of the novice. If the challenge is too easy or too hard, then the new player may decide that the game is not for them as it is not engaging enough. The veteran player will push a new player into interesting situations, providing them space to learn, and challenge to rise to. Can this approach be replicated with an Artificial Intelligence (AI)?

This project aims to research methodologies for building effective game playing AI agents which can teach human players not only how to play a game, but also how to improve their current skill level.

Students will be expected to complete the following as part of this project:

1. Identify a game, tabletop or video game, which they would like to develop an AI for.
 - a. Implement a version of this game if no appropriate implementations are available.
2. Develop an AI game playing algorithm that performs to a very high level.
3. Research and implement novel methods to adapt the skill level of the AI to the human player's current skill level.
4. Evaluate the performance of the AI with human players.

MSc Project students will be expected to build an implementation of their chosen game themselves. This project is also suitable for students taking MSc Advanced Computer Science with AI.

ANDE03 - AI for General Game Playing

Academic: Anderson, Damien

Last updated: 2025-01-13 11:33:39

Project is suitable for 5 students

Artificial Intelligence (AI) agents are very good at learning how to solve a single problem, but are quite bad at tackling multiple problems. As an example, if we train an AI agent to perform well at playing Chess, it will be very bad at playing other games such as checkers or Go. How can we develop AI which are capable of general problem solving?

This project aims to develop novel techniques for tackling general problem solving in AI. Games provide an excellent platform for this, as they can represent a diverse range of problems.

Students will be expected to complete the following as part of this project:

1. Identify an appropriate library of games that provides a diverse variety of challenges (Some examples are LUDII, GVGAI, etc).
2. Identify and develop AI techniques which can solve a variety of problems.
3. Evaluate their performance against other datasets such as human performance, or tailor-made AI agents.
4. Improve the agent in general terms to either increase overall performance or widen the generality of the problems that can be solved.

MSc Project students will be expected to develop a more robust, complete system. This project is also suitable for students taking MSc Advanced Computer Science with AI.

ANEO01 - Analysis of Cyber Attacks per country

Academic: Neofytou, Andreas

Last updated: 2025-01-13 11:33:39

The increasing frequency of cyber attacks presents a significant challenge to every country. Understanding potential patterns and trends of cyber attacks across different countries is vital and thus a key strategy is to develop such effective predictive methods. This project aims to utilize machine learning tools to analyze and predict cyber attacks. The project will involve the collection of global cyber attack data, data analysis and the prediction of future attacks with forecasting models. The student could work and focus on clustered countries or regions. Students also need to explore the effectiveness of different types of cyber attacks, like phishing or DDoS attacks. What are the main factors that influence these attacks to different countries, such as economic status and cybersecurity infrastructure.

ANEO02 - Predicting Heart Anomalies Using Wearable Data

Academic: Neofytou, Andreas

Last updated: 2025-01-13 11:33:39

Nowadays, wearable devices and wearable data provide vital information for various health conditions. This project aims to use machine learning tools to predict heart anomalies, mainly by analyzing key data from those wearable devices. Some key data may involve heart rate, blood pressure and other key indicators. The student should identify which elements are highly correlated with what heart anomaly and thus develop forecasting models that can effectively identify potential early signs of heart irregularities. This will involve extensive data preprocessing and data analysis. The final step will be the development of an effective and reliable machine learning algorithm, which can detect these patterns that may indicate potential heart issues or other heart conditions. A real-time predictive tool could provide early warnings to users, thus the accuracy of those models is vital, by identifying a minor anomaly before it escalates into a serious health problem.

ANEO03 - Predictive Maintenance in Manufacturing

Academic: Neofytou, Andreas

Last updated: 2025-01-13 11:33:39

Maintenance in manufacturing is a key element for success for every company in production planning. Limiting unexpected breakdowns implies reduced costs. As a result, it's vital to predict potential equipment failures and reduce downtime. Students need to work with data collected from industrial sensors, identify and decide which features are important, including temperature, vibration and other metrics. The final step is to develop machine learning models that can forecast when a machine is: likely to fail, require maintenance soon or works fine. The effectiveness and reliability of these models are vital in these time-series analysis and the employment of anomaly detection could give more insights to preventing maintenance.

BELL04 - Predicting outcomes

Academic: Bell, William

Last updated: 2025-01-13 11:33:39

Project is suitable for 3 students

Machine learning and traditional statistical methods can be used to predict outcomes following a series of events. Data can be considered as a set of time-series events or a set of events without date time information.

The project is to build an application that is capable of predicting learning outcomes or trends, such that early intervention can be implemented to try to influence the outcome. The application could read simulated Moodle action log data or use data with a longer timeline such as the longitudinal education outcomes data set that has been recently published by the UK government.

BMIT01 - Gaming The System: make a game about disabilities



Academic: Mitchell, Brian

Last updated: 2025-01-15 15:36:24

Project is suitable for 5 students

Nearly everyone experiences some form of disability temporarily or permanently. We all have our own preferences for learning. This project is a chance to educate others and yourself.

I consider any student who wants to do this project as suitable. However it is your responsibility to ensure you meet the criteria — especially any about communication — and feel happy about them. Before you select this project, think carefully whether 3 solid months of doing this with me is really for you. Even if the project suits you, I might not suit you as a supervisor. So first carefully read the "Projects Read Me First" section on my website <https://personal.cis.strath.ac.uk/brian.mitchell> and the further section specific to this project. If you are not really sure you want do this project, then it's safest not to apply for it.

The game you make can be any type (educational, serious), any genre (action, adventure, puzzle, role-play, simulation, strategy), any style (text, graphics, with or without audio), any implementation (whatever language(s) and platform(s) you wish), and on any disability (or health condition, mental or physical).

The simpler the implementation, the more sophisticated the game design must be. Do not underestimate the time needed to make a decent story line or goal, no matter how simple the game.

Most of all, have fun.

You can choose which disabilities or conditions you want to accommodate and that may include hidden disabilities. If you want the game to work in a browser, it definitely needs to work in Firefox, any others browsers are a bonus. The likely hardest or longest parts of this project will be:

* designing the story line for the game;

* designing accessibility into the game;

* finding (and integrating) freely available existing resources so you don't have to make everything the game needs.

Setting up the infrastructure and tool chain on your own computer can be problematic and should ideally be done between IPP and the project. Use your IPP coursework to evaluate which infrastructure, tools, and resources seem best.

Disclaimer: I am not an expert in accessibility or disability or graphics or design (or Design Informatics). I just thought this was a cool idea for a project and great for inclusivity.

BMIT02 - Map Time: make an accessible interactive map that helps students reach their classroom on time 🎉 ⏱️ 🚶 🎉 🎉

Academic: Mitchell, Brian

Last updated: 2025-01-13 16:54:51

Project is suitable for 5 students

I consider any student who wants to do this project as suitable. However it is your responsibility to ensure you meet the criteria — especially any about communication — and feel happy about them. Before you select this project, think carefully whether 3 solid months of doing this with me is really for you. Even if the project suits you, I might not suit you as a supervisor. So first carefully read the "Projects Read Me First" section on my website <https://personal.cis.strath.ac.uk/brian.mitchell> and the further section specific to this project. If you are not really sure you want do this project, then it's safest not to apply for it.

When someone or some device tells you it takes 5 minutes to get somewhere, how do they know it will take you 5 minutes? Never assume.

Travel time varies not just with mobility difficulties (which includes temporary disabilities such as a minor injury and situational disabilities such as carrying a heavy bag).

A common symptom of conditions like AD(H)D and ASD is difficulty meeting deadlines, which includes getting to class on time. People with those conditions can often feel so anxious about being late that they feel not attending is less worse than being late.

This project is a chance to help.

If possible, try to make a map of a real University building, but proof-of-concept will suffice.

If you make this a browser-based product then I only care that it works on Firefox, any other browser is a bonus. If you are making this browser-based then you will need ECMAScript (JavaScript) and PHPStorm, and perhaps a virtual machine with a database server and webserver. Programming in ECMAScript requires a thick skin and considerable programming experience.

If you make this an installable app then it needs to be really easy to install, by which I mean a single install, not first installing a million other things.

However you implement this project, the interface must be accessible. It is up to you to

find accessibility standards and check compliance.

Disclaimer: I am not an expert in accessibility or disability or graphics or design (or Design Informatics). I just thought this was a cool idea for a project and great for inclusivity.

BMIT03 - What The File: An intuitive system to manage experiment results and data



Academic: Mitchell, Brian

Last updated: 2025-01-13 16:56:24

Project is suitable for 5 students

This project is a Software Engineering and development project, not a Machine Learning project. It helps if you have done some Machine Learning but it is not necessary.

I consider any student who wants to do this project as suitable. However it is your responsibility to ensure you meet the criteria — especially any about communication — and feel happy about them. Before you select this project, think carefully whether 3 solid months of doing this with me is really for you. Even if the project suits you, I might not suit you as a supervisor. So first carefully read the "Projects Read Me First" section on my website <https://personal.cis.strath.ac.uk/brian.mitchell> and the further section specific to this project. If you are not really sure you want do this project, then it's safest not to apply for it.

This is a programming project (you may make it as software engineered as you wish) for managing experiments, most likely Machine Learning, their data and results. The ultimate goal is to make a flexible, robust, intuitive system to help people manage experiments, data, and results easily. This may not sound much but as anyone who has needed to run many experiments on different versions of data sets will tell you, the number of permutations and generated files can become messy all too quickly and easily.

The completed system should be intuitive, configurable, and robust. It needs to be easily maintained and, crucially, easily installed and used. Ideally it should not need a massive tool chain installing first to make it work, so be careful if you think Python might be the answer. Your program must assist the user in managing data, running experiments, and managing results. Ideally the code should try to be written and documented to standards for open source publishing, though it will remain private. If you write a user guide, it must be clear enough for someone who is a Machine Learning user but not a Machine Learning expert.

I would love to use such a system because the cost of headache pills is becoming too much.

Your system can be on any platform you want but you need to try to make it easy to use and easy to install from scratch. Ideally you will also try to make it accessible. The likely hardest or longest parts of this project will be:

- * designing for simplicity;
- *designing the user interface or interfaces (ideally CLI and GUI);
- * writing the user guide (if you do this);
- * finding the right development tools and techniques.

Setting up the infrastructure and tool chain on your own computer can be problematic and should ideally be done as soon as possible but you need to evaluate different tools as part of the project.

I am not an expert in accessibility or graphics or design (or Design Informatics) or — spoiler — Machine Learning.

CCHA02 - Diversification in Recommendations for Improving Divergent Thinking

Academic: Chavula, Catherine

Last updated: 2025-01-13 14:56:29

Project is suitable for 5 students

Diversification of search results aims to provide users with a broader view of the topic as well as to cover the different aspects of a topic. Divergent thinking is one of the thought processes that has been proposed as a technique to generate creative ideas. This project aims to investigate whether recommendation diversification of academic articles can enhance two dimensions of divergent thinking, namely: fluency and flexibility. Idea fluency refers to the ability to generate as many ideas as possible, and flexibility refers to the ability to produce ideas in numerous categories.

The project will include two components. The first part will include implementing an academic search system that uses a model that optimizes diversity of recommendation of articles to improve either flexibility or fluency. The algorithms will be evaluated using creativity and flexibility or fluency metrics. This component will be completed by two students with each focusing on either flexibility or fluency.

Domain: Information Retrieval

Related work

Castells, P., Hurley, N.J., Vargas, S. (2015). Novelty and Diversity in Recommender Systems. In: Ricci, F., Rokach, L., Shapira, B. (eds) Recommender Systems Handbook. Springer, Boston, MA. https://doi.org/10.1007/978-1-4899-7637-6_26

Patrik Dokoupil, Ludovico Boratto, and Ladislav Peska. 2024. User Perceptions of Diversity in Recommender Systems. In Proceedings of the 32nd ACM Conference on User Modeling, Adaptation and Personalization (UMAP '24). Association for Computing Machinery, New York, NY, USA, 212–222. <https://doi.org/10.1145/3627043.3659555>

Chavula, C., Choi, Y., & Rieh, S. Y. (2023). Searching for creativity: How people search to generate new ideas. Journal of the Association for Information Science and Technology, 1–16. <https://doi.org/10.1002/asi.24857>

Maxwell, D., Azzopardi, L. & Moshfeghi, Y. The impact of result diversification on search behaviour and performance. Inf Retrieval J 22, 422–446 (2019). <https://doi.org/10.1007/s10791-019-09353-0>

Kaiping Zheng, Hongzhi Wang, Zhixin Qi, Jianzhong Li, and Hong Gao. 2017. A survey of

query result diversification. *Knowledge Information Systems* 51, 1 (April 2017), 1–36. <https://doi.org/10.1007/s10115-016-0990-4>

Santos, R.L., Macdonald, C., & Ounis, I. (2015). Search Result Diversification. *Foundations Trends Information Retrieval*, 9, 1-90.

CLIF01 - Generative AI as a Tool for Software Development Education

Academic: Clift, Lee

Last updated: 2025-01-13 14:56:29

Project is suitable for 4 students

Generative AI is becoming increasingly popular within society, and we have seen proof that senior software engineering industry members wish graduates to be aware of how they can use it as an effective tool. Currently, research shows that when learners are allowed to use the tool, they can constructively use it effectively, and it can generally improve work quality without reducing learnt content.

This project will investigate using Generative AI tools to aid software development, specifically in higher education. You will need to understand how Generative AI works and how it can be incorporated into education. You will also need to look into different computing topics and think about how they can be used in different ways.

A few different ways to investigate this project could be investigated here, such as comparing tools for use, creating a custom 'Duck' type tool, comparing the usage of novice and non-novice programmers, using it within different Software Engineering practices, converting pseudocode to high-level code, comparing access ways, etc.

This project would require a learner who knows software engineering education and is interested in improving HE computing education. Strong programming skills are not necessary, but adaptability would be a great skill to have!

CLIF04 - Creating a JIT Block-Based Language for Mobile App Development for Novice Programmers

Academic: Clift, Lee

Last updated: 2025-01-13 14:56:29

Project is suitable for 2 students

In the modern world, one of the main ambitions of novice programmers is to create Mobile Apps. Given how one of the main ways people interact with the online world is through mobile devices, this ambition is not surprising.

Many of the languages used to create mobile apps are not suitable for novice programmers, given their relative complexity and the requirement to understand basic programming paradigms, such as OOP before development can begin. On the contrary, the languages made for novice programmers either do poorly or do not serve the creation of mobile apps.

This project aims to fill this gap by taking an established language used for mobile application development (Flutter and Dart) and creating a block-based language that can be parsed into it. Using many of the features of Flutter, such as JIT compilation and the front-end, tree-like structures, should allow for an interesting conversion into something which isn't purely textual.

There are two possible ways to design this new language: either as a traditional block-based language, like Google Blockly, Scratch, Make-Code, etc. or by leveraging the tree structure to create interactive Trees.

This project is only suitable for students with a strong programming background, likely in web and mobile technologies. It would also be interesting to test this out within a school setting (DBS and time-reliant).

DEVA01 - Implementing and Benchmarking Cost-Space Path Planners in OMPL

Academic: Devaurs, Didier

Last updated: 2025-01-13 14:56:29

Project is suitable for 4 students

Despite their conceptual simplicity, sampling-based path planning algorithms can efficiently explore a high-dimensional space in a probabilistic manner and build a graph representing the topology of this space. They had traditionally been used in simple robotic applications to find feasible (i.e., collision-free) paths, without considering path quality. However, many applications require to compute high-quality (i.e., low-cost) paths or even optimal paths, in the context of cost-space path planning or optimal path planning.

This project will involve implementing various sampling-based algorithms for (optimal) path planning in cost spaces within the popular OMPL (Open Motion Planning Library) platform. These algorithms are all based on the classical RRT (Rapidly-exploring Random Tree) technique, and more specifically the RRT* and T-RRT (Transition-based RRT) methods. Students will be able to choose among the following algorithms: T-RRT* (Transition-based RRT*) [1], AT-RRT (Anytime T-RRT) [1], Multi-T-RRT [2], or Parallel-T-RRT [3].

Students will then have the opportunity to evaluate the algorithm they choose to implement and compare it to other sampling-based path planners available in OMPL, using the benchmarking functionalities of this platform. The main goal of this project is eventually to make these cost-space planners available to a broad audience. In the process, students will benefit from becoming familiar with a motion planning platform that is very popular in the robotics community, and with a classical family of sampling-based path planners.

[1] D Devaurs, T Siméon, J Cortés. Efficient sampling-based approaches to optimal path planning in complex cost spaces. Algorithmic Foundations of Robotics XI (selected contributions from WAFR '14), 2015, doi: 10.1007/978-3-319-16595-0_9

[2] D Devaurs, T Siméon, J Cortés. A multi-tree extension of the Transition-based RRT: Application to ordering-and-pathfinding problems in continuous cost spaces. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2014

[3] D Devaurs, T Siméon, J Cortés. Parallelizing RRT on large-scale distributed-memory architectures. IEEE Transactions on Robotics 29(2):571-579, 2013, doi: 10.1109/TRO.2013.2239571

DEVA02 - Implementing and Evaluating a Web Server for Molecular Caging Prediction

Academic: Devaurs, Didier

Last updated: 2025-01-13 14:56:29

Project is suitable for 4 students

A molecular caging complex is defined as a pair of molecules in which a so-called host (or cage) features an internal cavity that can enclose a so-called guest, preventing its escape. In synthetic biochemistry, a host molecule is usually created with dynamic covalent bonds allowing its self-assembly around a guest molecule and its later disassembly in response to a specific stimulus (such as temperature, pH, or light). This paradigm has produced exciting biomedical applications, for example in targeted drug delivery, virus trapping, or medical imaging. Despite its promises, the use of molecular caging complexes remains challenging, with the discovery or synthesis of host molecules being the main bottleneck. There is thus a need for computational screening methods that can predict whether a given pair of molecules form a caging complex. We have proposed such a method, based on a caging verification algorithm that was initially designed for applications in robotic manipulation [1].

This project will involve implementing this method as a web server, and evaluating it on real-life molecular caging complexes. Students will be able to choose whether they want to work on the web server development part or on the evaluation part of the project. Indeed, the method has already been implemented as Linux-based software and can be evaluated without the use of a web server.

The main goals of this project are eventually to demonstrate the power of this molecular caging prediction approach, and make it available to a broad audience. In the process, students will benefit from becoming familiar with the development process of a web server and/or with classical methodologies for software evaluation.

[1] O Kravchenko, A Varava, F Pokorny, D Devaurs, L Kavraki, and D Kragic. A robotics-inspired screening algorithm for molecular caging prediction. *Journal of Chemical Information and Modeling* 60(3):1302-1316, 2020, doi: 10.1021/acs.jcim.9b00945

DEVA03 - Elucidating Structural Changes in Proteins via Guided Molecular Modelling

Academic: Devaurs, Didier

Last updated: 2025-01-13 14:56:29

Project is suitable for 4 students

Studying a protein's three-dimensional structure allows understanding its function and possible dysfunctions. Computational techniques exist to explore a protein's conformational space, i.e., the space of all possible states (or conformations) of the protein. However, experimentally describing and computationally modelling large proteins remain critical challenges for structural biology. Therefore, we have developed a novel approach integrating experimental data (obtained through hydrogen exchange, or HX, monitoring) in a computational method to efficiently explore a protein's conformational space [1].

Following this approach, this project will involve integrating experimental HX data into molecular simulations performed with the popular computational modelling tool Rosetta [2] to elucidate structural changes in various proteins of interest. As parts of the computational pipeline have already been implemented, students will mostly have to adapt it to the specific molecular system they will be working on. They will be able to ask a research question relevant to the protein they choose to study, and answer this question through simulation and data analysis.

This project will involve the molecular modelling tool Rosetta, the molecular visualization tool PyMOL, and the programming language Python. Students can expect to gain first-hand experience with computational techniques that are widely used in numerous areas of bioinformatics. This project could lead to a publication featuring students as co-authors. This is also a great opportunity for students to develop their network internationally, as collaborators providing the experimental data are located in different countries.

[1] D Devaurs, D Antunes, M Papanastasiou, M Moll, D Ricklin, J Lambris, and L Kavraki. Coarse-grained conformational sampling of protein structure improves the fit to experimental hydrogen-exchange data. *Frontiers in Molecular Biosciences* 4(13), 2017. DOI: 10.3389/fmolb.2017.00013

[2] R Alford, A Leaver-Fay, J Jeliazkov, M O'Meara, F DiMaio, H Park, and others. The Rosetta all-atom energy function for macromolecular modeling and design. *Journal of Chemical Theory and Computation* 13(6), 2017. DOI: 10.1021/acs.jctc.7b00125

DEVA04 - Improving the Coverage of Deep Mutational Scanning Using Machine Learning

Academic: Devaurs, Didier

Last updated: 2025-01-13 14:56:29

Project is suitable for 4 students

By combining extensive mutagenesis, phenotypic selection and high-throughput DNA sequencing, deep mutational scanning (DMS) experiments allows assessing genetic mutations on extremely large scales. This promises great benefits, as knowing the effects of mutations in important genes is crucial to many people, from physicians and pharmacists to patients carrying such mutations. However, it is unrealistic to expect that DMS experiments could systematically reach full coverage of the mutational space of any protein.

This project will involve machine learning techniques to impute missing mutation-associated scores in DMS datasets and improve their coverage. This work is only made possible by recent advances in the field of deep learning, which have led to so-called “protein language models”. Central to this work is a protein encoder, called ESM (Evolutionary Scale Modelling), initially developed as a large language model and recently extended to protein sequences [1]. Our DMS prediction method will rely on a bilayer machine learning architecture. In the first layer, the ESM protein encoder will generate numerical features from protein sequences. In the second layer, a machine learning regressor will predict DMS mutation-associated scores from these features. Students will evaluate various combinations involving 17 versions of the ESM encoder and 16 machine learning regressors. Consensus approaches will also be evaluated on several DMS datasets. Students will benefit from the fact that parts of this computational pipeline have already been implemented. The final goal of this project will be to make our prediction approach available to DMS practitioners as a web server. In the process, students will benefit from becoming familiar with a cutting-edge application of large language models, and with an exciting research topic in bioinformatics.

[1] A Rives, J Meier, T Sercu, S Goyal, Z Lin, J Liu, and others. Biological structure and function emerge from scaling unsupervised learning to 250 million protein sequences. PNAS 118(15), 2021. DOI: 10.1073/pnas.2016239118

DONG02 - Evaluating Large Language Models for few shot learning

Academic: Dong, Feng

Last updated: 2025-01-13 15:00:16

The project aims to evaluate the effectiveness of in-context learning in large language models (e.g. ChatGPT) for few-shot learning. The overarching goal is to enhance the model's ability to generalize and perform accurate predictions when provided with limited examples during the training phase.

Few-shot learning involves training models to perform a task with very limited examples, mimicking the way humans can quickly adapt to new concepts with minimal exposure. The project will involve designing and conducting experiments that explore the impact of incorporating relevant context during the training of these models for regression., assessing their ability to generalize and adapt to new tasks with minimal examples.

The research will include developing a framework for creating in-context learning datasets, tailoring them to specific tasks, and training large language models on these datasets. Through systematic experimentation, we will analyse the impact of different contextual inputs on the model's few-shot learning capabilities. The evaluation metrics will include accuracy, generalization, and efficiency, providing a comprehensive understanding of the strengths and limitations of in-context learning in large language models. The findings from this project can contribute valuable insights to the field of natural language processing, offering practical implications for improving the adaptability and performance of language models in various applications.

The significance of this research lies in its potential to advance the understanding of how in-context learning can be harnessed to enhance the few-shot learning capabilities of large language models. By shedding light on the mechanisms behind effective adaptation and generalization, this project aims to contribute to the ongoing efforts to improve the efficiency and versatility of artificial intelligence models in real-world scenarios.

Reference

<https://arxiv.org/pdf/2005.14165.pdf>

<https://crfm.stanford.edu/2023/03/13/alpaca.html>

DONG03 - Transformers, In-Context Learning and Optimisation

Academic: Dong, Feng

Last updated: 2025-01-13 15:00:16

This project aims to evaluate and enhance our understanding of the impressive in-context learning capabilities exhibited by transformers, which are utilized in models like ChatGPT. In simpler terms, in-context learning refers to the model's ability to tackle new tasks using training and test examples without modifying its parameters. The study will investigate whether transformers can effectively perform a wide range of common machine learning tasks within a specific context. These tasks include standard algorithms like least squares, ridge regression, Lasso, convex risk minimization for generalized linear models, and gradient descent on two-layer neural networks. The goal is to assess how well transformers can achieve accurate predictions across different in-context data distributions for these tasks.

The experiments will involve rigorous testing and validation using benchmark datasets and diverse optimization scenarios. Performance metrics such as convergence speed, accuracy, and robustness will be employed to assess the effectiveness of the proposed approach in comparison to traditional gradient descent methods. The outcomes of this MSc project have the potential to contribute valuable insights to the optimization community, providing a deeper understanding of the benefits and limitations of in-context learning for gradient descent and paving the way for improved optimization algorithms in machine learning applications.

Reference

<https://arxiv.org/abs/2212.07677>

<https://arxiv.org/abs/2208.01066>

<https://arxiv.org/abs/2306.04637>

DONG05 - Investigating the Use of ChatGPT Agents for Task Automation

Academic: Dong, Feng

Last updated: 2025-01-13 15:00:16

The aim of this student project is to explore and evaluate the use of ChatGPT agents for automating and completing a variety of tasks. ChatGPT agents, powered by advanced natural language processing (NLP) models, can interact with users, understand their intents, and execute commands across different applications. This project seeks to investigate how effectively these agents can be utilized for practical tasks such as scheduling meetings, managing emails, conducting preliminary research, or even performing simple coding tasks. By focusing on specific use cases, the project aims to demonstrate the potential of ChatGPT as a versatile tool in task automation, thereby enhancing productivity and efficiency in both professional and personal environments.

Studies have shown that extensive language models can effectively translate abstract planning tasks, expressed in natural language (like "make breakfast"), into specific actionable steps (such as "open fridge"). This project seeks to assess whether adequately sized pre-trained models, when prompted appropriately, can proficiently break down complex tasks into intermediate-level plans without the need for additional training.

Building on the demonstrated capacity of large language models to ground high-level planning tasks into actionable steps, this MSc project aims to delve deeper into the potential of pre-trained models for the decomposition of complex tasks into intermediate plans. The focus is on evaluating the efficacy of adequately sized models without additional fine-tuning, aiming to streamline the planning process by leveraging the inherent capabilities of these models. The evaluation will primarily build upon the methodologies outlined in the provided reference.

The project methodology involves conducting a systematic evaluation of pre-trained models, considering factors such as model size, prompt design, and the nature of high-level tasks. Using insights from the referenced work, the project will assess the ability of these models to autonomously generate coherent mid-level plans for a variety of high-level tasks expressed in natural language. The evaluation process will involve diverse scenarios and task domains to ensure the robustness and generalization of the proposed approach.

The outcomes of this MSc project are expected to contribute valuable insights into the practical applicability of large language models for task decomposition, offering a nuanced understanding of their capabilities and limitations. Additionally, the findings may pave the way for more streamlined and efficient planning systems that leverage

pre-trained models without the need for extensive domain-specific fine-tuning.

Reference:

<https://arxiv.org/abs/2201.07207>

DONG06 - Explainable Deep Learning Models

Academic: Dong, Feng

Last updated: 2025-01-13 15:00:16

One of the major limitations of deep neural networks is its poor explainability. Most of them act like a black- box. At the moment, it is generally recognised that model performance and explainability act as two requirements that are hard to be met simultaneously – often a better performed model comes with poor explainability. To break this deadlock, it is expected that future deep neural networks will need to significantly improve their explainability.

Recent research in deep learning have come up with new approaches that can explain the prediction outcomes from deep neural networks to a certain extent. Examples include LIME, DeepLift – to name but a few. Especially, the recent work in SHAP (SHapley Additive exPlanations) has offered an unified approach based on game theory to explain the output of any machine learning model.

The goal of the project is to evaluate the outcomes from the SHAP in terms of their performance and explainability in different use cases. This will be based on open datasets that are publicly available. We will also use models from the GitHub repository as the starting point.

The student is expected to have background knowledge in AI, data processing and practical skills (e.g. python and PyTorch), especially in deep learning and neural network. You will be expected to run the models from the repository and carry out an evaluation with selected datasets.

[1] A Unified Approach to Interpreting Model

Predictions <https://arxiv.org/abs/1705.07874>

[2] <https://github.com/slundberg/shap>

EDUJ03 - Artificial Intelligence for Automated Penetration Testing

Academic: Edu, Jide

Last updated: 2025-01-13 15:00:16

Project is suitable for 6 students

Penetration testing simulates a cyberattack on a computer system, network, or web application to evaluate system security. Penetration testing aims to identify vulnerabilities and weaknesses in a system that malicious attackers can exploit. The main objective of this project is to apply artificial intelligence techniques to automate pen testing. Possible concepts include but not limited to:

- i) Phishing detection using machine learning, where the student builds an app that uses AI to analyse emails and determine their likelihood of being phishing attempts. The student will train a model on a dataset of phishing emails. The app will analyse the content, structure, sender details, and embedded links to classify emails. It notifies users if the received email is suspicious.
- ii) Automated threat intelligence gathering, where the student creates an app that collects, parses, and categorises cyber threat intelligence from various online sources using AI. Using NLP and machine learning, the app can scrape different online forums, news sources, and dark web locations for emerging threat vectors, providing timely alerts and insights to cybersecurity professionals.

ELAW04 - Aesthetic estimation/enhancement for photographs using mobile devices

Academic: Elawady, Mohamed

Last updated: 2025-01-13 15:00:16

Project is suitable for 2 students

* Summary: In this project, the student(s) will develop a computer vision method to identify / improve the aesthetic level of a scene inside an image. Such methods will contribute to the photography community in capturing professional photos with high aesthetic response. Tools: Google Colab, Github Repository / Actions, W&B Experiments Tracking, HuggingFace Spaces. Prerequisite: Good programming skill in Python / MATLAB, and prior knowledge in fundamentals of computer vision.

* Datasets:

** AVA: <https://www.kaggle.com/datasets/nicolacarrassi/ava-aesthetic-visual-assessment>

** AADB: <https://www.ics.uci.edu/~skong2/aesthetics.html>

** EVA: <https://github.com/kang-gnak/eva-dataset>

* References:

** Hosu, Vlad, Bastian Goldlucke, and Dietmar Saupe. "Effective aesthetics prediction with multi-level spatially pooled features." proceedings of the IEEE/CVF conference on computer vision and pattern recognition. 2019.

** Sheng, Kekai, et al. "Attention-based multi-patch aggregation for image aesthetic assessment." Proceedings of the 26th ACM international conference on Multimedia. 2018.

** Talebi, Hossein, and Peyman Milanfar. "NIMA: Neural image assessment." IEEE transactions on image processing 27.8 (2018): 3998-4011.

** Ma, Shuang, Jing Liu, and Chang Wen Chen. "A-lamp: Adaptive layout-aware multi-patch deep convolutional neural network for photo aesthetic assessment." Proceedings of the IEEE conference on computer vision and pattern recognition. 2017.

** Zhang, Jiajing, Yongwei Miao, and Jinhui Yu. "A comprehensive survey on computational aesthetic evaluation of visual art images: Metrics and challenges." IEEE Access 9 (2021): 77164-77187.

ELAW05 - Semantic segmentation and object detection of street-view and aerial images

Academic: Elawady, Mohamed

Last updated: 2025-01-13 15:00:16

Project is suitable for 2 students

* Summary: In this project, the student will segment the street-view and aerial images in urban and rural environments using computer vision techniques, in order to detect objects and label each pixel within images captured from street-level and aerial perspectives. This technology is crucial for applications such as autonomous vehicles, urban planning, and environmental analysis. Prerequisites: Good programming skill in Python / MATLAB, and prior knowledge in fundamentals of computer vision.

* Datasets:

** Cityscapes: <https://www.cityscapes-dataset.com>

** Mapillary Vistas: <https://www.mapillary.com/dataset/vistas>

**

KITTI: https://www.cvlibs.net/datasets/kitti/eval_semseg.php?benchmark=semantics2_015

** Google Street View: https://www.crcv.ucf.edu/data/GMCP_Geolocalization/

** DOTA: <https://captain-whu.github.io/DOTA/>

** iSAID: <https://captain-whu.github.io/iSAID/index.html>

** AID: <https://captain-whu.github.io/AID/>

** LandCover.ai: <https://landcover.ai.linuxpolska.com>

** SODA: <https://shaunyuan22.github.io/SODA/>

* References:

** Xia, Gui-Song, et al. "DOTA: A large-scale dataset for object detection in aerial images." Proceedings of the IEEE conference on computer vision and pattern recognition. 2018.

** Han, Jiaming, et al. "Redet: A rotation-equivariant detector for aerial object detection." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2021.

** Ding, Jian, et al. "Learning RoI transformer for oriented object detection in aerial images." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2019.

** Ding, Jian, et al. "Object detection in aerial images: A large-scale benchmark and challenges." IEEE transactions on pattern analysis and machine intelligence 44.11 (2021): 7778-7796.

** Lin, Chih-Yang, et al. "Global-and-local context network for semantic segmentation of street view images." Sensors 20.10 (2020): 2907.

** Dong, Genshun, et al. "Real-time high-performance semantic image segmentation of urban street scenes." *IEEE Transactions on Intelligent Transportation Systems* 22.6 (2020): 3258-3274.

** Ma, Xiangyuan, et al. "Measuring human perceptions of streetscapes to better inform urban renewal: A perspective of scene semantic parsing." *Cities* 110 (2021): 103086.

ELAW06 - Underwater Image analysis (fish recognition / coral classification / enhancement)

Academic: Elawady, Mohamed

Last updated: 2025-01-13 15:00:16

Project is suitable for 3 students

* Summary: The student(s) will focus on developing image processing algorithms to improve the visible quality of aquatic scenes and to distinguish underwater objects in this project (i.e. fish, coral). These algorithms will aid in the discovery of the aquatic environment using automated machinery (i.e. ROV, AUV). Prerequisite: Good programming skill in Python / MATLAB, and prior knowledge in fundamentals of computer vision.

* Datasets

** Fishnet Open Images: <https://www.fishnet.ai/>

** DeepFish: <https://alzayats.github.io/DeepFish/>

** Moorea Labeled Corals

(MLC): <https://portal.edirepository.org/nis/mapbrowse?scope=knb-lter-mcr&identifier=5006>

** EILAT: <https://data.mendeley.com/datasets/86y667257h/2>

** EILATV2: <https://data.mendeley.com/datasets/86y667257h/2>

** RSMAS: <https://sci2s.ugr.es/CNN-coral-image-classification>

** LSUI: https://lintaopeng.github.io/_pages/UIE%20Project%20Page.html

** UIEB: https://li-chongyi.github.io/proj_benchmark.html

** EUVP: <https://irvlab.cs.umn.edu/resources/euvp-dataset>

* References

** Beijbom, Oscar, et al. "Automated annotation of coral reef survey images." 2012 IEEE conference on computer vision and pattern recognition. IEEE, 2012.

** Mahmood, Ammar, et al. "Deep learning for coral classification." Handbook of neural computation. Academic Press, 2017. 383-401.

** Lumini, Alessandra, Loris Nanni, and Gianluca Maguolo. "Deep learning for plankton and coral classification." Applied Computing and Informatics (2020).

** Zhao, Shili, et al. "Application of machine learning in intelligent fish aquaculture: A review." Aquaculture 540 (2021): 736724.

** Li, Chongyi, et al. "An underwater image enhancement benchmark dataset and beyond." IEEE Transactions on Image Processing 29 (2019): 4376-4389.

** Islam, Md Jahidul, Youya Xia, and Junaed Sattar. "Fast underwater image enhancement for improved visual perception." IEEE Robotics and Automation Letters 5.2 (2020): 3227-3234.

** Anwar, Saeed, Chongyi Li, and Fatih Porikli. "Deep underwater image enhancement."

arXiv preprint arXiv:1807.03528 (2018).

** Fu, Xueyang, et al. "Two-step approach for single underwater image enhancement." 2017 international symposium on intelligent signal processing and communication systems (ISPACS). IEEE, 2017.

** Wang, Yang, et al. "A deep CNN method for underwater image enhancement." 2017 IEEE international conference on image processing (ICIP). IEEE, 2017.

ELAW07 - Image enhancement (super-resolution / restoration/ text)

Academic: Elawady, Mohamed

Last updated: 2025-01-13 15:00:16

Project is suitable for 3 students

* Summary: In this project, the student(s) will work in developing computer vision algorithms to enhance the visual details of low-resolution or old images. These algorithms have been useful in security systems (i.e. human re-identification in different surveillance cameras, text readability from far-side views) or in editorial systems (i.e. video colorization of old movies). Prerequisite: Good programming skill in Python / MATLAB, and prior knowledge in fundamentals of computer vision.

* Datasets

** DIV2K: <https://data.vision.ee.ethz.ch/cvl/DIV2K/>

** TextZoom: <https://github.com/WenjiaWang0312/TextZoom>

** UHDM: <https://xinyu-andy.github.io/uhd़-page/>

** SIDD: <https://www.eecs.yorku.ca/~kamel/sidd/dataset.php>

* References

** Wang, Xintao, et al. "Esrgan: Enhanced super-resolution generative adversarial networks." Proceedings of the European conference on computer vision (ECCV) workshops. 2018.

** Ulyanov, Dmitry, Andrea Vedaldi, and Victor Lempitsky. "Deep image prior." Proceedings of the IEEE conference on computer vision and pattern recognition. 2018.

** Wan, Ziyu, et al. "Bringing old photos back to life." proceedings of the IEEE/CVF conference on computer vision and pattern recognition. 2020.

** Zamir, Syed Waqas, et al. "Learning enriched features for real image restoration and enhancement." European Conference on Computer Vision. Springer, Cham, 2020.

GEMA04 - Learning from Data through Data Mining and Analysis

Academic: El Gemayel, Joseph

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

Data mining involves the automatic extraction of non-obvious, hidden patterns and knowledge from large volumes of data. This extracted knowledge can significantly enhance decision-making processes, which, in turn, can improve operational efficiency across various domains. In this project, students will identify a dataset (or multiple datasets) and apply data mining techniques to perform tasks such as classification, clustering, or feature detection.

The project's objectives can be ambitious, with a wide range of potential methods to explore. Students might choose datasets that are numeric, textual, or visual, or even delve into more specialized data types such as MIDI files for music analysis. The variety of possible data science projects is extensive, from sentiment analysis and image recognition to predictive modelling and anomaly detection. The key challenge, however, is selecting a dataset that is complex and non-trivial, requiring a deep understanding of data mining techniques and methodologies.

If the chosen dataset is particularly large or complex, the project may begin with a feasibility study to assess the best approaches for handling and processing the data. This may involve data cleaning, pre-processing, and exploratory data analysis to determine which algorithms and techniques are most suitable for extracting meaningful insights. Students will then implement and evaluate their chosen methods, iterating on their approach as needed to achieve optimal results.

This project provides practical experience in handling real-world data, offering a hands-on approach to mastering data mining and machine learning techniques. Students will have the opportunity to work with a range of data types and apply different algorithms to uncover hidden patterns, enhancing both their analytical and technical skills. Additionally, the project encourages creativity in problem-solving and the ability to think critically about data quality, feature selection, and model evaluation.

Before starting this project, students should be familiar with basic concepts in data science, such as data pre-processing, statistical analysis, and machine learning algorithms. Experience with python programming language and knowledge of libraries such as pandas, NumPy, Scikit-Learn, or TensorFlow, will be beneficial. A good understanding of the domain from which the data is sourced can also help in selecting the most appropriate methods and achieving meaningful results.

GEMA05 - Developing Advanced AI for Games Using Search-Based Techniques

Academic: El Gemayel, Joseph

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

This project explores the innovative application of search-based AI techniques in games, with the primary goal of creating an AI algorithm that may outperform any human player or existing AI in a specific game. The chosen game and the techniques used to develop the AI can vary widely, allowing for flexibility and creativity. The project encourages experimentation with different types of games and AI approaches, such as tree search algorithms, neural networks, reinforcement learning, or even hybrid methods that combine multiple techniques.

While winning a game is often a primary objective, the aim of an AI program is not always to dominate. In some cases, the AI's goal is to help human players improve their skills in a particular game. This project also offers the option to develop an AI that plays not solely to win but to provide a rewarding challenge for human players, mimicking the behaviour of a good teacher or mentor. The AI could dynamically adjust its strategy to match the player's skill level, offering hints, guidance, or varying levels of difficulty to encourage learning and improvement. This aspect of the project could be particularly well-suited to two-player board games, utilizing techniques such as Minimax, Monte Carlo Tree Search, or machine learning.

The first step for students is to select a game for their project. This could involve choosing from a range of existing challenges and competitions, such as the "Angry Birds AI Competition," which aims to create AI players capable of mastering various levels of Angry Birds. After selecting a game, students will research existing AI players and strategies for that game and work towards developing a more advanced agent that can either achieve superior performance or function as an effective learning companion for human players.

If a graphical front end is required to visualize the AI in action, students can use the PyGame library to create a user interface, providing a dynamic way to test and demonstrate their AI's capabilities. The project involves designing and implementing algorithms that enable the AI to learn and adapt to the game's mechanics, optimize its decision-making processes, and continually improve its performance over time, whether by competing to win or by supporting human skill development.

This project allows students to delve into the exciting intersection of game development and artificial intelligence, providing practical experience with cutting-edge AI techniques. Students will gain hands-on experience with advanced search methods,

machine learning, and game development, all of which are valuable in both academic research and industry applications. The project fosters critical thinking and creativity, challenging students to push the boundaries of what is possible with AI in gaming environments. It also adds an educational dimension, exploring how AI can be used not only to compete but to teach and improve human players' abilities.

Before starting this project, students should have a basic understanding of AI concepts, including search algorithms, neural networks, reinforcement learning, and player modelling. Familiarity with Python programming, particularly libraries such as PyGame, TensorFlow, or PyTorch, will be helpful. Knowledge of game mechanics, AI competition environments, and pedagogical approaches in gaming will also aid in developing a more effective AI player.

GEMA06 - Developing Image and Video Recognition Systems Using AI Techniques

Academic: El Gemayel, Joseph

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

Image recognition is the process of identifying objects, features, or patterns within an image. In the context of machine vision, it encompasses the ability to recognize a wide range of elements such as objects, places, people, handwriting, actions, and other meaningful information from images or video streams. To achieve accurate and effective image recognition, advanced technologies combining machine vision, cameras, and artificial intelligence (AI) software are employed. This technology underpins numerous applications, from smartphone facial recognition systems to automated fault detection, attendance recording, and surgical imaging.

This project focuses on developing an AI-based image or video recognition system tailored to a specific application. Students will train machine learning or deep learning algorithms, such as neural networks, to detect and interpret various elements within images. For example, they could develop a facial recognition system capable of identifying and distinguishing between different human faces, detecting facial expressions (e.g., happy, sad, stressed, drowsy), or comparing two images to determine if they belong to the same person. This involves creating a model that learns to recognize unique facial features, cross-referencing them against a database to verify identity, check memberships, or record attendance.

Alternatively, students may focus on object detection, where the goal is to identify specific objects or patterns within an image or video. For instance, they could develop a system that detects and categorizes different activities of a pet, such as a cat sitting, walking, or standing, by analysing live video feeds or static images. This could involve applying machine learning or deep learning algorithms to generate optimized outputs that can accurately identify and classify objects under varying conditions.

The project offers hands-on experience with cutting-edge AI and computer vision technologies, which are rapidly expanding fields with numerous real-world applications. Students will gain experience in handling complex datasets, training models, and applying image recognition techniques to solve practical problems.

Before starting this project, students should have a basic understanding of AI concepts, including machine learning and deep learning algorithms, as well as experience in programming with Python and using libraries such as OpenCV, TensorFlow, or PyTorch. Familiarity with data pre-processing, neural network architectures, and model evaluation techniques will also be helpful for successfully completing the project.

GOOD01 - Develop Approaches to Automated Marking of Programming Exercises

Academic: Goodfellow, Martin

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

Manual marking of programming exercises for large classes is time consuming. To allow fast feedback, in order to not hold back student learning, automated marking systems can be utilised. Various approaches to automated marking have been used including unit testing, static analysis and more advanced techniques using machine learning and natural language processing. The aim is to develop an application capable of setting programming challenges and automatically marking them. Alternatively, this could involve extending an existing open source automated marking tool to improve it by doing things like extending the testing capability or improving the provided feedback.

Related work

Marcus Messer, Neil C. C. Brown, Michael Kölling, and Miaojing Shi. 2024. Automated Grading and Feedback Tools for Programming Education: A Systematic Review. ACM Trans. Comput. Educ. 24, 1, Article 10 (March 2024), 43 pages. <https://doi.org/10.1145/3636515>

Martin Goodfellow, Andrew Abel, Konstantinos Liaskos, and John Levine. 2024. Automated Marking in Undergraduate Programming Classes. In Proceedings of the 8th Conference on Computing Education Practice (CEP '24). Association for Computing Machinery, New York, NY, USA, 13–16. <https://doi.org/10.1145/3633053.3633060>

Note: this project requires you to be a strong programmer. Each student will have to implement a separate approach to automated marking or a separate improvement to an automated marking system, e.g., if one student takes a static analysis approach, other students will have to select a different method.

GOOD02 - Improving Code Comprehension using GenAI

Academic: Goodfellow, Martin

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

In introductory programming classes students are able to write working code. However, after achieving this they may not have a full understanding of how the code works, this could be due to them editing similar code samples until they reach their goal. This fragile knowledge may not become evident until later in their programming journey when they are faced with much larger and more complex problems. It's important that before students reach these problems they have full comprehension of what they have previously written, and not just surface knowledge, in order to successfully solve them.

A previous project explored generating questions based on student's submitted code. The aim of this project is to look at other areas we can improve code comprehension using GenAI. This project could focus on adding code comprehension into other question types (such as "Explain-in-plain-English" questions or Parsons problems) or providing automatically generated code comprehension questions on a sample solution or a code fragment which is isomorphic to the sample solution.

Related Work

Paul Denny, David H. Smith, Max Fowler, James Prather, Brett A. Becker, and Juho Leinonen. 2024. Explaining Code with a Purpose: An Integrated Approach for Developing Code Comprehension and Prompting Skills. In Proceedings of the 2024 on Innovation and Technology in Computer Science Education V. 1 (ITiCSE 2024). Association for Computing Machinery, New York, NY, USA, 283–289. <https://doi.org/10.1145/3649217.3653587>

David H. Smith and Craig Zilles. 2024. Code Generation Based Grading: Evaluating an Auto-grading Mechanism for "Explain-in-Plain-English" Questions. In Proceedings of the 2024 on Innovation and Technology in Computer Science Education V. 1 (ITiCSE 2024). Association for Computing Machinery, New York, NY, USA, 171–177. <https://doi.org/10.1145/3649217.3653582>

Teemu Lehtinen, Otto Seppälä, and Ari Korhonen. 2023. Automated Questions About Learners' Own Code Help to Detect Fragile Prerequisite Knowledge. In Proceedings of the 2023 Conference on Innovation and Technology in Computer Science Education V. 1 (ITiCSE 2023). Association for Computing Machinery, New York, NY, USA, 505–511. <https://doi.org/10.1145/3587102.3588787>

Note: this project requires you to be a strong programmer.

GOOD03 - Developing Virtual tutors to support programming Education

Academic: Goodfellow, Martin

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

This project will look at developing tutors (small language models, chatbots, etc.) to support programming education.

Related Work

Suqing Liu, Zezhu Yu, Feiran Huang, Yousef Bulbulia, Andreas Bergen, and Michael Liut. 2024. Can Small Language Models With Retrieval-Augmented Generation Replace Large Language Models When Learning Computer Science? In Proceedings of the 2024 on Innovation and Technology in Computer Science Education V. 1 (ITiCSE 2024). Association for Computing Machinery, New York, NY, USA, 388–393. <https://doi.org/10.1145/3649217.3653554>

Mark Liffiton, Brad E Sheese, Jaromir Savelka, and Paul Denny. 2024. CodeHelp: Using Large Language Models with Guardrails for Scalable Support in Programming Classes. In Proceedings of the 23rd Koli Calling International Conference on Computing Education Research (Koli Calling '23). Association for Computing Machinery, New York, NY, USA, Article 8, 1–11. <https://doi.org/10.1145/3631802.3631830>

Note: this project requires you to be a strong programmer.

IRFA02 - Detection of anomalies in Crowds.

Academic: Irfan, Muhammad

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

Monitoring crowds is paramount for public safety. Detecting unusual situations through human-based monitoring poses challenges, as abnormalities may be missed, potentially leading to catastrophic situations. Sensors, both visual and non-visual, can assist in identifying these events in advance. While research has extensively explored the use of visual information, challenges such as camera perspectives, camera availability, and image quality persist. Non-visual data, such as mobile data, could address these challenges and enhance detection, reducing the likelihood of any events being overlooked. For non-visual approach a dataset would need to be collected for experimentation purposes.

IRFA03 - Smart Parking Guide: A Solution for Dyslexia-Related Challenges

Academic: Irfan, Muhammad

Last updated: 2025-01-13 15:07:32

Project is suitable for 2 students

Dyslexia is a common learning difficulty that mainly causes problems with reading, writing and spelling. It's a specific learning difficulty, which means it causes problems with certain abilities used for learning, such as reading and writing [1].

In urban areas, people often park their cars in public or private car parks and sometimes on the street parking. Despite passing theoretical exams some people struggle to understand the on-street parking control signs and road markings [2]. For example, sometimes one may get confused whether I can park it here now for free or I have to pay etc.

Dyslexic people may struggle more to understand the on-street parking signs and need a system to interpret for them on what to do at that particular time.

This project proposes an intelligent system to interpret the parking signs using image recognition approach by taking a photo of it with a mobile phone and interpret the parking restrictions. This may be a text-based or audio-based interpretation of the parking signs.

[1] <https://www.nhs.uk/conditions/dyslexia/>

[2] <https://assets.publishing.service.gov.uk/media/656ef4271104cf0013fa74ef/know-your-traffic-signs-dft.pdf>

IRFA04 - Smartphone based exercise assistant.

Academic: Irfan, Muhammad

Last updated: 2025-01-13 15:07:32

Project is suitable for 2 students

Many people have smartphones with GPS and accelerometers. It would be useful to use these to estimate how much exercise you do in a day. There has been previous work on calibrating the device using GPS walking outdoors and then trying to estimate indoor distance only using the accelerometer. The objective of the project would be to develop a smartphone app to help the user determining how much exercise they have done in a day. This would require not only determining distance but also transforming this into speed and possibly trying to estimate calories burnt etc.

MOSH02 - Stock Exchange Bot

Academic: Moshfeghi, Yashar

Last updated: 2025-01-13 15:07:32

Project is suitable for 4 students

This is an AI/Data Science project to develop an agent that can predict stock price movements in real-time. To do so, the agent will take into account historical data as well as real-time data. The agent will be based on advanced deep learning models that monitor the market for a set of assets and predict the price movement in real-time. This is an excellent and fun project for those who want to increase their confidence in programming, Data Analytics, Deep Learning, and/or reinforcement learning models.

MOSH03 - Auditing a Chatbot Agent via User Study

Academic: Moshfeghi, Yashar

Last updated: 2025-01-13 15:07:32

Project is suitable for 4 students

This is a user study based project to audit a chatbot system. This is an excellent and fun project for those who want to increase their confidence in building a user interface, conducting user studies, and performing data analysis.

MOSH04 - RAG: Retrieval Augmented Generation

Academic: Moshfeghi, Yashar

Last updated: 2025-01-13 15:07:32

Project is suitable for 4 students

This is an AI/Data Science project to develop a RAG agent that can extract information to populate a generative AI model in real-time. To do so, the agent will take into account historical data as well as real-time data. The agent will be based on advanced deep learning models for natural language processing. This is an excellent and fun project for those who want to increase their confidence in programming, Natural Language Processing, Data Analytics, and/or Deep Learning.

REVI01 - Use of LLMs to enhance digital systems in animal health

Academic: Revie, Crawford

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

It is known that Large Language Models (LLMs) can aid in the capture of data from a variety of users, with the potential to utilise multi-modal inputs as a way to improve capture from those with more limited reading / writing skills. As such there may be potential for LLMs to provide diagnostic support to less well trained para-vets. In addition, the outputs coming from such digital systems may be better understood / used by end users if there are LLMs present at the final user interaction and interpretation phase.

Projects under this theme will explore ways in which LLMs might be used to support mobile-phone based health reporting systems in sub-Saharan African. In addition to the challenges of limited economic resources and levels of educational attainment, it may well be that LLMs can assist with needs for adaption to the context of the many ‘minority’ languages used in this context.

REVI02 - Using FHIR and UN WHO SMART guidelines in animal health contexts

Academic: Revie, Crawford

Last updated: 2025-01-13 15:07:32

Project is suitable for 4 students

The FHIR model is fairly well established in the domain of human health (<https://fhir.org/>) and the WHO SMART guidelines try to place this in a global context (<https://www.who.int/teams/digital-health-and-innovation/smart-guidelines>). This set of projects will look at the opportunities to apply that framework to data interoperability challenges in the domain of animal health. The FHIR framework focuses on the definition of common data models (which they refer to as "resources") and the operational use of these in an open source Web context (mostly based on RESTful APIs). As such the project offers opportunities to students from different MSc cohorts, who can hopefully learn from each other by 'reaching beyond' the confines of any specific degree. Potential topics within this broad area [with student cohort(s)] might include:

- best practices for including / developing controlled vocabularies and ontologies to support "value sets" within FHIR [ILS];
- ways to manage and encourage data sharing (DSA, anonymisation, international legal frameworks, etc.) in line with FHIR's open source philosophy [IM];
- creating an 'Implementation Guide' (IG), a widely-adopted approach to getting FHIR guidelines accepted in various communities for specific animal health use cases, such as sharing field and lab data, or facilitating disease prediction / diagnosis [ACS];

There are other potential topics; these are provided in the hope that they stimulate interest and give a sense as to the types of projects that might fall under this proposed area. The targets of the outcomes from this work are decision makers and animal health professionals in low and middle income countries (LMIC) where access to professional veterinary medical services are restricted and where we feel that mobile-based information platforms have a key role to play in supporting decision makers. I have many contacts with colleagues at the UN Food and Agriculture Organisation (FAO) and where appropriate this work can involve interaction with these colleagues as well as others at the UN WHO in Geneva and/or Berlin.

REVI03 - The value / use of ontologies in an era of LLMs

Academic: Revie, Crawford

Last updated: 2025-01-13 15:07:32

Project is suitable for 4 students

Much of the progress in ‘AI’ / deep-learning over the past 5 years has been based on a framework that does NOT require any explicit representation of knowledge (i.e. the ‘knowledge’ is embedded in the structures of the CNNs, transformers, etc.). As such, the value and utility of ontologies, knowledge graphs and other knowledge organisation systems (KOS) has come into question. The projects under this theme will look at the extent to which this is in fact the case – i.e. when looking at human-in-the-loop and other pre/post processing in LLMs are there in fact places where ‘traditional’ KOS are utilised.

REVI04 - Can LLMs be used to build controlled vocabularies or more complex ontologies, and are these even needed?

Academic: Revie, Crawford

Last updated: 2025-01-13 15:07:32

Project is suitable for 3 students

The success of large language models (LLMs) is often contrasted to previous generations of AI in that these in no explicit representation of knowledge (i.e. this is simply embedded in the ‘deep’ structures of the CNNs, transformers, etc.). However, in some contexts knowledge organisation systems (KOS) still perform an important role. The construction of KOS – such as controlled vocabularies, ontologies or knowledge graphs – is typically expensive and time-consuming. In this context it may be interesting to explore the ways in which LLMs and their NLP capacities can support the creation of KOS frameworks.

SAEG01 - Generative AI in the Metaverse

Academic: Saeghe, Pejman

Last updated: 2025-01-13 15:07:32

Project is suitable for 4 students

The advent of immersive displays (e.g., augmented and virtual reality displays) and generative AI (e.g., large language models and ChatGPT) points to a new era of digital media content creation and consumption. There is a need for experimentation to understand how these technologies can be used to maximise audience engagement while minimising harm.

In this project students will design/conduct a user study and build a prototype. The aim is to provide insights and guidelines for broadcasters and the HCI community and to help shape the landscape of digital media content consumption.

The project will likely involve human participants. Four students can work on the project. For instance, one student can develop a chatbot to provide programme related companion content to TV viewers, another student can develop a virtual companion, and another student can investigate viewers' trust in companion content. Specifics of the project will be discussed, shaped and informed by students' interest and skills.

See the following papers to get an idea of the type of work:

1. Saeghe, P., Weir, B., McGill, M., Clinch, S. and Stevens, R., 2022, June. Augmenting a Nature Documentary with a Lifelike Hologram in Virtual Reality. In ACM International Conference on Interactive Media Experiences (pp. 275-

280). <https://dl.acm.org/doi/abs/10.1145/3505284.3532974>

2. Saeghe, P., Clinch, S., Weir, B., Glancy, M., Vinayagamoorthy, V., Pattinson, O., Pettifer, S.R. and Stevens, R., 2019, June. Augmenting television with augmented reality. In Proceedings of the 2019 ACM International Conference on Interactive Experiences for TV and Online Video (pp. 255-261).

<https://dl.acm.org/doi/10.1145/3317697.3325129>

SHAF01 - Using a Language Model for an App Offering Short Answer Questions in Computer Science

Academic: Shafti, Leila Shila

Last updated: 2024-08-28 21:59:47

Project is suitable for 5 students

Automated marking of assignments can give students immediate feedback, which helps them improve their understanding. However, accurately marking short answer questions is challenging. Currently, a short answer must exactly match the correct answer to be marked as correct. Any variation is marked as incorrect.

The goal of this project is to create a web app that uses a Language Model (LM) to evaluate short answer questions and accept correct variations of the answer. The app will show short answer questions from a question bank and intelligently evaluate the user's responses. It should recognize correct variations of an answer, even if the user doesn't provide an exact match.

Example:

- Question: "What is the process of organizing data in a database to reduce redundancy?"
 - Correct Answer: "Normalization"
 - Accepted Variations: "Data Normalization," "Database Normalization," "Normalizing"
- The app will use an LM (like GPT-2) to understand different variations of correct answers. It should consider synonyms, abbreviations, and common terms. The LM needs to understand the context of both the question and the answer to ensure that variations are relevant. Fine-tuning the LM is necessary so it can recognize different valid answers as equivalent.

If the answer is incorrect, the app should give hints or partial credit based on how close the user's answer is to the correct one. The LM must also handle context-dependent answers carefully to ensure accurate evaluations.

SHAF02 - Gaelic language pronunciation app using language models

Academic: Shafti, Leila Shila

Last updated: 2024-08-28 22:00:20

Project is suitable for 5 students

Learning to write and pronounce Scottish Gaelic is challenging, especially because there aren't many resources available. Given this limited availability, this project aims to see if language models (LMs) such as GPT-2 can help generate phonetic and audio pronunciations for Gaelic.

The goal is to develop a mobile or web app where users can input text in English. The app will then translate the text into Scottish Gaelic, generate phonetic transcriptions for Gaelic words using an LM, and provide audio pronunciations based on these transcriptions. This will help users understand how to pronounce Gaelic words.

You might need to conduct user testing with native Gaelic speakers and learners. This will help you evaluate and improve translation accuracy, phonetic transcriptions, and audio pronunciations. The app should also collect user feedback to make ongoing improvements and expand its features.

One of the challenges of this project is the limited availability of Gaelic phonetic and translation resources. The project will need to work with the available data and LMs to overcome these limitations. Additionally, some knowledge of the Gaelic language is necessary to ensure that the phonetic transcriptions are accurate and adhere to Gaelic phonetic rules.

SHAF03 - Adaptive Coding Challenges and Quizzes App Powered by Language Models

Academic: Shafti, Leila Shila

Last updated: 2024-08-28 22:15:40

Project is suitable for 5 students

The goal of this project is to develop an intelligent app that offers coding challenges and quizzes tailored to each user's skill level. The app will use a language model (LM) to dynamically generate new challenges, provide hints, and assess user responses, adjusting the difficulty based on user performance. The app will help computer science students enhance their programming skills by providing coding problems suited to their abilities.

Using an LM like GPT-2, the app will generate a range of problems, from basic syntax exercises to complex algorithmic challenges. It will adapt the difficulty of tasks in real-time based on metrics such as completion rate, time taken, and the number of hints requested. The app will analyse user performance and offer feedback to help users improve. It will also collect feedback on perceived difficulty to fine-tune the scaling algorithm and ensure appropriate challenge levels.

By using a language model, the app aims to deliver a continuously engaging experience, keeping users challenged and improving their programming skills.

SMIK01 - Data Science for analysis of protein-protein interaction networks

Academic: Smith, Keith

Last updated: 2025-01-13 15:07:32

Project is suitable for 4 students

This topic will introduce you to the rich world of protein biology and allow you to apply your data science skills in a biomedical research context. You will study some aspect of protein-protein interaction networks making use of a vast open database of network for over 1800 species.

Topics include, but are not limited to:

Classification of life domain of protein-protein interaction networks using Graph Neural Networks (a highly topical interface between machine learning and graphs, see e.g. <https://research.google/pubs/pub51251>)

Comparisons of network complexity across the tree of life: studying correlations between the complexity of structure of protein networks and evolutionary development, using methods I developed in a recently published research article: <https://doi.org/10.1371/journal.pcsy.0000026>.

Modelling the evolution of protein-protein interaction networks: based on recent work, you will understand and apply network modelling algorithms in order to find insights into the network-level processes driving resilience in protein networks (Klein B et al., A computational exploration of resilience and evolvability in protein-protein interaction networks. Communications Biology, 4: 1352 (2021))

SMIK02 - Measuring the Complexity of Artificial Neural Networks

Academic: Smith, Keith

Last updated: 2025-01-13 15:07:32

Project is suitable for 2 students

The training of Artificial Neural Networks (ANNs) involves calibrating a huge number of weights between layers. The structure of the resulting networks is an interesting topic with implications of e.g. how to efficiently initialise an ANN.

In a recently published work I provided a normalised measure of statistical complexity of networks (<https://doi.org/10.1371/journal.pcsy.0000026>). This project will explore the application of statistical complexity as a measure for gaining a deeper understanding of ANN weight architecture. The overall objective of this project is to explore whether statistical complexity is positively associated with ANN performance and what the implications of this could be for understanding and developing ANNs.

Exceptional projects may lead to conference submission.

<https://www.mdpi.com/1099-4300/22/2/204>

<https://www.preprints.org/manuscript/202207.0139/v2>

SMIK03 - Computational analysis of functional connectivity of the human brain in Alzheimer's disease

Academic: Smith, Keith

Last updated: 2025-01-13 15:07:32

Project is suitable for 4 students

Alzheimer's disease is a widespread degenerative condition in old age which destroys brain cells over many years. It is becoming more accepted that psychological symptoms of this condition represent a dysconnectivity syndrome, where regions of the brain become functionally disconnected due to cell death. To advance our understanding in this area, this project will involve working with a collaborators to derive and analyse networks of functional connectivity from the ADNI cohort, an open-source dataset of MRI scans and other variables in populations effected by Alzheimer's disease. We can then explore the dysconnectivity hypothesis from different angles.

All projects will involve an initial stage of learning how to implement processing pipelines to derive the functional connectivity networks from the MRI scans. After this, the student may choose from a number of topics for the analysis of these networks, including:

- i) Machine learning: this topic will explore using machine learning of functional connectivity network metrics to predict Alzheimer's disease.
- ii) Consistency of networks from scan: neuroimaging scans are subject to noise and interference that diminish the reliability of their outputs. This project will look into generating connectivity networks from neuroimaging scans and look at how these scans can be consistently analysed to study the onset of Alzheimer's disease
- iii) Hierarchical complexity: this topic will explore associations between the hierarchical complexity (<https://doi.org/10.1016/j.neuroimage.2019.02.028>) of fMRI functional connectivity and Alzheimer's disease.
- iv) FAST functional connectivity: This project will explore the application of a newly developed methodology-- Filter Average Short-Term (FAST) functional connectivity-- for robust and reliable measurement of functional connectivity at high temporal resolution in the ADNI cohort

These are computational projects. No knowledge of neuroscience is required or expected. Exceptional projects will have potential for publication.

ZHAO01 - Interactive Visualization of Intention-Context Alignment

Academic: Zhao, Yingying

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

Reading is a fundamental skill that significantly contributes to lifelong learning, personal growth, and professional success. The science of reading has consistently attracted interest from research communities, including Human-Computer Interaction (HCI) [Sun et al. (2024); Yuan et al. (2023)], educational psychology, pedagogy, and cognitive science. Studying the science of reading can aid in developing front-end reading assistant systems, improving reading comprehension efficiency and supporting struggling readers, such as those with dyslexia, across various Human-Computer Interaction (HCI) scenarios.

This project involves creating an interactive visualization tool that represents the aligned intention time series when users read [Qi et al. (2023)] and structured knowledge graph extracted from the text context [Melnyk et al. (2022)]. The tool can incorporate features such as zooming and historical reading trajectory.

The goal is to provide readers with a “what you see is what you get” reading experience, enabling them to track and recall their reading intentions more effectively, thereby enhancing overall reading efficiency.

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ZHAO02 - Temporal and Cognitive Cue Analysis in Reading Processes

Academic: Zhao, Yingying

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

Reading is a fundamental skill that significantly contributes to lifelong learning, personal growth, and professional success. Understanding how people read has consistently been attracting interest from research communities, including Human-Computer Interaction (HCI) [Qi et al. (2023); Sun et al. (2024); Yuan et al. (2023)], educational psychology, pedagogy, and cognitive science.

This project investigates the role of temporal and cognitive cues in reading. Temporal cues refer to the timing-related aspects of reading, such as the duration spent on specific words, sentences, or paragraphs, as well as the sequence of eye movements across the text. Cognitive cues, on the other hand, are indicators of the mental processes occurring during reading, such as shifts in focus, or comprehension difficulties [Qi et al. (2023)]. For example, students will analyse sequential eye-tracking data collected during reading to identify temporal patterns, such as fixations and saccades, which indicate where and for how long a reader's attention is focused. These temporal cues can reveal which parts of the text are challenging or engaging and how quickly readers process information. Cognitive cues can be inferred from this data by examining patterns such as regressions (where the reader looks back at previously read text), which may indicate confusion or a need to reinforce understanding.

The project has two primary goals. Firstly, it aims to extract temporal and cognitive cues from eye-tracking data collected during reading. This includes identifying key moments when a reader pauses, re-reads, or rapidly scans the text, which can provide insights into their cognitive engagement and processing strategies. Secondly, it seeks to investigate how these cues are linked to reading efficiency and comprehension. By understanding these relationships, the project has the potential to contribute to the development of more effective reading interventions tailored to the individual needs of learners, particularly those facing challenges with reading.

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CriTrainer: An Adaptive Training Tool for Critical Paper Reading. In Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology. 1–17.

ZHAO03 - Cognitive Load Management in Writing Through Structured Guidance

Academic: Zhao, Yingying

Last updated: 2025-01-13 15:07:32

Project is suitable for 5 students

Despite advances in writing assistant technologies [Yuan et al. (2023); Zhang et al. (2023)], achieving optimal efficiency in these activities remains challenging, especially in knowledge-dense professions such as accessing research papers [Du et al. (2024)]. Writing research papers requires high levels of logical reasoning, necessitating rapid shifts in hierarchical text contexts [Melnyk et al. (2022); Zhang et al. (2023)]. These shifts include navigating different logical branches and transitioning between high-level summaries and detailed supporting materials within the same logical branch. Such rapid changes introduce additional time and cognition costs for writers. More critically, these shifts can disrupt the current chain of thoughts, making it difficult to recall progress.

This project aims to develop tools that assist writers in reducing cognitive load by providing structured support during the writing process. By breaking down writing tasks into smaller, manageable components and offering step-by-step assistance, the system aims to alleviate cognitive strain and enhance writing productivity.

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