WESTERN SYDNEY UNIVERSITY

School of Computer, Data and Mathematical Sciences

Summer Scholarship Research Program 2021

Project Lists

Project 30: A Simulation Platform for Intelligent Traffic Control in the Era of Autonomous Driving

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Project Description

In recent years, the studies on communications between vehicles (V2V) and interactions between vehicles and smart infrastructures (V2I), have led to the development of new methods and facilities for traffic control and management based on the real-time traffic data. With the advance of autonomous driving technologies, these technologies bring about great potential for further improvement of road safety and traffic control efficiency but also introduce more challenges for implementation due to high sophistication and uncertainty of autonomous vehicles. This project aims to develop a simulation platform for testing game-theoretical properties of traffic network under different traffic control protocols with different setting of road network and traffic situations. We assume that all vehicles are autonomously controlled with settings of travel preferences, including origin-destinations, safety requirements, tolerance of delay and preference of routes. The project will focus on how autonomous vehicles and intelligent roadside infrastructures make decision to maximize their utilities based on our game theoretical model of traffic network.

The proposed simulation platform will be built based on an existing software system initially created by the AI Laboratory in the Department of Computer Sciences at University of Texas at Austin and further extended in the past years by our research group at WSU, including the students who received Summer Project Scholarships in the previous years. The existing system, named AIMPlus as an extension of the original system AIM4, is capable of simulating three fixed traffic management protocols – First-Come-First-Served (FCFS), Stop signs and Traffic signal with scalable road length and speed limitations. The project is to further extend the system so that it can accommodate simulations with any pre-set traffic control protocols based on the graph representation of road network, and furthermore to perform experiments under different game-theoretical settings of vehicle/intersection utilities to discover optimal traffic control strategies for intelligent roadside infrastructures and route selection strategies for autonomous vehicles.

Project Aims

The aim of this project is to develop a simulation platform for testing game-theoretical properties of traffic network under different traffic control protocols with different setting of road network and traffic situations:

- Further extend the existing system so that it can accommodate simulations with any pre-set traffic control protocols based on the graph representation of road network;
- Generate data into the required format to facilitate game-theoretical analysis;
- Perform experiments under different game-theoretical settings of vehicle/intersection utilities to discover optimal traffic control strategies for intelligent roadside infrastructures and route selection strategies for autonomous vehicles.

Project Methods

The simulation system was built up on the Autonomous Intersection Management (AIM4) with extensions of fixed traffic control protocols and scalable road length. The system was implemented in Java using multi-agent system paradigm. The system is very well written with stand-alone application and well-designed user interface. The main programmer for the extension is a currently enrolled PhD student. The task of this project is to further extend the system so that traffic control at each intersection can be configurated with any given graph representation of priority and performs experiments based on the system to find the game-theoretical properties of different settings of vehicles and intersections. The extension will be written in Java. However, it is also possible to use the current system's APIs as base and further extend it with other languages, such as Python, for the purpose of data collection. MATLAB will be the main tool for data analysis.

Opportunity for Skill Development

The student who undertakes this project will have a chance to learn the frontier technologies of autonomous vehicles, intelligent robotics and multi-agent systems. The student can work with HDR students and get help from them to learn robot programming and run road network simulations. By conducting this project, the student can also develop their research skills for Higher Degree Research and programming/system development skills for industry jobs.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

Students in year 2 or 3 of Bachelor of Computer Science, Bachelor of Computer Science (Advanced) and Bachelor of Information and Communication Technology (Advanced) with excellent programming skills are suitable for this project.

Project 31: Automation of Machine Learning Interpretability Support in Industry Data Science Process Methodology CRISP-ML

Supervisor(s): Simeon Simoff - s.simoff@westernsydney.edu.au
Principal Supervisor

Inna Kolyshkina
Second Supervisor, External Partner, **Analytikk Consulting**

Project Description

Having a good process methodology is important for the success of industry data science projects. Through the years, data science practitioners have adapted CRISP-DM (CRoss-Industry Standard Process for Data Mining), created in the late 1990s, to different applied areas. These fragmented inconsistent modifications of CRISP-DM (for instance, CRISP-MED-DM tailored to address project needs in healthcare and medical domains) indicated the need for new industry, tool, and application agnostic process methodology. To address this gap, which emerged with the diversifying of machine learning (ML) methodologies, the supervisors in this project have developed CRISP-ML (CRoss-Industry Standard Process for Machine Learning). CRISP-ML is the first data science process methodology that explicitly embeds interpretability in a formal way in the machine learning process. The aim of this project is to develop tangible computational support for CRISP-ML, in particular, for handling its interpretability component at each stage. Central to this component are the notions of necessary level of interpretability and the interpretability matrix. The expected outcome will contribute to providing means for computational support and automation of CRISP-ML in industrial settings. Such means will impact the efficiency and quality of industrial data science projects.

Project Aims

The aim of this project is to develop tangible computational support for CRISP-ML, which can automate the application of CRISP-ML in industry data science projects.

Objective 1.
Familiarise with the formal structure and components of CRISP-ML and the notion of interpretability in machine learning. This will require initial work with the two main publications on CRISP-ML, familiarising with the individual stages, the notion of necessary level of interpretability and interpretability matrix and their specifics for each stage of CRISP-ML.

Objective 2.
Develop conceptually the formal structures for adequate capturing the necessary level of interpretability and required information for the interpretability matrix on each stage of CRISP-ML. The work will contribute to the development of CRISP-ML from perspective of process automation.

Objective 3.
Develop computational means for capturing and managing information and data about:

a) The necessary level of interpretability, and
b) The interpretability matrix

The work on the project will also allow the student to develop an appreciation of the complexity of the technical research in explainable artificial intelligence and how it can be supported realistically in organisational settings.

Project Methods

The methods, used to conduct this research include:

- Developing an understanding of the CRISP-ML process model from perspective of automation. The student will work with major publications describing CRISP-ML and real-world case studies of specific use of CRISP-ML, in order to understand the anatomy of each stage in CRISP-ML.
- Higher level study of interpretability in machine learning and how it relates to data science project processes, including its conceptualization in CRISP-ML. Working with essential core set of survey papers on interpretability methods and on data science process methodologies, and specific examples from case studies with the use of CRISP-ML, the student will focus on the main pillars: the necessary level of interpretability and interpretability matrix.
- An instance of design science research method related to the conceptual design and formal representation required in Objective 2. The student, jointly with the supervisors will plan the steps of conceptual and information design and validation of the work.
- Practical implementation of the data and information structures, and computational methods for Objective 3. The student will be involved in an iterative research process with the supervisors, where the supervisors will play also the role of users for evaluation of respective information designs.
- Documenting research. The student will be engaged following industrial research project management style of documenting of intermediate research results, which will capture intermediate research details, assisting the student in writing the final report.
- Writing of quality research paper. This is independent of the research report and will expose the student to the art of preparing research publication for quality public outlets.

Opportunity for Skill Development

The project offers the student the opportunity for the development of the following set of skills:

- Independent lateral thinking for critical assessment of processes and processes methodologies;
- Knowledge of the language, used in the analytics profession and industrial data science projects;
- Skills in process components formalisation and conversion into computational and algorithmic components.
- Concept discovery, and elicitation of concepts and concept structures from collections of publications in computer science, with tools, facilitating knowledge discovery from such collections, for instance, the bibliographic explorer and LitMap of Cornell University's arXiv.org collection.
- Industrial research project management skills.
- Interaction styles which appeal to the analytics industry.
- Writing for quality profile research outlets.
- Appreciation of research methodologies and validation of knowledge.
- Entrepreneurial skills necessary to establish data analytics company.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

1. A preferably 3rd year advanced computer science student, a data science student or a 3rd year advanced information systems student (with understanding of knowledge management, information design and visualization, and technical skills).

   Prerequisite subjects: 301034 Predictive Modelling; 300580 Programming Fundamentals; 300104 Database Design and Development

2. Good programming skills, preferably in (but not limited to) Python, Java, Objective-C/Swift or C++.

3. Excellent communication skills.

4. Desirable: Ability to work to agreed deadlines.

5. Desirable: It will be beneficial if the student has prior familiarity with the following work:

Project 32: Causal Interpretability of Black Boxes: The suitability of Model-Agnostic Methods SHAP and LIME

Supervisor(s): Simeon Simoff - s.simoff@westernsydney.edu.au
Principal Supervisor

Inna Kolyshkina
Second Supervisor, External Partner, **Analytikk Consulting**

Project Description

Black box models, including deep neural networks (DNNs) and tree-based methods (TBMs) have attracted attention of the machine learning (ML) community due to their promising performance in handling various ML and artificial intelligence (AI) tasks, especially, due to the accuracy of performance. However, as a rule, it is difficult to understand the prediction outcomes, generated by black box models and how/why they have reached those predictions. In recent years, research work in interpretability in ML have produced many methods for interpretability of "black-boxes" and respective interpretation tools, with mixed success. There is a recognized for developing deeper understanding of these methods and their applicability.

This project investigates two families of generic interpretation methods for black boxes:

1. The family of SHapley Additive exPlanations (SHAP) methods, which are based on Shapley values, developed in game theory, and are used to explain the contribution of individual data attributes to specific predictive outputs of the black box; and
2. The family of Local Interpretable Model-agnostic Explanation (LIME) methods, which examine the variations of the black box outputs when given specific perturbations in the input data, which then are analysed for explanation with interpretable machine learning models.

The study will explore and apply performance metrics for evaluating interpretation algorithms of from families of methods. Attention will be given to comparison of methods within each family in supporting interpretability of predictions vs interpretability of the cause and causal connections. The black boxes will include developed DNNs and TBMs trained on industry data. The student will adapt libraries implementing SHAP and LIME methods for exploring the anatomy of provided interpretation and the difference between interpretability of predictions and interpretability of cause-effect relations. The project involves data sets from healthcare and manufacturing domains. The student will gain research experience in interpretability and interpretation in machine learning, in two major suites of interpretability methods – SHAP and LIME. As an added value, the student will learn interpretability aspects in CRISP-ML (CRoss-Industry Standard Process for Machine Learning) process methodology, as the outcomes will be connected with the interpretability elements of CRISP-ML. The project impact is in the contribution to the development of scientific discovery tools.

Project Aims

The aim of this project is to develop the distinction between ML interpretability in black boxes for predictions and for causal insights. To achieve this aim, the project sets the following objectives:

Objective 1.
Familiarise with two families of generic interpretation methods for black boxes - SHAP and LIME. This will require from the student initial work with selected surveys on interpretability methods and specific two publications on SHAP and LIME methods.

Objective 2.
Familiarise with examples of black box DNNs and TBMs (at least one example from each type) and the decision tree interpretable model (the later is used by LIME). This will require from the student theoretical background work and experimental studies with specific software implementations, utilising datasets focused on prediction accuracy and datasets with known causal relations from the industry partner (or from similar applied areas from UCI ML repository), in tandem with the supervisors.

Objective 3.
Adapt agreed implementations of SHAP and LIME methods, in order to experiment with generating interpretations of the outcomes from the experimental studies in Objective 2. The implementation of SHAP for the experiments can be done in Python, utilising shap package or R, utilising shapper and fastshap packages.

Objective 4.
Explore and identify specific differences in SHAP and LIME generated interpretations in the case of explaining causal relationships, and connecting the findings with the with the interpretability elements of CRISP-ML.

The work on the project will also allow the student to develop an appreciation of the diversity of interpretability of research methods in machine learning – an emerging research area in machine learning and explainable artificial intelligence, which expected to play key role in the broader adoption of respective technologies in decision advising and making.

Project Methods

The methods, used to conduct this research include:

- Theoretical study of SHAP and LIME methods. This work will be based on the excellent 2020 summary work "Explaining by Removing: A Unified Framework for Model Explanation".
- Experimental (with theoretical assistance) study of selected examples of DNNs and TBMs (at least one technique from each type). The selection of these techniques aims also to allow to underline the properties of the interpretability methods when applied together with respective techniques.
- Higher level study of interpretability in machine learning in order to understand the positioning of SHAP and LIME. Working with essential core set of survey papers on interpretability methods and specific examples from case studies with the use of CRISP-ML, the student will focus on connection of properties of SHAP and LIME interpretability methods with the main pillars of CRISP-ML - the necessary level of interpretability and interpretability matrix.
- Practical implementation of interpretability methods and experimentation for Objective 3. The student will be involved in an iterative research process with the supervisors.
- Documenting research. The student will be engaged following industrial research project management style of documenting of intermediate research results, which will capture intermediate research details, assisting the student in writing the final report.

- Writing of quality research paper. This is independent of the research report and will expose the student to the art of preparing research publication for quality public outlets.

Opportunity for Skill Development

The project offers the student the opportunity for the development of the following set of skills:

- Data science/analytics foundation skills in working with data sets and machine learning technique
- Highly sought skills in interpretability in machine learning
- Knowledge of the language, used in the analytics profession and industrial data science projects;
- Concept discovery, and elicitation of concepts and concept structures from collections of publications in computer science, with tools, facilitating knowledge discovery from such collections, for instance, the bibliographic explorer and LitMap of Cornell University's arXiv.org collection.
- Industrial research project management skills.
- Interaction styles which appeal to the analytics industry.
- Writing for quality profile research outlets.
- Appreciation of research methodologies and validation of knowledge.
- Entrepreneurial skills necessary to establish machine learning technology company.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

1. A preferably 3rd year advanced computer science student, a data science student or a 3rd year mathematics student.
    a. Prerequisite subjects: 301034 Predictive Modelling; 200027 Linear Algebra; 300580 Programming Fundamentals; 301107 Analytics Programming
    b. Desirable subject: 301250 Probabilistic Models and Inference.
2. Good programming skills, preferably in Python, R.
3. Excellent communication skills.
4. Desirable: Ability to work to agreed deadlines.
5. Desirable: It will be beneficial if the student has prior familiarity with the concepts of explaining blackbox models:
    a. Explain Your Model with the SHAP Values (https://towardsdatascience.com/explain-your-model-with-the-shap-values-bc36aac4de3d)
    b. Explain Your Model with LIME (https://medium.com/dataman-in-ai/explain-your-model-with-lime-5a1a5867b423)
6. Desirable: It will be beneficial for the start of the project if the student has prior familiarity with the theoretical foundations of SHAP and LIME methods from the following work:
    a. Ian Covert, Scott Lundberg, Su-In Lee (2020) Explaining by Removing: A Unified Framework for Model Explanation. https://arxiv.org/pdf/2011.14878.pdf
7. Desirable: It will be beneficial for the start of the project if the student has prior familiarity with the packages for implementation of SHAP for the experiments:
    a. Python's shap package - https://github.com/slundberg/shap, or/and
    b. R packages:
        i. shapper - https://modeloriented.github.io/shapper/
        ii. fastshap - https://github.com/bgreenwell/fastshap

Project 33: Image Creating and Transformation using Generative Adversarial Networks (GANs)

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Principal Supervisor

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Second Supervisor

This project is in partnership with **Fujitsu Australia**

Project Description

Many problems in image processing and computer vision can be viewed as image-to-image translation where an image from a domain is translated into another image in a different domain. In most of existing works in this area, both input domain and output domain are known, the translation becomes a problem of finding a mapping between these two domains. In this project, we consider a much more general situation: given two input domains and two images from these two domains, respectively, we want to merge these two images, and generate a new image which is in some unknown domain, while such output images should be meaningful in terms of some abstract mathematic concepts, such as infinity, recursion, loop, embeddedness, etc., from an artistic viewpoint.

In this project, we will develop a novel architecture of generative adversarial networks which can be applied as a generic GAN (Generative Adversarial Network) model to merge images from different domains and then generate new images which belong to some undefined new domain. The output images from MergeGAN should be of sufficient resolution and details and able to be further expended.

One direct outcome of this project is along the line of AI created art. The generated images will be of artistic values and should be also helpful for health mediation purpose. There are other potential applications from this project, such as automatic image editing, dynamic image transformation and predicting, etc.

Project Aims

The ultimate goal of this project is to develop an AI model which can automatically generate some meaningful images which belong to some unknown domains.

Our current aim is to generate so-called "deep mountain" images, where some abstract concepts of recursion, infinity, loop, and embeddedness are virtually represented in a mountain image. Under this task, our research consists of four steps:

- Step 1: Develop a GAN model to generate generic mountain features – in this step, we develop a general GAN model and build a mountain training dataset, through an extensive training process, the GAN model eventually can automatically generate mountain-like images.

- Step 2: Based on the outcome of step 1, we develop a new GAN model, which is mainly focusing on learning finer details of mountain elements such as finer mountain ridge, forest patches on the mountain bodies, etc., where the first GAN model will be used as input image generator for this new GAN model.

- Step 3: We develop a new GAN which will be used to generated images with defined recursion, infinity, etc. represented. The challenge of this step is to first build a proper image dataset which represents certain types of shapes, and then through training process, the GAN can eventually generate those abstract patterns.

- Step 4: in this final step, we develop a MergeGAN which can successfully merge the generated mountain images from step 2 and the abstract patterns from step 3 into abstract mountain images with clear recursion and infinity patterns.

Project Methods

This project will be conducted using the state-of-the-art AI technology Generative Adversarial Networks (GANs). Our project will employ some of the most advanced GAN techniques such as PatchGAN and BigGAN architectures, etc., and extend these architectures to fit our needs.

To achieve our purpose, understanding and analysis of the current GAN models are essential. Once getting a deep understanding of these advanced GAN architectures, we will develop our own GAN architecture, using TensorFlow – which is an end to end open source platform of machine learning. We will also build sound dataset of mountain images by ourselves, because the existing various datasets for image recognitions do not fit to our specific requirements for generating abstract mountain images.

Computational capacity is an important requirement for implementing deep neural networks. For our project, we will use both Fujitsu Australia's NVIDIA DGX V100 station, DGX V100 platform, as well as the school GPU facility.

Opportunity for Skill Development

By participating in this project, the student will gain excellent opportunities for developing the following skills:

- Theory and practices of machine learning, in particular, in the areas of deep learning and generative adversarial networks (GAN) technologies.
- Various machine learning programming skills such as Python and TensorFlow programming.
- Practical skills of building datasets for real world machine learning problems.

Students are required to have the following skills/meet the following pre-requisite(s) to apply

To successfully apply for this summer scholarship, the applicant should meet the following essential requirements:

- A 2nd or 3rd year computer science student, and
- Good programming skills in Python.