

CS 486/686 Project Instructions

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1 Overview

The purpose of the course project is for you to gain some experience working on an artificial intelligence problem of your choice.

You are expected to perform the following tasks.

- Choose a topic in an area of Artificial Intelligence.
- Identify a specific problem in your chosen topic.
- Summarize a few recent research papers that tackled your problem of interest.
- Identify a question related to your problem of interest and form a plan to answer the question by implementing a program.
- Implement the program and produce results.
- Discuss your findings and future directions.

There are two deliverables for the project. See the next few sections for details.

2 Deliverable Instructions

2.1 Proposal

For the proposal, you must complete the following tasks.

- Find group members. Join a group on Learn.
For CS 486 students, find two other group members. See section 3 for some tips on searching for group members. For both CS 486 and CS 686 students, join a group on Learn. Each CS 486 student should join a group with 2 other CS 486 students. A CS 686 student should join a group by themselves. See the available groups on Learn at Connect > Groups > View Available Groups. Each group has a number attached to it on Learn.
- For any CS 486, complete the group contract. You must use the template posted on Learn.
- Choose a project topic, and review a number of research papers on the topic.
For CS 486 students, please cite at least 5-7 research papers. For CS 686 students, please cite at least 10-12 research papers. See section 4 for some tips on finding a project topic.
- Complete the Introduction, Related Work, and Methodology sections of the project report. You must use the template posted on Learn.

Check out the marking rubric titled “Project Proposal” on Learn for how you will be evaluated for this deliverable.

What to submit:

1. Submit the partially completed project report.
Comment out all the irrelevant texts from the project report template. Submit one PDF file named **GroupNumber_proposal.pdf**. For example, if you are in group 80, the file name should be **80_proposal.pdf**.
2. For CS 486 students, submit the group contract on Learn. The PDF file should be named **GroupNumber_contract.pdf**. For example, if you are in group 80, the file name should be **80_contract.pdf**.

See the project report template for more details.

2.2 Final Report

For the final report, you must complete the following tasks.

- Complete the implementation.
- Complete the project report.
- Make a public Piazza Post.
- Make a video demo.

See the project report template for more details.

Check out the marking rubric titled “Project Final Report” on Learn for how you will be evaluated for this deliverable.

What to submit:

1. Submit the complete project report.
Submit one PDF file named **GroupNumber_final.pdf**. For example, if you are in group 80, the file name should be **80_final.pdf**.
2. Submit the Piazza post.
3. Include a link to video demo to the dropbox on Learn.

2.2.1 Make a Piazza Post

Make a public Piazza post for your group and include the following parts in your post.

The title of your post should be: Project Group XXX (Title of your project report)

Include the names of your group members.

If you are comfortable, include a link to your demo video.

1. (1 paragraph) Summarize your project. Highlight the best/most interesting/most surprising result!
 - Our group tackled the problem ...
 - Our results show that ...

2. (1-2 paragraphs) Copy and paste your abstract (or your conclusion if you want to give a bit more detail).
3. (1 paragraph) Describe a few challenges you encountered while working on the project and how you overcame these challenges.

2.2.2 Make a Video Demo

Create a video demo for your project.

Format

- Time length: 5-10 minutes
- Every group member's face should show up in the video at least once.
- Don't think of this as a dull academic presentation. Instead, imagine you are a popular tech You-Tuber trying to make a viral video about a cool AI project.
- Take advantage of any visual that helps demonstrate your work. It is not required to make slides, but highly recommended if you have lots of graphs to show.
- Upload your video to YouTube and submit a shareable link to the Learn dropbox. If you don't have access to YouTube, submit your video to the Learn dropbox.
- Make sure your video is view-able through the link at least until your grades became official on Quest. You can choose to make the video public or private (only visible to people through the link). However, if your video is public, people may find your video by searching certain keywords on YouTube, which can benefit your future career if you are confident in the quality of work.
- The title of your video doesn't have to be the same as your report. Especially if you decide to make it public on YouTube, make the title interesting and easy to search.

Recommended structure

- Introduction (2 minutes)
 - What is the problem tackled?
 - Motivation
- Method (1-2 minute)

- Explain the proposed solution at a high level. Do not go into details of the algorithm
- Result (the core of the presentation)
 - Interesting challenges in your implementations
 - Walk us through how to run your program and showcase the result.
 - For data science projects, present findings from your data-set
 - Performance analysis
 - Anything else interesting you want to share

Tools

Feel free to use any software to record or edit the video. We understand that group members may not be able to meet each other physically due to Covid 19. Here is a (non-exhaustive) list of software we recommend for you to make virtual group presentations:

- Zooms/Teams: you can record your desktop with a video of all group members virtually in Zoom or Teams. Zoom is free for the meeting shorter than 40 minutes, and Teams is provided by the university. Here is [a tutorial that explains how to record presentations for zoom](#).
- PowerPoint: you can record narrations directly in PowerPoint. Advantage: each person can record one slide at a time and you can change a slide without having to re-record the narration. Here is [a tutorial for recording presentations in PowerPoint](#). You will need a desktop version of PowerPoint, which is also provided by the university.
- OpenShot: open-source video editor where you can post-process any video (trim sections, combine various tracks, add overlays) on any platform (Windows, Mac, Linux). Advantage: free. Here is [a tutorial that explains the basic features available in OpenShot](#).
- Screencast-o-matic: record and edit videos. Advantage: professional comprehensive software for both recording and editing. You can record your desktop with narrations and a video of yourself. You can also post-process the resulting videos (trim sections, combine various tracks, add overlays). While you can record videos of up to 15 minutes for free, a subscription of US\$1.65/month allows you to record videos of any length and to edit them.

Tips

- Please do not just pick several sentences from your paper and read them out. Oral communication is very different from written communication. The effectiveness of your communication will make up a large portion of your mark.

- This is also not a video summary of your paper. Unlike the paper, you don't need to go into the details of the algorithm. In this video, you should focus on what you accomplished and try to "sell" your model. Be creative and tell interesting stories.
- Demo your model in different scenarios. For example, if you are building a sentiment analysis tool, you should probably show us how your model behaves when the input is a positive sentence and when the input is a negative sentence.
- We do not expect you to spend lots of time editing the video. Feel free to just record it in Zoom or Teams, and you can still get the full mark. Of course, you are more than welcome to edit to make your video more professional and fancy.
- Your video should be self-contained for people who haven't read your paper.
- The following videos are some excellent demo videos for AI projects. Feel free to watch them before you start:

[My AI Projects by Maanas Peri](#)

[Jetson Nano: Vision Recognition Neural Network Demo](#)

[Multi-Agent Hide and Seek by OpenAI](#)

3 Tips on searching for group members

If you have had experience working in a group, then you would know that having group members that work well together can contribute significantly to the success of the project. I've provided a few suggestions below about how you can go about finding group members for the project.

It is difficult to predict how well you will work with a person before spending significant time working with them. Thus, when trying to find a group member, you should try to get as much information about them as you can and use the information to predict how well you will work together. This is still difficult nonetheless. (If you have had experience interviewing someone, you would know how difficult it is to get to know someone from a 30 minute conversation.)

If you already have friends in the course and you know them well, it may be a good idea to work with them. If you don't know anyone well in the course, consider doing a search through Piazza to look for team mates.

Please make use of the Search for Teammates post on Piazza. In the post, you may want to include the following information.

- Your program and year level.
- Your time zone. (It would be easier to meet if you are in the same time zone.)
- How much time can you devote to this project? How many other courses are you taking this term? What other responsibilities do you have?

In addition, here are some additional questions that you may want to ask your potential group members. You can include some of these information in the Piazza post. Alternatively, you could ask these questions through email or talk about them during a meeting.

- What is your goal for the project? What do you want to get out of working on the project? How well do you want to perform on it?
- Have you worked on a group project before? Have you encountered any conflicts or disagreement while working on the project? How did you deal with it?
- Have you worked on an open-ended project before? In an open-ended project, you have to choose a topic and deal with many unexpected issues while working on the project. Have you encountered any challenges while working on an open-ended project? How did you deal with these challenges?

- How much do you know about AI/ML through coursework, Co-op, online courses, etc.? Is there any specific topic that you want to explore?
- How do you prefer to communicate (emails, meetings, slack, etc)? What are your expectations regarding the timeliness of responses to emails / slack messages?
- How do you prefer to work on the project? Do you prefer to divide and conquer or do you want to work on a component together? Do you prefer to work on your own or do you prefer to work together during an online meeting?
- What role do you want to take as part of the group? Do you want to be the Leader, Organizer, Editor(s), Researcher(s), Writer(s), Trouble-Shooter/Brainstormer, or Presenter(s)?

See [this handout](#) for details of the roles.

Finding a group member is a two-way process. Don't feel obliged to accept the first person who contacted you. Take some time to communicate with the potential group members through email and meetings. In my experience, the success of a project depends more on how well group members work together and less on the individual abilities of the group members.

4 Tips on finding a project topic

It is likely that you do not have a lot of experience working on a project on artificial intelligence. You might feel anxious and overwhelmed about finding a project topic. Don't worry! Here are a few suggestions on how you could get started.

- Examine your daily lives. Perhaps, a problem that frustrates you will end up becoming a project topic worth exploring.
- Look through the latest research papers in conference proceedings.
- Look through the topics that students work on during previous terms.

Alice: Aim to find a topic that you are curious or passionate about. This will motivate you to put in effort into the project and get the most out of it.

4.1 Look at what is happening around you

Artificial Intelligence is becoming ubiquitous in our daily lives. If you encounter a problem in your everyday life, chances are that we can apply an artificial intelligence algorithm to solve it.

To find a project topic, think about problems that you encounter in your daily lives. Perhaps, you can do a project on it. Alternatively, think about recent news articles that you have read. Does any emerging technology catch your eye? You can possibly find a related project topic as well.

4.2 Look through conference proceedings

The most up to date research in computer science is published in annual conferences. One way of searching for a topic is to look through conference proceedings.

You do not need to read through the papers and understand them. Instead, look at the titles of the papers. Does any keyword catch your eye and sound interesting to you? If the title looks interesting, then read a few paragraphs in the introduction section. If you are still interested in exploring this topic, then you can write it down as a candidate topic. Gather a few candidate topics with your group members and decide on one of them together.

See section 7 for a list of top conferences on artificial intelligence.

4.3 Project Topics from the Spring 2020 Term

Sports:

- Predicting all-star players in NBA
- Predicting the Outcomes of NBA Playoffs

Stock Market:

- Predicting the direction of the Amazon stock using historical prices and news articles
- Realizing short-term capital gains in the stock market using historical market data
- Predicting Short Term Stock Market Trends

Recommender Systems:

- A job recommender system for WaterlooWorks
- Cross-platform Video Recommendation
- Recommending movies to a group of people

Music:

- Generating Music based on its Style
- Detecting Emotion from Musical Phrases Using Supervised Learning
- Can a transformer learn and generate music pieces in ternary form?
- Predicting the popularity of songs
- Determine the genre for a song
- Identifying the local key centres of a musical piece
- Personalized Music Recommendation
- AI-generated Lo-fi music with different layers of instruments

Natural Language Processing:

- Semantic translation of Chinese proverbs into English
- Create a trading bot using Donald Trump Tweet sentiment analysis
- Sentiment Analysis on the IMDB Movie Review Data-set
- Facial Sentiment Intensity Analysis
- Sentiment analysis of COVID-19 social distancing tweets
- Paper Abstract Generator
- Detecting Phishing Emails
- AI to combat fake news
- Automatic text summary generation using keyword extraction and other NLP techniques
- Optical Handwritten Chinese character recognition
- Comparing different architectures (e.g. ALEXNET, VGG, GOOGLNET) on MNIST data set
- Example-Based Font Generation
- Determine if a Twitter account is run by a human or a bot

Computer Vision:

- Detecting Brain Conditions using Medical Scans
- Generating captions for images
- Handwritten Chinese Character Recognition
- COVID Prediction using Chest X-Ray Images
- Transforming a landscape image into an animated time-lapsed video
- Detecting license plates in images
- Compare the performance of face detection between the Viola-Jones algorithm with more recent CNN-based ones
- Facial Recognition using Deep Learning

- Image De-noising for increasing the sharpness of the image on different categories by training a Deep Learning NN Model
- De-blurring Images
- Optimal Music Recognition: Transforming Hand-written Sheet Music to Digital Sheet Music
- Doodle Recognition
- Video Frame Interpolation using CNNs
- Convert Face Sketches to Realistic Portrait Images using GAN
- Text to Image Synthesis using GAN
- Mobile Game character art generation with GANs
- Verification of government identification
- Signature Verification
- Style Transfer of Paintings
- Classifying road signs with CNNs
- Classifying YouTube Video Titles

Games:

- Playing Battlesnake using Reinforcement Learning
- Playing Tetris Optimally
- Benchmarking Modern Reinforcement Learning against other well-known search algorithms (e.g Minimax search, Alpha Beta Search) using Chess
- Beating Pac-Man
- Determine the winner of a Pokemon 6x6 Battle
- Comparing Evolution Strategies with model-free Reinforcement Learning in Dr. Mario
- Play Connect 4 optimally.
- Nonogram solver using CSP
- AI predicting Pokemon matches
- Love Letter AI

- Beating the game 1010! Puzzle with reinforcement learning
- Playing the Billiards Game using AI
- Drafting winning decks for the card game Sushi Go
- Solving variants of the 2048 game using the Expectimax algorithm
- Exploring Solutions to Sparse Rewards during Reinforcement Learning in a Multi-agent Real-time Tank Game
- Solving the game mastermind
- Beat the first level in Mario using reinforcement learning
- Solving the match-3 puzzle
- Beating the QWOP Game
- Solving evil 2048
- Beating the T-Rex Game using Reinforcement Learning
- Determine the winner of a League of Legends Game
- Comparing the Dueling Deep Q algorithm and Double Deep Q algorithm on the Atari game Breakout.
- Transfer learning between finite state games
- Solving the Rubik's Cube
- Object detection in a screenshot of the game Touhou 15 (Kanjuden Legacy of Lunatic Kingdom)
- Detecting Hidden Roles in Multi-Player Deception Games such as Avalon
- AI for Tetris
- Beating Othello with Self-play Reinforcement Learning
- AI for the Board Game Coup
- Implementing Prioritized Replay Buffer with Deep Reinforcement Learning for Flappy Bird

Other Machine Learning Topics:

- Optimizing Traffic Light Control

- Predicting Airbnb Prices
- Human trajectory prediction
- Discover and recommend an optimal schedule to a user
- Categorizing inappropriate and violent content on the web

4.4 Project Topics from the Spring 2019 Term

Alice: Many projects below were literature survey papers. Therefore, the titles tend to be quite general. If you were to choose one of the topics below, you need to narrow it down to a manageable scope.

Computer Vision:

- Automatic Image Captioning
- Image Recognition based on Tree Boosting Methods
- Detection of Diabetic Retinopathy based on Fundus Retinal Images using Neural Networks
- Image Classification: Linear Classifier vs Neural Network
- Detecting small objects in images (A small object occupies less than 1% of the image.)
- Generative Adversarial Networks for Image-to-Image Translation
- Image Classification and Localization by Deep Learning

Natural Language Processing:

- Machine Translation Models
- Classifying Sports Articles as Subjective/Objective
- Unsupervised Word Sense Disambiguation
- Automatic Text Summarization
- Short Message Service (SMS) Spam Detection

Games:

- Modelling Dynamic Opponents in Commercial Predator/Prey Video Games
- Solving Flappy Bird using Reinforcement Learning
- An Artificial Intelligence Model for StarCraft 2
- The Rainbow Variant of the Hanabi Board Game
- An AI Agent for Playing the Hanabi Board Game
- Texas Hold'em Poker
- Reinforcement Learning in Pacman
- Supervised Learning for Chess Engines Heuristics
- Chess Engine Comparison
- Applying Monte-Carlo Tree Search for Real-Time Games (League of Legends, DOTA)

Other Topics:

- Modelling the survivals of ant-colonies as a multi-agent problem (inspired by Google's AI challenge in 2011)
- Automatic generation of Britpop-style lyrics with recurrent neural networks and n-gram models
- Comparing discretization methods for machine learning algorithms
- Point of Interest Recommendation Systems
- Evolution of Condition-based Maintenance with Deep Learning
- Gaussian Mixture Model and K-Means on Breast Cancer DataSet
- Deep-Learning-Based Facial Recognition
- Comparing Algorithms for Planning Problems
- Defense Against Adversarial Example Through Random Mutation In Input
- Artificial Intelligence for Algorithmic Trading
- Credit Card Fraud Detection
- Automated Test Case Generation
- Comparing Heuristics for Optimization Problems
- Increasing Compute Density of Quantized Convolutional Neural Networks using FPGAs
- Modelling Ranking of Product Reviews

5 Tips on identifying a research question

This may be one of the most challenging steps for you. The question should be more specific than the problem. For example, the problem you want to solve could be playing a game using reinforcement learning algorithms. Then, the specific question you want to answer could be which of the two variants of reinforcement learning algorithm allows an agent to play the game better?

A good research question usually involves some sort of comparison. For example, it does not make much sense to aim for the goal of “reaching a 80% prediction accuracy on a problem” since an accuracy of 80% means different things in different contexts. It makes much more sense to compare two algorithms and determine which one achieves a better accuracy on a given problem.

Here are a few examples of research questions.

- Compare two algorithms. Determine which algorithm achieves a better accuracy or performance when solving a given problem.
- Compare different parameter values for a complex algorithm, such as a neural network. Determine which combination of parameter values allows the algorithm to achieve the best accuracy or performance on a given problem.
- Take an algorithm trained on one data set and evaluate how it performs on a similar data set. For example, take a reinforcement learning algorithm trained on one level of Super Mario and evaluate it on another level of Super Mario. For another example, take a neural network trained on pictures in daylight and evaluate it on pictures with night scenes.

6 Tips on finding and summarizing related work

6.1 Purpose of performing a literature review

One of the first steps of writing the project proposal is to do a literature review. By doing a literature review, you are trying to answer the following questions.

- Have people studied a problem that is similar to the one I am interested in?
Alice: The answer to this question is probably yes. It's going to be difficult to find a problem that nobody has tried to study before. Nevertheless, it is good to be sure.

- What variants of the problem have they studied? What methodologies did they use? What results did they obtain?
- How does this paper relate to other papers on the same topic?

Alice: When tackling a difficult problem, researchers build on each other's work to make progress. Incidentally, reading the related work section of a paper gives you a good idea of how the authors of this paper are building on prior work.

6.2 Find relevant papers on a topic

To get started, you need to find one relevant paper. Let's call this paper X. Starting with paper X, you can find more related papers as follows:

- To find papers that are more recent than paper X, you can use the "Cited by" feature in Google Scholar. When you find paper X on Google Scholar, you can find out other papers that cite paper X. These other papers are likely related to paper X and are more recent than paper X. This is a good way to find recent papers on a topic.
- To find papers that are older than paper X, you can skim through the related work section of paper X. The related work section should give you a good overview of the older related papers and explain how the related papers are connected to paper X. Alternatively, you could simply skim through the references in paper X.

Here are some ways of finding the first paper that is relevant to your topic.

- Type in keywords in a search engine like Google Scholar.
- Visit the websites of the top conferences or journals and look through the recent proceedings.

In Computer Science, you will find the most up to date research results in conference papers. Conferences happen annually and it takes a few months of intense work to produce a high quality conference paper. In contrast, it may take up to 2-3 years to publish a journal paper because of the rigorous review process. Sometimes, when a journal paper is finally published, the results are already well known.

See section 7 for a list of top conferences on artificial intelligence.

Focus on recent papers. (Unless you know that a paper is classic and everyone cites it.) Note the number of citations for each paper. The citation count is a good indicator of the importance/popularity of a paper.

6.3 How to read a research paper

A useful approach is the three-pass approach. Check out the following two links:

- [How to Read a Paper by S. Keshav, University of Waterloo](#)
- [How to read scientific papers by Christoph Schmidl](#)

I will summarize the three-pass approach below.

Motivation for the three-pass approach:

- Reading research papers is rarely taught at Universities and can lead to massive frustrations.
- A common mistake is to focus on details and miss the big picture.
- The three-pass approach allows you to read a paper incrementally from getting a general overview to understanding the details.

Alice: If you are writing a literature review, the first pass is necessary to get a high level idea of the paper. If you need to mention details of the paper or compare/contrast it with other papers, then the second pass is also useful. The third pass is unnecessary unless you want to use the implementation in the paper or replicate the results of the paper.

The first pass

- Goal is to get the big picture of the paper.
Alice: If you don't have a lot of experience reading papers, it's okay to spend a lot of time on the first pass.
- Skim the titles of the sections and the subsections to understand the structure.
- Read the title, abstract, introduction and conclusions entirely.
Alice: The abstract tends to be dense. I would skip it the first time around.
- As you read each paragraph, try to summarize it in 1-2 sentences.
- As you read the introduction, try to come up with vague questions in your head. What do you anticipate the authors are going to say?
- As you read the introduction, try to answer the following questions.

1. What is the application/real-world problem of interest?
 2. What is the specific problem they are trying to solve? Did the authors make any assumptions to simplify the problem? Are the assumptions valid?
 3. Why is this problem challenging to solve?
 4. What methodology did the authors use to solve this problem? Did they perform a theoretical analysis, implement an algorithm, or conduct an experiment?
 5. What are their main results? Are these results meaningful and useful?
- After reading the conclusion, revisit and revise your answers above.
 - If the paper is worth reading, proceed to the second pass.

If the paper is worth reading, proceed to the second pass.

The second pass

- Read the entire paper.
Alice: This step may be useful when writing a literature review. It helps you to get a better sense of the exact techniques used in the paper so that you can compare and contrast it with other related papers.
- Ignore technical details such as proofs and math equations.
- Try to summarize every 1-2 paragraphs. Rephrase the key points in your own words. Form a high-level story of the narrative in the paper.

The third pass

- This step can take several hours. You need to make sure that the paper is worth reading.
Alice: This step is not necessary when writing a literature review. It is only necessary when you want to make use of the ideas in the papers or replicate the results of the paper.
- Read the complete paper with all its math equations and details.
- Try to re-derive the theoretical results and re-implement the paper.

7 Conferences on Artificial Intelligence

Top conferences on Artificial Intelligence:

- AAAI Conference on Artificial Intelligence.
[AAAI 2020 Conference Program](#)
- IJCAI: International Joint Conference on Artificial Intelligence
[IJCAI 2020 Accepted Papers](#)
[IJCAI 2020 Full Program Schedule](#)
- AAMAS 2019: International Conference on Autonomous Agents and Multi-agent Systems
[AAMAS 2019 Conference Program](#)

Top conferences on Machine Learning:

- NeurIPS 2019: Conference on Neural Information Processing Systems
[NIPS 2019 Conference Website](#)
- ICML 2019: International Conference on Machine Learning
[ICML 2019 Conference Website](#)