Course Proposal

MANU 465, Intelligent Manufacturing

Course Overview

This course is intended to be a technical elective course in the Manufacturing Engineering (MANU) Program. This course reviews core issues necessary for understanding the application of ML (Machine Learning) and AI (Artificial Intelligence) in Manufacturing.

The course consists of four Modules: (i) An introduction to Machine Learning Techniques (ii) Potential Applications of ML in Manufacturing (iii) Industrial Case Studies (iv) Capstone Project

After completion of Module 1, students will learn fundamental techniques in ML: Classifiers, Support Vector Machine, Decision Tree, Naïve Bayes, Linear Discriminant Analysis, Clustering, Principal Component Analysis, Deep Learning (ANN (Artificial Neural Network) and CNN (Convolutional Neural Network)) as well as other fundamental techniques. Students will learn these techniques, coding with Python, and how to use Python libraries in ML through various analyses for some prepared data.

Module 2 is intended to be a short introductory topic, where students will become familiar with some use cases of AI in manufacturing, without in-depth analyses of each. In this module, through many examples, it is shown to students that AI can perform quality control, perform predictive maintenance, reduce environmental impact by cutting down materials waste, improve production, eliminates the need to program movements of a robot by using the CAD models. They learn how in manufacturing, with AI adoption, industries are able to make rapid, data-driven decisions, optimize manufacturing processes, minimize operational costs, and improve the way they serve their customers.

Then students will become familiar with some applications of these techniques in particular manufacturing processes, such as machining, cutting, additive manufacturing, etc, through some industrial case studies in Module 3.

Students will master these topics through completing a capstone project (developing an AI system) in Module 4. The course capstone project, involves forming a team (3 or 4 students), proposing a project, developing test plan, conducting tests and real data acquisition, developing and testing the AI.

3 Credit [3-0-1] - Lectures (Two 1.5-hours), Tutorial (One 1-hour)

Course description for calendar: Machine learning techniques, Deep learning, Python Libraries for machine learning (Scikit-learn, TensorFlow, and Keras), Basic signal processing techniques, Data Acquisition, Applications of AI in Manufacturing, Use sounds to evaluate a CNC, Use AE sensor to evaluate Metal 3D printing	
Instructor: Ahmad Mohammadpanah **Contact**: mpanah@mail.ubc.ca	Date/Time
Pre-Requisite: MECH 368 (or equivalent course in Measurements and Instrumentations), Either STAT 251 or MECH 305/6, or a basic course in statistics **Co-Requisite**: for MECH and IGENS (Mech 392)	
Required Textbook: None	

Course Format

The course will be delivered through lectures supported by application examples in manufacturing engineering and guiding students in developing an AI for a particular manufacturing process. Python will be the main coding program in this course. This course will be delivered in four main Modules:

Module I: An introduction to Machine Learning Techniques

In this Module, students will become familiar with fundamental machine learning techniques for data analyses. They will learn how to apply each of these techniques for various data analyses. Prepared data will be given to students from different examples (not necessarily related to engineering or manufacturing). Students will also become familiar with different Python Libraries for machine learning (eg. Scikit-learn, Theano, TensorFlow, and Keras). This module consists of four main chapters:

- **Classifiers**
    - K-NN (K-Nearest Neighbor)
    - SVM (Support Vector Machine)
    - Decision Tree

  - Naïve Bayes
  - LDA (Linear Discriminant Analysis)
- **K-Mean Clustering**
- **PCA (Principal Component Analysis)**
- **Deep Learning**
  - ANN (Artificial Neural Network)
  - CNN (Convolutional Neural Network)

Module II: An introduction to Potential Applications of Machine Learning in Manufacturing

This module intends to briefly explain how data analyses and machine learning can be used in manufacturing, and how it can improve manufacturing, the effect of AI in manufacturing, and what the future of manufacturing would look like. This is just an introductory topics without any in depth study or analyses.

Through many examples, it is shown to students that AI can perform quality control, shorten design time, and reduce materials waste, improve production, perform predictive maintenance, and many more. In this module students will learn that Artificial intelligence is a game-changing technology for any industry. As the technology matures and its costs drop, AI is becoming more accessible for many companies. They learn how in manufacturing, with AI adoption, industries are able to make rapid, data-driven decisions, optimize manufacturing processes, minimize operational costs, and improve the way they serve their customers. Students will become familiar with some use cases of AI in manufacturing, including:

- **Quality checks -** Machines can be equipped with cameras to detect defects on the production line and spot any imperfections. The process can be fully automated, applying AI.
- **Prediction of failure modes -**Products can fail in a variety of ways, but with enough data on how products are tested and how they perform, AI can identify the areas that need to be given more attention in tests.
- **Predictive maintenance -** Predictive maintenance predicts when machines need maintenance and prevents unplanned downtime by using machine learning. Technologies

such as sensors and machine learning embedded in manufacturing equipment enable predictive maintenance.

- **Environmental impact -** AI can help to transform manufacturing by reducing waste and its environmental impact and optimizing energy efficiency.
- **Making use of logistics data -**Big data can be used to the benefit of manufacturers in many ways, such as Supply chain management, risk management, predictions on sales volume, product quality maintenance, prediction of recall issues
- **Unprogrammed Robotics -** The conventional robots need to be provided with a fixed procedure of assembling parts but AI-Powered robots can interpret CAD 3D models, which eliminates the need to program their movements.

Module III: Case studies of AI in Manufacturing

In this module students will see real world industrial examples of ML and AI in manufacturing. Here is a tentative list of cases. Depends on the availability there will be also guest speakers from industry. For each case, students will be given the data, so they could implement some of the techniques they learn in Module 1 to process the data.

- Smart Machining (ANN and Sound)
- Smart CNC (AE sensor)
- Monitoring parts made by Powder Metallurgy with AE sesnsor
- Welding process monitoring, using sound, image processing and ANN
- Application of Temperature data in different process monitoring
- Artificial intelligent and Additive Manufacturing
  - Techniques for monitoring Selective Laser Sintering (SLS) using AE sensor
- Application of CNN (Convolutional Neural Network) with Image processing during different manufacturing processes
- AI Hardhat

Module IV. Course capstone project (One of these 3 options)

After completing the first 3 modules, students are ready to start their capstone experiment. Depends on the availability of equipment, student will form teams of 3 or 4. They prepare a project proposal based on the three available options:

- Develop an AI for a CNC process, using data from one of these sources (AE Sensor, Acc. Sensor, Temperature, or Sound)
- Develop an AI for a Metal 3D Printing (using data from AE Sensor)
- Propose your own project

After confirming the project proposal by the supervisor, they will conduct the experiment and collect data. For example, if their project is related to developing an AI for a CNC process, using sound. They may design a simple part, create the Tool-path and its G-code. Then, using the CNC machine, make the part, and record the sound. They need to repeat the same process several times. They apply the techniques they learn to develop a smart CNC process for making this simple part.

Course Objectives

The objective of this course is to enable students to improve their skill in developing, conducting and interpreting any types of data first. Then gaining a solid understanding of which machine learning technique is plausible to be used for a certain data set or application. A good knowledge of which parameter (signal) should be measured or which sensor should be used for each application is essential. For instance, depends on a process or machine, one may have the option to measure Temperature, Sound, Acceleration, or Acoustic Emission, or manifold of other signals. The question is, which of these signals can provide a better representation of the machine behavior. Module 3 of the course includes several specific industrial case studies (successful and unsuccessful projects) to help students develop these skills.

After completion of this course, students learn the basic Machine Learning techniques, such as: Classifiers, Support Vector Machine, Decision Tree, Naïve Bayes, Linear Discriminant Analysis, Clustering, Principal Component Analysis, Deep Learning (ANN (Artificial Neural Network) and CNN (Convolutional Neural Network)) as well as other fundamental techniques. Students learn how

to write codes with Python for implementing each of these techniques. They learn how to use Python libraries in ML, such as Scikit-learn and Keras through various analyses for some prepared data. Students become familiar with some applications of these techniques in particular in manufacturing processes, such as machining, cutting, additive manufacturing, and more. They learn data acquisition techniques and its requirement (i.e. sampling frequencies, iterations, …) in using different sensors.

Students will be introduced to some example of applications of AI in manufacturing, such as performing quality control, predictive maintenance, cutting down materials waste, improving production, eliminates the need to program movements of a robot.

They become familiar with challenges of developing an AI for a manufacturing process through completing a capstone experiment.

Learning Outcomes

- Obtain meaning from physical observations (measurements), data, data presentations, and interpretation of data
- Become familiar with some basic measurements, using sensors such as accelerometer, acoustic emission sensor, microphone, temperature.
- Learn data acquisition techniques and its requirement (i.e. sampling frequencies, iterations, …) in using different sensors.
- Become familiar with different Machine Learning terminologies, Python coding, and its libraries
- Write basic codes to apply different ML techniques with various data
- Apply different Classifiers with a certain data sets and compare the results
- Know how to use ANN (Artificial Neural Network) for a specific set of data
- Know how to use CNN (Convolutional Neural Network) for a specific set of images
- Be able to conduct FFT (Fast Fourier Transformation) on a set of data (i.e. recorded sound, or the accelerometer data)
- Write code to create frequency spectrogram for a set of data
- Know how to do basic image processing (e.g. edge detection, color change)
- Understand the current trends and application of AI in Engineering

- Apply different ML techniques (e.g. A classifier or ANN) for a certain set of prepared data pertained to a manufacturing process
- Be able to plan, conduct tests and measurements to obtain data from a specific manufacturing process
- Apply ML techniques to the recorded data
- Obtain meaning from the ML results
- Use the ML results to develop a basic AI for the process you conducted the tests and measurement
- Divide the recorded data to “Training” and “Test” sets to generate the “Confusion matrix” and evaluate the AI you develop
- Gain insight on the future of manufacturing and the application of ML and AI in manufacturing

Evaluation Criteria

The assessment strategy for this course is typical of many engineering courses, as we routinely assess students on the basis of their ability to recall and apply relevant facts and theories, to perform calculations correctly and evaluate their responses for plausibility, to demonstrate competence in design methodologies, and to be able to communicate technical information effectively.

Assignments (small programming projects) in this course allow students to practice and apply newly learned techniques. These assignments are frequently programing-based and thus quite mathematical in nature. The topics in this course build upon each other, and so material presented early in the term (mainly in Module 1) is critical to the understanding of material presented later in the term (in Module 2 and 3), and later critical for applying them (in Module 4). Giving some weight to weekly or bi-weekly assignments encourages students to practice the material covered in the course consistently throughout the term, which improves the overall outcome for the students. Because the students do have the ability to work with others and seek help during office hours, or seek help from the TA, who will focus on Python programming techniques.

After Module 1, there will be a midterm exam (quiz), which give the students an opportunity to demonstrate their knowledge in a controlled testing environment and may include a combination of

calculation-based problems, coding, interpreting data, applying different ML techniques to a certain data set or illustration of knowledge of relevant facts and techniques pertained to Machine learning. The results of the exam, plus the assignments will be used to assess the students' understanding of the fundamental theorems and concepts before moving on to the next module.

The course instructor would be remiss in his duty if he neglects to underscore the fact that learning the concepts in each module in this course is demanding and takes time. One Key in true and lasting knowledge in this course is practicing through writing codes and applying various ML techniques to different sets of data. Luckily, there are a plethora of free data available to practice various ML techniques. Examples from industry will also be used to show how these theories and concepts may apply in practice.

The capstone project in this course, which involves developing a complete AI for a certain manufacturing process verifies that students have mastered a majority of the material covered in the class, are able to work in a team, write a technical document, and ability to present their work. Grading of the capstone project will be based on both appropriate methods and correctness of chosen methods in applying the ML techniques. These serve to assess a multiple learning outcome in combination, thus giving the ability to assess the capacity of the students to understand the application of ML and AI in manufacturing.

Possible Grading scheme:

Module 1 Assignments: 10%

Midterm: 30%

Module 2 and 3 Quiz: 10

Individual works on the capstone project: 10%

Capstone project: 40%

Course Schedule *(tentative)*

Date	Module	Topics
Week 1	1	Introduction, Data presentation, review of basic statistics, Classifiers, K-NN (K-Nearest Neighbor), SVM (Support Vector Machine)
Week 2		Decision Tree, Naïve Bayes, LDA (Linear Discriminant Analysis), K-Mean Clustering, PCA (Principal Component Analysis)
Week 3		Deep Learning, ANN (Artificial Neural Network), CNN (Convolutional Neural Network)
Week 4		Examples, Review Problems, Discussions, Midterm
Week 5	2	What is intelligent manufacturing? Current trends in applications of AI in Manufacturing, Potential applications of ML in manufacturing
Week 6	3	Review some case studies
Week 7		Work on the data from these cases
Week 8		Review and discussion of the results
Week 9	4	Project proposal and planning
Week 10		Conducting tests and data recording
Week 11		Programing and Developing AI
Week 12		Testing and evaluating the AI
Week 13		Documentation
Week 14	Capstone Project Presentation	Capstone Teams presentation

Academic Integrity

The academic enterprise is founded on honesty, civility, and integrity. As members of this enterprise, all students are expected to know, understand, and follow the codes of conduct regarding academic integrity. At the most basic level, this means submitting only original work done by you and acknowledging all sources of information or ideas and attributing them to others as required. This also means you should not cheat, copy, or mislead others about what is your work. Violations of academic integrity (i.e., misconduct) lead to the breakdown of the academic enterprise, and therefore serious consequences arise and harsh sanctions are imposed. For example, incidences of plagiarism or cheating may result in a mark of zero on the assignment or exam and more serious consequences may apply if the matter is referred to the President's Advisory Committee on Student Discipline. Careful records are kept in order to monitor and prevent recurrences.

A more detailed description of academic integrity, including the University's policies and procedures, may be found in the Academic Calendar at

http://calendar.ubc.ca/vancouver/index.cfm?tree=3,54,111,0.