Course Name: Machine Learning **Prerequisites: STAT115, CSCS202**		
Course Code: CSCS 460	**Course Type (Elective)**	**Course Credits: 3**
Class Timings: TBD	**Section: A**	**Student Meeting Hours/ Office Hours: TBD**
Instructor Name: Dr. Muhammad Haroon Shakeel		

A Note from the Instructor:

- The course will have an emphasis on hands-on along with theoretical concepts. Thus, expect 4-5 programming assignments, though the assignments would be short (just 1-2 tasks per assignment).
- We will use Python for assignments/project.
- All assignments are interconnected. We will take one problem and build upon that for the next assignment.
- The case studies 1-5 will translate to your assignments.

Instructor Contact Details:
Email: muhammadharoon@fccollege.edu.pk

Course Description:
The course is primarily focused on Supervised learning, classification, regression, bias-variance analysis, maximum-margin classification, kernel methods, evaluation, validation, dimensionality reduction, and sequential data modeling. The students will not only learn the theoretical aspects of the machine learning algorithms, but also hands-on with latest tools and libraries.
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Main Mode of Instruction: in person, Moodle
Technology Requirements *Check moodle on daily basis, internet is required to access material*
Considerations for Students with Limited Internet/Technology Access: you need to inform in prior about limited access to internet to instructor**.**

Course Objectives (Cos) or Student Learning Outcomes (SLOs)

COs

1. Motivate the class about data driven problem solving paradigm.
2. Introduce the concepts of data gathering, crowd sourcing, labeling, and annotator agreement.
3. Introduce the basic theory and applications of machine learning algorithms.
4. Provide a solid foundation to analyze and propose solutions for real world problems using machine intelligence.
5. Familiarize the students with generative and discriminative classifiers

Textbook:

1. Machine Learning: A Probabilistic Perspective, Murphy, Kevin P. MIT press, 2012 – Murphy.
2. The Elements of Statistical Learning: Data mining, Inference, and Prediction, Hastie, Trevor, Robert Tibshirani, and Jerome Friedman, Springer Science & Business Media, 2009 – ESLII

Reference books:

1. Machine Learning, Tom Mitchell, McGraw Hill, 1997 – TM
2. Speech and Language Processing by Jurafsky and Martin, Ed 3 (online draft) – SLP
3. Pattern Recognition and Machine Learning, Christopher M. Bishop, Springer, 2006 – Bishop.
4. Introduction to Machine Learning, Ethem Alpaydin, Ed 2, MIT Press, 2010 – Alpaydin.

Course Content, Learning Material & Activities Schedule

WEEK	TOPICS	READING
1.	**Course Overview** 1- Traditional CS VS ML 2- History of ML 3- ML VS AI 4- Classification VS Regression 5 - Supervised VS Unsupervised VS Semi-Supervised Learning 6- Challenges and Opportunities of ML 7- Explainability 8- Fairness and Societal Biases	Murphy Chapter 1 Alpaydin Chapter 1 TM Chapter 1
2.	**Labeled Data Sources** 1- Expert Annotators 2- Crowd Sourcing 3- Problems in Data Annotations 4- Missing Labels 5- Handling Missing Data 6- Inter-annotator Agreements 7- Cohen's Kappa and Krippendorff's Alpha	Murphy Chapter 1 Alpaydin Chapter 1

	Case Study 1 1- Creating your own dataset for your face recognition	
3-4	**Supervised Learning** 1- Features VS Labels 2- Representative Datasets 3- Training, Validation, and Testing 4- Splitting Dataset 5- Stratified Split 6- Random Split 7- Splitting Time Series Data 8- Feature Spaces and Feature Vectors 9- Sparse and Dense Feature Vectors 10- One-hot Vectors 11- Bag of Words Features 12- Label Spaces 13- Label Spaces for classification (Binary and Multiclass) and regression 14- Hypothesis Spaces 15- The No Free Lunch Theorem 16- Choosing Hypothesis class *H* and hypothesis *h* 17- Bias-Variance Tradeoff 18- How to reduce bias and variance? 10- Cross Validation 11- Feature Selection Methods **Case Study 2** 1- Converting your dataset into features	Murphy Chapter 1
5	**Hypothesis Space** 1- Traversing Hypothesis 2- Random Pick 3- Try every h 4- Memorizer 5- Evaluating Hypothesis: Loss Functions and Optimization Goals 6- Zero-one 7- Squared 8- Absolute	Murphy Chapter 1

	9- Loss Reduction and Generalization in Learning 10- Memorizers 11- Smoothing and Priors	
6	**<u>Dimensionality Reduction</u>** 1- Manual Feature Selection 2- Scatter Diagrams and Plots 3- Eyeballing Correlations 4- Mutual Information 5- Entropy 6- Information Gain 7- Entropy and Decision Tree	Murphy Chapter 6 ELSII Chapter 2 Murphy Chapter 1
7	**<u>Classification Algorithms</u>** 1- Support Vector Machines 2- The Perceptron and the optimal separating hyperplane 3- Hard Margin Linear Support Vector Machines 4- Soft Margin Linear Support Vector Machines 5- Kernels and Kernel SVMs 6- Multiclass Classification 7- One-vs-all (one-vs-rest) 8- One-vs-One **<u>Evaluation of Classifiers</u>** 1- Receiver Operating Characteristic (ROC) and Precision Recall (P-R) Curves 2- ROC Area Under the Curve (AUC) 3- Equal Error Rate (ERR) 4- Case Study (Application) **<u>Case Study 3</u>** 1- Face recognition from webcam video stream using SVM and Evaluation	Murphy Chapter 14
8	**Midterm Exam**	
9	**<u>Classification Performance Evaluation</u>** 1- The Confusion Matrix 2- Binary and Multi-Label 3- Type I and Type II Errors 4- Accuracy, Sensitivity, Specificity	SLP3 Chapter 4

	5- Handling Imbalanced Classes 6- Precision/Recall and F-measure 7- Metrics for Multi-class Classification 8- Micro and Macro Averaging of Precision, Recall, and F-measure **Case Study 4** 1- Multiclass classification of faces from images	
10	**Regression** 1- Linear and Logistic Regression 2- Intuition and Derivation 3- Regression for Classification 4- "Squishing" between 0 and 1 5- Sigmoid non-linearity 6- Sentiment Classifier using Logistic Regression 7- Visualization LR decision boundary 8- Hyperplanes, linear and non-linear decision boundaries 9- Cost function 10- Convex and non-convex cost functions – Global and local optima 11- Derivation of Cross-Entropy (log loss) 12- Learning Algorithm 13- Batch, Stochastic and mini-batch gradient descent 14- The softmax activation function and multivariate log loss	SLP3 Chapter 5 ESLII Chapter 4 Murphy Chapter 8
10	**Neural Networks and Multilabel Classification** 1- The Perceptron 2- Perceptron and its limitations 3- Linear separability in low and high dimensional spaces 4- From the step function to other activation functions 5- The perceptron learning algorithm and its geometric interpretation 6- Proof of convergence 7- The Neuron and Linear Decision Boundaries	Murphy Chapter 8

	8- Non-Linear Activation	
12	**Multi-Layer Perceptron** 1- How ANNs work? 2- Non-Linear and Complex Decision Boundaries 3- Universal Approximation and Logistic Regression 4- Feature Scaling, local minima, ravines, saddle points, tracking progress in GD 5- Hyperparameters: Learning rate and Momentum **Case Study 5** 1- Clothing category and color classification from images and videos	SLP Chapter 7 ESLII Chapter 11
13	**Ensemble Methods** 1- Bagging and Random Forests 2- Decomposition of Generalization Error 3- Bias/Variance/Noise 4- Detecting High bias and high variance regimes 5- Variance reduction 6- The weak law of large numbers 7- Bootstrapping 8- Bootstrapped Aggregation (Bagging) 9- Random Forests, Algorithm, Examples and Benefits, The hyperparamters m and k 10- No need of normalization and feature scaling 11- Resilience to the curse of dimensionality 12- Using for feature selection 13- Using for handling missing data 14- Using for clustering	ESLII Chapter 8, 10, 15, 16
14	**Ensemble Methods** 1- Boosting, Gradient Boosting Trees, AdaBoost 2- Bias Reduction 3- Generic Boosting 4- Gradient Boosted Regression Trees 5- AdaBoost **Convolutional Neural Networks** 1- CNNs 2- Using Pre-trained models **Optional Topics**	ESLII Chapter 8, 10, 15, 16

	1- Self-Organizing Maps (Optional) 2- Discriminative VS Generative Models (Optional)	
15	**Case Studies** 1- Satellite images classification and remote sensing 2- Multiclass images classification 3- Multilabel classification 4- Face recognition-based attendance system	
16	**Final Exam**	

The breakup is as follows:

Assignments:	20 %
Quizzes:	10 %
Midterm exam:	25 %
Final term exam:	30 %
Project (or Additional Assignments)	10 %
Class Participation:	5%
TOTAL	**100%**

Missed Assignments/ Make-Ups/ Extra Credit

- Late assignments will be accepted with 50% deduction
- No retake of quiz or exam unless approved.

Grade Determination & Course Assessment as per FCC Policy:
Relative grading will be done so giving your solved assignments and homeworks to your friends can have negative impact on your grade

Changes to the Syllabus:
This syllabus was designed to convey course information and requirements as accurately as possible. It is important to note however that it **may** be subject to change during the course depending on the needs of the class and other situational factors. Such changes would be for your benefit and you will be notified of them as soon as possible.

Student Support Services

Student Counseling Services.Students can contact the Campus Counseling Center at 0331-444-1518 or email ccc@fccollege.edu.pk.
Writing Center
Mercy Health Center

Other Useful FCCU Policy Documents:

Sexual Harassment Policy
Anti-Corruption Policy
Academic integrity
Plagiarism Policy
Academic Calendar