DS 625: Computing for Data Compression, Image and Signal Processing

Spring 2023

Instructor: Prashant Shekhar, PhD	**Email:** Prashant.Shekhar@erau.edu
Class Time: Tu,Th: 3:45PM – 5:00PM	**Class Venue:** Bldg COAS Rm. 407
Office Hours (OH): Tu,Th: 2:30PM – 3:30PM	**OH Venue:** Room 301.26, COAS.

Topics Included: This is a project-based course. Broadly, major topics covered in this course include

1. Linear Data Compression
2. Non-Linear Data Compression
3. Computing for Data Compression
4. Deep Generative Models

The concepts that you learn in this course can be utilized to solve problems in the general area of machine learning and data science. Starting from the concepts of linear data compression, we will look into applications such as image compression, image encoding and general dimensionality reduction. Then we will explore the concepts related to non-linear data reduction, particularly studying the concepts related to autoencoders and variational autoencoders. We will look into a variety of applications such as image/data sampling, image compression, anomaly detection etc.

Text Book: In this course, I will borrow material from a variety of sources. Some of the major references include:

- Jakub M. Tomczak, Deep Generative Modeling, Springer, 18 February 2022
- Diederik P. Kingma and Max Welling, An Introduction to Variational Autoencoders, Link, 2019
- **Python and Machine Learning:** Aurelien Geron, Hands-on Machine Learning with Scikit_learning, Keras & TensorFlow. O'Reilly, second edition, September 2019.

Grading: Your grade will be determined as follows:

1. Project: 50%
   (a) Homework 1 (10%)
   (b) Homework 2 (10%)
   (c) Final submission (30%)
      i. Class presentation (10%)
      ii. Project report (10%)
      iii. Slides + Code (10%)
2. Quizzes: 40%
3. Class participation and attendance: 10%

The grading is expected to follow the standard scale
A: 90% - 100%
B: 80% - 89.5%
C: 70% - 79.5%
D: 60% - 69.5%
F: <60%
However, based on the performance of the entire class, I might curve the grading scale later.

Attendance: I will take attendance in every class. I encourage you to participate in class activities because attendance is usually found to be heavily correlated with the course grade. Additionally, a portion of the course grade depends on class participation making attendance very important.

Quizzes: You will have 4 quizzes. Make-ups on the quizzes may be allowed only for valid extenuating circumstances when I am informed before the test takes place – please see me about conflicts as soon as they occur. **In case you are missing a quiz, it is your responsibility to schedule a makeup quiz with me within one week of the actual quiz date. After that makeup quiz is not possible**.

Project: During the semester you will be supervised to work on a project which combines classroom materials and real-world applications. It is supposed to be an individual project and I will work with each of you separately to identify a topic of your interest and find a relevant project in that domain. I will announce project topics, guidelines, and rubric soon. The project will be divided in 3 stages:

1. Homework 1 (Stage 1): Here you will finalize the project topic and will present your understanding of the topic with some preliminary results and a proposed timeline for the remaining semester.
2. Homework 2 (Stage 2): Here you will present your progress, additional results. If you are stuck in some particular research related problem, then describe that as well.
3. Finals (Stage 3): Here you will give a class presentation of your research project. Along with these slides, you will submit the project report and the code.

Academic Integrity: Embry-Riddle Aeronautical University maintains high standards of academic honesty and integrity in higher education. To preserve academic excellence and integrity, the University prohibits academic dishonesty in any form, including, but not limited to, cheating and plagiarism. More specific definitions of these violations and their consequences are described in the Dean of Students' Honor Codes and Student Policies.

Disability Services DSS Administration Office: Bldg 500; Contact: (386) 226-7916; email: dbdss@erau.edu
Testing Center: The Annex Building 2nd floor, room 217; Contact: (386) 226-2903; email: dbdss@erau.edu

- Student Disability Services: Students with disabilities who believe that they may need accommodations in this class are encouraged to contact the Office of Disability Services. Professors cannot make appropriate disability accommodations. Students are encouraged to register with DSS at the beginning of the term to better ensure that such accommodations are implemented in a timely fashion. Accommodations are not granted until official notice is received from DSS.
- DSS Testing Procedures: It is the responsibility of the student to notify DSS the date and time of test once s/he has been made aware of the scheduled test. DSS requires a 2 days minimum notification.

DS625 Computing for Data Compression, Image and Signal Processing

Instructor: Prashant Shekhar, PhD

Tentative Schedule for Spring 2023

Week Number: Days	*Topic/Quizzes*	*Homework*	*Learning Outcome*
Linear/Non-Linear Data Compression			
1: 12^{th} Jan (Th)	Course Introduction		1-10
2: 17^{th} Jan/ 19^{th} Jan (Tu,Th)	Singular Value Decomposition (SVD) Image Compression		2,3 3,4
3: 24^{th} Jan/ 26^{th} Jan (Tu,Th)	Image Encodings (eigenbases) Principal Component Analysis (PCA)	HW 1 released	3,4,5 3,5
4: 31^{st} Jan/ 2^{nd} Feb 2 (Tu, Th)	Introduction to Autoencoders (AE) Applications of AEs + Quiz 1		2,7,8 2,7,8,9
Latent Generative Models: VAE			
5: 7^{th} Feb/ 9^{th} Feb (Tu,Th)	Probabilistic PCA Variational Autoencoders (VAEs) Intro.		1,5 2,9,10
6: 14^{th} Feb/ 16^{th} Feb (Tu,Th)	VAEs: II VAEs: III	HW 1 due	2,9,10 2,9,10
7: 21^{st} Feb/ 23^{rd} Feb (Tu,Th)	VAEs: IV VAEs: V + Quiz 2	HW 2 released	2,9,10 2,9,10
Advanced Topics in VAEs			
8: 28^{th} Feb/ 2^{nd} Mar (Tu,Th)	Flexible priors in VAEs: I Flexible priors in VAEs: II		8,9,10 8,9,10
9: 7^{th} Mar/ 9^{th} Mar (Tu,Th)	Expressive posteriors for VAEs: I Expressive posteriors for VAEs: II		8,9,10 8,9,10
Spring Break			
11: 21^{st} Mar/ 23^{rd} Mar (Tu,Th)	Hierarchical VAEs: I Hierarchical VAEs: II	 HW 2 due	8,9,10 8,9,10
12: 28^{th} Mar/ 30^{th} Mar (Tu,Th)	Coding exercises VAEs summary + Quiz 3		2,8,9,10 8,9,10
Computing for Data Compression			
13: 4^{th} Apr/ 6^{th} Apr (Tu,Th)	Optimizing MLPs: Classification Optimizing MLPs: Classification		2,6 2,6
14: 11^{th} Apr/ 13^{th} Apr (Tu,Th)	Optimizing MLPs: Regression Autoencoder with Linear Layers		2,6 2,6
15: 18^{th} Apr/ 20^{th} Apr (Tu,Th)	Autoencoders with Convolutional Layers Course Summary + Quiz 4		2,6 2,6
Project			
16: 25^{th} Apr/ 27^{th} Apr (Tu,Th)	Project Presentation I Project Presentation II	 Project due	2,11 2,11

Learning outcome: After successful completion of this course, you will acquire knowledge in the following fields:

1. Basics of linear data compression
2. Python for data compression and image processing
3. SVD decomposition
4. Linear image compression and encoding
5. Linear dimensionality reduction
6. Computing/Optimization in neural networks
7. Basics of non-linear data compression
8. Autoencoders and its variants
9. Applications of non-linear data reduction
10. Deep generative models
11. Application to Real life problems