Lahore University of Management Sciences

EE 414/517, CS 437/5317: Deep Learning

Fall 2023

Tutorial # 1: PyTorch and NumPy

This document provides a compact and super quick-access summary of the contents covered in Tutorial # 1 which can be viewed on YouTube by clicking the hyperlink(s) at the end of the first reference i.e., **(T1)**. The contents of the summary table below are self-explanatory. Students are required to study the contents carefully, thoroughly, and timely as the materials covered in this document will be extensively used throughout the course and assignments. Students are most welcome to discuss with the instructor(s) in-person and/or over email.

Topic	Time Stamp	References
Introduction to Colab	0 – 1 minutes (Part A)	**T1**, **J1**, **MB**
Random Number Generator	1 – 3 minutes (Part A)	**T1**, **J1**, **MB**
Defining NumPy arrays	3 – 7 minutes (Part A)	**T1**, **J1**, **JV:** Chapters 2 & 3, **MB**
Random functions in NumPy	7 – 10 minutes (Part A)	**T1**, **J1**, **JV:** Chapters 2 & 3, **MB**
Indexing and Slicing NumPy arrays	10 – 12 minutes (Part A)	**T1**, **J1**, **JV:** Chapters 2 & 3, **MB**
Operations on NumPy arrays	12 – 18 minutes (Part A)	**T1**, **J1**, **JV:** Chapters 2 & 3, **MB**
Defining PyTorch Tensors	18 – 21 minutes (Part A)	**T1**, **J1**, **PM:** Chapters 1 & 2
Tensor Constructors	21 – 22 minutes (Part A)	**T1**, **J1**, **PM:** Chapters 1 & 2
Indexing and Slicing Tensors	22 – 26 minutes (Part A)	**T1**, **J1**, **PM:** Chapters 1 & 2
Random functions in Tensors	26 – 27 minutes (Part A)	**T1**, **J1**, **PM:** Chapters 1 & 2
Permuting a Tensor	27 – 29 minutes (Part A)	**T1**, **J1**, **PM:** Chapters 1 & 2
Helpful NumPy Functions	0 – 12 minutes (Part B)	**T1**, **J1**, **JV:** Chapters 2 & 3, **MB**

References

- **(T1)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Tutorial # 1: PyTorch and NumPy**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2023). [Part A, Part B]
- **(J1)** Shujah ur Rehman, Ahmed Rashid Qazi, and Hassan Mohy-ud-Din, **Tutorial 1 - PyTorch and Numpy.ipynb**, Jupyter Notebook, (2022). [2201 SSE Deep Learning (CS 437 S1-Lecture) Resources/Tutorials]
- **(JV)** Jake VanderPlas, **Python Data Science Handbook: Essential Tools for Working with Data**, O'Reilly Media, Inc., (2016). [Weblink]
- **(PM)** Pradeepta Mishra, **PyTorch Recipes**, Apress, Springer, (2019). [Ebook]
- **(MB)** Marcus D. Bloice and Andreas Holzinger Holzinger, **A Tutorial on Machine Learning and Data Science Tools with Python**, Machine Learning for Health Informatics, pp 435-480, Springer, (2016). [Weblink]

Prepared and revised by:	**Dr. Hassan Mohy-ud-Din**
Revision Date:	**September 3, 2023**

Lahore University of Management Sciences

EE 414/517, CS 437/5317: Deep Learning

Fall 2023

Tutorial # 2: Assignment # 1

This document provides a compact and super quick-access summary of the contents covered in Tutorial # 2 which can be viewed on YouTube by clicking the hyperlink(s) at the end of the first reference i.e., **(T2)**. The contents of the summary table below are self-explanatory. Students are required to study the contents carefully, thoroughly, and timely as the materials covered in this document will be extensively used throughout the course and assignments. Students are most welcome to discuss with the instructor(s) in-person and/or over email.

Topic	Time Stamp	References
Introduction	0 – 2:30 minutes	**T2**, **J2**
Dataset Generator	2:30 – 3:30 minutes	**T2**, **J2**
Analytical Solution	3:40 – 6 minutes	**T2**, **J2**, **TH:** Chapters 3.1 – 3.2
Linear Regression Class - Gradient Descent Optimizers	6 – 13 minutes	**T2**, **J2**, **PK:** Chapter 2, **SR**, **LJ**, **APP**
Training the model	13 – 18:20 minutes	**T2**, **J2**
Gradient Descent Visualization	18:20 - 22:40 minutes	**T2**, **J2**, **LJ**, **APP**
Learning Rate Decay	23 – 29 minutes	**T2**, **J2**, **STB1**, **STB2**
Summary of Tasks	29:20 – 30:50 minutes	**T2**, **J2**
Thought Provoking Practice Tasks	31 – 33 minutes	**T2**, **J2**, **STB1**, **STB2**, **SR**

References

- **(T2)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Tutorial # 2: Assignment # 1**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2023). [Video Link]
- **(J2)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Assignment 1.ipynb**, Jupyter Notebook, (2022). [2201 SSE Deep Learning (CS 437 S1-Lecture) Resources/Tutorials]
- **(STB1)** Syed Talha Bukhari and Hassan Mohy-ud-Din, **A systematic evaluation of learning rate policies in training CNNs for brain tumor segmentation**, Physics in Medicine and Biology, 66(10), (2021). [Weblink] *Also available @ LMS under Resources/Syllabus, Ebooks, etc./*
- **(STB2)** Syed Talha Bukhari, **Impact of Learning Rate Policies on Training a U-Net for Brain Tumor Segmentation**, MS Thesis, LUMS, (2020). *Available @ LMS under Resources/Syllabus, Ebooks, etc./*
- **(LJ)** Lili Jiang, **A Visual Explanation of Gradient Descent Methods**, Towards Data Science, (2020). [Weblink]
- **(APP)** Teach LA Dev Team, **Let's play with gradient descent**, Online Application, (2020). [Weblink]
- **(PK)** Phil Kim, **MATLAB deep learning – With Machine Learning, Neural Networks and Artificial Intelligence**, Springer, (2017). [Ebook]
- **(SR)** Sebastian Ruder, **An overview of gradient descent optimization algorithms**, arXiv, (2016). [Weblink]
- **(TH)** Trevor Hastie, Robert Tibshirani, and Jerome Friedman, **The Elements of Statistical Learning Data Mining, Inference, and Prediction**, Volume 2, Springer, (2009). [Weblink]

Prepared and revised by:	**Dr. Hassan Mohy-ud-Din**
Revision Date:	**September 19, 2023**

Lahore University of Management Sciences

EE 414/517, CS 437/5317: Deep Learning

Fall 2023

Tutorial # 3: Neural Networks and Assignment # 2

This document provides a compact and super quick-access summary of the contents covered in Tutorial # 3 which can be viewed on YouTube by clicking the hyperlink(s) at the end of the first reference i.e., **(T3)**. The contents of the summary table below are self-explanatory. Students are required to study the contents carefully, thoroughly, and timely as the materials covered in this document will be extensively used throughout the course and assignments. Students are most welcome to discuss with the instructor(s) in-person and/or over email.

Topic	Time Stamp	References
2-Layer Neural Network Example	0 – 3:30 minutes	**T3, J3, MN:** Section 1.6**, PM:** Chapter 4
Initialize weights, biases	3:30 – 8:40 minutes	**T3, J3, TH:** Chapters 3.1 – 3.2**, PM:** Chapter 4
Forward Pass	8:40 – 10:40 minutes	**T3, J3, MN:** Section 1.6, Chapter 2**, NK:** Chapter 3**, CA:** Chapter 3**, PM:** Chapter 4
Backward Pass	10:40 – 16:40 minutes	**T3, J3, MN:** Section 1.6, Chapter 2**, NK:** Chapter 3**, CA:** Chapter 3**, PM:** Chapter 4
Weight Update	16:40 – 17:40 minutes	**T3, J3, MN:** Section 1.5 – 1.6**, NK:** Chapter 8**, CA:** Chapter 3**, PM:** Chapter 4
Overview of Assignment # 2	17:40 – 20 minutes	**T3, J3**
Classification, Regression Tasks	20 – 22 minutes	**T3, J3, NK:** Chapter 2**, FC:** Chapter 3**, CA:** Chapter 3**, TZ:** Chapter 10 – 11

References

- **(T3)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Tutorial # 3: Neural Networks and Assignment # 2**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2023). [Video Link]
- **(J3)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Assignment 2.ipynb**, Jupyter Notebook, (2023). [2201 SSE Deep Learning (CS 437 S1-Lecture) Resources/Tutorials]
- **(MN)** Michael Nielsen, **Neural Networks and Deep Learning**, Determination press, (2015). [Ebook]
- **(NK)** Nikhil Ketkar, **Deep Learning with Python: A hands-on introduction**, APress, (2017). [Ebook]
- **(FC)** Francois Chollet, **Deep Learning with Python**, Manning Publications, (2018).
- **(CA)** Charu C. Aggarwal, **Neural Networks and Deep Learning**, Springer International Publishing, (2018). [Ebook]
- **(TZ)** Teik T. Teoh and Zheng Rong, **Artificial Intelligence with Python**, Springer International Publishing, (2022). [Ebook]
- **(PM)** Pradeepta Mishra, **PyTorch Recipes**, Springer International Publishing, (2022). [Ebook]

Prepared and revised by:	**Dr. Hassan Mohy-ud-Din**
Revision Date:	**October 5, 2023**

Lahore University of Management Sciences

EE 414/517, CS 437/5317: Deep Learning

Fall 2023

Tutorial # 4: Computational Graphs

This document provides a compact and super quick-access summary of the contents covered in Tutorial # 4 which can be viewed on YouTube by clicking the hyperlink(s) at the end of the first reference i.e., **(T4)**. The contents of the summary table below are self-explanatory. Students are required to study the contents carefully, thoroughly, and timely as the materials covered in this document will be extensively used throughout the course and assignments. Students are most welcome to discuss with the instructor(s) in-person and/or over email.

Topic	Time Stamp	References
Computational Graphs	27 minutes	**T4**
Backpropagation, Handcrafted Example	-	**HM** from LMS\Resources\Tutorials\4 - Computational Graphs\
Backpropagation, Numerical Example	-	**SR** from LMS\Resources\Tutorials\4 - Computational Graphs\
Backpropagation	-	**MN: Chapter 2**
Backpropagation with Computational Graphs	-	**CA: Chapter 3.2**

References

- **(T4)** Ahmed Rashid Qazi, **Tutorial # 4: Computational Graphs**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2023). [Video Link]
- **(HM)** Hassan Mohy-ud-Din, **Backpropagation, Handcrafted Example**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2022).
- **(SR)** Shujah ur Rehman, **Backpropagation, Numerical Example**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2022).
- **(MN)** Michael Nielsen, **Neural Networks and Deep Learning**, Determination press, (2015). [Ebook]
- **(CA)** Charu C. Aggarwal, **Neural Networks and Deep Learning**, Springer International Publishing, (2018). [Ebook]

Prepared and revised by:	**Dr. Hassan Mohy-ud-Din**
Revision Date:	**October 5, 2023**

Lahore University of Management Sciences

EE 414/517, CS 437/5317: Deep Learning

Fall 2023

Tutorial # 5: Assignment # 3

This document provides a compact and super quick-access summary of the contents covered in Tutorial # 5 which can be viewed on YouTube by clicking the hyperlink at the end of the first reference i.e., **(T5)**. The contents of the summary table below are self-explanatory. Students are required to study the contents carefully, thoroughly, and timely as the materials covered in this document will be extensively used throughout the course and assignments. Students are most welcome to discuss with the instructor(s) in-person and/or over email.

Topic	Time Stamp	References
Review of previous assignments	0 – 1:40 minutes	**T2**, **J2**, **T3**, **J3**
Weight Initialization	1:40 – 6:10 minutes	**CA: Chapter 3.3.3**, **DM**
Code – Weight Initialization	6:10 – 8:30 minutes	**T5**, **J5**, **AZ: Chapter 4.2**
Activation Functions	8:30 – 10:20 minutes	**PM: Chapter 4**, **AZ: Chapter 4.1**, **SD**
Code – Activation Functions	10:20 – 11:20 minutes	**T5**, **J5**
Code - Optimizers	11:20 – 14:50 minutes	**T5**, **J5**
Regularization	14:50 – 18:50 minutes	**CA: Chapter 1.4**, **4.4**, **4.5.4**, **4.6**, **AZ: Chapter 4.4**, **4.5**, **4.6**
Code - Overview of Tasks	18:50 – 24:10 minutes	**T5**, **J5**
Summary of Tasks	24:10 – 25:40 minutes	-

References

- **(T5)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Tutorial # 5: Assignment # 3**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2023). [Video Link]
- **(J5)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Assignment # 3.ipynb**, Jupyter Notebook, (2023). [2201 SSE Deep Learning (CS 437 S1-Lecture) Resources/Tutorials]
- **(T2)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Tutorial # 2: Assignment # 1**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2023). [Video Link]
- **(J2)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Assignment 1.ipynb**, Jupyter Notebook, (2023). [2201 SSE Deep Learning (CS 437 S1-Lecture) Resources/Tutorials]
- **(T3)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Tutorial # 3: Neural Networks and Assignment # 2**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2023). [Video Link]
- **(J3)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Assignment 2.ipynb**, Jupyter Notebook, (2023). [2201 SSE Deep Learning (CS 437 S1-Lecture) Resources/Tutorials]
- **(CA)** Charu C. Aggarwal, **Neural Networks and Deep Learning**, Springer International Publishing, (2018). [Ebook]
- **(PM)** Pradeepta Mishra, **PyTorch Recipes**, Springer International Publishing, (2022). [Ebook]
- **(AZ)** Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola, **Dive into Deep Learning**, arXiv, (2021). [Ebook]
- **(NK)** Nikhil Ketkar, **Deep Learning with Python: A hands-on introduction**, APress, (2017). [Ebook]
- **(SD)** Shiv Ram Dubey et al., **Activation functions in deep learning: A comprehensive survey and benchmark**, Neurocomputing, 503, (2022). [Weblink]
- **(DM)** Dmytro Mishkin and Jiri Matas, **All you need is a good INIT**, arXiv, (2015). [Weblink]

Prepared and revised by:	**Dr. Hassan Mohy-ud-Din**
Revision Date:	**October 17, 2023**

Lahore University of Management Sciences

EE 414/517, CS 437/5317: Deep Learning

Fall 2023

Tutorial # 6: Convolutional Neural Networks with PyTorch

This document provides a compact and super quick-access summary of the contents covered in Tutorial # 6 which can be viewed on YouTube by clicking the hyperlinks at the end of the first reference i.e., **(T6a, T6b, T6c)**. The contents of the summary table below are self-explanatory. Students are required to study the contents carefully, thoroughly, and timely as the materials covered in this document will be extensively used throughout the course and assignments. Students are most welcome to discuss with the instructor(s) in-person and/or over email.

Topic	Time Stamp	References
Convolution	-	**T6a, SD: Chapter 2, RS: Chapter 3.2, WB: Chapter 5.3**
Convolutional Neural Network	-	**T6b, CA: Chapter 8, AZ: Chapter 6, 7, IG: Chapter 9, NB: Chapter 5, RS: Chapter 5.4, GL**
Convolutional Neural Network with PyTorch	-	**T6c, AZ: Chapter 6, 7, NK: Chapter 5, PM: Chapter 3, 4, 5**
Introduction	0:00 - 1:30	**T6c**
Overview of Colab	1:30 - 4:44	**T6c, J6**
Overview of CNNs	4:44 - 11:18	**T6c, J6, PS, MS**
Definition of the Problem	11:18 - 12:03	**T6c, J6**
Importing Libraries, Setting up your device	12:03 - 14:19	**T6c, J6**
Import Dataset, Read Image Paths	14:19 - 16:37	**T6c, J6**
Set Hyperparameters, Preprocessing Function	16:37 - 19:38	**T6c, J6**
Batch Generator Function, PyTorch Data Loader	19:38 - 23:53	**T6c, J6**
Resnet Architecture, Define Model Class	23:53 - 37:45	**T6c, J6**
Define Loss and Optimizer Criteria	37:45 - 38:57	**T6c, J6**
Mount Google Drive	38:57 - 40:11	**T6c, J6**
Compute Training and Validation Loss	40:11 - 44:59	**T6c, J6**
Train Resnet Model	44:59 - 47:27	**T6c, J6**
Plot Training and Validation Loss, Analysis of the Graph	47:27 - 49:13	**T6c, J6**
Read Test Data, Load Model Weights	49:13 - 50:44	**T6c, J6**
Making Predictions on Test Data, Calculate Accuracy	50:44 - 56:12	**T6c, J6**
Plot and Analyze Confusion Matrix	56:12 - 60:16	**T6c, J6**

References

- **(T6a)** Ahmed Rashid Qazi and Hassan Mohy-ud-Din, **Tutorial # 6a: Convolution**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2023). [Video Link]
- **(T6b)** Ahmed Rashid Qazi and Hassan Mohy-ud-Din, **Tutorial # 6b: Convolutional Neural Networks**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2023). [Video Link]
- **(T6c)** Fatima Naweed and Hassan Mohy-ud-Din, **Tutorial # 6c: Convolutional Neural Networks with PyTorch**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2023). [Video Link]
- **(J6)** Fatima Naweed and Hassan Mohy-ud-Din, **Tutorial 6 - CNN with PyTorch.ipynb**, Jupyter Notebook, (2023). [2201 SSE Deep Learning (CS 437 S1-Lecture) Resources/Tutorials]
- **(PS)** Pranshu Sharma, **Basic Introduction to Convolutional Neural Network in Deep Learning**, Analytics Vidhya, (2022). [Weblink]
- **(MS)** Matthew Stewart, **Simple Introduction to Convolutional Neural Networks**, Towards Data Science, (2019). [Weblink]
- **(CA)** Charu C. Aggarwal, **Neural Networks and Deep Learning**, Springer International Publishing, (2018). [Ebook]
- **(AZ)** Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola, **Dive into Deep Learning**, arXiv, (2021). [Ebook]
- **(IG)** Ian Goodfellow, Yoshua Bengio, Aaron Courville, **Deep Learning**, MIT Press, (2016). [Ebook]
- **(NB)** Nikhil Buduma and Nicholas Lacascio, **Fundamentals of Deep Learning: Designing next-generation machine intelligence algorithms**,

O'Reilly Media, Inc., (2017). [Weblink]

- **(NK)** Nikhil Ketkar, **Deep Learning with Python: A hands-on introduction**, APress, (2017). [Ebook]
- **(PM)** Pradeepta Mishra, **PyTorch Recipes**, Springer International Publishing, (2022). [Ebook]
- **(SD)** Sandipan Dey, **Hands-On Image Processing with Python**, Packt Publishing Ltd, (2018). [Weblink]
- **(RS)** Richard Szeliski, **Computer Vision Algorithms and Applications**, Springer Nature, (2022). [Ebook]
- **(WB)** Wilhelm Burger and Mark J. Burge, **Principles of Digital Image Processing – Fundamental Techniques**, Springer, (2009). [Ebook]
- **(WB)** Wilhelm Burger and Mark J. Burge, **Principles of Digital Image Processing – Fundamental Techniques**, Springer, (2009). [Ebook]
- **(GL)** Grace W. Lindsay, **Convolutional Neural Networks as a Model of the Visual System: Past, Present, and Future**, Journal of Cognitive Neuroscience 33, No. 10, (2021). [Weblink]

Prepared and revised by:	**Dr. Hassan Mohy-ud-Din**
Revision Date:	**October 18, 2023**

Lahore University of Management Sciences

EE 414/517, CS 437/5317: Deep Learning

Fall 2023

Tutorial # 7: Autoencoder, Self-Supervised Learning, and Assignment # 5

This document provides a compact and super quick-access summary of the contents covered in Tutorial # 7 which can be viewed on YouTube by clicking the hyperlinks at the end of the first reference i.e., **(T7)**. The contents of the summary table below are self-explanatory. Students are required to study the contents carefully, thoroughly, and timely as the materials covered in this document will be extensively used throughout the course and assignments. Students are most welcome to discuss with the instructor(s) in-person and/or over email.

Topic	Time Stamp	References
Introduction	0 – 1 minutes	**T7**, **J7**
MNIST Dataset	1 – 2:40 minutes	**T7**, **J7**
Denoising Autoencoder	2:40 – 4:18 minutes	**T7**, **J7**, **IG: Chapter 14**, **NB: Chapter 6**, **GS**, **PV**, **DB**
Train + Test	4:18– 7:30 minutes	**T7**, **J7**
Self-supervised Learning	7:30 – 9:20 minutes	**T7**, **J7**, **LE**, **LJ**
Dataloaders	9:20 – 10:12 minutes	**T7**, **J7**
Supervised Learning	10:12 – 11:32 minutes	**T7**, **J7**
Train Autoencoder with unlabeled + labeled samples	11:32 – 13:34 minutes	**T7**, **J7**, **PM: Chapters 3.11-3.12**
Encoder + Classifier	13:34 – 16:50	**T7**, **J7**

References

- **(T7)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Tutorial # 7: Autoencoder and Self-Supervised Learning**, EE 414/517, CS 437/5317: Deep Learning, SBASSE, LUMS, (2022). [Video Link]
- **(J7)** Shujah ur Rehman and Hassan Mohy-ud-Din, **Assignment # 5.ipynb**, Jupyter Notebook, (2022). [2201 SSE Deep Learning (CS 437 S1-Lecture) Assignments/Assignment # 5]
- **(DB)** D. Bank et al., **Autoencoders**, arXiv, (2021). [Weblink]
- **(GS)** G. Spigler, **Denoising Autoencoders for Overgeneralization in Neural Networks**, IEEE Transactions on Pattern Analysis and Machine Intelligence, 42, No. 4, (2019). [Weblink]
- **(PV)** P. Vincent et al., **Extracting and composing robust features with Denoising Autoencoders**, International Conference on Machine Learning, (2008). [Weblink]
- **(IG)** Ian Goodfellow, Yoshua Bengio, Aaron Courville, **Deep Learning**, MIT Press, (2016). [Ebook]
- **(NB)** Nikhil Buduma and Nicholas Lacascio, **Fundamentals of Deep Learning: Designing next-generation machine intelligence algorithms**, O'Reilly Media, Inc., (2017). [Weblink]
- **(PM)** Pradeepta Mishra, **PyTorch Recipes**, Springer International Publishing, (2022). [Ebook]
- **(LJ)** L. Jing and Y. Tian, **Self-Supervised Visual Feature Learning with Deep Neural Networks: A Survey**, IEEE Transactions on Pattern Analysis and Machine Intelligence, 43, No. 11, (2020). [Weblink]
- **(LE)** L. Ericsson et al., **Self-Supervised Representation Learning: Introduction, advances, and challenges**, IEEE Signal Processing Magazine, 39, No. 3, (2022). [Weblink]

Prepared and revised by:	**Dr. Hassan Mohy-ud-Din**
Revision Date:	**November 15, 2023**