Deep Learning Foundations and Applications

LTP = 3-1-0, Lectures = 34 (Foundations (F) = 14, Applications (A) = 20), Tutorials = 13

Evaluation = 20 (Teacher's assessment) + 30 (Mid-term) + 50 (End-term)

Target: B. Tech (4th Year), Dual Degree (4th and 5th Years), Int. M. Sc. (4th Year), M. Tech and PhD

Objective:

This subject aims to provide students with foundational concepts required for deep learning which is now prevalent across various applications ranging across speech and natural language processing to machine vision to medical imaging. The course will introduce the fundamental principles of deep neural networks and the important paradigms of deep learning. On having studied this subject a student is expected to be able to build analytics solutions to problems in signal, image and text paradigm using deep neural networks.

The course will focus on demonstrating different applications of deep neural networks to a number of examples across domains including computer vision and NLP.

The course will contain tutorials which will focus on hands-on session and implementation of deep neural networks and applications that use them.

Students on completion are expected to be able to understand the concepts of deep neural networks and will be able to develop solutions using deep neural networks.

Contents

- Foundational concepts of linear algebra, probability, neural networks and learning theory
- Familiarity with software toolkits and deep learning libraries
- Convolutional and recurrent neural networks
- Regularization and learning concepts
- Basics of dataset handling for deep learning
- Deep learning for machine translations and text summarization
- Building chatbots with cognitive capability
- Deep learning for image classification, scene understanding
- Semantic segmentation and single shot multibox detection
- Medical image classification, compression and super resolution
- Deep learning for Digital Pathology and Digital Radiology

Module 1: Foundation Concepts

11F+0A+3T

1 Lecture (F)	Linear Algebra for Deep Learning *Scalars, vectors, matrices, tensors. Multiplication on matrices and tensors, trace operator and determinant.*
1 Lecture (F)	Probability and Information Theory *Maximum likelihood estimation, Bayes Rule. Concepts of Entropy and Information Theory.*
1 Lecture (F)	Machine Learning Basics *Supervised vs. Unsupervised Learning, Classification vs. Regression, Cross validation, Performance Metrics.*
2 Lectures (F)	Neural Networks *Perceptron model, feed-forward neural network. Error minimization and Gradient based learning rule. Backpropagation. Chain rule of gradient computation. Hidden units. Non linear transfer function.*
1 Lectures (F)	Cost Functions *Cost functions for classification viz. Cross-entropy, log-loss, and Regression viz. MSE*
2 Tutorials	Deep Neural Network Design and Learning *Simple exercises with Deep Neural Network Libraries viz. PyTorch/TensorFlow. Acceleration with CUDA on GPUs and MKL/OpenMPI on CPUs. Training models on Cloud/HPC viz. Amazon AWS, Microsoft Azure Cloud, Google Colab, Intel AI DevCloud.*
1 Lecture (F)	Convolutional Neural Networks *Convolution operation in 1D, 2D, 3D and n-D. Strided convolution, paddings. Pooling. Back-propagation learning rule for a CNN.*
1 Lecture (F)	Recurrent Neural Networks *Recurrent neural networks (RNNs), Bidirectional RNN, Encoder-Decoder Sequence-to-sequence architectures, Deep Recurrent Networks,*
1 Lecture (F)	Optimization for Training a Deep Neural Network *Gradient descent, Stochastic gradient descent, Adaptive momentum.*

2 Lectures (F)	Regularization for Deep Learning *Parameter norm penalties, Norm penalties for Constrained Optimization, Dataset augmentation, Noise robustness, Dropouts*
1 Tutorial	Building your First Deep Neural Network *Organizing a dataset, Loader utilities for various datasets, Custom dataset handling, Fully connected neural network model, training the model for classification.*

Module 2: Deep Learning for Speech and Natural Language Processing

2F+5A+3T

2 Lectures (F)	Sequence Modeling with Recurrent Networks *Long Short-term Memory (LSTM) and Gated Recurrent Units (GRU), Backpropagation through time (BPTT)*
2 Lectures (A)	Machine Translation and Text Summarization *Word Vectors, RNN Language Model, attention mechanism for sequence generation with applications to machine translation and text summarization.*
1 Tutorial	Name Classification *Build a RNN based system and train it for classifying names to nationality.*
1 Tutorial	Text Summarization *Build a RNN based text summarizer and a machine translation system.*
2 Lectures (A)	Chatbots *Open-domain vs. closed domain chatbot models: datasets, recent advances and future directions, Mem2Seq*
1 Lecture (A)	Cognitive Chatbots *The cognitively enabled Ruuh chatbot from Microsoft.*
1 Tutorial	Making your own Chatbot *Develop a seq2seq chatbot on Ubuntu Dialog Corpus*

Module 3: Deep Learning for Machine Vision

1F+7A+4T

1 Lecture (F)	Vector Convolutional Networks *Vector Convolution for rotation and scale invariance/equivariance, Learnable Deconvolution.*
1 Lecture (A)	Digit, Handwriting and Hieroglyph Classification *LeNet-5 for MNIST, FashionMNIST, NIST SD-19, Egyptian Heiroglyph, Rotation equivariant and scale invariant LeNet-5.*
1 Tutorial	Building your Handwritten Digit Recognition System *Building and training your first LeNet-5 for handwritten digit recognition (MNIST) and handwritten character recognition (NIST SD-19), Rotation and scale invariant handwriting recognition.*
1 Tutorial	Fashion Classification *Building your fashion and clothing style classification system using a simple CNN*
1 Lecture (A)	Object Recognition and Classification *AlexNet, VGG, ResNet, DenseNet on CIFAR-10.*
1 Lecture (A)	Object Localization *Single shot multi-box detection and classification. Regional Proposal CNN (rCNN), Fast rCNN and Faster rCNN, YOLO-9000*
1 Lecture (A)	Cognitive Vision with CNNs *Age, gender and emotion recognition with CNNs in the Microsoft CNTK.*
2 Lecture (A)	Semantic and Instance segmentation *Fully Convolutional Network (FCN), mask-RCNN, Segmentation via dilated convolution, Semantic segmentation*
2 Tutorials	Building and Training CNNs for Object Localization and Semantic Segmentation *YOLO-9000, Faster r-CNN, Mask RCNN2GO, SegNet*
1 Lecture (A)	Visual Question Answering (VQA) *Visual dialog, text meets images and videos, image captioning, visual question answering.*

Module 4: Deep Learning for Healthcare and Medical Imaging

0F+8A+3T

1 Lecture (A)	ECG Signal Classification *ECG signal filtering, segmentation and classification using 1D CNN*
2 Lectures (A)	Digital Pathology *Blood pathology classification on ALL-IDB using transfer learning of ImageNet pre-trained models, Multiple Instance Learning of CNN for Histopathology Whole Slide Classification*
1 Lecture (A)	Digital Radiology *Chest X-ray Classification, Brain Lesion Classification and Segmentation in MRI.*
1 Lecture (A)	Super Resolution Imaging *Microscopy / CT image super-resolution using Adversarial Learning and Generative Modeling*
1 Lecture (A)	Medical Image Compression *Compression of Radiographs, Whole Slide Images, Ultrasound Images using Auto-encoding CNNs under Adversarial Learning.*
2 Lecture (A)	Deep Genomics *Deep learning for genomic data filtering, quality analysis, sequence alignment.*
3 Tutorials	*Exercises on ECG Classification, Digital Pathology and Radiology, Super Resolution and Image Compression*

Text Books:

1. "Deep Learning", I. Goodfellow, Y, Bengio, A. Courville, MIT Press, 2016.
2. "Neural Networks and Learning Machines", S. Haykin, 3rd Edition, Pearson, 2008.

Reference Books:

1. "Neural Networks for Pattern Recognition", C. M. Bishop, Oxford University Press, 1995.
2. "Pattern Classification", R. O. Duda, P. E. Hart, D. G. Stork, 2nd Edition, Wiley, 2001.
3. "A Sampler of Useful Computational Tools for Applied Geometry, Computer Graphics and Image Processing", D. Cohen-Or, C. Greif, T. Ju, N. J. Mitra, A. Shamir, O. Sorkine-Hornung, H. Zhang, CRC Press, 2015.
4. "Machine Learning", T. M. Mitchell, Mc. Graw Hill Education, 1997.
5. "Pattern Recognition and Machine Learning", C.M. Bishop, 2nd Edition, Springer, 2011.