Course Code:

Course Title: Introduction to Neural Computing

Instructors: Santosh Ansumali

Credits: 2+1+1

Note: Those taking four credit will have to do a project.

I. Python for Data Science

i. Setting Up the Development Environment (e.g., Jupyter, Anaconda, CUDA)
ii. Numpy basics
iii. Introduction to Plotting and Visualization (Matplotlib,Pandas and seaborn)
iv. Key Libraries for AI: PyTorch, Tensorflow

2. Introduction to Neural Networks

I. Introduction to Neural Networks
II. McCulloch-Pitts (MP) Neuron
III. Perceptron and Multilayer Perceptron
IV. Learning rules
    i. Hebb's Rule
    ii. Gradient descent
    iii. Loss function
    iv. Stochastic gradient descent
V. Activation functions (Step function, Sigmoid, ReLU)
VI. Backpropagation

3. Introduction to Deep Neural Networks

I. Universal approximation theorem
II. Deep Neural Networks (DNN)
III. Activation functions (Step function, Sigmoid, ReLU, GELU)
    i. Regularization (dropout, L2)
    ii. Batch Normalization
    iii. Architectures: Feedforward DNNs, introduction to convolutional and recurrent networks
IV. Challenges: overfitting, computational cost

4. **Convolutional Network**
    - **I.** Motivation & CNN Intuition
    - **II.** Core CNN Building Block
    - **III.** Modern CNN Architectures
    - **IV.** Inductive Biases & Generalization
    - **V.** Applications to image processing
5. **Energy Based Neural Networks**
    - I. Introduction to Energy-Based Models
    - II. Hopfield Network and associative memory
    - III. Capacity of Neural Networks (e.g., Hopfield Network capacity)
    - IV. Boltzmann Machines
    - V. Restricted Boltzmann Machines

6. **Transformers**
    - I. Introduction to Transformers
    - II. Evolution from RNNs and LSTMs to transformers
        - i. Encoder-Decoder Architecture
        - ii. Self-Attention Mechanism
        - iii. Training transformers (Pre-training and fine-tuning)
        - iv. Optimization (e.g., Adam, learning rate scheduling)
7. **Physics Informed Neural Network and PDE**
    - I. Motivation & PINN Paradigm
    - II. Core Formulation of PINNs
    - III. Applications
    - IV. Radial Basis network and alternates