CSE-5368 Neural Networks Fall 2024 Exam_02

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Prob #	**1**	**2**	**3**	**4**	**Total**
Points	**18**	**21**	**21**	**40**	

Time: 80 Minutes

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$$F(\mathbf{x}) = F(\mathbf{x}^*) + \nabla F(\mathbf{x})^T\Big|_{\mathbf{x}=\mathbf{x}^*}(\mathbf{x}-\mathbf{x}^*) + \frac{1}{2}(\mathbf{x}-\mathbf{x}^*)^T\nabla^2 F(\mathbf{x})\Big|_{\mathbf{x}=\mathbf{x}^*}(\mathbf{x}-\mathbf{x}^*) + \cdots$$

$$\frac{\mathbf{p}^T\nabla F(\mathbf{x})}{\|\mathbf{p}\|} \qquad \frac{\mathbf{p}^T\nabla^2 F(\mathbf{x})\mathbf{p}}{\|\mathbf{p}\|^2} \qquad \alpha_k = -\frac{\mathbf{g}_k^T\mathbf{p}_k}{\mathbf{p}_k^T\mathbf{A}\mathbf{p}_k}$$

$$\mathbf{x}_{k+1} = \mathbf{x}_k - \alpha_k\mathbf{g}_k \qquad \mathbf{x}_{k+1} = \mathbf{x}_k + \alpha_k\mathbf{p}_k$$

$$L_i = \sum_{j\neq i} max(0, y_j - y_i + \Delta)$$

$$S(y_i) = \frac{e^{y_i}}{\sum_j e^{y_j}}$$

$$H(p,q) = -\sum_x p(x)log(q(x))$$

$$L_i = -log(\frac{e^{y_i}}{\sum_j e^{y_j}})$$

$$KL\ Divergence = -\frac{1}{2}\sum(1 + \log(\sigma^2) - \mu^2 - \sigma^2)$$

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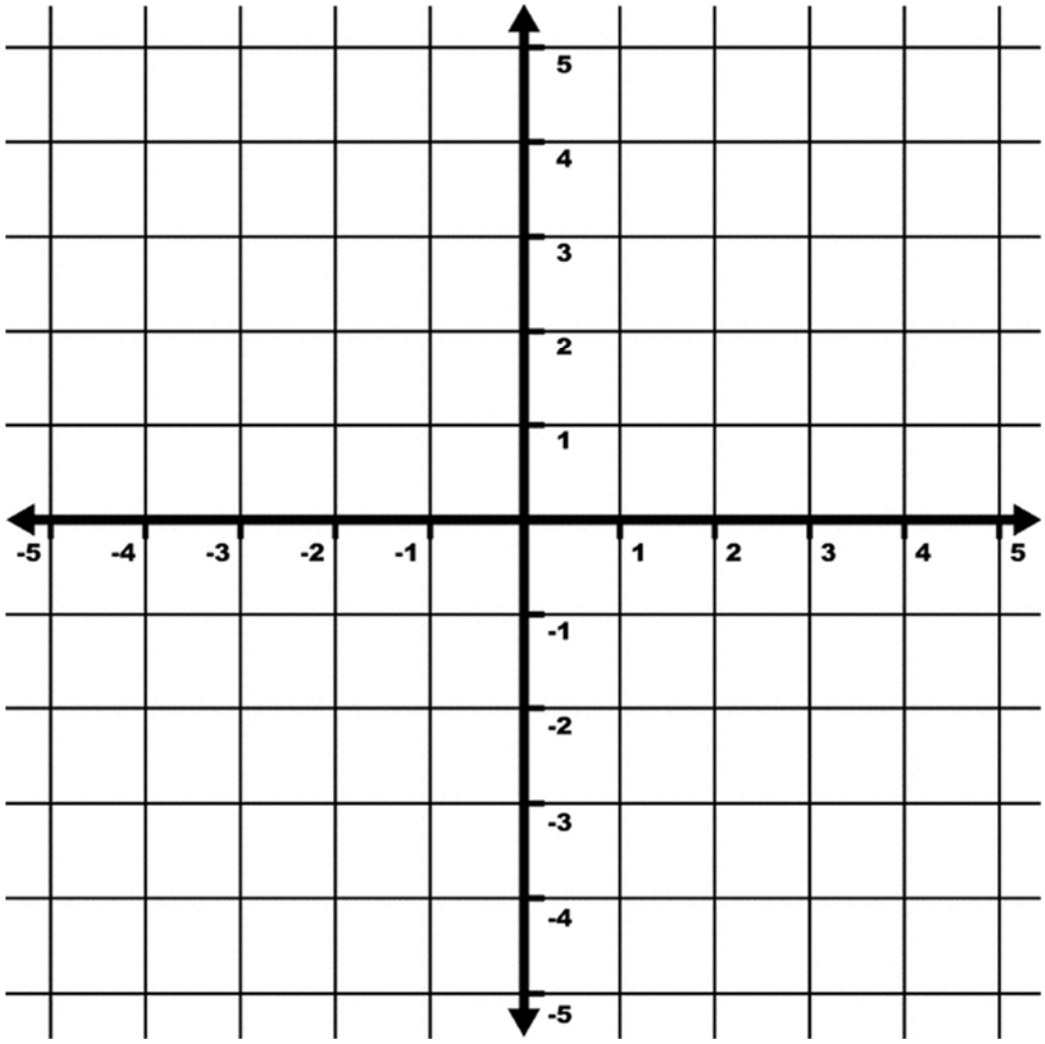
1. Consider the following data where p is the input and t is the desired output

$$\left\{p_1 = \begin{bmatrix}4.5\\0\end{bmatrix}, t_1 = 0\right\}, \left\{p_2 = \begin{bmatrix}-3.5\\0\end{bmatrix}, t_2 = 0\right\}, \left\{p_3 = \begin{bmatrix}0\\2.5\end{bmatrix}, t_3 = 0\right\},$$
$$\left\{p_4 = \begin{bmatrix}3.5\\0\end{bmatrix}, t_4 = 1\right\}, \left\{p_5 = \begin{bmatrix}-2.5\\0\end{bmatrix}, t_5 = 1\right\}, \left\{p_6 = \begin{bmatrix}0\\1.5\end{bmatrix}, t_6 = 1\right\}$$

DESIGN a two-layer Perceptron neural network which will correctly classify the input data. Assume the activation function for all the nodes are hardlimit with the output of 0 and 1. Show the weight matrices and biases for both layers. Biases should be included in the weight matrix in the first column.



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Problem 1 Continued

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2. Consider a convolutional neural network.

Note: **Do NOT consider Biases**.

Input layer:

Input to this CNN are color images of size **67x67x3** with the **batch size = 90**

Next layer is Conv2D layer:

Number of filters: **20**, filter size: **7x7**; stride: **2x2**; padding: **2x2**

Q1: What is the shape of the weight matrix for this layer? **Q1:** _____

Q2: What is the shape of the output (tensor) of this layer? **Q2:** _____

Next layer is Conv2D layer:

Number of filters: **30**, filter size: **5x5**; stride: **3x3**; padding: **4x4**

Q3: What is the shape of the weight matrix for this layer? **Q3:** _____

Q4: What is the shape of the output (tensor) of this layer? **Q4:** _____

Next layer is Flatten layer:

Q5: What is the shape of the output (tensor) for this layer? **Q5:** _____

Next layer is Dense layer:

Number of nodes: **50**

Q6: What is the shape of the weight matrix for this layer? **Q6:** _____

Q7: What is the shape of the output (tensor) for this layer? **Q7:** _____

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Problem 2 Continued

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3. Assuming that the actual output and the desired output of a neural network are given.

   Complete the code for the following function to calculate the **mean cross entropy** loss for a batch of data.

   Note:

   Assume that actual output and desired output are logits. This means you have to apply **softmax** to both **actual outputs** and **desired outputs** before cross entropy calculation.

Notes:

Only use numpy. Do NOT use PyTorch or any other package.

You may use the numpy helper functions such as `np.log()` and `np.sum()`

```
def calculate_mean_cross_entropy_loss(y_hat,y):
Import numpy as np
""" This function calculates the mean cross entropy loss.
:param y_hat: actual output [number_of_samples,number_of_classes].
:param Y: Desired output [number_of_samples,number_of_classes].
:return: mean cross-entropy loss
"""
```

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Problem 3 Continued

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4. Complete the following function. This function should initialize a variational autoencoder and return the mean loss over all the samples. **Only use numpy.**

Notes:
Ignore biases. Initialize all weights to **ones**. Assume all layers are **fully connected**.
Activation function for layers are **Sigmoid**.
Loss is: **MSE + KL divergence**
Decoder has the same structure as the encoder in reverse order. #

Complete the incomplete functions

```
import numpy as np

def variational_autoencoder(input, encoder_layers):
# input: numpy array of inputs [nof_train_samples, input_dimensions]
# encoder_layers: list of integers representing number of nodes in
# each layer of the encoder. The last number represents the dimension of latent
space
# return: mean_loss

# Step 1 (8 points)
  list_of_encoder_weights,list_of_decoder_weights =
initialize_encoder_and_decoder_layers(encoder_layers,input)
# Step 2 (8 points)
   mu, var = encoder_forward_pass(input, list_of_encoder_weights)
# Step 3 (8 points)
  z = sampling_trick(mu,var)
# Step 4 (8 points)
  reconstructed_input = decoder_forward_pass(z, list_of_decoder_weights)
# Step 5 (8 points)
  mean_loss = calculate_loss(input,reconstructed_input, mu,sigma)
  return mean_loss
```

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def initialize_encoder_and_decoder_layers(encoder_layers,input):

```
# encoder_layers: list of integers representing number of nodes in
# each layer of the encoder. The last number represents the dimension
of latent space
# return list_of_encoder_weights, list_of_decoder_weights # as list of
numpy arrays
```

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Problem 4 Continued

```
def encoder_forward_pass(input, list_of_encoder_weights):
# input: numpy array of inputs [nof_train_samples, input_dimensions]
# return mu, var
```

```
def sampling_trick(mu,var)
# return z  # sampled latent variable
```

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Problem 4 Continued

```
def decoder_forward_pass(z, list_of_decoder_weights):
#z:numpy array of latent varibales [nof_train_samples,latent_dimension]
# return reconstructed_input [nof_train_samples, input_dimensions]
```

```
def calculate_loss(input, reconstructed_input, mu, sigma):
# input: numpy array of inputs [nof_train_samples, input_dimensions]
# return mean_loss (MSE + KL divergence) it should be a single number
```