AY: 2024-2025
EXAM | **AI-ECUE322**
Jan. 2025

M2-S3: Dept. of Electrical Engineering
Teacher: A. Mhamdi
Time Limit: $1\frac{1}{2}$ **h**

This document contains **7** pages numbered from **1/7** to **7/7**. As soon as it is handed over to you, make sure it is complete. The **2** tasks are independent and can be treated in the order that suits you.

The following rules apply:

❶ **A handwritten double-sided A4** sheet is permitted.

❷ **Any electronic material**, except basic calculator, is prohibited.

❸ **Mysterious or unsupported answers** will not receive full credit.

❹ **Round results** to the nearest thousandth *(i.e., third digit after the decimal point)*.

❺ **Task N°2:** Each correct answer will grant a mark with no negative scoring.

Task N°1

⌛ 30mn | (7 points)

You are given a single-channel input image, a convolutional filter (kernel), and a bias term. Your task is to compute the output of a convolution operation followed by the application of an activation function and a pooling operation.

- **Input Image ($\mathfrak{I}$):** A 4×4 grayscale image:

$$\mathfrak{I} = \begin{bmatrix} 1 & 2 & 0 & 1 \\ 3 & 1 & 2 & 2 \\ 0 & 1 & 1 & 0 \\ 2 & 3 & 0 & 1 \end{bmatrix}$$

- **Filter (Kernel) (K):** A 2×2 kernel:

$$\mathsf{K} = \begin{bmatrix} 1 & -1 \\ 0 & 1 \end{bmatrix}$$

- **Activation Function:** ReLU (Rectified Linear Unit)
- **Pooling Operation:** Max pooling with a 2×2 window and a stride of 2.

(a) (3 points) Compute the output of the convolution operation with stride 1 and no

padding. The formula for convolution is:

$$O_{i,j} = \sum_{n=1}^{2} \sum_{m=1}^{2} I_{i+n-1,\, j+m-1} \cdot K_{n,\, m} + b$$

We compute the convolution output (0) for each valid position of the 2×2 kernel on the 4×4 input image. With a stride of 1 and no padding, the output size is 3×3.

$$O = \begin{bmatrix} O_{1,1} & O_{1,2} & O_{1,3} \\ O_{2,1} & O_{2,2} & O_{2,3} \\ O_{3,1} & O_{3,2} & O_{3,3} \end{bmatrix}$$

Where:

$$O_{1,1} = (1)(1) + (2)(-1) + (3)(0) + (1)(1) + 1 = 1 - 2 + 0 + 1 + 1 = 1$$

$$O_{1,2} = (2)(1) + (0)(-1) + (1)(0) + (2)(1) + 1 = 2 + 0 + 0 + 2 + 1 = 5$$

$$O_{1,3} = (0)(1) + (1)(-1) + (2)(0) + (2)(1) + 1 = 0 - 1 + 0 + 2 + 1 = 2$$

Similarly, compute for all positions:

$$O = \begin{bmatrix} 1 & 5 & 2 \\ 4 & 1 & 1 \\ 3 & 1 & 3 \end{bmatrix}$$

(b) (2 points) Apply the ReLU activation function to the convolution output.

The ReLU activation function is defined by:

$$\text{ReLU}(x) = \max(0, x)$$

Activated output:

$$O_{\text{ReLU}} = \begin{bmatrix} \max(0,1) & \max(0,5) & \max(0,2) \\ \max(0,4) & \max(0,1) & \max(0,1) \\ \max(0,3) & \max(0,1) & \max(0,3) \end{bmatrix} = \begin{bmatrix} 1 & 5 & 2 \\ 4 & 1 & 1 \\ 3 & 1 & 3 \end{bmatrix}$$

(c) (2 points) Perform max pooling with a 2×2 window and a stride of 2 on the activated output.

Pooling regions:

① *Top-left region:*

$$\begin{bmatrix} 1 & 5 \\ 4 & 1 \end{bmatrix}, \quad \text{Max: } 5$$

② *Top-right region:*

$$\begin{bmatrix} 2 \\ 1 \end{bmatrix}, \quad \text{Max: } 2$$

③ *Bottom-left region:*

$$\begin{bmatrix} 3 & 1 \end{bmatrix}, \quad \text{Max: } 3$$

④ *Bottom-right region:*

$$\begin{bmatrix} 3 \end{bmatrix}, \quad \text{Max: } 3$$

Final pooled output:

$$O_{\text{pool}} = \begin{bmatrix} 5 & 2 \\ 3 & 3 \end{bmatrix}$$

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ANSWER SHEET

Task N°2 ⌛ 60mn | (13 points)

(a) ($\frac{1}{2}$ point) What is the purpose of the ! symbol at the end of a function name in Julia?

- ◯ It indicates the function returns a Boolean value
- √ It is purely a convention indicating that the function modifies its arguments
- ◯ It enforces immutability on function inputs
- ◯ It performs element-wise operations

(b) ($\frac{1}{2}$ point) Which layer type is typically used to extract local features in a CNN?

- √ Convolutional layer
- ◯ Pooling layer
- ◯ Fully connected layer
- ◯ Activation layer

(c) ($\frac{1}{2}$ point) When applying a horizontal flip to an input image *(mirroring)*, which of the following statements is true about a standard CNN's ability to recognize the same object?

- ◯ The CNN will always fail to recognize the flipped image since the features are now in different positions
- ◯ The CNN will recognize the flipped image just as well as the original because CNNs are naturally invariant to horizontal flips
- √ The CNN will only recognize the flipped image if horizontal flipping was used during training data augmentation
- ◯ The CNN will recognize the flipped image with the same accuracy because convolution operations are horizontally symmetric

(d) ($\frac{1}{2}$ point) What is the main difference between Variational Autoencoders (VAEs) and traditional autoencoders?

- ◯ VAEs use linear transformations, while traditional autoencoders use nonlinear transformations

√ VAEs introduce a probability distribution in the latent space, while traditional autoencoders do not

○ VAEs are only applicable to image data, while traditional autoencoders can handle any type of data

○ VAEs include reconstruction loss in their loss function, while traditional autoencoders do not

(e) ($^1/_2$ point) What are the two main components of the loss function used to train VAEs?

√ Reconstruction loss and KL divergence

○ Mean squared error and cross-entropy

○ Binary cross-entropy and cosine similarity

○ Euclidean distance and Manhattan distance

(f) ($^1/_2$ point) Which of the following statements about VAEs is true?

○ VAEs can only generate new data points from previously seen examples

○ VAEs learn the distribution of input data but cannot generate new samples

√ VAEs can generate new, previously unseen data points by sampling from the latent space

○ VAEs always produce blurry images

(g) ($^1/_2$ point) Which component of a GAN is responsible for generating synthetic samples?

√ Generator ○ Discriminator ○ Encoder ○ Decoder

(h) ($^1/_2$ point) How does the generator component in a GAN learn to generate realistic samples?

○ By minimizing the loss function of the discriminator

○ By maximizing the loss function of the discriminator

√ By minimizing the loss function of the generator

○ By maximizing the loss function of the generator

(i) ($^1/_2$ point) What is the purpose of tokenization in NLP?

○ Identifying parts of speech

○ Removing stop words

√ Breaking text into words or phrases

○ Analyzing sentiment

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(j) (½ point) What is stemming in NLP?

- √ Reducing words to their base or root form
- ◯ Assigning sentiment scores to words
- ◯ Analyzing grammatical structure
- ◯ Identifying named entities

(k) (½ point) What is the primary purpose of transfer learning?

- ◯ To train models from scratch for every task
- √ To leverage pre-trained models for new tasks
- ◯ To improve model performance on small datasets
- ◯ To reduce computational costs

(l) (½ point) Which part of a pre-trained neural network is usually fine-tuned in transfer learning?

- ◯ Only the input layer
- ◯ Only the output layer
- ◯ All layers
- √ Only the last few layers

(m) (½ point) What is the primary goal of reinforcement learning?

- ◯ To minimize the loss function
- √ To maximize cumulative rewards over time
- ◯ To reduce the number of features
- ◯ To generate labeled data

(n) (½ point) Which component in reinforcement learning is responsible for learning?

◯ Environment √ Agent ◯ Policy ◯ Reward

(o) (½ point) What does the term “environment” refer to in reinforcement learning?

- ◯ The training data
- √ The external system with which the agent interacts
- ◯ A type of algorithm
- ◯ The loss function

(p) (½ point) What is the purpose of rewards in reinforcement learning?

Do not write anything here

- ◯ The total number of actions taken
- √ A signal given to the agent to indicate how good or bad an action is
- ◯ The loss value of the agent's model
- ◯ The final state of the environment

(q) ($^1/_2$ point) What does the term "policy" mean in reinforcement learning?

- ◯ The function that maps actions to rewards
- √ The strategy that defines how the agent selects actions
- ◯ The model used to predict future states
- ◯ The algorithm used to update the environment

(r) ($^1/_2$ point) Which command creates a copy of an existing Git repository?

◯ `git copy` √ `git clone` ◯ `git replace` ◯ `git move`

(s) ($^1/_2$ point) The "______________" command is a convenient way to set configuration options for defining the behavior of the repository, user information, and preferences.

◯ `git head` ◯ `git conflict` ◯ `git status` √ `git config`

(t) ($^1/_2$ point) The files that can be committed are present in Git's "______________" area.

◯ working directory √ staging area ◯ unstaged area

(u) ($^1/_2$ point) A head is nothing but a reference to the last commit object of a branch.

√ Yes ◯ No ◯ Can not say

(v) ($^1/_2$ point) What is Docker used for?

◯ Virtualization √ Containerization ◯ Programming Language

(w) ($^1/_2$ point) Which of the following is a keyword of Docker?

◯ Develop ◯ Ship ◯ Run √ All of the previous

(x) ($^1/_2$ point) What is a Dockerfile used for?

◯ Building a container ◯ Running a container √ Creating an image

(y) ($^1/_2$ point) Which command is used to build a new image from a Dockerfile and a "context"?

◯ docker pull ◯ docker run √ docker build ◯ docker commit

(z) ($^1/_2$ point) What is a Docker registry used for?

- √ Storing and distributing Docker images
- ◯ Running Docker containers
- ◯ Deleting Docker images
- ◯ Building Docker images