| Faculty of Mathématics and Informatics | Date : 11.01.2026 | Class : Master II, ISSI |
|---|---|---|
| Department of Computer Science | Duration: 02 h | Course: Introduction to AI |

# END OF SEMESTER EXAM

| EXERCISE 01 | Course Questions | 15 Minutes | 3.0 points |
|---|---|---|---|

1. Give the dual equivalent of each of the following expressions: ***(01 pt )***

$\neg \exists x\, \varphi$ $\qquad \neg \forall x\, \varphi$ $\qquad \neg (\varphi \vee \psi)$ $\qquad \neg (\varphi \wedge \psi)$

2. What are applications of AI in the following domains : NLP, Handwriting Recognition ***(02 pts)***

| EXERCISE 02 | First-Order Predicate Logic | 35 Minutes | 4.0 points |
|---|---|---|---|

1. Conversion into First-Order Predicate Logic of the Following Natural Language Sentences:
***(0.5 point/ assertion) :***

1. There is a module that no student understands.
2. Although nobody makes any noise, Omar cannot concentrate.
3. All students except Nassim are present.
4. Some students master mathematics and some others do not master it.
5. All students belonging to a specialty have a fundamental teaching unit that they must acquire.
6. The rule of the game is that a team can neither win nor lose against itself.

2. Transformation of the Two Assertions Expressed in First-Order Predicate Logic Using the Duality Principle of Quantifiers: ***(01 pt)***

a. $\exists x Follow(x,News)$
b. $\forall x Master(x,Language) \Leftrightarrow$

| EXERCISE 03 | Machine Learning | 40 Min | 8.5 points |
|---|---|---|---|

Given a Dataset of 2300 Biscuits. We have four types of biscuits: Petit Four, Cookies, Maxon, and Kool.
For each biscuit, we have the following characteristics:

- The biscuit is small or large
- It is sweet or less sweet
- It contains chocolate or vanilla

Our dataset is presented as follows:

| Type | Small | Large | Sweet | Not sweet | chocolate | Vanilla | Total |
|---|---|---|---|---|---|---|---|
| Petit four | 350 | 250 | 400 | 200 | 400 | 200 | 600 |
| Cookies | 150 | 350 | 200 | 300 | 100 | 400 | 500 |
| Maxon | 300 | 100 | 250 | 150 | 200 | 200 | 400 |
| Kool | 500 | 300 | 350 | 450 | 500 | 300 | 800 |
| **Total** | **1300** | **1000** | **1200** | **1100** | **1200** | **1100** | **2300** |

Let the biscuit be characterized by : ***B = <Large, Sweet,Vanilla>***

1. Apply the Naive Bayes Algorithm to Determine the Type of This Biscuit

| EXERCISE 04 | Deep Learning | 30 Min | 5.5 points |
|---|---|---|---|

Convolutional Neural Networks (CNNs) have been applied in the field of image processing and computer vision CV for long time.

1. Which of the following is important application in image processing? ***(0.75 pts)***

   A. Feature extraction and image classification
   B. 3D image reconstruction
   C. Augmented reality gaming
   D. Image style transfer

2. Explain briefly explain the principle of convolution operation is and its the role in CNNs. ***(0.75 pts)***

3. Draw (or cite) a simple CNN architecture and explain its main components. ***(01 pt)***

4. Let be an input image size of 200x200 pixels, using a filter size of 5x5, a stride of 1, and no padding.
   Calculate the size of the output Image. ***(0.5 pt)***

5. What challenges might you encounter during the training process of deep CNNs? ***(01 pt)***

   A. Vanishing or exploding gradients
   B. Overfitting
   C. High computational resource requirements
   D. Class imbalance

6. Give some well-known CNNs architectures ***(0.5 pts)***

The figure bellow represents an image IM1 of size 4x4 and a kernel (a filter) K1 of size 3x3

| | | | |
|---|---|---|---|
| 35 | 30 | 90 | 50 |
| 45 | 0 | 2 | 5 |
| 0 | 30 | 25 | 0 |
| 255 | 100 | 65 | 0 |

**Une Image 4X4**

| | | |
|---|---|---|
| 1 | 1 | 2 |
| 0 | 0 | 0 |
| -1 | -1 | -2 |

**Un filtre 3X3**

7. Do the convolution of the image matrix IM1 and the kernel K1 and give the obtained image IM2. ***(01 pt)***

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# END OF SEMESTER EXAM: A STANDARD CORRECTION

| EXERCISE 01 | Course Questions 15 Minutes | 3.0 points |
|---|---|---|

**1. Give the equivalent expression of each of the following expressions:** ***(01 pt )***

$\neg \exists x\ \varphi$ *is* equivalent to $\forall x\ \neg\varphi$

$\neg \forall x\ \varphi$ *is* equivalent to $\exists x\ \neg\varphi$

$\neg\ (\varphi \vee \psi)$ *is* equivalent to $\neg\varphi \wedge \neg\psi$

$\neg\ (\varphi \wedge \psi)$ *is* equivalent to $\neg\varphi \vee \neg\psi$

**2. What are applications of AI in the following domains : NLP, Handwriting Recognition** ***(02 pts)***

In NLP :

- Understanding of natural language.
- QA systems
- Automatic Translation.
- Text Summarizing.
- Smart Chatbots
- Human-machine interaction (replace high-level languages).

In Handwriting Recognition

- Archeology
- Credit Fraud detection for checks.
- Police investigations.
- Correction of exam papers, ...
- Educational Systems

| EXERCISE 02 | First-Order Predicate Logic 35 Minutes | 4.0 points |
|---|---|---|

**1. Conversion into First-Order Predicate Logic of the Following Natural Language Sentences:** ***(0.5 point/ assertion) :***

**1. There is a module that no student understands.**

$\exists x, \forall y\ (Module(x) \wedge Student(y) \wedge \neg Understand(y,x))$

**2. Although nobody makes any noise, Omar cannot concentrate.**

$\forall x\ (Person(x) \wedge \neg Make(x,Noise) \Rightarrow \neg Concentrate(Omar))$

**3. All students except Nassim are present.**

$\forall x\ (Student(x) \wedge (x \neq Nassim) \wedge Present(x))$

**4. Some students master mathematics and some others do not master it.**

$\exists x\ (Student(x) \wedge Master(x,Mathematics) \wedge (\exists y,\ Student(y) \wedge \neg Master(y,Mathematics)))$

$\exists x,\ \exists y\ (Student(x) \wedge Student(y) \wedge Master(x,Mathematics) \wedge \neg Master(y,Mathematics)))$

**5. All students belonging to a specialty have a fundamental teaching unit that they must acquire.**

$\forall x, \exists y, \exists z\ (Student(x) \wedge Specialty(y) \wedge FundamentalUnit(z) \wedge Belong(x,y) \wedge Acquire(x,z))$

**6. The rule of the game is that a team can neither win nor lose against itself.**

$\forall x\ (Team(x) \wedge \neg Win(x,x) \wedge \neg Lose(x,x))$

**2. Transformation of the Two Assertions Expressed in First-Order Predicate Logic Using the Duality Principle of Quantifiers:** ***(01 pt)***

c. $\exists x Follow(x,News) \Leftrightarrow \neg\forall x \neg Follow(x,News)$

d. $\forall x Master(x,Language) \Leftrightarrow \neg\exists x \neg Master(x,Language)$

| EXERCISE 03 | Machine Learning | 40 Min | 8.5 points |
|---|---|---|---|

Given a Dataset of 2300 Biscuits. We have four types of biscuits: Petit Four, Cookies, Maxon, and Kool.
For each biscuit, we have the following characteristics:

- The biscuit is small or large
- It is sweet or less sweet
- It contains chocolate or vanilla

Our dataset is presented as follows:

| Type | Small | Large | Sweet | Not sweet | chocolate | Vanilla | Total |
|---|---|---|---|---|---|---|---|
| Petit four | 350 | 250 | 400 | 200 | 400 | 200 | 600 |
| Cookies | 150 | 350 | 200 | 300 | 100 | 400 | 500 |
| Maxon | 300 | 100 | 250 | 150 | 200 | 200 | 400 |
| Kool | 500 | 300 | 350 | 450 | 500 | 300 | 800 |
| **Total** | **1300** | **1000** | **1200** | **1100** | **1200** | **1100** | **2300** |

Let the biscuit be characterized by : ***B = <Large, Sweet,Vanilla>***

1. Apply the Naive Bayes Algorithm to Determine the Type of This Biscuit

To classify this biscuit into one of the types ***(Petit Four, Cookies, Maxon, Kool)***, we need to compute the following four probabilities: **(01 pt)**

- P(Petit Four|large, sweet, vanilla) : The probability that the biscuit is a Petit Four given that it is ⟨large, sweet, vanilla⟩.
- P(Cookies|large, sweet, vanilla) : The probability that the biscuit is a Cookies given that it is ⟨large, sweet, vanilla⟩
- P(Maxon|large, sweet, vanilla) : The probability that the biscuit is a Maxon given that it is ⟨large, sweet, vanilla⟩
- P(Kool|large, sweet, vanilla) : The probability that the biscuit is a Kool given that it is ⟨large, sweet, vanilla⟩

The type of the **"unknown" biscuit** to be classified is the one with the **highest probability**. Using the following Bayes formula:

$$P(X|C_i) = \frac{P(C_i|X_j).P(C_i)}{P(X)}$$

We must calculate: ***(01 pt)***

$$\text{P(petit four |Large, Sweet, Vanilla)} = \frac{P(Large|petit\ four)*P(sweet|petit\ four*P(vanilla|petit\ four)}{P(Large)*P(Sweet)*P(Vanilla)} * P(petit\ four) \quad \textbf{(1)}$$

$$\text{P(Cookies|Large, Sweet, Vanilla)} = \frac{P(Large|Cookies)*P(Sweet|Cookies)*P(Vanilla|Cookies)}{P(Large)*P(Sweet)*P(Vanilla)} * P(Cookies) \quad \textbf{(2)}$$

$$\text{P(Maxon| Large, Sweet, Vanilla)} = \frac{P(Large|Maxon)*P(Sweet|Maxon)*P(Vanilla|Maxon)}{P(Large)*P(Sweet)*P(Vanilla)} * P(Maxon) \quad \textbf{(3)}$$

$$\text{P(Kool| Large, Sweet, Vanilla)} = \frac{P(Large|Kool)*P(Sweet|Kool)*P(Vanilla|Kool)}{P(Large)*P(Sweet)*P(Vanilla)} * P(Kool) \quad \textbf{(4)}$$

Than we calculate : ***(01 pt)***

$$P(petit\ four) = \frac{Cardinal(petit\ four)}{Total\ biscuit} = \frac{600}{2300} = \frac{6}{23} = 0.261$$

$$P(Cookies) = \frac{Cardinal(Cookies)}{Total\ biscuit} = \frac{500}{2300} = \frac{5}{23} = 0{,}217$$

$$P(Maxon) = \frac{Cardinal(Maxon)}{Total\ biscuit} = \frac{400}{2300} = \frac{4}{23} = 0{,}174$$

$$P(Kool) = \frac{Cardinal(Kool)}{Total\ biscuit} = \frac{800}{2300} = \frac{8}{23} = 0{,}3478$$

We can culculate or neglict the following probabilities :

$$P(Large) = \frac{Cardinal(Large)}{Total\ biscuit} = \frac{1000}{2300} = \frac{10}{23} = 0.435$$

$$P(Sweet) = \frac{Cardinal(Sweet)}{Total\ biscuit} = \frac{1200}{2300} = \frac{12}{23} = 0.522$$

$$P(Vanilla) = \frac{Cardinal(Vanilla)}{Total\ biscuit} = \frac{1100}{2300} = \frac{11}{23} = 0.478$$

For (1), we calculate : ***(0.75 Pt)***

$$P(Large|petit\ four) = \frac{Cardinal(Petit\ four\ AND\ Large)}{Cardinal(Petit\ four)} = \frac{250}{600} = \frac{5}{12} = 0.417$$

$$P(Sweet|Petit\ four) = \frac{Cardinal(Petit\ four\ AND\ Sweet)}{Cardinal(Petit\ four)} = \frac{400}{600} = \frac{2}{3} = 0.667$$

$$P(Vanilla|Petit\ four) = \frac{Cardinal(petit\ four\ AND\ vanilla)}{Cardinal(petit\ four)} = \frac{200}{600} = \frac{1}{3} = 0.333$$

Thus, the final result of (1) is : **(0.5 pt)**

$$\text{P(petit four | Large, Sweet, Vanilla)} = \frac{0.417*0.667*0.333}{0.435*0.522*0.478} * 0.261 = \frac{0.0242}{0.1085} = \mathbf{0.223}$$

For (2), we calculate : ***(0.75 Pt)***

$$P(Large|Cookies) = \frac{Cardinal(Cookies\ AND\ Large)}{Cardinal(Cookies)} = \frac{350}{500} = \frac{35}{50} = 0.7$$

$$P(Sweet|Cookies) = \frac{Cardinal(Cookies\ AND\ Sweet)}{Cardinal(Cookies)} = \frac{200}{500} = \frac{2}{5} = 0.4$$

$$P(Vanilla|Cookies) = \frac{Cardinal(Cookies\ AND\ Vanilla)}{Cardinal(Cookies)} = \frac{400}{500} = \frac{4}{5} = 0.8$$

Thus, the final result of (2) is : ***(0.5 pt)***

$$\text{P(Cookies|Large, Sweet, Vanilla)} = \frac{0.7*0.4*0.8}{0.435*0.522*0.478} * 0.217 = \frac{0.048608}{0.1085} = \mathbf{0.448}$$

For (3), we calculate: ***(0.75 Pt)***

$$P(Large|Maxon) = \frac{Cardinal(Maxon\ AND\ Large)}{Cardinal(Maxon)} = \frac{100}{400} = \frac{1}{4} = 0.25$$

$$P(Sweet|Maxon) = \frac{Cardinal(Maxon\ AND\ Sweet)}{Cardinal(Maxon)} = \frac{250}{400} = \frac{5}{8} = 0.625$$

$$P(Vanilla|Maxon) = \frac{Cardinal(Maxon\ AND\ Vanilla)}{Cardinal(Maxon)} = \frac{200}{400} = \frac{2}{4} = 0.5$$

Thus, the final result of (3) is : **(0.5 pt)**

$$\text{P(Maxon| Large, Sweet, Vanilla)} = \frac{0.25*0.625*0.5}{0.435*0.522*0.478} * 0.174 = \frac{0.013594}{0.1085} = \mathbf{0.125}$$

For (4), we calculate : ***(0.75 Pt)***

$$P(Large|Kool) = \frac{Cardinal(Kool\ AND\ Large)}{Cardinal(Kool)} = \frac{300}{800} = \frac{3}{8} = 0.375$$

$$P(Sweet|Kool) = \frac{Cardinal(Kool\ AND\ Sweet)}{Cardinal(Kool)} = \frac{350}{800} = \frac{35}{80} = 0.4375$$

$$P(Vanilla|Kool) = \frac{Cardinal(Kool\ AND\ Vanilla)}{Cardinal(Kool)} = \frac{300}{800} = \frac{3}{8} = 0.375$$

Thus, the final result of (4) is : **(0.5 pt)**

$$\mathrm{P(Kool|\ Large, Sweet, Vanilla)} = \frac{0.375*0.4375*0.375}{0.435*0.522*0.478} * 0{,}3478 = \frac{0{,}0213978}{0.1085} = \mathbf{0.197}$$

Finally, we will have :

$\mathrm{P(petit\ four\ |\ Large, Sweet, Vanilla)} = \mathbf{0.223}$
$\mathrm{P(Cookies|\ Large, Sweet, Vanilla)}$ = **0.448**
$\mathrm{P(Maxon|\ Large, Sweet, Vanilla)} = \mathbf{0.125}$
$\mathrm{P(Kool|\ Large, Sweet, Vanilla)}$= **0.197**

We conclude that the probability that the biscuit will be Cookies $\mathrm{P(Cookies|\ Large, Sweet, Vanilla)}$ is greater than the other probabilities ==> The given biscuit is classified in the class Cookies **(0.5 pt)**

| EXERCISE 04 | Deep Learning | 30 Min | 5.5 points |
|---|---|---|---|

Convolutional Neural Networks (CNNs) have been applied in the field of image processing and computer vision CV for decades.

**1. Which of the following is important application in image processing? (0.75 pts)**

A. Feature extraction and image classification
B. 3D image reconstruction
C. Augmented reality gaming
D. Image style transfer

A, B, D are important applications in CNNs, but C is not

**2. Explain briefly explain the principle of convolution operation is and its the role in CNNs. (0.75 pts)**

The Convolution is a mathematical operation that consists to multiply successively a matrice by a set of filters where each filter (also called kernel) is a two-dimensional 2D matrix containing integer values.

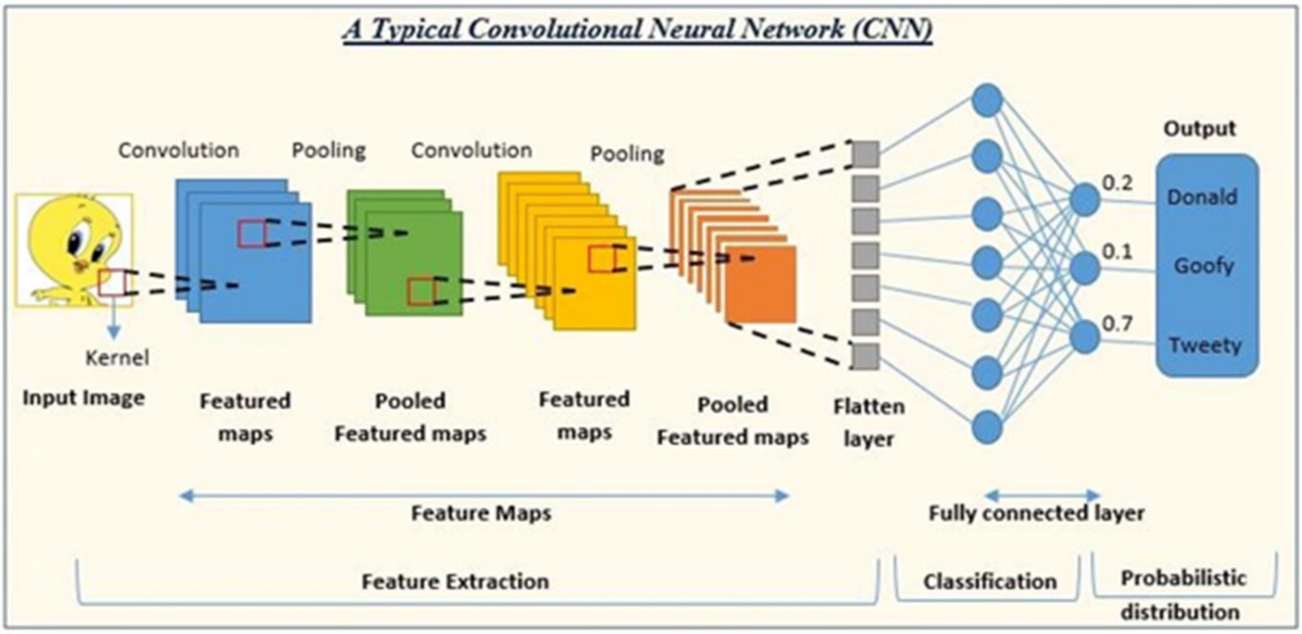
**Main Objectives :**

- Reduce the size of the input image ==> Reduce the memory space and processing time.
- Extract the most significant (relevent) feature (pixel) in the image without loosing information.

**3. Draw (or cite) a simple CNN architecture and explain its main components. (01 pt)**

This CNN consists of :

1. Convolutional layers
2. Followed by an activation function layer (e.g., ReLU)
3. Pooling layers.
4. A Fully Connected Layer




**4. Let be an input image size of 200x200 pixels, using a filter size of 5x5, a stride of 1, and no padding. Calculate the size of the output Image. (0.5 pt)**

The size of the output image can be calculated using the formula:

***Output size = [(Input size — Filter size + 2*Pad) / Stride)] + 1.***

Input Image Size = 200 , Filter Size = 5 ; Pad=0 ; Stride = 1

Thus, for a 200x200 input image, a 5x5 filter, Padding = 0, and a stride of 1, the output image size is [(200–5+2*0) / 1] + 1 = 196x196 pixels.

**5. What challenges might you encounter during the training process of deep CNNs? (01 pt)**

A. Vanishing or exploding gradients
B. Overfitting
C. High computational resource requirements
D. Class imbalance

Encountered challenges during the training process of deep CNNs are : A, B, C ; D

**6. Give some well-known CNNs architectures (0.5 pts)**

LeNet, AlexNet, VGG, ResNet, etc

The figure bellow represents an image IM1 of size 4x4 and a kernel (a filter) K1 of size 3x3

| | | | |
|---|---|---|---|
| 35 | 30 | 90 | 50 |
| 45 | 0 | 2 | 5 |
| 0 | 30 | 25 | 0 |
| 255 | 100 | 65 | 0 |

**Une Image 4X4**

| | | |
|---|---|---|
| 1 | 1 | 2 |
| 0 | 0 | 0 |
| -1 | -1 | -2 |

**Un filtre 3X3**

7. **Do the convolution of the image matrix IM1 and the kernel K1 and give the obtained image IM2.** ***(01 pt)***

| | | | |
|---|---|---|---|
| 35 | 30 | 90 | 50 |
| 45 | 0 | 2 | 5 |
| 0 | 30 | 25 | 0 |
| 255 | 100 | 65 | 0 |

**IM1(4, 4)**

| | | |
|---|---|---|
| 1 | 1 | 2 |
| 0 | 0 | 0 |
| -1 | -1 | -2 |

**F1(3, 3)**

| | |
|---|---|
| 165 | 165 |
| -436 | -153 |

**IM2(3, 3)**