

Family Name:

First Name:

KIMP_CII UE2 and GTL_S43-b Final Test

Arts et Métiers

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Day : 1st December 2023

Duration : 1.5h

Document allowed : None

Complete when possible directly on this document and give it back at the end of this exam. Don't forget to put your name on the top of this document. You can complete the exercise in the order you want: they are independant.

Exercise 1: Fuzzy Logic

The goal of this exercise is to calculate the final mark of a course composed by two projects and one final test. The fuzzy logic engine considers then three input parameters: Project1, Project2 and Final_Exam. These ones are defined graphically in Figure1. The output parameter, the final mark is graphically described in Figure 2 as well.

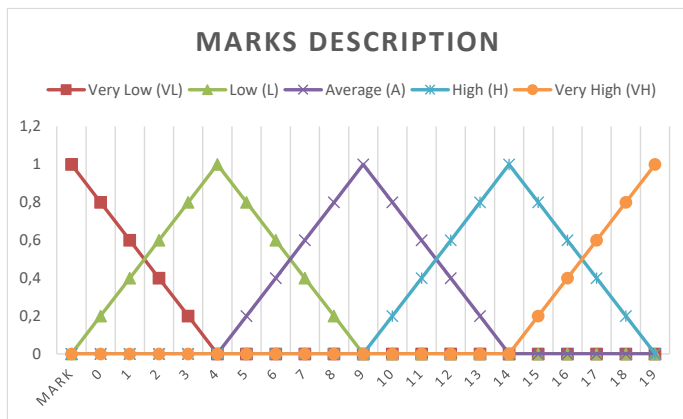


Figure 1 : Membership functions of Project1, Project2 and Final_Exam (inputs)

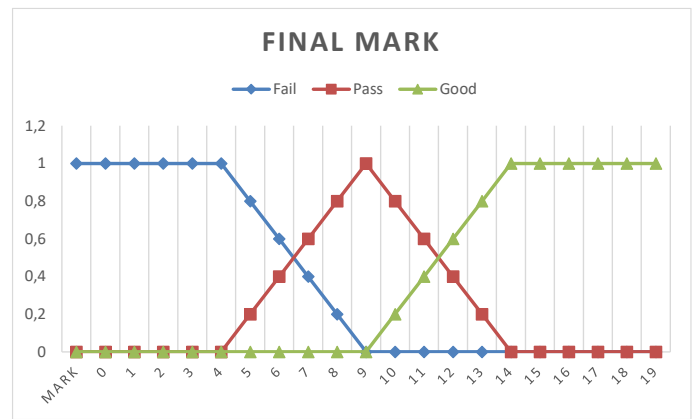


Figure 2: Membership function of Final Mark (output)

An intermediate fuzzy calculus is proposed to calculate the fuzzy average mark of the two projects with the rules described with the matrix displayed on Figure 3. It is important to underline that OR operator is used for this step (the upper left cell of Figure 3 means: "if Project1 is VL **OR** Project2 is VL then Project average is VU").

OR		Project 1				
		VL	L	A	H	VH
Project 2	VL	VU	VU	U	U	A
	L	VU	U	U	A	A
	A	U	U	A	S	S
	H	U	A	S	S	VS
	VH	A	S	S	VS	VS

Figure 3: Rules to assess project average mark

Aggregation: **Sum**

AND		Final Exam				
		VL	L	A	H	VH
Project average	VU	fail	fail	fail	pass	pass
	U	fail	fail	pass	pass	pass
	A	fail	pass	pass	pass	good
	S	pass	pass	pass	good	good
	VS	pass	pass	good	good	good

Figure 4: Rules to calculate the final mark

Aggregation: **Maximum**

Defuzzication: **Mean of Maximum**

The results are then not defuzzycated since they are directly integrated in the second calculus step. This second step aims at calculating the final mark, by using the same matrix form proposed in Figure 4 and as inputs: the mark of the final test and the average mark of projects. In that case, AND operator is used (the upper left cell of Figure 4 means: "if Project average is VU **AND** Final Exam is VL then final mark is fail"). For each step, their aggregation and defuzzycation operators are specified.

Work to complete: By detailing and justifying each step of your reasoning on the proposed areas below, give the final mark of a student having these three intermediate results: **17/20 for the first project, 4/20 for the second project and 8/20 for the final exam** (take care of the offset on x-axis in Figures 1 and 2 that is due to Excel display).

Fuzzycation Step – Give the membership of all the three input parameters

Project1:

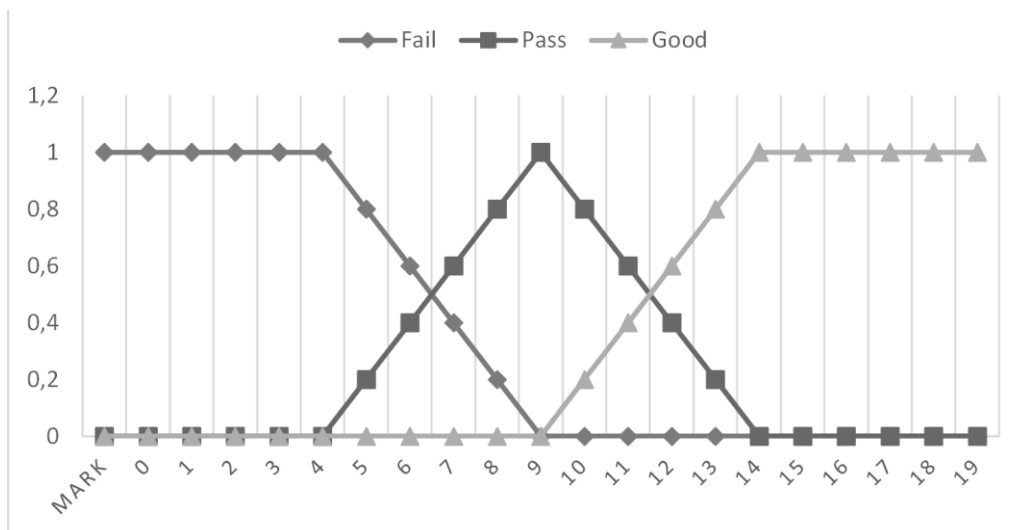
Project2:

Final_Exam:

Inference of the first step – Put below all outputs being not null after the inference and propose their final value after aggregation. You can write on Figure 3.

Inference of the second step – Put below all outputs being not null after the inference. You can write on Figure 4.

Aggregation of the second step – Draw directly the output shape on this document (clearly and cleanly)



To pass a module, its mark should be greater or equal to 10. Do the student pass this module?

Defuzzycation – Calculate the final mark of the student and conclude if he will pass or not.

Exercise 2: Constraint Satisfaction Problem: Operator allocation on an assembly line

A company wants to allocate wisely operators on an automatic assembly line. These operators' tasks are mainly monitoring and logistic (feed the automatic systems with parts). We want to take into consideration human factors in this allocation to prevent some people of walking too much a day. The assembly line is composed by 14 workstations.

To define the factory, two main parameters are defined:

- $WorkTime_j$ is a list giving the work time of the j^{th} workstation
- $WalkTime_{i,j}$ is a matrix giving the time needed to walk from the i^{th} workstation to j^{th} workstation.

Several hypotheses are proposed to model this problem:

- Only one operator on a workstation
- No free workstation (all workstations must be allocated)
- An operator can work on several workstations
- An allocation is considered as valid when all workers can do their jobs and movements in the takt time, which is an input parameter ($Takt_Time$).
- The amount of operator (Nb_Op) is an input parameter.

Question 2.1: Model the problem by defining: the variable(s), domain(s) and the constraint(s). You may need to introduce extra variables. Please justify your decisions clearly. You may express your constraints either mathematically or in words, but they must be expressed in terms of relationships between the variables in the problem. You should explain how each of the points above is captured by your formulation (please answer in point form).

Question 2.2: We want to balance the work time among all operators. Explain and justify how to manage this new requirement on your model

Exercise 3: Artificial Neural Network

We want to design and train a regression neural network.

Question 3.1: Assess the number of parameters of this regression network having 4 input parameters, two outputs and only one hidden layer composed by 10 neurons. Detail your calculus.

Question 3.2: Regarding the network type of the previous question, cross out the Tensorflow.keras functions that certainly won't be useful: `sigmoid`, `linear`, `relu`, `binary_crossentropy`, `mean_squared_error`, `accuracy`, `mean_absolute_error`, `tanh`, `confusion_matrix`. For the one(s) you crossed, explain why:

Question 3.3: The network is configured to be trained on a set of 5000 training points with 200 epochs. We define a `validation_split` equals to 0.1. Complete the table below with different gradient descent strategies, by giving and justifying the number of updates (backpropagations) that the network will go through.

Stochastic descent	Batch descent	Mini batch of 100 points

Question 3.4: The figures (Figure 5 and Figure 6) show two different configurations of the training of the network. For each case, explain what could be the reason of this evolution of the loss and explain briefly how to reduce this issue.

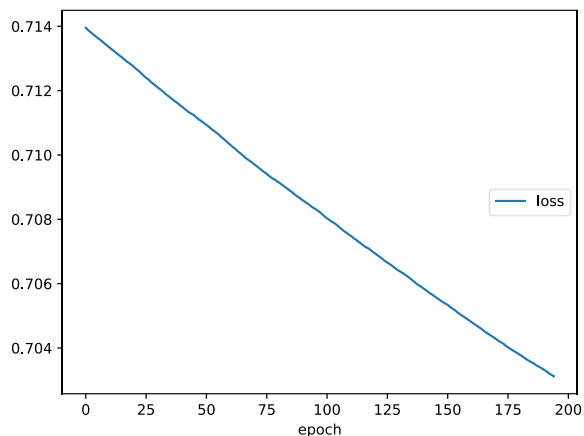


Figure 5: Configuration 1

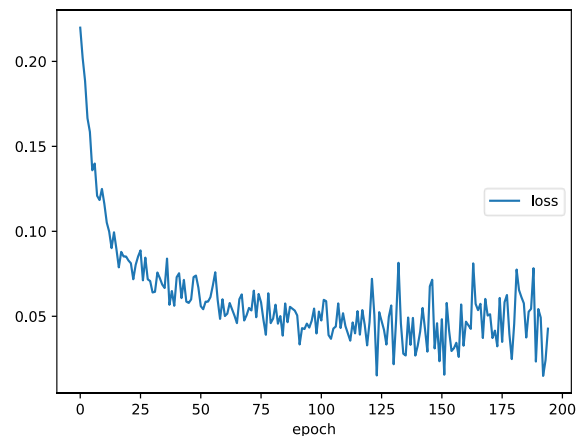


Figure 6: Configuration_2

Reason + Solution:

Reason + Solution:

Exercise 4: Expert Systems

The rule base of an order 0 expert system is composed by this set of rules:

R1	IF A THEN G AND H
R2	IF C AND (B OR A) THEN F AND G
R3	IF D THEN J AND C
R4	IF D AND E THEN B
R5	IF D AND I THEN A
R6	IF K THEN E
R7	IF L THEN D AND I
R8	IF D THEN J

Figure 7: Rules base

The selection step of the expert system follows these meta-rules:

- **P1:** Priority to the rule having the most numerous **conditions**,
- **P2:** If the first criterion is not enough, priority to the rule having the most numerous **conclusions**,
- **P3:** If the two first criteria are not enough; the priority is given regarding the **order** of the rule in the rule base (the number in the first column in Figure).

Question 4.1: By using the forward chaining in this priority strategy, detail all steps followed by the expert system from an initial fact base composed by the two facts $\{I, D\}$ (and detail the facts base for each step).

Question 4.2: By applying the backward chaining and the priority strategy previously defined, determine if it is possible to prove G , having as available facts L in the fact database. Justify by showing the detailed explored tree.