First Name:

Family Name:

2018/2019 Academic year

Session 2018-1

Final Exam - 1 hour

GTL

Module S43b

Teacher : Alain ETIENNE

Number of pages and exercises:	3 independent exercises
Allowed materials:	Personal notes Course materials Calculator Dictionary
Instructions:	Do not hesitate to explain or justify your choices! Good luck and good work! **Give back this statement at the end of the exam complete with your first name and family name**

1. Constraint Satisfaction Problem (≈40%):

The CSP exercise is an old little puzzle that occurred one day at an archery meeting. A young woman who carried off the first prize scored exactly one hundred points. The scores on the target are: 16, 17, 23, 24, 39 and 40.

Can you figure out how many arrows she must have used to accomplish the feat?

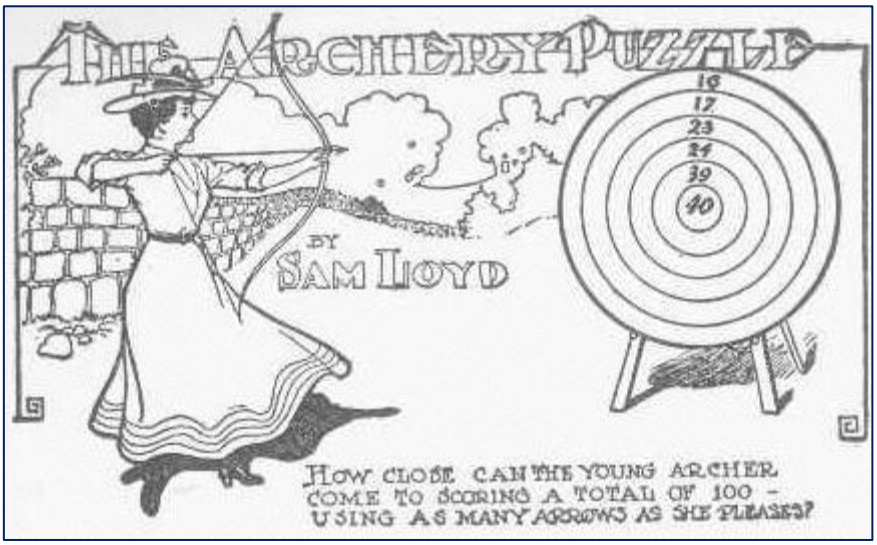


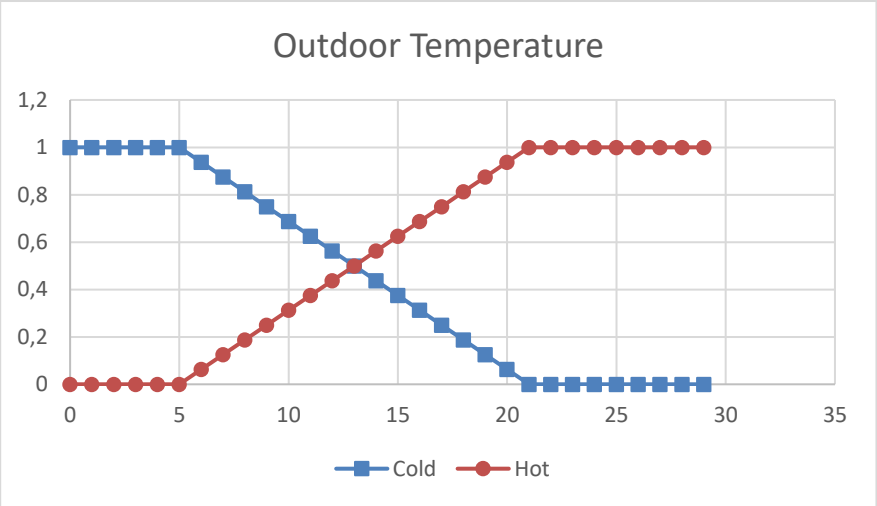
Figure 1 : Archery Puzzle – by Sam Loyd

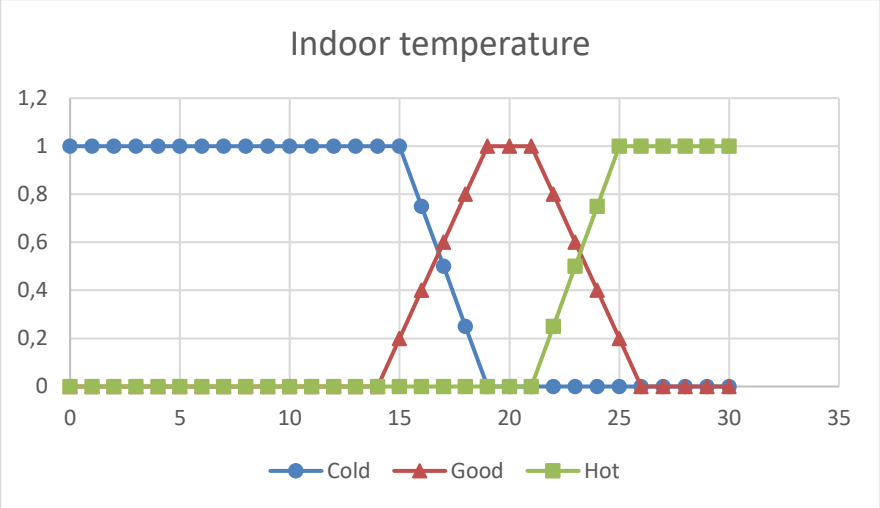
Question 1.1: Perform the mathematical modeling (as defined by Montanari) of this Constraint Satisfaction Problem by identifying: What are the variables in this problem? What are their respective domains?
Question 1.2: Detail mathematically the relationships and constraints linking the variables identified and modelled in the previous question.
Question 1.3: Detail and justify the four first steps of backtracking algorithm applied to this problem. Represent this solution exploration in the tree representation as the one we performed during the lecture. For the selection of the value to consider for the variable assignment, you can select the first available in the domain.
Question 1.4: Select one constraint of this problem and express it in MiniZinc's language (this is not requested to define the variables and other mandatory constraints, outputs formatting…).

2. Fuzzy Logic (≈30%):

We want to control the heating system of ENSAM school thanks to 2 temperature probes and one fuzzy logic controller. The behavior of the fuzzy controller is based on the following parameter definitions:

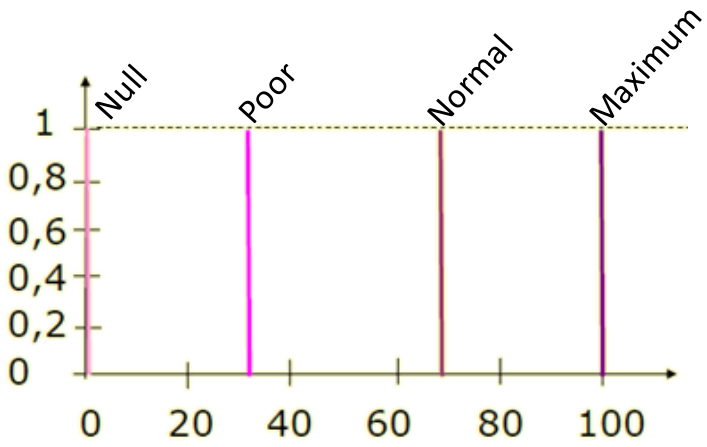
- Input parameters, *Outdoor temperature* and *Indoor temperature*, are described with the following definitions:





- To handle the output parameter (*Heating Power*), a simple model to defuzzy is selected. This one is based one single values: the membership value is equal to 0 in the whole domain but in only one point its value is equal to 1:
  - *Null*, for a heating power of 0%
  - *Poor*, for a heating power of 33%
  - *Normal*, for a heating power of 67%
  - *Maximum*, for a heating power of 100%

  In a more graphical way, this output parameter looks like:



- We use the fuzzy operators defined by Mamdami (AND, OR…)
- The aggregator operator is: **Max**
- The fuzzy laws are defined in the table above:

R1	**IF** Outdoor T° is Cold AND Indoor T° is Cold **THEN** Power is Maximum
R2	**IF** Outdoor T° is Cold AND Indoor T° is Good **THEN** Power is Normal
R3	**IF** Outdoor T° is Cold AND Indoor T° is Hot **THEN** Power is Poor
R4	**IF** Outdoor T° is Hot AND Indoor T° is Cold **THEN** Power is Normal
R5	**IF** Outdoor T° is Hot AND Indoor T° is Good **THEN** Power is Poor
R6	**IF** Outdoor T° is Hot AND Indoor T° is Hot **THEN** Power is Null

Figure 2 : Fuzzy rules to consider in this exercise

Question 2.1: In the case: **Indoor T°= 15°C and Outdoor T°= 15°C**, identify what are the memberships of the input parameters and evaluate them. After triggering the fuzzy rules, synthetize their results and draw the shape of the output parameter *Heating Power*.

Question 2.2: By using the defuzzycation operator "Center of Gravity", estimate the parameter *Heating Power*.

3. Expert Systems (≈30%):

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

R1	**IF** A OR V OR O **THEN** I
R2	**IF** Y **THEN** R
R3	**IF** C **THEN** A
R4	**IF** H AND I **THEN** G AND F
R5	**IF** X AND F **THEN** V
R6	**IF** B AND R **THEN** H
R7	**IF** X OR Y **THEN** B AND O
R8	**IF** Y **THEN** A AND Z

Figure 3: Rules base

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

- P1: Priority to the rule having the most numerous conclusions,
- P2: If the first criterion is not enough, priority to the rule having the most numerous conditions
- 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 3)

The initial fact base is composed by these facts **{Y, C}**.

Question 3.1: By using backward chaining and the rule selection strategy expressed previously, determine and detail the rule path leading to the wanted fact **G**.

Question 3.2: Express the rule R4 by using LISP language (the one used in CLIPS software).