The Higher Ministry of Education **The Higher Future Institute for Specialized Technology Studies**	**Course:- Expert Systems** **Exam:- Final September 2017** **Fourth Year**	**Year:- 2016/2017** **Department:- CS** **Time:- 2 Hours**

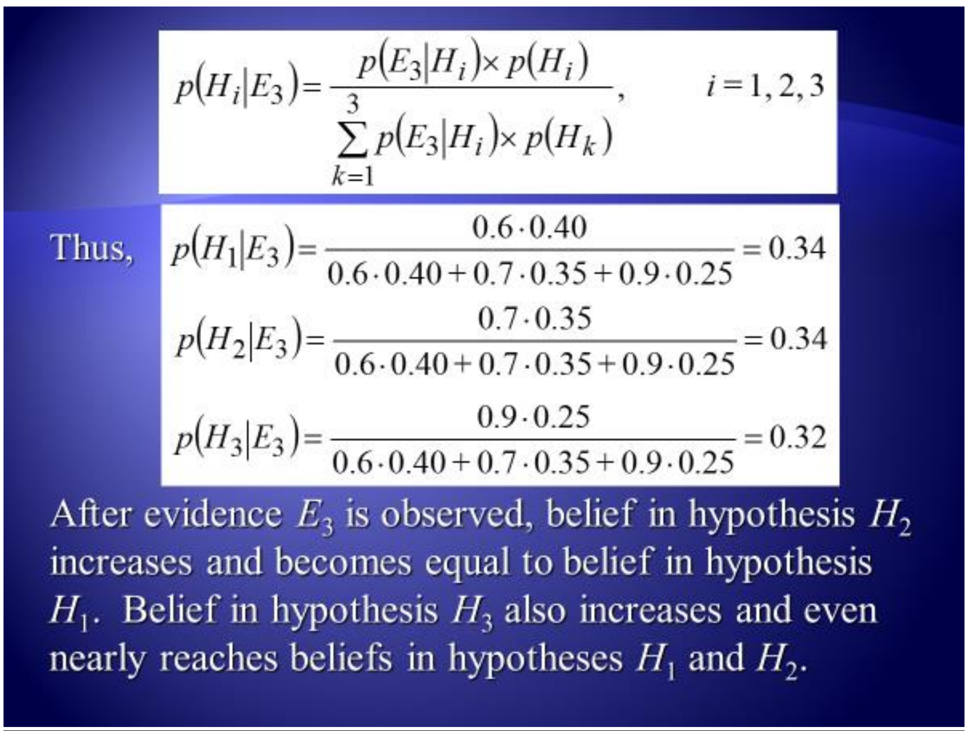
<u>Question One:</u>

Suppose an expert, given three conditionally independent evidences E_1, E_2 and E_3, creates three mutually exclusive and exhaustive hypotheses H_1, H_2 and H_3, and provides prior probabilities for these hypotheses – $p(H_1)$, $p(H_2)$ and $p(H_3)$, respectively.

The expert also determines the conditional probabilities of observing each evidence for all possible hypotheses. The following Table illustrates the prior and conditional probabilities provided by the expert.

Probability	Hypothesis		
	i=1	i=2	i=3
$P(H_i)$	0.25	0.40	0.35
$P(E_1\|H_i)$	0.5	0.3	0.8
$P(E_2\|H_i)$	0.7	0.9	0.0
$P(E_3\|H_i)$	0.9	0.6	0.7

a. compute the following
   1. $P(Hi|E_1)$ where i=1.
   2. $P(Hi|E_1E_2)$, $P(Hi|E_1E_3)$, $P(Hi|E_2E_3)$ where i=2.
   3. $P(Hi|E_1E_2\,E_3)$ where i=3.



Suppose now that we observe evidence E_1. The posterior probabilities are calculated as

$$p(H_i|E_1E_3) = \frac{p(E_1|H_i) \times p(E_3|H_i) \times p(H_i)}{\sum_{k=1}^{3} p(E_1|H_i) \times p(E_3|H_i) \times p(H_k)}, \qquad i = 1, 2, 3$$

Hence,

$$p(H_1|E_1E_3) = \frac{0.3 \cdot 0.6 \cdot 0.40}{0.3 \cdot 0.6 \cdot 0.40 + 0.8 \cdot 0.7 \cdot 0.35 + 0.5 \cdot 0.9 \cdot 0.25} = 0.19$$

$$p(H_2|E_1E_3) = \frac{0.8 \cdot 0.7 \cdot 0.35}{0.3 \cdot 0.6 \cdot 0.40 + 0.8 \cdot 0.7 \cdot 0.35 + 0.5 \cdot 0.9 \cdot 0.25} = 0.52$$

$$p(H_3|E_1E_3) = \frac{0.5 \cdot 0.9 \cdot 0.25}{0.3 \cdot 0.6 \cdot 0.40 + 0.8 \cdot 0.7 \cdot 0.35 + 0.5 \cdot 0.9 \cdot 0.25} = 0.29$$

Hypothesis H_2 has now become the most likely one.

After observing evidence E_2, the final posterior probabilities for all hypotheses are calculated:

$$p(H_i|E_1E_2E_3) = \frac{p(E_1|H_i) \times p(E_2|H_i) \times p(E_3|H_i) \times p(H_i)}{\sum_{k=1}^{3} p(E_1|H_i) \times p(E_2|H_i) \times p(E_3|H_i) \times p(H_k)}, \qquad i = 1, 2, 3$$

$$p(H_1|E_1E_2E_3) = \frac{0.3 \cdot 0.9 \cdot 0.6 \cdot 0.40}{0.3 \cdot 0.9 \cdot 0.6 \cdot 0.40 + 0.8 \cdot 0.0 \cdot 0.7 \cdot 0.35 + 0.5 \cdot 0.7 \cdot 0.9 \cdot 0.25} = 0.45$$

$$p(H_2|E_1E_2E_3) = \frac{0.8 \cdot 0.0 \cdot 0.7 \cdot 0.35}{0.3 \cdot 0.9 \cdot 0.6 \cdot 0.40 + 0.8 \cdot 0.0 \cdot 0.7 \cdot 0.35 + 0.5 \cdot 0.7 \cdot 0.9 \cdot 0.25} = 0$$

$$p(H_3|E_1E_2E_3) = \frac{0.5 \cdot 0.7 \cdot 0.9 \cdot 0.25}{0.3 \cdot 0.9 \cdot 0.6 \cdot 0.40 + 0.8 \cdot 0.0 \cdot 0.7 \cdot 0.35 + 0.5 \cdot 0.7 \cdot 0.9 \cdot 0.25} = 0.55$$

Although the initial ranking was H_1, H_2 and H_3, only hypotheses H_1 and H_3 remain under consideration after all evidences (E_1, E_2 and E_3) were observed.

<u>Question Two:</u>

a. What is the difference between a crisp set and a fuzzy set?

b. Compute the membership in the set of the following hedges:

very, extremely, very very, more or less

for a man has a 0.91 membership in the set of tall men.

c. Suppose we have the following fuzzy sets of tall men and very tall men which define as follow:

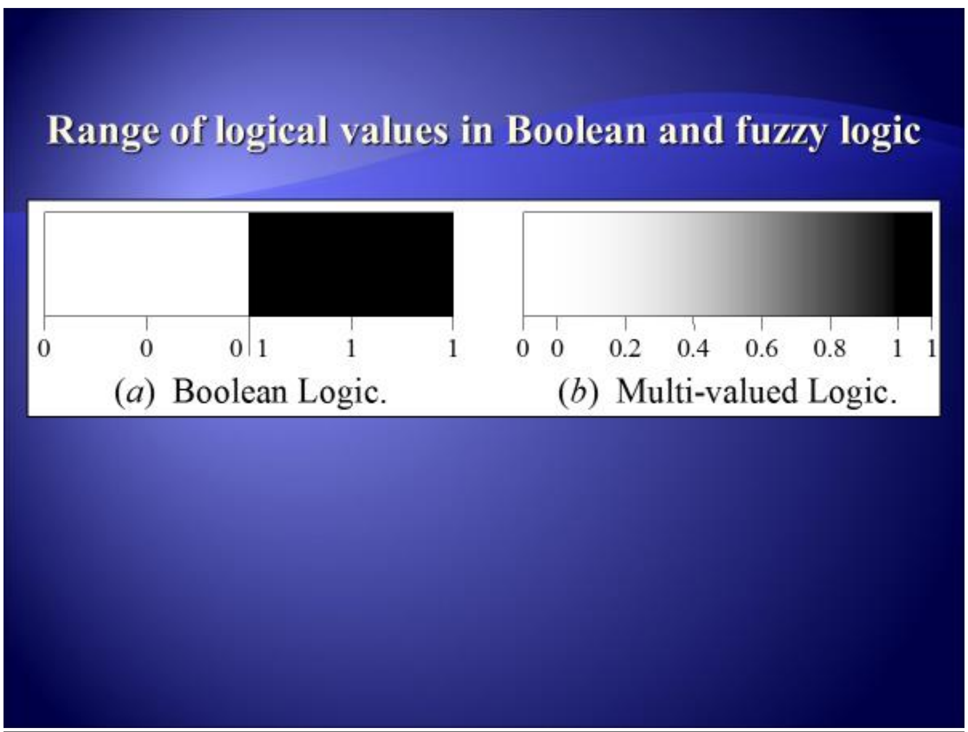
Tall men = {0/180, 0.25/182.5, 0.50/185, 0.75/187.5, 0.5/185, 1/190}

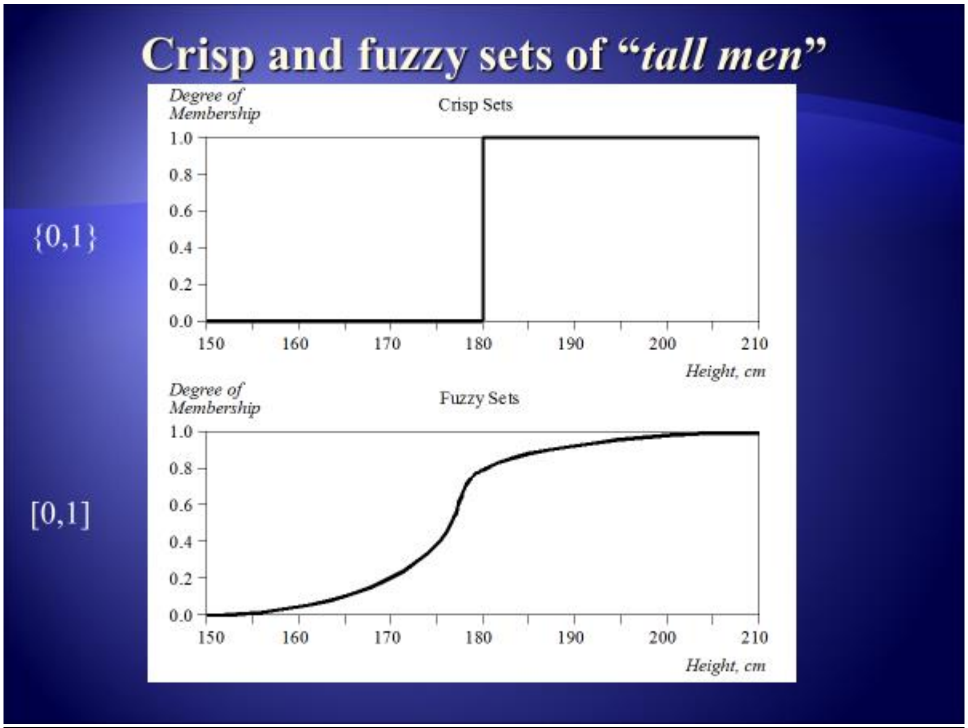
Very tall men = {0/180, 0.06/182.5, 0.25/185, 0.56/187.5, 0.5/185, 1/190}

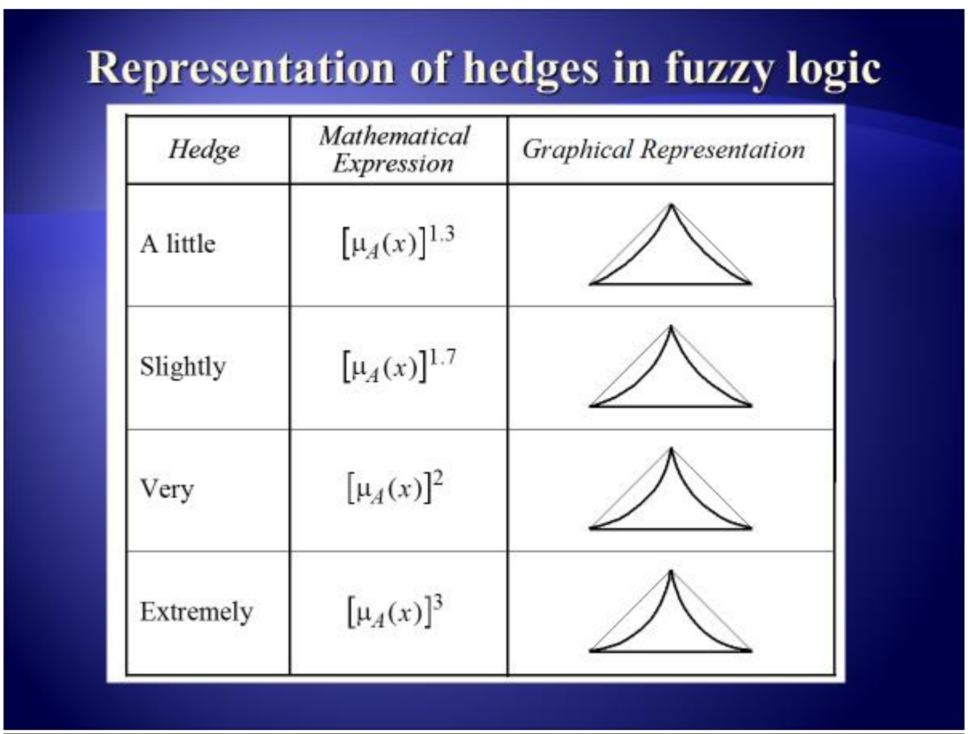
where each element in the set defines as membership *degree / the actual tall*

Compute the fuzzy set of the following fuzzy sets operations:

Complement of tall men fuzzy set, intersection of tall men fuzzy set and very tall men fuzzy set, union of tall men fuzzy set and very tall men fuzzy set.

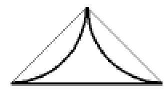
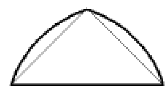






Hedge	*Mathematical Expression*	*Graphical Representation*
A little	$[\mu_A(x)]^{1.3}$	
Slightly	$[\mu_A(x)]^{1.7}$	
Very	$[\mu_A(x)]^{2}$	
Extremely	$[\mu_A(x)]^{3}$	

Representation of hedges in fuzzy logic (continued)

Hedge	*Mathematical Expression*	*Graphical Representation*
Very very	$[\mu_A(x)]^4$	
More or less	$\sqrt{\mu_A(x)}$	
Somewhat	$\sqrt{\mu_A(x)}$	
Indeed	$2\,[\mu_A(x)]^2$ if $0 \le \mu_A \le 0.5$ $1 - 2\,[1 - \mu_A(x)]^2$ if $0.5 < \mu_A \le 1$	

$$tall\ men = (0/180, 0.25/182.5, 0.5/185, 0.75/187.5, 1/190)$$
$$NOT\ tall\ men = (1/180, 0.75/182.5, 0.5/185, 0.25/187.5, 0/190)$$

$$tall\ men \cap average\ men = (0/165, 0/175, 0/180, 0.25/182.5, 0/185, 0/190)$$

$$tall\ men \cup average\ men = (0/165, 1/175, 0.5/180, 0.25/182.5, 0.5/185, 1/190)$$

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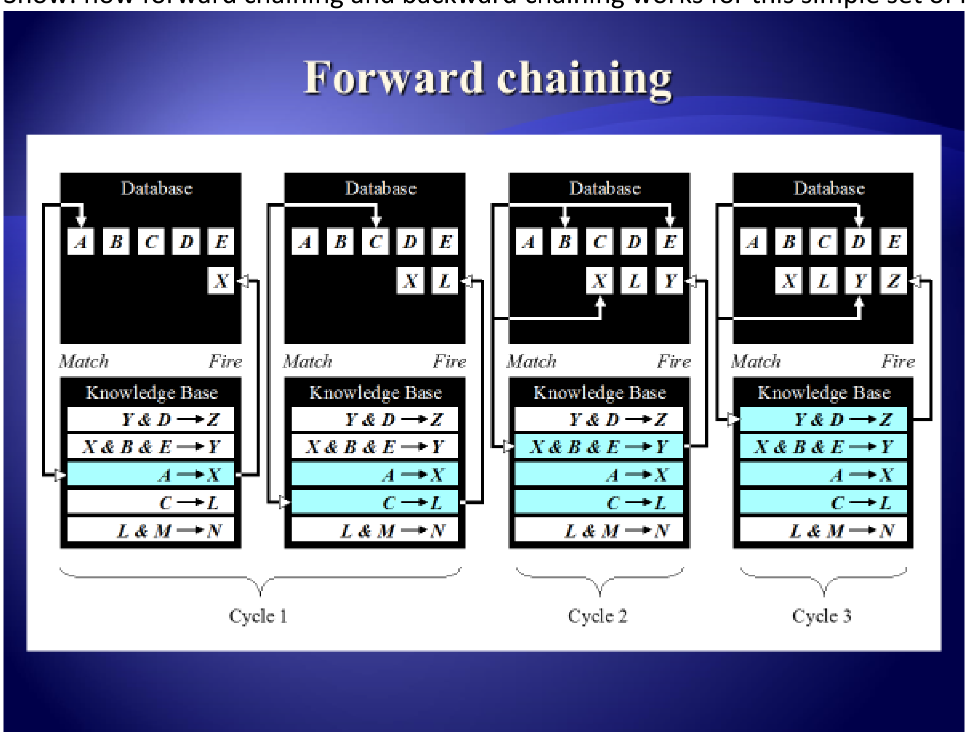
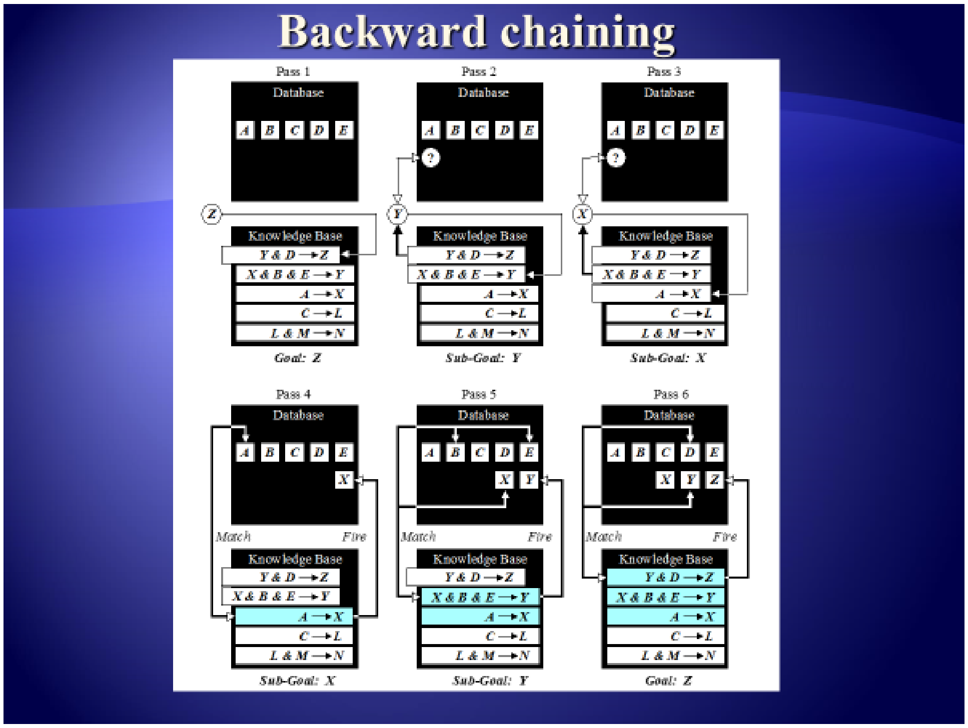
<u>Question Three:</u>

a) Explain the main players in the development team of expert systems.
b) Describe the complete structure of a rule-based expert system.
c) Compare between the expert systems with conventional systems and human experts.
d) Let you have the following rules

$$Y \,\&\, D \rightarrow Z$$
$$X \,\&\, B \,\&\, E \rightarrow Y$$
$$A \rightarrow X$$
$$C \rightarrow L$$
$$L \,\&\, M \rightarrow N$$

And the facts A, B, C, D and E are true, where Z is the goal
Show: how forward chaining and backward chaining works for this simple set of rules?





Backward chaining
Pass 1
Database
A B C D E
Knowledge Base
Y & D → Z
X & B & E → Y
A → X
C → L
L & M → N
Goal: Z
Pass 2
Sub-Goal: Y
Pass 3
Sub-Goal: X
Pass 4
Match
Fire
Sub-Goal: X
Pass 5
Sub-Goal: Y
Pass 6
Goal: Z

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Question Four:

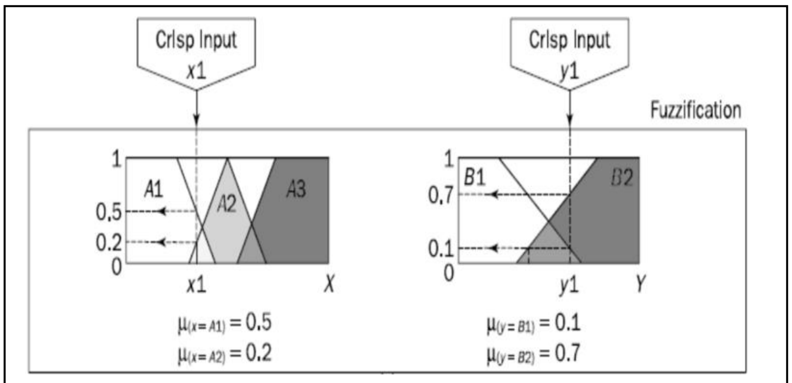
Draw the basic structure (Mamdani-style) that simulate the Fuzzy inference(Fuzzification, Rule evaluation, Aggregation of rule consequents, Defuzzification) for the following rules

1. *IF project_funding is adequate*
   OR project_staffing is small
   THEN risk is low
2. *IF project_funding is marginal*
   AND project_staffing is large
   THEN risk is normal
3. *IF project_funding is inadequate*
   THEN risk is high

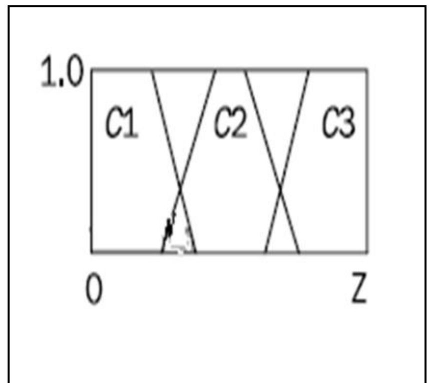
Suppose the ranges of project funding and project staffing between 1 to 100 per cent.

And the crisp input x1=0.35 and y1=0.6

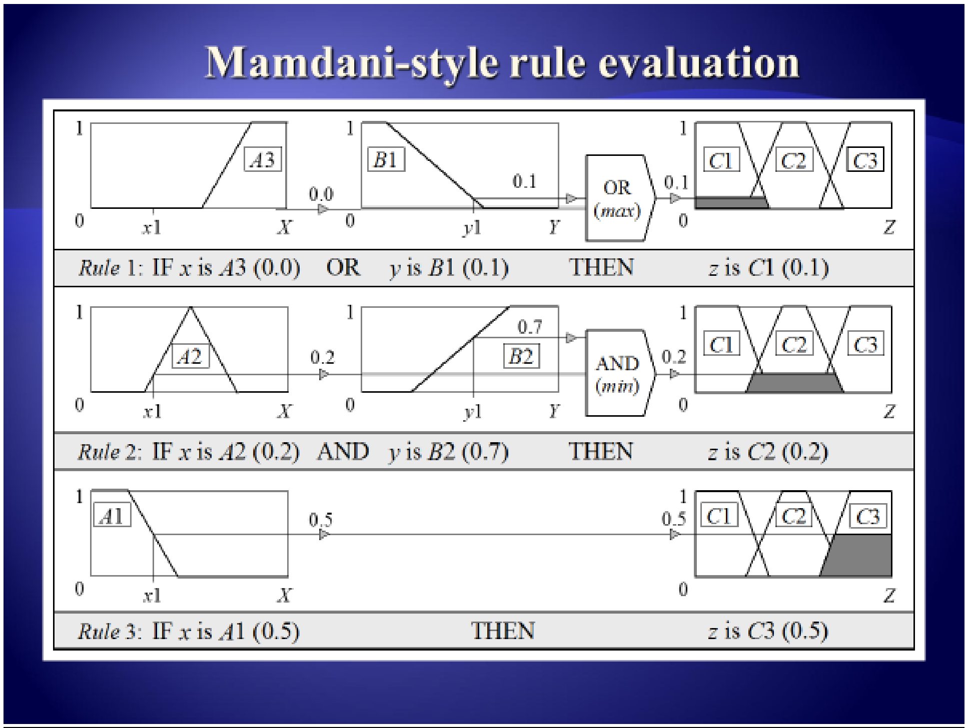
The membership degree for project funding and project staffing and risk as follow:



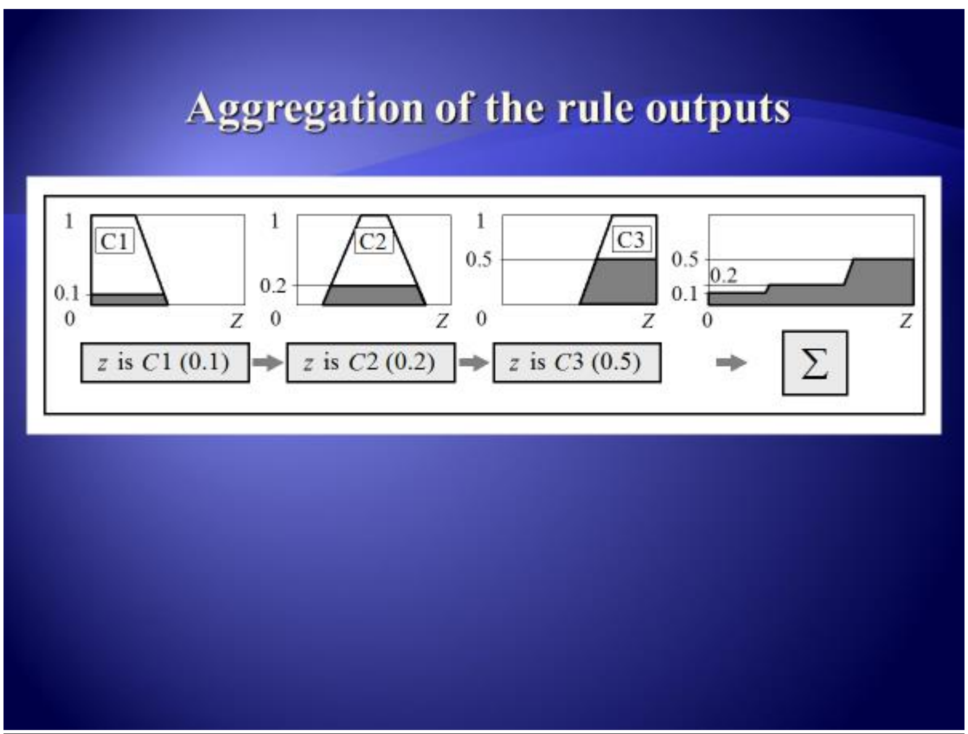
The membership degree for project funding and project staffing



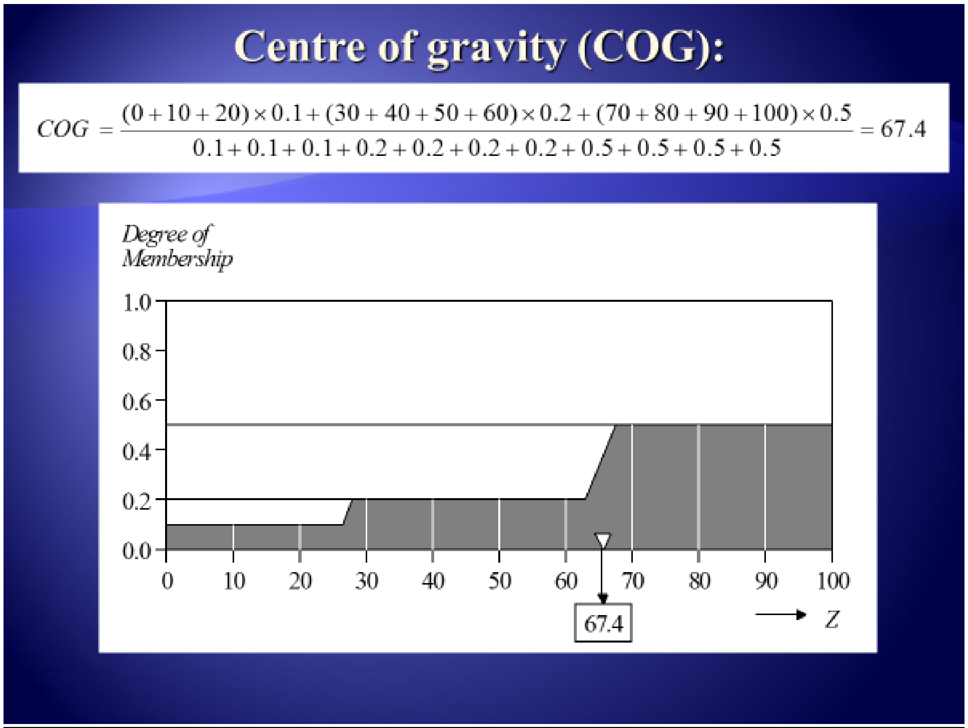
The membership degree for risk



Mamdani-style rule evaluation
Rule 1: IF x is A3 (0.0) OR y is B1 (0.1) THEN z is C1 (0.1)
Rule 2: IF x is A2 (0.2) AND y is B2 (0.7) THEN z is C2 (0.2)
Rule 3: IF x is A1 (0.5) THEN z is C3 (0.5)
OR (max)
AND (min)



Aggregation of the rule outputs
z is C1 (0.1)
z is C2 (0.2)
z is C3 (0.5)
Σ



Centre of gravity (COG):
$COG = \frac{(0+10+20)\times 0.1+(30+40+50+60)\times 0.2+(70+80+90+100)\times 0.5}{0.1+0.1+0.1+0.2+0.2+0.2+0.2+0.5+0.5+0.5+0.5} = 67.4$
Degree of Membership
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
67.4
Z