ARTIFICIAL INTELLIGENCE

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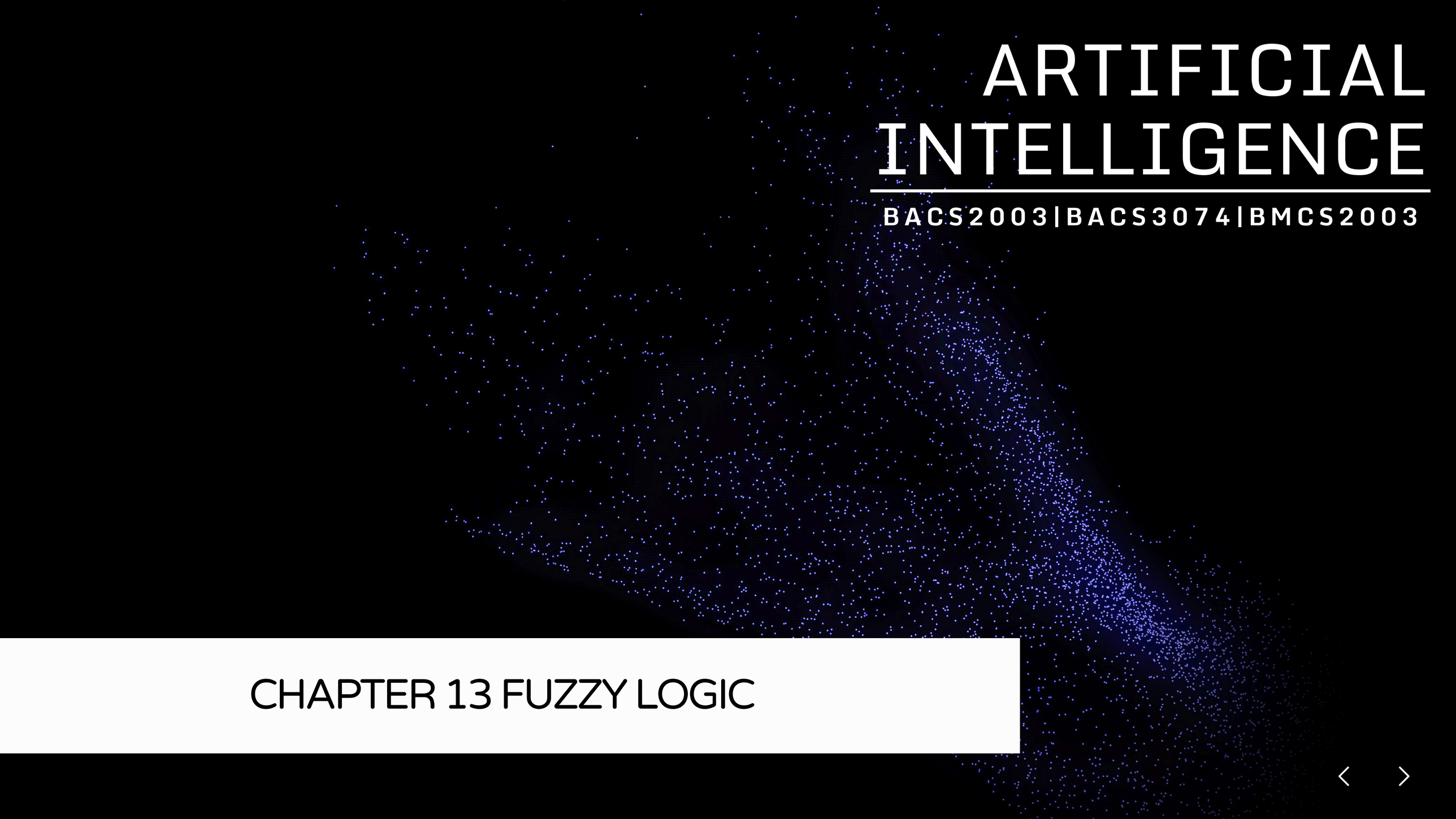
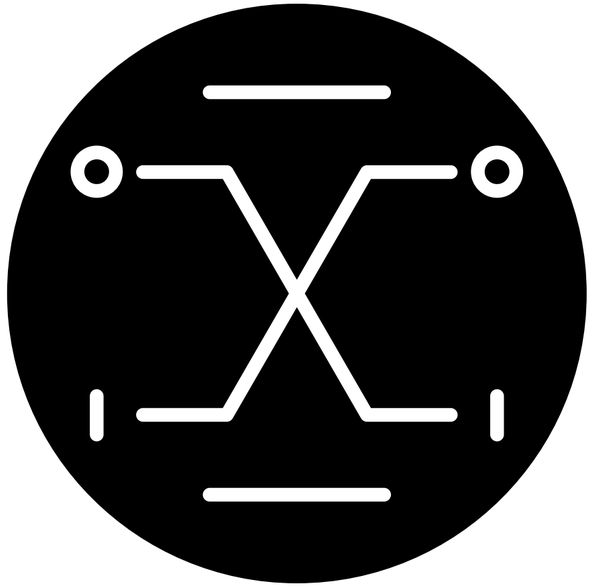


CHAPTER 13 FUZZY LOGIC

OUTCOMES

1. **Fuzzy Set vs Crisp set**
2. **Degree of Membership & Membership Function**
3. **Fuzzy Set & Fuzzy Rule**
4. **Fuzzy Inference System**



FUZZY LOGIC

1. Fuzzy logic is a form of many-valued logic where the truth value of variables may be any real number between 0 and 1, representing degrees of truth rather than the binary true or false found in classical Boolean logic.
2. It is employed to handle the concept of partial truth, where the truth value may range between completely true and completely false.
3. Boolean logic uses sharp distinctions. It forces us to draw lines between members of a class and non- members.

<u>For instance</u>

Tom’s height is 181 cm. Is he tall? & David’s height is 179 cm. Is he tall?

If we draw a line at 180 cm to differentiate between a tall man and a short man, Tom is Tall and David is not tall.

However if we use fuzzy logic, a man's tallness is expressed on a scale (e.g., 0 to 1), with varying degrees of tallness (also, a man's shortness is expressed on a scale, with varying degrees of shortness). Tom can be 0.82 tall and David can be 0.78tall by using fuzzy logic.

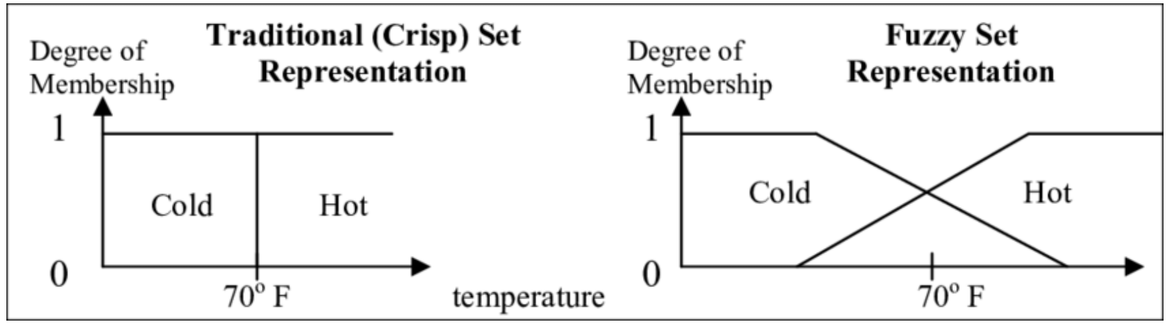
FUZZY SET VS CRIPS SET

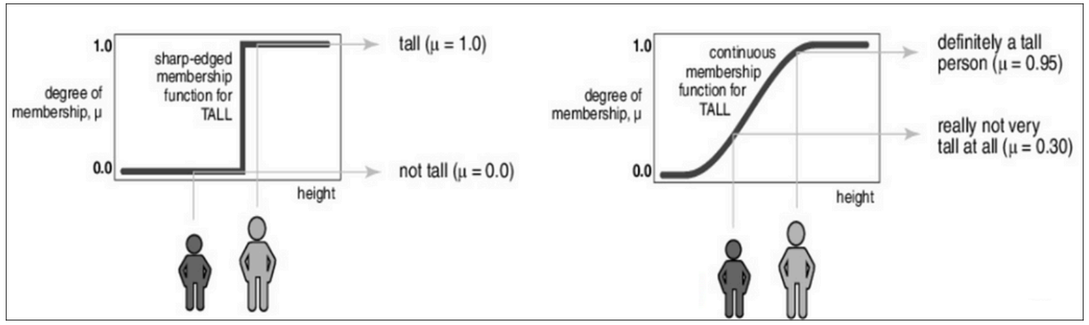
FUZZY SET

Defines value between 0 or 1

CRISP SET

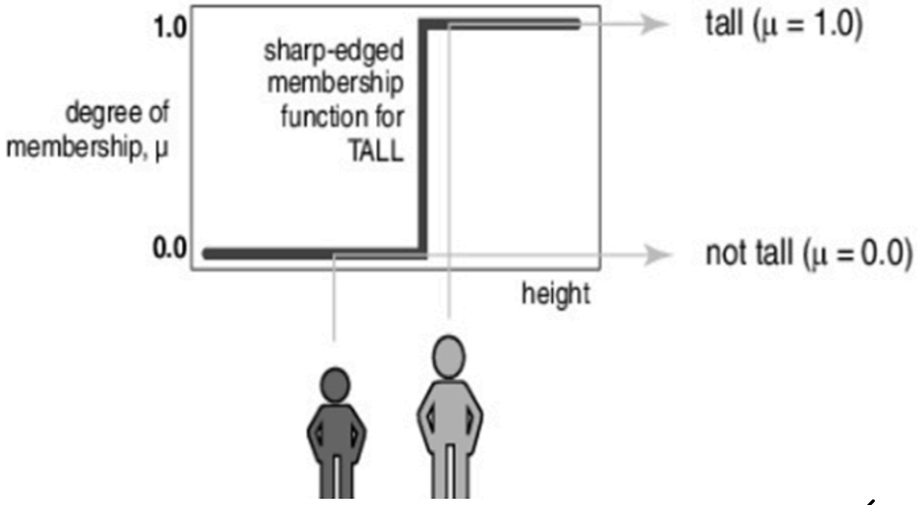
Defines either value is 0 or 1





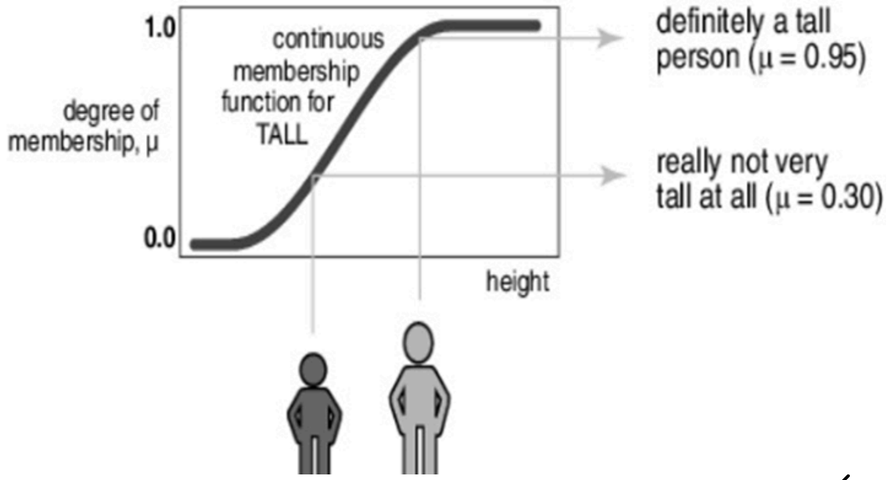
DEGREE OF MEMBERSHIP OF “TALL MEN”

Name	Height, cm	Degree of Membership	
		Crisp	*Fuzzy*
Chris	208	1	
Mark	205	1	
John	198	1	
Tom	181	1	
David	179	0	
Mike	172	0	
Bob	167	0	
Steven	158	0	
Bill	155	0	
Peter	152	0	



DEGREE OF MEMBERSHIP OF “TALL MEN”

Name	Height, cm	Degree of Membership	
		Crisp	*Fuzzy*
Chris	208	1	1.00
Mark	205	1	1.00
John	198	1	0.98
Tom	181	1	0.82
David	179	0	0.78
Mike	172	0	0.24
Bob	167	0	0.15
Steven	158	0	0.06
Bill	155	0	0.01
Peter	152	0	0.00

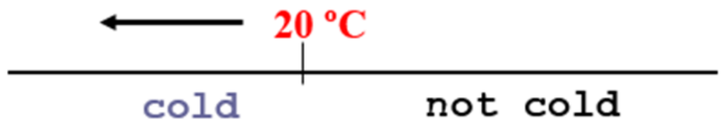


FUZZY LOGIC – CREATING FUZZY SET

In the context of a rule-based system, we might imagine asking ‘Is the water cold?’

Yes / No / very cold / a bit cold

We might fixing a strict changeover point.

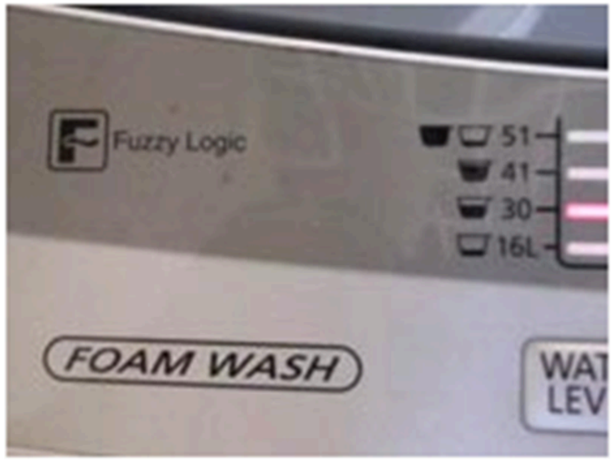


Temp		*Function Value*	
- 273	→	1	(cold)
- 40	→	1	(cold)
0	→	0.9	(not quite cold)
5	→	0.7	(on the cold side)
10	→	0.3	(a bit cold)
15	→	0.1	(barely cold)
100	→	0	(not cold)
1000	→	0	(not cold)

The degree of fuzzy sets is usually between 0 to 1.

APPLICATIONS

Fuzzy Logic



Advanced washing machines come with fuzzy logic where the whole wash cycle is performed by pushing one button. The Fuzzy Logic senses the amount of laundry placed in the wash tub and sets a wash program according to it. It controls the water level, the detergent and the washing time.

EXERCISE

A washing machine can load up to 9kg clothes, and minimum 0.1kg clothes to perform its washing task. It has 3 options to weight the clothes: low, medium, high

Create:

1. A fuzzy set to demonstrate the spectrum of ‘degrees of heaviness ’.
2. a membership function of the clothes heaviness,
3. a graph to represent the membership function.

EXERCISE

A fuzzy set to demonstrate the spectrum of ‘degrees of heaviness ’.

Fuzzy set:

EXERCISE

Membership function of the clothes heaviness

low(x) =
{ 0, if weight(x) >=3,
f(weight(x)) if 0.1 < weight(x)< 3,
1, if weight(x) <= 0}

medium(x) =
{ 0, if weight(x) <= or weight(x) >= 6,
f(weight(x)) if 3 < weight(x)< 6,
1, if weight(x) = 4.5}

heavy(x) =
{ 0, if weight(x) <= 6,
f(weight(x)) if 6 < weight(x)< 9,
1, if weight(x) >= 9}

EXERCISE

Graph to represent the membership function.

low(x) =
{ 0, if weight(x) >=3,
f(weight(x)) if 0.1 < weight(x)< 3,
1, if weight(x) <= 0}

medium(x) =
{ 0, if weight(x) <= or weight(x) >= 6,
f(weight(x)) if 3 < weight(x)< 6,
1, if weight(x) = 4.5}

heavy(x) =
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f(weight(x)) if 6 < weight(x)< 9,
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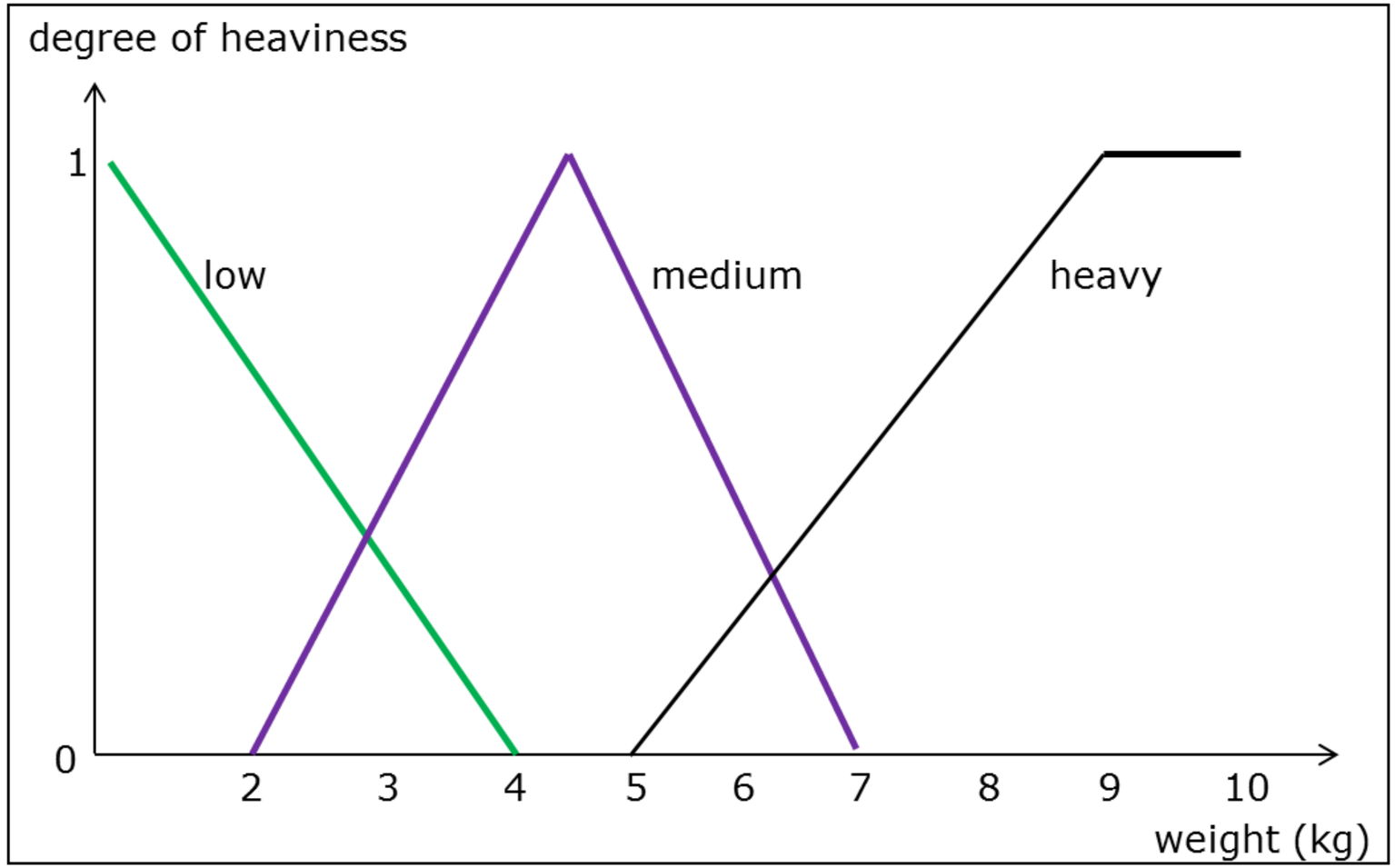


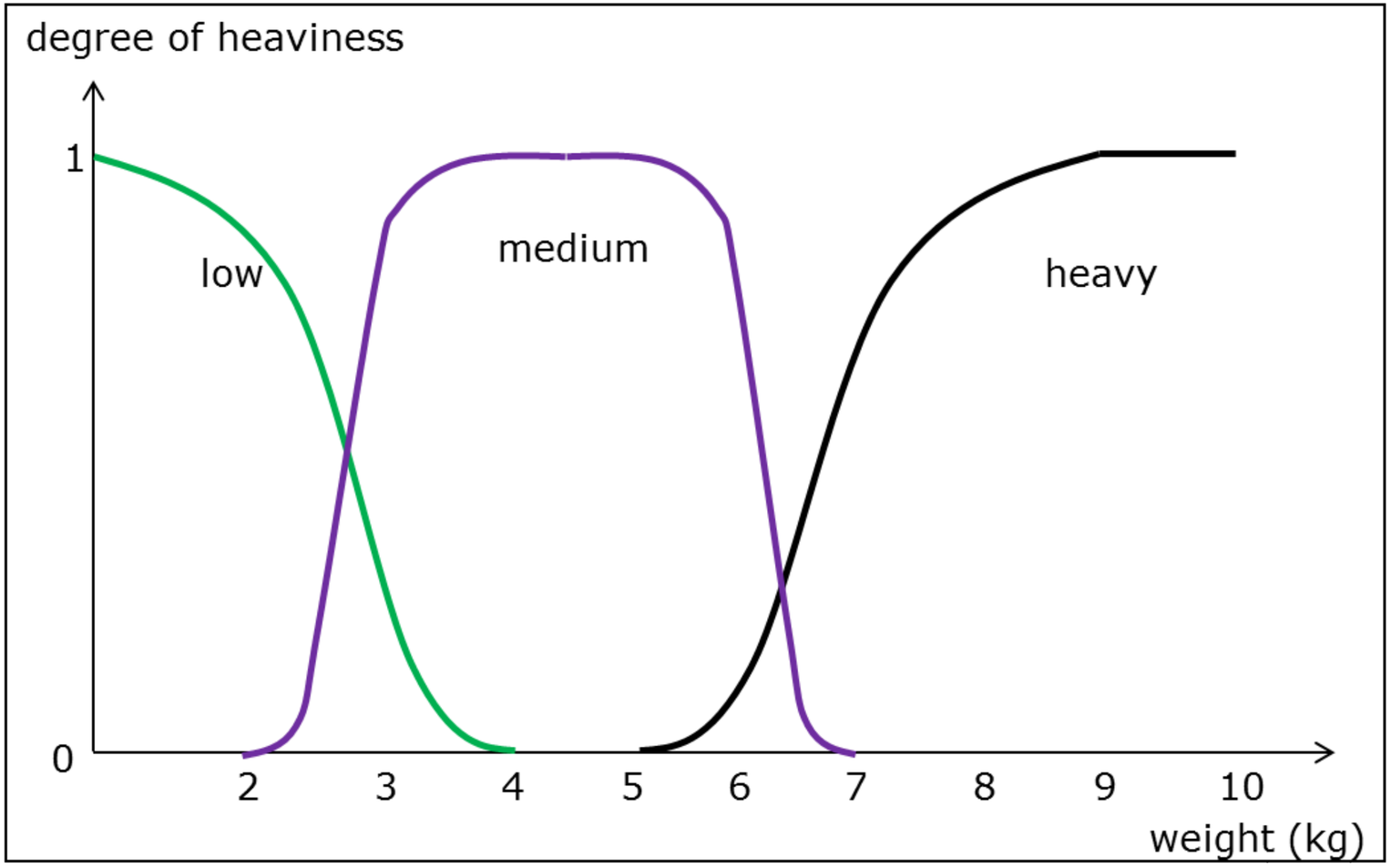
EXERCISE

Alternative Membership Function

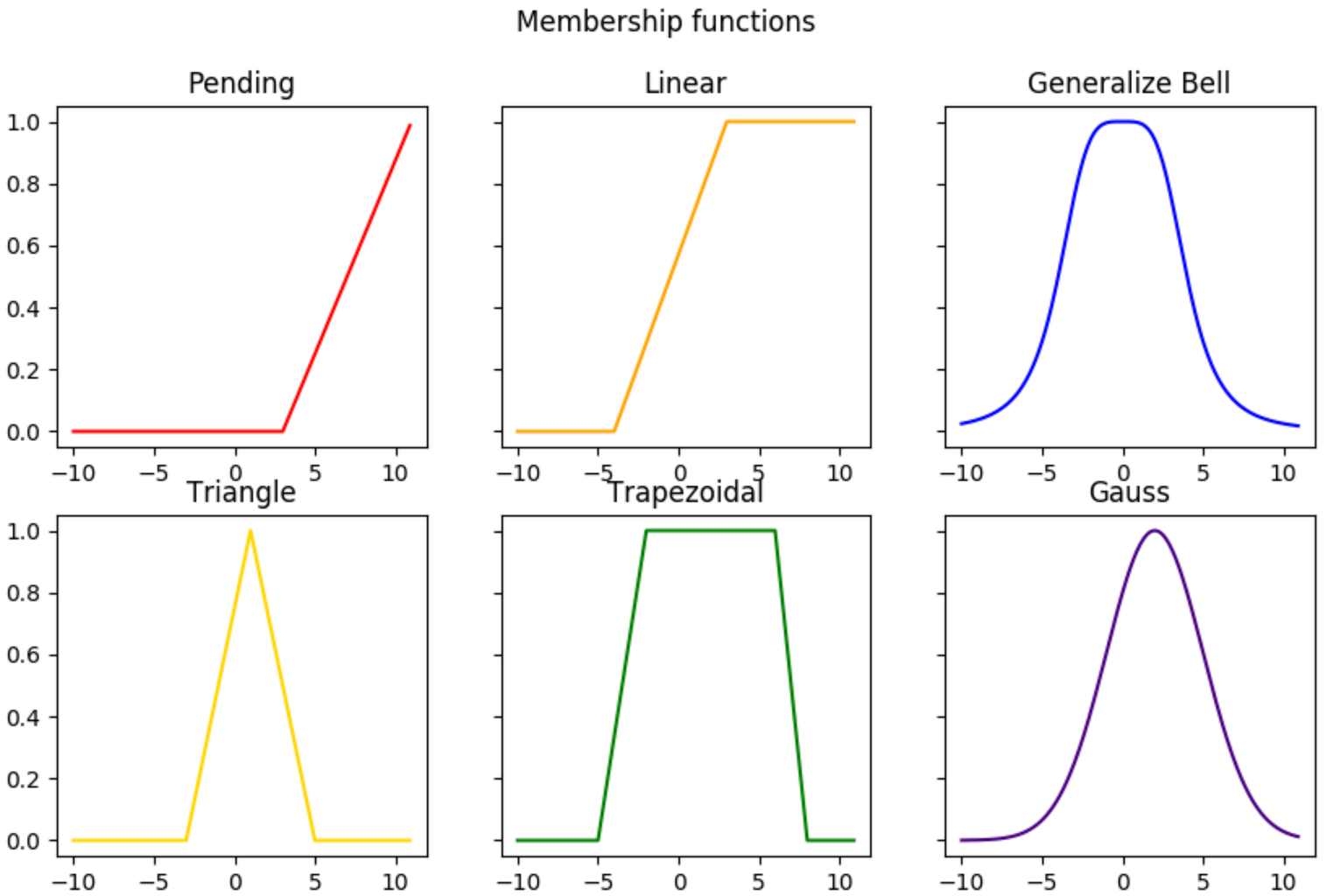
low(x) =
{ 0, if weight(x) >=3,
f(weight(x)) if 0.1 < weight(x)< 3,
1, if weight(x) <= 0}

medium(x) =
{ 0, if weight(x) <= or weight(x) >= 6,
f(weight(x)) if 3 < weight(x)< 6,
1, if weight(x) = 4.5}

heavy(x) =
{ 0, if weight(x) <= 6,
f(weight(x)) if 6 < weight(x)< 9,
1, if weight(x) >= 9}



TYPES OF MEMBERSHIP FUNCTIONS



FUZZY RULE

A fuzzy rule can be defined as a conditional statement in the form:

IF x is A
THEN y is B

Linguistic values

Linguistic variables

Example:

IF Weight is Heavy THEN Water Level is High

CLASSIC VS FUZZY RULES

A classic IF-THEN rule uses binary logic, for example,

Rule: 1		Rule: 2	
IF	speed is > 100	IF	speed is < 40
THEN	stopping_distance is long	THEN	stopping_distance is short

We can also represent the stopping distance rules in a fuzzy form:

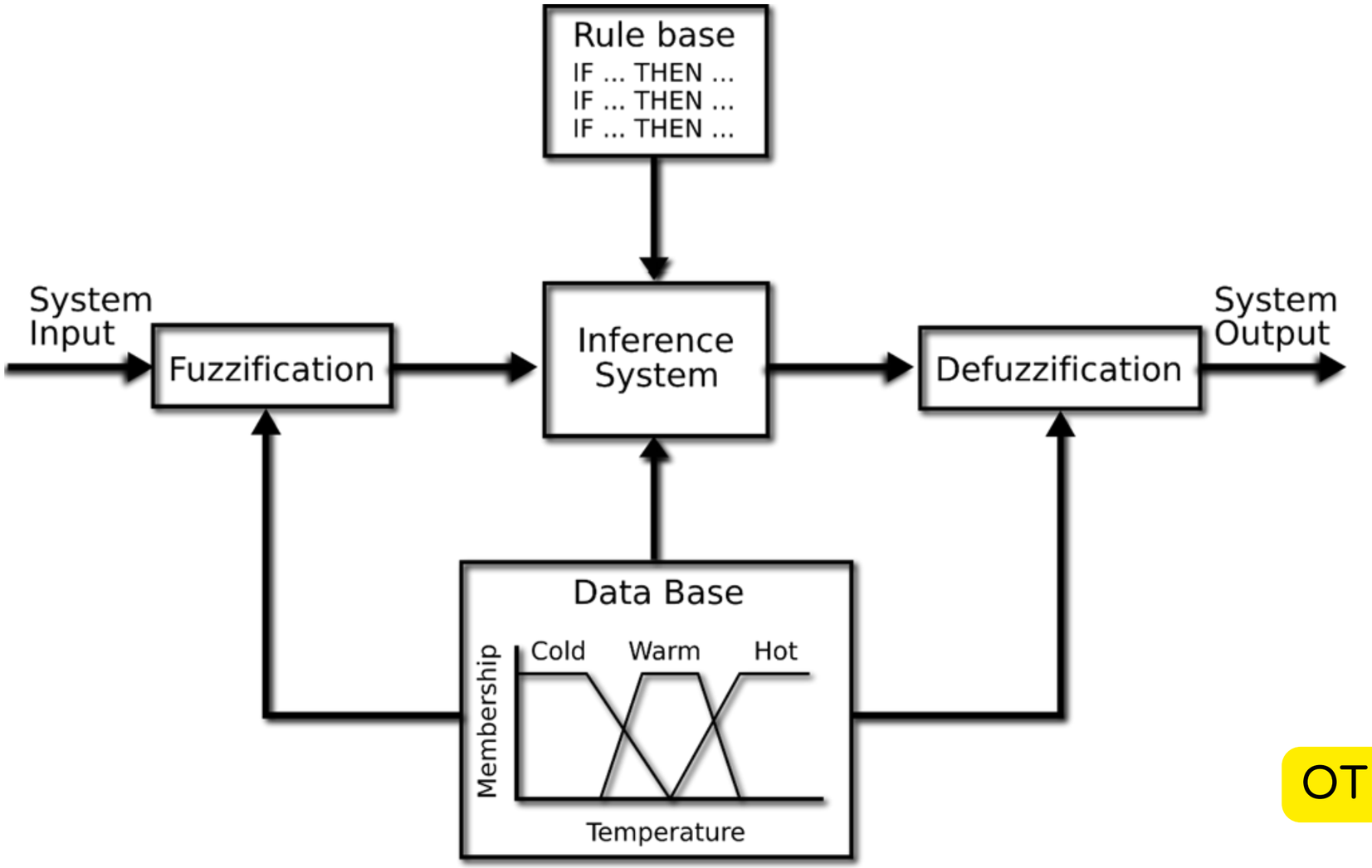
Rule: 1		Rule: 2	
IF	speed is fast	IF	speed is slow
THEN	stopping_distance is long	THEN	stopping_distance is short

In fuzzy rules, the linguistic variable speed also has the range (the universe of discourse) between 0 and 220 km/h, but this range includes fuzzy sets, such as slow, medium and fast.

The universe of discourse of the linguistic variable stopping_distance can be between 0 and 300 m and may include such fuzzy sets as short, medium and long.

FUZZY INFERENCE SYSTEM

Mamdani

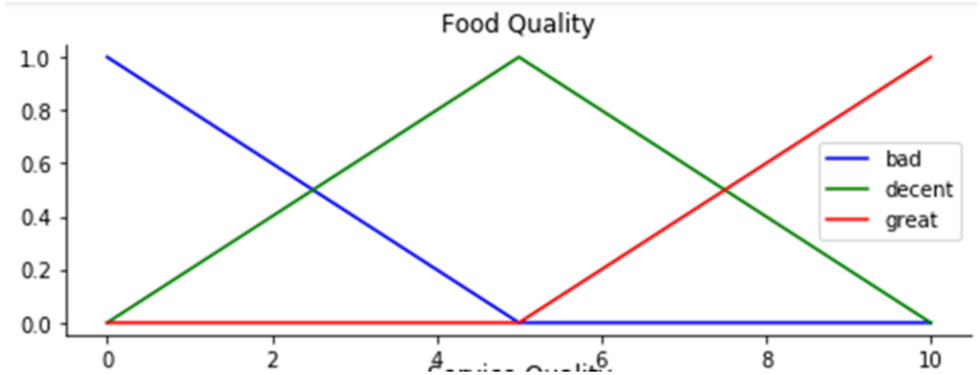


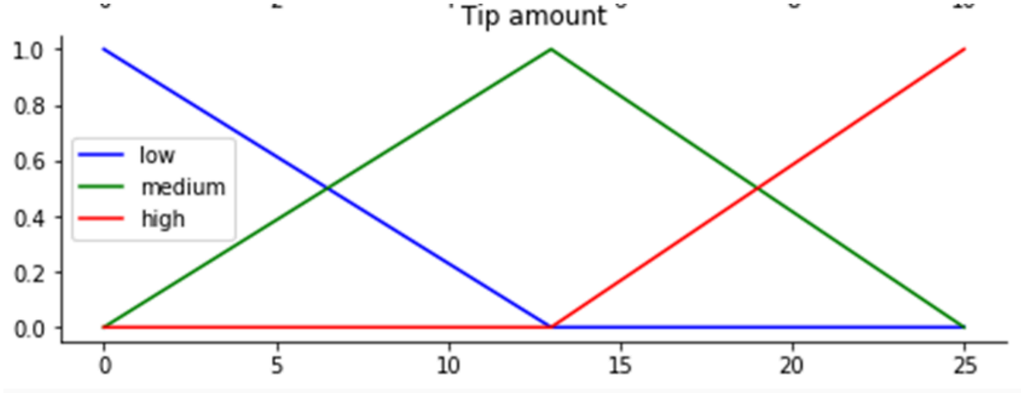
OTHER FUZZY MODEL:

SUGENO

EXAMPLE (MAMDANI-STYLE)

1. If the food is bad OR the service is poor, then the tip will be low
2. If the service is acceptable, then the tip will be medium
3. If the food is great OR the service is amazing, then the tip will be high.





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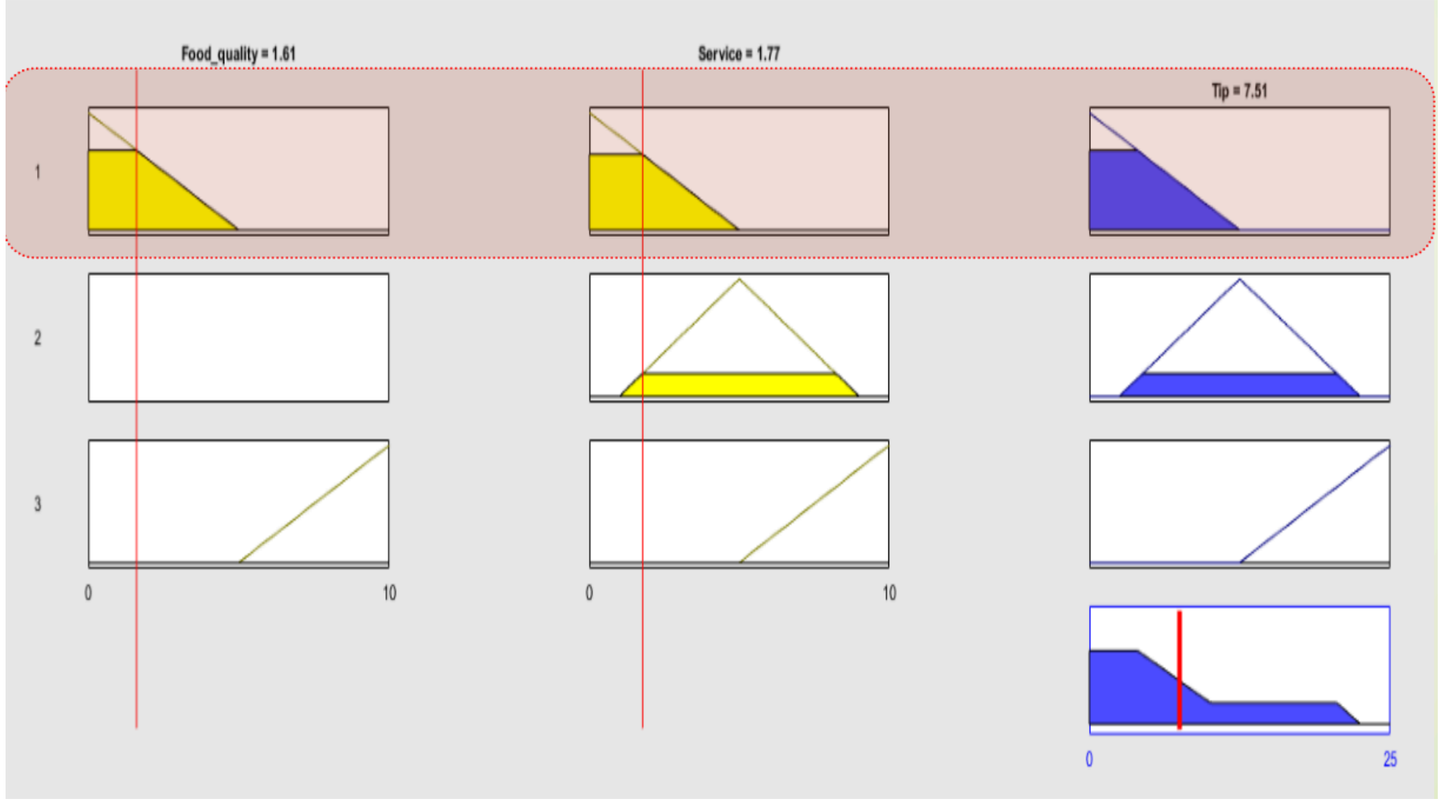

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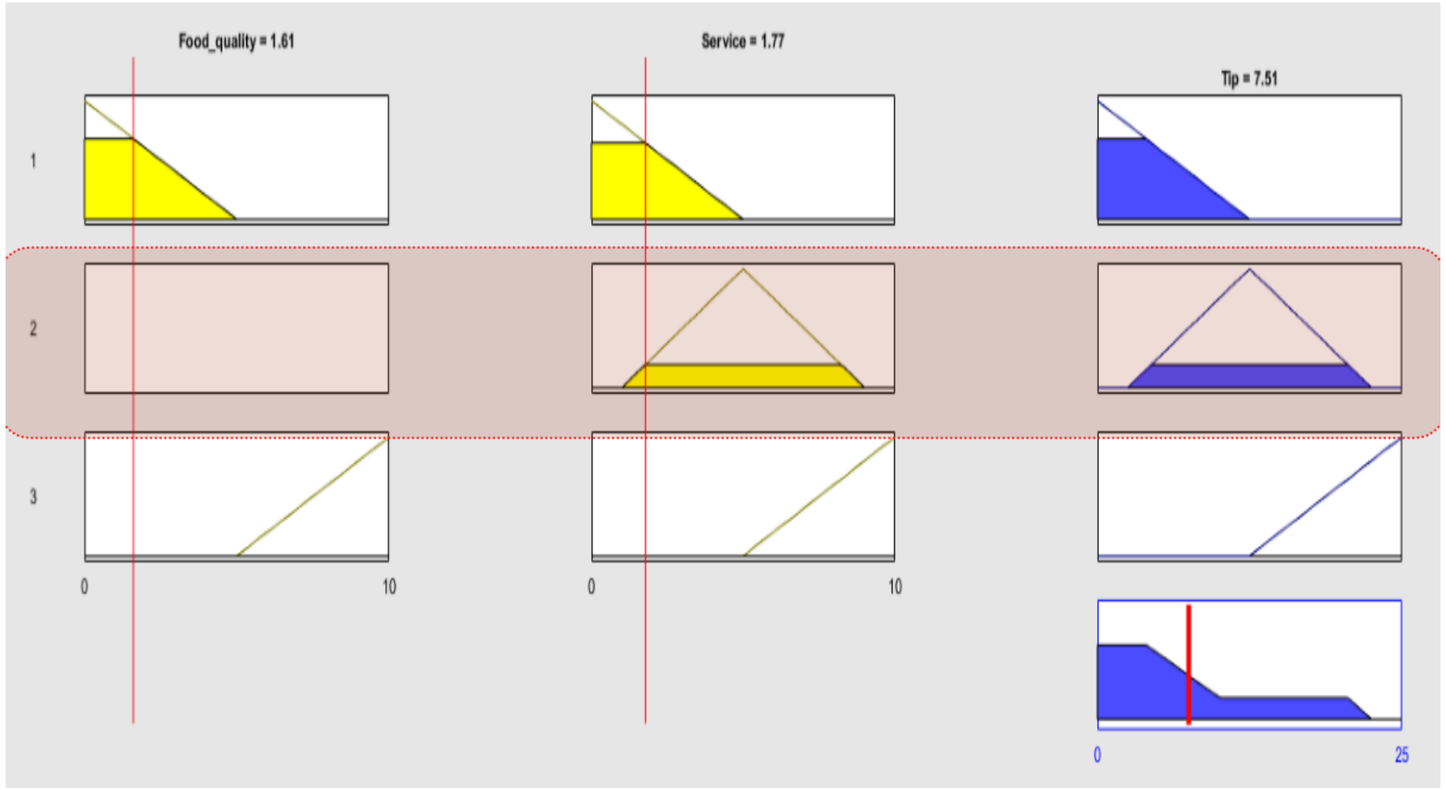

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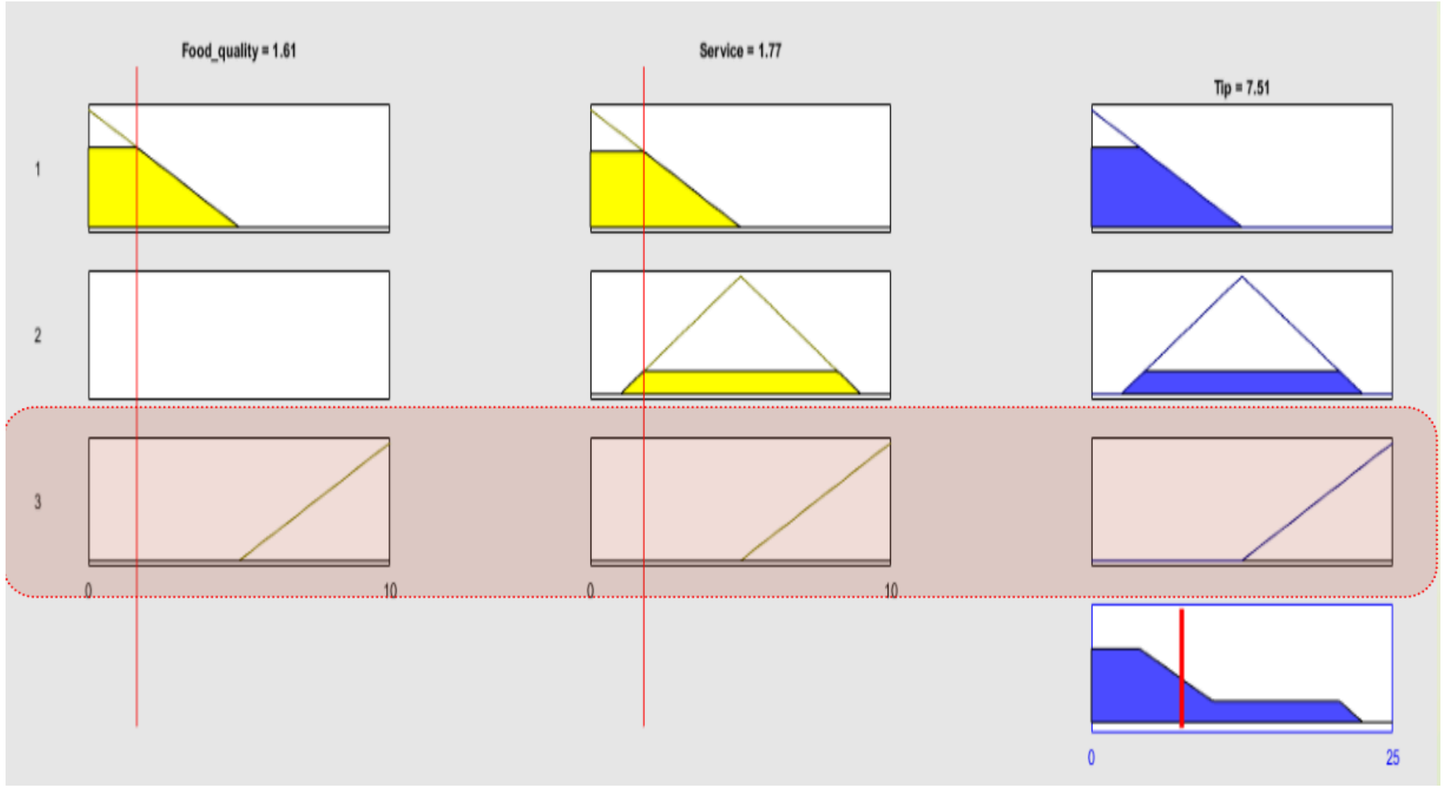

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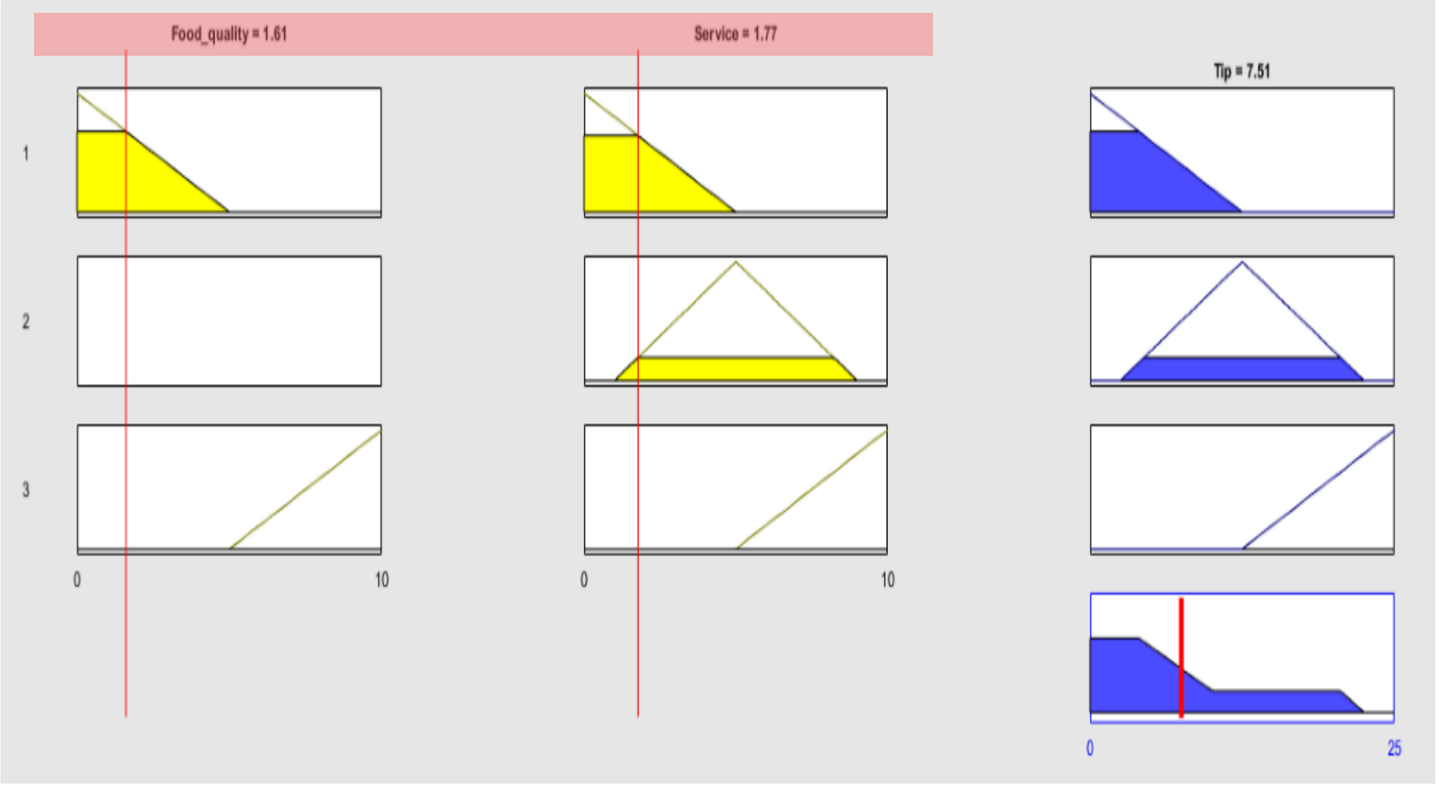

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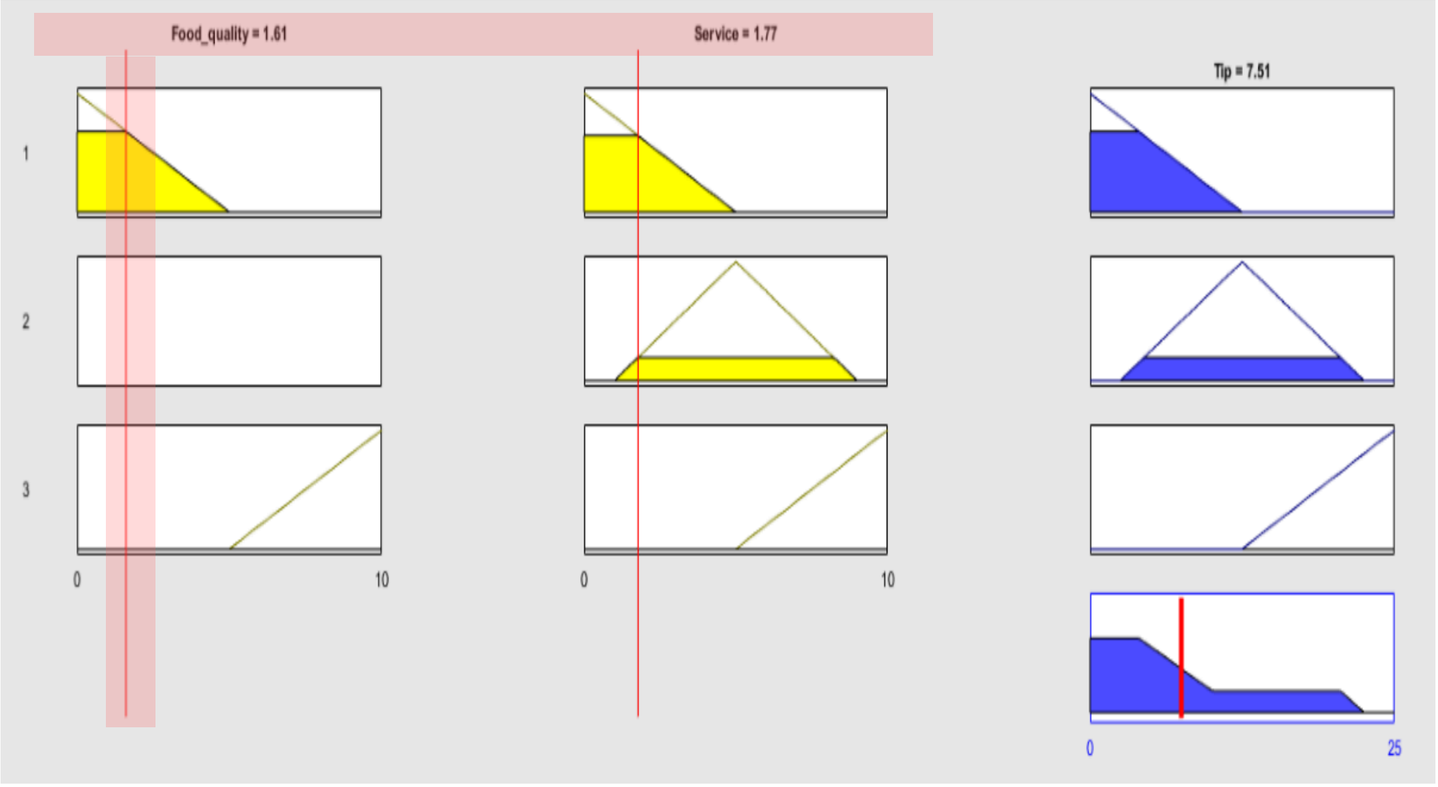

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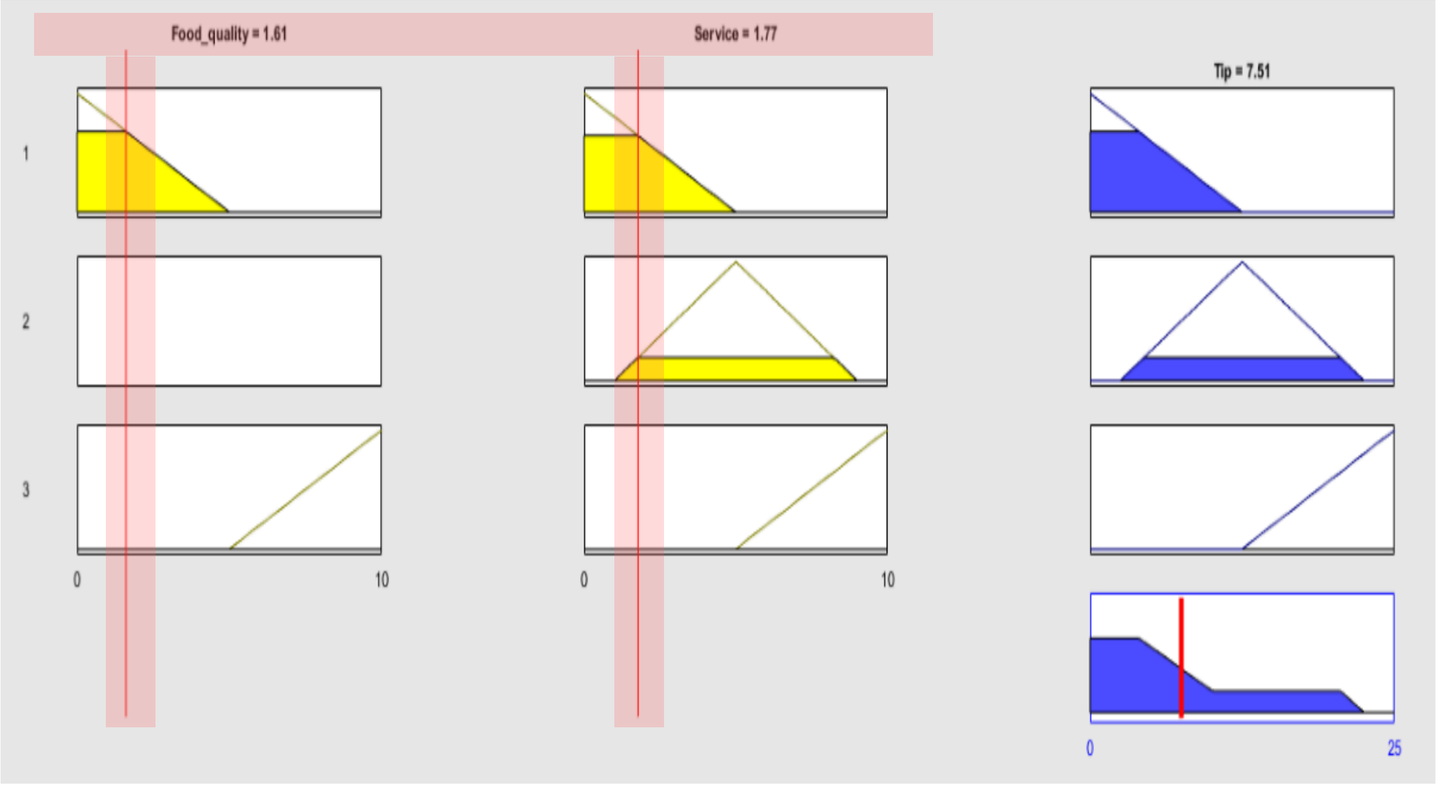

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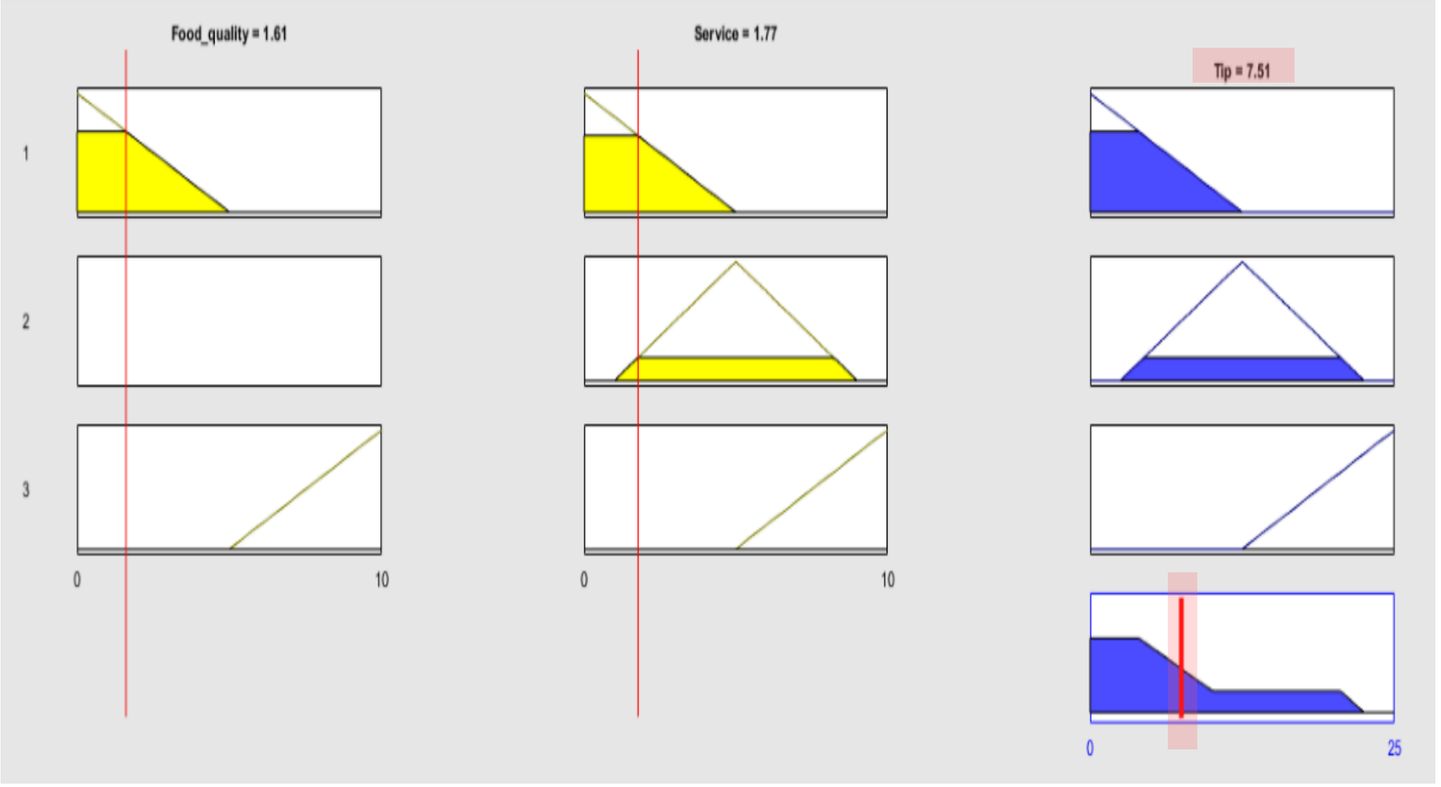

centre of gravity (COG)

$$COG = \frac{\int_a^b \mu_A(x)\, x\, dx}{\int_a^b \mu_A(x)\, dx}$$

other methods:

1. weighted average
2. bisector
3. mean of maximum
4. smallest of maximum

etc

EXAMPLE 2

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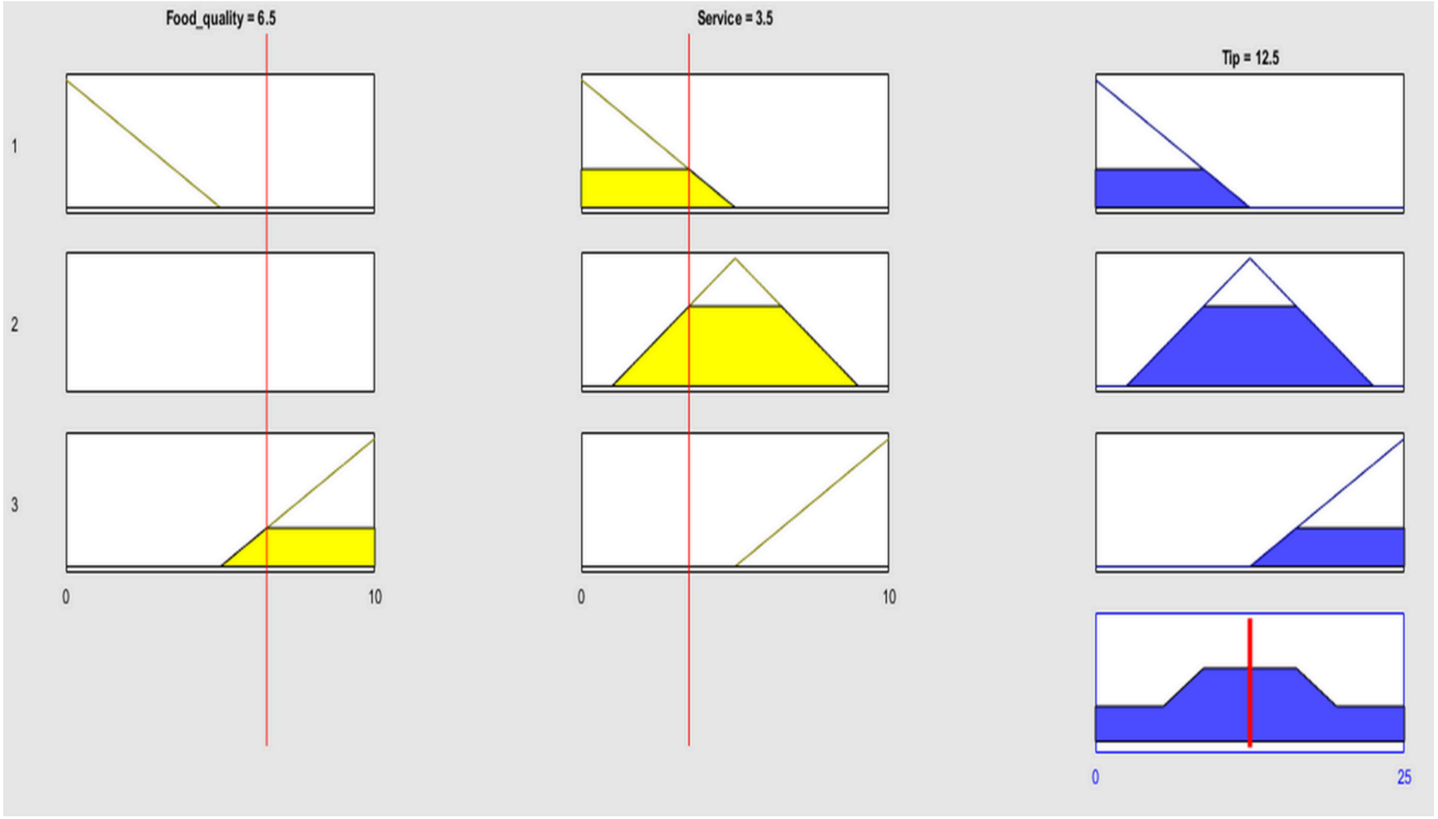

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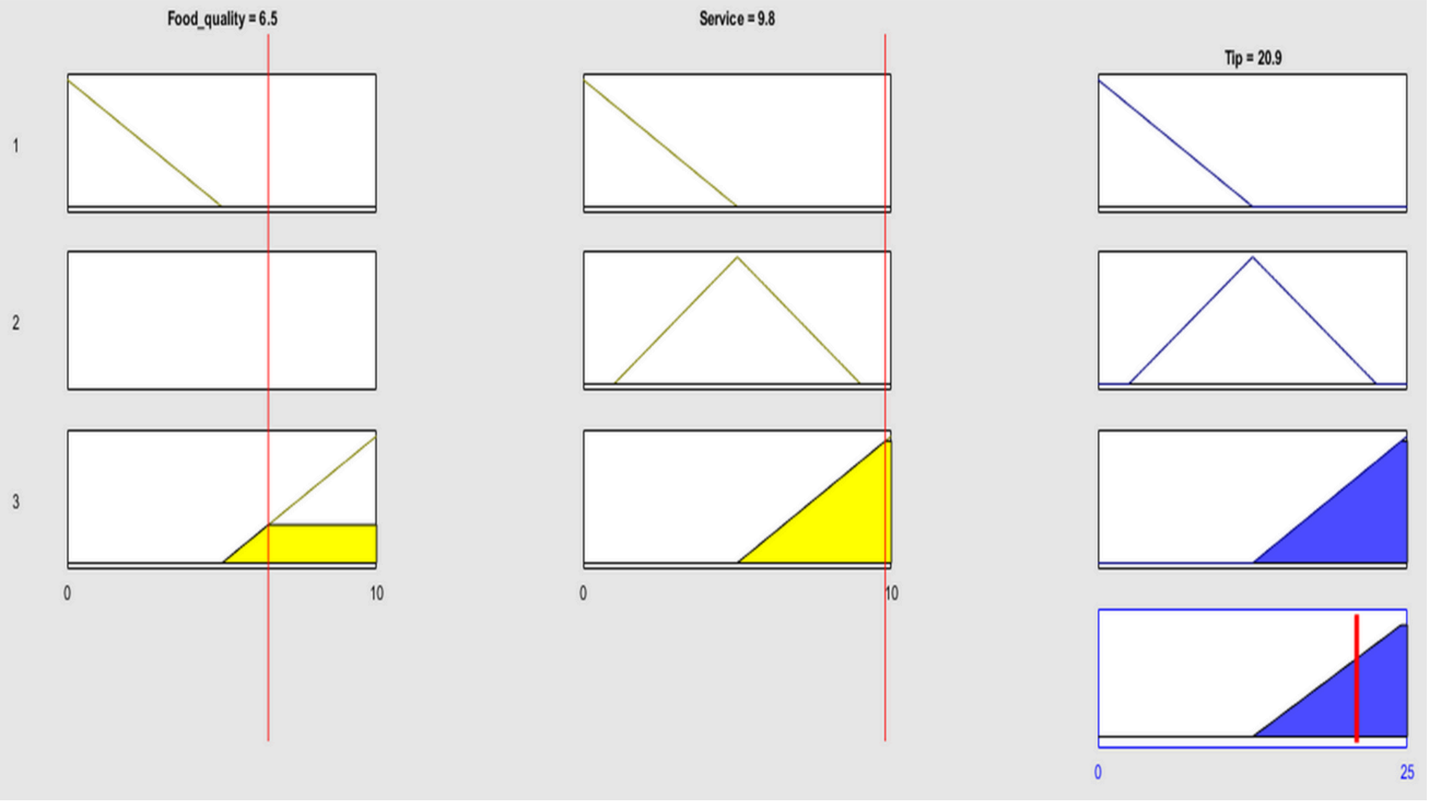

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etc

THE END

NEXT LECTURE

Modeling and Simulation