The Artificial Intelligence Toolbox
Part II – CS26210

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Using Qwizdom QVR

On any web-enabled device go to:

http://qvr.qwizdom.com

Select **I have a Session Key**

Enter the code **Q5VN94**

If you aren't already using AU Eduroam wireless have a look at
http://www.inf.aber.ac.uk/advisory/faq/253/

Thursday 7th February 2013

- Set Theory
- Fuzzy Logic and Fuzzy Sets (graphical and vector) representation
- Crisp Sets
- Membership values and membership functions

Friday 8th February 2013

- Hedges
- Fuzzy Operators
- Fuzzy Inference
  - Fuzzification of input
  - Rules
  - Defuzzification

Hedges

Hedges modify mathematically an existing fuzzy set to account for adverbs (e.g., very, slightly, somewhat, etc.)

Concentration (very)

Construct the fuzzy set “very tall persons” from the fuzzy set “tall persons”

$$f_{con(A)}(x_i) = (f_A(x_i))^2$$

Dilation (more or less)

Construct the fuzzy set “more or less medium persons” from the fuzzy set “medium persons”

$$f_{dil(A)}(x_i) = (f_A(x_i))^{0.5}$$

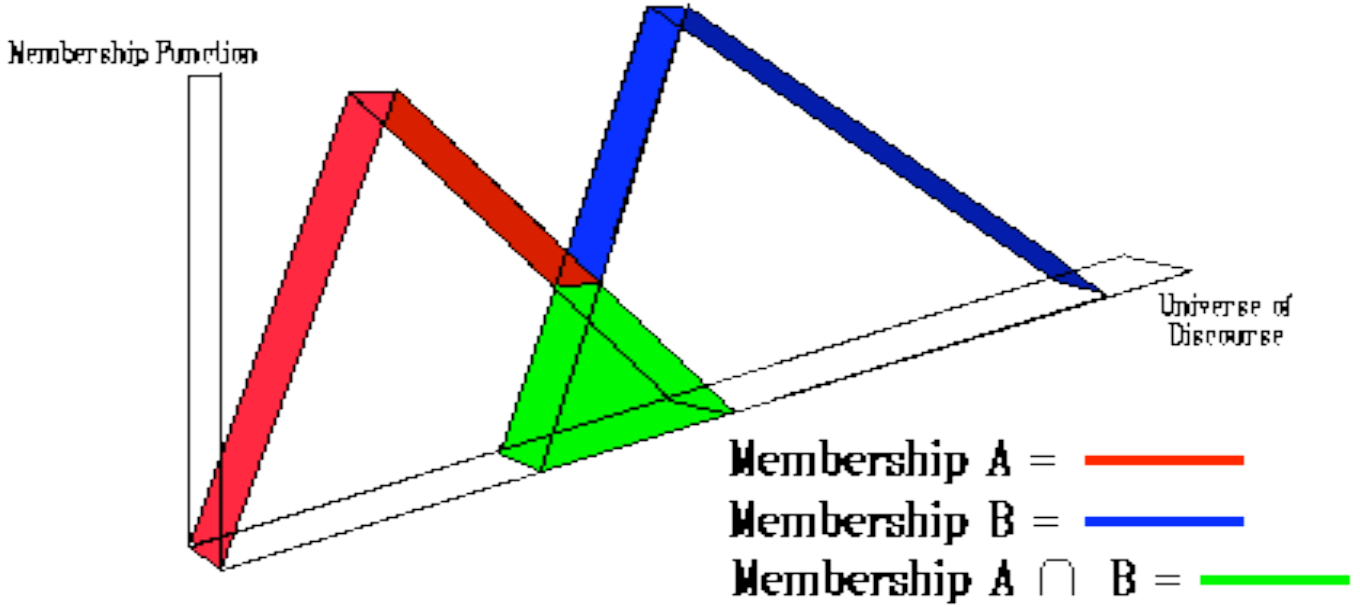
See also **Intesification (Indeed)** and **Power (very very)**

Interaction (A∩B) - MIN

In fuzzy sets, an element may be partially in both of the sets A and B.

To account for this, the fuzzy operation for creating the **INTERSECTION** of two fuzzy sets A and B defined on X is given as

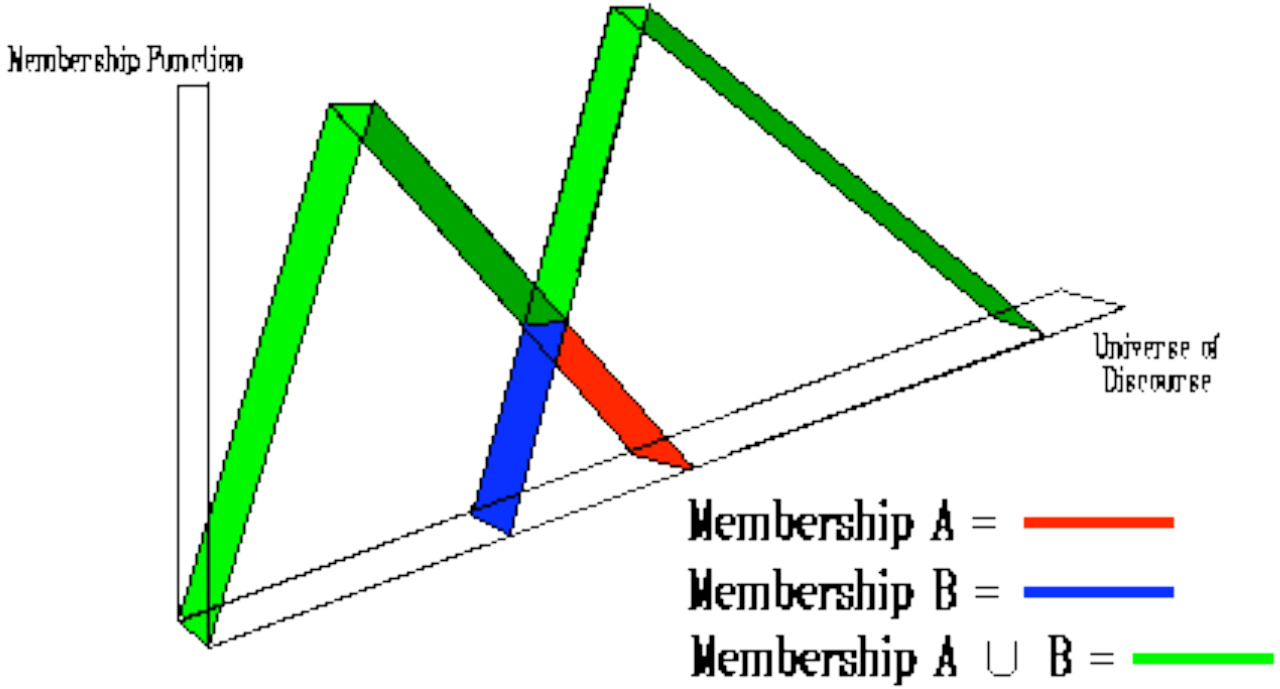
$$f_{A \cap B}(x_i) = \min (f_A(x_i), f_B(x_i))$$



Union (A ∪ B) - MAX

In fuzzy sets, an element may be partially in both of the sets A and B. To account for this, the fuzzy operation for creating the **UNION** of two fuzzy sets A and B defined on X is given as

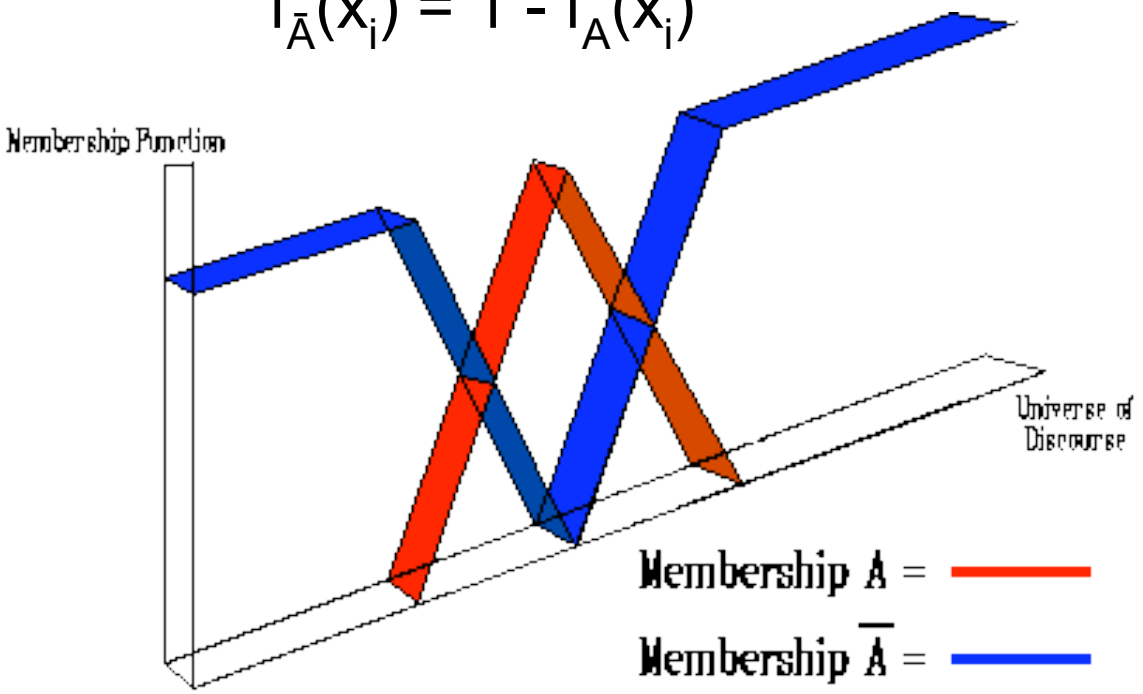
$$f_{A \cup B}(x_i) = \max\left(f_A(x_i), f_B(x_i)\right)$$



Complementation

Given the fuzzy set A. we can find its complement Ā by the following operation

$$f_{\bar{A}}(x_i) = 1 - f_A(x_i)$$



True or False

IF

$A = (0.3/1, 0.4/2, 0.5/3);$

$B = (0.2/2, 0.3/3, 0.4/4, 0.5/5);$

THAN

$A \cup B = (0.3/1, 0.4/2, 0.5/3, 0.4/4, 0.5/5)$

True or False

IF

$A = (0.3/1, 0.4/2, 0.5/3);$

$B = (0.2/2, 0.3/3, 0.4/4, 0.5/5);$

THAN

$A \cap B = (0.0/1, 0.2/2, 0.3/3, 0.0/4, 0.0/5)$

True or False

IF

A = (0.3/1, 0.4/2, 0.5/3);

B = (0.2/2, 0.3/3, 0.4/4, 0.5/5);

THAN

Very A = (0.09/1, 0.16/2, 0.25/3)

Very B = (0.04/2, 0.09/3, 0.16/4, 0.25/5)

Fuzzy Inference

Drawing conclusions from premises.

Examples:

IF A THEN B
IF A and B THEN C
IF A or B THEN C

… the difficult part is that input and output values are members of fuzzy (rather than classic) sets.

Fuzzy Inference

IF X is A THEN Y is B

IF Temperature is normal
THEN Velocity is medium

Temperature and Velocity are the linguistic variables normal and medium are the fussy sets (or linguistic values)

Fuzzy Inference

IF Temperature is normal THEN Velocity is medium

Temperature

$$f_{\text{normal}}(x) = \begin{cases} 0 & \text{if } x < 10 \\ (x-10)/5 & \text{if } 10 \le x \le 15 \\ 1 & \text{if } 15 < x < 20 \\ -(x-25)/5 & \text{if } 20 \le x \le 25 \end{cases}$$

$$f_{hot}(x) = \begin{cases} (x-15)/10 & \text{if } 15 \le x \le 25 \\ 1 & \text{if } 25 < x \end{cases}$$

Velocity

$$f_{medium}(x) = \begin{cases} (x-30)/10 & \text{if } 30 \le x \le 40 \\ -(x-50)/10 & \text{if } 40 < x \le 50 \end{cases}$$

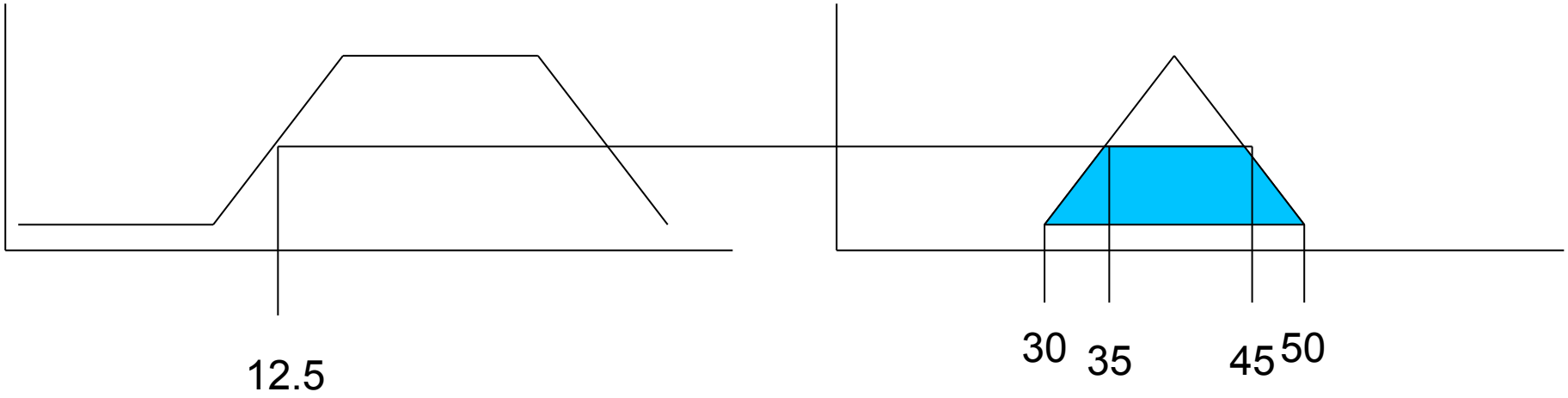
$$f_{fast}(x) = \begin{cases} (x-40)/10 & \text{if } 40 \le x \le 50 \\ 1 & \text{if } 50 < x \le 60 \end{cases}$$

Fuzzy Inference

IF Temperature is normal THEN Velocity is medium

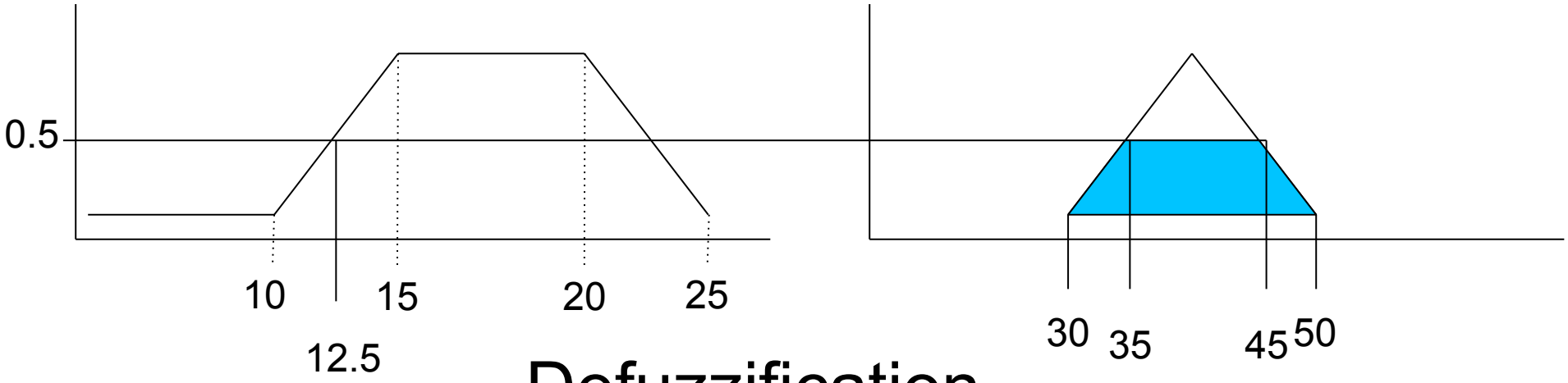
If Temperature is 12.5 THEN Velocity is ?

$$f_{\text{normal}}(12.5) = 0.5$$



Fuzzy Inference

IF Temperature is 12.5 THEN Velocity is ?



Defuzzification

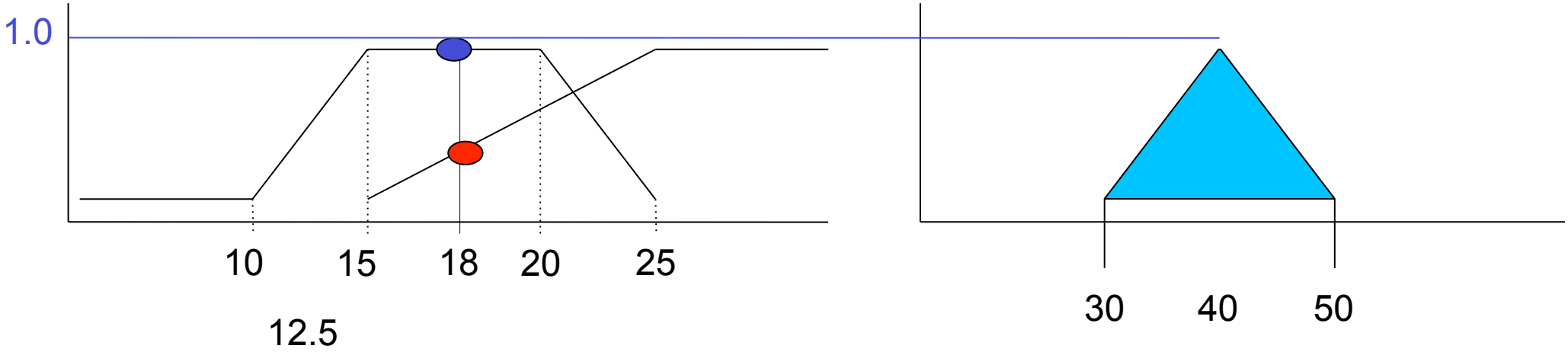
$$Velocity = \sum_{1}^{n} p_i * f_{medium}(p_i) \Big/ \sum_{1}^{n} f_{medium}(p_i)$$

$$\frac{30*0 + 35*0.5 + 45*0.5 + 50*0}{0 + 0.5 + 0.5 + 0} = 40$$

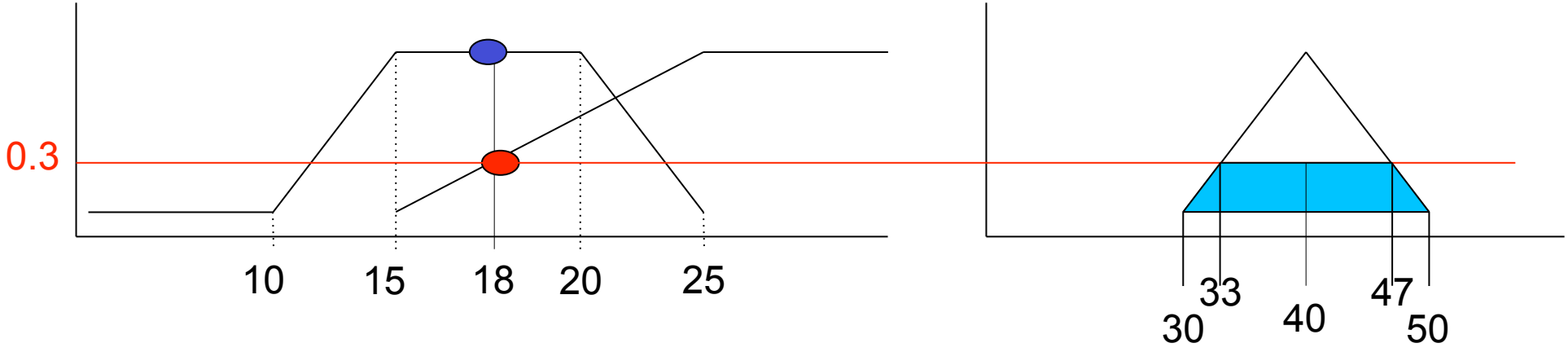
Fuzzy Inference

If Temperature is 18 THEN Velocity is ?

IF Temperature is normal or hot THEN Velocity is medium



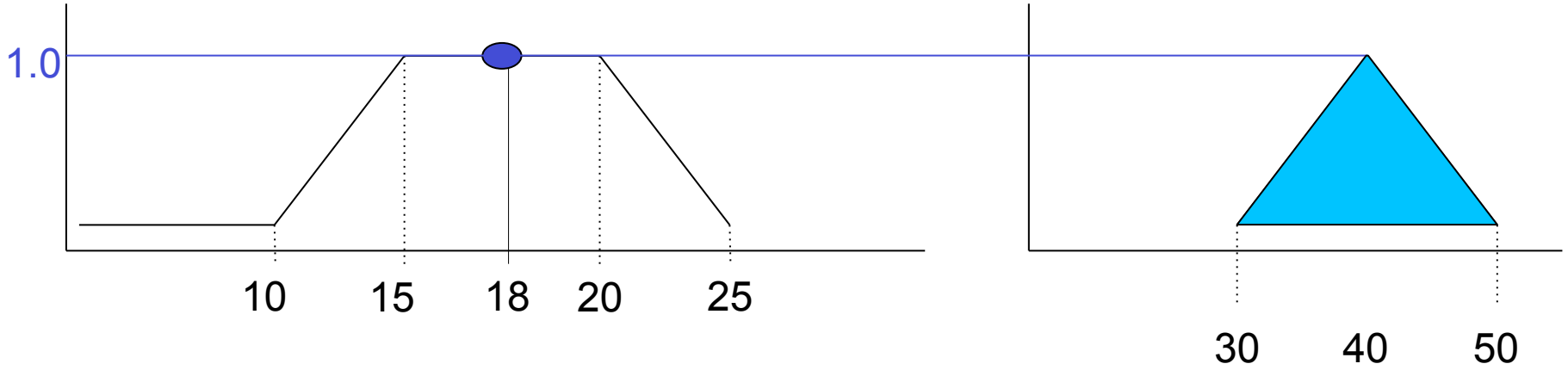
IF Temperature is normal and hot THEN Velocity is medium



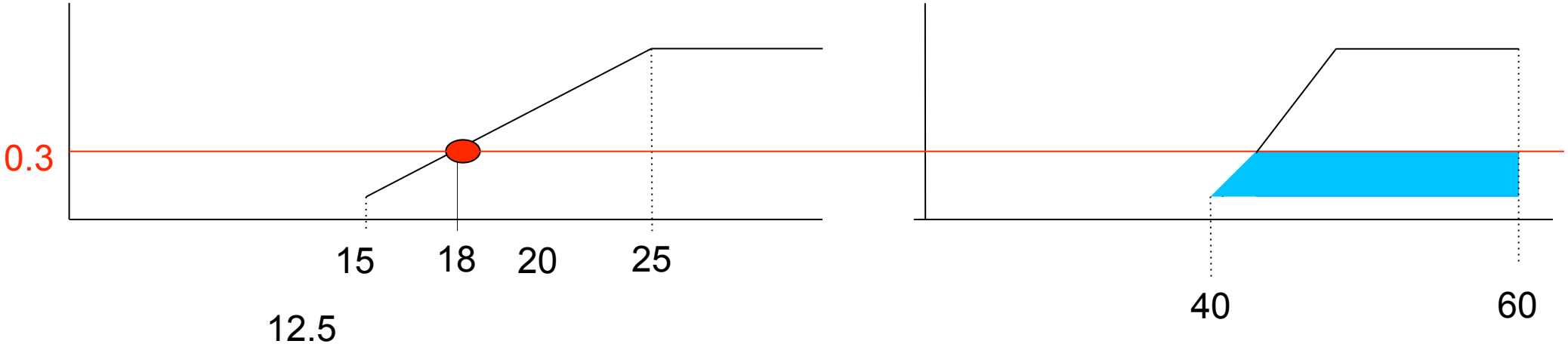
Fuzzy Inference

If Temperature is 18 THEN Velocity is ?

RULE 1: IF Temperature is normal THEN Velocity is medium



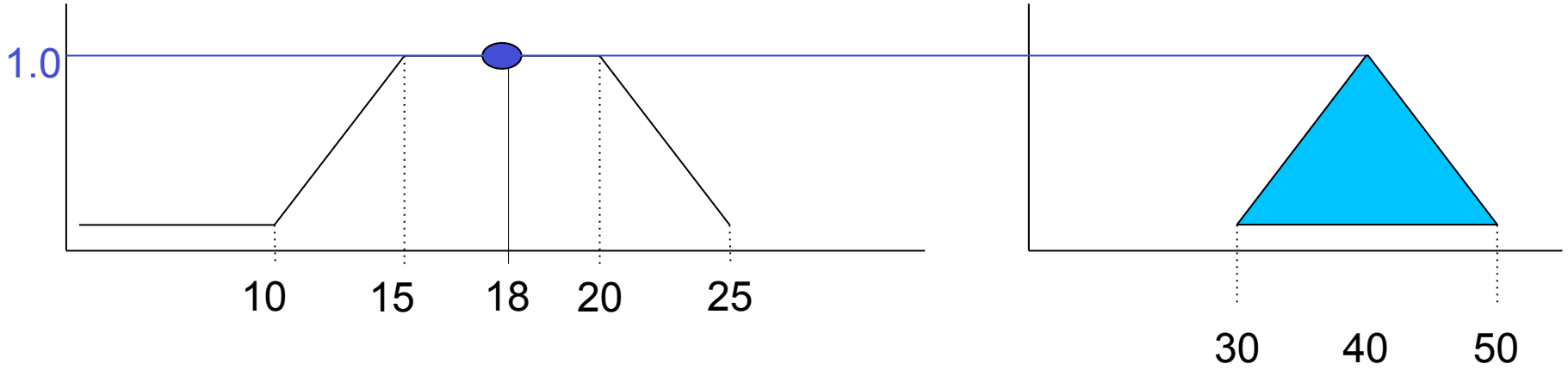
RULE 2: If Temperature is hot THEN Velocity is fast



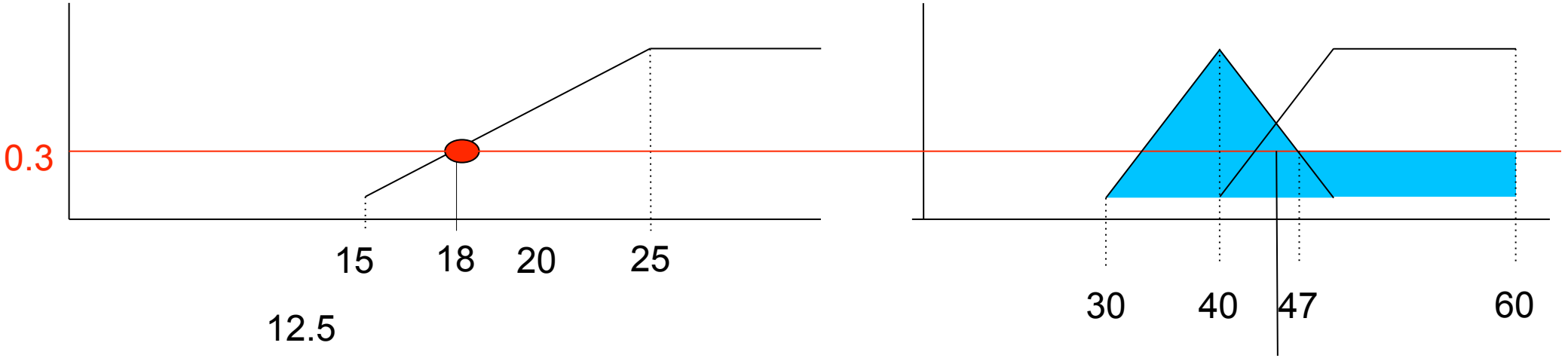
Fuzzy Inference

If Temperature is 18 THEN Velocity is ?

RULE 1: IF Temperature is normal THEN Velocity is medium



RULE 2: If Temperature is hot THEN Velocity is fast



Velocity is 45.06

Defuzzification (fuzzy centroid method)

Defuzzification is about moving from a fuzzy set to a crisp value.

Fuzzy set

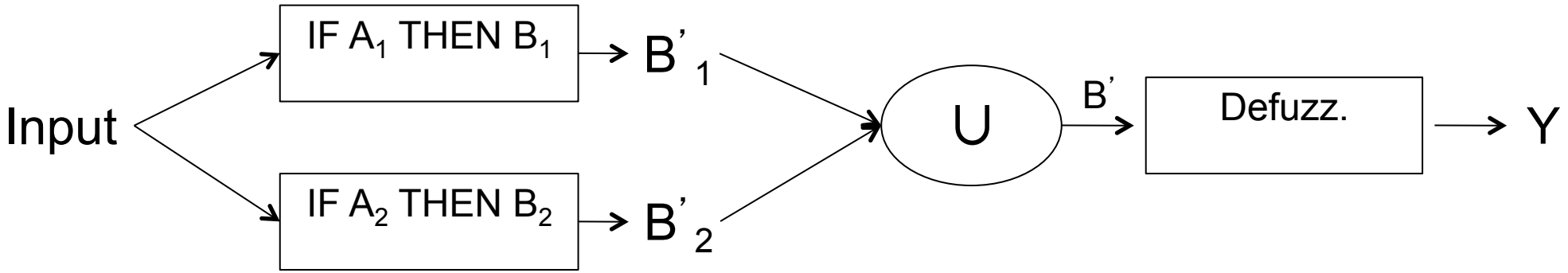
$B^1 = (0/10, 0.5/20, 0.5/30, 0.5/40, 0/50)$

$B^1 = (b^1_1/y_1, b^1_2/y_2, b^1_3/y_3, b^1_4/y_4, b^1_5/y_5)$

Crisp value

$$\mathbf{Z = (\sum y_j b^1_j)/(\sum b^1_j)}$$

Multiple fuzzy rules



IF	temperature is normal (A_1)
OR	pressure is low (B_1)
THEN	velocity is medium (C_1)
IF	temperature is normal (A_2)
AND	pressure is normal (B_2)
THEN	velocity is low (C_2)