The Artificial Intelligence Toolbox
Part II – CS26210

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Using Qwizdom QVR

On any web-enabled device go to:

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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/

Week 1

7/02 Set Theory, Fuzzy Logic (319)
8/02 Fuzzy Logic (B20) - Hand-out Assignment 1

Week 2

14/02 Fuzzy Logic - Further Exercises (319)
15/02 Theory of Probability (B20)

Week 3

21/02 Conditional Probability (319)
22/02 Conditional Probability (B20) - Hand-in Assignment 1 (Blackboard)

Week 4

~~28/02 In Class Test (319) (Set Theory, Prior and Conditional Probability)~~
~~1/03 Bayesian Networks (B20)~~

28/02 Bayesian Networks (319)
1/03 In Class Test (B20)

Week 5

7/03 Bayesian networks (319) - Hand-out Assignment 2
8/03 Discussion, further exercises (B20)

22/03 Hand-in Assignment 2 (Blackboard)

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

Thursday 14th February, 2013

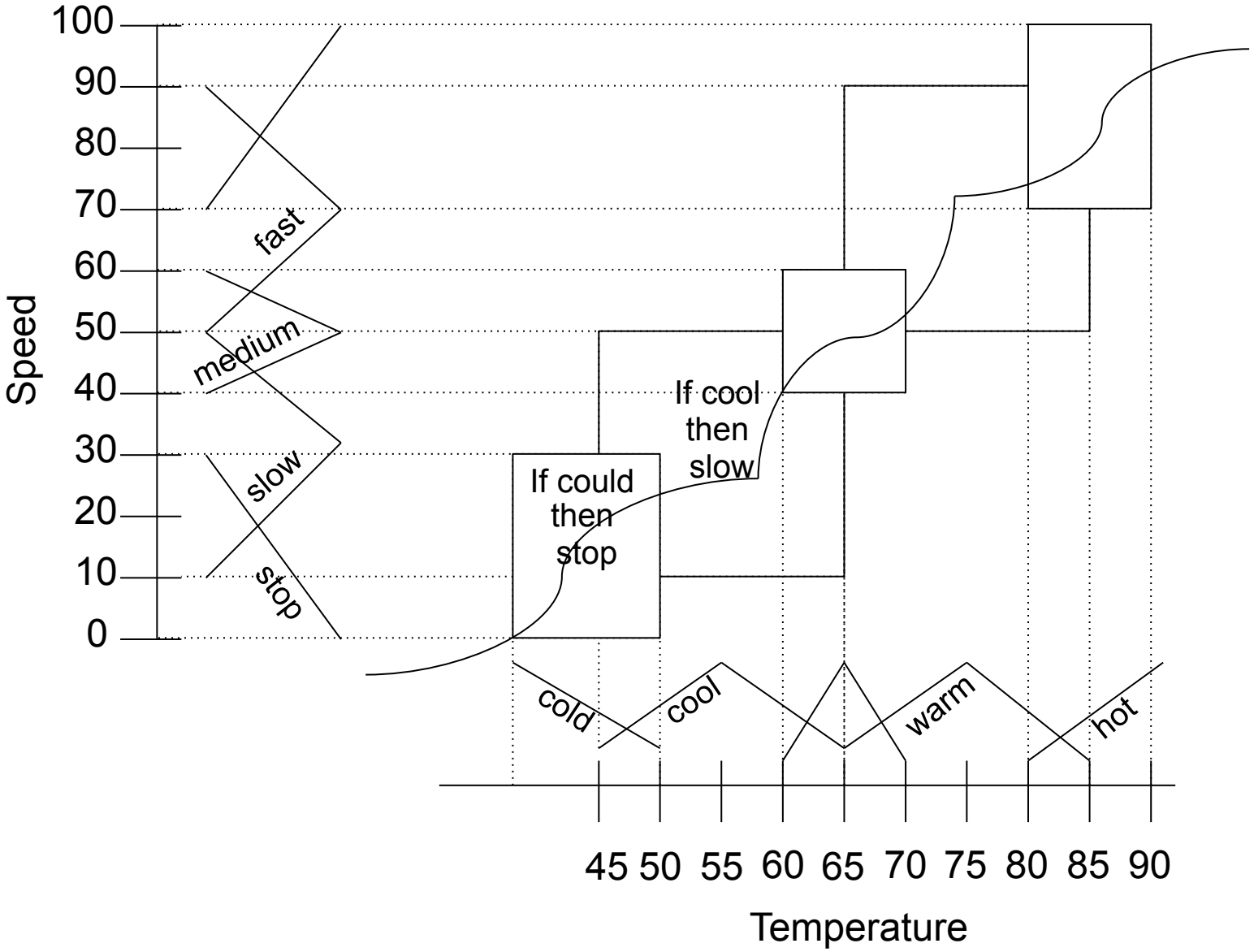
Today we do two exercises on Fuzzy Systems

- Assignment 1
  - PDF only.
  - Please, your name only on page 1 of the assignment, or no name at all.
  - Questions?

Fuzzy logic is used in the operation or programming of:

- Air conditioners
- Automobile and such vehicle subsystems as automatic transmissions, ABS, etc.
- Tokyo monorail
- Cameras
- Digital image processing, such as edge detection
- Elevators
- Some microcontrollers and microprocessors (e.g. Freescale 68HC12)
- Hydrometeor classification algorithms for polarimetric weather radar
- Language filters on message boards and chat rooms for filtering out offensive text
- The Massive engine used in the *Lord of the Rings films, which allowed large-scale* armies to enact random yet orderly movements
- Mineral Deposit estimation
- Pattern recognition in Remote Sensing
- Video game artificial intelligence
- Home appliances (e.g. washing machine, dishwashers, rice cookers)

Non-linearity



Building a Fuzzy Logic Expert System

- Define the problem
- Define the linguistic variables
- Define the fuzzy sets (or linguistic values)
- Define the fuzzy rules (IF …AND/OR … THEN)
- Building the system
- Test and Tune the system

To remember

Intersection (AND) - $f_{A \wedge B}(x_i) = \min (f_A(x_i), f_B(x_i))$
Union (OR) - $f_{A \vee B}(x_i) = \max (f_A(x_i), f_B(x_i))$
Complementation (NOT) - $f_A(x_i) = 1 - f_A(x_i)$

Defuzzification
Crisp value $\mathbf{Z = (\sum y_j b'_j)/(\sum b'_j)}$

Exercise 1

Compute the degree of risk in issuing a credit card to a customer by a bank:

Rule 1: IF Income is low, THEN Risk is high

Rule 2: IF Income is high, THEN Risk is low

Income and Risk = Linguistic Variables

Low and high = Linguistic values

f_{low}(income) = {1/0, 1/5, 1/10, (2/3)/15, (1/3)/20, 0/25, 0/30, 0/35, 0/40};

f_{high}(income) = {0/0, 0/5, 0/10, 0/15, (1/3)/20, (2/3)/25, 1/30, 1/35, 1/40};

f_{low}(risk) = {1/0, 1/10, 1/20, 1/30 , (2/3)/40, (1/3)/50 , 0/60, 0/70 ,0/80, 0/90, 0/100};

f_{high}(risk) = {0/0, 0/10, 0/20, 0/30, 0.25/40, 0.5/50 , 0.75/60, 1/70 ,1/80, 1/90, 1/100};

Exercise 1

First, draw the membership functions for each linguistic variable in both domains. Then, assuming a customer has an income of 22, answer the following questions:

- What is the membership value of an income 22 that belongs to both the fuzzy set low income and high income?

- What is the membership value of an income 22 that does not belong to the fuzzy set low income?

- What risk (%) will the bank take if it issues a credit card to the customer with an income of 22?

Exercise 1

The membership functions for each linguistic value in both linguistic domains

$$f_{low}(income)\begin{cases}1 & \text{if } 0 \le x \le 10 \\ -(x-25)/15 & \text{if } 10 < x \le 25 \\ 0 & \text{if } 25 < x \le 40\end{cases}$$

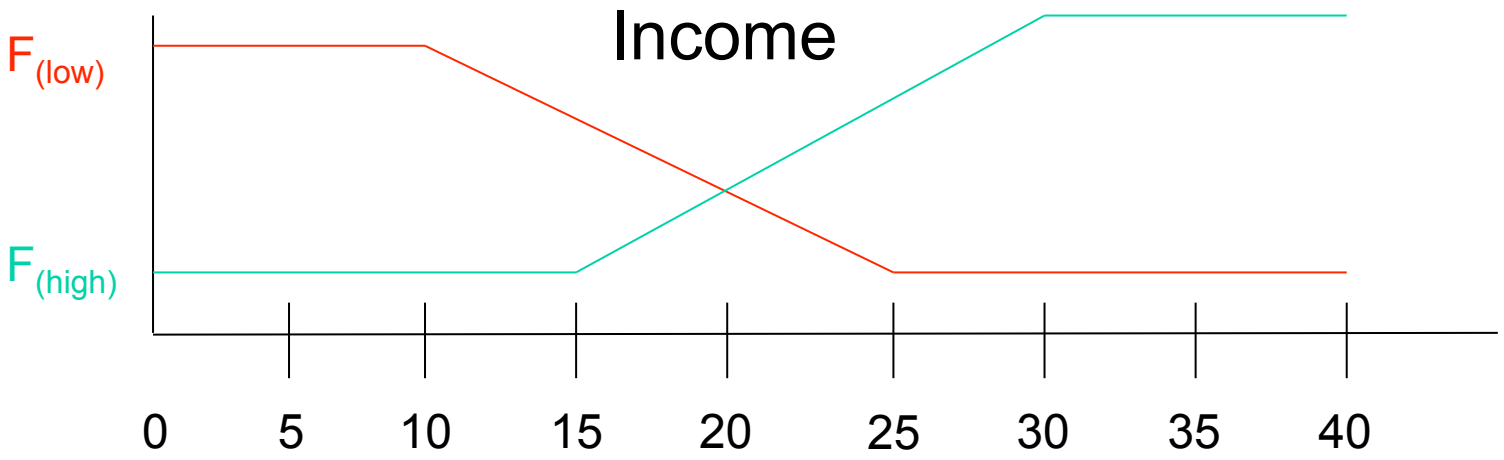
$$f_{high}(income)\begin{cases}0 & \text{if } 0 \le x \le 15 \\ (x-15)/15 & \text{if } 15 < x \le 30 \\ 1 & \text{if } 30 < x \le 40\end{cases}$$

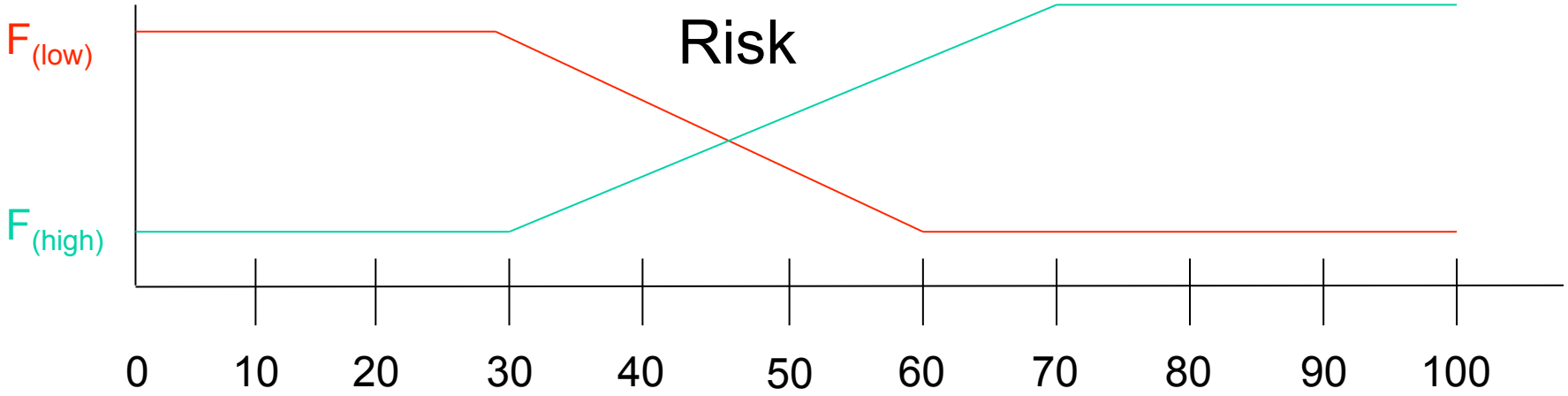
$$f_{low}(risk)\begin{cases}1 & \text{if } 0 \le x \le 30 \\ -(x-60)/30 & \text{if } 30 < x \le 60 \\ 0 & \text{if } 60 < x \le 100\end{cases}$$

$$f_{high}(risk)\begin{cases}0 & \text{if } 0 \le x \le 30 \\ (x-30)/40 & \text{if } 30 < x \le 70 \\ 1 & \text{if } 70 < x \le 100\end{cases}$$

Exercise 1

The membership functions for each linguistic value in both linguistic domains





Exercise 1

What is the membership value of an income 22k that belongs to both the fuzzy set low income and high income?

f_{low}(income) = {1/0, 1/5, 1/10, (2/3)/15, (1/3)/20, 0/25, 0/30, 0/35, 0/40};

f_{high}(income) = {0/0, 0/5, 0/10, 0/15, (1/3)/20, (2/3)/25, 1/30, 1/35, 1/40};

Intersection

$F_{low\text{-}income}(22k) \cap F_{high\text{-}income}(22k)$

$F_{low\text{-}income}(22k) = 0.2$

$F_{high\text{-}income}(22k) = 0.46$

$F_{low\text{-}income}(22k)$ AND $F_{high\text{-}income}(22k) = 0.2$

Exercise 1

What is the membership value of an income 22k that does not belong to the fuzzy set low income?

$f_{low}(income) = \{1/0, 1/5, 1/10, (2/3)/15, (1/3)/20, 0/25, 0/30, 0/35, 0/40\};$

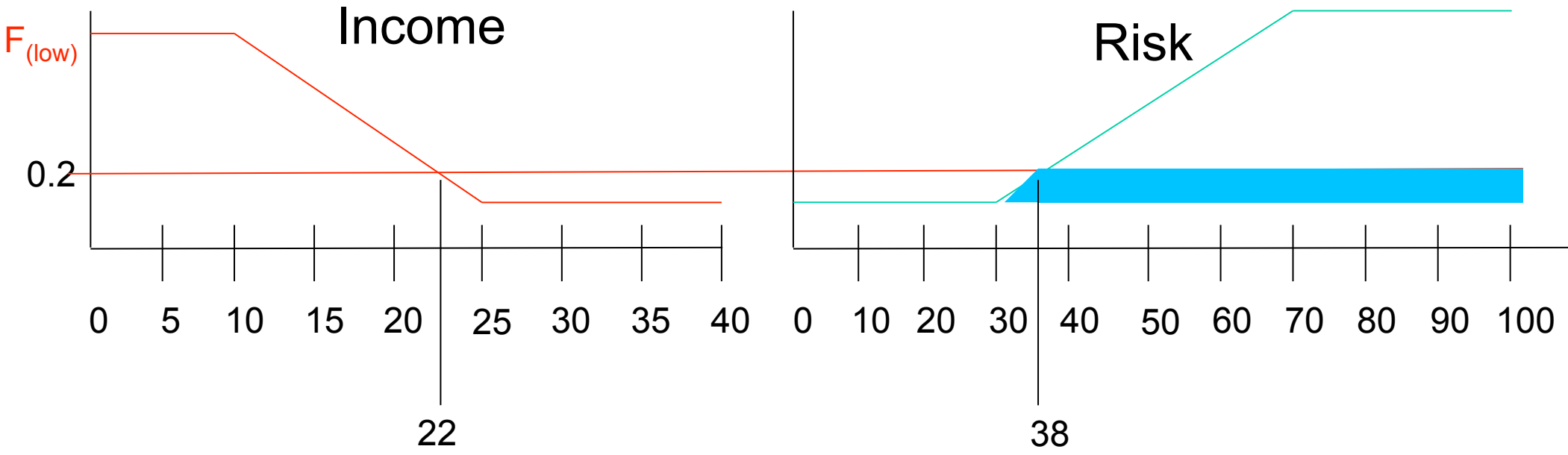
Complement (Not)

$$F_{not\text{-}low\text{-}income}\,(22k) = 1.0 - F_{low\text{-}income}\,(22k) = 1.0 - 0.2 = 0.8$$

Exercise 1

What risk (%) will the bank take if it issues a credit card to the customer with an income of 22k?

IF income is low, THEN risk is high



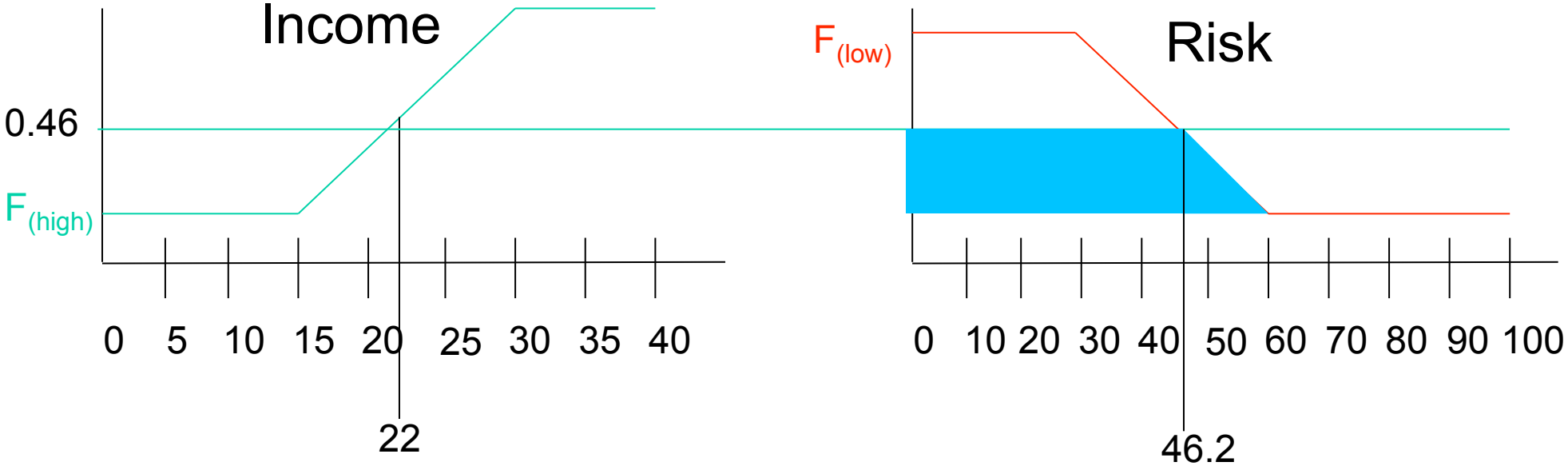
IF income is low, THEN risk is high

$B^1 = \{0/30, 0.2/38, 1/100\}$

Exercise 1

What risk (%) will the bank take if it issues a credit card to the customer with an income of 22k?

IF income is high, THEN risk is low



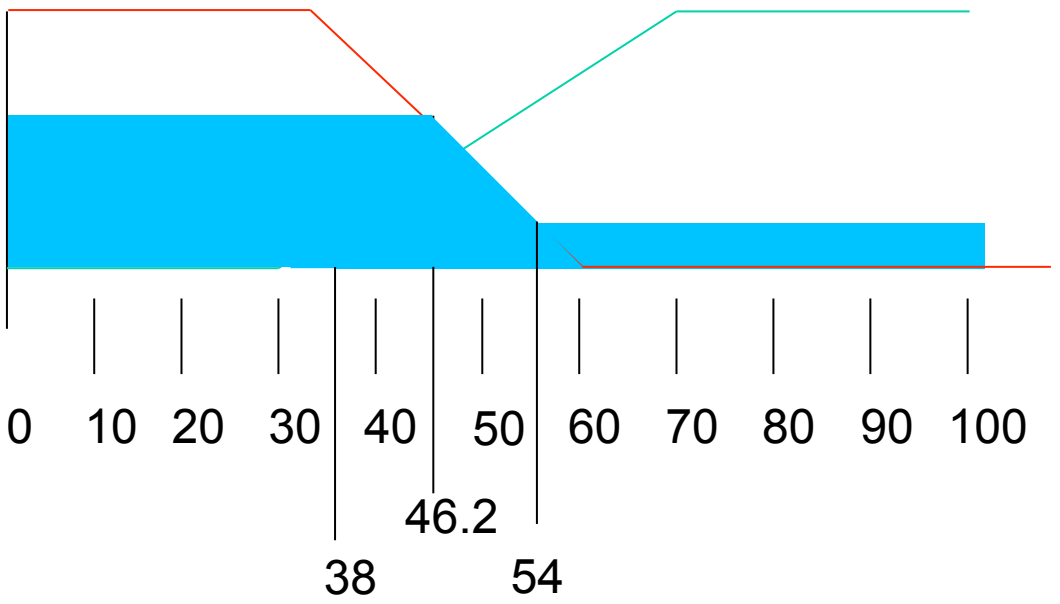
F income is high, THEN risk is low

B^2 = {1/0, 0.46/46.2, 0/60}

Exercise 1

What risk (%) will the bank take if it issues a credit card to the customer with an income of 22k?

IF income is low, THEN risk is high
IF income is high, THEN risk is low



B = {1/0, 0.46/46.2, 0.2/54, 1/100}

Exercise 1

$$B = \{1/0, 0.46/46.2, 0.2/54, 1/100\}$$

Defuzzify (B^3) = risk;

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

$$\frac{1*0 + 0.46*46.2 + 0.2*54 + 1*100}{1+0.46+0.2+1} = 53$$

Multiple-premises rules
Input crisp value

IF X is A AND Y is B THEN Z is C

x_k= single value in A, y_i= single value in B $a_i = f_A(x_k)$ $b_j = f_A(y_j)$

$A^1 = \{a_i / x_k\}$, $B^1 = \{b_i / y_i\}$, $C = \{c_1/y_1, c_1/y_1, c_2/y_2 \ldots\}$

C'	Premise Joining	Inference
$\min(a_i, b_j) \wedge f_c(z)$	AND	Max-Min
$\max(a_i, b_j) \wedge f_c(z)$	OR	Max-Min
$\min(a_i, b_j) \cdot f_c(z)$	AND	Max-Product
$\max(a_i, b_j) \cdot f_c(z)$	OR	Max-Product

Exercise 2

IF walk pace (wp) is fast or not slow, THEN set power supply (ps) to low

where :

$f_{fast}(wp) = \{0/1, 0/2, 0.3/3, 0.6/4\ 1.0/5\}$

$f_{slow}(wp) = \{1.0/1, 1.0/2, 0.5/3, 0/4\ 0/5\}$

$f_{low}(ps) = \{1.0/1, 1.0/2, 0/3, 0/4\ 0/5\}$

Suppose that the walking pace is now measured to be:

$f_{observed} = 3.5$

Use this measurement and the fuzzy relation produced above to compute a crisp value for the power supply, (ps).

Exercise 2

IF walk pace (wp) is fast or not slow, THEN set power supply (ps) to low

F_{fast} (wp) = {0/1, 0/2, 0.3/3, 0.6/4 1/5}

F_{slow} (wp) = {1/1, 1/2, 0.5/3, 0/4 0/5}

F_{low} (ps) = {1/1, 1/2, 0/3, 0/4 0/5}

$F_{not\text{-}slow}$ (wp) = {0/1, 0/2, 0.5/3, 1/4 1/5}

$F_{fast\ or\ not\text{-}slow}$ (wp) = {0/1, 0/2, 0.7/3, 1/4 1/5}