

THE ULTIMATE BEGINNERS GUIDE TO FUZZY LOGIC

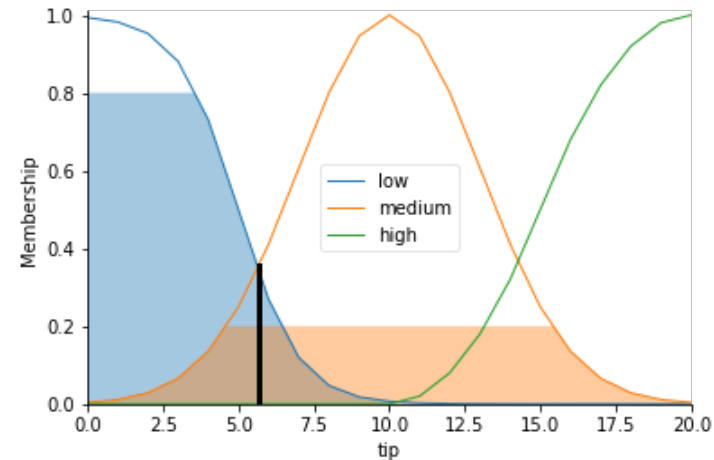


COURSE CONTENT

- Part 1 – basic intuition
 - Linguistic variables, antecedents, consequent, membership functions, fuzzification, math for defuzzification
- Part 2 – implementation with skfuzzy library
 - Tipping problem
 - Vacuum cleaner problem
- Part 3 – clustering with fuzzy c-means
 - Credit card clients
- Suitable for beginners

FUZZY LOGIC – BASIC INTUITION

- Applications
- First understanding
- Linguistic variables and membership (pertinence)
- Steps for fuzzy inference
- Mathematical calculations



FUZZY LOGIC – APPLICATIONS

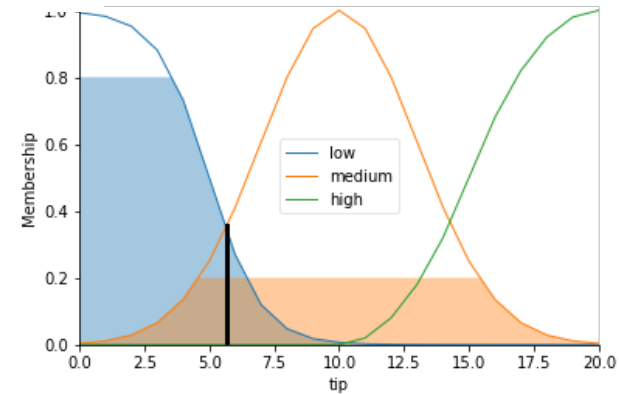
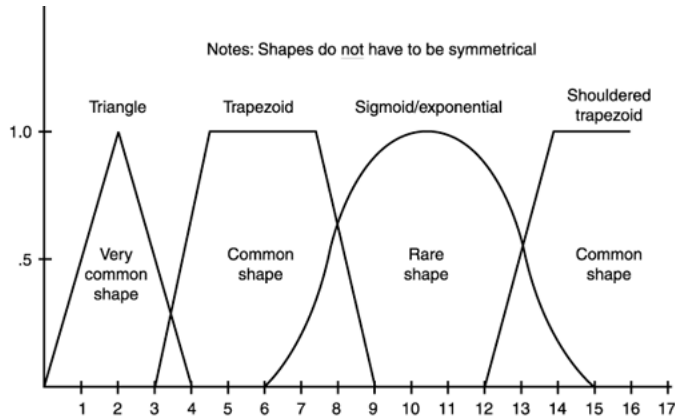
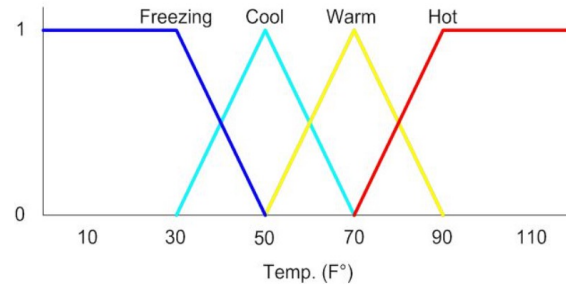


FUZZY LOGIC

- *If cost LOW and benefit HIGH then cost-benefit HIGH*
 - *If cost HIGH and benefit HIGH then cost-benefit MEDIUM*
 - *If cost LOW and benefit LOW then cost-benefit MEDIUM*
 - *If cost HIGH and benefit LOW then cost-benefit LOW*
-
- High cost and high benefit can be “half true” or “half false”
 - If $\text{cost-high} < 0.2$ and $\text{benefit-high} > 0.8$ then cost-benefit HIGH
 - Cost high = a little bit false
 - Benefit high = truer

FUZZY LOGIC

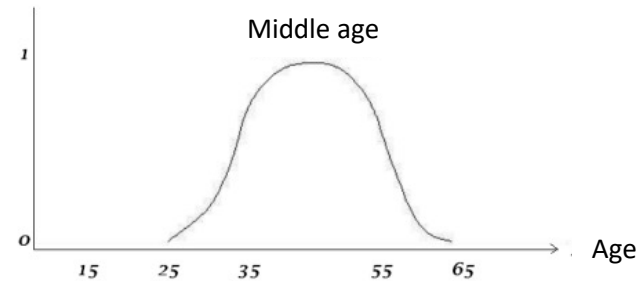
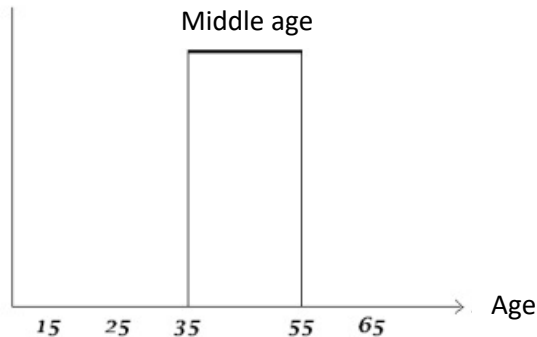
- Boolean logic: full glass or empty glass
- Empty, half empty, half full, full



Fonte: http://www.yaldex.com/games-programming/0672323699_ch12lev1sec11.html

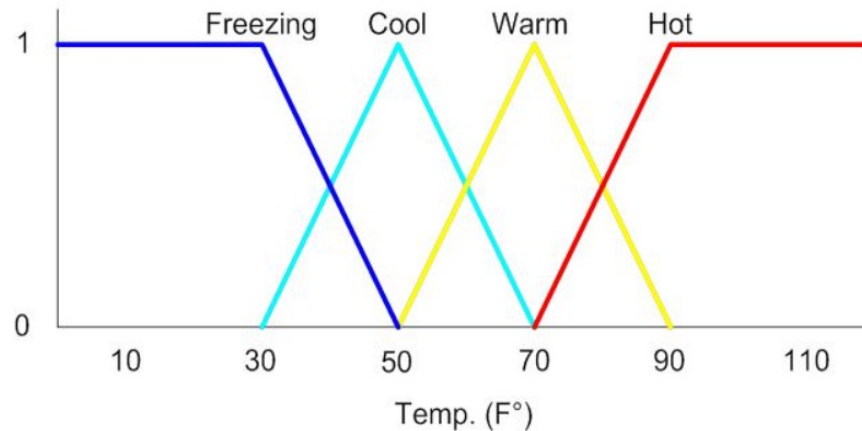
FUZZY LOGIC

- Jan Lukasiewicz (1878 – 1956)
- Lofti Asker Zadeh is considered to be the first author of article on fuzzy logic – 60's
- Original paper: *Fuzzy Sets* published on *Journal Information and Control*
- It is not possible to answer only “yes” or “no”, but “maybe” or “almost”
- Values in the range from 0 to 1: 0.9 (almost true) e 0.1 (almost false)



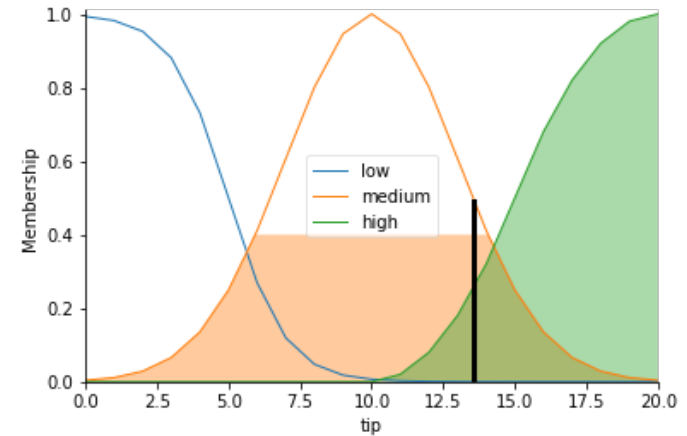
FUZZY LOGIC

- Linguistic variables (names for the fuzzy sets)
- Membership functions (pertinence functions)
 - Temperature until 30: membership degree = 1 considering “Freezing”
 - The membership degree in the “Freezing” group decreases as the temperature increases
 - Temperature equal to 50 belongs “fully” to the “Cool” group
 - Temperature above 90: membership degree = 1 considering “Hot”

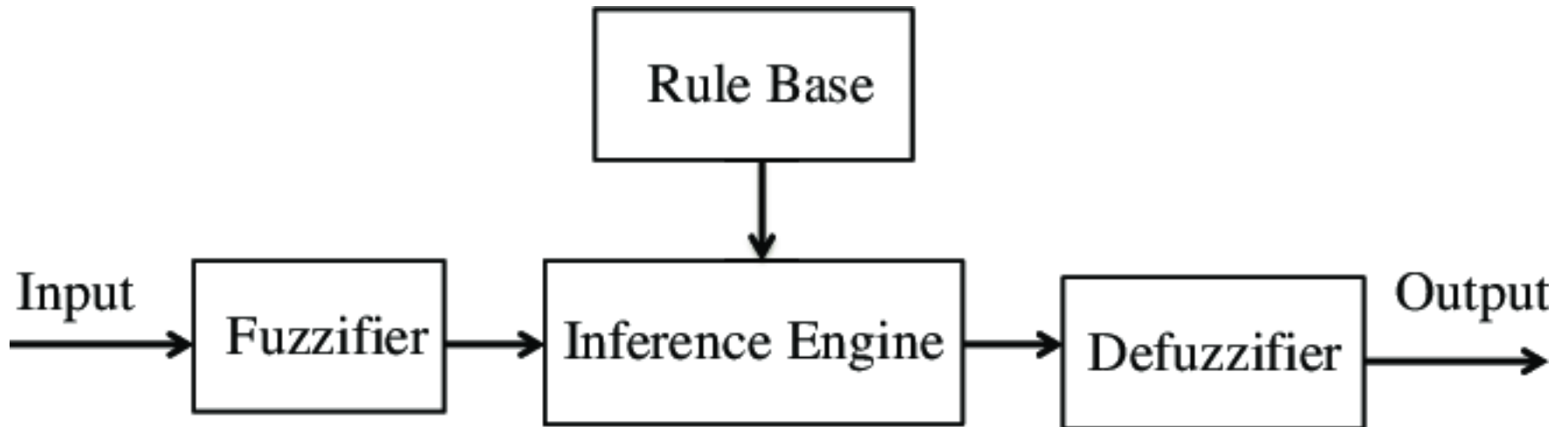


FUZZY LOGIC – COMPONENTS

- Input variables (antecedents)
 - Food quality (bad, decent or great)
 - Service quality (bad, decent or great)
- Output variable (consequent)
 - Tip (low, medium or high)
- Rules
 - If the service is great and food is also great then the tip will be high
- To get the result (or the prediction), the **defuzzification** calculation is executed



FUZZY LOGIC – COMPONENTS



Source: https://www.researchgate.net/figure/Components-of-a-fuzzy-logic-controller_fig2_264416989

CENTROID DEFUZZIFICATION

Calculation of “X” central of the areas:

- Centroid in X **freezing**: 3.5
- Centroid in X **cool**: 8.5

Trapeze calculation: find the smallest and largest base on X, considering the membership degree in Y

Area calculation:

Membership degree * (smaller base + larger base)/2

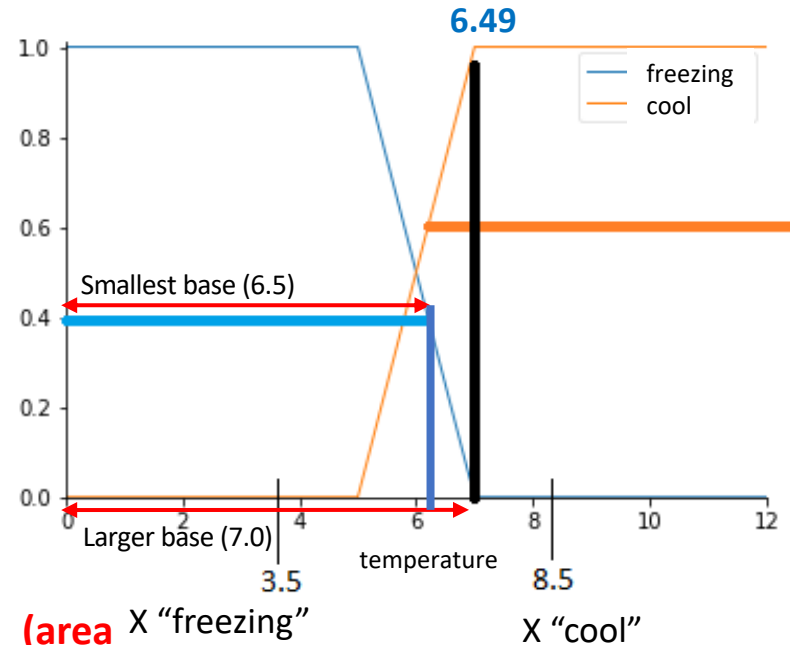
Area “freezing”: $0.4 * (6.5 + 7) / 2 = 2.7$

Area “cool”: $0.6 * (6.5 + 7) / 2 = 4.05$

Weighted average calculation

$(X \text{ “freezing”} * \text{area freezing} + X \text{ “cool”} * \text{area cool}) / (\text{area freezing} + \text{area cool})$

Weighted average: $(3.5 * (2.7) + 8.5 * (4.05)) / (2.7 + 4.05) = 6.49$



BISECTOR DEFUZZIFICATION

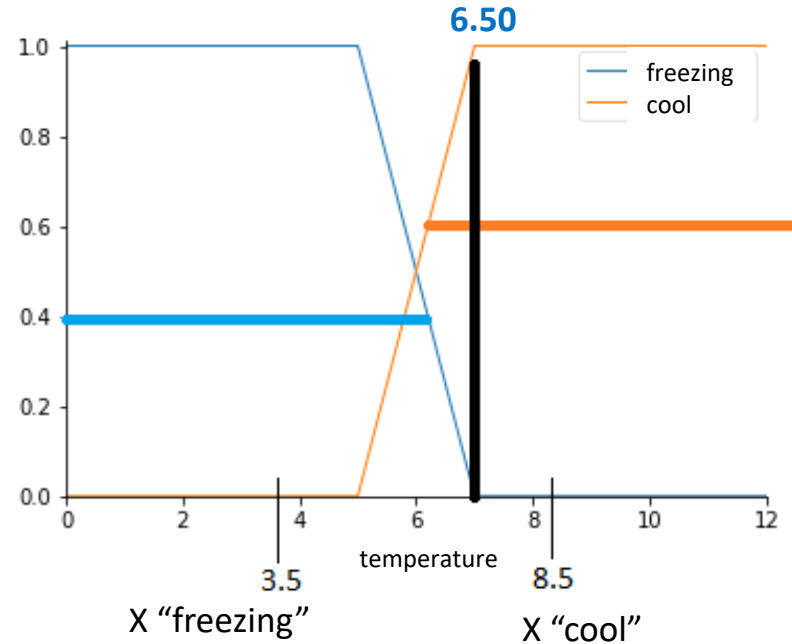
Calculation of “X” central of the areas:

- Centroid in X freezing: **3.5**
- Centroid in X cool: **8.5**

Weighted average calculation (bissector):

$$(X \text{ “freezing”} * Y \text{ “freezing”}) + (X \text{ “cool”} * Y \text{ “cool”}) / X \text{ “freezing”} + Y \text{ “cool”}$$

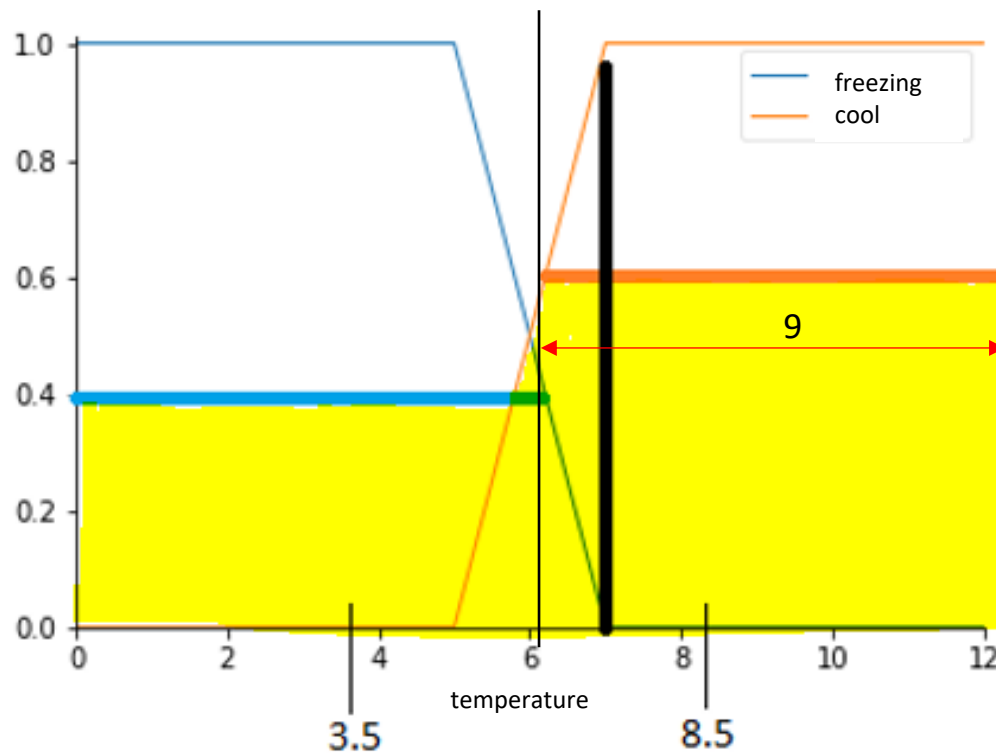
$$\text{Weighted average: } (3.5 * 0.4) + (8.5 * 0.6) / 0.4 + 0.6 = 6.5$$



MOM DEFUZZIFICATION – MEAN OF MAXIMUM

It is the value in the middle of X axis

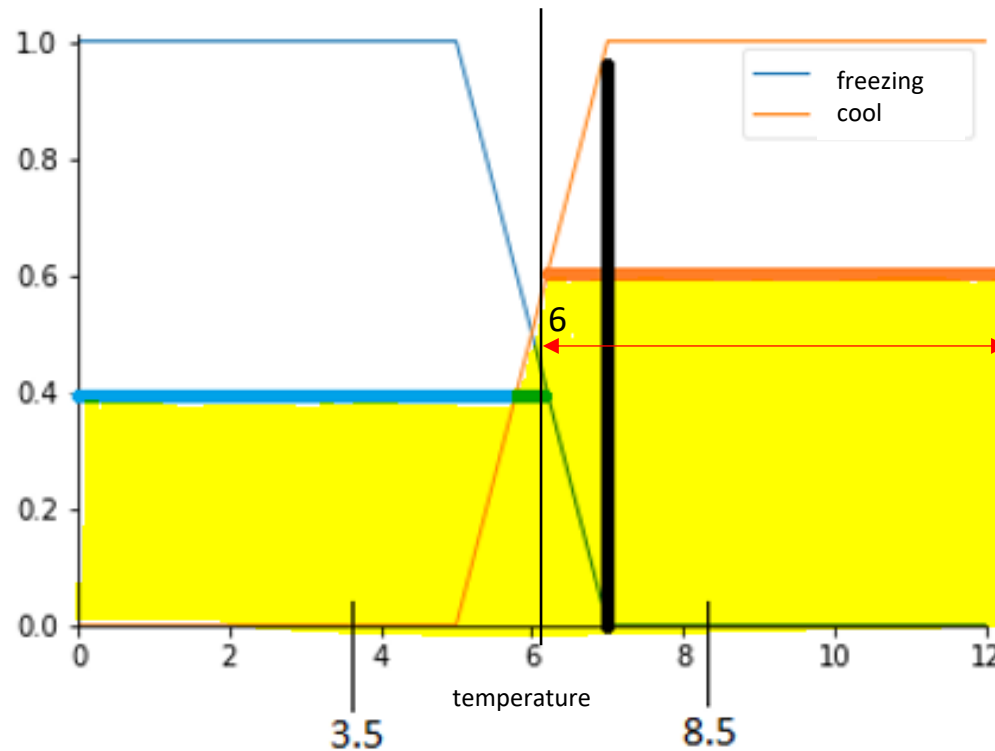
MOM = 9



SOM DEFUZZIFICATION – SMALLEST OF THE MAXIMUM

It is the smallest value of the X axis

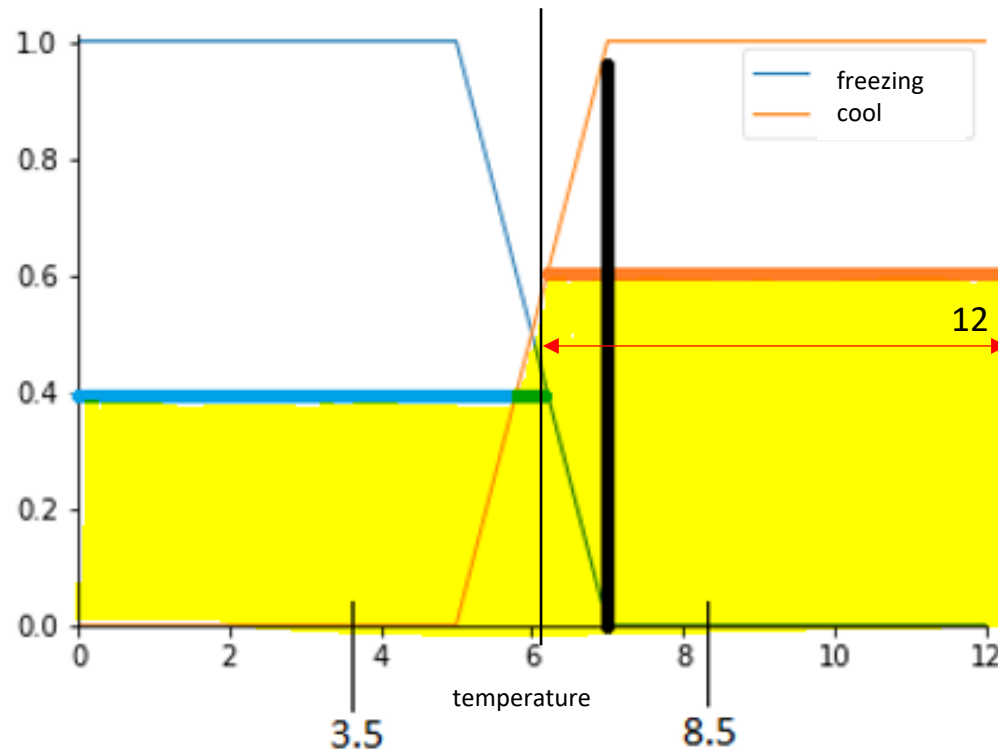
SOM = 6



LOM DEFUZZIFICATION – LARGEST OF MAXIMUM

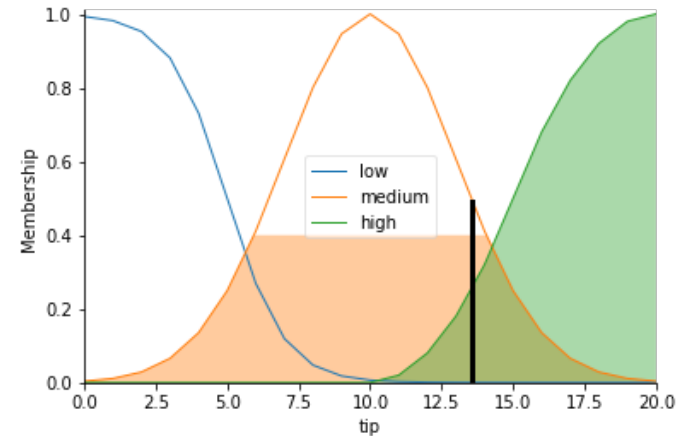
It is the highest value of the X axis

LOM = 12



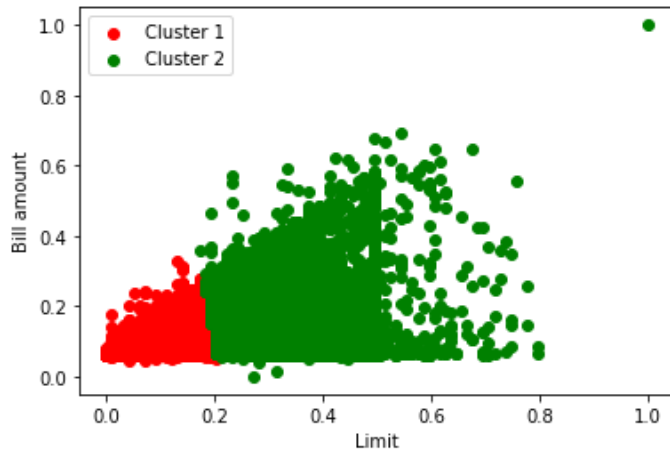
FUZZY SYSTEMS – IMPLEMENTATION

- skfuzzy library
- Tipping problem
- Vacuum cleaner problem
- Easy way and hard way
- More defuzzification functions

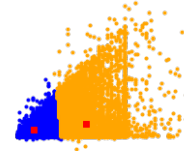


CLUSTERING WITH FUZZY C-MEANS

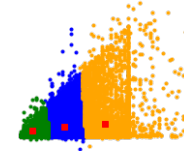
- Clustering – intuition
- Preprocessing the dataset
- Choosing the number of clusters
- Interpreting the results



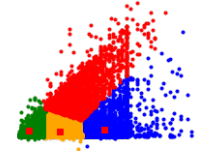
Centers = 2 - FPC = 0.805775589155035



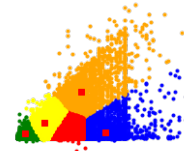
Centers = 3 - FPC = 0.7255208315549783



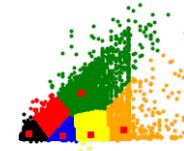
Centers = 4 - FPC = 0.7051324643025866



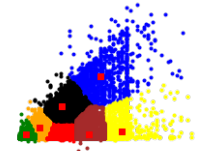
Centers = 5 - FPC = 0.6466795467604307



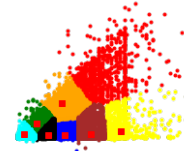
Centers = 6 - FPC = 0.6425849221749463



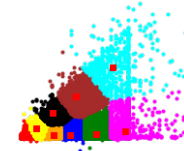
Centers = 7 - FPC = 0.6185966303941195



Centers = 8 - FPC = 0.6025658619110328



Centers = 9 - FPC = 0.5760207005049526



Centers = 10 - FPC = 0.5686319561959731

