Raven Notes 3: Fuzzy Logic

CSCI 321

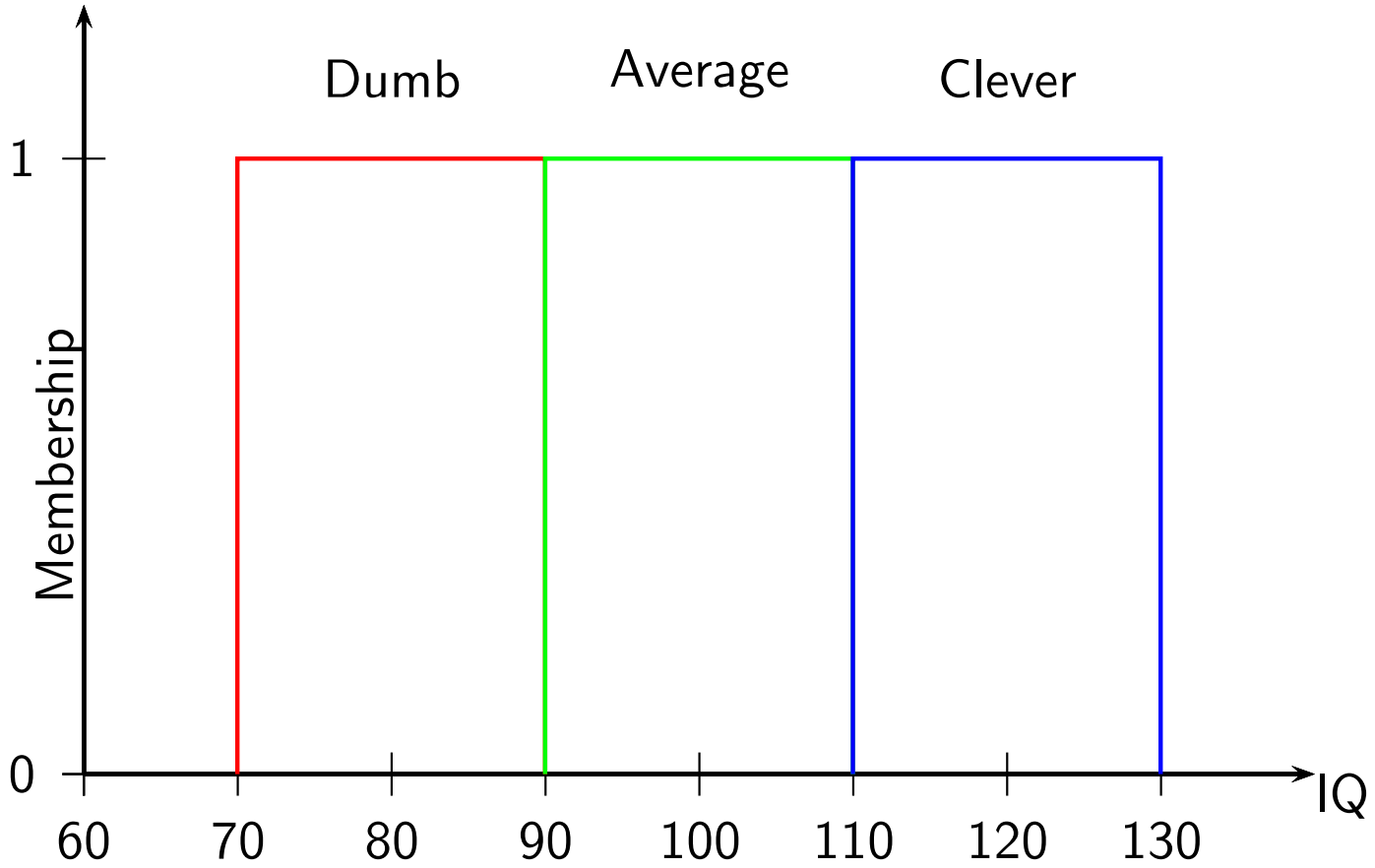
Based on *Programming Game AI by Example*, Buckland

November 30, 2017

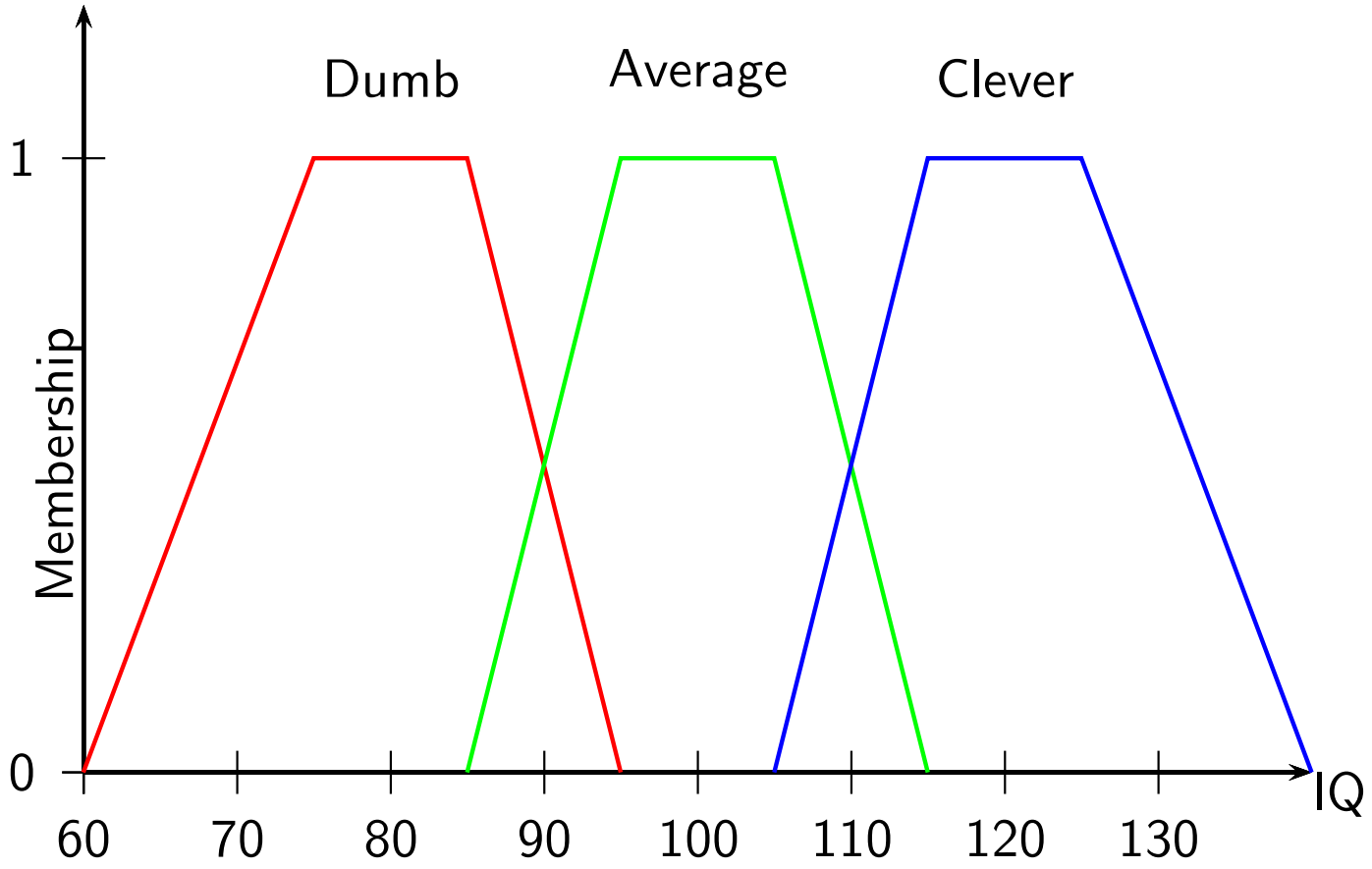
Fuzzy Logic

- A more intuitive alternative to mathematical formulas for making decisions.
- Examples of fuzzy quantities:
  - A large piece of pie
  - A fairly strong wind
  - Low health
  - Hit the ball very hard
  - Far away

Crisp sets


Dumb
Average
Clever
1
0
Membership
IQ
60
70
80
90
100
110
120
130

Fuzzy sets


Dumb
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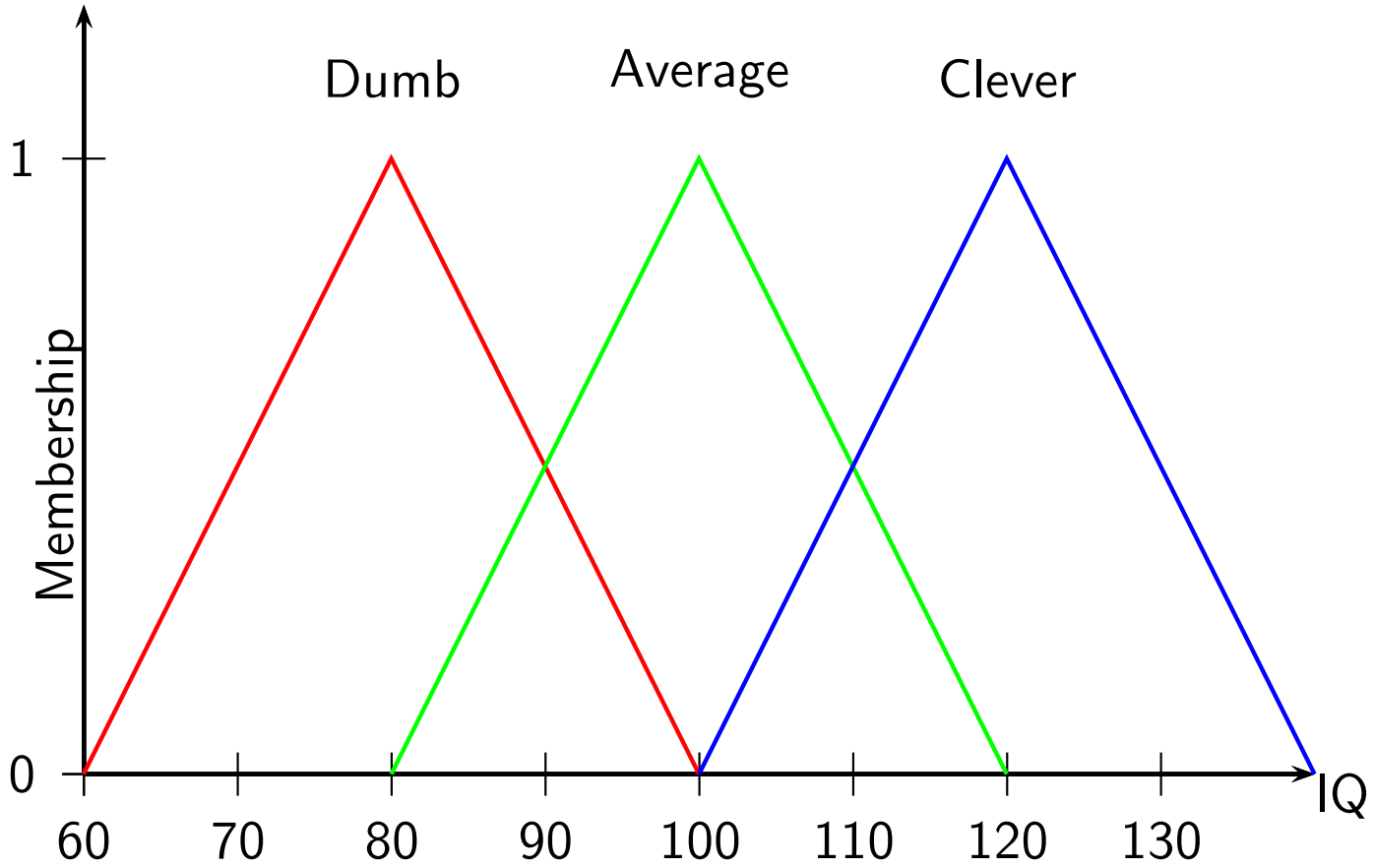
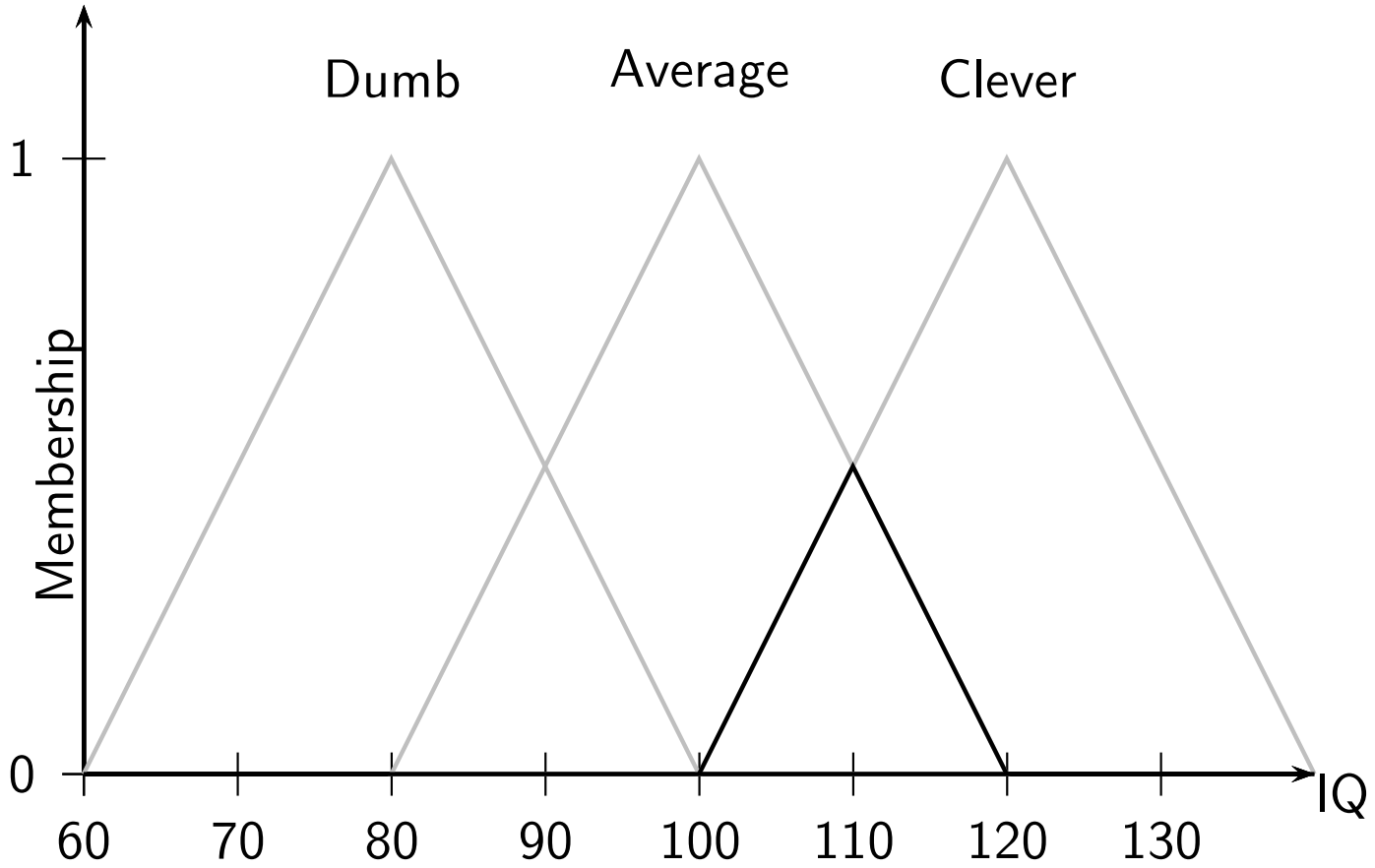
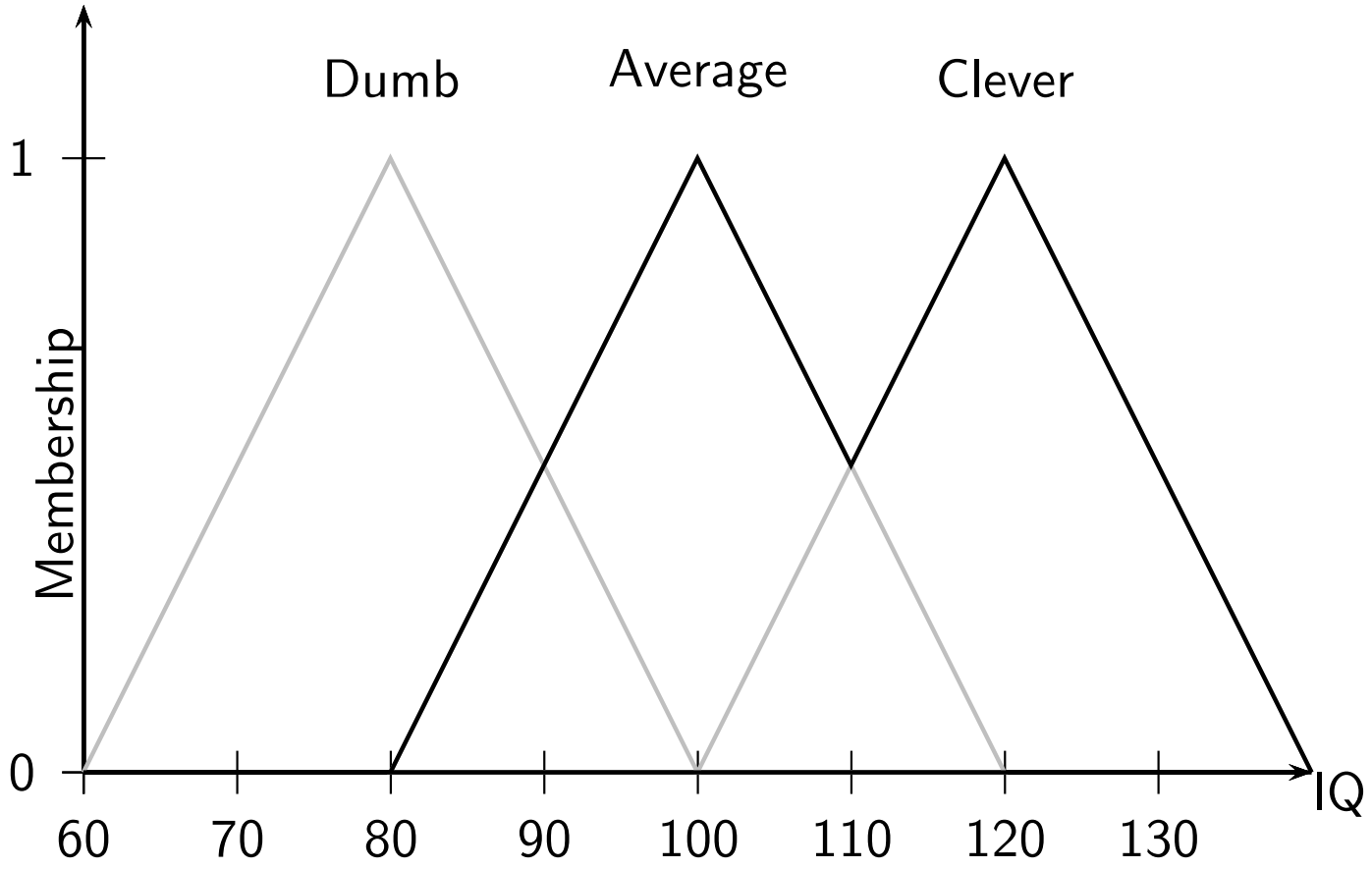
Fuzzy sets


Dumb
Average
Clever
1
0
Membership
IQ
60
70
80
90
100
110
120
130

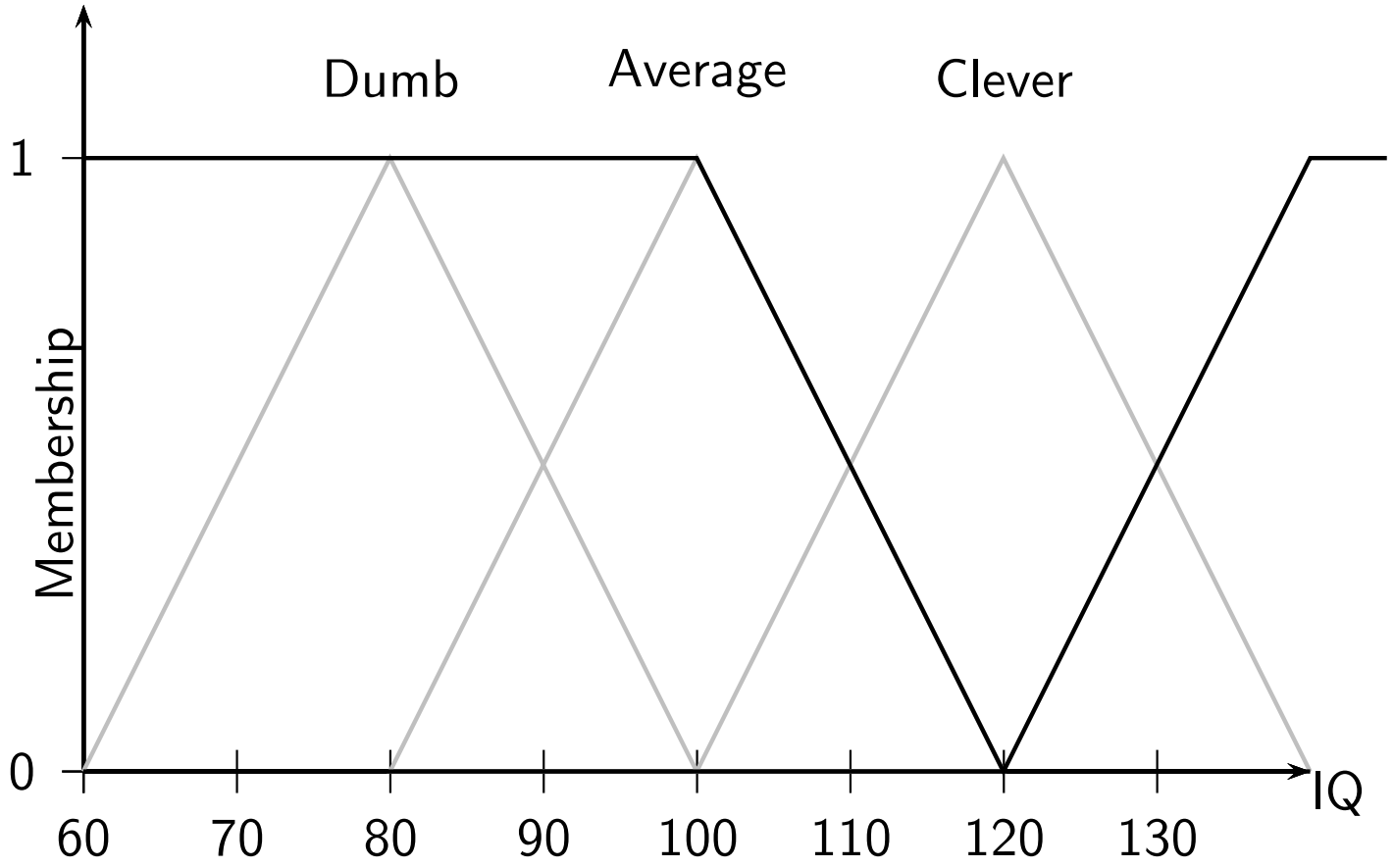
Average AND Clever



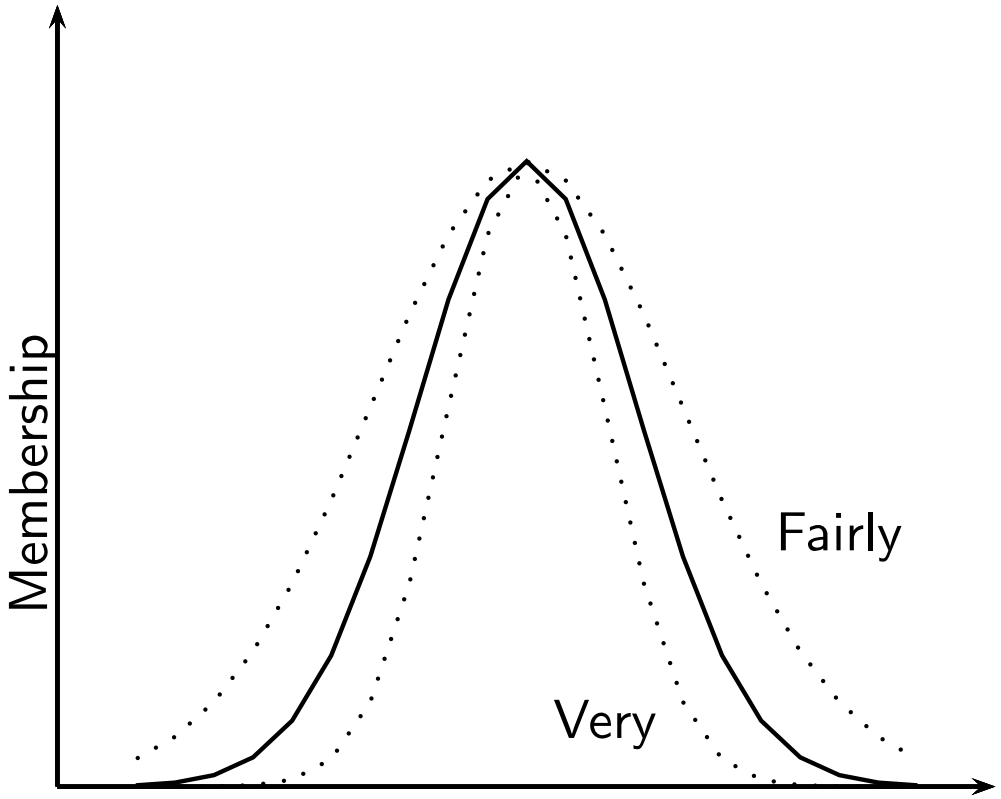
Average OR Clever



NOT Clever


Dumb
Average
Clever
1
0
Membership
IQ
60
70
80
90
100
110
120
130

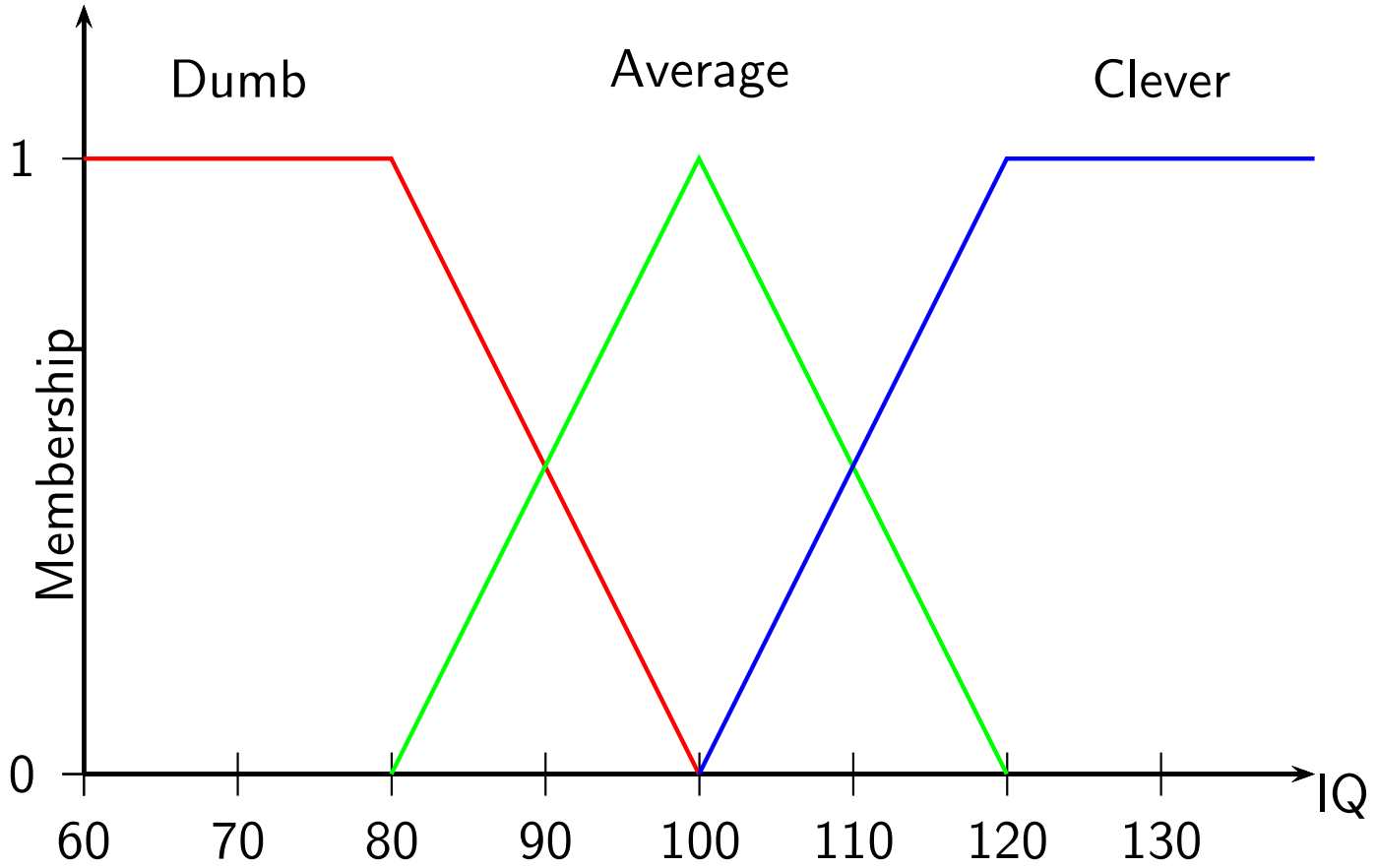
Hedges



Fairly = square root

Very = square

Fuzzy Linguistic Variable



IQ = (Dumb, Average, Clever)

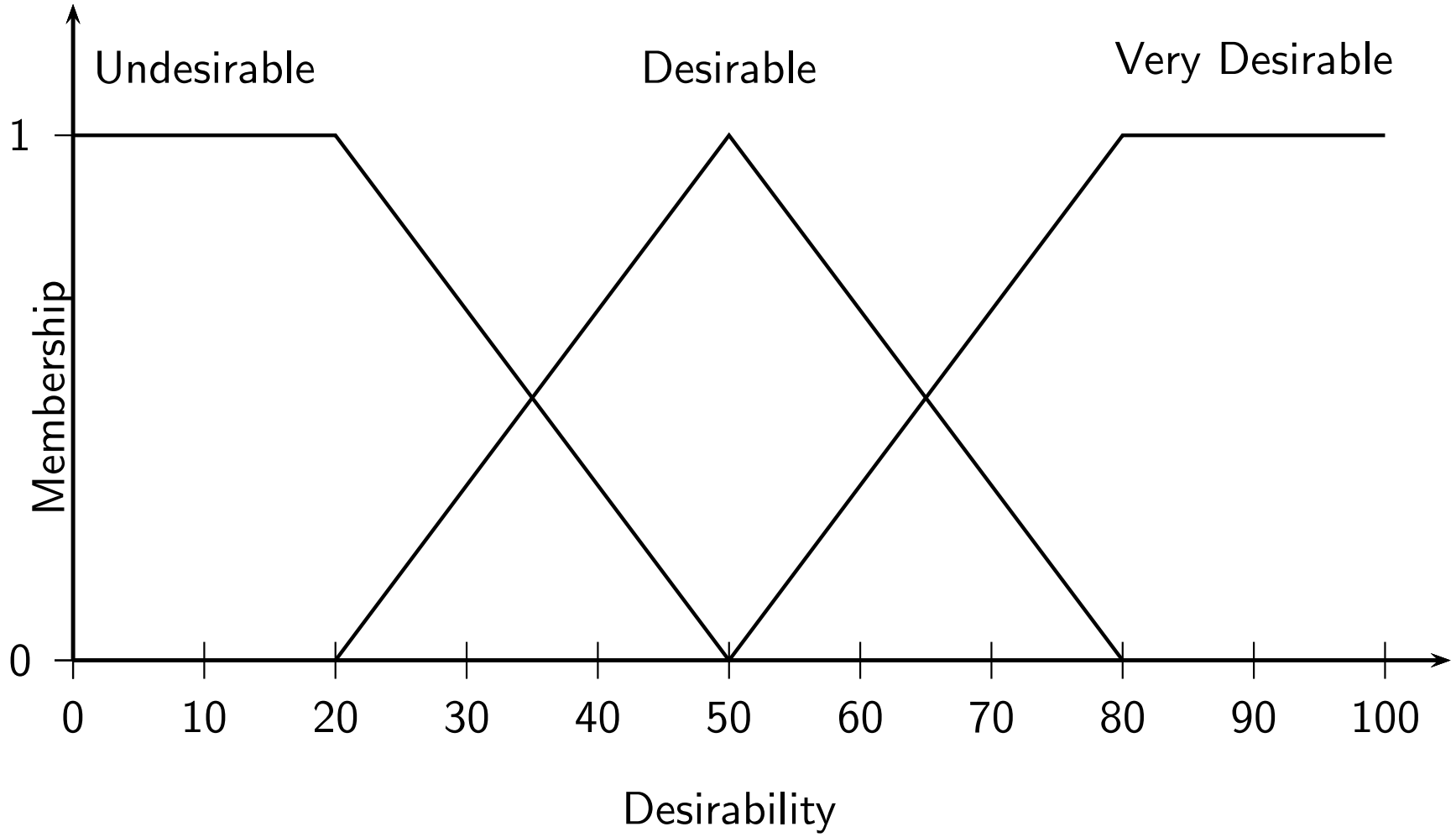
Each crisp IQ has a fuzzy value: $IQ(115) = (0.0, 0.25, 0.75)$

Usually sum to 1.

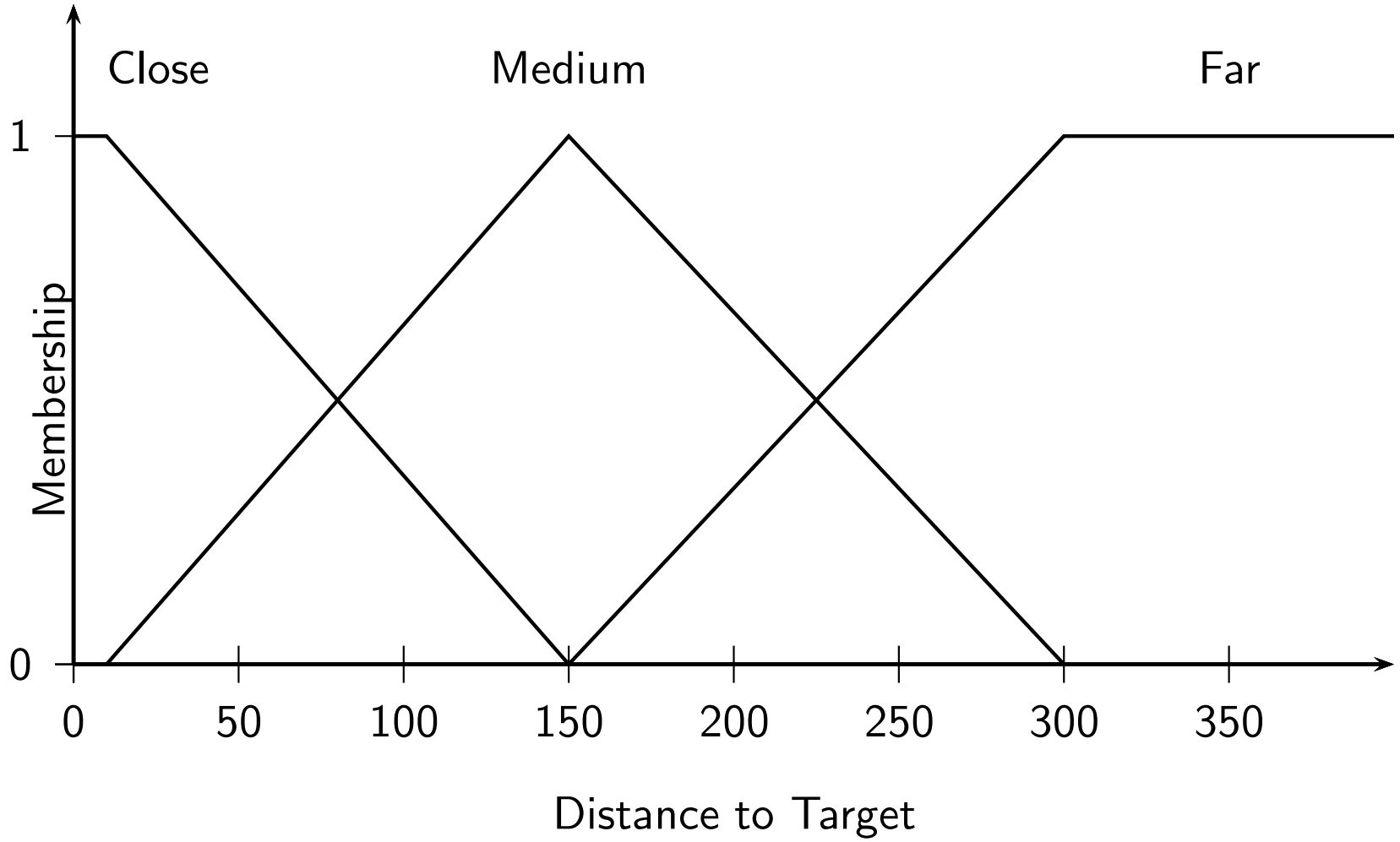
Reasoning with FLV's

- Define FLV's for all quantities of interest:
  - Distance: close, medium, far
  - Ammo: low, okay, loads
  - Desirability: undesirable, desirable, very desirable
- Define fuzzy rules (*e.g* desirability of using rocket launcher):
  - If target is far and ammo is loads then desirable
  - If target is close then undesirable
  - *etc.*
- Start with crisp values (measurements) of distance and ammo
- Fuzzify crisp values to fuzzy values
- Reason with fuzzy values
- Come to fuzzy conclusion
- Defuzzify conclusion

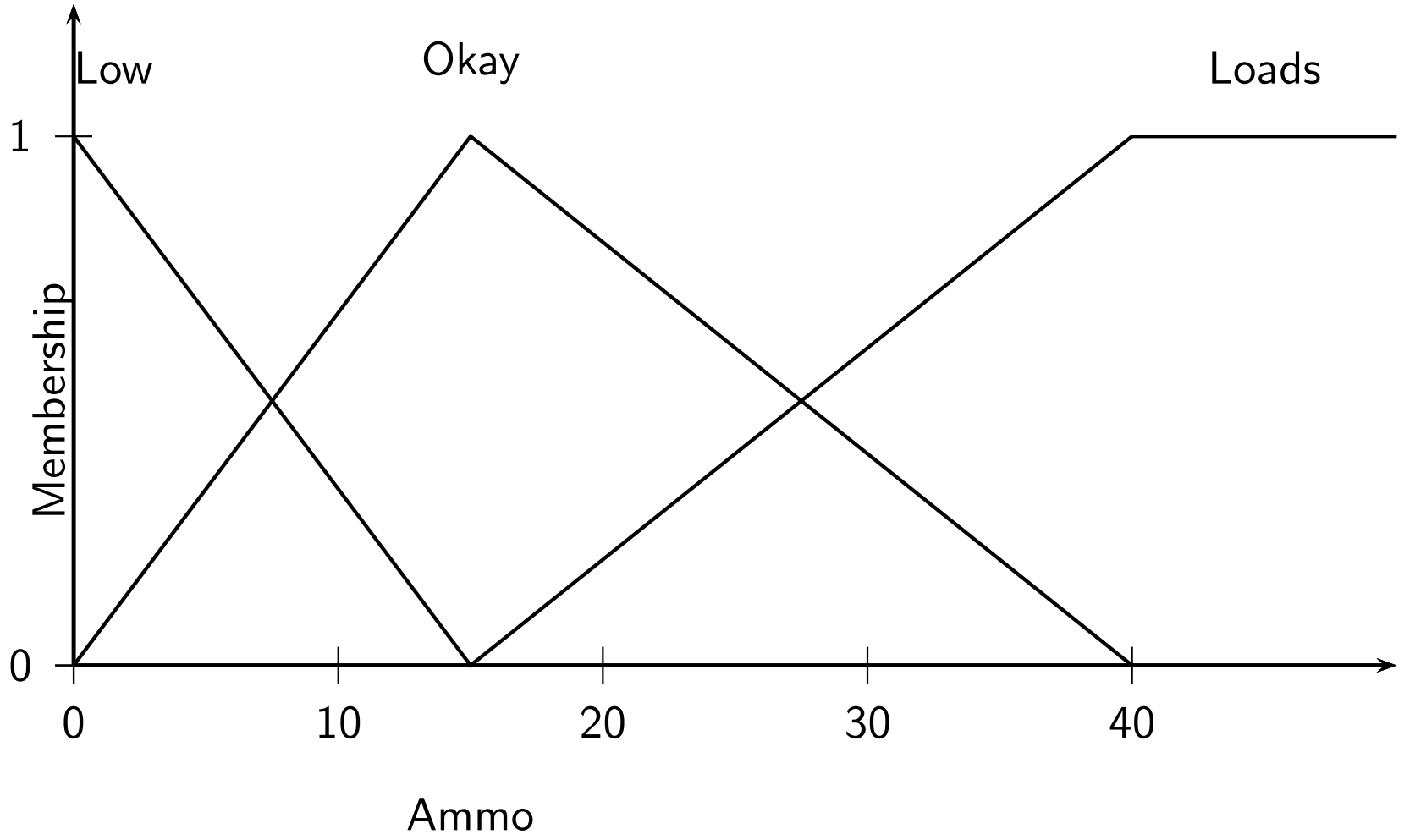
Fuzzy Desirability



Fuzzy Distance to Target



Fuzzy Ammo Status



Fuzzy Rules for Desirability of Rocket Launcher

1. If target is far and ammo is loads then desirable
2. If target is far and ammo is okay then undesirable
3. If target is far and ammo is low then undesirable
4. If target is medium and ammo is loads then very desirable
5. If target is medium and ammo is okay then very desirable
6. If target is medium and ammo is low then desirable
7. If target is close and ammo is loads then undesirable
8. If target is close and ammo is okay then undesirable
9. If target is close and ammo is low then undesirable

Fuzzy Inference

1. For each rule,
   1.1 For each antecedant, calculate the degree of membership of the input data
   1.2 Calculate the rule's inferred conclusion based on these values
2. Combine all the inferred conclusions into a single fuzzy conclusion
3. Defuzzify the conclusion

Example

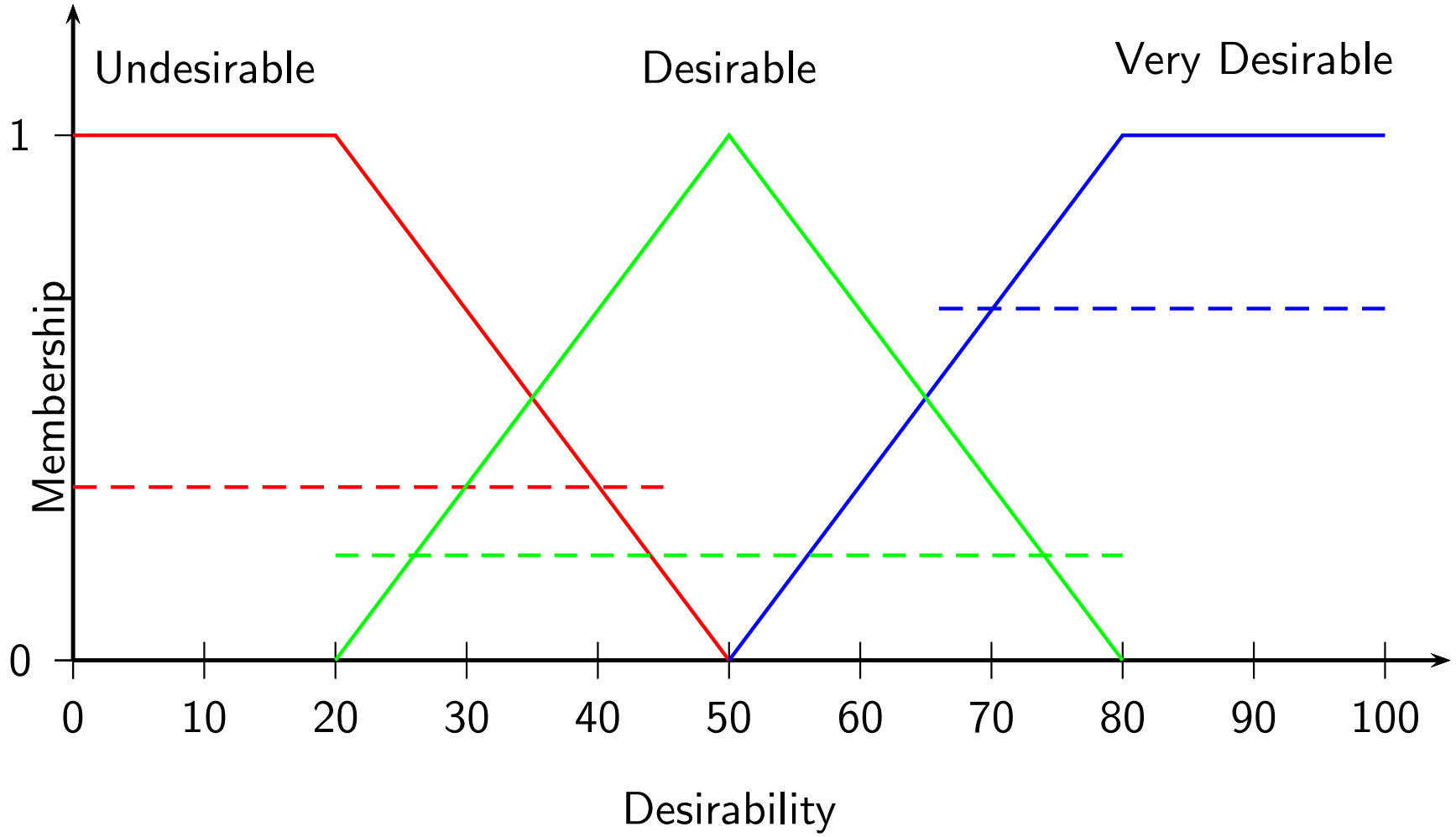
- Suppose target is at distance 200 and ammo is 8 rockets remaining.
- **Rule one:** If target is far and ammo is loads then desirable
  - Distance 200 means target far has DOM 0.33
  - Ammo 8 means ammo loads has DOM 0.0
  - ANDing these together means desirable is 0.0
- **Rule two:** If target is far and ammo is okay then undesirable
  - Distance 200 means target far has DOM 0.33
  - Ammo 8 means ammo okay has DOM 0.78
  - ANDing these together means undesirable is 0.33
- **Rule three:** If target is far and ammo is low then undesirable
  - Distance 200 means target far has DOM 0.33
  - Ammo 8 means ammo low has DOM 0.2
  - ANDing these together means undesirable is 0.2

FAM: Fuzzy Associative Matrix

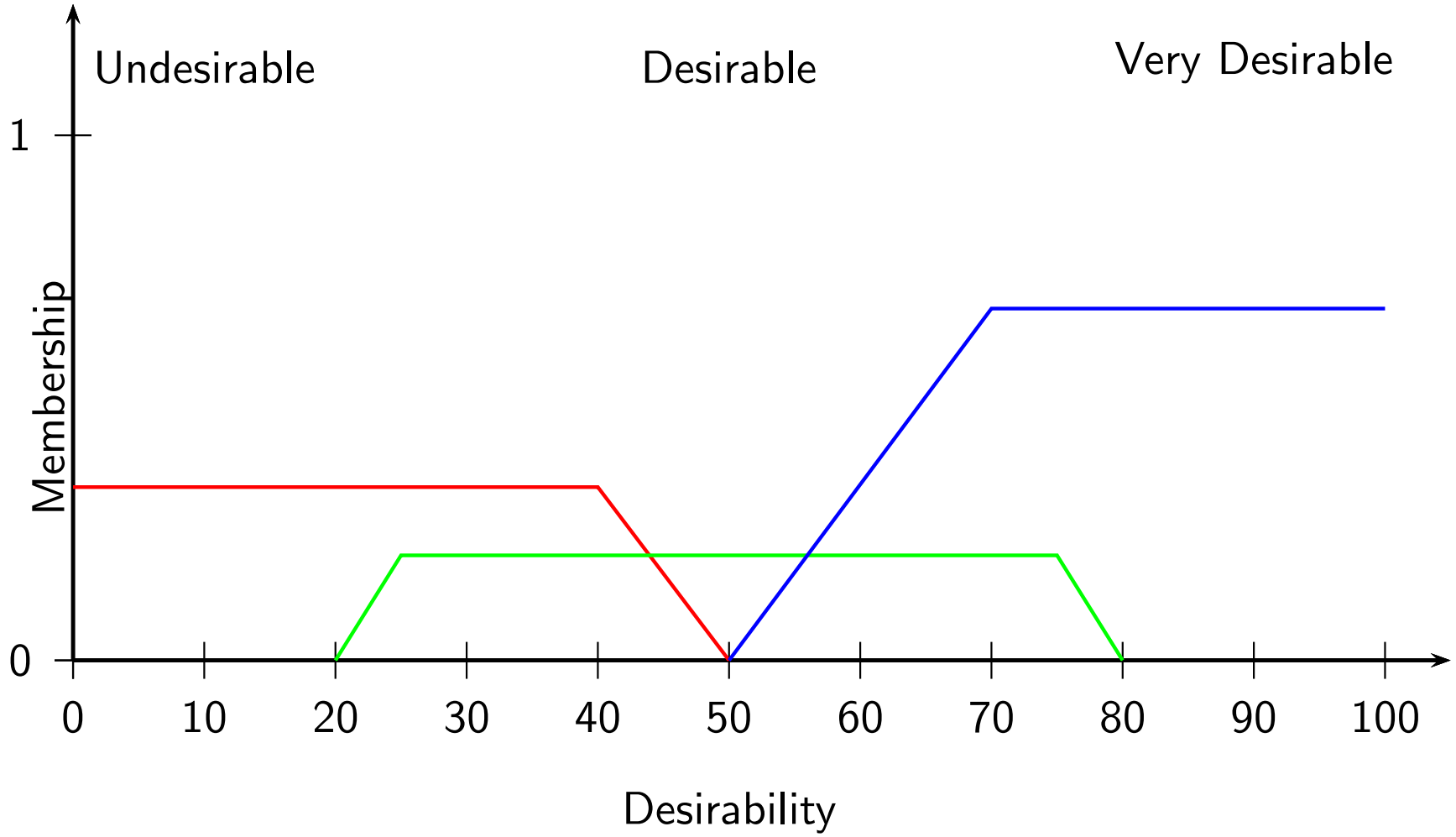
	Target close	Target medium	Target far
Ammo low	Undesirable 0	Desirable 0.2	Undesirable 0.2
Ammo okay	Undesirable 0	VeryDesirable 0.67	Undesirable 0.33
Ammo loads	Undesirable 0	VeryDesirable 0	Desirable 0

Consequent	Confidence
Undesirable	0.33
Desirable	0.2
VeryDesirable	0.67

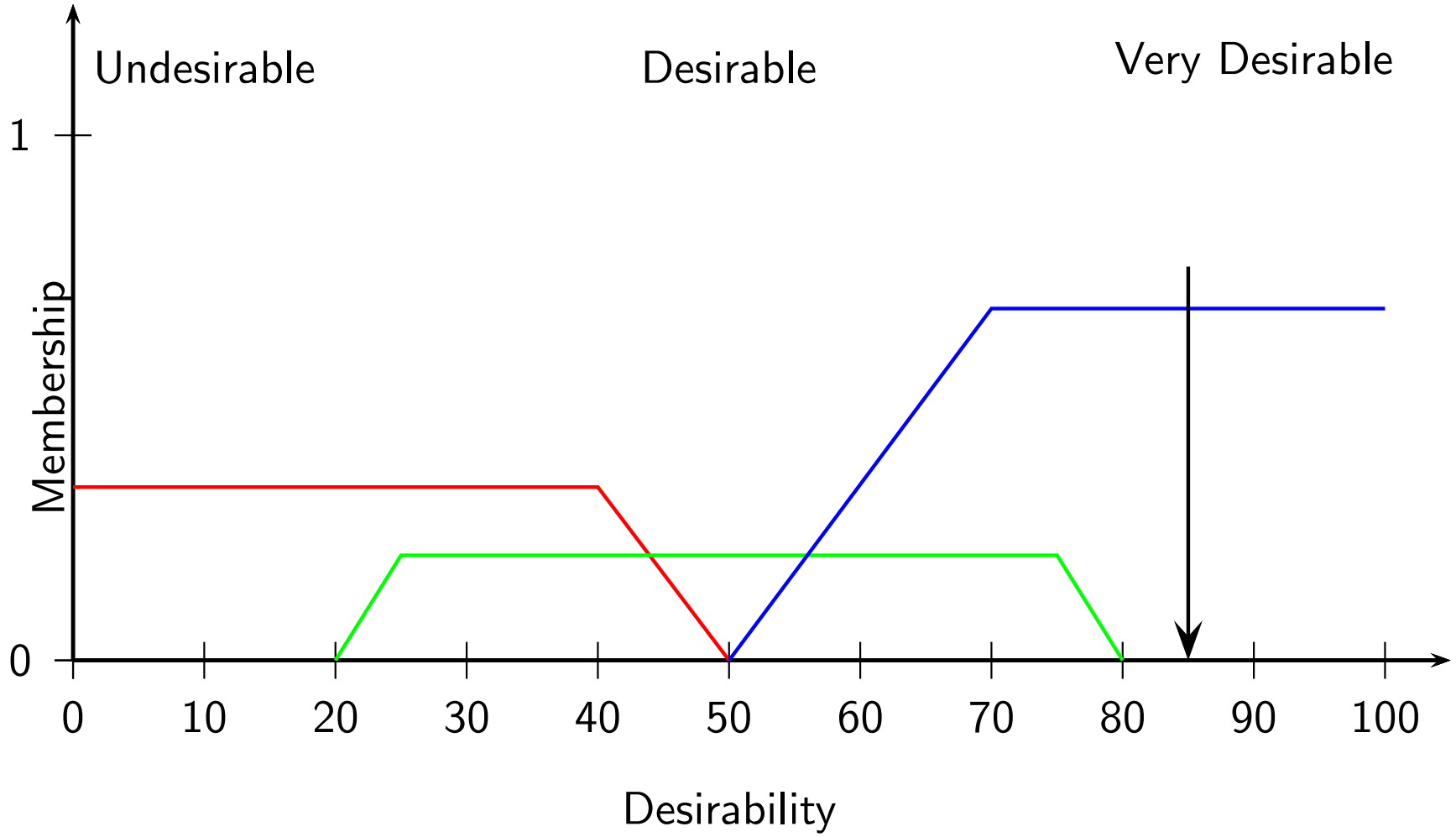
Fuzzy Conclusion: Truncate each set



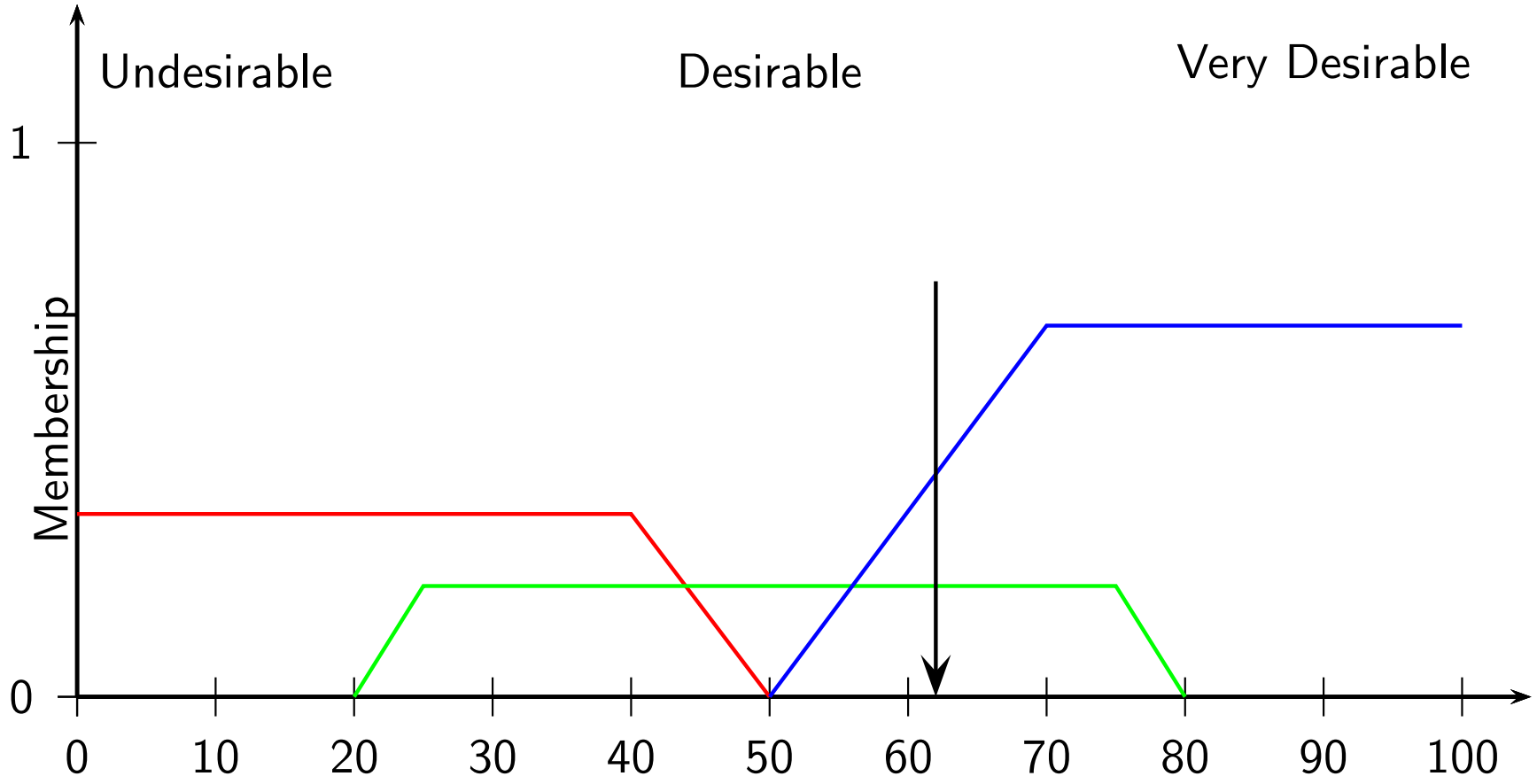
Fuzzy Conclusion: Truncate each set



Defuzzify: Mean of Maximum

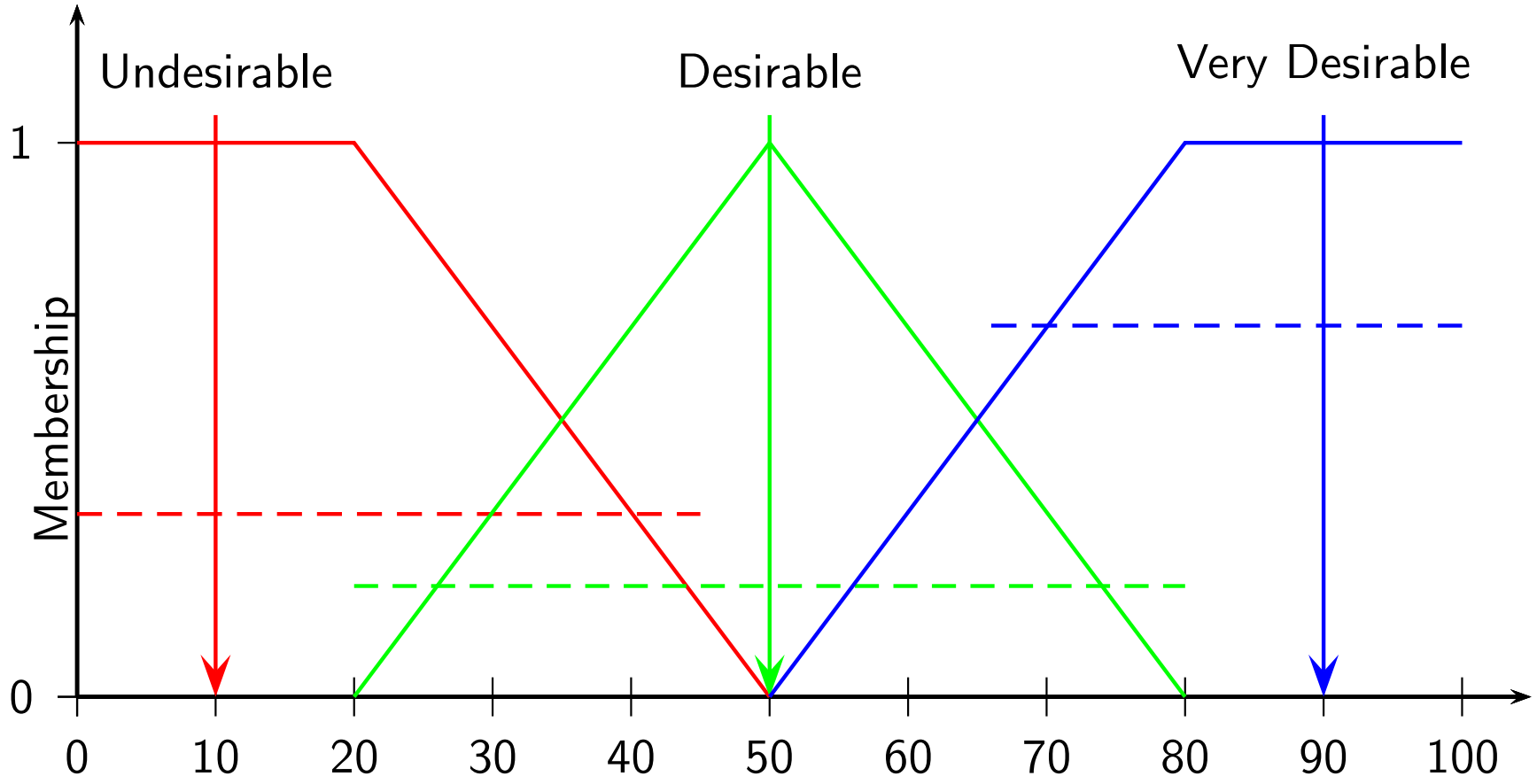


Defuzzify: Centroid



$$\sum_i \frac{i(membership_i)}{\sum_i membership_i}$$

Defuzzify: Average of Maxima



$$\frac{\sum_i (value_i)(confidence_i)}{(\sum_i confidence_i)}$$

Combinatorial explosion of rules

If A_i and B_i and C_i and D_i then Consequent

If each FLV has 5 possible values, then we have $5^4 = 625$ rules.

If we had 6 LFV's instead of 4, there would be $5^6 = 15625$ rules.

Rewrite rules for ease of computation

If A_i and B_i and C_i and D_i then Consequent

is equivalent to

If A_i then Consequent
OR
If B_i then Consequent
OR
If C_i then Consequent
OR
If D_i then Consequent

Using equivalences like this we can usually greatly reduce the number of rules. For example, the three rules for desirability of using the rocket launcher when the target is close can all be reduced to one:

If target is close then undesirable

This simplification can be done automatically.