Fuzzy Logic

IMDL

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Fuzzy Logic: What is it???

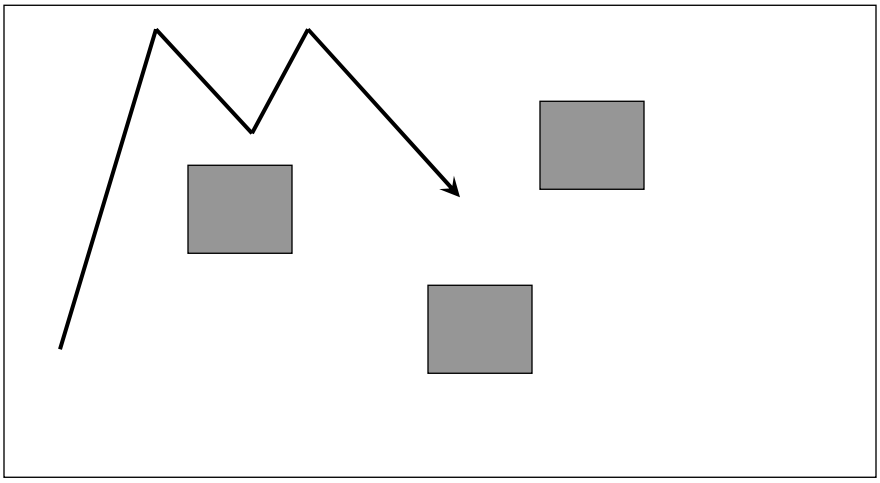
- It does not involve putting fake fur on robots.
- It is a different way of looking at the world.
- It is a superset of Boolean logic!
- It deals with “shades of gray!”

A Better Method to Deal With the Real World

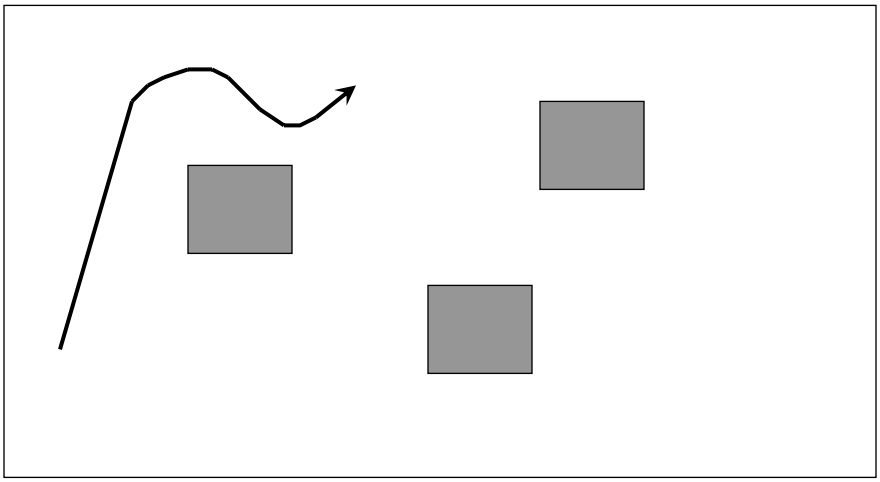
- Not just “True” and “False.”
- Takes on a range of values
  - True
  - Mostly True
  - Half True
  - Kind of True
  - False
- Values range from 0 to 1.
  - Including decimal values (0.2, 0.7, etc.)

Why?

Without Fuzzy Logic



With Fuzzy Logic



Without Fuzzy Logic

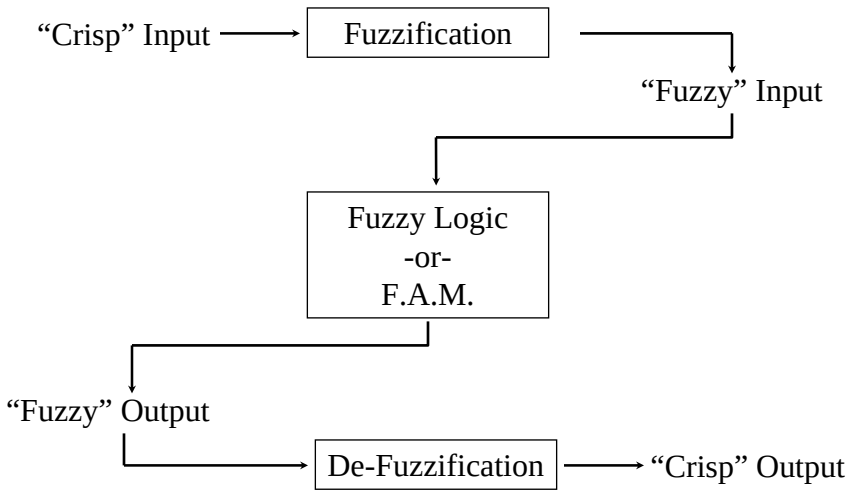
```
#include <confusing.h>

void bladder();
{
  if ( read_sensor(3.14159) > sqrt(42) )
  {
    do_something_confusing( make_noise(12) );
  }

  junk[max(my_IQ,my_shoe_size)]= peek(0x0f00);

  four_score[7] = “years ago”;
}
```

With Fuzzy Logic

Left	Right	Right
Left	Straight	Straight
Left	Straight	Straight

Now, Let's see how this works...

Fuzzy Logic Process



The First Step...

Fuzzification

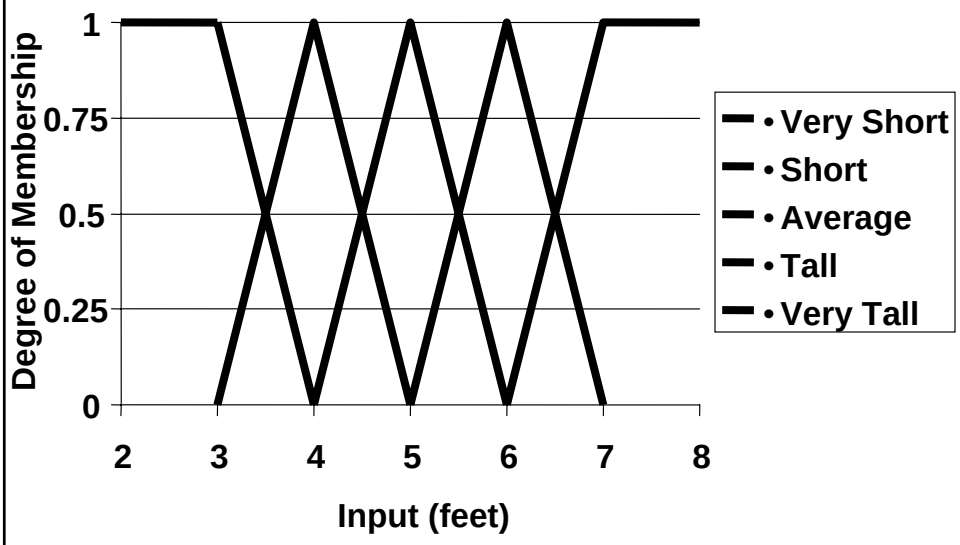
How tall is Kevin?

- Very Tall?
- Tall?
- Average?
- Short?
- Very Short?

How tall is Kevin?

- Very Tall (7 feet)?
- Tall (6 feet)?
- Average (5 feet)?
- Short (4 feet)?
- Very Short (3 feet)?

Fuzzification Rules



Some Examples:

If you are **5** feet:

- Very tall - 0%
- Tall - 0%
- Average - 100%
- Short - 0%
- Very Short - 0%

Same as Boolean logic (so far…)

- Very Tall (7 feet)?
- Tall (6 feet)?
- Average (5 feet)?
- Short (4 feet)?
- Very Short (3 feet)?

Some Examples:

If you are **5½** feet:

- Very tall - 0%
- Tall - **50%**
- Average - **50%**
- Short - 0%
- Very Short - 0%

NOT Boolean logic (Whoa. Cool!)

- Very Tall (7 feet)?
- Tall (6 feet)?
- Average (5 feet)?
- Short (4 feet)?
- Very Short (3 feet)?

How tall is Kevin?

Kevin is 6’ 2”

- Very Tall - 16%
- Tall - 84%
- Average - 0%
- Short - 0%
- Very Short - 0%

Fuzzy Representation

- All fuzzy variables are theoretically represented as a number between 0 and 1.
- The fuzzy number can be represented on a computer as a number between 0 and 255.

Some Hints

- Fuzzy values are **NOT** probabilities.
- HOWEVER, it might help to think of them as probability values.

The Second Step...

Fuzzy Logic & the FAM

Fuzzy Operators: AND

FAND(*A*,*B*) - Fuzzy AND = min(*A*,*B*)

FAND(100, 30) = 30

FAND(20, 250) = 20

FAND(1, 0) = 0 -- *Just like boolean logic*

FAND(1, 1) = 1 -- *Geeeee. This too!*

Fuzzy Operators: OR

FOR(*A*,*B*) - Fuzzy OR = max(*A*,*B*)

FOR(100, 30) = 100

FOR(20, 250) = 250

FOR(1, 0) = 1 -- *Just like boolean logic*

FOR(0, 0) = 0 -- *Geeeee. This too!*

Fuzzy Operators: NOT

FNOT(*A*) - Fuzzy NOT = 100% - *A*

(100% defined as 255)

FNOT(100) = 155

FNOT(250) = 5

FNOT(255) = 0

FNOT(0) = 255

– *See the similarity to Boolean logic?????*

Fuzzy Associative Memory (FAM)

The Next Step

Fuzzy Associative Memory

- It is a Fuzzy Truth Table
- Shows all possible outputs for all possible inputs
- Easy to create!

FAM Example

FUZZY-BOT

First, the sensors

Sharp Sensor Mappings:

- Nothing = 80
- Very Far = 100
- Far = 120
- Near = 130 -- *Note: non-linear spacing*
- Very Near = 140

Second, the Motors

Direction Output Mappings:

- Hard Left = -100
- Left = -20
- Straight = 0
- Right = 20
- Hard Right = 100

Lastly, the FAM (rule table)

Left Sensor	Right Sensor				
	VN	N	F	VF	VVF
VN	HL	HR	HR	HR	HR
N	HL	L	HR	R	R
F	HL	HL	L	S	S
VF	HL	L	S	S	S
VVF	HL	L	S	S	S

- V=Very
- N=Near
- F=Far
- N=Near
- H=Hard
- L=Left
- R=Right
- S=Straight

FAM Operation

- AND the associated inputs…
- OR the result with the result for that output group.

FUZZ-BOT Example

- Left Sensor
  - Very Near = 80%
  - Near = 20%
- Right Sensor
  - Near = 30%
  - Far = 70%

Left Sensor	Right Sensor				
	VN 0%	N 30%	F 70%	VF 0%	VVF 0%
VN 80%	HL 0%	HR	HR	HR 0%	HR 0%
N 20%	HL 0%	L	HR	R 0%	R 0%
F 0%	HL 0%	HL 0%	L 0%	S 0%	S 0%
VF 0%	HL 0%	L 0%	S 0%	S 0%	S 0%
VVF 0%	HL 0%	L 0%	S 0%	S 0%	S 0%

HL = 0%
L = 20%
S = 0%
R = 0%
HR = 30% OR 70% OR 20% = 70%

NOTE:
0+20+0+0+70 ≠100%

Can We Simplify This???

Removing the FAM

Simplifying the Table

1) Group the common Outputs (similar to K-Maps)

2) For each block:
   (each value OR'd together) AND
   (each value OR'd together)

3) OR the output of each block together

Left Sensor	Right Sensor VN 0%	N 30%	F 70%	VF 0%	VVF 0%
VN 80%	HL 0%	HR 30%	HR 70%	HR 0%	HR 0%
N 20%	HL 0%	L 20%	HR 20%	R 0%	R 0%
F 0%	HL 0%	HL 0%	L 0%	S 0%	S 0%
VF 0%	HL 0%	L 0%	S 0%	S 0%	S 0%
VVF 0%	HL 0%	L 0%	S 0%	S 0%	S 0%

HL =
(RVN AND (LVN OR LN OR LF OR LVF OR LVVF))
OR
(LF AND RN)

FUZZ-BOT Example

- HL = (RVN AND (LVN OR LN OR LF OR LVF OR LVVF)) OR (LF AND RN)
- L = (LN AND RN) OR (LF AND RF) OR ((LVF OR LVVF) AND RN)
- S = ((LVF OR LVVF) AND (RF OR RVF OR RVVF)) OR (LF AND (RVF OR RVVF))
- R and HR are left as an exercise to the student.

The Final Chapter...

De-Fuzzification

Defuzzification: Two Methods

1) Winner Take All

2) Weighted Average

Winner Take All

- Output “Hard Right” = 70%
- It is the winner!
- Output = **100** (from output mapping)
- Looses some of the smoothness of fuzzy logic.

Direction Output Mappings

•Hard Left = -100
•Left = -20
•Straight = 0
•Right = 20
•Hard Right = 100

Output of FAM

HL = 0%
L = 20%
S = 0%
R = 0%
HR = 70%

Weighted Average

- Output “Hard Right” = 70%
- Output “Left” = 20%
- Output = **73.3**

Direction Output Mappings

•Hard Left = -100
•Left = -20
•Straight = 0
•Right = 20
•Hard Right = 100

Output of FAM

HL = 0%
L = 20%
S = 0%
R = 0%
HR = 70%

Any Questions?