FUZZY LOGIC

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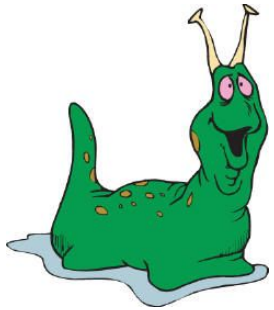
WHAT IS FUZZY LOGIC?

- Definition of fuzzy
  - Fuzzy – “not clear, distinct, or precise; blurred”
- Definition of fuzzy logic
  - A form of knowledge representation suitable for notions that cannot be defined precisely, but which depend upon their contexts.

TRADITIONAL REPRESENTATION OF LOGIC



Slow

Speed = 0

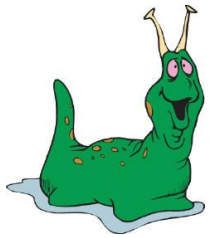
Fast

Speed = 1

```
bool speed;
get the speed
if ( speed == 0) {
    //  speed is slow
}
else {
    //  speed is fast
}
```

FUZZY LOGIC REPRESENTATION

- For every problem must represent in terms of fuzzy sets.
- What are fuzzy sets?



Slowest

[0.0 – 0.25]

Slow

[0.25 – 0.50]

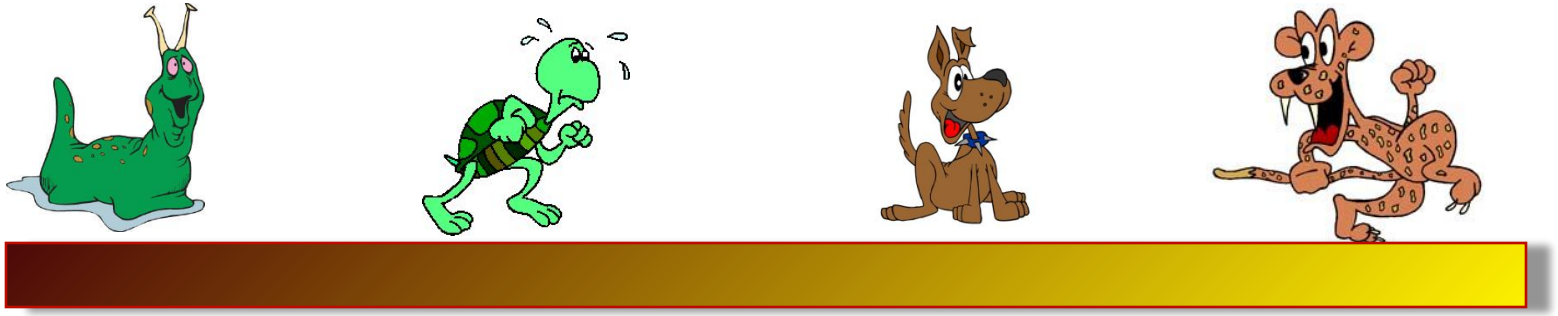
Fast

[0.50 – 0.75]

Fastest

[0.75 – 1.00]

FUZZY LOGIC REPRESENTATION CONT.



Slowest Slow Fast Fastest

```
float speed;
get the speed
if ((speed >= 0.0)&&(speed < 0.25)) {
     //  speed is slowest
}
else if ((speed >= 0.25)&&(speed < 0.5))
{
     //  speed is slow
}
else if ((speed >= 0.5)&&(speed < 0.75))
{
     //  speed is fast
}
else // speed >= 0.75 && speed < 1.0
{
     //  speed is fastest
}
```

ORIGINS OF FUZZY LOGIC

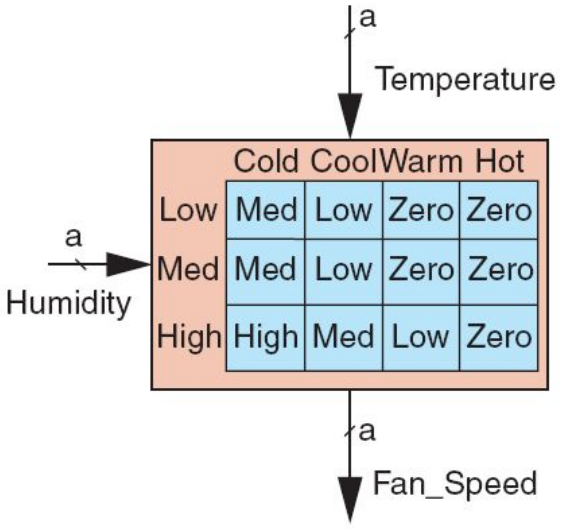
- Traces back to Ancient Greece
- Lotfi Asker Zadeh (1965)
  - First to publish ideas of fuzzy logic.
- Professor Toshire Terano (1972)
  - Organized the world's first working group on fuzzy systems.
- F.L. Smidth & Co. (1980)
  - First to market fuzzy expert systems.

FUZZY LOGIC IN CONTROL SYSTEMS

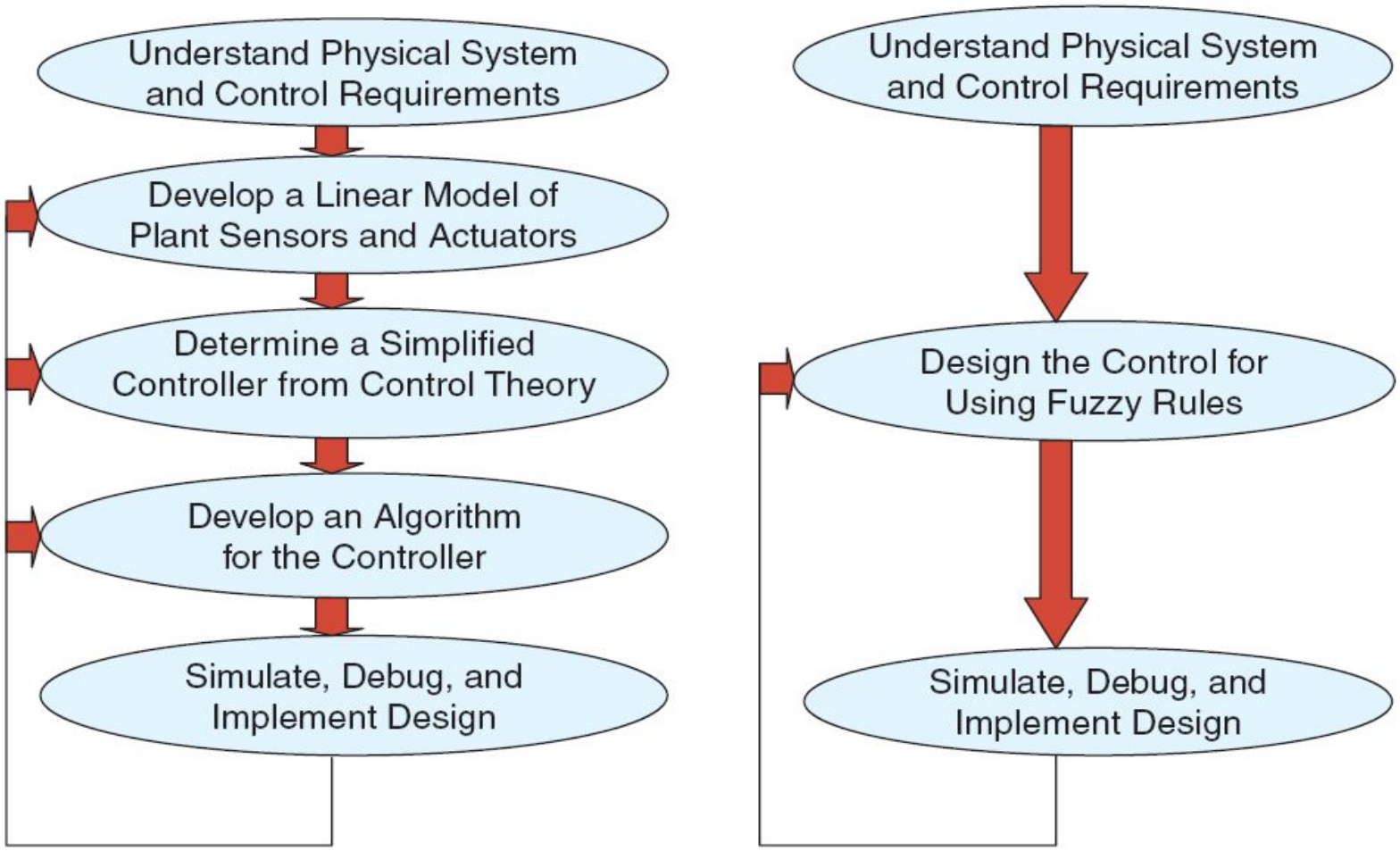
- Fuzzy Logic provides a more efficient and resourceful way to solve Control Systems.
- Some Examples
  - Temperature Controller
  - Anti – Lock Break System (ABS)

TEMPERATURE CONTROLLER

- The problem
  - Change the speed of a heater fan, based on the room temperature and humidity.
- A temperature control system has four settings
  - Cold, Cool, Warm, and Hot
- Humidity can be defined by:
  - Low, Medium, and High
- Using this we can define the fuzzy set.



BENEFITS OF USING FUZZY LOGIC



ANTI LOCK BREAK SYSTEM (ABS)

- Nonlinear and dynamic in nature
- Inputs for Intel Fuzzy ABS are derived from
  - Brake
  - 4 Wheel Drive
  - Feedback
  - Wheel speed
  - Ignition
- Outputs
  - Pulsewidth
  - Error lamp

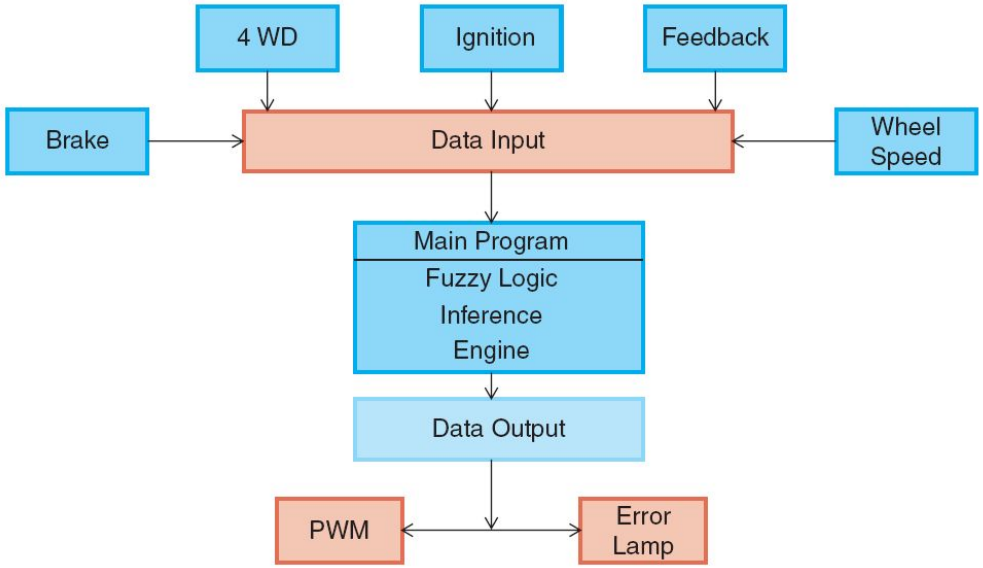


Fig. 6 ABS block diagram

FUZZY LOGIC IN OTHER FIELDS

- Business
- Hybrid Modeling
- Expert Systems

CONCLUSION

- Fuzzy logic provides an alternative way to represent linguistic and subjective attributes of the real world in computing.
- It is able to be applied to control systems and other applications in order to improve the efficiency and simplicity of the design process.

U=All Students

G=Good Students

B=Bad Students

- Remember: In fuzzy set all elements are in form of ordered pair

G={G, μ(G)}

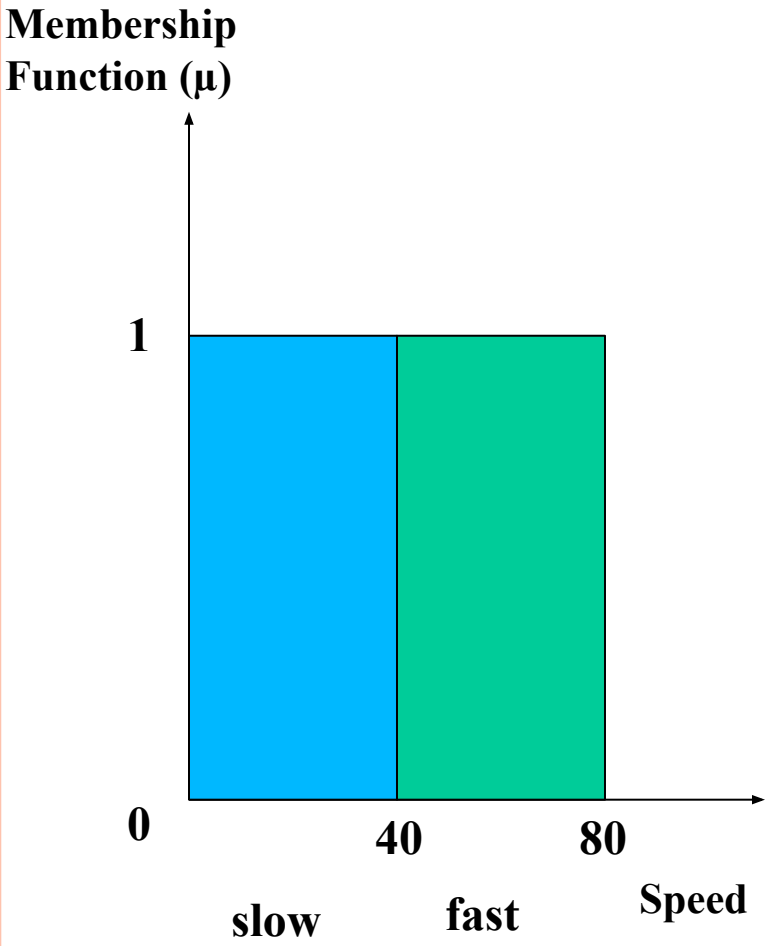
- μ is membership function and returns the membership value, i.e. degree of membership.
- Here μ() it measure degree of Goodness
- U={A, B, C, D}
- G={ (A,0.9), (B,0.7), (C,0.3), (D,0.2) }
- B={ (A,0.1), (B,0.3), (C,0.7), (D,0.8) }
- Member ship value tells that element is a member of this fuzzy set, higher membership value tells us that the corresponding element strongly belongs to the fuzzy set and vice-versa.

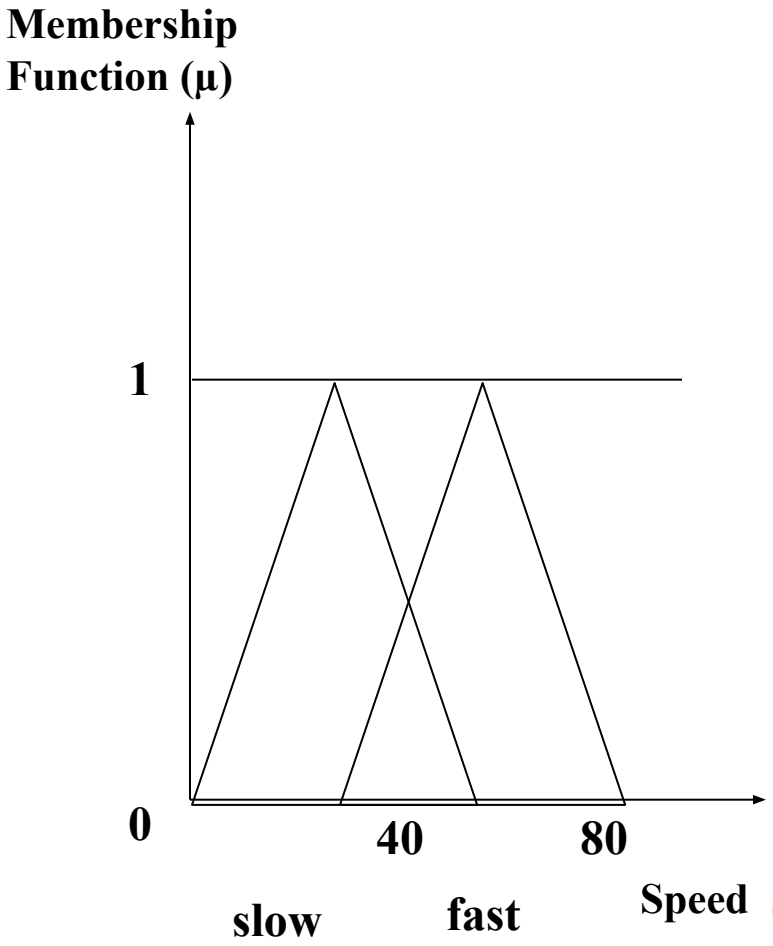
- In crisp set an element can only belongs to only one set not more than one as they have strict boundaries.

but

- In fuzzy set an element can belong to more than one set with different membership values.
- Fuzzy sets are more flexible while crisp sets are more restricted.
- Fuzzy logic represents the belongingness of a member of a crisp set to a fuzzy set

- If speed of car is 0-40 then speed is slow
- And if speed of car is 40-80 then speed is fast





- To check the degree of fastness
  - 0, if speed(x) ≤40
  - $\frac{\text{Speed(x)-40}}{10}$, if 40<speed(x)<50, Here 10 is interval between 40 and 50
  - 1, if speed(x)≥50

Let

1. speed(x)=30

   then 30 <40, So μ is 0,

   Therefore element in fuzzy set will be like (30,0)

2. speed(x)=60

   then 60 > 40, So μ is 1,

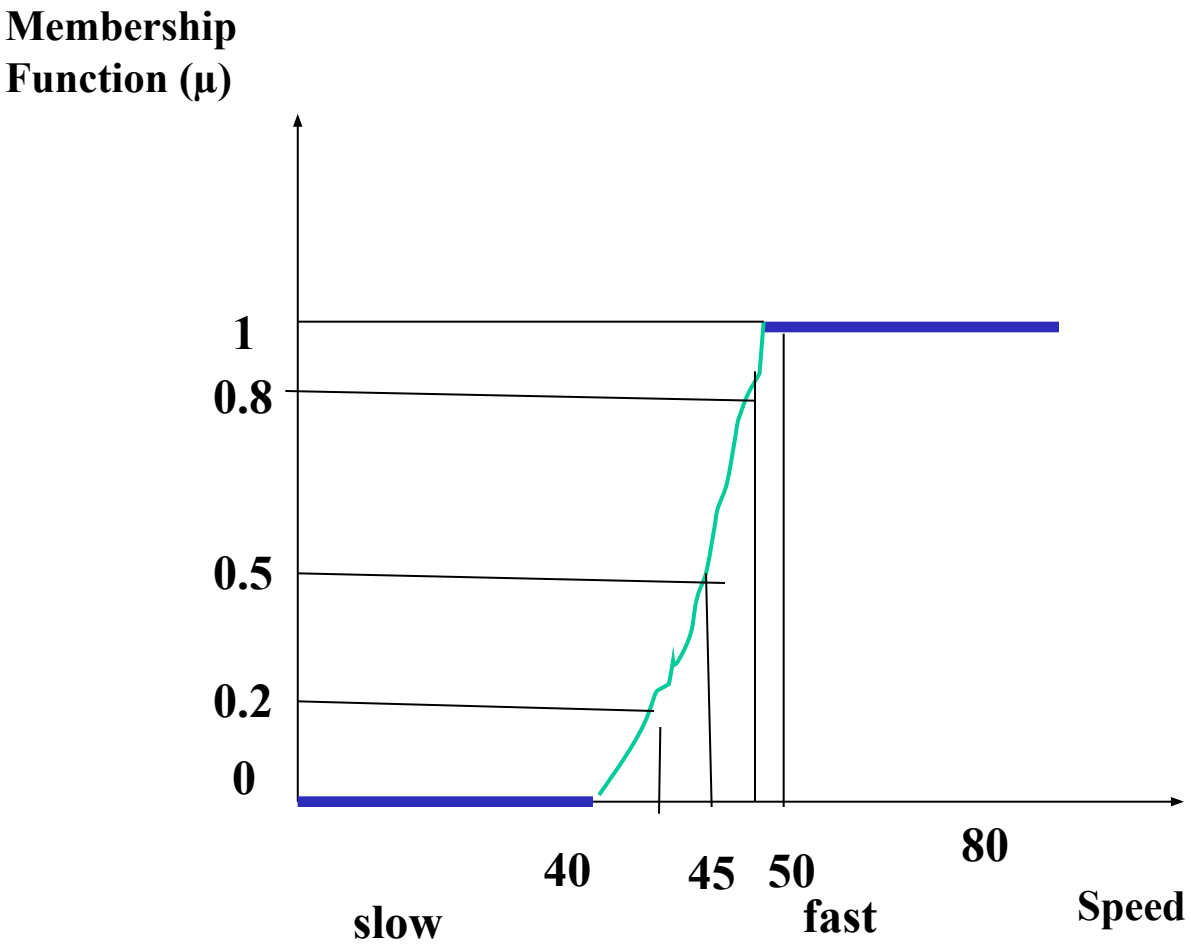
   Therefore element in fuzzy set will be like (60,1)

3. speed(x)=45

   then (45-40)/10, So μ is 0.5,

   So we can say speed is fast but upto the degree of 0.5

   Therefore element in fuzzy set will be like (45,0.5)

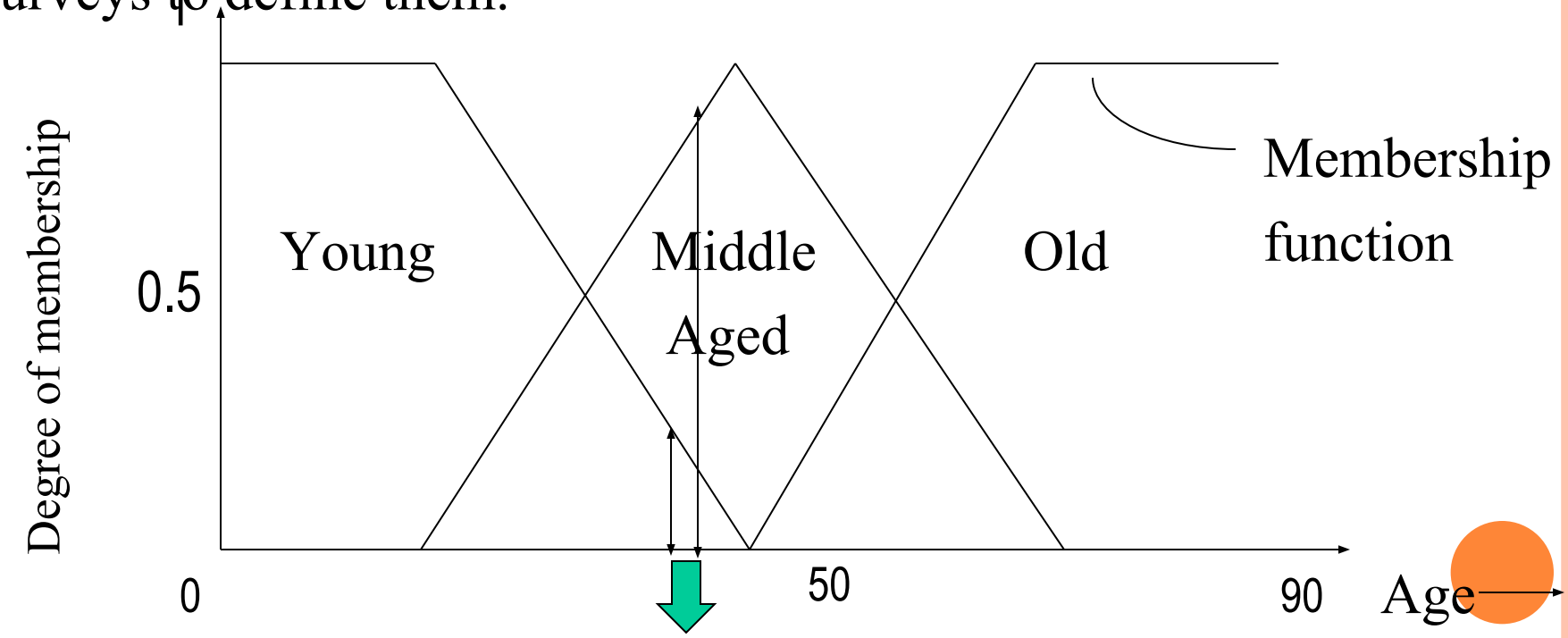

Membership
Function (μ)
1
0.8
0.5
0.2
0
40
45
50
80
slow
fast
Speed

Fuzzy Sets

We give things a degree of membership between 0 and 1 in several sets (to a combined total of 1).

We then label these sets using human terms.

Encapsulates terms with no consensus definition, but we might use surveys to define them.



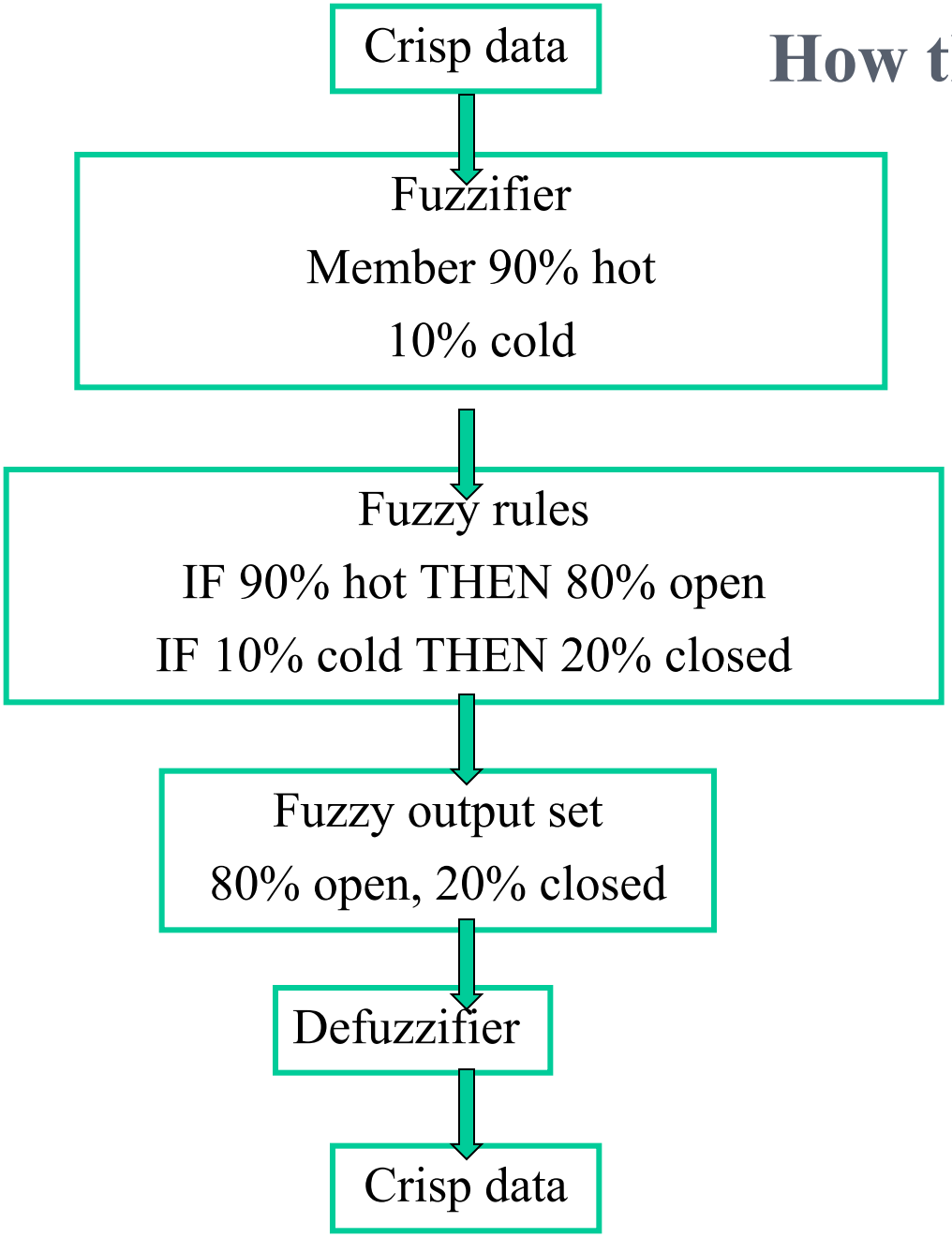
38yr old = 10% Young + 90% Middle Aged

Fuzzy Logic models

We give our variables membership functions, and express the variables as nouns (“length”, “temperature”) or adjectives (“long”, “hot”).

We can then build up linguistic equations (“IF length long, AND temperature hot, THEN openWindow”).

How the models work



Inputs converted to degrees of membership of fuzzy sets.

Fuzzy rules applied to get new sets of members.

These sets are then converted back to real numbers.

Uses in geography

Spatial Interaction: modelling flows between regions. Can capture the following kind of rules..

- If distance is SHORT then TRIPS are LOTS.
- If distance is MEDIUM then TRIPS are some.
- If distance is LONG then TRIPS are few.

GIS, remote sensing, land evaluation.

- Fuzzy viewsheds.
- Fuzzy GIS - expert system shell on an intelligent GIS.
- Classification of land cover (vegetation, soils) from satellite imagery.

fuzzy numbers

- A fuzzy number is a convex, normalized fuzzy set $\tilde{A} \subseteq \mathbb{R}$ whose membership function is at least segmentally continuous and has the functional value $\mu_A(x) = 1$ at least one element.
- This can be likened to the funfair game "guess your weight," where someone guesses the contestant's weight, with closer guesses being more correct, and where the guesser "wins" if he or she guesses near enough to the contestant's weight, with the actual weight being completely correct (mapping to 1 by the membership function).

fuzzy interval

- A fuzzy interval is an uncertain set $\tilde{A} \subseteq \mathbb{R}$ a mean interval whose elements possess the membership function value . As i$\mu_A(x) = 1$bers, the membership function must be convex, normalized, at least segmentally continuous.

Stochastic search

Sophisticated search techniques form the backbone of modern machine learning and data analysis. Computer systems that are able to extract information from huge data sets (data mining), to recognize patterns, to do classification, or to suggest diagnoses, in short, systems that are adaptive and — to some extent — able to learn, fundamentally rely on effective and efficient search techniques. The ability of organisms to learn and adapt to signals from their environment is one of the core features of life. Technically, any adaptive system needs some kind of search operator in order to explore a feature space which describes all possible configurations of the system.

Usually, one is interested in "optimal" or at least close to "optimal" configurations defined with respect to a specific application domain: the weight settings of a neural network for correct classification of some data, parameters that describe the body shape of an airplane with minimum drag, a sequence of jobs assigned to a flexible production line in a factory resulting in minimum idle time for the machine park, the configuration for a stable bridge with minimum weight or minimum cost to build and maintain, or a set of computer programs that implement a robot control task with a minimum number of commands.

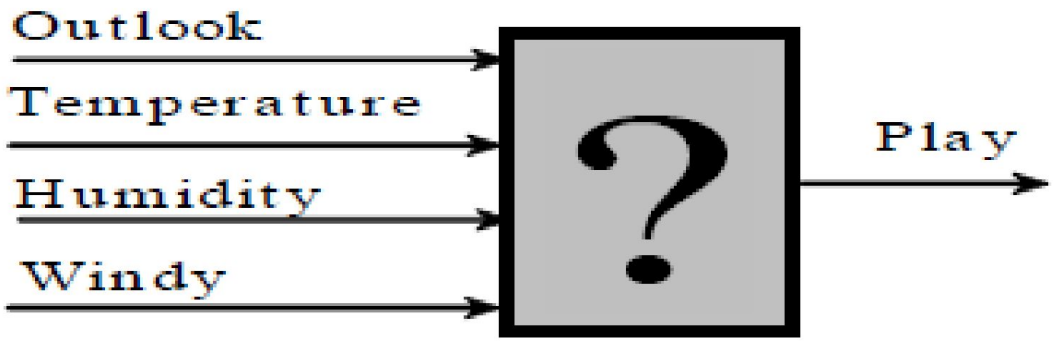
stochastic search methods

- Desired properties of search methods:
  - – high probability of finding near-optimal solutions (effectiveness)
  - – short processing time (efficiency)
- They are usually conflicting; a compromise is offered by stochastic techniques where certain steps are based on random choice
- Many stochastic search techniques are inspired by processes found in nature

  Examples are arranging molecules as regular, crystal structures at appropriate temperature reduction, creating adaptive, learning organisms through biological evolution

fuzzy decision trees

- Decision Support Systems are a specific class of computer-based information systems that support your decision-making activities.
- A decision support system analyzes data and provide interactive information support to professionals during the decision-making process.



Decision Trees

- A *decision tree* T encodes d (a classifier or regression function) in form of a tree.
- A node t in T without children is called a *leaf node*. Otherwise t is called an *internal node*.
- Each internal node has an associated *splitting predicate*. Most common are binary predicates. Example predicates:
  - Age <= 20
  - Profession in {student, teacher}
  - 5000*Age + 3*Salary – 10000 > 0

Internal Nodes: Splitting Predicates

- Binary Univariate splits:
  - Numerical or ordered X: X <= c, c in dom(X)
  - Categorical X: X in A, A subset dom(X)
- Binary Multivariate splits:
  - Linear combination split on numerical variables:

    Σ aiXi <= c
- k-ary (k>2) splits analogous

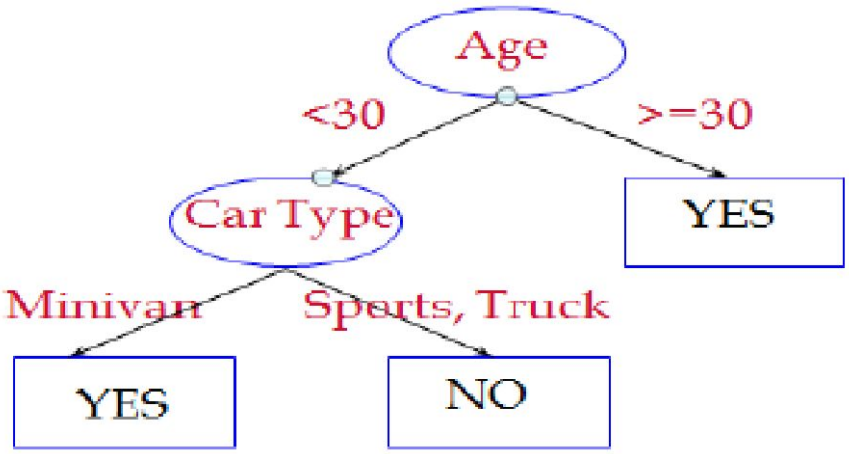
- **Leaf Nodes**

Consider leaf node t

- Classification problem: Node t is labeled with one class label c in dom(C)
- Regression problem: Two choices
  - Piecewise constant model:

    t is labeled with a constant y in dom(Y).
  - Piecewise linear model: t is labeled with a linear model

    $Y = yt + \Sigma aiXi$



Encoded classifier:

If (age<30 and
carType=Minivan)
Then YES

If (age <30 and
(carType=Sports or
carType=Truck))
Then NO

If (age >= 30)
Then NO

- **Classification Algorithms**
- Tree-structure classifiers:
  - IND, S-Plus Trees, C4.5, FACT, QUEST, CART, OC1, LMDT, CAL5, T1
- Statistical methods:
  - LDA, QDA, NN, LOG, FDA, PDA, MDA, POL
- Neural networks:
  - LVQ, RBF