# Introduction to Artificial Intelligence

Unit # 16



## Course Outline

- Overview of Artificial Intelligence ✔
- State Space Representation ✔
- Search Techniques ✔
- AI in Games ✔
- Machine Learning ✔
- Propositional and Predicate Logic ✔
- Probabilistic Reasoning ✔
- ~~Introduction to Robotics~~ (To be taught separately)
- Evolutionary Algorithms ✔
- Ant Colony Optimization ✔
- Fuzzy Logic

## What is Fuzzy Logic*

- Definition of Fuzzy
  - Fuzzy: “not clear, distinct, or preicse; blurred”
- Definition of Fuzzy Logic
  - A form of knowledge representation suitable for notations that cannot be defined precisely but which depend upon their contexts.

* Source: Shane Warren, Brittney Ballard @ University of Nevada, Reno



## Examples of Fuzzy Concepts from Natural Language*

- John is tall
- The weather is rainy
- Turn the volume up a little
- Dr. Bridges’ tests are long
- Add water until the dough is the right consistency
- There was very little change in the cost
- The water bill was somewhat high

* Source: Susan Bridges @ Mississippi State University

# Some Fuzzy Background*

Lofti Zadeh has coined the term "Fuzzy Set" in 1965 and opened a new field of research and applications
A Fuzzy Set is a class with different degrees of membership. Almost all real world classes are fuzzy!
Examples of fuzzy sets include: {'Tall people'}, {'Nice day'}, {'Round object'} …

If a person's height is 1.88 meters is he considered 'tall'?

What if we also know that he is an NBA player?

* Source: Raphael Steinberg @ Technion University



# Linguistic (or Fuzzy) Variable*

- Usually corresponds to a noun
- The values of a linguistic variable are fuzzy sets (which corresponds to adjectives)
- Examples

| Linguistic Variable | Fuzzy Sets |
|---|---|
| Height | Short Medium Tall |
| Weight | Light Average Heavy |
| Temperature | Cold Cool Typical Warm Hot |
| Speed | Slow Medium Fast |

* Source: Susan Bridges @ Mississippi State University

## Example of Linguistic Imprecision*
*Unusual and Real-Life Quotes*

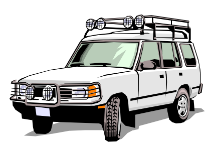
- How was the weather like yesterday?
- Oh! It was rainy with 98% humidity and hot with temperature of 35.5 deg C
- Oh! It was very humid and really hot.

Fuzzy logic can handle such linguistic imprecision
where other techniques have difficulty in handling

* Source: University Malaysian Pahang



## Fuzzy logic can handle linguistic imprecision where other techniques have difficulty in handling*



- When you are at 10 metres from the junction start braking at 50% pedal level.
- When you are near the junction, start braking slowly.

* Source: University Malaysian Pahang

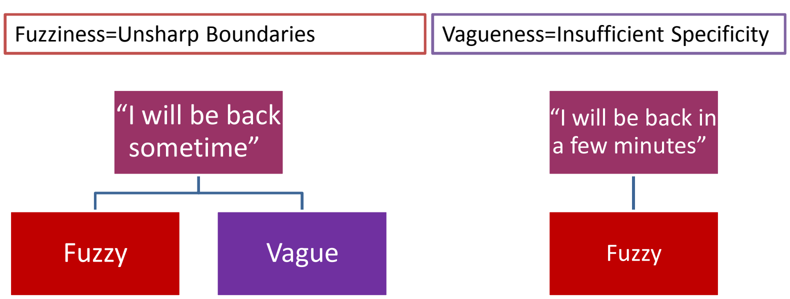
# Uncertainty vs Vagueness*

- Certainty – degree of belief
  - There is a 50% probability of rain today
  - I am 30% sure the patient is suffering from pneumonia
- Vaugeness – the degree to which an item belongs to a category
  - The man is tall
  - Move the wheel slightly to the left
  - The patient's lungs are highly congested

* Source: Susan Bridges @ Mississippi State University



# Fuzziness Vs. Vagueness*




* Source: Raphael Steinberg @ Technion University

## Some important points to note*

- Fuzziness is connected with the degree to which events occur rather than the likelihood of their occurrence (probability).
- For example, the degree to which a person is young is a fuzzy event rather than a random event.

* Source: University Malaysian Pahang



## Fuzzy Thinking*

- Not logic that is fuzzy, but logic that used to describe fuzziness; the theory of fuzzy sets, sets that calibrate vagueness
- Based on idea that all things admit of degree
  – Eg: Temperatures, height, speed

* Source: University Malaysian Pahang

## Bivalent Logic

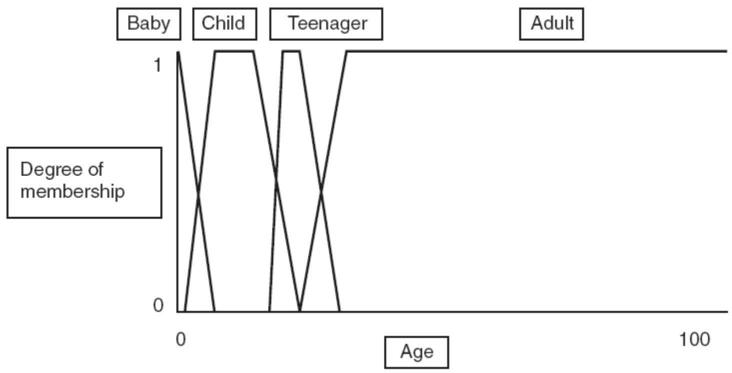
- In classical logic, which is often described as Aristotelian logic, there are two possible truth values: propositions are either true or false.
- Such systems are known as **bivalent logics because they involve two logical values.**
- The logic employed in Bayesian reasoning and other probabilistic models is also bivalent: each fact is either true or false, but it is often unclear whether a given fact is true or false.
- Probability is used to express the likelihood that a particular proposition will turn out to be true.



## Example

- Bill is 7 feet tall, and so it is pretty clear that he is included in the set of tall people.
- John is only 4 feet tall, and so most would say that he is not included in the set.
- What about Jane, who is 5 feet 10 inches tall? Some would certainly say she is tall, but others would say she is not.
- The fuzzy set of tall people contains Bill, and it also contains Jane, and it even contains John.
- Each is a member of the set to some degree and is not a member of the set to some degree.

# Degree of Membership

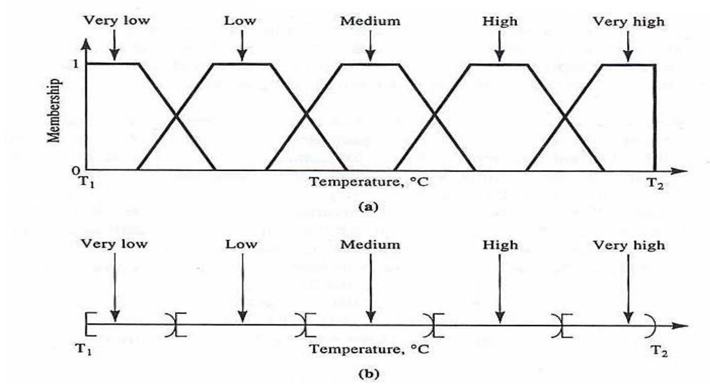





# Definitions

- **Error** is the difference between the exact value (a real number) and a value at hand (an approximation).
- **Precision** is the maximum number of digits that are used to measure an approximation. It is the property of the instrument that is being used to measure or calculate the (exact) value.
- **Accuracy** is the number of correct digits in an approximation.
- **Ambiguity:** a one to many relationship; for example, she is tall, he is handsome. There are a variety of alternatives
  - **Non-specificity:** Suppose one has a heart blockage and is prescribed a treatment. In this case "treatment" is a non-specificity in that it can be an angioplasty, medication, surgery (to name three alternatives).
  - **Dissonance/contradiction:** One physician says to operate and another says go to Myrtle Beach.
- **Vagueness:** lack of sharp distinction or boundaries, our ability to discriminate between different states of an event, undecidability (is a glass half full/empty)

# Crisp vs. Fuzzy Variable



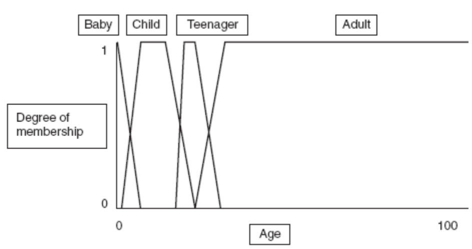

Temperature in the range $[T_1, T_2]$ conceived as: (a) a fuzzy variable; (b) a traditional (crisp) variable.



# Example of a Fuzzy Variable

$$M_B(x) = \begin{cases} 1 - \frac{x}{2} & for\ x \le 2 \\ 0 & for\ x > 2 \end{cases}$$

$$M_C(x) = \begin{cases} \frac{x-1}{6} & for\ x \le 7 \\ 1 & for\ x > 7\ and\ x \le 8 \\ \frac{14-x}{6} & for\ x > 8 \end{cases}$$




- We represent a fuzzy set using a list of pairs, where each pair represents a value and the fuzzy membership value for that value.
- For example, we might define *B*, the fuzzy set of babies as follows:
  - *B* = {(0, 1), (2, 0)}
- Similarly,we could define the fuzzy set of children,*C*, as follows:
  - *C* = {(1, 0), (7, 1), (8, 1), (14, 0)}

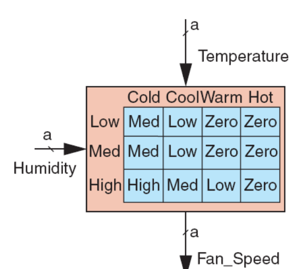
# Fuzzy Set Operations

- In classical logic
  - A V ¬A = True
  - A Λ ¬A = False
- In fuzzy logic, these do not hold - A V ¬A can be, to some extent, false, and A Λ ¬A can to some extent be true.
- Union:  A V B = MAX(A, B)
- Intersection: A Λ B = MIN(A, B)
- Complement: ¬A = 1 – A
  - Compliment of C: {(1, 0), (7, 1), (8, 1), (14, 0)} = ?



# Temperature Controller

- The Problem
  - Change the speed of a heater fan, based off 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 defined the fuzzy set




* Source: Shane Warren, Brittney Ballard @ University of Nevada, Reno

# Fuzzy Inference

Let us suppose that we are designing a simple braking system for a car, which is designed to cope when the roads are icy and the wheels lock.

The rules for our system might be as follows:

Rule 1 IF pressure on brake pedal is medium
THEN apply the brake

Rule 2 IF pressure on brake pedal is high
AND car speed is fast
AND wheel speed is fast
THEN apply the brake

Rule 3 IF pressure on brake pedal is high
AND car speed is fast
AND wheel speed is slow
THEN release the brake

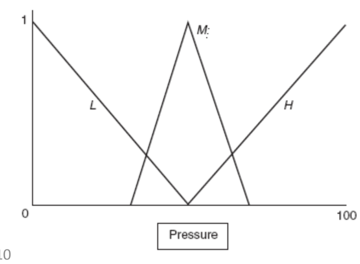
Rule 4 IF pressure on brake pedal is low
THEN release the brake

For this simple example, we will assume that brake pressure is measured from 0 (no pressure) to 100 (brake fully applied). We will define brake pressure as having three linguistic values: high ($H$), medium ($M$), and low ($L$), which we will define as follows:

$H = \{(50, 0), (100, 1)\}$

$M = \{(30, 0), (50, 1), (70, 0)\}$

$L = \{(0, 1), (50, 0)\}$






# Fuzzy Inference

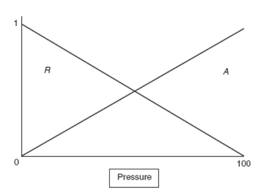
Similarly, we must consider the wheel speed. We will define the wheel speed as also having three linguistic values: slow, medium, and fast. We will define the membership functions for these values for a universe of discourse of values from 0 to 100:

$S = \{(0, 1), (60, 0)\}$

$M = \{(20, 0), (50, 1), (80, 0)\}$

$F = \{(40, 0), (100, 1)\}$

For the sake of simplicity, we will define the linguistic variable *car speed* using the same linguistic values ($S$, $M$, and $F$ for slow, medium, and fast), using the same membership functions. Clearly, in a real system, the two would be entirely independent of each other.



# Fuzzy Inference

- In a given situation, pressure value is 60, wheel speed is 55, and the car speed is 80.
  - $M_L(60) = 0.0$
  - $M_M(60) = 0.5$
  - $M_H(60) = 0.2$
  - $M_S(55) = 0.083$
  - $M_M(55) = 0.833$
  - $M_F(55) = 0.250$
  - $M_S(80) = 0.0$
  - $M_M(80) = 0.0$
  - $M_F(80) = 0.667$



# Defuzzification

- Fuzzy values obtained from the four rules are:
  - **Rule 1: 0.5**
  - Rule 2: Min(0.2, 0.667, 0.25) = 0.2
  - Rule 3: Min(0.2, 0.667, 0.083) = 0.083
  - Rule 4: 0
- The process of obtaining a crisp value from a set of fuzzy variables is known as **defuzzification**.