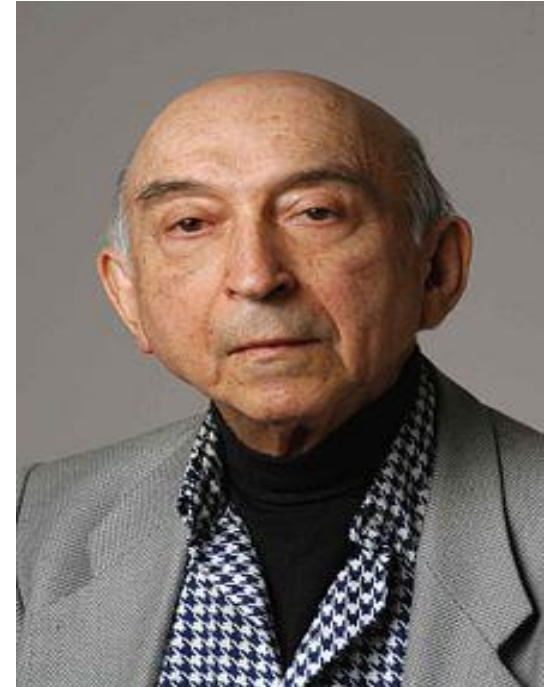# Fuzzy Logic In AI

Prof. Dr. A K M Akhtar Hossain

Dept. of CSE, RU

Fuzzy Logic History

- The term *fuzzy logic* was introduced by **Lotfi A. Zadeh** in the year **1965.**

    Lotfi Aliasker Zadeh was born in 4 February 1921 in Baku, Azerbaijan, SSR.

What is Fuzzy Logic?

- **Fuzzy logic** is a form of **many-valued logic** in which the truth values of variables may be any real number between 0 and 1, considered to be "fuzzy".

- In Boolean logic, the truth values of variables may only be 0 or 1, often called "crisp" values.

- **Fuzzy logic has been employed to handle the concept of partial truth, where the truth value may range between completely true and completely false.**

- Furthermore, when linguistic variables are used, these degrees may be managed by specific (membership) functions.

Fuzzy logic

- Fuzzy logic is a branch of fuzzy set theory, which deals with the representation and inference from knowledge. Fuzzy logic, unlike other logical systems, deals with imprecise or uncertain knowledge.

- In this narrow, and perhaps correct sense, fuzzy logic is just one of the branches of fuzzy set theory.

Fuzzy Applications

- Pattern recognition and classification
- Fuzzy clustering
- Image and speech processing
- Fuzzy systems for prediction
- Fuzzy control
- Monitoring
- Diagnosis
- Optimization and decision making
- Group decision making
- **Washing machines**
- **Electric Fan**; etc.

Applications

- **Washing machines** now use fuzzy logic. They can sense how heavy a load is and determine the correct amount of water and detergent, speed of agitation, and length of the wash cycles.

- There is no single standard for the dirty laundry. Fuzzy logic enables the machine's computer to make "in between" decisions.

Example:

- **Words like young, tall, good, or high are fuzzy.**

❑ There is no single quantitative value which defines the term **young**.

❑ For some people, age **25 is young**, and for others, **age 35 is young.**

❑ The concept young has no clean boundary.

❑ Age 1 is definitely **child** and age 100 is definitely **not child**;

❑ Age 35 has some possibility of being young and usually depends.

- **On the context in which it is being considered.**

Examples: Fuzzy Linguistic variables

- Fuzzy sets and concepts are commonly used in natural language :-
- John is tall.
- Dan is smart.
- Alex is happy .
- Today is hot .
- Car runs faster.

Fuzzy set theory

- Fuzzy set theory is an extension of classical set theory where elements have varying degrees of membership.

- A logic based on the two truth values, *True and False, is sometimes inadequate when* describing human reasoning.

- Fuzzy logic uses the whole interval between **0 (false) and 1 (true) to describe human reasoning.**

A **Fuzzy Set**

- A **Fuzzy Set is any set that allows its members to have different** degree of membership, called **membership function**, *in the interval*

  [0 , 1].

- The **degree of membership or truth is not same as probability;**

❑ fuzzy truth is not likelihood of some event or condition.

❑ fuzzy truth represents membership in vaguely defined sets;

Fuzzy logic

- **Fuzzy logic is derived from fuzzy set theory dealing with reasoning** that is approximate rather than precisely deduced from classical predicate logic.

- Fuzzy logic is capable of handling inherently imprecise concepts.

- Fuzzy logic allows in linguistic form the set membership values to imprecise concepts like **"slightly", "quite" and "very".**

- Fuzzy set theory defines Fuzzy Operators on Fuzzy Sets.

Crisp and Non-Crisp Set

The notations used to express these mathematically are

$$A : X \rightarrow [0, 1]$$

$$A(x) = 1, \quad x \text{ is a member of } A$$

$$A(x) = 0, \quad x \text{ is not a member of } A$$

Eq.(1)

Crisp and Non-Crisp Set

Alternatively, the set **A** can be represented for all elements $x \in X$ by its characteristic function $\mu_A(x)$ defined as

$$\mu_A(x) = \begin{cases} 1 & \text{if } x \in X \\ 0 & \text{otherwise} \end{cases} \qquad \text{Eq.(2)}$$

Thus in classical set theory $\mu_A(x)$ has only the values **0** ('false') and **1** ('true''). Such sets are called **crisp sets.**

Non-Crisp Set

– For Non-crisp sets the characteristic function $\mu_A(x)$ can be defined.

  ▪ The characteristic function $\mu_A(x)$ of Eq. (2) for the crisp set is generalized for the Non-crisp sets.

  ▪ This generalized characteristic function $\mu_A(x)$ of Eq.(2) is called **membership function**.

  Such Non-crisp sets are called **Fuzzy Sets**.

– Crisp set theory is not capable of representing descriptions and classifications in many cases; In fact, Crisp set does not provide adequate representation for most cases.

Crisp and Non-Crisp Value
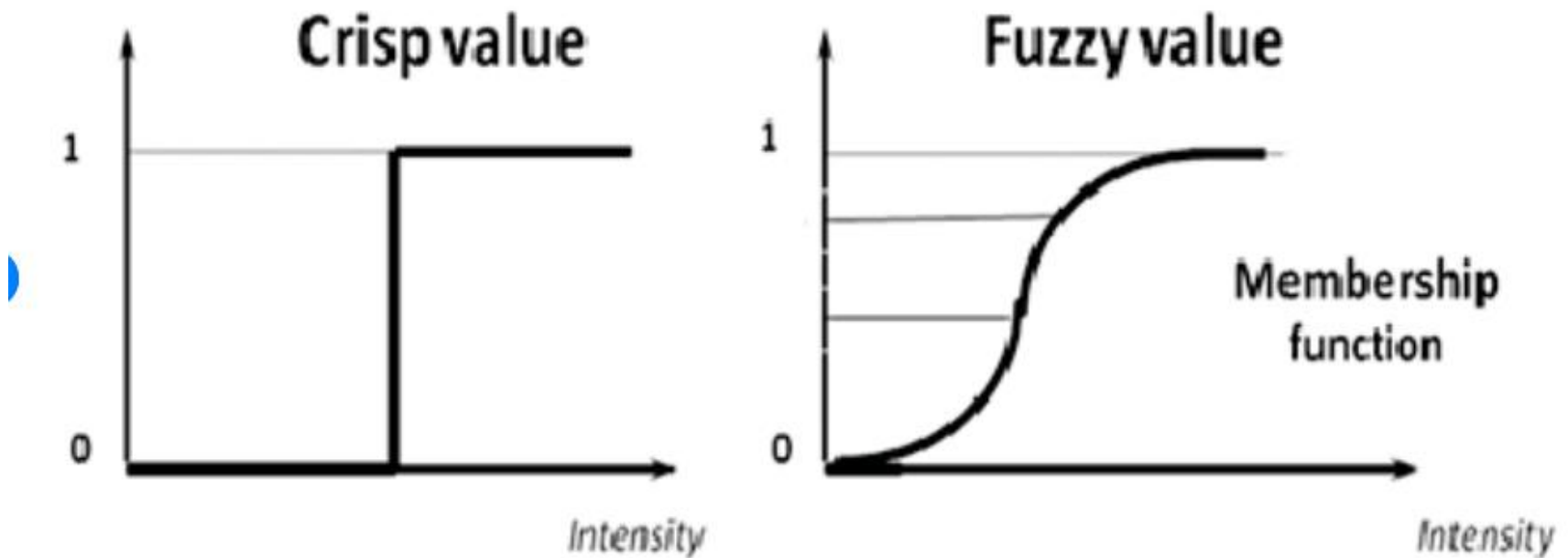
Difference between Crisp and Fuzzy Sets.

More Definitions (On Fuzzy Logic)

- Fuzzy logic is a set of mathematical principles for knowledge representation based on **degrees of membership**.

- Unlike two-valued Boolean logic, fuzzy logic is **multi-valued**. It deals with **degrees of membership** and **degrees of truth**.

- Fuzzy logic uses the continuum of logical values between 0 (completely false) and 1 (completely true). Instead of just black and white, it employs the spectrum of colours, accepting that things can be partly true and partly false at the same time.

| 0 | 0 | 0 | 1 | 1 | 1 |

(*a*) Boolean Logic.

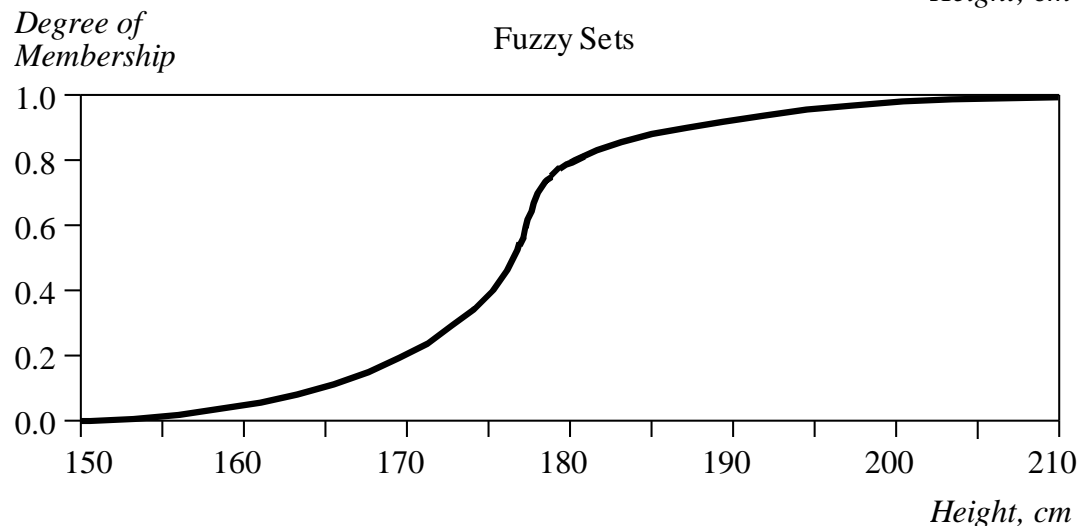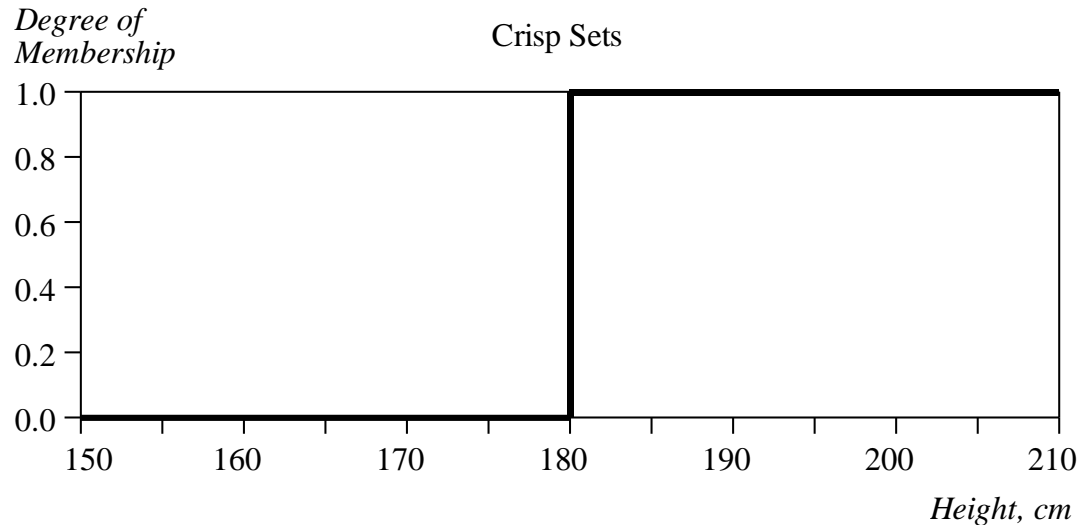| 0 | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1 |
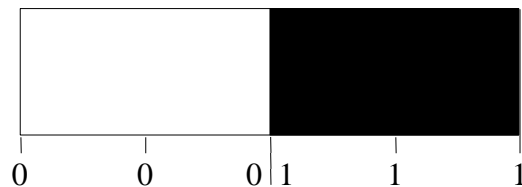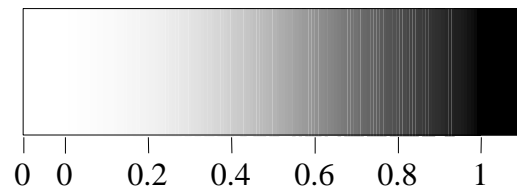
(*b*) Multi-valued Logic.

Crisp Vs Fuzzy Sets

The x-axis represents the **universe of discourse** – the range of all possible values applicable to a chosen variable. In our case, the variable is the man height. According to this representation, the universe of men's heights consists of all tall men.

The y-axis represents the **membership value of the fuzzy set**. In our case, the fuzzy set of "tall men" maps height values into corresponding membership values.

Degree of Membership   Crisp Sets

1.0
0.8
0.6
0.4
0.2
0.0
150   160   170   180   190   200   210

Height, cm

Degree of Membership   Fuzzy Sets

1.0
0.8
0.6
0.4
0.2
0.0
150   160   170   180   190   200   210

Height, cm

Example: Fuzzy Sets

- **Hard science with IF-THEN rules:-**

- Example:- The logic for a simple temperature regulator that uses a fan might look like this:-

Example:

- IF temperature is **very cold** THEN **stop fan**
- IF temperature is **cold** THEN fan speed is **zero**
- IF temperature is **warm** THEN fan speed is **moderate**
- IF temperature is **hot** THEN fan speed is **high**

- **THE END**

- **Thanks**