

Fuzzy Logic In AI

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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

- Topology;
- Linguistics;
- Automata theory;
- Game theory;
- Pattern recognition;
- Medicine;
- Law;
- Decision support;
- Information retrieval; etc.

Fuzzy Logic History

- The term *fuzzy logic* was introduced with the 1965 proposal of fuzzy set theory by Lotfi A. Zadeh.

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 young and age 100 is definitely not young;
 - ❑ Age 35 has some possibility of being young and usually depends.
- on the context in which it is being considered.

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

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

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

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

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

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

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

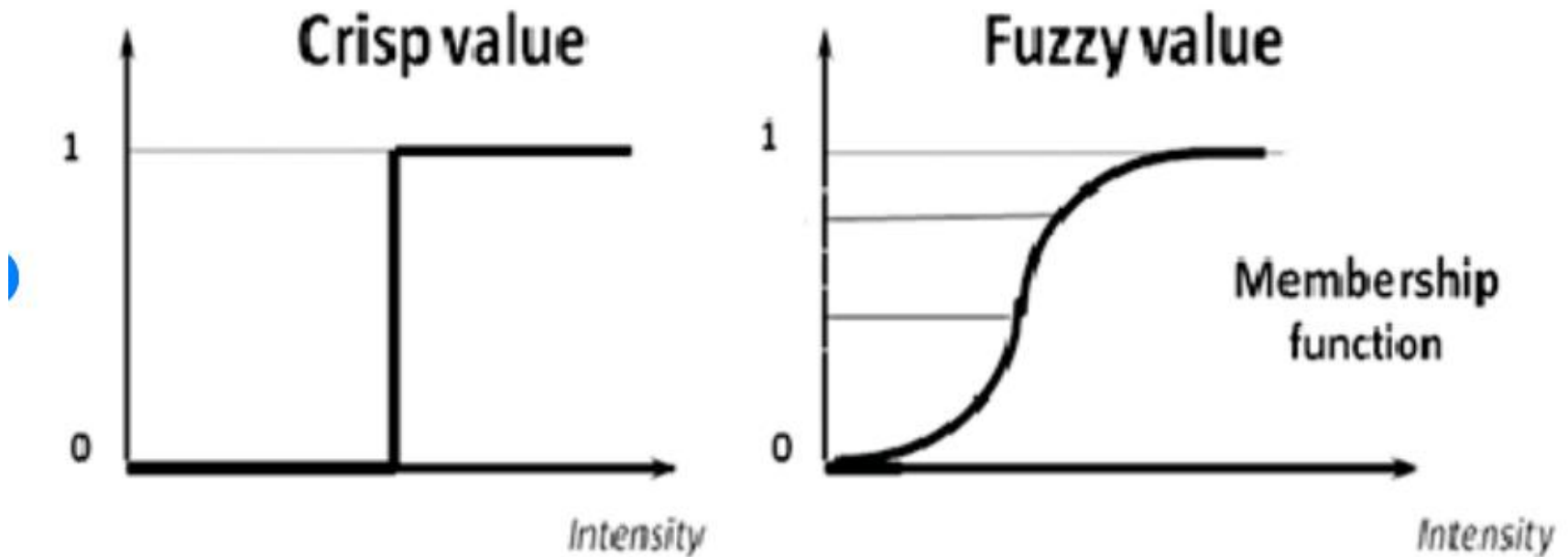
Non-Crisp Set

- 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.

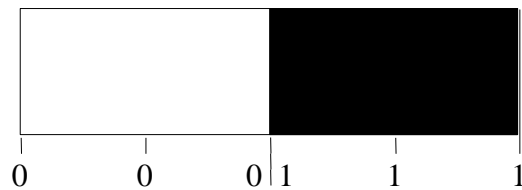
Crisp and Non-Crisp Value



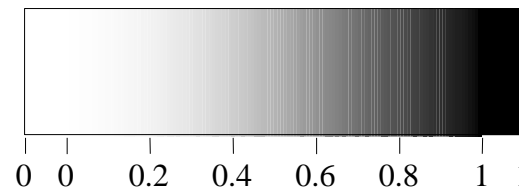
Difference between Crisp and Fuzzy Sets.

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.



(a) Boolean Logic.

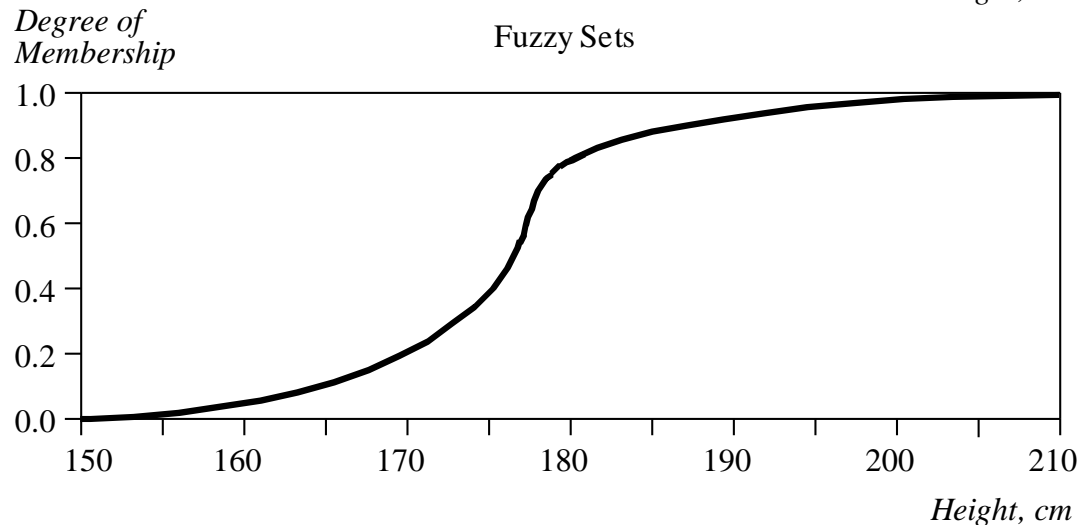
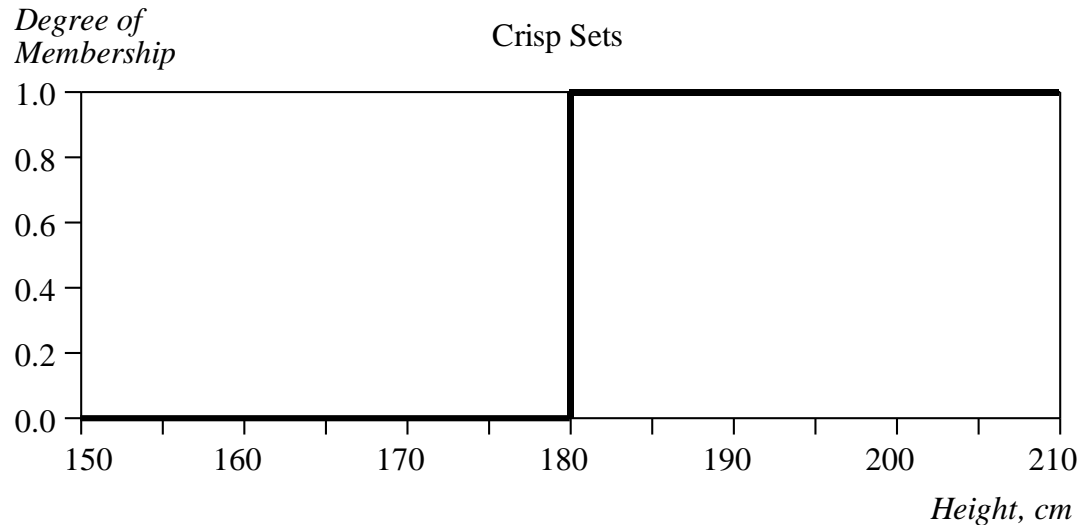


(b) Multi-valued Logic.

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.



Example: Fuzzy Sets

- **Hard science with IF-THEN rules**
- For example, the logic for a simple temperature regulator that uses a fan might look like this:

- 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**

Characteristics of Fuzzy Logic

Following are the characteristics of fuzzy logic:-

- This concept is flexible and we can easily understand and implement it.
- It is used for helping the minimization of the logics created by the human.
- It is the best method for finding the solution of those problems which are suitable for approximate or uncertain reasoning.

Characteristics of Fuzzy Logic

- It always offers two values, which denote the two possible solutions for a problem and statement.
- It allows users to build or create the functions which are non-linear of arbitrary complexity.
- In fuzzy logic, everything is a matter of degree.
- In the Fuzzy logic, any system which is logical can be easily fuzzified.
- It is based on natural language processing.

Characteristics of Fuzzy Logic

- It is also used by the quantitative analysts for improving their algorithm's execution.
- It also allows users to integrate with the programming.