Inefficiency of Computers

why can't the computers do what we want them to?

- Problems in engineering software: specification, design, and testing.
- Algorithms (the basis of computer programs) cannot deal with partial information, with uncertainty.
- Much of human information processing relies significantly on approximate reasoning.

Soft Computing

- Soft computing differs from conventional (hard) computing in that:" Its tolerance to imprecision, uncertainty, partial truth, and approximation.
- The model for soft computing is the human mind.
- The guiding principle of soft computing is: Exploit the tolerance for **imprecision**, **uncertainty**, **partial truth**, and **approximation** to achieve tractability, robustness and low solution cost.
- Soft computing is used as an umbrella term for sub-disciplines of computing, including fuzzy logic and fuzzy control, neural networks based computing and machine learning, and genetic algorithms, together with chaos theory in physics.

Fuzzy Systems

- Example: Motion Detection

Suppose we create a robot that will react to certain situations, displaying emotions. We will deal

with the motion of "intruders" relative to the robot. We wish it to have the following basic emotions:

Perception	Emotion
If the intruder is far away	no fear
If the intruder is near	no surprise
If the intruder is stationary	no fear
If the intruder is moving fast	no anger

near and far are quite relative terms, as is fast.

The solution to the above problem of computers is soft computing

Examples of Fuzzy Controllers

- Fuzzy Logic washing machine: Fuzzy Logic detects the type and amount of laundry in the

drum and allows only as much water to enter the machine as is really needed for the loaded amount.

- less water will heat up quicker
- less time
- less energy consumption.

Other Applications:

- ✓ Food cookers
- ✓ Cars

Introduction to Fuzzy Logic

Fuzzy logic is being developed as a discipline to meet two objectives:

- As a professional subject dedicated to the building of systems of high utility - for example fuzzy control.
- As a theoretical subject - fuzzy logic is a symbolic logic with a comparative notion of truth

  developed fully in the spirit of classical logic. It may be considered branch of many-valued logic based on the paradigm of inference under vagueness.

Fuzzy Logic

- superset of Boolean logic that has been extended to handle the concept of partial truth
- central notion of fuzzy systems is that truth values (in fuzzy logic) or membership values (in fuzzy sets) are indicated by a value on the range [0.0, 1.0], with 0.0 representing absolute Falseness and 1.0 representing absolute Truth. deals with real world vagueness

Fuzzy Logic

Fuzzy Logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise.

Fuzzy logic is not a vague logic system, (Not a logic that is fuzzy) but a system of logic for dealing with vague concepts (able to describe fuzziness)

As in fuzzy set theory the set membership values can range (inclusively) between 0 and 1, in

fuzzy logic the degree of truth of a statement can range between 0 and 1 and is not constrained to

the two truth values true/false as in classic predicate logic.

Fuzzy Logic

Fuzzy logic reflects how people think. It attempts to model our sense of words, our decision making and our common sense. As a result, it is leading to new, more "human", intelligent systems

Boolean logic uses sharp distinctions between sets.

For instance, we may say, H is tall because his height is 181 cm. If we said tall people starts from 180 cm. we would find that D, who is 179 cm, is small. Is D really a small man or we have just drawn an arbitrary line in the sand?

Helpful Textbook

An introduction to Fuzzy Logic and Fuzzy sets
By
J.J. Buckley and E.Eslami

Multi-Valued Logic

Multi-valued logic was introduced in the 1930s by **Jan Lukasiewicz**, a Polish philosopher. While classical logic operates with only two values 1 (true) and 0 (false), Lukasiewicz introduced logic that extended the range of truth values to three numbers in the interval between 0 and 1. He used a number in this interval to represent the *possibility* that a given statement was true or false. For example, the possibility that a man 181 cm tall is really tall might be set to a value of 0.86. It is *likely* that the man is tall. This work led to an inexact reasoning technique often called **possibility theory**.

Introduction to Fuzzy Logic

- Fuzzy, or "multi-valued" logic was introduced in the 1930s by **Jan Lukasiewicz**, a Polish philosopher. While classical logic operates with only two values 1 (true) and 0 (false), Lukasiewicz introduced logic that extended the range of truth values to all real numbers in the interval between 0 and 1. He used a number in this interval to represent the ***possibility*** that a given statement was true or false. For example, the possibility that a man 181 cm tall is really tall might be set to a value of 0.86. It is ***likely*** that the man is tall. This work led to an inexact reasoning technique often called **possibility theory**.

Introduction to Fuzzy Logic

- Later, in 1937, **Max Black** published a paper called "Vagueness: an exercise in logical analysis". He argued that a continuum implies degrees.
- He accepted **vagueness as a matter of probability**.

Introduction to Fuzzy Logic

- In 1965 **Lotfi Zadeh**, published his famous paper "Fuzzy sets". Zadeh extended the work on possibility theory into a formal system of mathematical logic, and introduced a new concept for applying natural language terms. This new logic for representing and manipulating fuzzy terms was called **fuzzy logic**, and Zadeh became the Master of ***fuzzy logic***.

Introduction to Fuzzy Logic

- ***Why fuzzy?***

  As Zadeh said, the term is concrete, immediate and descriptive; we all know what it means.

  Many people –Until now- were repelled by the word ***fuzzy***, because it is usually used in a negative sense.
- ***Why logic?***

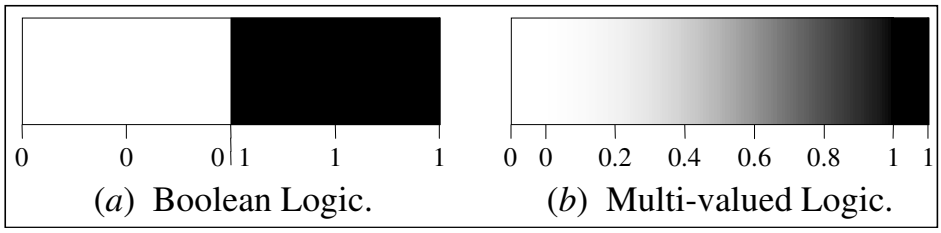
  Fuzziness rests on fuzzy set theory, and fuzzy logic is just a small part of that theory.

Introduction to Fuzzy Logic

Fuzzy logic is 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.

Range of logical values in Boolean and fuzzy logic



(*a*) Boolean Logic. (*b*) Multi-valued Logic.

Fuzzy sets

- The concept of a **set** is fundamental to mathematics.
- However, our own language is also the supreme expression of sets. For example, ***car*** indicates the ***set of cars***. When we say ***a car***, we mean one out of the set of cars.

Fuzzy sets

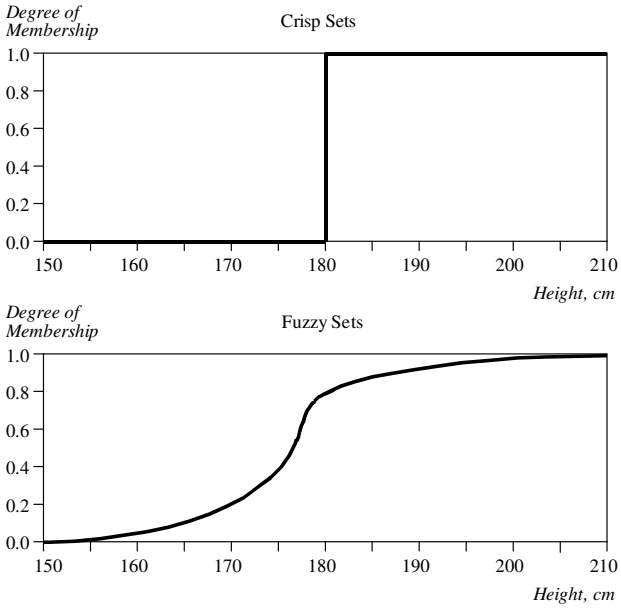
- (Crisp) set theory is governed by a logic that uses one of only two values: true or false. This logic cannot represent vague concepts, and therefore fails to give the answers on the paradoxes.
- The basic idea of the fuzzy set theory is that an element belongs to a fuzzy set with a certain degree of membership. Thus, a proposition is not either true or false, but may be partly true (or partly false) to any degree. This degree is usually taken as a real number in the interval [0,1].

Fuzzy sets

- The classical example in fuzzy sets is ***tall men***. The elements of the fuzzy set "tall men" are all men, but their degrees of membership depend on their height.

Name	Height, cm	Degree of Membership	
		Crisp	*Fuzzy*
Chris	208	1	1.00
Mark	205	1	1.00
John	198	1	0.98
Tom	181	1	0.82
David	179	0	0.78
Mike	172	0	0.24
Bob	167	0	0.15
Steven	158	0	0.06
Bill	155	0	0.01
Peter	152	0	0.00

Crisp and fuzzy sets of "*tall men*"



Fuzzy sets

- Fuzzy Logic uses imprecision to provide robust, tractable solutions to problems.
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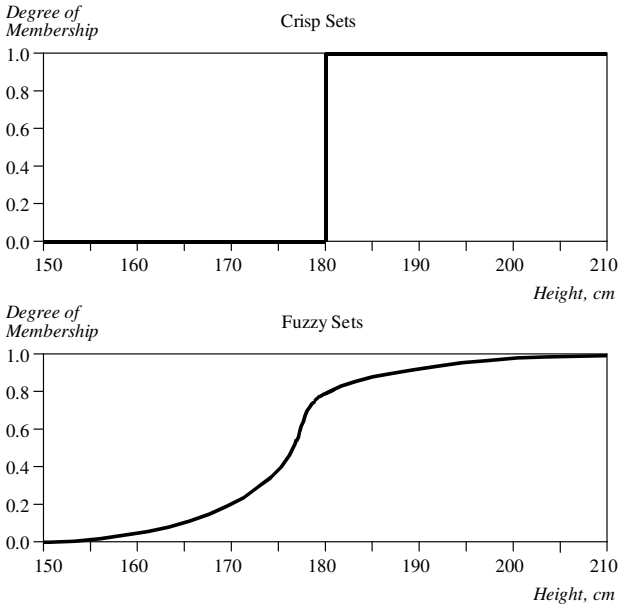
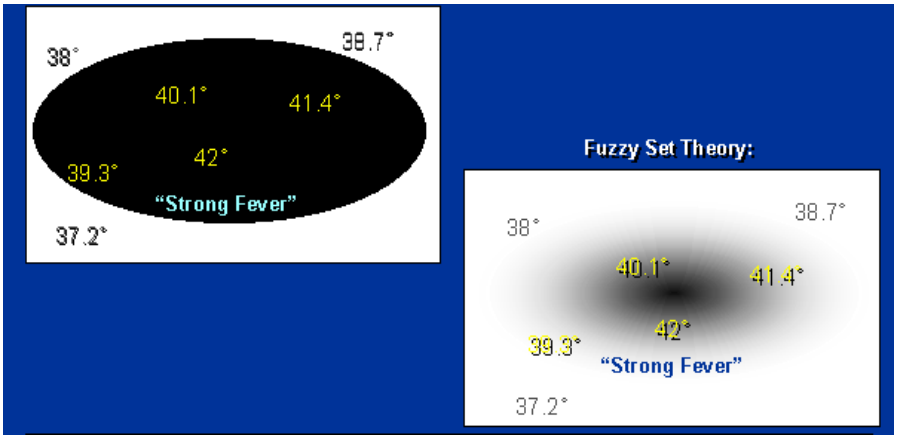


The word “Fuzzy”



Fuzzy Logic

“Because **Fuzzy Logic** is similar to the way we talk and think, it is easier for us to adjust” Cynthia Taylor

- Fuzzy Logic is particularly good at handling uncertainty, vagueness and imprecision.
- This is especially useful where a problem can be described linguistically (using words) or, as with neural networks, where there is data and you are looking for relationships or patterns within that data.
- Fuzzy Logic uses imprecision to provide robust, tractable solutions to problems.
- Fuzzy logic relies on the concept of a ***fuzzy set***.

Fuzzy sets, logic, inference, control

Explanation of some terms. The following have become widely accepted:

Fuzzy logic system

anything that uses fuzzy set theory

Fuzzy control

any control system that employs fuzzy logic

Fuzzy associative memory

any system that evaluates a set of fuzzy *if-then* rules uses fuzzy inference. Also known as **fuzzy rule base** or **fuzzy expert system**

Fuzzy inference control

a system that uses fuzzy control and fuzzy inference

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Remark: different authors and researchers use the same term either for the same thing or for different things.

Fuzzy Logic

- It is hard to characterize the truth of "John is old" as unambiguously true or false if John is 60 years old.
- In some respects he is old, being eligible for senior citizen benefits at many establishments,
- But in other respects he is not old since he still can work.
- ***The truth value of the statement could be tv(John is old) = 70***
- ***The negation of the statement may be*** $tv(\neg p) = 1 - tv(p)$
- ***We need also to find*** $tv(p \wedge q)$ ***and*** $tv(p \wedge q)$

T-norm and T-conorm

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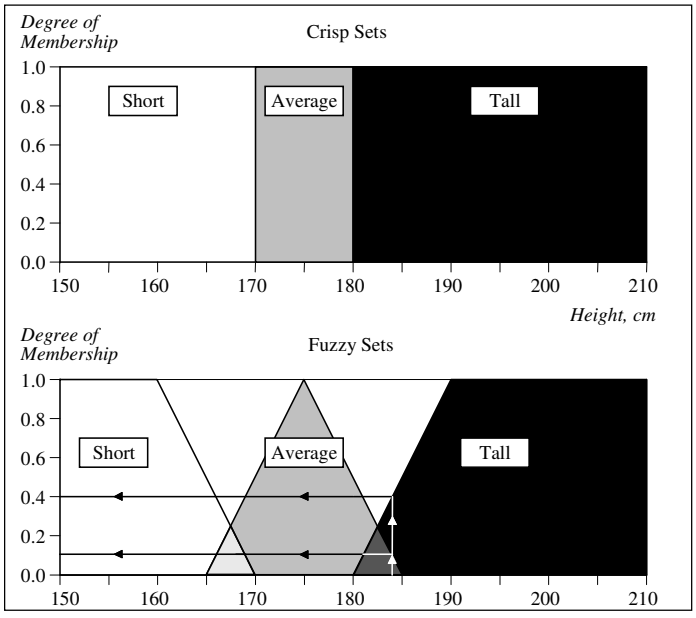
How to represent a fuzzy set in a computer?

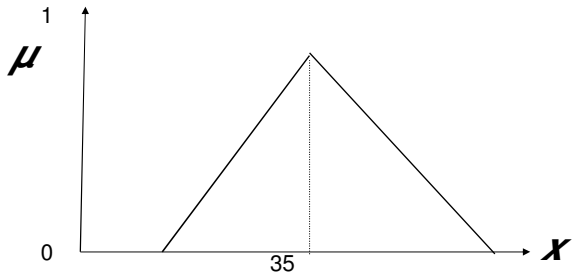
- First, we determine the membership functions. In our "***tall men***" example, we can obtain fuzzy sets of ***tall***, ***short*** and ***average*** men.
- The universe of discourse – the men's heights – consists of three sets: ***short***, ***average*** and ***tall men***. As you will see, a man who is 184 cm tall is a member of the ***average men*** set with a degree of membership of 0.1, and at the same time, he is also a member of the ***tall men*** set with a degree of 0.4.

Crisp and fuzzy sets of short, average and tall men



Imprecision / Vagueness / Uncertainty

In many physical systems, measurements are never precise
Fuzzy numbers are one way of capturing this imprecision by having a fuzzy set representing a real number where the numbers in an interval near to the number are in the fuzzy set to some degree.



The fuzzy number 'About 35'