EE4305 Fuzzy/Neural Systems for Intelligent Robotics

PART II: FUZZY SYSTEMS

Chapter 1: Introduction

In part I, we have learned that neural networks can be used to approximate any continuous maps as along as sufficient amount of data are available.

Hence, neural networks have been applied to solve many real world applications with amazing results.

Of course, Neural Networks is not a panacea! It has a number of limitations. What is the most serious weakness of NN?

It is essentially a blackbox! It can produce desired output, but it does not offer any explanation on why.

Many people do not like this. For us, we always prefer something which we can easily understand and communicate with.

For example, if we want to design a smart switch for AC, we would like it to follow a simple rule like

"If it is hot, turn on the AC ."

Can you write a code to implement this rule directly?

Not really, because the machine does not understand the meaning of "hot".

Then is there any alternative to implement this rule indirectly?

Probably you may replace it with the following rule:

If the temperature reading $T \geq T_0$

Then turn on the AC.

What is "hot"?

It is hot when the temperature is 30℃ or higher.

Can you feel the temperature difference of 0.1℃ ? Or can you feel the difference between 30℃ and 29.9℃?

If 30℃ is considered as "hot", we should also consider 29.9℃ as "hot", right?

If 29.9℃ is considered as "hot", we should also consider 29.8℃ as "hot" because we cannot feel the difference of 0.1℃, right?

If we follow this logic, we will easily conclude that 0℃ is also considered as "hot" too, which is of course absurd!

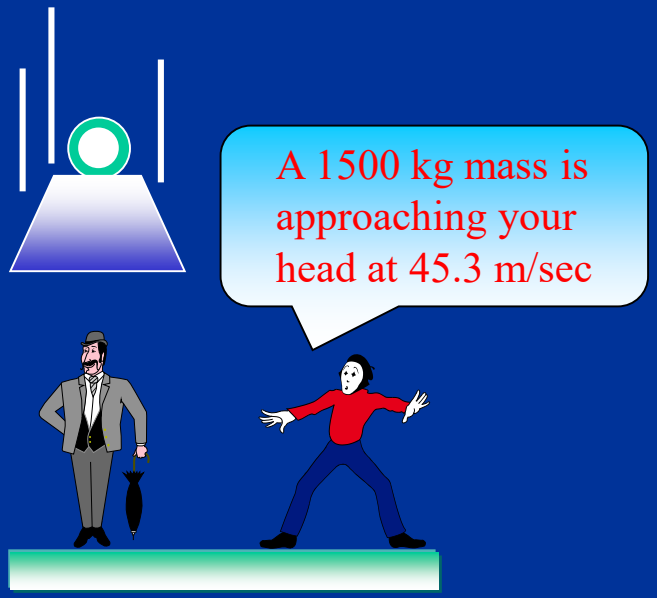
Fuzziness is inherent in human language and perception, which cannot be handled properly by classical logic.

We need a new logic to deal with that!

Topics to be Covered (Part II)…

- Fuzzy sets and crisp sets
- Fuzzy operations and fuzzy relations
- Extension principle and fuzzy numbers
- Approximate reasoning and fuzzy inference
- Fuzzy knowledge based control (FKBC)
- Fuzzy applications

Some preliminaries on Fuzziness



Precision

Significance

Grill Chicken

Take the chicken out of the oven when the temperature inside the oven reaches 375°F

Take the chicken out when the top of the chicken turns light brown

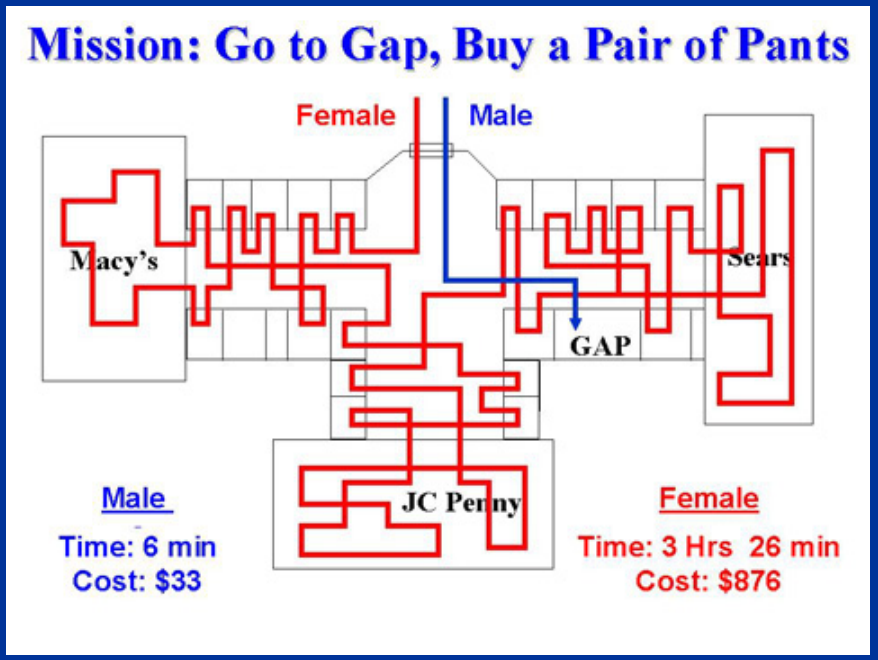
More examples:

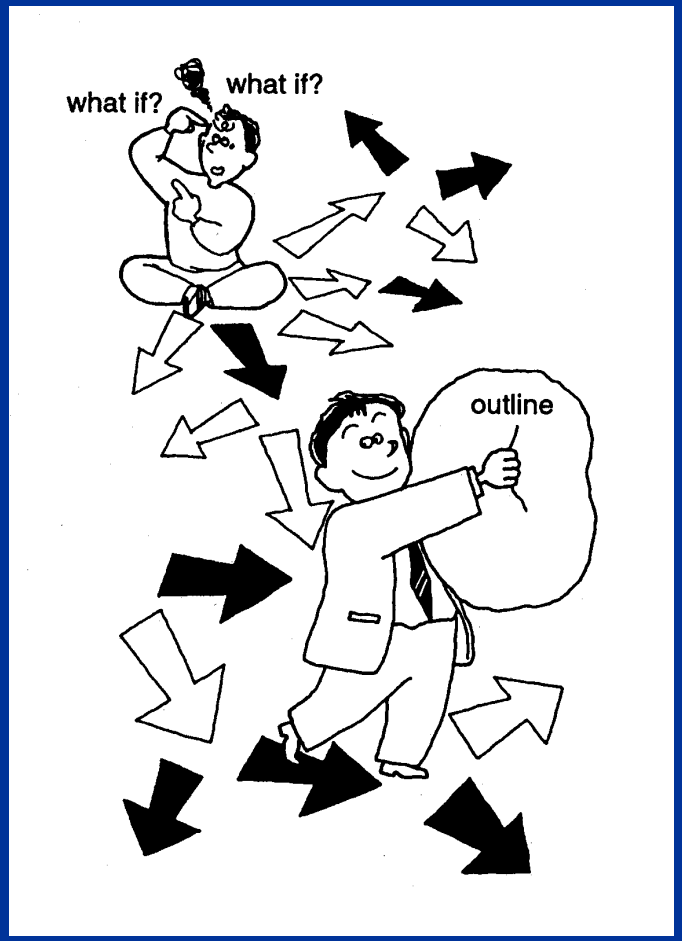
- Question: 44 + 33 = ? (5 marks)
- Human logic is ambiguous…

  - *Slow down when it is raining…*

  - *Planning a schedule…*

  - *Fuzziness of Man and Woman…*





Albert: The car is going *'fast'*.

Ben: What do you mean by 'fast'?

Albert: I mean 'fast' because it is driving at 80 kmph.

Ben: What about if it is at 79 kmph, does it mean it is '*slow*'?

Albert: OK, I shall say 'fast' if it is at 75 kmph or higher.

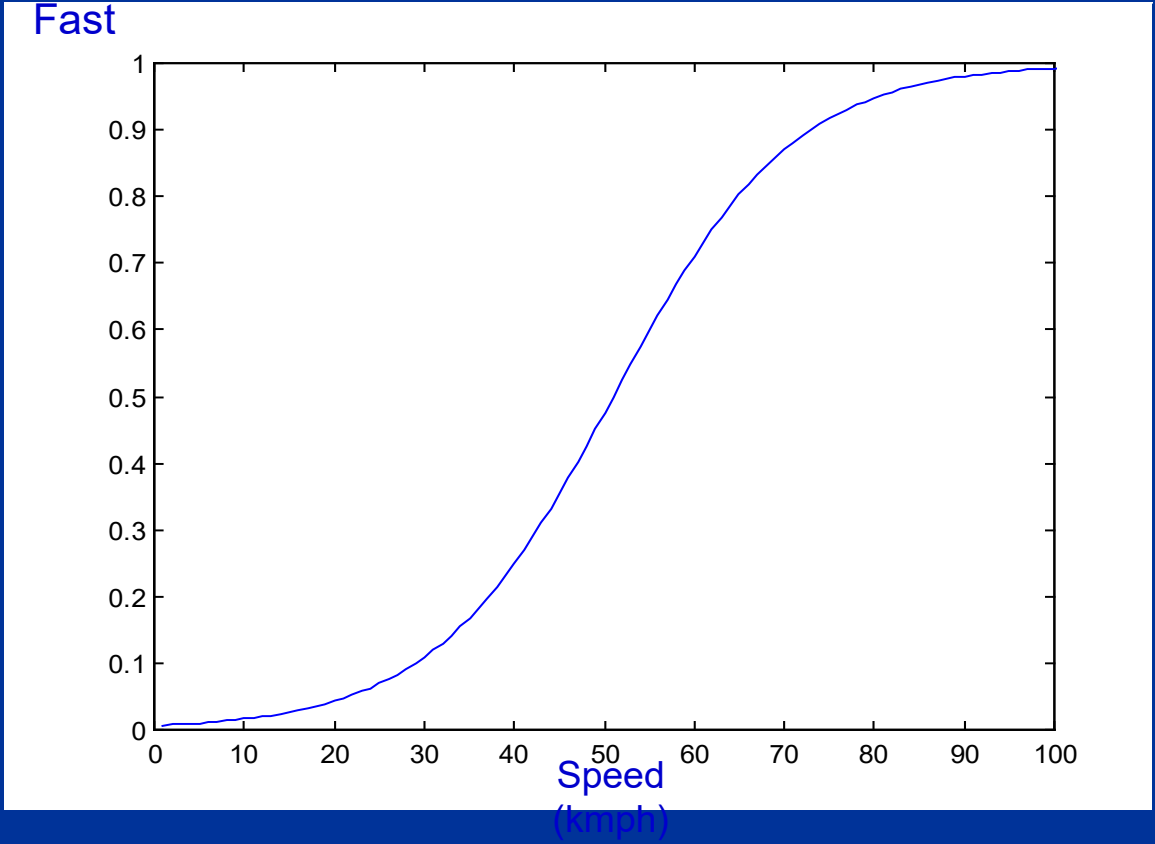
Ben: Then, what about if it is at 74 kmph, does it mean it is 'slow'?

How to appropriately define the concept '*fast*' using numbers?

Although we consider both 80 kmph and 75 kmph as fast, we should differentiate them with some numbers.

And that number should also indicate 5 kmph is definitely not "fast" .

Is there any simple way to assign a number to different speeds to fulfill this task?



A membership function ranges from 0 – 1, with a larger value indicating a higher *degree of truth*.

How to appropriately define the human perception concepts like '*fast*' and 'hot'?

In order to resolve the paradox caused by the classic logic, the concept of 'fast' may introduce vagueness by allowing some sort of gradual transition from speeds that are considered to be 'fast' and those that are not.

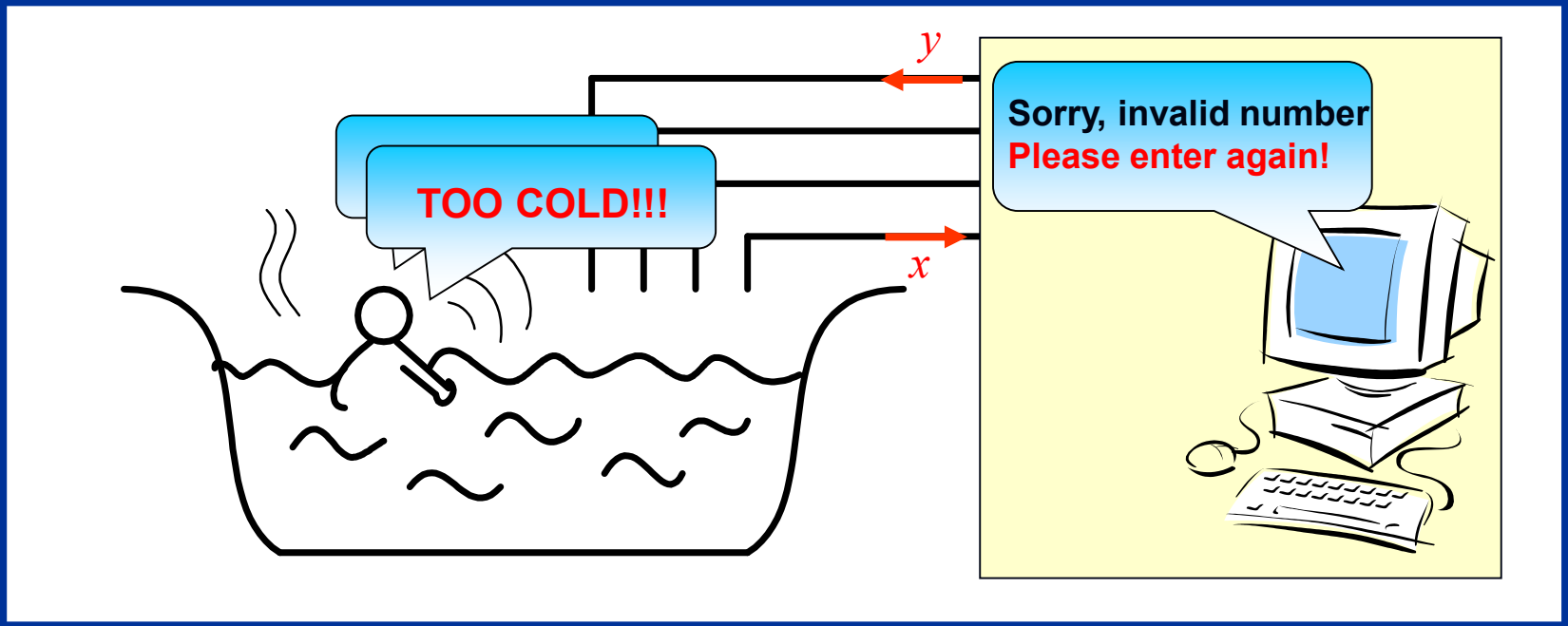
This is, in fact, precisely the basic concept of the *fuzzy* set, a concept that is both simple, and intuitively pleasing and that forms, in essence, a generalization of the classical or crisp set.

The crisp set is defined in such a way that all the elements are divided into two groups: members (i.e., 'fast') and non-members (i.e. 'not fast').

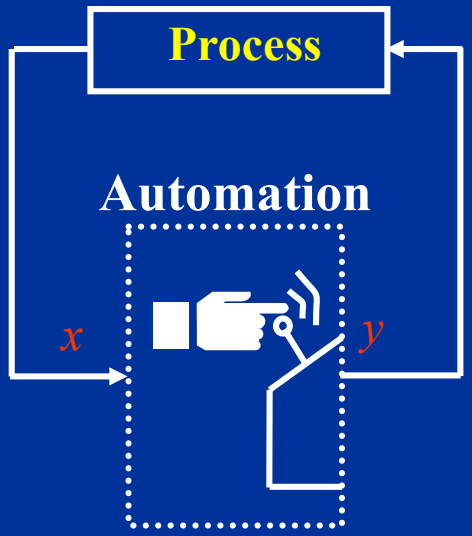
A fuzzy set instead assigns to each element a value representing its grade of membership in the set. This grade corresponds to the degree to which that individual is similar or compatible with the concept represented by the fuzzy set.

What is a Fuzzy System?

Example: Temperature Control of a Bath-Tub



- How to represent such a concept so that a machine can understand?



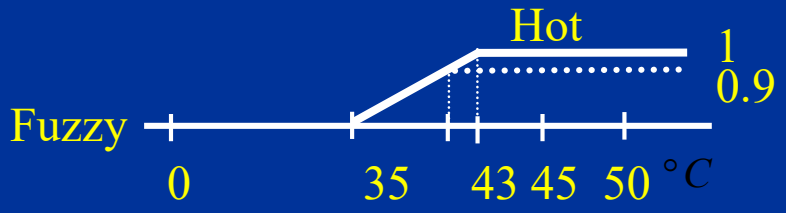
Knowledge Inference: Rule Base

If	x	is	A ,	Then	y	is	B
	error		small		action		small
	temp		hot		opening		large

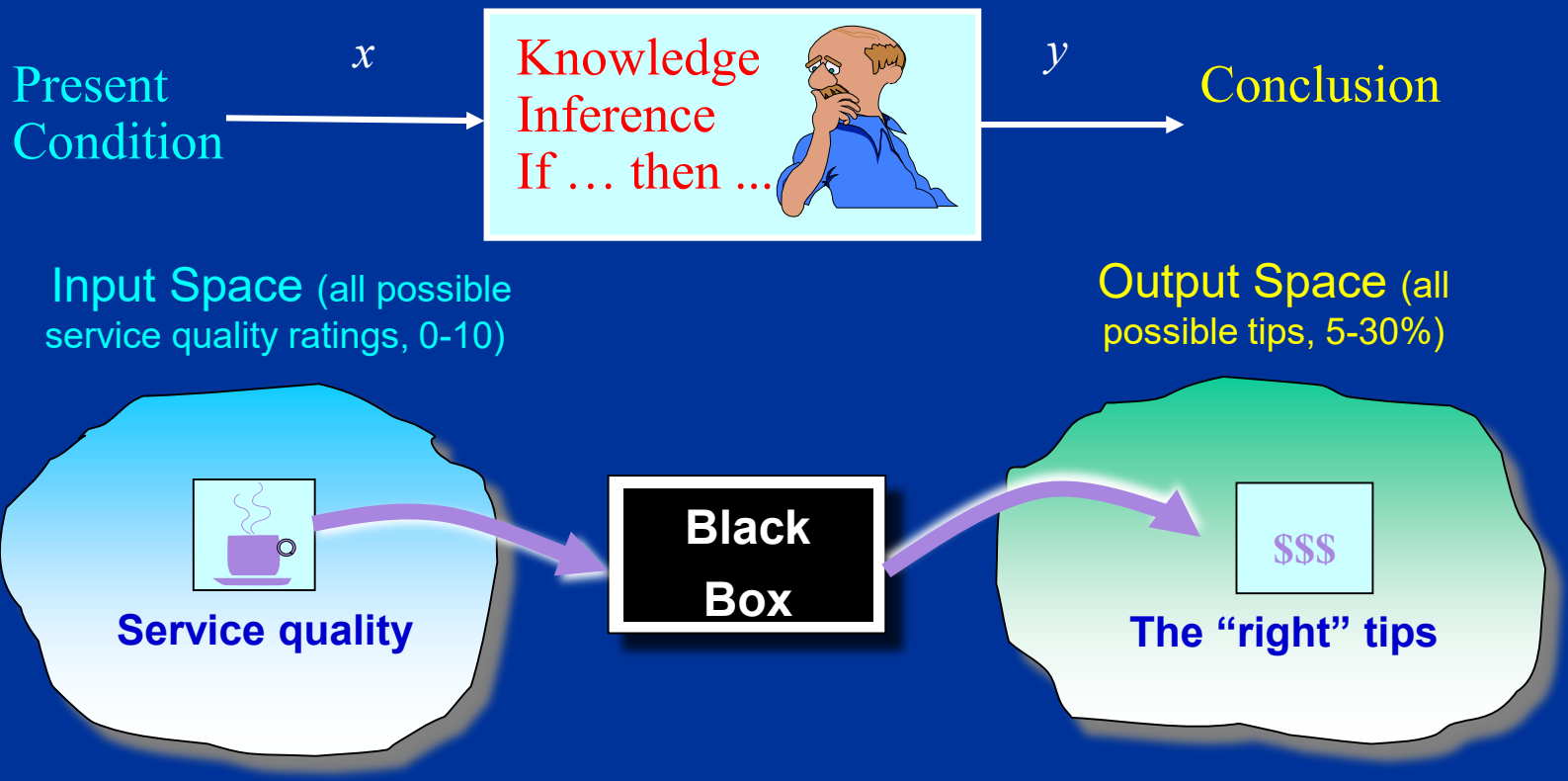
membership function

- What is “hot” ? What is the difference between “42°C ” and “ hot” ?

  → “Hot” is not a single quantity but a set of quantities.



♦ Fuzzy system is *a convenient way* to code human knowledge.



What could go into the black box?

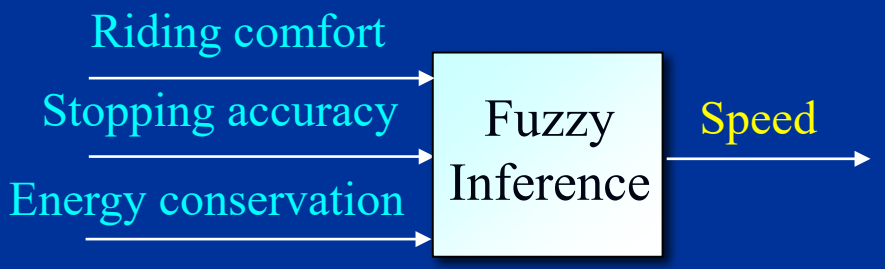
- Mathematic model, e.g., $\frac{dy}{dx} = \ldots$
- Look-up table
- Neural network ...

Fuzzy Logic?

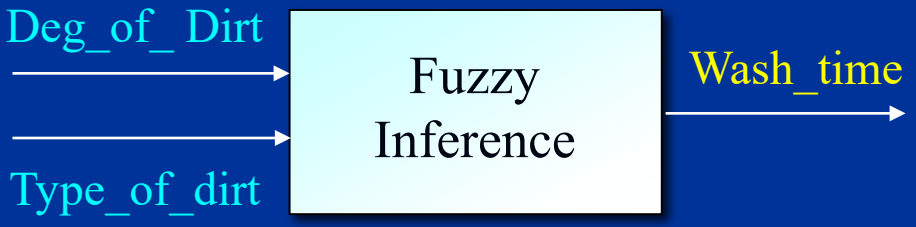
♦ Fuzzy logic applications…

Sendai Subway System (1987)

Fuzzy-ATO (Automatic Train Operation)



Fuzzy Washing Machine



Fuzzy Logic vs. Neural Networks

Fuzzy Logic is an efficient tool that allows us to use the human knowledge (expert knowledge) directly because it can deal with human concepts directly.

Even if you have years of classifying data in one area, the neural networks cannot use your expert knowledge directly. What it needs is only the labelled data. The expert knowledge is almost useless in designing and training the neural networks.

Neural Networks are data-driven. Without data, it cannot work. Fuzzy logic is knowledge (expert)-driven that does not depend upon availability of the data to operate.