FUZZY LOGIC: THE BALLOON EXPERIMENT

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Abstract : The aim of this paper is to find simple fuzzy logic rules based on the decision tree generated .We have used balloons dataset where there are four data sets representing different conditions of an experiment and out of which adult-stretch is used in this paper .For fuzzy rule based and decision tree learning algorithms, choosing the right combination of attributes and fuzzy sets which have the most information is the key point to obtain good accuracy. Thus ID3 algorithm gives an efficient model to select the right combinations. Compared to other fuzzy models, simple fuzzy logic rules (IF ... THEN... rules) based on triangular or trapezoidal shape fuzzy sets are much simpler and easier to understand[1]. The results seem to be accurate and encouraging as this paper applies to achieve a more effective and distinct way of predicting the inflation of balloon .

Keywords: ID3 algorithm,Decision tree,fuzzy rules,membership function,fuzzy sets

1 Introduction

A balloon is an air-tight bag made out of a light material that can be inflated with air or gas. Toy balloons are available at birthday parties and other festive occasions in different colours with different sizes by different actions which results in inflation of the balloon as a new balloon can be stretched several times before attempting to inflate it for the first time while if you inflate the balloon using dipping then its radius increases but its curvature decreases so now the balloon doesn't dip as deep .[3]. Also sometimes adult possesses exuberant strength in comparison to child for inflating balloons.
In such prediction problems, we would like the model to be as simple as possible and provide an easy means of providing an explanation for the result. The fuzzy logic rules (IF ... THEN... rules) are good choice, because they are not only much simpler than the other models but also formulate human reasoning and decision-making into a set of easily understandable linguistic clauses. For explanation purpose, we have to use the simple triangular or trapezoidal shape fuzzy sets, so that simple fuzzy logic rule model based on these fuzzy sets are produced. [1]
Fuzzy logic has rapidly become one of the most successful of today technologies for developing sophisticated control systems. The reason for which is very simple. Fuzzy logic addresses such applications perfectly as it resembles human decision making with an ability to generate precise solutions from certain or approximate information. It fills an important gap in engineering design methods left vacant by purely mathematical approaches.[2]

1.1 Description of the dataset

Dataset is chosen from Balloon databases to carry out the experimentation ,here the following variable are used to determine whether the balloons are inflated or not. The attributes are as follows : Colour, Age, Action and Size.
In order to get an insight of the Fuzzy Control system out of the four experiments performed the first experiment is considered as the two attributes used in determining the target attribute are age and action. These two attributes are defined using the following: Child, adult and Dip, Stretch respectively which can be considered as fuzzy in nature.

2 **Explanation for the methods implemented**

Fuzzy Logic resembles the human decision-making methodology. It deals with vague and imprecise information. This is gross oversimplification of the real-world problems and based on degrees of truth rather than usual true/false or 1/0 like Boolean logic refer fig 1. It shows that in fuzzy systems, the values are indicated by a number in the range from 0 to 1. Here 1.0 represents **absolute truth** and 0.0 represents **absolute falseness**. The number which indicates the value in fuzzy systems is called the **truth value**.

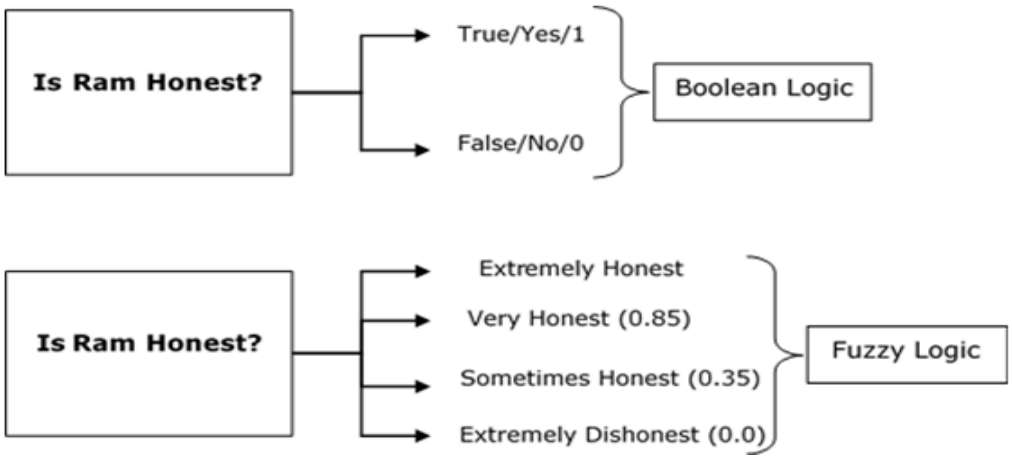


Fig1 :Example illustrating the difference between the Boolean Logic and Fuzzy Logic [4]

We have used chronological sequence of following different methods in order to execute the Balloons dataset to obtain the desired result of predicting whether the balloon will be inflated or not under certain set of given conditions.

2.1 Membership Functions

A *membership function* (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the *universe of discourse*, a fancy name for a simple concept.
The only condition a membership function must really satisfy is that it must vary between 0 and 1. The function itself can be an arbitrary curve whose shape we can define as a function that suits us from the point of view of simplicity, convenience, speed, and efficiency.

A classical set might be expressed as

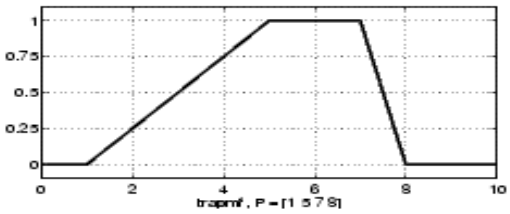
- $A = \{x \mid x > 6\}$

A fuzzy set is an extension of a classical set. If X is the universe of discourse and its elements are denoted by *x*, then a fuzzy set A in X is defined as a set of ordered pairs.

- $A = \{x, \mu_A(x) \mid x \in X\}$

$\mu_A(x)$ is called the membership function (or MF) of *x* in A. The membership function maps each element of X to a membership value between 0 and 1.The simplest membership functions are formed using straight lines. Of these, the simplest is the *triangular* membership function, and it has the function name trimf. It's nothing more than a collection of three points forming a triangle. The *trapezoidal* membership function, trapmf, has a flat top and really is just a truncated triangle curve. These straight line membership functions have the advantage of simplicity.

trimf



trapmf

Fig2 : Demonstrating the trapezoidal and triangular figures by *trapezoidal* membership function. [5]

2.2 Decision tree ID3 algorithm

'Decision tree learning is a method for approximating discrete valued target functions, in which the learned function is represented by a decision tree. Decision tree learning is one of the most widely used and practical methods for inductive interference'.
Decision trees classify instances by traverse from root node to leaf node. We start from root node of decision tree, testing the attribute specified by this node, then moving down the tree branch according to the attribute value in the given set.
The basic idea of ID3 algorithm is to construct the decision tree by employing a top-down, greedy search through the given sets to test each attribute at every tree node. In order to select the attribute that is most useful for classifying a given sets, we introduce a metric--- information gain.
In order to define **information gain** precisely, we need to discuss **entropy** first.
Entropy: ID3 algorithm uses entropy to calculate the homogeneity of a sample. If the sample is completely homogeneous the entropy is zero and if the sample is an equally divided it has entropy of one.
It is calculated using the following formula.

$$E(S) = \sum_{i=1}^{c} - p_i \log_2 p_i$$

`Information Gain:` To minimise the decision tree depth, when we traverse the tree path, we need to select the optimal attribute for splitting the tree node, which we can easily imply that the attribute with the most entropy reduction is the best choice.
Constructing a decision tree is all about finding attribute that returns the highest information gain (i.e., the most homogeneous branches).

$$Gain(T, X) = Entropy(T) - Entropy(T, X)$$

A decision tree can easily be transformed to a set of rules by mapping from the root node to the leaf nodes one by one.

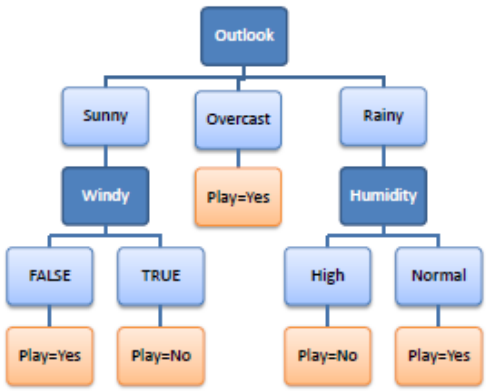
R_1: IF (Outlook=Sunny) AND (Windy=FALSE) THEN Play=Yes

R_2: IF (Outlook=Sunny) AND (Windy=TRUE) THEN Play=No

R_3: IF (Outlook=Overcast) THEN Play=Yes

R_4: IF (Outlook=Rainy) AND (Humidity=High) THEN Play=No

R_5: IF (Outlook=Rain) AND (Humidity=Normal) THEN Play=Yes



`Fig3:Example of` Decision Tree to Decision Rules [6][7]

2.3 Fuzzy Rules

Human beings make decisions based on rules. Although, we may not be aware of it, all the decisions we make are all based on computer like if-then statements. If the weather is fine, then we may decide to go out. If the forecast says the weather will be bad today, but fine tomorrow, then we make a decisions not to go today, and postpone it till tomorrow. Rules associate ideas and relate one event to another.
Fuzzy machines, which always tend to mimic the behaviour of man, work the same way. However, the decisions and the means of choosing that decision are replaced by fuzzy sets and the rules are replaced by fuzzy rules. Fuzzy rules also operate using a series of if-then statements. For instance, if X then A, if y then b, where A and B are all sets of X and Y. [8]
A fuzzy IF-THEN rule associates a condition described using linguistic variables and fuzzy sets to an output or a conclusion. The IF part is mainly used to capture knowledge by using the elastic conditions, and the THEN part can be utilised to give the conclusion or output in linguistic variable form. This IF-THEN rule is widely used by the fuzzy inference system to compute the degree to which the input data matches the condition of a rule.[9]

2.4 Fuzzy Inference Process

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves all the pieces that are described in Membership Functions, Logical Operations, and If-Then Rules. This section describes the fuzzy inference process and uses the example of the two-input, one-output, three-rule tipping problem from The Basic Tipping Problem. The basic structure of this example is shown in the following diagram:

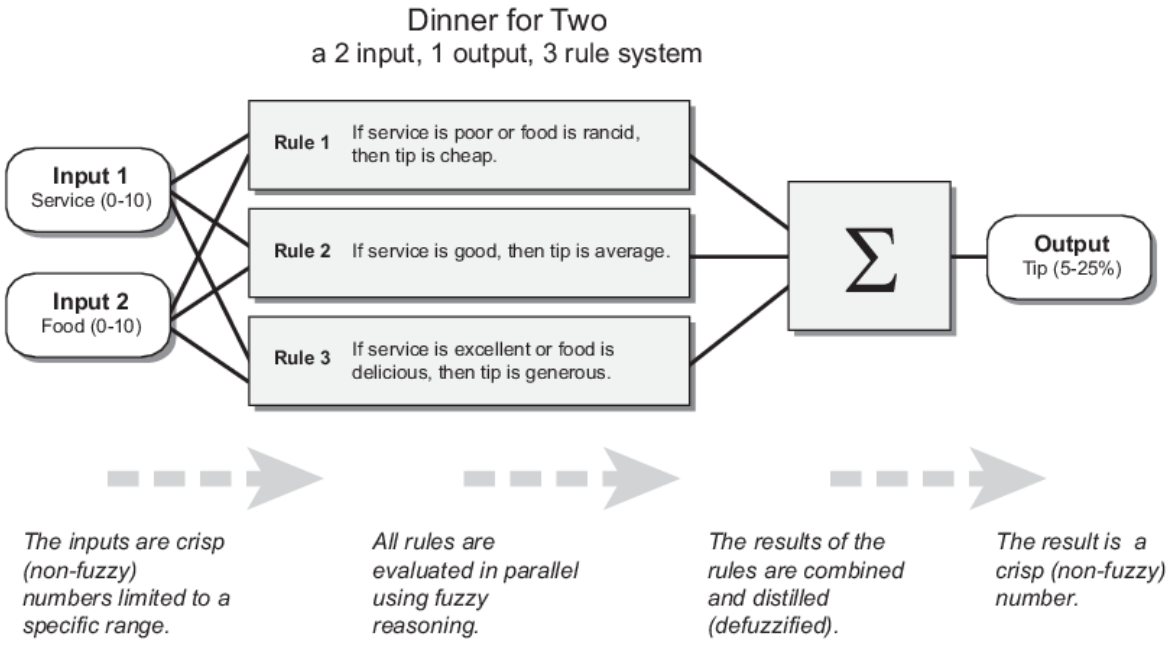


Fig4: A Basic Fuzzy Inference System

Fuzzification
The first step is to take the inputs and determine the degree to which they belong to each of the appropriate fuzzy sets via membership functions. In Fuzzy Logic Toolbox™ software, the input is always a crisp numerical value limited to the universe of discourse of the input variable (in this case, the interval from 0 through 10) . The output is a fuzzy degree of membership in the qualifying linguistic set (always the interval from 0 through 1). Fuzzification of the input amounts to either a table lookup or a function evaluation.

Defuzzification
The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number. However, the aggregate of a fuzzy set

encompasses a range of output values, and so must be defuzzified to obtain a single output value from the set.

[10]

3 RESULTS AND COMPARISON WITH PAPER

Implementation of id3 classification trees which that partitions a data set on the attribute and maximises information gain is done by running the code with the python interpreter.[11]

```
u6424156@anaconda:~/Downloads/Aditi_4660_Ass2/id3/resources$ cd ..
u6424156@anaconda:~/Downloads/Aditi_4660_Ass2/id3$ python3 id3.py ./resources/data1.cfg
Command line args are ['id3.py', './resources/data1.cfg']:
IF Action EQUALS DIP AND Age EQUALS ADULT THEN T
IF Action EQUALS STRETCH THEN T
IF Action EQUALS DIP AND Age EQUALS CHILD THEN F
u6424156@anaconda:~/Downloads/Aditi_4660_Ass2/id3$
```

Fig 5: Generated Decision Tree

This fuzziness is best characterised by its membership function. In other words, we can say that membership function represents the degree of truth in fuzzy logic.[4]
A *membership function* is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the *universe of discourse*, a fancy name for a simple concept.[10]
In this paper ,degree of membership is mapped against age ,action which are inputs and inflated which is output.

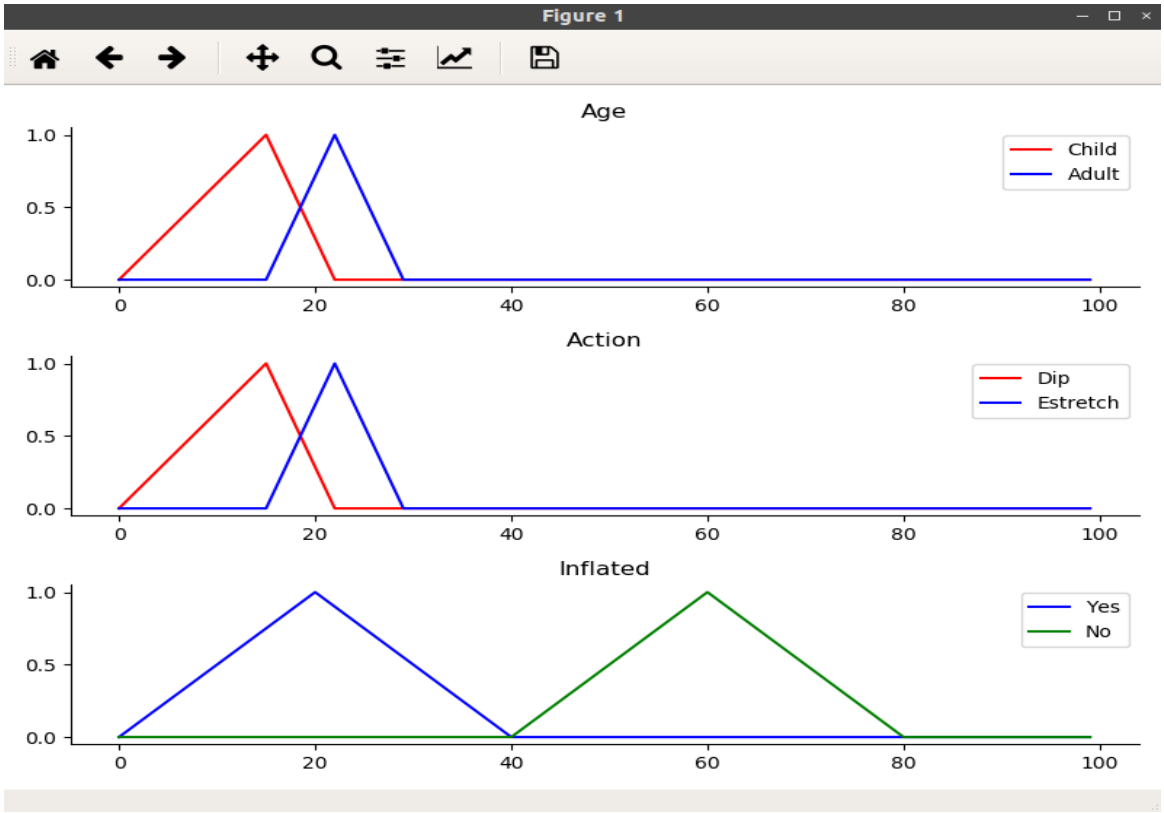


Fig 6: Membership Functions for the input and output attribute

The if else form generated by decision tree is written in form of fuzzy rules and then we combine membership functions with the control rules to derive the fuzzy output. In Fuzzification,we use membership functions to graphically describe a situation.[9]

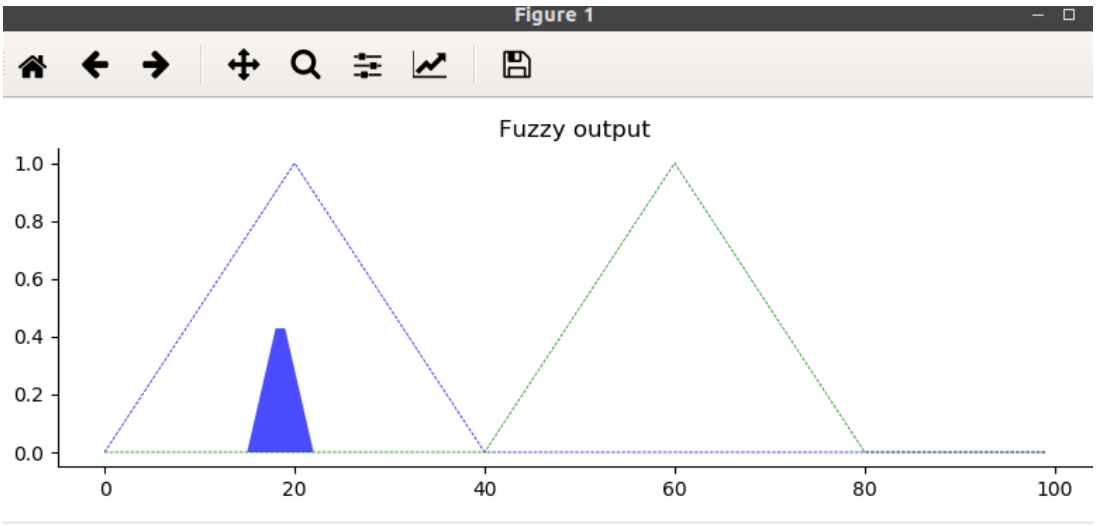


Fig 7: Fuzzy output

In the end,we use defuzzification where we reduce a fuzzy set into a crisp set or to convert a fuzzy member into a crisp member. As the fuzzification process involves conversion from crisp quantities to fuzzy quantities. In a number of engineering applications, it is necessary to defuzzify the result or rather “fuzzy result” so that it must be converted to crisp result. Mathematically, the process of Defuzzification is also called “rounding it off”.[4]

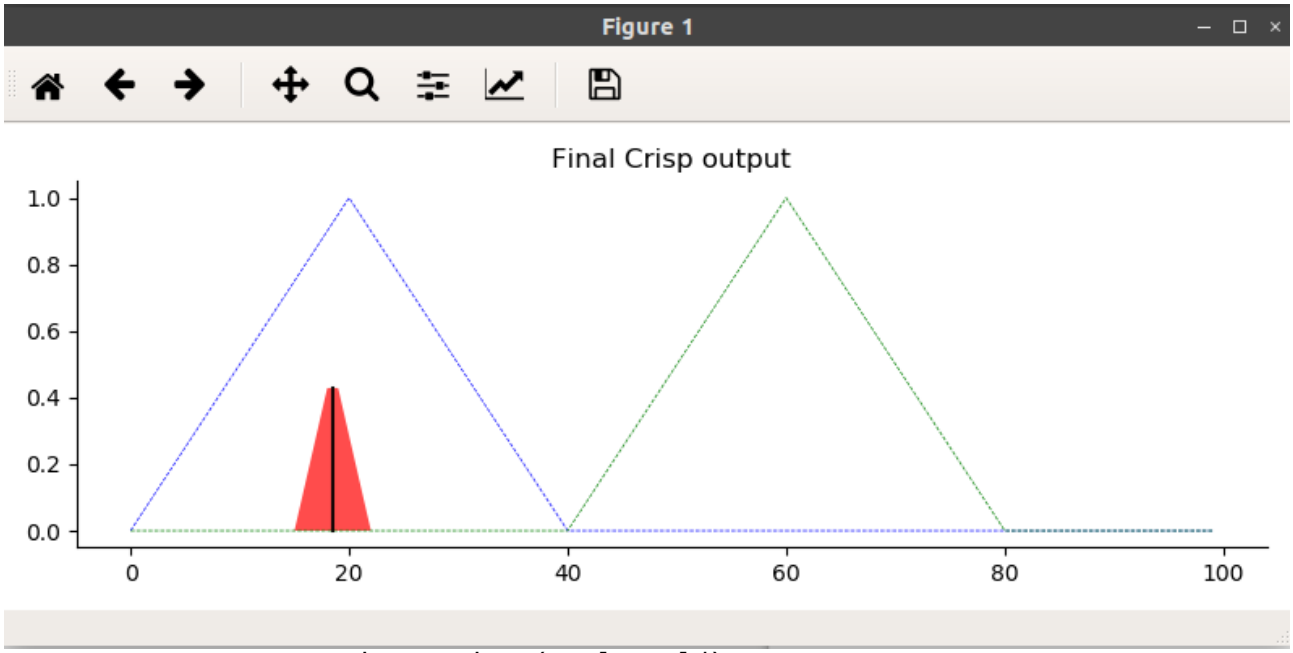


Fig 8 Crisp (Real World) output

This means out of 40, 18 times the balloon will be inflated.

Result of the paper stated with this dataset [12] says that balloon gets inflated in one of the two cases:
1)case 1:when age=adult
2)case2: when age = child and action = stretched
Which by comparing with the decision tree generated in Fig 5 matches. Thus This paper implemented it using Fuzzy Logic as Age and Action are fuzzy in nature since the word **fuzzy** refers to things which are not clear or are vague. Any event, process, or function that is changing continuously cannot always be defined as either true or false, which means that we need to define such activities in a Fuzzy manner.[4]

4 Conclusions and Future Work

Fuzzy sets describe vague concepts for an example fast runner, hot weather, weekend days. A fuzzy set admits the possibility of partial membership in it. (Friday is sort of a weekend day, the weather is rather hot).

The degree an object belongs to a fuzzy set is denoted by a membership value between 0 and 1. (Friday is a weekend day to the degree 0.8).

Interpreting if-then rules is a three-part process.

1. **Fuzzify inputs**: Resolve all fuzzy statements in the antecedent to a degree of membership between 0 and 1. If there is only one part to the antecedent, then this is the degree of support for the rule.
2. **Apply fuzzy operator to multiple part antecedents**: If there are multiple parts to the antecedent, apply fuzzy logic operators and resolve the antecedent to a single number between 0 and 1. This is the degree of support for the rule.
3. **Apply implication method**: Use the degree of support for the entire rule to shape the output fuzzy set. The consequent of a fuzzy rule assigns an entire fuzzy set to the output. This fuzzy set is represented by a membership function that is chosen to indicate the qualities of the consequent. If the antecedent is only partially true, (i.e., is assigned a value less than 1), then the output fuzzy set is truncated according to the implication method.[10]

However since the dataset is small then it cannot be predicted with complete accuracy that the result will always be true because there can be a child who would dip and cause inflation.To keep that in account we can use fuzzy signature neural networks where fuzzy signatures replace hidden neurons in a neural network similar to a radial basis function neural network which improves the improve robustness of the fuzzy signature neural networks and gives more accurate result.[13]

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