Title: Fuzzy Inference System with Natural Language Processing

CSC-215

Fall 2017

Term Project: Study/ Documentation

12/09/2017

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Abstract

The focus of this study is on classification and sequential inferences. We could apply Natural Language Processing, fuzzy set conversions and inference rules to deduce results from input statements.

The proposed system will take the goal as an input. It will work on backward chaining by deducing what facts could make the goal assertion true. The idea of this study is to describe pre-requisite topics and initiate the procedure to implement inference engine using Fuzzy Logic and Natural Language Processing with rules.

The primary application of this system could be in a domain such as automated chatbots and, robotics.

Introduction

An Inference engine is one of the main components of expert systems. It applies various logical rules to the base knowledge and concludes new information from it.

The inference engine should be able to deduce relations among input statements by applying inference rules and map it as an output result. All the transitions, such as inputs to the inference engine, inference engine to output would use fuzzifications techniques. We have described two types of fuzzy approaches, that is, Mamdani [1] and, Sugeno [2]; to see which technique is more suitable and address this domain more accurately.

This system can be further developed to respond to question/answer type of conversations deducing from knowledge gathered from past conversations and predicting the answers to the questions asked.

Expert Systems:

Expert systems are one of the prominent research domain of Artificial Intelligence. It was first introduced by Stanford University. Complex problem can be solved by expert systems based computer applications in a domain the level of extraordinary human intelligence and expert expertise so the other computer applications developed to solve certain human problems, which require high level of intelligence. Some of the characteristics of expert systems are high performance, understanding, reliability and high response rates.

Artificial intelligence expert systems can advise, instruct and assist humans in decision-making and demonstrate what they have learned from the knowledge they have, derive solutions, do diagnosis of any infection or disease, can interpret the input, can predict the results and justify the conclusion. The expert system possesses the capability to substitute human decision-makers and produce accurate output for inadequate knowledge base. It will be possible for expert system to refine its knowledge.

Expert systems are a combination of different components. First one is knowledge base; Domain-specific and high-quality knowledge is required to exhibit intelligence. The accuracy of any Expert system is dependent on the collection of data and knowledge based precise facts. So, all the knowledge required for an expert system to work is stored in the knowledge base and this knowledge is given by humans, and it is fed into the artificial intelligence system's knowledge base.

What is knowledge? It is a collection of facts in form of data. Information is organized as data and facts about the task or domain information and past experience that combined together to form knowledge. So, knowledge is the information about a specific area of expertise which has been inputted by human's exports into the expert system and this knowledge is stored in an area called knowledge base.

Other components are inference engine and user-inference. For knowledge-based experts, Inference Engine gets knowledge facts from knowledge base and it computes other related knowledge based on that and it stores back to knowledge base. So, the inference engine is used to understand the knowledge from the knowledge base and using the knowledge to come at a solution. The user interface interacts between the expert system and its so the user interface is responsible for communication between user of the expert system and expert system itself. It is generally natural language processing to be used by the user to convert its input into appropriate system through various NLP techniques which are well-versed in its task domain.

So, the user understands the tasks which he/she has to perform and he/she will interact using natural language in the form of voice (speech) or written with an artificial intelligent expert system. the user in this case need not be necessarily an expert in artificial intelligence you can use natural language processing to interact with the expert system some applications like diagnosis system which deduce the cause of diseases from observed data, conduction of medical operation on humans etc. comparing data continuously with observed system or with prescribed behaviors such as leakage monitoring in long petroleum pipeline. finding out false in vehicles computer in such application the use of expert system with high level of knowledge base is used.

So, the first goal is to understand that language processing requires a very intuitive understanding of the difficulties of human language for which you not only do you need to know that language but you also need to understand why so. (even if in some cases there is no logical reason). For example, machine translation and parsing the language is something NLP has to figure out on its own rather than humans providing rules for it. Using specific statistical techniques or specific language resources and finally and just as importantly are we need to understand the limitations of these methods**.**

Basic Concepts and Terminologies

Traditional logic consists of two logic systems.

- Propositional logic
- Predicate logic

Propositional logic is a system which uses true or false statements to form or to prove other statements as true or false. It consists of two types of statements,

- Simple sentences
- Compound sentences

Simple sentences are propositional constants, such statements have value as either true or false.

Compound sentences are generated using two or more simple sentences as the operand. We use, negation (¬), disjunctions (∨), conjunctions (∧), equivalence (⇔), reductions (⇐), implication (⇒) and more as the operator among the operands in the compound sentences.

In propositional logic, we cannot use generic rule because each rule is separate and there is no way to abstract non-Boolean values. This limitation could be overcome by predicate logic.

Predicate Logic is a system in which predicate is a statement that may be true or false depending on the value of the variable. For example, X is a good person, where X is a variable and the statement could be true or false based on the value of X.

Two types of quantifiers are used in predicate logic. A Universal quantifier "all" (∀), and for the existential quantifier "exists" (∃).

Fuzzy concepts were first introduced by Zadeh in the 1960s and 1970s. [3]

Unlike Boolean or Propositional logic, which has values either true or false, Fuzzy logic has different values based on the degree to which a certain value is true or false. Fuzzy logic is the approach to computing based on the degree of membership rather than true or false values. Fuzzy logic uses fuzzy sets and fuzzy rules to model the problem and make decisions about it. Fuzzy logic attempts to reflect the human way of thinking.

Consider an example in which we want to find out if Jay is a good person.

In Boolean logic, it would either Yes (1) or No (0).

However, in Fuzzy logic, we could have multiple answers depending upon the specific level that Jay is a good person. So, answers could be, extremely good (1.0), very good (0.8), good at times (0.6), not good (0.2) and extremely worst person (0.0)

As seen in above example, the values 1.0, 0.8 to 0.0 are called the degree of membership and could range from 1 to 0.

Crisp Set

It contains an element which is either a member or not a member of the set. For example, let's consider a fruit set A = {apple, mango, banana, strawberry} now if any new value potato could not be the part of the set as potato is not a fruit but it's a vegetable. So, the potato could be a member of the vegetable set not in fruit set.

Crisp Value

The elements in the crisp set are crisp values. As in the example of fruit set, apple, mango, banana, strawberry are the crisp values.

Fuzzy Set

It allows the element to be partially a part of the set. Every element in the set contains a degree of membership in a set. The range of membership value is from 0 (element not a member of the set) to 1(element a member of the set). If only extreme membership values are allowed, that is, 0 and 1 then the fuzzy set would be equivalent to crisp set.

Linguistic Variables

Variables whose values are linguistic rather than numerical are linguistic variables. For example, the height of the person is very short, short, medium, tall, very tall, rather than 4'10'',5'2'', 5'6'', 5'11'', 6' 12'' which leads to fuzzy logic.

Linguistic Values

The values of the linguistic variables are linguistic values. Such as in the example of height which is a linguistic variable, very short, short etc. are the linguistic values.

Linguistic hedge

It is used as a modifier for a basic term in linguistic values. For example, words such as very, a bit, somewhat etc.

Fuzzy rule

A Fuzzy Rule contains 3 sets of fuzzy values which are represented as the condition, result and input elements of a fuzzy rule. Following is the syntax for writing a rule:

if condition1 and condition2 and … and conditionN

then result1 and result2 and … and resultM

The condition1, condition2 …. conditionN are the premises of the rule that must be true before the result of the rule can be asserted. By attaching a set of fuzzy value inputs to the rule that correspond to actual values for the rules, a set of actual result can be determined by executing the rule, using the Fuzzy Rule Executor that is associated with the rule. The executor will implement algorithms for fuzzy inferencing such as the Mamdani min inference operator with the Max-Min composition operator. The fuzzy rule can be expressed using Fuzzy Associative matrix and it is abbreviated as FAM.

We could consider fuzziness when the boundary of information is not precise. Consider an example of the linguistic variable such as height, good, speed. One could say the speed of 65 miles per hour is a fast speed while for some others 100 miles per hour is a fast speed. Speed is just one example to observe how different people could classify different speed values in different classes.

Membership Function

A membership function for a fuzzy set B on the universe of discourse U is defined as $\mu_B: U \rightarrow [0,1]$. The membership function may be of any shape such as triangular, trapezoidal, Gaussian or any other shape.

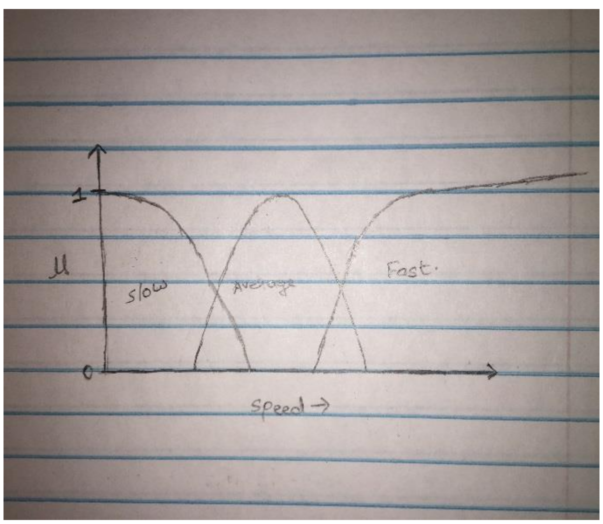

Fig. 1: Gaussian Membership function

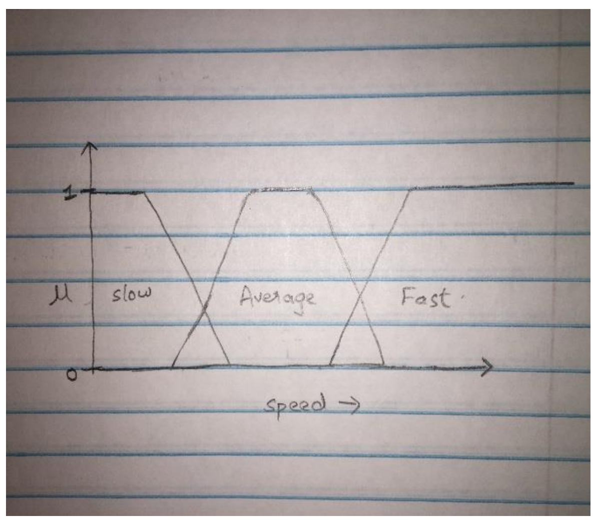

Fig. 2: Trapezoidal Membership function.

In $\mu_B: U \rightarrow [0,1]$, every element of U is mapped to a value between the range of 0 to 1. It is called membership value or degree of membership. It quantifies the degree of membership of the element in U to the fuzzy set B.

- the x-axis represents the universe of discourse.
- the y-axis represents the degrees of membership in the [0, 1] interval.

There can be multiple membership functions applicable to fuzzify a numerical value.

Fuzzy Term: *fast*	
Speed	**Grade of membership**
35	0.0
55	0.2
65	0.4
75	0.6
85	0.8
105	1.0

A grade of membership values constitutes a possibility distribution of the term fast as applied to the fuzzy variable speed. Graphical representation of a table is shown below.

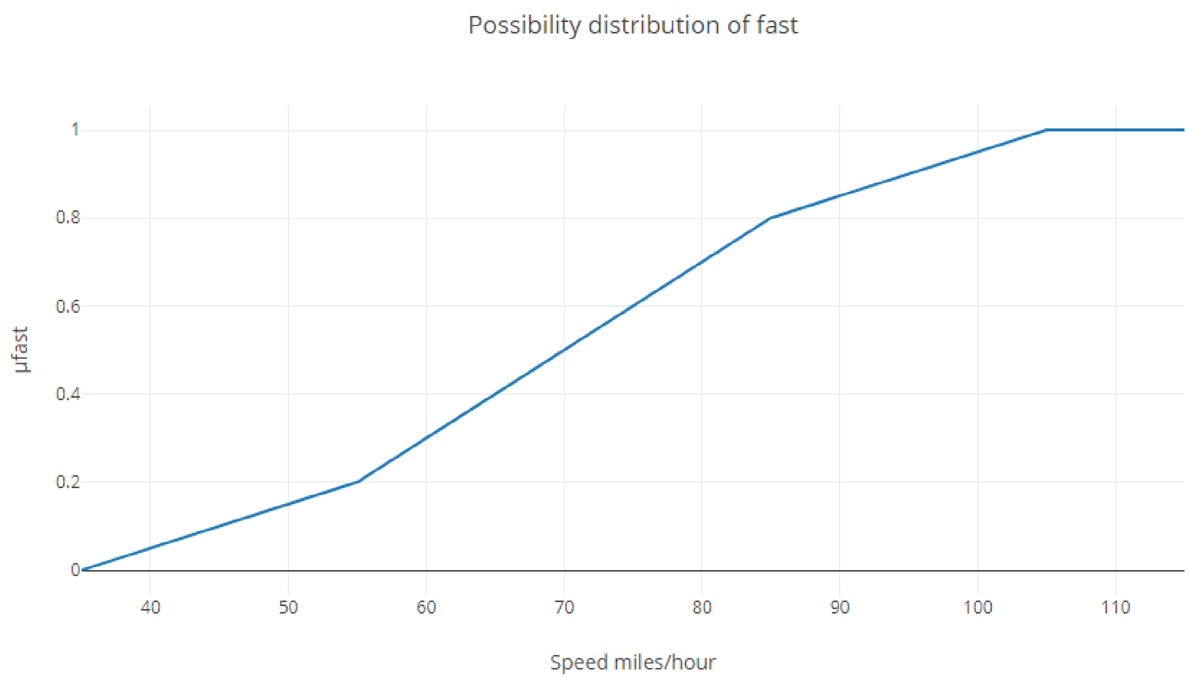

Fig. 3: Possibility distribution of fast

Propositional fuzzy logic:

The most important propositional fuzzy logics are [6]:

- Monoidal t-norm-based propositional fuzzy logic
- Basic propositional fuzzy logic
- Łukasiewicz fuzzy logic
- Gödel fuzzy logic
- Product fuzzy logic
- Pavelka's logic

Predicate fuzzy logic:

These extend fuzzy propositional logic by adding universal and existential quantifiers in a manner similar to the way that predicate logic is created from propositional logic. [6]

Simple Fuzzy Operators

Zadeh who introduced Fuzzy concept used Gödel t-norm

- NOT (x) = 1 – μ(x)
- x AND y = min (x, y)
- x OR y = max (x, y)

An alternative representation of fuzzy operators which uses different t-norms is listed below.[7]

- Product t-norm for AND operator: $\mu_X(y) * \mu_Y(y)$
- Lukasiewicz t-norm for AND operator: max $(\mu_X(y) + \mu_Y(y) - 1, 0)$
- Product t-conorm for OR operator: $\mu_X(y) + \mu_Y(y) - \mu_X(y) * \mu_Y(y)$
- Lukasiewicz t-conorm for OR operator: min $(\mu_X(y) + \mu_Y(y), 1)$

Types of Inference Systems

A system which uses fuzzy set features to map to its outputs is called Inference System. In this report, we would like to describe two types of Inference systems using which we could implement Inference Engine.

- Mamdani Style Fuzzy Inference System [1].
- Sugeno Style Fuzzy Inference System [2].

Mamdani Style Fuzzy Inference System [1]

Mamdani Style Fuzzy Inference System is the common fuzzy technique used by many scientists. It was proposed by Ebrahim Mamdani [1] in 1975 as an "attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators". It has four steps,

1. **"Fuzzification"**

   It is the process of converting the measured numerical values into fuzzy linguistic values. In other words, in fuzzification, membership functions are applied and degree of membership is determined for every element in the set.

2. **"Rule Evaluation"**

   It combines different conditions in the rule and asserts the result only when the condition is true. It uses AND, OR and NOT operations.

3. **"Aggregation"**

   It is the process of expressing the multiple results obtained from rule evaluation as the single fuzzy output distribution set.

4. **"Defuzzification"**

Defuzzification is the process of producing a quantifiable or crisp value. Sometimes it is important to get the crisp value if one is trying to classify a text. Defuzzification interprets the degree of membership in the fuzzy sets into a real value. There exist many complicated methods to defuzzify output distribution set but in this study, we have explored only two:

- Center of Mass [4]
- Mean of Maximum [4]

Center of Mass is the technique which takes input as the single fuzzy output distribution set and finds the center of mass to give output as the real or crisp value.

$$A = \frac{\sum_{k=1}^{m} A_k u\ (A_k)}{\sum_{k=1}^{m} u\ (A_k)}$$

where the center of mass is A and u is the membership in class at value A_k. An example output for any arbitrary input value of the speed of the vehicle as crisp value is shown in Fig. 4.

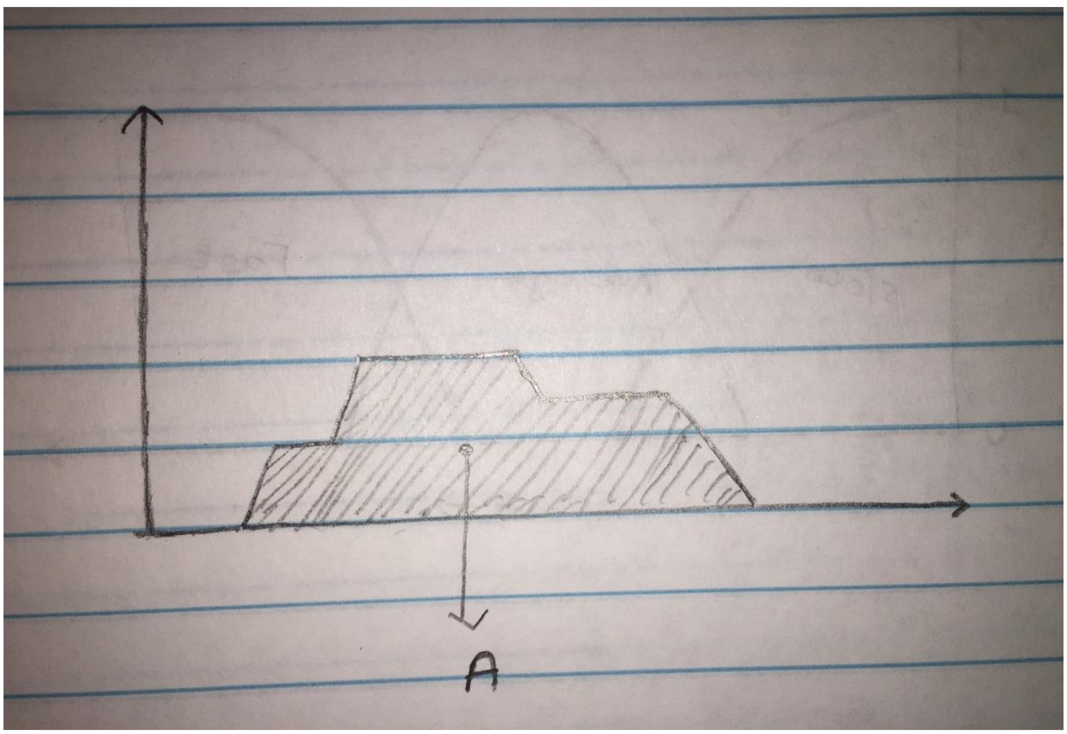

Fig. 4: Defuzzification with Center of Mass

Mean of Maximum is the technique which takes input as the single fuzzy output distribution set and finds mean of maximum to give output as the real or crisp value. It can be calculated as

$$A = \sum_{k=1}^{m} A_k/m$$

where the mean of maximum is A, the point where the membership function is maximum is A_k, and l is the number of times the output distribution reaches the maximum level. An example output for any arbitrary input value of the speed of the vehicle as crisp value is shown in Fig. 5.

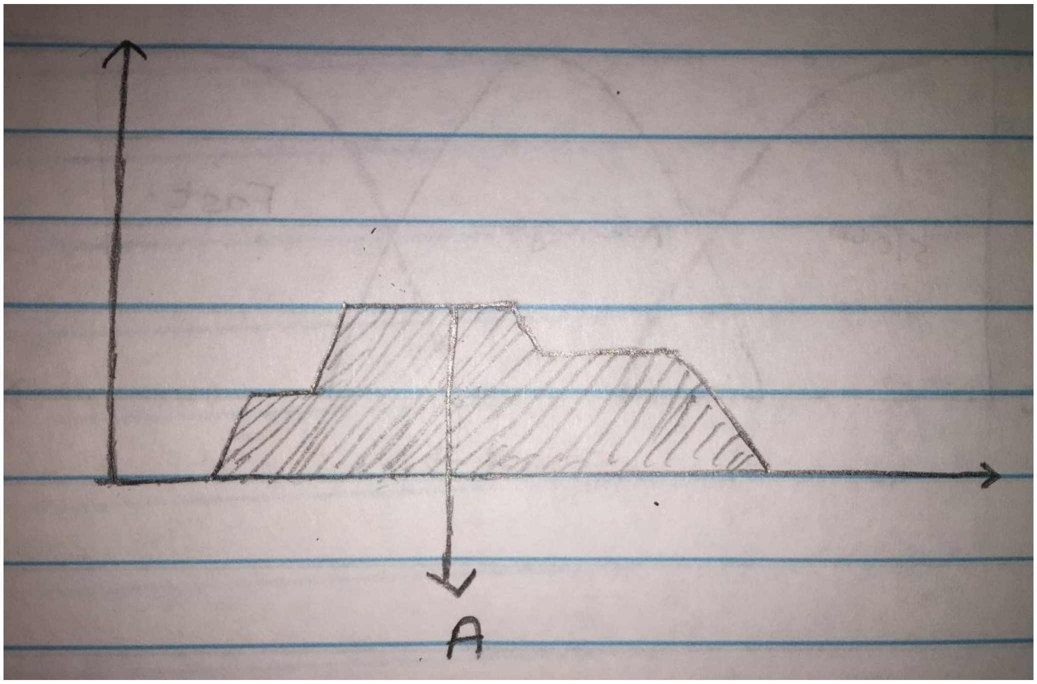

Fig. 5: Defuzzification with Mean of Maximum

<u>Sugeno Style Fuzzy Inference System [2]</u>

It was proposed by Sugeno, and introduced in 1985. This method is like Mamdani, except for the 3rd and 4th step. In Sugeno style fuzzy inference system, the condition of the rule will have fuzzy inputs while the result will be a function of the inputs. The function could be linear, quadratic or any other function based on the type of the problem.

Sugeno Fuzzy Inference System, like Mamdani, does not have Defuzzification technique. Instead, it computes the weighted average.

Weighted Average = $\sum_{i=1}^{n}(\alpha_i * y_i) * \sum_{i=1}^{n}\frac{1}{\alpha_i}$

Here α (alpha) is minimum of the condition_i, y is the result_i for the condition_i where i ranges from 1 to n.

Let's consider an example, of two rules each with 3 conditions.

In fig. 6 and fig. 7, x-axis is X^i_1, X^i_2, X^i_3 and the y-axis shows the μ. $\alpha_1 and\ \alpha_2$ are the minimum value of the condition. We use 'and' fuzzy operator to find the minimum value. Let the result be the linear function of the input values. The result for rule 1 could be defined as $y_1 = x_1^1 + x_2^2 + x_3^3$. The result for rule 1 could be defined as $y_1 = x_1^1 + x_2^1 + x_3^1$ and the result for rule 2 could be defined as $y_2 = x_1^2 + x_2^2 + x_3^2$.

So, the weighted average for the example stated here could be calculated as below:

Weighted Average = $(\alpha_1 * y_1 + \alpha_2 * y_2)/(\alpha_1 * \alpha_2)$

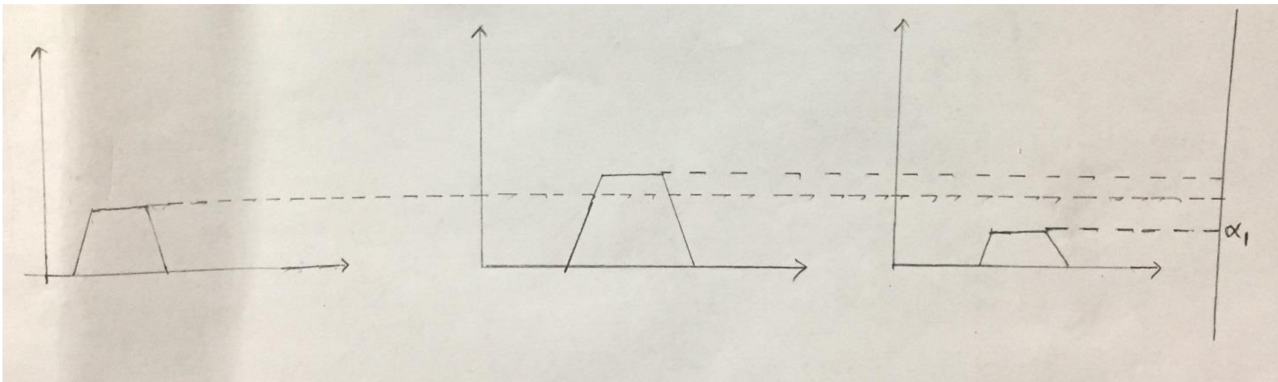

Fig. 7: 3 Conditions for a rule #1. Sugeno Inference System. X-axis, $x_1^1 + x_2^1 + x_3^1$,Y- axis μ

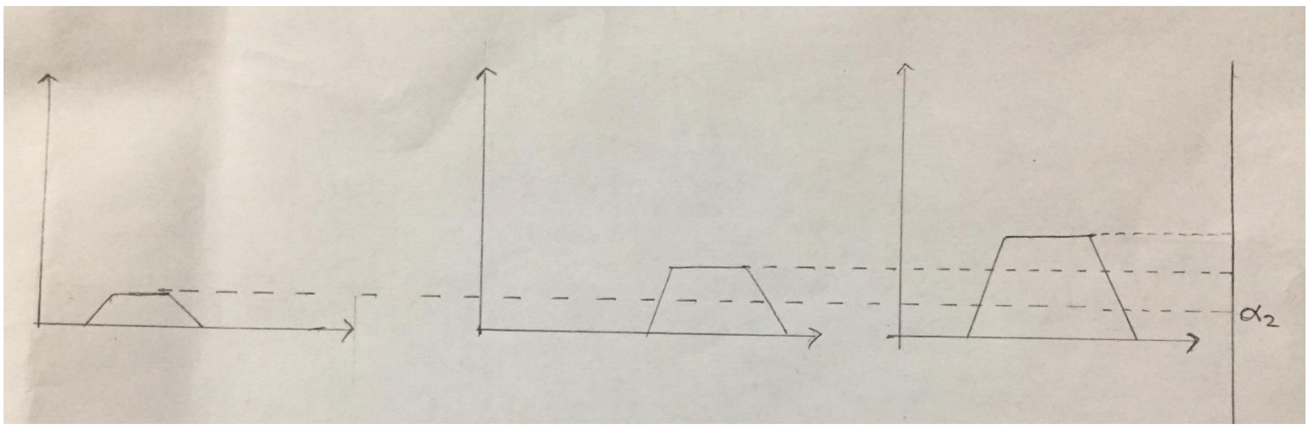

Fig. 7: 3 Conditions for a rule #2. Sugeno Inference System. X-axis, $x_1^2 + x_2^2 + x_3^2$,Y-axis μ

Inference Engine

Inference Engine, as shown in fig. 8, can work in either of the 2 styles of work flow available. Depending on the problem to be solved selecting one of these 2 methods is trivial. In brief, these are the 2 very different approaches. Both have their own preference depending on the nature of the problem.

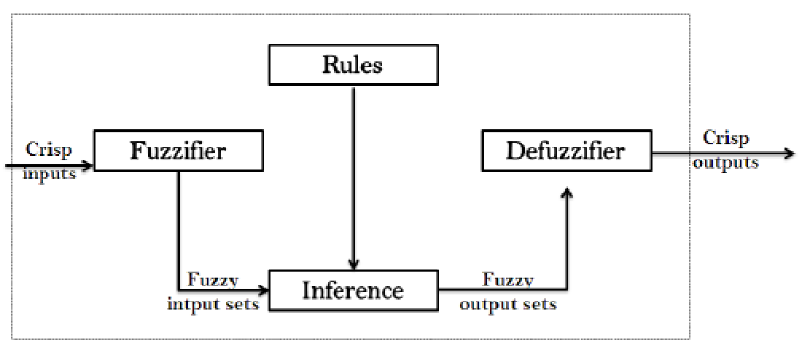

Fig. 8: Inference Engine [12]

Forward Chaining:

In the interface Engine with the data in the knowledge base is forward chaining and backward chaining should be so basically the methods to build algorithms in the forward way or the backboard way to the forward chaining starts with the available data and uses inference rules to extract more data for example until goal is reached so there may be certain rules which may be defined in the system and based on those rules certain facts can be derived and those facts will derive certain more associated facts and rules which will finally lead us to the solution or the goal state. And that's how this forward chaining method is implemented.

Now, this whole process starts with collection of information. So firstly, a problem is defined. Then information is collected based on that problem. That information will be leaded to the solution of that problem and specific reasoning is applied to this all information to obtain logical operations based on which that problem can be solved.

So, based on this information, certain rules are written and they are fed to the knowledge base as the knowledge of how to this system will work. So now we have developed certain algorithms which are based on these stated rules about how the system is going to operate. Hence forward chaining method, the system is a pool of established rules based on the knowledge base and the system searches the most appropriate rules among them in this knowledge base for each required condition.

This process can generate new conditions from the resultant of previously applied rules on already available conditions. These new conditions will be added to the knowledge base and processed again. So, this is, in brief, the operation of forward chaining method.

Rules are in memory and generated by inference engine as shown in block diagram below. Inference engine will have logic and algorithm to generate new rules and those will be added to knowledge base. Consider an example with following rules:

R1: if speed of car is greater than 80mph then apply brakes with paddling force of constant 0.6

R2: if speed of car is between 70-80 mph then apply brakes with paddling force of constant 0.5

R3: if distance between 2 cars is less than 15ft than apply brakes

F1: speed of cars

F2: distance between 2 cars.

Here R1, R2, R3 are the rules defined regarding braking mechanism of a car. And F1, F2 are the facts provided which can form new conditions and can generate new rules and facts. So let's say if the fact is that the distance between 2 cars is less than 15ft then "add brakes to be applied" to the knowledge. Now based on rule R1 and rule R2 we can deduce new information like what could be the speed, in that case, could be related with that fact.

Backward Chaining:

Here Reasoning is done in backward direction. System starts with a goal state and generate reasons in backward directions. So, in this case, there are 2 actions to consider. First is to choose a goal state and rules which is associated with goal state. Secondly, to generate sub goals to be satisfied for the main goal state to be true. Then establish initial conditions which are required to satisfy sub goals. Then initial state and newly generated sub goal states are compared to see whether its conditions are satisfied. Here in this example if the brakes are applied then distance should be less than 15ft should be deduced. Here we must find certain sub goal states that can be executed based on primary goal. So first the primary goal is defined and based on that certain sub goal states will be defined for which the primary goal holds true.

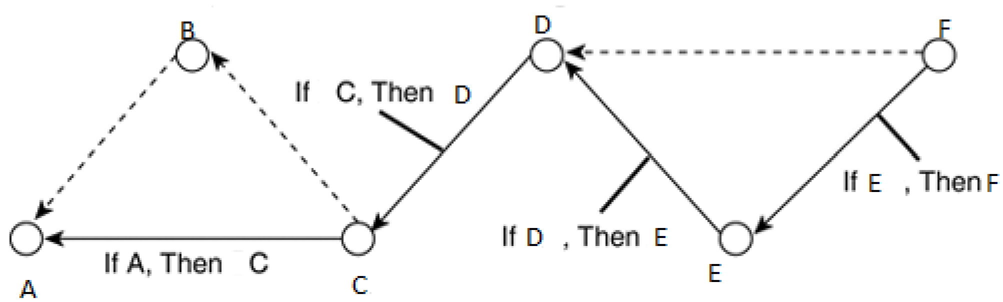

Fig. 9: Backward Chaining

Following are the major differences between forward and backward chaining.

If goal hypothesis is properly defined then backward chaining is better and more goal driven. So, if goals are clear then backward chaining is preferable. Like, for example, Medical Expert Systems. Forward chaining is preferable when goal is variable and unclear and want to explore what can be concluded from the current state. For example, given a polynomial equation if we are supposed to find a value of 'x' then it is backward chaining where goal state is defined. Given a value of variable 'x', if we must predict what can be the polynomial equation to satisfy for that value of x. (Forward Chaining).

Defuzzification

Defuzzification is a process to produce a quantifiable result in crisp real-world scaler logic value. This crisp value generated is the output of this process given corresponding membership functions and fuzzy sets outputs. Basically, it maps the output in a fuzzy set to a crisp set.

For example. Consider a weather condition. It depends on various parameters like air pressure, direction of wind, speed of wind, humidity etc. and our goal state is to predict the weather. Which means to conclude whether it is sunny, cloudy, rainy, foggy, partial cloudy etc. So, after passing through the whole process of inference, setting rules and generating new facts, it gives an output in fuzzy sets. For our example, it would be like the change in various above-mentioned parameters which can contribute in the change in weather. But those output values of individual parameters do not state our actual goal state which is to define weather and not the values of those resulting units.

So, what defuzzification does, is to map these parameter output values to more abstract type which is much more understandable category format like sunny, cloudy, rainy etc. So, this process decides which one among this category is more likely to satisfy all the conditions of the above mentioned resultant output values of parameters. So, like fuzzy set would be air pressure is 0.5 atm, humidity 90%. However, defuzzifying this values we will get a crisp set defining weather. In a lot of cases, this defuzzification is very difficult to map fuzzy sets to crisp sets.

One of the common used techniques is center of gravity. For this, the shape of the graph is made trapezoidal or similar quadrilateral shape by cutting non-required edges accordingly. Then all these trapezoids are superimposed on one another, forming a pattern of trapezoids. Then centroid of this patterned trapezoidal is calculated. This centroid is called "fuzzy centroid" [9]. The x coordinate of this centroid gives us a crisp value or a defuzzied value. [9] This value is not exactly same as fuzzy value as it is not exactly on the fuzzy graphs. It can be calculated by following equation. [10]

$$ {}^{x}COA = \frac{\int_{x} \mu A(x)\, x\, dx}{\int_{x} \mu A(x)\, dx} $$

Where COA is the centroid of area, A is the area generated under the curve, x is the coordinate which defines the graph.

Also, there might be an issue where this centroid value is in such a grey area that it cannot be defined in the properly in the real world (where some problems are in Boolean scale domain). So, in this case of defuzzification process becomes difficult.

Here area and distribution methods show the nature of continuous graphs and because of that, they are preferable for fuzzy controllers. Also for fuzzy reasoning systems defuzzification techniques related to finding maxima in a graph is more preferred.

Natural Language processing:

When Google, Yahoo Bing, and some other search engines operate in other languages like by doing Chinese translation, use natural language processing technologies to understand norms in human language and find its appropriate matching while performing search optimization algorithm. An Answering bot, for example, a few years ago or IBM's Watson system famously played on the best human contestants in 'Jeopardy' and one there are nowadays monitor system such as Apple's Siri and Google Assistant, and some computer software to generate the reports about earthquakes automatically.

All those techniques use natural language processing and since many years progress in this field is increasing more and more. First, computers do not understand human language that will teach computers how to use language, how to understand language and Linguistics which is the study of language for fields like Computer Science and Mathematics, Statistics Artificial Intelligence etc. finding new patterns and rules about the language.

NLP is a series of tasks to be done one at a time to decipher the language.

Lemmatization:

Recognizing Parts of Speech: Due to ambiguity in language identifying a true meaning of a word is very trivial whether that word is adjective, noun or a verb.

Parsing: here the sentence is looked from grammatical point of view. Which contains multiple possibilities. Dependency parsing aims create an association among different words like relating objects and predicates. Consistency parsing checks for errors and is responsible for generating context free grammar.

Segmentation: Here sentences and words are broken down into smallest unit of meaningful language. Here morphemes are identified.

Sentence breaking: Here different sentences are identified and there reach or influence to other sentences are recognized. So, sentences containing punctuations should be associated accordingly.

Stemming: In languages like Japanese and Chinese, words are not separated by spaces. So here identifying the difference and separating those words take place. It takes high amount of knowledge regarding that language's vocabulary.

Lexical: understand meaning of each word for computation.

Natural Language – Fuzzy integration.

Approach to use here is to make the system work in Question/Answers format. This prevents the system from going into any unpredictable directions or ending up in a loop or dead lock. [9] System analysis's first question or response and then based on that it has to make a decision whether the information it has is sufficient to support its goal claims. If not then it moves to next response or inputs until it has formed a clear understanding about the association. Since Inference processing is done after NLP, language based dictionaries are also attached so that the system can understand what is the context before forwarding it to inference engine.

Issues with NLP: :

- **Machine Translation** – from one language automatically translate text to another by following grammatical rules and semantics which might be different from the real world. etc.
- **Source Document** format– Parsing of textual data in documents like webpages, files, images etc. might not be in a clean format or it may be related to other unknown formats which might not be known by the system. (unable to read other extension files produces irrelevant texts which makes no sense but it's hard to detect.
- **Natural Language Understanding and its context generation**– Sometimes the chunk of data the system processes is constant. So, it might be possible that due to this limited window the system is unable to understand the broader aspect of the text and takes a decision based on just the text it has.
- **Text Summarization** – Sometimes system is unable to detect a sarcastic or humor comment and it takes in a very different context.
- **Optical Character Recognition** – Certain slangs and using words of different language might create ambiguity in understanding text.

Limitation of Fuzzy system

- Fuzzy system is does not able to capability of machine learning type of pattern identification.

- It is very difficult to analyze and verify the validity of fuzzy generated facts and information. Especially when it is integrated with Natural language processing, there is no way to test whether the established information in knowledge base is correct or not. This happens because the rules are generated first and then they are verified based on the facts. Hence if the contact is misunderstood then rules will satisfy the factual conditions.
- Testing of fuzzy knowledge base is hardware intensive and logic based which is very difficult to achieve.
- Determining the exact value of membership function and its corresponding fuzzy rules is very difficult. [11]
- It might be possible that fuzzy is unable to connect the dots, as a result, it loses its stability and confidence in resultant output.
- System response time increases with the increase in number of rules.
- With the change in data, rules have to be modified. Which means rules with the data of variable values cannot be defined in a general case.
- In a very large complex system, fuzzy logic becomes the bottom neck for system reliability.
- Unable to learn from its own mistakes. Not smart enough to recognize similar patterns

Advantages

- Works on the principle of the intensity of a property (how much hot, how much cold) rather than the probabilistic principle of the likelihood of that property (What is the probability of hotness)
- Carefully models the grey area in the domains where linear separation is not easily possible.
- Rules defined in the knowledge base are not dependent on one another unlike neural network
- Eliminates edge cases (area in domain where crisp values change)
- No need for extensive hardware support like high processing power.

Application of Fuzzy logic based inference systems

- Automatic Electronic controllers and systems.
- Medical advising and diagnosis system
- Controllers in home appliances.
- In combination with other soft systems like Neural Network and Genetic Algorithm. (all such hybrid systems have their own pro and cons and are designed focusing on its application and available data and facts.
- When integrated with Natural language processing techniques, such systems can develop smart autonomous chatbots which can communicate with a target audience like online service assistive chatbots, entertainer chatbots for kids and in smart home automation systems like Amazon Echo and Google Home.

One current issue to note

Other than the above-mentioned application one noticeable issue we came across was that of Amazon voice assistive system Alexa. Currently, Alexa cannot remember its past conversation very accurately. It can only answer one question and then it is not able to find or connect any link between the previous question and the next one. For a simple demonstration, If Alexa is asked: “who is the president of United States?” Alexa answers it correctly. But if its next question is “What is his birthday?” then Alexa failed to answer because it is not able to link “his” in current question to “President” in its previous question. Inference system can solve this type of issues and generate new rules and establish new facts. This is one of the main purposes of such communications. Many times, it is not possible to extract all the information in just one statement or query. So, this is more than just helpful; it's important.

Sometimes due to limited use of it in voice assistant in customer care of any consumer firm, a customer may get frustrated because of the communication going in an endless loop whose one of the main reasons is limited knowledge given to such expert systems. This is still one of the major concerns remains for expert system designers that who to detect if there is any fault or false information available in the system.

Conclusion

Using Natural Language Processing techniques along with fuzzy inference system is a challenge to implement. Since both fields have very different goals they are unable to adapt and accept each other’s techniques. As a result, both functionals independently. Also, errors since both of these work in serial coordination with one another (output of NLP will work as an input of inference engine). Some common knowledge base is needed to establish which can be used by both the processes to work together as one system.

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