AN IN-DEPTH STUDY FOR APPLICATION OF FUZZY LOGIC IN BETTER UNDERSTANDING OF CRIMINAL PSYCHOLOGY

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Abstract: *According to a report that was released by National Crime Record Bureau (NCRB) namely, "Crime in India – 2020", the crime rate in India increased to 487.8 (crimes per 1 Lakh people) in 2020 from 385.5 (crimes per 1 Lakh people) in 2019 [1]. Not just in India, the crime rate is drastically getting increased all over the globe in recent years. In such situations, the criminal psychology is given high importance, the criminal psychologist mainly investigates the motivation that derives criminals to commit crimes and thereby, would tell how to stop such activities [1].*

Understanding the criminal psychology can be thought of as a part of medical diagnosis. The process of medical diagnosis, like many other fields, must pass various stages of uncertainty, especially in cases where the data is mostly available in linguistic format. Under such circumstances of vague data, application of fuzzy logic concepts can play an important role in extracting approximate information which in turn may help in reaching to a particular conclusion about criminal psychology. This study is devoted to the application of fuzzy logic in the psychological domain. The paper provides a detailed literature review on the use of fuzzy logic membership functions and fuzzy rules in analyzing the different aspects of psychological behavior of human beings especially the criminals.

Natural Language is known for its ambiguity and vagueness. Fuzzy Logic can be applied to NLP in understanding the natural language in a more efficient manner [9]. The authors have applied Fuzzy Logic to health care domain to understand related diseases precisely and acquired successful results [10]. This paper focuses on recent developments and the current state of fuzzy set theory and its applications in psychology. Beginning with Fuzzy Logic, the work in this paper focuses on various steps of Fuzzy Logic that helps in understanding the criminal psychology. It also focuses on the dataset considered and in-depth survey of applying Fuzzy Logic has been made in understanding the criminal psychology.

Keywords: **NLP, Fuzzy Set, Fuzzy Logic, Membership Functions and Fuzzy Rules**

1. INTRODUCTION

The authors have utilized the Fuzzy Logic in health care for better understanding of the disease and the results of their work were extremely encouraging [10]. As a next steppingstone in application of Fuzzy Logic to the health care and societal domains, the authors have chosen the area of criminal psychology.

Psychology is the field where it is totally unexpected and unpredictable. It can throw enough challenges to the entire global mankind. Many Computer Science Researchers are doing huge amounts of work related to Artificial Intelligence applying to various domains. Research work related to understanding of the Criminal Psychology using Fuzzy Logic has been initiated in this paper which may help the people around the globe to understand the psychological aspects and develop more responsible citizens in the society.

Especially, psychology is a study which helps in understanding the reasons for people's action. A psychologist has this kind of professional insight and so he can help people in improving their decision making, stress management and social behaviour. The psychologist is capable in understanding the past behaviour which can be used in predicting the future behaviour in a much better way. This helps the people in acquiring a more successful career, better relationships, more self-confidence.

The importance of psychology is highlighted in two aspects as discussed.

Theoretical Aspects: Psychology examines in its theoretical aspects, psychological phenomena and behavioural patterns that appear on the individual's external behavioural reactions to access general principles and laws.

Application Aspects: Through applied studies, psychology employs theoretical principles and laws in the process of mentoring, controlling and changing human behaviours for the better.

Applied psychology designs criteria and standards that depend on distinguishing normal behaviours from abnormal behaviours, i.e., judging behaviour whether it is normal or abnormal through these criteria and standards.

Performing psychological tests to determine a suspect's mental health is an integral part of the adjudication process. It is the responsibility of a psychologist to determine whether a suspect's mental state is stable to stand trial or not. One more responsibility of a criminal psychologist is to provide psychotherapy for criminals and to people who have such criminal thoughts. The major role of a criminal psychologist will be in helping their clients to cope with the criminal behaviour and thoughts, making them understand the consequences of such criminal activities and assisting them in their rehabilitation so they become productive members of society.

Artificial Intelligence can be applied to the field of psychology to understand the abnormalities in a much better way. Recent developments in the field of AI have emerging applications towards criminal psychology. Fuzzy Logic which is a subset of Artificial Intelligence can be applied to understand the Criminal Psychology. As the Natural language is known for its vagueness and ambiguity, Fuzzy Logic which deals with the natural language helps in understanding and generating more quality output in understanding the criminals. This work helps in understanding the criminals in a much better way which might help in the overall improvement of the global future generations.

2. DATA

The dataset is considered from Kaggle website [11]. In this dataset, three antisocial personalities were considered and they are classified to be Machiavellianism, Narcissism and Psychopathy. They are known to be dark as they have malevolent qualities.

Manipulation and exploitation of others, absence of morality, unemotional callousness, and a higher level of self-interest are the characteristics of Machiavellianism. The main characteristics of Narcissism are grandiosity, pride, egotism, and a lack of empathy. The usual characteristics of Psychopathy are continuous antisocial behaviour, impulsivity, selfishness, callous and remorselessness. For each of these categories, nine different questions were framed by the psychologists and they were asked to certain criminals. The responses were obtained in the dataset.

The set of questions that can be asked by the psychologists can be rated by the criminals on a scale of 1 to 5 (1=disagree and 5=agree). The responses given by the criminals can belong to the scale of values {Agree, Neutral, Disagree}. Fuzzy Logic can be applied to the data to classify the criminals into three categories. They are as shown.

- Most Dangerous
- Manageably Dangerous
- Not much Dangerous

3. FUZZY LOGIC SYSTEM

The Fuzzy Logic System takes the crisp value as input and generates an output based on inferencing. It consists of four important components. The Fuzzy Logic System can be depicted as shown.
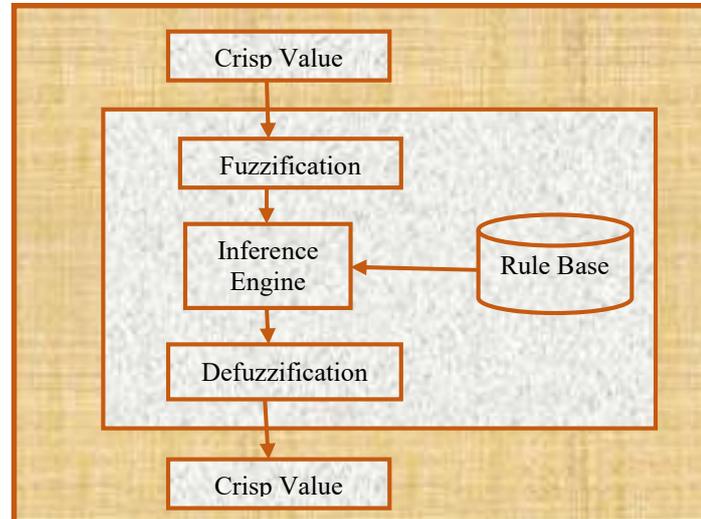

Figure 1: Fuzzy Logic System

As observed from the Fuzzy Logic System, the four important components are as listed and discussed briefly.
A) Fuzzification / Fuzzifier
B) Rule Base
C) Inference Engine
D) Defuzzification / Defuzzifier

A. Fuzzification / Fuzzifier
The Fuzzifier takes the crisp value as input. With the help of membership functions the crisp value is represented as a fuzzy value. So, the output from a Fuzzifier is a fuzzy value.

B. Rule Base
The Rule Base consists of rules represented in the fuzzy form.

C. Inference Engine
The Inference Engine infers an output using the rules from the Rule Base for the fuzzy value which is the output from the Fuzzifier. The output from the Inference Engine is a fuzzy value [6, 8].

D. Defuzzification/ Defuzzifier
The Defuzzifier takes the fuzzy value from the Inference Engine as input and using the defuzzification methods it produces a crisp value as output [7].
The various stages of the Fuzzy Logic System applied to the criminal psychology database.

4. MEMBERSHIP FUNCTIONS

Membership function helps in representing the crisp value as a fuzzy value. It plays a major role in Fuzzification. Membership function is used to characterize the fuzziness [3, 4]. It is used to represent the degree of truth in fuzzy logic [2]. In this work, Triangular Membership Function is used for fuzzification of the crisp value to a fuzzy value. The responses given by the criminals can be given as input to the Fuzzifier using Triangular Membership Function for getting a fuzzy value as output.

Triangular Membership Function is described briefly as shown.

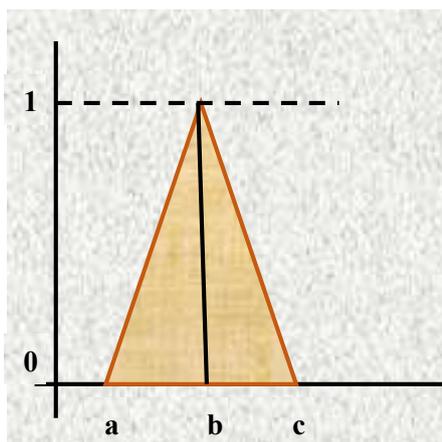The graphical representation of Triangular Membership Function is as shown.

Figure 2: Triangular Membership Function

The formula for Triangular Membership Function is given as shown.

$$\mu(x) = \begin{cases} 0 \leq x \leq 0 \\ \dfrac{x-a}{b-a} & a \leq x \leq b \\ \dfrac{c-x}{c-b} & b \leq x \leq c \\ 0 & x \geq 0 \end{cases}$$

Here a and c are called feet and b is called the peak of the triangle.

5. RULE BASE

The Rule Base consists of rules which are in fuzzy form. The knowledge of an expert in any related domain specific field of application can be considered as Fuzzy control rule [3]. A fuzzy IF-THEN rule associates a condition and a conclusion [3, 5].

Fuzzy Rules are framed according to the expert's knowledge and these rules can be further used in inferencing.

The general form of an IF-THEN rule is as shown: IF antecedent THEN consequent

Antecedent is the condition part and the consequent is the action to be taken when the condition is met [5]. In the rules the short representations as N, M, P are used instead of the entire term representations as Narcissism, Machiavellianism, and Psychopathy. Few rules used in this work are as shown.

IF M IS HIGH AND P IS HIGH AND N IS HIGH THEN CLASS IS Most Dangerous
IF M IS HIGH AND P IS HIGH AND N IS LOW THEN CLASS IS Most Dangerous
IF M IS HIGH AND P IS LOW AND N IS HIGH THEN CLASS IS Manageably Dangerous
IF M IS HIGH AND P IS LOW AND N IS LOW THEN CLASS IS Manageably Dangerous
IF M IS LOW AND P IS LOW AND N IS HIGH THEN CLASS IS Not much Dangerous
IF M IS LOW AND P IS LOW AND N IS LOW THEN CLASS IS Not much Dangerous

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Few Rules used in the Rule Base

6. RESULTS AND DISCUSSIONS

All the results were obtained using Jupyter IDE and written in Python language Anaconda framework. The dataset comprises of 18,192 records or rows and 29 different columns. Out of 29 columns only 27 are identified to be important for further analysis. So, the size of the dataset considered for further analysis is 18,192 rows X 27 columns. The dataset after selecting the required number of columns is as shown.

```
[18192 rows x 29 columns]
       M1 M2 M3 M4 M5 M6 M7 M8 M9 N1  ...  N9 P1 P2 P3 P4 P5  \
0       4  4  4  4  4  4  4  3  4  2  ...   4  3  4  3  2  4
1       2  1  5  2  2  1  2  2  3  1  ...   2  1  1  1  5  4
2       3  3  3  5  1  1  5  5  3  2  ...   5  3  5  3  1  3
3       5  5  4  5  5  5  5  5  5  5  ...   5  5  1  5  2  5
4       4  4  2  5  5  5  4  1  4  3  ...   5  4  5  3  1  4
...    .. .. .. .. .. .. .. .. .. ..  ...  .. .. .. .. .. ..
18187   1  5  2  4  4  5  4  3  5  4  ...   2  3  3  3  5  5
18188   5  4  5  4  5  4  5  4  5  4  ...   3  3  2  2  1  5
18189   4  3  3  4  2  3  4  3  4  3  ...   3  2  5  3  1  1
18190   5  4  3  3  4  4  4  3  4  3  ...   4  4  3  3  4  4
18191   4  4  4  5  3  4  4  3  3  3  ...   4  3  3  3  2  4

       P6 P7 P8 P9
0       4  4  4  4
1       1  5  3  2
2       1  2  3  1
3       5  5  1  5
4       3  5  4  1
...    .. .. .. ..
18187   3  2  3  3
18188   2  2  3  4
18189   1  2  4  1
18190   3  4  1  3
18191   3  3  4  4

[18192 rows x 27 columns]
```

Figure 3: Data Set after selecting the required columns

In this work, all the ratings are considered with equal priority for all the three categories. The three fuzzy regions considered for each category are represented to be m_lo, m_md, m_hi for LOW, MEDIUM, HIGH of the category Machiavellianis,

n_lo, n_md, n_hi for LOW, MEDIUM, HIGH of the category Narcissism, p_lo, p_md, p_hi for LOW, MEDIUM, HIGH of the category Psychopathy .The fuzzy regions for the three categories namely Machiavellianism, Narcissism and Psychopathy are obtained as shown.

```
The scale range values for M, N, P are:

m: [1 2 3 4 5]
n: [1 2 3 4 5]
p: [1 2 3 4 5]
The fuzzy regions values for M are:

m_lo: [1.        0.09090909 0.        0.        0.       ]
m_md: [0.        0.33333333 1.        0.        0.       ]
m_hi: [0.        0.        0.0625   0.6875   0.66666667]
The fuzzy regions values for N are:

n_lo: [1.        0.09090909 0.        0.        0.       ]
n_md: [0.        0.33333333 1.        0.        0.       ]
n_hi: [0.        0.        0.0625   0.6875   0.66666667]
The fuzzy regions values for P are:

p_lo: [1.        0.09090909 0.        0.        0.       ]
p_md: [0.        0.33333333 1.        0.        0.       ]
p_hi: [0.        0.        0.0625   0.6875   0.66666667]
```

Figure 4: Fuzzy Regions obtained for three categories

In this work, the Triangular Membership Function is used to obtain the fuzzy value for a crisp value given as input. The Machiavellianism, Narcissism and Psychopathy values are considered for nine different questions for each category. The nine values for each category can be treated as a single value by following any one of the statistical measures. In this work, "mode" statistical measure is used for considering a single value for each category. The fuzzy values obtained for an arbitrary record of Machiavellianism, Narcissism and Psychopathy values are as shown.

```
Triangular Membership Function for various fuzzy regions of M with a given value

arbitrary_m_lo: 0.0
arbitrary_m_md: 1.0
arbitrary_m_hi: 0.0625000000000006

Triangular Membership Function for various fuzzy regions of N with a given value

arbitrary_n_lo: 0.09090909090909098
arbitrary_n_md: 0.3333333333333333
arbitrary_n_hi: 0.0

Triangular Membership Function for various fuzzy regions of P with a given value

arbitrary_p_lo: 0.0
arbitrary_p_md: 0.0
arbitrary_p_hi: 0.6875
```

Figure 5: Fuzzy values obtained for an arbitrary record

7. CONCLUSIONS AND FUTURE WORK

Criminal psychology can be considered as an emerging and essential discipline that help in enhancing the performance of law enforcement agencies and courts. It is

also helpful in foreseeing crimes and understand criminals efficiently. The criminal psychology is still in early stages of development in many countries. The psychology students and researchers of various domains are getting attracted towards criminal psychology and more and more research and experiments can be done to get a better outcome. In this paper, an in-depth study has been made for application of Fuzzy Logic in understanding the criminal psychology behaviour. The so far obtained results are further used in the continuation of this work in classifying the criminal psychology behaviour. The proposed work helps in understanding the criminals in a better way and helping the criminals in developing a better personality and thereby a healthy society.

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